CTBT Science and Technology Conference 2021 (SnT2021)

Monday 28 June 2021 – Friday 02 July 2021

Book of Abstracts

Welcome and introduction

It is my pleasure to welcome you to SnT2021, which is the sixth event in the CTBT: Science and Technology conference series.

SnT2021 is special and different from previous SnT conferences, and not only in terms of its hybrid-virtual format.

It has two important themes that are unique for this year — the 25th anniversary of the opening for signature of the CTBT, and the Covid-19 pandemic that has affected us all. We will mark the 25th anniversary with a series of invited talks and panels that will address various aspects of the verification system over the past 25 years and the challenges and prospects for the Treaty in the future. The global nature of the Covid-19 pandemic resulted in a world-wide resilience test. This was especially true for the CTBT verification regime, which relies on continuous data gathering, transmission and analysis. We will reflect upon this experience and the lessons that can be learnt from it in a dedicated panel and a series of oral presentations distributed over several sessions.

The sessions related to the 25th anniversary include high level discussions on the opening day (28 June) as well as technological and scientific panels over the remainder of the Conference (29 June – 2 July). These panels will cover the topics of sensors, data analysis, regional data, lessons from historical data, preparedness for OSI, as well as scientific and civil applications.

It is heartening to see that the level of interest for the SnT conferences continues to grow as we expect more than 1100 participants and 620 presentations that will cover a wide range of disciplines, including seismology, meteorology, acoustics, nuclear sciences, computer sciences, system engineering and maintenance, information and communication technology, and disarmament and non-proliferation diplomacy.

Let me also take this opportunity to express my gratitude to all of the staff who have tirelessly supported this complex undertaking of organizing a hybrid conference setting for the first time and under unprecedented circumstances.

Undoubtedly, we would have preferred to welcome everyone again here in Vienna. However, our hope is that the diverse programme and hybrid format will still inspire and enable your active engagement with this important initiative. These SnT conferences are an important contribution to the rich repository of knowledge that will serve as a resource for generations to come.

Lassina Zerbo
Executive Secretary

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G1 – SNT21@25th anniversary of the CTBT: Ceremonial Opening and Political Remarks

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High-level speakers in order of appearance:
• Mr. Lassina Zerbo, Executive Secretary, CTBTO
• Ms. Ghada Waly, Director-General of UNOV, delivering a message on behalf of the United Nations Secretary-General Antonio Guterres
• Mr. Peter Launsky-Tieffenthal, Secretary-General of the Federal Ministry of European and International Affairs of Austria
• Mr. Li Yong, Director General, UNIDO
• Mr. Rafael Grossi, Director General, IAEA
• Mr. Bruno Rodríguez Parrilla, Minister of Foreign Affairs of Cuba
• Mr. Dhoihir Dhoulkamal, Minister of Foreign Affairs and International Cooperation, in charge of the Diaspora, of the Union of the Comoros
• Mr. Stephan Klement, Ambassador, Head of the EU delegation in Vienna delivering a message on behalf of the High Representative of the European Union for Foreign Affairs and Security Policy, and Vice President of the European Commission

High Level Opening - session 1

G2 – Facilitated dialogue on CTBT@25 years: Evolution of the CTBT, the Organization and its technologies & CTBT's model function of inclusion and science cooperation

Master of Ceremony: Ms. Sanam Shantayei, Senior Journalist, France 24

Co-Facilitator: Ms. Sabine Bauer, Special Assistant to the Executive Secretary

High-level Speakers in order of appearance:
• Mr. Jaap Ramaker, Ambassador of the Kingdom of the Netherlands and Chair of the 1996 CTBT Negotiations, and former Special Representative to promote the Ratification of the CTBT, 2004 - 2009
• Mr. Grigory Berdennikov, Ambassador Extraordinary and Plenipotentiary; Head of the Russian Delegation at the CTBT Negotiations; Deputy Minister of Foreign Affairs of the Russian Federation (1992–1993; 1999–2001), member of GEM
• Ms. Jenifer Mackby, Senior Fellow, Federation of American Scientists
• Ms. Anne Strømmen Lycke, Chief Executive Officer of NORSAR
• Mr. Ernest Moniz, United States Secretary of Energy (2013-2017), Co-Chair and Chief Executive Officer of the Nuclear Threat Initiative (NTI)
• Mr. Desmond Henry Browne, Lord of Ladyton, Secretary for Defence of the United Kingdom (2006-

2008), Vice-Chairman of NTI and convener of the European Leadership Network for Multilateral Disarmament and Non-proliferation, member of GEM
• Ms. Tarja Halonen, Eleventh President of Finland and GEM member and Champion for a Nuclear Test Free World towards a Nuclear Weapons free world
• Mr. Ban Ki-moon, Eighth United Nations Secretary-General and Founder of the Ban Ki-moon Centre for Global Citizens

CTBTO-CYG
• Ms. Sitara Noor, Senior Research Fellow, Centre for Aerospace and Security Studies, Islamabad, Pakistan
• Ms. Magdalene Wangui Wanyaga, Project Manager, SandRose Ltd, Kenya
• Mr. Jaona Andriamampandry, Assistant Researcher, Institute of Geophysics and Observatory of the University of Antananarivo, Madagascar

High Level Opening - session 2

Master of ceremony: Bethany Bell, BBC foreign correspondent

G3 – Artificial Intelligence (AI) to Transform Nuclear Explosion Monitoring and Verification: Thoughts on Opportunities and What It Might Take to Get There.

Author: Dimitri Kusnezov[1]

[1] *Deputy Under Secretary for AI and Technology at the US Department of Energy*

Artificial Intelligence (AI) has the potential to revolutionize the very ways we live our lives and make our world more sustainable and equitable. Today's AI based methods, which are still nascent and narrowly applied, are already providing means to innovate and impact everything including science, environment, energy, health, and climate. AI impacts the U.S. Department of Energy (DOE) across all missions, businesses, and operations, and has become central to accelerating scientific discovery and the development of transformational new technologies. The DOE, like the CTBTO PrepCom, needs trustworthy AI systems that are accurate with high confidence and proven to be unbiased and reliable. Working in collaboration with global partners, DOE – the largest sponsor of physical sciences in the United States and largest generator of Nobel-prize winning scientists in the world – is driving high-risk research and development to advance the science of AI to create AI-enabled technologies that fulfill these requirements. This presentation will highlight a number of examples of AI in practice at DOE today, emerging areas of interest, and insights on opportunities presented by AI for the CTBTO PrepCom, drawing on decades of experience developing cutting-edge science and technology capabilities to deter and detect nuclear explosive tests.

High Level Opening - session 2

G4 – Space science and technology for global sustainable development, peace, and security

Space has become an indispensable tool for our way of life. Addressing global challenges requires utilization of all available assets and space is one. Overall, space has transformed society and is instrumental for sustainable development at large.
Today, we are witnessing changes to the conventional ways of operating in space, unlocking an immense range of opportunities, but also leading to challenges, requiring immediate attention and resolution. The dramatic increase in the number and type of actors in space and the consequent rapid growth of satellites have strong implications on the space environment.
The United Nations has served as a convener for deliberations on space affairs since the beginning of space activities and has been successful in addressing the most pressing issues. It provides a unique

intergovernmental and global platform for the benefit of everyone. Proactive multilateralism within the UN serves not only to expand access to space, but to ensure responsible behaviour in space for the benefit of human mankind.

Chaired by Ms. Simonetta di Pippo, Director UN Office for Outer Space Affairs

Introductory keynote on "Monitoring our planet from space": Mr. Josef Aschbacher, Director General of the European Space Agency

Panellists (subject to further updates):
• Mr. Marcos Pontes, Minister of Science, Technology and Innovation of Brazil, former air force pilot and first South American astronaut in space
• Mr. Jean Loup Chrétien, a retired Général de Brigade in the Armée de l'Air de France and former CNES and NASA astronaut. He was the first Western European in space and the first non-American and non-Russian to perform an extra vehicular activity.
• Ms. Ilaria Cinelli, AIKO Space Autonomous Missions, Mentor of Space4Women network of UNOOSA, president of the Aerospace Human Factors Association
• Ms. Zainab Azim, Co-Founder of G.I.V.E and Youngest Member of Virgin Galactic's Future Astronaut Program

EU-CTBTO panel discussion on Youth

G5 – Securing a nuclear test-free world for Youth and the next generations

The European Union and the Comprehensive Nuclear-Test-Ban Treaty Organization enjoy a long-lasting partnership, underpinned by the EU's political commitment to promote the universalization and the entry into force of the CTBT. The extra-budgetary support received over the past ten years from the European Union averages almost 30 mio EUR. Under specific focus has been the EU staunch support to the CTBTO work on engaging the next generation of experts through the CTBTO Youth Group, which bring together over 1200 young people from over 115 countries to advance with the EU imperative of strengthening international cooperation.

The EU-CTBTO panel will examine how the cooperation between the EU and the CTBTO has contributed to the CTBTO efforts to engage youth in amplifying the efforts to advance the CTBT entry into force, strengthen their capacities in the nuclear non-proliferation and disarmament spheres and move a step closer to the EU's commitment of a world without nuclear weapons. It will also discuss the main requests and suggestions from youth to policy makers on advancing the CTBT.

Moderator: Ms Maria Chepurina (CTBTO Preparatory Commission, Vienna, Austria)

Welcoming remarks:
• Mr. Lassina Zerbo, Executive Secretary, CTBTO

Panellists:
• Mr. Stephan Klement, Ambassador and Head of the EU delegation in Vienna and Permanent Representative to the Vienna International Organizations
• Ms. Leena Al-Hadid, Ambassador of the Hashemite Kingdom of Jordan to the Vienna based International Organizations and CTBTO
• Ms. Marjolijn Van Deelen, EU Special Envoy on Non-Proliferation and Disarmament
• Ms. Yeseul Woo, CTBTO Youth Group
• Mr. Alan Juarez, CTBTO Youth Group

Highlight talks

Highlight talk on the Solid Earth and its Structure

H1-720 – Imaging the Earth's Deep Interior using seismic waves

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Forty years ago, the first global seismic tomographic models revealed the presence of two large, antipodal, structures at the base of the Earth's mantle, now known as "large low shear velocity provinces" (LLSVPs), that had no obvious relation to surface geology or mantle dynamics as understood from plate tectonics theory, and as reflected in near surface seismic structure.
With the expansion of digital, very broadband seismic networks and related on-line databases, combined with improvements in theory and computer power, the resolution of mantle elastic structure has progressively improved. In this lecture, I will illustrate how state-of-the-art imaging techniques allow us to: track the fate of tectonic plates that dive back into the mantle beneath the Pacific "ring of fire", improve our understanding of the morphology and role of the LLSVPs, and follow the paths of deeply rooted hot mantle plumes, as they ascend towards the surface and are expressed there in the form of hotspot volcanism (of which Hawaii and Iceland are prominent examples). I will present some of the open science questions, technical challenges for further progress in full waveform tomography, as well as possible paths ahead to address them, combining tools from seismology and other geophysical disciplines.

Highlight talk on the Oceans and their Properties

H2-716 – Improving ocean monitoring through the expansion of the global seismographic network on the seafloor

Author: John Orcutt[1]

[1] *University of California, San Diego, CA, USA*

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There is rapidly expanding interest in the application of seismological tools for exploring the structure and dynamics of the seafloor from the inner core to the nature of the ubiquitous sediments which cover most of the seafloor. New technologies are making access to the oceans less expensive, while recently acoustic telemetry has supported the continuous transfer of data from broadband systems at the seafloor to autonomous vehicles and thence to satellites and laboratories with latencies of 2-3 minutes. The growing availability of Low Earth Orbit (LEO) communications satellites will reduce latency while increasing bandwidth.
New seafloor sensors have reduced noise levels comparable to those of the best stations on land. New batteries and compact electronics have extended seafloor lifetimes to 1-3 years. There are few barriers to growth of capabilities at rates that are comparable to consumer electronics with technological turnovers of no more than three years. Of course, this requires a continuous evolution of the

seafloor technologies at a similar pace.
Novel ocean technologies have the potential of enhancing the monitoring of the ocean environment and complement the CTBTO's hydrophone network of moored hydrophones. Surveillance systems that serve ocean data will become ubiquitous and less expensive than present systems. Overall, improved data rates and enhanced knowledge of the complex structure of the seafloor can contribute to a wide range of scientific initiatives linked to the United Nations sustainable development goals and hazard mitigation.

Highlight talk on the Atmosphere and its Dynamic

H3-715 – Progress and Challenges in Atmospheric Sciences

Author: Guy Brasseur[1]

[1] *Max Planck Institute for Meteorology, Hamburg, Germany*

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Our understanding of atmospheric processes has increased dramatically since the 19th century with important advances in observational techniques and global monitoring, numerical modeling as well as weather, climate and air quality forecasting. Efforts continue around the questions of atmospheric and climate predictability as well as the combined role of dynamical, physical and chemical processes from the lower to the upper atmosphere. The present paper will provide an historical perspective on the progress made during the last two centuries and highlight by some specific examples our ability to treat today complex questions related to the Earth system. The response of the atmospheric chemical system to the slowdown of the world economy during the COVID-19 pandemic will be presented to illustrate our current modeling and observational capability.

Invited talks

The 25th anniversary for opening the CTBT for signature: invited talk on Seismic technology

I01-722 – Challenges and Achievements of Monitoring for Nuclear Test Explosions in the Context of the CTBT

Author: Paul G. Richards[1]

[1] *Lamont-Doherty Earth Observatory of Columbia University, New York, NY, USA*

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Close acquaintance with details of the CTBTO's International Monitoring System and the International Data Centre can tempt a keynote speaker to present the work as highly complicated, with success coming only via enormous effort. But stepping back from details such as the very size of datastreams received by headquarters in Vienna, and of datasets accumulated after nearly 25 years of operations, it is more important to note the main achievement of the IMS and IDC — namely that the CTBTO draws appropriate attention to events which member States can choose to study in greater or lesser detail. Intense efforts can then be brought to bear on events of particular interest, as deemed necessary by any data user.
This presentation will review the basic steps in detecting and analyzing the variety of types of signals generated by nuclear test explosions. It will then present examples of how nuclear test explosions were recorded, first in the earliest days of nuclear weapons development; how these data changed over the forty years leading up to the agreed CTBT text of 1996; and then how data acquired in the present century can be processed using the latest methods applied to broad areas.

The 25th anniversary for opening the CTBT for signature: invited talk on Hydro-acoustic technology

I02-718 – The CTBT Hydroacoustic Network at 25 years

Author: Martin Lawrence[1]

Co-authors: Georgios Haralabus[2]; Mario Zampolli[2]; Peter Louring Nielsen[2]; Jerry Stanley[2]

[1] *Sydney Institute of Marine Science, Sydney, Australia*

[2] *CTBTO Preparatory Commission, Vienna, Austria*

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This presentation addresses the history of the CTBT hydroacoustic network, from its broad definition during negotiations of the Treaty through its establishment over the 25 years following the opening for signature of the CTBT.
Hydroacoustic network discussions during the negotiation of the CTBT will be addressed, including rationale for decisions that were made. The network concept was further solidified during the early years of the CTBTO, leading to the first Hydroacoustic Operational Manual.
The early work on establishing the hydrophone stations required innovative thinking to establish

stations that would work as specified, be highly reliable, and be as maintainable as possible.
The progressive build-up of the hydroacoustic network has led to its current status of being the only fully certified technology in the CTBT network. It is a unique global observatory which is providing data not just for CTBT purposes, but also data for various civil and scientific uses. The underwater location of major elements of the hydrophone stations causes difficulties in sustaining them. Underwater repairs/replacement are very expensive, complex, and time consuming which provides a challenge in both installing highly reliable equipment and dealing with failure when it does occur.

The 25th anniversary for opening the CTBT for signature: invited talk on Infrasound technology

I03-714 – 25 years of infrasound monitoring: achievements and new challenges

Author: Elisabeth Blanc[1]

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The infrasound International Monitoring System (IMS) is a unique tool for atmospheric observations due to its high capacity for long-range detection and localisation. Its development motivated technological innovation in sensors, array stations and automatic detection algorithms. The rapidly increasing number of certified stations provided a large diversity of man-made and natural events, well identified thanks to their precise description. Numerical simulations, based on revisited propagation laws, quantified its high performances and variability. Data analyses then clearly demonstrated that the simulation uncertainties originate from the middle atmosphere variability, which controls the infrasound waveguides and is under-represented in models. Unexpectedly, relevant atmospheric parameters were identified in signals from well-known sources such as volcanoes, opening new remote sensing possibilities. The IMS is associated to complementary networks in the Atmospheric dynamics Research InfraStructure in Europe (ARISE) framework, providing an improved description of the middle atmosphere disturbances relevant both for infrasound monitoring and applications such as medium-range weather predictions. Today, archived data reveals climate change effects on specific events such as icebreaking or lightning activity and a remote volcano monitoring system is developed to provide alert to civil aviation, showing the high IMS potential for weather, climate and civil security applications.

The 25th anniversary for opening the CTBT for signature: invited talk on Radionuclide technologies

I04-717 – The IMS radionuclide network- a unique machine not yet fully exploited

Author: Anders Ringbom[1]

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The IMS Network of 80 particulate and 40 radioxenon measurement systems is one of its kind in several ways. The global coverage combined with high time resolution contributes to a unique, steadily growing data set available to all CTBT member states.
The requirements of the verification regime, formulated more than 25 years ago, prompted the development of new measurement technologies, such as automated particulate samplers and radioxenon systems. The area of radioxenon detection in particular got a considerable boost, and still remains a very active research area.

However, I believe we just got started on the journey towards an even more effective verification regime. Besides describing the development of the past 25 years, I will try to look into the future and discuss a few topics that I believe will be important in the years to come.
The development has so far mainly been focused on the individual measurement systems, achieving high measurement sensitivity with high reliability. Less effort has been put on optimizing the network as a whole, with the goal to maximize the combined capability to detect, locate and characterize release sources. I am convinced that by viewing the network as a single measurement system, many improvements still can be made, both with respect to measurements as well as data analysis.
Another important remaining task is to identify as many background sources as possible. There are many unexplained detections in the network, and understanding the causes for these is absolutely crucial to the CTBT verification regime.

The 25th anniversary for opening the CTBT for signature: invited talk on Challenges of On-Site Inspections

I05-727 – Status of Preparations for the Support of On-site Inspections

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Twenty-five years ago, in 1996, the opening of the CTBT for signatures was followed by the Resolution of the General Assembly on establishing the Preparatory Commission (PrepCom) for the CTBTO (Resolution). According to this Resolution the PrepCom is required to make all necessary preparations for the support of on-site inspections (OSI) from the entry into force of the Treaty.
This contribution will provide an overview of the remarkable development and interrelationship of OSI capabilities particularly regarding the methodology for the planning and conduct of an inspection, the application of the permitted inspection techniques and the training of (surrogate) inspectors. It will also assess the status of preparations as specified in paragraph 15 of the Annex to the Resolution. Examples of co-operation between the States Signatories and the Provisional Technical Secretariat will illustrate some of the achievements.
Ongoing technical developments and innovations will be discussed with a view to identifying opportunities for further improvement of OSI capabilities within the framework of the Treaty and its Protocol in order to make inspections more efficient and effective. Finally, thanks to the current status of the OSI capabilities, the potential for and ideas on using these capabilities for civil applications will be presented as well.

Invited talks on Civil and Scientific Applications

I06-719 – Sustainable Development, Disaster Risk Reduction and CTBTO Verification Regime

Author: Ocal Necmioglu[1]

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Natural disasters are increasing in frequency and intensity, becoming extreme and complex and have been affecting many countries over recent years. The UN 2030 Agenda for Sustainable Development recognizes and reaffirms the urgent need to reduce the risk of disasters. The need for modern, multi-hazard disaster response systems to strengthen the national and collective ability to prevent and prepare for emergencies is evident. Early warning is a major component of disaster risk reduction with the potential to prevent loss of life and reduce the economic and material impacts of disasters. The Sendai Framework for Disaster Risk Reduction 2015-2030 recognizes the benefits

of multi-hazard early warnings systems and places them in one of its seven global targets. Noting that approximately 2.5 billion USD has been invested in the CTBT Verification Regime so far, the recognition and promotion of the civil and scientific use of its data, ranging from tsunami warning to volcano monitoring, from climate change to better understanding of the ocean processes and marine life, is critical to maintain Member State and public interest and investment in this state-of-art system, even beyond Entry Into Force of the CTBT, also to preserve national CTBT verification capacity in a sustainable manner.

Invited talks on Civil and Scientific Applications

I06-721 – Civil and Scientific Applications of IMS Data

Author: Zeinabou Mindaoudou Souley[1]

[1] *CTBTO Preparatory Commission, Vienna, Austria*

Although the main purpose of the International Monitoring System (IMS) is nuclear explosion monitoring, this unique asset of available global data may also be used for scientific and civil purposes. Scientific applications follow the decision of the CTBTO PrepCom from November 2000, in which it was stated that the PTS may provide IMS data and IDC products to organizations for the purpose of conducting research associated with the development of the IMS and IDC. Since 2011, the virtual Data Exploitation Centre (vDEC) has allowed scientists and researchers access to the CTBT's IMS data. Following the Sumatra earthquake on 26 December 2004, it was decided that national and regional tsunami warning centres recognized by IOC/UNESCO can sign an arrangement with the CTBTO to receive IMS data for tsunami early warning. After the Fukushima Daiichi nuclear power plant accident, the CTBTO became a member of the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE). Further civil applications for disaster risk reduction have been proposed. This presentation reviews the progress on civil and scientific applications made in the 25 years since the opening of the CTBT for signature.

Invited talk on Risk Mitigation

I07-529 – Use of infrasound data for early notification of Volcanic Ash Advisory Centres

Authors: Philippe Hereil[1]; Greg Brock[2]; Paula Acethorp[3]; Andrew Tupper[4]; Pierrick Mialle[5]; Alexis Le Pichon[6]; Emanuele Marchetti[7]

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[5] *CTBTO Preparatory Commission, Vienna, Austria*

[6] *Commissariat à l'énergie atomique et aux énergies alternatives (CEA), France*

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Continuous progress has been made in the potential use of infrasound data in support of the International Civil Aviation Organization (ICAO) International Airways Volcano Watch. This work was initiated by a collaboration between CTBTO and the Toulouse Volcanic Ash Advisory Centre (VAAC), resulting in the development of the Volcanic Information System (VIS), under the ARISE (Atmospheric dynamics Research Infra-Structure in Europe) project. VIS provides notifications of possible volcanic activity based on infrasound observations by stations in the IMS (International Monitoring System) and other national or research installations. After successful tests using recent

eruption data, an alerting bulletin prototype based on VIS has been designed for Toulouse VAAC. Two types of notifications are worthwhile: one in the far field (for early detection of eruptive activity and possible ash emission from poorly instrumented explosive volcanoes); and one in the close field (to enrich the description of the kinetic energy of the eruption and of the volcanic ash release). ICAO and World Meteorological Organization (WMO) encourage the effort to continue with the extension of the proposed approach to other VAACs. This essential step will help in designing new automated products that could contribute to reducing the impact of ash clouds on aviation.

Promotional text: With the recent progress in the potential use of infrasound data in support of the International Airways Volcano Watch, another step forward has been made towards the implementation of an early notification of ash clouds by an information system based on infrasound data.

Preceding talk on Human versus Machine

I08-723 – Knowledge vs Data

Author: Stuart Russell[1]

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For most of its history, AI focused on knowledge-based systems – that is, systems that know things and can reason with that knowledge. In the preceding decade, knowledge was replaced by data and reasoning disappeared. Unfortunately, the absence of knowledge means that modern AI systems based on deep learning require vast amounts of training data and generalize very poorly. In contrast, humans know a lot and learn effectively from very few examples. This is not a
coincidence. It is entirely possible to combine knowledge and data, reasoning and learning. One technology that does this is
probabilistic programming, which combines several important ideas from mathematics including logic, probability, and universal machines. I will illustrate these ideas in the context of CTBT monitoring.

Preceding talk on Synergy among monitoring systems to address hazard mitigation and global challenges

I09-742 – Welcome to risk: As we know it or, do we?

Author: Loretta Hieber-Girardet[1]

[1] *United Nations Office for Disaster Risk Mitigation, Geneva, Switzerland*

Risk is systemic, interconnected and cascading. The COVID-19 pandemic has just sent a stark reminder to the world that the days of one hazard, one impact are over. A NATECH event like a tsunami leading to a nuclear disaster is just another manifestation of the cascading nature of risk. Climate change is further driving risk across borders, with impacts on all sectors and with long-lasting, debilitating socio-economic and environmental consequences. The people hit hardest are those who have done the least to cause these significant changes.
It is this complex nature of risk that underpins the Sendai Framework for Disaster Rick Reduction 2015-2030 that marks a paradigmatic shift towards a prevention lens for disaster risk management. UNDRR supports UN Member States in strengthening their risk knowledge, monitoring and capacity-development to accelerate risk-informed development pathways and humanitarian action.
As Member States move forward with the 2030 Agenda, they need to identify and analyse the broad range of risks they face and put in place appropriate measures to address the systemic nature of risk. 'Business as usual' approach will keep us off-track the development trajectory and we need a transformative change to enhance the resilience of the planet and its people.

Series of talks on the Antropocene

I10-749 – Multiple Reasons for the Anthropocene – Paul Crutzen's Contribution to Save Planetary Boundaries

Author: Hartmut Grassl[1]

[1] *Max Planck Institute for Meteorology, Germany*

The present geological epoch is now called "Anthropocene" by most scientists and increasingly by the public, largely stimulated by Paul Crutzen's papers of 2000 and 2006 with this title. This geological epoch is not yet officially accepted, and the exact start time is debated. Whether the Anthropocene started with the steam engine in 1834, Crutzen's proposal in 2006, or the Trinity nuclear test explosion in 1945 as proposed by the Anthropocene Working Group is rather secondary. It is clear that homo sapiens is dominating planet Earth and has already transgressed save planetary boundaries for several element cycles (e.g. carbon, nitrogen). Hence, we have to reverse the trend by global governance. As done successfully with the Montreal Protocol as part of the Vienna Convention to Protect the Ozone Layer, for which Paul Crutzen's Nobel Prize honored research laid the foundation, and as since 2016 tried by the Paris Agreement to the United Nations Framework Convention on Climate Change. We have not only to discuss but to avoid very close tipping points of the climate system, like the complete melting of the Greenland ice sheet. To many of these scientific challenges Paul Crutzen has strongly contributed.

Series of talks on the Antropocene

I10-752 – Artificial radionuclide fallout: a marker for the start of the Anthropocene Epoch

Author: Colin Waters[1]

[1] *University of Leicester, United Kingdom*

The Anthropocene Working Group of the Subcommission on Quaternary Stratigraphy is tasked with gathering evidence to assess the Anthropocene as a potential new formal unit within the Geological Time Scale. If approved, this would be the first such unit that directly reflects a pervasive shift in the Earth System due to human activities. Evidence includes the appearance and rapid dispersal of many new mineral forms, rock types and modification of sedimentary processes. Biological evidence includes the irreversible consequences of extinctions, unprecedented species invasions and dominance of domesticated species. Recent climate and sea level trends are outside the trajectory of the previous ~11,000 years. Chemical signals include isotope patterns altered by unprecedented perturbations to the carbon and nitrogen cycles, with many disseminated metal and persistent organic pollutants forming novel signatures. Anthropogenic influence on geological signals commenced thousands of years ago, but the mid-20th century provides the most pronounced inflection in most global trends, reflecting surges in human population, energy consumption (especially hydrocarbons), technological innovation and international trade. Despite atmospheric testing of nuclear devices not being a fundamental cause of this Earth System shift, these detonations have left almost globally synchronous radionuclides traces ideal for marking the onset of the Anthropocene in multiple geological archives. This presentation details the variable nature and associated problems related to using the so-called "bomb-spike" and ongoing plans for developing a proposal for a formal "golden-spike" section in potential host environments.

Invited short talks

Series of talks on 25 years of CTBT: Seismic technology

Is1-353 – New applications at the IDC for SHI Expert Technical Analysis

Authors: Ivan Kitov[1]; Mikhail Rozhkov[2]; Yuri Starovoyt[2]; Ronan Le Bras[1]

[1] *CTBTO Preparatory Commission, Vienna, Austria*

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The Preparatory Commission for the CTBTO (Commission) routinely process time-series data from a global network of seismic, hydro-acoustic, and infrasound (SHI) stations. The data are processed to detect, build, locate, and screen events that may have characterization parameters similar to those from nuclear explosions. The observation and processing systems are required to be sensitive to small (e.g. low-magnitude) events, especially in unusual locations (e.g. aseismic regions). In order to match this requirement and to assist the State Parties to identify the source of specific events the IDC develops services combined in one SHI Expert Technical Analysis (ETA) Suite. The Parametrical Moment Tensor Estimator, ParMT (depth and magnitude determination through the moment tensor estimation) and the IDC historical master event-based Spot Check Tool, SCT, are the ongoing IDC developments. A promising avenue to improve the ParMT results, as well as for enhancement of IDC (mostly regional) locations, is to embrace the Ambient Noise Tomography technique in IDC practice. Receiver velocity models underneath IMS stations can be improved using the vast amount of gathered seismic background data. The same approach can be utilized for OSI data processing using the ANT-based velocity models produced with the noise data from SAMS array.

Promotional text: New applications for in-depth analysis of the SHI data are under development at the IDC.

Series of talks on 25 years of CTBT: Hydro-acoustic technology

Is2-283 – Advancements in hydroacoustic signal processing at CTBT IDC during the past two decades and plans in the future

Author: Peter Louring Nielsen[1]

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Since its establishment in 1997, the CTBT IDC has been receiving data continuously from an increasing number of hydroacoustic stations. These stations are at present composed of 11 hydrophone triplets in the ocean and 5 T-stations (seismometers) on land monitoring for nuclear explosions in the oceans. This presentation summarizes advancements in the IDC automatic processing system

from the early deployment of the system receiving data from a couple of hydroacoustic stations until today's hydroacoustic network. The advancement in IDC processing of hydrophone data has been obtained in underwater signal travel time modelling, improved rule-based signal classification, estimate of underwater signal detection and direction of arrival, introduction of early artificial intelligence for signal classification, and global network processing based on an advanced Bayesian framework (NET-VISA). These advances have improved the automatic signal classification, detection and event localization and therefore importantly reduced the amount of human interaction in the data processing. Further improvements of the processing are envisioned that includes detailed oceanographic models and databases, efficient complex signal propagation models, the Progressive Multi-Channel Correlation (PMCC) algorithm and the rapid development of machine learning algorithms. These future elements are proposed in an updated IDC automatic data processing paradigm.

Promotional text: Advances in oceanographic and hydroacoustic physics-based models, data processing algorithms and high-performance computing facilities provide opportunities to reduce uncertainties in monitoring and verification of possible nuclear explosions in the oceans.

Series of talks on 25 years of CTBT: Infrasound technology

Is3-381 – Infrasound processing system at the IDC, from rudimentary to maturity

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In 2001, when the first data from an IMS infrasound station started to arrive in near real-time at the IDC, its infrasound processing system was in a premature state. The IDC then embarked for a multi-year design and development of its dedicated processing system, which led to operational IDC automatic processing and interactive analysis systems in 2010. The IDC went on in the next ten years to produce over 40,000 infrasound events reviewed by expert analysts.
In an effort to continue advancing its methods, improving its automatic system and providing software packages to CTBTO users, the IDC focused on several projects. First, the automatic system for the identification of valid signals was redesigned with the development of DTK- PMCC (Progressive Multi-Channel Correlation), which is made available to CTBTO users within NDC-in-a-Box. And second, an infrasound model was developed for automatic waveform network processing software NET-VISA with an emphasis on the optimization of the network detection threshold by identifying ways to refine signal characterization methodology and association criteria.
Future improvements of the IDC processing system are planned to further reduce analyst workload that includes atmospheric propagation modeling and enhancements of the automatic pipeline components.

Promotional text: A review of 20 years of infrasound technology at the IDC, from the first IMS data received to the introduction into IDC operations, and a glimpse into the future IDC infrasound system.

Series of talks on 25 years of CTBT: Atmospheric Transport Modeling (ATM)

Is4-332 – Advancements in Atmospheric Transport Modelling (ATM) at the CTBTO PTS during the past two decades and plans for the future.

Author: Jolanta Kusmierczyk-Michulec[1]

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CTBT monitoring for nuclear explosions is based on detection of waveform signals and the related event localization and on detection of traces of treaty-relevant radioisotopes in the atmosphere. However, 25 years ago it was a challenge to obtain a clear link between a seismic event and a series of radionuclide detections. This was changed when the proper Atmospheric Transport Modelling (ATM) system with special postprocessing routines was implemented and the relevant expertise built up. The effectiveness was demonstrated by providing ATM support during events of special interest like the Fukushima accident and the nuclear tests announced by the DPRK. The lessons learnt triggered enhancements. For example, the ATM support during the first DPRK event in 2006 led to the extension of backward trajectories from 6 to 14 days. More recent enhancements include an increase of spatial resolution from 1 degree to 0.5 degree and of time resolution from 3 hours to 1 hour. PTS aims at developing a world-class ATM system and takes all opportunities to validate it against systems from other major ATM centres like participation in multi-model exercises called ATM Challenge. This presentation also addresses the plans for the next years and vision for the longer term.

Promotional text: The challenge to link a seismic event and radionuclide detections is mastered by atmospheric transport modelling with special postprocessing routines. Its effectiveness was demonstrated on special events like nuclear tests announced by the DPRK, but more enhancements are planned.

Series of talks on 25 years of CTBT: On-Site Inspections

Is5-239 – Development of the first comprehensive draft list of equipment for use during OSIs

Author: Gregor Malich[1]

Co-authors: Xavier Blanchard[1]; Peter Labak[2]; Robin Riedmann[1]; Guillermo Rocco[3]; Aled Rowlands[1]

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The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (Commission) is required to develop and prepare a list of equipment for use during on-site inspections (OSIs). The Commission started work on this verification task as early as during the first OSI workshop in 1997 and has since considered both the structure of the list and the specifications of the equipment to be listed.
A proposal for the first comprehensive draft list of equipment for use during OSIs has been presented by the Provisional Technical Secretariat of the Commission as a result of the implementation of OSI Action Plan 2016-2019. Taking into account relevant Treaty provisions and guidance from the Commission's policy making organs, it covers all permitted inspection activities and techniques with the exception of drilling and is currently undergoing review by States Signatories.

This presentation provides a summary of the development of the first comprehensive draft list of equipment for use during OSIs from the outset. It highlights how advances of science and technology have influenced proposed specifications of OSI equipment since the CTBT opened for signature and outlines why the draft list will mark an important milestone in the development of OSI capabilities.

Promotional text: The presentation shows how advances of science and technology have influenced the development of OSI capabilities since the CTBT opened for signature and therefore contributes to the objective of identifying opportunities and methods for improving verification.

Series of talks on 25 years of CTBT: Data analysis

Is6-454 – Machine learning prospects for automatic SHI processing

Authors: Christos Saragiotis[1]; Ronan Le Bras[1]; Vera Miljanovic Tamarit[1]; Megan Slinkard[1]

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At the time of the opening of the Comprehensive Nuclear-Test-Ban Treaty for signature in 1996, machine learning was a relatively young but already established data analysis method in some fields. However, in seismology it had not reached a sufficient level of maturity to be considered for Treaty monitoring purposes. Furthermore, machine learning requires computational capabilities that exceeded the capabilities of most data centres at that time. Automatic processing at the International Data Centre (IDC) followed the standard, tested and established processing methods benefitting from knowledge that the seismological community had been accumulating for decades. As the years have progressed these barriers have been overcome; computational capabilities have reached unprecedented heights and numerous machine learning methods and tools have been developed in the field of seismology, including the NET-VISA software, a physics-based bayesian approach, used operationally at the IDC. We will discuss further machine learning prospects for the IDC and in particular how deep learning can help the IDC enhance its capabilities regarding phase detection, identification, association as well as event location and classification.

Promotional text: Machine and deep learning prospects in the IDC to enhance phase detection, identification, association as well as event location and classification.

Series of talks on 25 years of CTBT: Radionuclide Technologies

Is7-604 – Review and outlook of radionuclide screening methods for discriminating nuclear explosion signals from normal radioactivity background in the atmosphere

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For the International Monitoring System (IMS) to be effective, it is vital that nuclear explosion signals can be distinguished from natural and man-made radioactivity in the atmosphere. The International

Data Centre (IDC) applies standard event screening criteria, with the objective of characterizing, highlighting, and thereby screening out, events considered to be consistent with natural phenomena or non-nuclear, man-made phenomena. This presentation looks back to the initial understanding of possible screening methods in the early years of CTBT negotiations, summarizes the development of the categorization schemes and screening flags applied in the IDC reports for each particulate and noble gas sample, and reviews new proposals and open issues for discriminating nuclear explosion signals from normal radioactivity background in the atmosphere. There is still high need and ample room for enhancing radionuclide screening methodologies. This presentation sketches out what methods that were already demonstrated can be enhanced and implemented in the coming years, which novel methods appear promising to be developed and it creates a vision of highly effective screening for the longer future.

Promotional text: Much has been achieved in developing methods for radionuclide screening, but future developments will make the detection of radionuclide signals of nuclear explosions much more effective.

Panel discussions

Panel discussion on Resilience of the CTBT monitoring regime, including Lessons learned from the COVID-19 pandemic crisis

J02 – Lessons learned from the COVID-19 pandemic crisis as a Resilience of the CTBT monitoring regime

Moderator: Stefka Stefanova[1]

Panellists: Alexey Anichenko[2]; David Hardman[3]; David McCormack[4]; Katrin Hafner[5]; Paola García Peña[6]

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The global pandemic of the past year has put a substantial amount of strain on many systems, with the CTBT monitoring regime being no exception. At the same time, the crisis has proved to be a significant and valuable resilience test. This panel explores the impacts of the COVID-19 pandemic on the establishment, operation, maintenance and sustainment of the IMS monitoring network, and the measures that were taken to ensure continued data availability and timely delivery of monitoring products. Lessons learned, possible follow-up steps and measures to assure a sustainable and resilient monitoring regime into the future are also discussed, with perspectives provided from Member States Station Operators, National Data Centres (NDCs) and the point of view of organizations with operational experiences gathered from the field during this period of time.

Panel discussion on Lessons from historic nuclear test explosions and value of recorded signals for monitoring science

J03 – Lessons from historic nuclear test explosions and value of recorded signals for monitoring science

Moderator: Rong Song Jih[1]

Panellists: David Bowers[2]; Inna Sokolova[3]; Lars Ceranna[4]; Paul G. Richards[5]; Xiaoming Wang[6]; Yurii Dubasov[7]

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The nuclear tests announced by the DPRK provided an opportunity to test methods and gain experience with respect to the estimation of the absolute and relative event location, depth and magnitude. However, this experience is limited to one specific test location. Much broader experience can be gained by applying modern analysis methods to the vast amount of data recorded on more than 2000 historic nuclear test explosions. To support such developments, valuable progress towards preserving and making available for research digitized data of historic nuclear explosions has been made. The goal of this session is to identify the priorities for continuing and expanding these efforts. Historic data are needed from as many as possible different regions and geological characteristics. Signals should be preserved from tests in the atmosphere, underwater and underground. While most ongoing efforts focus on seismic data, the historic hydroacoustic and infrasound data are rare and radionuclide data are sparse.

Panel discussion on Innovation affecting CTBT – pertinent to IMS monitoring system (sensors)

J04 – Innovation affecting CTBT: pertinent to IMS monitoring system (sensors)

Moderator: Nurcan Meral Özel[1]

Panellists: Geoffrey Cram[2]; Guilhem Douysset[3]; Roger Waxler[4]; Shuichi Kodaira[5]; Thomas Bruns[6]

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The CTBT IMS employs four monitoring technologies: seismology, infrasound, hydroacoustics and radionuclide (both particulate and noble gas). It is vital that the PTS stays abreast of new developments related to all sensor types to maintain its high-performance level, and network sustainability, in order to safeguard and improve the Treaty Verification capability. This panel will discuss new generation sensors that may already be available, and innovative efforts for future developments. Potential areas of discussion are networks of infrasound sensors, combination of rotational and directional seismic sensors, modular design hydroacoustic hydrophone stations, SMART underwater cables and sensors, fibre-optic seismometers and hydrophones, improved concepts for particulate radionuclide stations, new generation of noble gas stations.

Panel discussion on Innovation affecting CTBT – pertinent to IDC data analysis

J05 – Innovation affecting CTBT: pertinent to IDC data analysis; needs, ideas and implementation pathways

Moderator: Megan Slinkard[1]

Panellists: Claire Labonne[2]; Harry Miley[3]; Hua Li[4]; Nimar Arora[5]; Stephen Myers[6]

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The purpose of this panel is to generate discussion about how data and data analysis approaches can improve IDC processing, and how to go about introducing new approaches at the IDC. It will leave participants with a better understanding of where data analysis improvements are still desired by the PTS, what new tools are emerging which might be intriguing to apply to our scenarios, where new analysis approaches have made a big difference, and how things need to be tested in order to facilitate ease of acceptance at the IDC.
Themes in data analysis include moving from parameters to full waveform, using machine learning and pattern-recognizing approaches, and improving understanding of uncertainties. Discussion will include focus on these themes, and also on data-fusion applications, new pipeline paradigms, and cases where improvements in multiple areas may have non-linear improvements.

Panel discussion on Civil and scientific applications

J06 – Civil and scientific applications - prospects

Moderators: Georgios Haralabus[1]; Jolanta Kusmierczyk-Michulec[1]

Panellists: Alexandra Iezzi[2]; Christian Maurer[3]; Mohamed Nabil Mohamed ElGabry[4]; Ocal Necmioglu[5]; Wenbo Wu[6]; Xyoli Pérez-Campos[7]

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[7]*National Seismological Service, Mexico*

The data recorded by CTBT's International Monitoring System constitute a unique trove of knowledge with a broad range of civil and scientific applications. In the last decade, thanks to the establishment of the virtual Data Exploitation Centre (vDEC), it became possible for international experts to have access to these data to conduct research and to publish new findings, while the organization would gain from the knowledge transfer and interaction between internal and external experts. The list of possible applications that exploit CTBT data is long and includes e.g. scientific studies on bolides, marine mammal migration studies, discrimination between earthquakes and man-made events, investigation of the Earth's interior, investigation of source depth characteristics from large explosions or validation of atmospheric transport modelling. It includes as well civil applications, such as contribution to tsunami warning centres, the impact of ocean noise on whales, ocean thermometry and climate change.

Panel discussion on Regional data for treaty monitoring

J07 – Regional data for treaty monitoring

Moderator: Christos Saragiotis[1]

Panellists: Atalay Ayele[2]; Michelle Grobbelaar[3]; Nortin Peter-David Titus[4]; Robert Mellors[5]; Ronnie Quintero[6]

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[2] *Institute of Geophysics, Space Science and Astronomy of Addis Ababa University (IGSSA), Ethiopia*

[3] *Council for Geoscience, Pretoria, South Africa*

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The International Monitoring System (IMS) was designed as a sparse global network with the purpose of detecting nuclear explosions. The sparseness of the network, the complexity of wave propagation in the Earth's interior, the oceans and the atmosphere and the lack of accurate models that describe it limit the accuracy of the location of events detected by the IMS stations. To improve location capabilities the IMS depends on reference events, also known as ground truth events, that is, events the spatiotemporal origin of which is known with high confidence. The characterization of events as ground truth requires the use of dense national and regional networks and cooperation among National Data Centres (NDCs). Furthermore, such cooperation enhances the monitoring capabilities of the NDCs as it allows them to surpass the capabilities of the IMS. This panel will discuss the synergy between the IMS, regional experts and the NDCs and in particular the benefits Treaty monitoring has reaped from regional expert contributions, how the CTBTO contributes to regional needs and how this synergy can be facilitated and further extended in the future.

Panel discussion on Human versus Machine

J08 – Human versus Machine

Moderator: Heidi Kuzma[1]

Panellists: Anima Anandkumar[2]; Dimitri Kusnezov[3]; Kardi Teknomo[4]; Stuart Russell[5]; Tegawendé F. Bissyandé[6]

[1] *LRH Energy Capital LLC, CA, USA*

[2] *California Institute of Technology, CA, USA*

[3] *Deputy Under Secretary for AI and Technology at the US Department of Energy*

[4] *Petra Christian University, Indonesia*

[5] *University of California, Berkeley, CA, USA*

[6] *University of Luxembourg, Luxembourg*

Big Data, Machine Learning (ML), and Artificial Intelligence are more and more parts of our daily lives with applications such as self-driving cars, multimedia streaming and shopping suggestions, identification of financial crimes, and medical diagnosis.
For CTBT, early adoption of ML methods took place in the 1990s with applications ranging from the monitoring of the network, to data processing and analysis, to the way OSI inspections can be conducted. The methods currently in place could probably be boosted by incorporating improved algorithms, for instance with the use of full waveform-based approaches, and by making full use of the twenty years of accumulated data. Progress has been made recently with a Bayesian approach for network processing.
Even though overall results of applying ML methods are often impressive, domain experts may formulate objections to their use. Reasons may be:
• Skepticism that an ML algorithm would find a solution if the learning data set does not contain an exact example of the result. Are Bayesian methods a way to dispel these criticisms?
• Interpretation of the results. How can a particular result be explained to an expert or a client when many ML methods have imbedded decision-making processes which remain opaque to the user?

Panel discussion on Synergy among monitoring systems to address hazard mitigation and global challenges

J09 – Synergy among monitoring systems to address hazard mitigation and global challenges

Moderator: Bruce Howe[1]

Panellists: Dwikorita Karnawati[2]; Esline Garaebiti[3]; Etienne Charpentier[4]; Steve MacFeely[5]

[1] *University of Hawaiʻi at Mānoa, HI, USA*

[2] *Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG), Jakarta, Indonesia*

[3] *Ministry of Climate Change (MoCC), Vanuatu*

[4] *World Meteorological Organization, Geneva, Switzerland*

[5] *United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland*

This panel will discuss existing or potential synergies between the CTBT and International Organizations and Agencies to address global challenges, disaster risk prevention and mitigation of natural hazards. From the CTBTO's perspective, these synergies are envisioned in the form of International Monitoring System (IMS) data contribution to institutions that utilize data fusion platforms in order to enhance their mission. Initially, the CTBTO provided data to tsunami warning centres (the CTBTO now has a total of 18 tsunami warning agreements in 17 countries). In recent years the scope of this concept was broadened to include earthquake monitoring, volcano eruption monitoring for aviation and maritime safety, underwater acoustic anomalies monitoring, extreme weather events and phenomena, as well as detection of radioactive emission(s) and its dispersion to warn and protect citizens. The objectives of such monitoring systems are in-line with global challenges and the goals outlined in the United Nations' Sustainable Development Goals (2030 Development Agenda), the Paris Climate Agreement, and the Sendai Framework on Disaster Risk Reduction. These links will be addressed in the panel.

Panel discussion on Science communication

J11 – Communicating uncertainty among scientists, to policy makers and the public

Moderator: Peter Rickwood[1]

Panellists: Angela Me[2]; James Gillies[3]; Nimar Arora[4]; Sayed Mekhaimer[5]

[1] *Atomic Reporters*

[2] *Chief Research and Trend Analysis Branch at the United Nations Office on Drugs and Crime (UNODC, Vienna)*

[3] *Particle Physicist and Senior Communications Advisor at CERN (Geneva, Switzerland), former Head of Communications at CERN*

[4] *founder of Bayesian Logic Inc., Berkeley, (California, USA) and inventor and developer of NET-VISA, a Bayesian machine-learning tool for Seismo-Acoustic automatic event association*

[5] *National Data Centre & National Institute of Astronomy and Geophysics (NRIAG), Cairo (Egypt), expert on application of Bayesian inference approaches to address the uncertainty in radionuclide source term estimation*

Uncertainty inherently affects every measurement and each scientific statement. This basic fact is often overlooked in communication between scientists, and even more so in the public conversation on scientific topics. Scientific results, be they the product of preliminary investigations or firmer outcomes of peer-reviewed studies, are often perceived as immutable, overlooking the fact that all findings are subject to continuous scrutiny and revision as new data or theories become available. Regional and cultural perspectives also play a role in the communication and perception of uncertainty. Failure to communicate effectively on this issue can undermine public confidence and have a direct impact on perceptions of risk, and the consequences of such misconceptions have become especially prominent in the context of the global coronavirus pandemic. In the CTBT context, uncertainty is an inescapable element of the characterization and communication of Treaty-relevant

events, as well as in the framework of civil and scientific applications. This panel discussion addresses strategies for effectively communicating uncertainty when reporting about science, with the objective of delivering a clear message to audiences. It is relevant for scientists, policy makers and public information professionals.

Events

Event 1 - Resilience of the CTBT monitoring regime

M1 – Event 1 on Resilience of the CTBT monitoring regime, including lessons learned from the COVID-19 pandemic crisis

Author: Thomas Ludwig Hoffmann[1]

Co-authors: Franz Ontal[1]; Josphat Kyalo Mulwa[2]; Marten Kihlstrom[1]; Nicholas Mascarenhas[1]; Nicolau Wallenstein[3]; Ryohei Emura[4]; Yutaka Tomita[5]

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The COVID-19 pandemic is a major topic of interest for the SnT2021. The global nature of it produced a resilience test for many, and in particular for a global monitoring system, such as the CTBTO's, that relies on continuous data gathering, transmission and analysis. The objective of this series of two events is to provide the audience with pertinent case histories and lessons learned from IMS stations e.g. during O&M activities, station upgrades or logistics challenges, faced by the station operators and PTS during the restrictions imposed by covid-19.
Topics presented in Event 1 are (i) the steps taken to ensure operation and maintenance activities for optimal performance of the IMS stations IS32 and PS24 in Kenya during COVID-19 restrictions, (ii) the upgrade of five auxiliary seismic stations in Japan and how the COVID-19 limitations and restrictions were overcome, (iii) restrictions under the COVID-19 crisis imposed on the operation and maintenance of the radionuclide stations RN37 and RN38 in Japan and how JAEA is working with PTS, manufacturers of RASA and SAUNA, and local operators in order to overcome this challenge, (iv) timeline of the active cases at IS42 infrasound station in the Azores, Portugal, the related constraints and O&M actions taken, with PTS support, to guarantee the Mission Capability of the station. (v) CTBTO/OSI will present a brief review of the OSI Training section's interventions, designed to mitigate the loss of onsite technical training and achieve and maintain true blended learning during and after COVID-19 and (vi) CTBTO IMS/MFS will share examples of logistics and maintenance cases that could have affected data availability and show contingency measures that were implemented.

Event 2 - Resilience of the CTBT monitoring regime

M2 – Event 2 on Resilience of the CTBT monitoring regime, including lessons learned from the COVID-19 pandemic crisis

Author: Stefka Stefanova[1]

Co-authors: Fernando Villacis[2]; Juan Pablo Aguiar[3]; Marcelo Alejandro Fernandez[4]; Nortin Peter-David Titus[5]; Jorge Perez[2]; Thomas Ludwig Hoffmann[1]

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Topics presented in Event 2 are (i) the basis on which INPRES, Argentina, was able to continue providing its essential services during the COVID-19 pandemic and how the face-to-face work and the use of Software for Telework and new work standards affected some PLCA/PS01 station metrics, (ii) how the COVID-19 restrictions affected the operation and maintenance of the IMS infrasound and radionuclide stations operated in Argentina by ARN, (iii) the technical and logistical challenges faced and overcome by INOCAR, Ecuador, while operating and maintaining IS20 and RN24 in Galapagos during the COVID-19 pandemic. (iv) A demonstration of how technical, environmental, logistical and administrative challenges faced at IS35 infrasound station, Namibia, in conjunction with COVID-19 lockdowns, were overcome to bring the station back to life and return it to mission capability, and (v) examples presented by CTBTO IDC/OPS of restrictions imposed by the COVID-19 pandemic that affected the resolution of operational issues with impact on timely data availability/data quality, together with contingency measures employed.

Oral presentations

O1.1 The atmosphere and its dynamic

O1.1-320 – Obtaining the infrasound bulletin for IS08

Authors: Gonzalo Antonio Fernandez[1]; Bastien Joly[2]

Co-authors: Mayra Nieto Canaviri[1]; Jonas Baldivieso[1]; Felipe Condori[1]; Stephanie Godey[2]; Julien Vergoz[2]; Nicolas Brachet[2]; Ruben Tintaya[1]

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The IS08 infrasound array in Bolivia contributes to the International Monitoring System of the Comprehensive nuclear-Test-Ban Treaty Organization since 1999. Real time data, which are received at the Bolivian National Data Center (Observatorio San Calixto, OSC) through a VSAT link, are used on a daily basis for scientific and civil applications. Installed in the Central Andes, IS08 has provided valuable high quality data to the CTBTO community. In 2019, staff from the Bolivian NDC attended a basic training in Costa Rica that provided complementary knowledge in infrasound data processing. Since then, thanks to the support of the French NDC and CTBTO, the OSC staff has achieved a major step by setting up the operational chain of processing for real-time infrasound data acquisition, detection and analysis. DTK-GPMCC and DTK-DIVA are used to produce local and regional infrasound bulletins. We are now able to present our first local IS08 bulletin from 2014 to 2020, which includes a wide variety of infrasound sources observed at different seasons such as microbaroms, volcanic explosions, earthquakes (M>7) and meteors. Further improvements to our daily routine analysis to enhance our local bulletin will include the comparison with Late Event Bulletin (LEB) from CTBTO.

Promotional text: Understanding the local infrasound sources is a challenging task, however we decided to start with local characterization of the most frequently sources observed at IS08 (microbaroms, earthquakes, volcano explosions).

O1.1-389 – The Coherent Infrasound Wavefield: New IMS Broadband Bulletin Products for Atmospheric Studies and Civilian Applications

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Our latest comprehensive reprocessing of the IMS infrasound database covers the period from January 2003 to December 2020, representing up to 53 stations considered. The resulting catalogue of coherent signals obtained using the Progressive Multi-Channel Correlation (PMCC) array processing algorithm with a one-third octave frequency band configuration permits more accurate signal and source discrimination. Here we focus on the relation of coherent ambient infrasound to middle atmosphere dynamics and present advanced bulletin products tailored to frequency bands of specific interest by relevant user groups. These bulletin data products consist of mountain-associated wave events (0.01-0.05 Hz), a low-frequency (0.1-0.3 Hz) and a high-frequency (0.4-0.6 Hz) microbarom dataset, and observations with centre frequencies of around 1 to 2 Hz. The latter include, for instance, large fireballs and volcanic eruptions and thus provide information relevant to dedicated applications for civil security. We present selected aspects of these data products and highlight potential applications for atmospheric studies.

Promotional text: This study builds upon the new global dataset of reprocessed IMS infrasound data (SnT poster by Hupe et al.). Here, we highlight applications and present tailored products being appropriate and useful for atmospheric studies and civil security.

O1.1-457 – Multi-disciplinary characterization of the June 2019 eruptions of Raikoke (Kuril Islands) and Ulawun (Papua New Guinea) volcanoes using remote technologies

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Retrospective eruption characterization is valuable for advancing our understanding of volcanic systems and evaluating our observational capabilities, especially with remote technologies (defined here as a space-borne system or non-local, ground-based instrumentation which include regional [15-250 km range] and remote [>250 km range] infrasound sensors). Two of the largest explosive volcanic eruptions of the past decade occurred in June 2019 at Raikoke, Kuril Islands and Ulawun, Papua New Guinea volcanoes. We integrated data from the International Monitoring System infrasound network, satellites (including Sentinel-2, TROPOMI, MODIS, Himawari-8), and globally-detected lightning (GLD360) with information from local authorities and social media to improve understanding of the eruptive behavior of these volcanoes. Remote infrasound data provide insight into changes in eruption intensity. During both eruptions, the infrasound peak frequency decreases upon transition to the Plinian phase. This may be related to changes in erupted jet and plume dynamics, such as an increase in vent diameter (observed in satellite). Our analysis illustrates the value of interdisciplinary analysis of remote data to illuminate eruptive processes.

Promotional text: Remote (non-local) infrasound data provide critical information in multidisciplinary characterization of two large volcanic eruptions in June 2019.

O1.1-531 – Global microbarom patterns: infrasound ambient noise modelling vs IMS observation database

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Microbarom signals are generated by wind-waves at the ocean surface and propagate all around the globe through the stratosphere and ionosphere. Microbaroms dominate the coherent infrasound ambient noise measured anywhere on Earth, with a particular peak for periods around 5 s. This ubiquitous signal can be used to monitor the medium in which it propagates, allowing to probe the properties of the middle atmosphere. Here we show the first quantitative validation of global microbarom modelling using a new source model, an ocean wave model, and atmospheric attenuation parameterization. The modelling results are compared to a reference database of microbaroms detected by the global infrasound International Monitoring System over seven years to evaluate the influence of ocean waves, source and propagation parameters. This study demonstrates that the new source model performs better than previous models, and is best when this model is combined with a wind-dependent attenuation and an ocean wave model that includes coastal reflection. Better knowledge of ambient ocean noise sources opens new perspectives to enhance the characterization of explosive atmospheric events, and provides additional integrated constraints on middle atmosphere dynamics.

Promotional text: This study main outcome is a first global and quantitative validation of a new microbarom source model. New perspectives arise from coupling this source model with refined propagation models in order to enhance coherent noise characterization and assess middle atmospheric models.

O1.1-536 – Reflection on the importance of IMS-like infrasound stations in volcanologically active areas

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With global increases in population and air traffic, our ability to forecast when and where a hazard will occur is of prime importance. In the case of volcanic eruptions, forecasting is not limited to when and where an eruption will take place, but also when and where the impact of such an eruption will be felt. Cross-boundary volcanic ash from explosive volcanic eruptions is hazardous. The dispersal of volcanic ash could be modeled, however the level of uncertainty drastically depends on our knowledge of the eruption itself. Critical parameters are the duration of the eruption as well as the height of the associated eruptive column. With those 2 parameters you can simulate a range of plausible ash dispersal scenarios. Such parameters could be retrieved by monitoring, research sensors or an array deployed on the flank of the volcanoes. However, in a region with hundreds of active or potentially active volcanoes this is not always possible. We would like to demonstrate a few recent examples for which the IMS and IMS-like (installed in Singapore) infrasound stations were used to extract eruption source parameters.

Promotional text: This presentation aims to demonstrate how useful IMS and IMS-like infrasound stations are in mitigating volcanic impact.

O1.1-596 – Modeling atmospheric transport and dispersion over complex terrain

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The accurate simulation of atmospheric transport and dispersion requires a numerical weather prediction model that is able to resolve both mesoscale meteorology, such as a storm front or sea breeze, and microscale meteorology near the plume source, which is strongly influenced by the presence of complex terrain (i.e., mountains or dense urban development). Current generation numerical weather prediction models are excellent tools for simulating mesoscale meteorology; however, model design constraints present challenges to running at microscale resolutions over complex terrain. These challenges include, but are not limited to, overcoming model restrictions on resolved terrain slopes, parameterizing the effects of turbulent mixing, and appropriately downscaling information from the mesoscale to the microscale. A sequence of field experiments in 2019 at the Lawrence Livermore National Laboratory Site 300 included the controlled generation, observation and monitoring of plumes in a region of complex terrain. Data from these field experiments are used to evaluate model performance and inform model development that will improve the accuracy of transport and dispersion simulations over complex terrain.

Promotional text: This research focuses on understanding and improving the accuracy of atmospheric models used for simulating transport and dispersion over complex terrain.

O1.2 The solid earth and its structure

O1.2-091 – 3D Dynamic Earthquake Rupture Simulations In The Sea Of Marmara

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The center of the Sea of Marmara, the region between the locations of 1912 Mürefte and 1999 Izmit M_w7.4 earthquakes, is prone to creating a large earthquake. The main objective of our study is to determine 3D dynamic earthquake rupture scenarios, considering non-planar and heterogeneous stress distribution in the Sea of Marmara. In this study, it is the first time that we attempt to generate realistic earthquake scenarios by putting constrains on initial stress on the fault using regional stress from earthquake focal mechanisms, in addition to stress release during past earthquakes and strain accumulation during interseismic period using geodetical measurements on slip-rate and locking depth at various segments. We use 3D Finite Element Method (PyLith) for dynamic earthquake simulations and tetragonal mesh for better smoothing at the fault bends, which allows us to implement nonplanar fault geometry and initial stress heterogeneity using slip-weakening friction law. We place constraints on initial shear stress from geodetic and seismic studies of locking depth and interseismic strain accumulation. We consider more than a hundred rupture scenarios and calculate slip distribution, rupture velocity and moment magnitude in addition to slip-rate and traction on the fault surface, and displacement and velocity on the ground surface.

Promotional text: We derive 3D dynamic earthquake fracture simulations for the nonplanar and heterogeneously stressed Main Marmara Fault which is prone to a large event and located very close to İstanbul Metropolitan.

O1.2-165 – P-wave arrival-time tomography of the Middle East

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High-resolution tomographic images of the MiddleEastern region are essential to accurately locate ground motion events during nuclear monitoring programs. The purpose of this study is to retrieve detailed models down to lowermantle beneath the Middle Eastern region using a set of reliable regionally observed teleseismic P arrival times from the ISC-EHB bulletin (Engdahl et al., 1998). Our current inversion results are consistent with the previous regional tomographic studies. In checkerboard tests of cell dimension as low as $\sim 2.4°$($\sim$ 280 km at surface) are well recovered down to a 1000 km depth beneath the Anatolian plateau where we currently have the densest coverage with ISC data. The Caucasus region and northern parts of the Iranian plateau shows good recovery of $\pm 4\%$ Vp perturbation amplitudes at depths $\sim 70 - 135$ km. There is fair recovery for a minimum of $\sim 2.4°$ cell size beneath the Iranian Plateau, Zagros mountain region, Persian gulf, and northeast Iraq. We are able to further improve coverage especially down to lithospheric depths within the Arabian peninsula using first arrival times measured from waveform data collected from regional networks.
The ultimate goal is to perform full-waveform inversion of the region constrained by the constructed P-wave model.

Promotional text: Seismic Imaging of Middle Eastern crust and mantle.

O1.2-238 – Monitoring sub-seafloor deformation in plate subduction zone

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Fault rupture in a subduction zone often causes devastating earthquake and tsunami hazards. Therefore, understanding a slip behavior along the fault is a crucial scientific topic and a deeply socially relevant problem. To understand the slip behavior along the fault, there are two kinds of essential geophysical datasets. One is seafloor displacement as a surface response of a fault slip, and the other is the sub-seafloor structure, which is needed to transform a surface displacement to a fault displacement. Recent studies reveal that surface displacements due to fault slips show a wide-spectrum of their frequency, from a regular earthquake (~10 Hz) to a long-term slow slip (~months). To monitor the entire spectrum of the fault slip, monitoring the displacement with a seismo-geodetic band in real-time continuously is necessary. And also, to transform the displacement to the slip along the fault, it is essential to know a realistic structure of a medium (lithospheric structure) in the subduction zone. JAMSTEC is conducting an integrated geophysical project to establish a real-time continuous seafloor geodetic network in the Nankai Trough, Japan, and construct a three-dimensional structural model using seismic data. We will present an outline and recent results of the project in this presentation.

Promotional text: The sensing and modeling the seafloor displacement can be utilize other kind of monitoring of signal propagating through the earth and/or the ocean, such as signals from Nuclear-Test-Ban.

O1.2-247 – Velocity structure of the uppermost mantle beneath the tanzanian craton and the surrounding proterozoic mobile belts from pn tomography

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The uppermost mantle structure beneath East Africa is investigated by inverting the Pn traveltimes to obtain a model of P wave velocities. The previous Pn tomography models of the region have been expanded. A total of 2870 new Pn travel time measurements of local and regional earthquakes have been made and modeled, improving the resolution of the uppermost mantle velocity structure across much of East Africa. The new Pn tomography model shows variations in uppermost mantle velocities across the region which can be used to understand the size of the Tanzania Craton and the differences between the Eastern and Western branches of the East African Rift System (EARS). Results reveal fast Pn velocities beneath the Tanzania Craton, the extension of these fast velocities beneath the Mozambique Belt to the east of the craton, the Kibaran Belt west of the craton, and beneath the northern half of the Ubendian Belt to the southwest of the craton. In addition, the fast Pn velocities beneath the Western Branch everywhere contrast with the slow Pn velocities of 7.5-7.8 km/s beneath the Eastern Branch in Kenya, showing that the upper mantle beneath the Eastern Branch has been altered much more than beneath the Western Branch.

Promotional text: the studyreveal fast Pn velocities beneath the Tanzania Craton, the extension of these fast velocities beneath the Mozambique Belt to the east of the craton, the Kibaran Belt west of the craton, and beneath the northern half of the Ubendian Belt to the southwest of the craton. I.

O1.2-277 – Teleseismic depth determination, techniques and uncertainties : an Himalayan case study

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Accurate estimates of the depth of seismic events allow determining whether they are associated to a given tectonic structure. It is also a good discriminator between earthquakes and explosions. However, automatic depth determination at teleseismic distance remains a challenge: the depth phases (pP, sP), reflected on the free surface, are sometime difficult to pick in the teleseismic signal. This is particularly true when the events are intermediate magnitudes (Mw<5), and fall at shallow depths in complex tectonic environments. To overcome that challenge, we implement two teleseismic depth estimation methods : (1) a cepstral analysis allowing to extract the pP-sP reflected waves in a the P-coda from their phase's similarity with the direct P wave and (2) an envelope stacking procedure aiming to highlight these secondary arrivals from their energetical contents. These two complementary methods allow improving signal over noise ratios and automatically identifying coherent depth phases among the thousands of teleseismic stations and arrays available from global teleseismic networks, including those of the International Monitoring System monitored by CTBTO. We confront our results to a set of well determined regional depths determined from a dense temporary network deployed in the Nepalese Himalayas, a region of high-topography and relatively shallow seismicity.

Promotional text: Our study characterizes uncertainties associated to teleseismic depth determination using global teleseismic networks, including the IMS. We propose solutions to overcome the limitations coming from depth phase identification for investigating the structure of tectonic plates.

O1.2-412 – A crustal P-wave velocity model for Israel to improve IMS capabilities in the Middle East

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The Israeli National Data Center is responsible for monitoring and characterising the seismicity of the Eastern Mediterranean region. The accuracy of seismic locations is mostly affected by the velocity model used, and no clear picture of the variations in seismic velocities in Israel has emerged in the recent years. We gathered a large dataset of seismic travel times recorded in Israel and nearby countries. After quality control and joint relocation of over 30,000 natural and man-made seismic events, we produced a revised dataset of more than 500,000 arrivals. From this dataset, we inverted *Pg* and *Pn* travel times for a crustal velocity model of the area using the *FMTOMO* tomographic inversion package. In order to do this, we put together a 3-D starting model that consists of an ensemble of 1-D velocity profiles for the various tectonic settings observed in the region. We present images

extracted from this model, as well as corresponding synthetic resolution tests to assess the quality of our results. This high-resolution model is to be integrated into the *Regional Seismic Travel Time* model and procedure in order to enhance the CTBT's International Monitoring System capabilities in the Middle East.

Promotional text: We build a new model for crustal seismic velocities in Israel using a local travel-time dataset we put together. The new model is to be integrated into the Regional Seismic Travel Time model and procedure in order to enhance the CTBT's monitoring capabilities in the Middle East.

O1.3 The oceans and their properties

O1.3-262 – Investigation of trends in ocean noise determined from the CTBTO hydroacoustic stations, including during the 2020 COVID-19 lockdown period

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This paper describes the determination of long term and seasonal trends in deep-ocean acoustic noise measured at the CTBTO hydroacoustic stations, and the investigation of the potential for changes in noise levels in 2020 during the COVID-19 pandemic.
The analysis method uses a flexible model that incorporates terms that capture long-term trends in the data, seasonal variations and short-term serial correlations, together with associated uncertainties. The measured data originate from a number of the hydro-acoustic monitoring stations operated by the CTBTO and span up to a maximum of 17 years. The analysis here focuses on the data from Cape Leeuwin Southern Ocean), Wake Island (Pacific Ocean), and Ascension Island (Atlantic Ocean). The trend analysis is applied to time series representing aggregated statistical levels for four frequency bands to obtain estimates for the change in sound pressure level with associated coverage intervals. The features of the data are described, including the differences observed in the seasonal variation and the long-term trends, with the latter often exhibiting negative gradients.
An examination is provided of changes observed in the 2020 data compared to the expected values based on earlier years, with the discussion informed by data for anthropogenic sources of sound.

Promotional text: Trends from deep-ocean noise data are derived from CTBTO stations including assessment of "COVID quietening" in 2020. Influence of anthropogenic and global environmental (climatic) factors are described.

O1.3-489 – Seismic ocean thermometry using CTBTO hydrophone data

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As the major buffer of Earth's energy imbalance, the ocean plays a key role in regulating global climate and temperature changes. However, accurate estimation of global ocean temperature change remains a challenging sampling problem. To complement existing point measurements, we have developed a novel and low-cost method of using travel time changes of acoustic waves from repeating natural earthquakes to infer basin-scale average ocean temperature changes. In this study, we implement this method using the CTBTO hydrophones H08 near Diego Garcia in the central Indian ocean and H01 near Cape Leeuwin off the southwest coast of Australia. We use the ISC cataloged earthquakes as templates to conduct template matching and obtain a more complete set of repeating earthquakes in 2005–2016 around the Nias Island off Sumatra. Adding these new detected earthquakes and using high-quality hydrophone data enable us to infer the large-scale ocean temperature changes with a high temporal resolution. For both H08 and H01, we detect not only seasonal signals generally consistent with that in previous oceanographic datasets of ECCO and Argo, but also more interesting features missing in ECCO and Argo. These results suggest that the global hydrophone network offers new opportunities for monitoring ocean warming.

Promotional text: We developed a novel and low-cost method of using acoustic waves recored by CTBTO hydrophones from repeating natural earthquakes to infer basin-scale average ocean temperature changes.

O1.3-513 – Long-term observations of a potential great whale call from the central Indian Ocean during 2002-2019

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This work presents observations of a potential great whale call at Diego Garcia (HA08N and HA08S). The whale calls which remain unidentified have only been referred to as the Diego Garcia Downsweep (DGD). The calls occur between 20-45 Hz, and constitute a set of tones similar to a comb, followed by a downsweep. The calls between 2002-2019 are used to present two analyses. The first shows that the DGD call-frequencies change across the years. The comb frequencies steadily increase, while that of the downsweep decrease but also branch into higher frequencies. The second set of results present angle and range estimates of the whale. For angle estimates this work uses a broadband beamformer which incoherently combines narrowband beamformer outputs across the multiple frequencies of the calls. For range, the work builds an Nx2-dimensional Parabolic Equation (PE) model to predict the received intensities across range. The model incorporates the local sound speed profiles, and the complicated bathymetry across a 1500 km area around HA08. The intensity predictions are compared against the received call levels to estimate ranges of the calling whales. Preliminary results show that the estimates pick out tracks of nearby whales, and some potentially distant calls.

Promotional text: Long-term recordings from the IMS stations at Diego Garcia suggest that the Indian Ocean abounds in marine mammal diversity, with several blue whale species. Recordings were used to study changing vocal behavior and migration paths of one potential whale species.

O1.3-648 – Using ambient noise at hydroacoustic stations for passive ocean sensing

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Conventional acoustic remote sensing techniques typically rely on controlled active sources which can be problematic to deploy and operate over the long term - especially if multiple sources are required to fully illuminate the ocean region of interest - or may not even be available at very low frequencies (~10 Hz). Conversely, receiver arrays are becoming increasingly autonomous, and capable of long term deployment thus enabling passive acoustics for ocean remote sensing applications by taking advantage of the ubiquitous ocean ambient noise. The archived ambient noise recordings made at the hydroacoustic stations of the Comprehensive Nuclear-Test-Ban Treaty (CTBTO) International Monitoring System (IMS), over decades at some locations, provide a unique platform for the scientific community to test this fully passive acoustic approach for ocean remote sensing. This presentation will present proof of concept of passive ocean remote methods using these hydroacoustic data such as passive acoustic thermometry to estimate deep ocean temperature variations and internal tides using coherent processing of low-frequency ambient noise. Challenges and opportunities for Ocean basin and global-scale passive ocean sensing will be discussed.

Promotional text: The archived ambient noise recordings made at the IMS hydroacoustic sessionsTreaty, over decades at some locations, provide a unique platform for the scientific community to investigate ocean remote sensing using passive acoustic.

O1.3-705 – SMART Subsea Cables for Observing the Ocean and Earth: An Update

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JTF SMART Subsea Cables (Joint Task Force, Science Monitoring And Reliable Telecommunications) is working to integrate environmental sensors (temperature, pressure, seismic acceleration) into submarine telecommunications cables. This will support climate and ocean observation, sea level monitoring, observations of Earth structure, tsunami and earthquake early warning and disaster risk reduction, with relevance to the CTBTO monitoring mission. Recent advances include regional SMART pilot systems that are initial steps to trans-ocean and global implementation. Building on the OceanObs'19 conference and community white paper (DOI 10.3389/fmars.2019.00424), this overview and description of the status of ongoing projects will include: The InSea wet demonstration project off Sicily at the EMSO Western Ionian Facility; Vanuatu and New Caledonia; Indonesia's Makassar Strait systems working toward systems for the Sumatra-Java megathrust zone and in the inner waters; and the CAM-2 triangle system connecting Lisbon, Azores and Madeira. Observing system design studies are reviewed. Funding reflects a blend of government, development bank, and commercial contributions. In addition to these notable scientific and societal benefits, the Telecom mission of societal connectivity will benefit as well, as environmental awareness improves both individual cable system integrity as well as that of the overall global communications network.

Promotional text: SMART Subsea Cables is integrating environmental sensors into submarine telecommunications cables to support climate and ocean observation, sea level monitoring, observations of Earth structure, tsunami and earthquake early warning and disaster risk reduction.

O2.1 Characterization of treaty-relevant events

O2.1-061 – Matching Electromagnetic Measurements to Infrasound Signals

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Measurements of electromagnetic (EM) fields have been proposed as a means of supporting and aiding infrasound signal analysis. As opposed to nuclear explosion, other natural and man-made infrasound sources don't produce an EM signal. Thus, if an IS signal isn't accompanied by an EM pulse, it's known that it's not originated from a nuclear explosion.
Lightning discharges are the main source of EM pulses. Due to their high abundance, fortuitous coincidence of lightning with an infrasound signal are a common situation. These events may be mistakenly assumed as a nuclear explosion. To avoid this obstacle, a reliable method for lightning detection and identification is required.

EM events were detected and recognized using spectrogram. From each segmented event, both time and frequency domain features were extracted. Based on these features, and using machine learning algorithms, all the detected events could be classified as either lightning or not lightning event with high reliability. Then, the non-lightning events were matched with infrasound events. The results show that coincidences of an unrecognized EM signal with an infrasound detection are rare and thus do not impose a real limitation. We conclude that information from EM measurements may enhance and ease the analysis of infrasound signals.

Promotional text: Measurements of EM fields may serve as a means of supporting infrasound signal analysis. Nuclear explosion is the only EMP source which produces also long range infrasound signal. The results show that coincidences of an unrecognized EMP with IS is rare.

O2.1-191 – Yield Estimation of the Aug 4, 2020 Beirut Explosion Using Seismic and Shockwave Data

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This study uses seismic waveform and shockwave data from the Aug 4, 2020 Beirut explosion to investigate whether the yield estimated by the shockwave data can predict the spectral level observed in the seismic data. Many stations from the IRIS Data Management Center (DMC) recorded this explosion up to hundreds of kilometers with good signal-to-noise ratios (SNR). Shockwaves were recorded by personal phones and cameras, and are from social media platforms. These shockwave data were used to obtain the arrival times at various ranges. This dataset was augmented by additional data from Rigby et al. (2020). Shockwave data were modeled using published empirical and theoretical relationships, which suggested its yield to be around 1 Kt TNT. This estimate is in agreement with the value derived by Rigby et al. based on a relation they developed using the shockwave data from Kingary and Bulmash (1984). These yield estimates were used to determine the consistency with respect to the P-wave spectra, which were corrected for the propagation and attenuation effects. Accuracy of the relationships used by various investigators is also examined by validating against the shockwave data collected for other explosions with known yields.

Promotional text: Results illustrates the consistency between the yields estimated using videos from the social media of the blast vs. seismic waveforms. This paper presents a further validation of formulae used to associate the blast data to the yield based on the GT explosions.

O2.1-208 – Implications of underground nuclear explosion cavity evolution for radioxenon isotopic composition

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Isotopic ratios of radioxenon captured in the atmosphere can be indicators of the occurrence of an underground nuclear explosion. However, atmospheric background from civilian sources of xenon isotopes can interfere with detection of nuclear testing signals according to a standard model of the evolution of radioxenon isotopic abundances in a nuclear explosion cavity. We find that this standard model is idealized by not including the effects of physical processes resulting in the partitioning of the radionuclide inventory between a gas phase and rock melt and by ignoring seepage of gases from the cavity or collapse zone. More realistic assumptions about the state of the detonation cavity produce isotopic activity ratios that differ from the civilian background more than the idealized standard model indicates, while also reducing the quantity of radioxenon available for atmospheric release and subsequent detection. Collapse of the cavity potentially has the greatest effect on partitioning of the refractory fission products that are precursors to radioxenon. The model allows for the possibility that post-detonation seismicity can be used to predict isotopic evolution.

Promotional text: An often-used model for predicting the radioxenon composition of released gases actually yields a bound on isotopic compositions because it is based on an idealized cavity model. Improved predictions of suspect UNE signals may be realized using detailed cavity evolution models.

O2.1-228 – Yield estimation of the 2020 Beirut explosion using open access waveform and remote sensing data

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We report on a multi-technique analysis using publicly available data for investigating the huge, accidental explosion that struck the city of Beirut, Lebanon, on August 4, 2020. Its devastating shock wave led to thousands of injured with more than two hundred fatalities and caused immense damage to buildings and infrastructure. Our combined analysis of seismological, hydroacoustic, infrasonic and radar remote sensing data allows us to characterize the source as well as to estimate the explosive yield. The latter ranges between 0.8 and 1.1 kt TNT (kilotons of trinitrotoluene) equivalent and is plausible given the reported 2.75 kt of ammonium nitrate as explosive source. Data from the International Monitoring System of the CTBTO are used for infrasound array detections. Seismometer data from GEOFON and IRIS complement the source characterization based on seismic and acoustic signal recordings, which propagated in solid earth, water and air. Copernicus Sentinel data serve for radar remote sensing and damage estimation. As there are strict limitations for an on-site analysis of this catastrophic explosion, our presented approach based on openly accessible data from global station networks and satellite missions is of high scientific and social relevance that furthermore is transferable to other explosions.

Promotional text: A multi-technique analysis of the 2020 Beirut explosion using open access seismological, infrasonic and radar satellite remote sensing data to independently and consistently estimate the explosive yield in the order of 1 kt TNT.

O2.1-275 – Detections at IMS hydrophone stations of Primary and Tertiary phases from the sixth announced DPRK underground nuclear test

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Primary seismic phases, P-phases, associated with the sixth announced DPRK underground nuclear test of 3 September 2017 (DPRK6) were identified at frequencies below 4 Hz at four of the six CTBT IMS hydroacoustic hydrophone stations, namely HA01, HA03, HA08 and HA11. The signals match P-phase arrival times for these stations except for HA03, where the arrival time matches a path through the outer core. No P-phase detections were made at the two remaining stations, HA04 and HA10, likely because they fall within shadow zones of core phases. Moreover, T-phases originating from the DPRK6 event were detected at both triplets of the station nearest to the test, HA11 Wake Island, at frequencies below 10 Hz. The arrival times of these T-phases are consistent with a P-phase travelling from the source through the Earth's crust, to an off-shore location along the Japan Trench where the bathymetry crosses the SOFAR channel and from there along water borne paths to both triplets of HA11. The back-azimuths of these T-phase arrivals point to this SOFAR crossing as the location where the P-phase coupled into the hydroacoustic paths. To the authors' best knowledge, DPRK6 is the first nuclear test detected at IMS HA hydrophone stations.

Promotional text: P-phases from the 6th announced DPRK underground nuclear test were detected at four of the six IMS HA hydrophone stations. Additionally, a T-phase consistent with this event was also detected at HA11. These appear to be the first detections of this kind at IMS HA stations.

O2.1-290 – Seismo-Acoustic signature of Beirut Port Explosion

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A large amount of ammonium nitrate has exploded in Beirut port on 4 August 2020 leaving behind large destruction. The explosion has triggered seismic, acoustic, infrasound, and hydroacoustic signals that propagated through the lithosphere, atmosphere and hydrosphere. The signal was widely recorded in the neighboring countries and even in the case of infrasound, it has been reported regionally. In this work we document the seismo-acoustic signature of the event and try to investigate the size of the source and the deformation associated with it, using different techniques. DInSAR analysis verified maximum damage area, extending 2 km around the blast site with two cm vertical displacement. Several local and regional seismological stations recorded three different phases from this event with velocities 7.92 km/s, 1.34 km/s, and 0.35 km/s respectively. These phases represent P waves, hydroacoustic signals, and shockwave signals, respectively. The propagation modeling of the infrasound waves reflects a westward propagation towards I48TN, I26DE, and I17CI infrasound stations of the International Monitoring Stations (IMS) of the Comprehensive Test Ban Organization (CTBTO). The location of the explosion is estimated accurately from the waveform data of the recording stations using the technique of the Progressive multi-channel cross-correlation

Promotional text: the abstracts deal with a very unique event of the Beirut Explosion using regional data records for Seismic, Infrasound, and Hydroacoustic signal. The explosion is very interesting especially if dealt with in the farm of the treaty provisions.

O2.1-420 – Detecting Underground Cavities Due to UNE Using Seismic Ambient Noise

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Detection and location of a cavity generated by an underground nuclear explosion is an important proof in case of suspicion of violating the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The resonance seismometry is one of the CTBT's permitted techniques during an on-site inspection (OSI). We present a new method for detecting and locating a horizontal position of cavity which uses the Finite-interval Spectral Power (FISP) of seismic ambient noise. The method requires measurements at a set of points (possibly irregularly distributed) at the Earth's free surface around and over a suspected cavity. Because the method gives better results for undistorted segments of noise records, we also present a method of automatic identification of such segments. We verified our method using records from a site near the Felsőpetény, Hungary, which were collected by the CTBT Organisation during a field test in the framework of developing OSI capabilities. We also show that it is possible to make the noise measurements sequentially. The minimum number of simultaneously measured locations is two. This allows to perform additional measurements, if needed, or to use a limited number of seismometers. The FISP method is ready for further tests at other sites and applications.

Promotional text: How to detect and locate a cavity at a site of a suspected UNE using records of seismic ambient noise?

O2.1-656 – Source parameters estimation of the 4th august Beirut explosion using 3D seismic modelling

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On 4th august 2020, A very large explosion blew up the city of Beirut, the capital of Lebanon, causing many casualties and high damage, leaving an estimated of 300000 people homeless. The explosion was caused by a large amount of ammonium nitrate stored at the port of Beirut. The CEA undertook study in order to estimate explosive source parameters – including the yield – based on the analysis of regional seismic waveforms. Data provided by the seismic stations of the International Monitoring System (IMS) have been retrieved and processed, as well as open access regional waveforms provided by IRIS and GEOFON institute. A first approach involves empirical (or semi empirical) source model, corrected of depth effect, as preconized by Ford and Walter (2014). Those preliminary results are investigated using 3D full waveform modelling, focusing on continental regional propagation through middle-east territory. 3D Green's functions are convoluted with source term derived from seismo-acoustic coupling model. The study shows the contribution of simulation for the source analysis and parameters uncertainty mitigation.

Promotional text: Investigation about accidental explosion requires to perform every key-topics of the forensic seismology, including multi-technology analysis, detection, localization, source screening and source modelling.

O2.2 Challenges of on-site inspection

O2.2-029 – Electrical Resistivity Tomography Geophysical Technique for Mapping Base Metal and Gold Mineralization Potential in Iperindo, Ilesha Schist Belt, Southwestern Nigeria

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Electrical Resistivity Tomography (ERT) geophysical technique has been applied in this study to evaluate the base metal and gold mineralization potential of Iperindo in Ilesha Schist Belt, southwestern Nigeria, where commercial exploitation capable of generating revenue and employment for the inhabitants has been challenged by lack of /inadequate subsurface geological/geophysical information. The filtered and inverted electrical resistivity data acquired by occupying five 336 m long E – W trending profiles, established 10 m apart from each other, delineate isolated near-surface but thick (> 30 m) low resistivity zones, especially at the eastern and western ends of the study area. Some of the delineated low resistivity zones (3 – 200 ⊠m) present sharp vertical edges, likely created by vertical faults that flank the zones on both sides. The low resistivity signatures of these zones could be attributed to the occurrence of conductive minerals such as gold and associated base metals which probably exist in pegmatitic veins within the zones. The resistivity/conductivity distribution generated by ERT mapping of spatial distribution of base metal within the subsurface clearly demonstrates the earth imaging strength of geophysics techniques which are applicable for on-site inspection and test ban verification.

Promotional text: The resistivity/conductivity distribution such as generated by ERT mapping of spatial distribution of base metal within the subsurface clearly demonstrates the earth imaging strength of geophysics techniques which are applicable for on-site inspection and test ban verification.

O2.2-108 – Provisioning and updating distributed software systems in network-isolated environments

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Security constraints of an On-Site Inspection dictate air-gapped isolation of networks, introducing challenges for the reliable provisioning and updating of distributed mission-critical software systems employed during an OSI. Further goals include process transparency and operational robustness, while accommodating domain-specific requirements. To this end, we propose a technical framework addressing the software configuration update in network-isolated environments. Within our comprehensive framework, dependencies are resolved using satisfiability modulo theories, ensuring correctness in terms of version compatibility. The end-to-end system facilitates the update and reconfiguration of isolated on-site systems, while being compatible with container-based software component management as used in practice. We demonstrate the framework over a case study representing a typical scenario.

Promotional text: The paper highlights the importance of appropriate measures to manage software systems during an OSI, ensuring transparency, robustness and availability of mission-critical software.

O2.2-199 – Potential Application of Unmanned Aerial Vehicles for On-Site Inspection

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In 2018 the 51st Session of Working Group B (WGB-51) of the Provisional Technical Secretariat of the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) noted potential applicability of remotely operated vehicles (ROVs) for OSI purposes, but their practical use raises several serious issues that WGB should discuss at its future sessions.
Implementation of OSI missions with application of unmanned aerial vehicles (UAV) for aerial multispectral imaging, gamma-radiation monitoring as well as geomagnetic field mapping specified in paragraph 69 Part II of the Protocol would be technically feasible. But at the same it will be necessary to consider legal, technical and organizational issues relating to UAV use for OSI purposes.
Based on the example of mostly geomagnetic field mapping technique this paper examines technical capability of UAV application for OSI purposes, its consistency with the Treaty provisions and potential approaches for their resolution.

Promotional text: Based on the example of mostly geomagnetic field mapping technique this paper examines technical capability of UAV application for OSI purposes, its consistency with the Treaty provisions and potential approaches for their resolution.

O2.2-657 – Geophysical modeling mathematical software

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The importance of mathematical modeling lies in the implementation of complex calculations and analysis of results using known computational methods. Mathematical modeling provides a qualitative and quantitative prediction of the behavior of an object or a system in cases their study is difficult in reality.
The aim of this work was to create mathematical software that allows modeling geophysical background fields and their anomalies for the purposes of the CTBT On-site Inspection. The simulation results helped to better understand and describe changes of studied values for the search for the epicentral zone of the geophysical anomaly. And the use of data fusion method increased the efficiency of the algorithms performed to identify the location of the geophysical anomaly.
To achieve this goal, the following tasks were solved:
• analysis of the CTBTO verification regime;
• problem statement for mathematical modeling of gravity, magnetic, radionuclide anomalies;
• development of algorithms for solving formalized models;
• analysis of the feasibility of using data fusion for the selected methods;
• development of method and algorithm for data fusion;
• development of mathematical software.
The result of the research work was the created mathematical software that allows modeling background geophysical fields and their anomalies.

Promotional text: This mathematical software can visualize geophysical anomalies after different geophysical events. And the ability to data fusion refine the location of the center of the anomaly. This application can be useful for CTBT On-site Inspection and for training potential inspectors.

O2.3 Seismoacoustic sources in theory and practice

O2.3-070 – Seismoacoustic observation of surface explosions in Israel region.

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The International Data Center (IDC) analyze routinely seismoacoustic data for producing a list of seismoacoustic events as part of the Comprehensive Nuclear-Test Ban Treaty (CTBT) verification regime.
However, the fusion between seismic and infrasound date is not yet satisfactory.
A set of seismoacustic events with known location, origin time and if possible their energy, is necessary in order to improve our understanding,
and to calibrate our algorithms and stations.
Sayarim shooting range is located at the south of Israel, it hosted several sets of dedicated calibration explosions during summer 2009 and winter 2011.
In addition several times per year, large explosions of the order of 20-40 ton, are detonated at the range.
Some of the explosions were detected by the IMS infrasound stations.
In this work, we present the results of seismic and infrasound analysis of these explosions based on data from IMS stations and local stations.

Promotional text: In this work, we present the results of seismic and infrasound analysis of explosions, in Israel, based on data from IMS stations and local stations.

O2.3-130 – Seismo-acoustic data fusion: determining the best acquisition designs for multi-phenomenological monitoring campaigns

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For low-yield monitoring applications, the combined analysis of seismic and infrasound data could lead to significant improvements in our understanding of the processes that simultaneously generate both types of signals. Assembling datasets that contain seismic and infrasound signals generated by a single source can provide a better understanding of specific source processes. The successful combination of signals requires understanding the fidelity of infrasound measurements – especially for local, temporary instrumentation. Therefore, the first part of this presentation will focus on understanding and constructing methods by which the quality of infrasound data can be enhanced to match that of seismic data. Then, we present an in-depth analysis on the current state of seismo-acoustic data fusion and examine its use in monitoring applications. This presentation will cover a series of seismo-acoustic datasets that contain signals generated by a variety of source processes, including earthquake sequences, avalanche/landslide signals, rocket launches, and industrial explosions. We also present findings from joint analyses of these datasets to examine the unique properties of each source type. Ultimately, we determine the best acquisition designs for multi-phenomenological monitoring campaigns with a focus on seismo-acoustic data fusion.

Promotional text: The presentation supports the conference goal to identify opportunities and methods for improving nuclear test monitoring and verification. Evaluating acquisition designs for multi-phenomenological monitoring campaigns leads to a better understanding of source processes.

O2.3-141 – Correlating shear content in seismic source functions to scaled depth-of burial for a series of buried chemical explosions

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We have previously used data from the Source Physics Experiment (SPE) to relate evidence of joint slip in the near field to the yield-scaled depth-of-burial (SDOB) of buried chemical explosions in granite. A sudden surge in tangential velocity occurs in velocity records just after the passage of the peak radial shock for moderately overburied tests. This surge does not appear for nominal SDOB tests or for the "over-buried" Green's function test. Further, we related this phenomenon to the estimated range of declared Democratic People's Republic of Korea tests in granite and the likelihood of those tests to confuse MS:mb earthquake/explosion discrimination methods.

To render these results practical for monitoring we studied SPE seismic data to identify a SDOB effect. Through constraining the known SPE test parameters (e.g., hypocenter, velocity model) we perform a suite of source inversions with varying tensor source components. Goodness-of-fit trends between recorded seismic data and synthetic waveforms identify the source parameters, such as unexpectedly large shear contributions, that give rise to the observed tangential response in the near field. The results provide an indication that near-field joint release can contribute to the far-field waveforms as excess shear energy. LA-UR-20-29210

Promotional text: This work supports the objective of improving nuclear test monitoring and verification by using chemical explosion test data to develop a geomechanical model to explain production in the near-source regime of unexpected shear content seen in the seismic monitoring regime.

O2.4 Atmospheric and subsurface radionuclide background and dispersion

O2.4-056 – Results of the 3rd ATM-Challenge 2019

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Estimating the radioxenon background based on a multi-input-multi-model ensemble modelling approach at IMS stations having frequent detections was the main goal of the 3rd ATM-Challenge.

The Challenge included four selected IMS stations. Participants were invited to calculate contributions to the signal captured in daily samples at CAX17 (St. John's), DEX33 (Schauinsland/Freiburg), SEX63 (Stockholm) and USX75 (Charlottesville) for up to 6 months. Up to 30 submissions per station from 16 different institutions were finally received.

Xe-133 stack emission data with daily temporal resolution for the time period June to November 2014 provided by IRE (Belgium) and CNL (Canada) radiopharmaceutical plants were used. In addition, publicly available emission estimates for nuclear power plants and research reactors as well as annual emissions from other several well-known facilities were also made available to participants.

The presentation will summarize the comprehensive results from this study. First, the added value of training an optimized ensemble per station will be discussed. Second, the beneficial impact of including contributions from minor emitters and thus rough emission estimates thereof will be demonstrated. The added value of simulating samples highly influenced by main emitters, i.e. radiopharmaceutical plants, based on actual daily emission data will be exemplified.

O2.4-106 – Production of Mo-99 without Use of Uranium

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NorthStar has embarked on two parallel paths to produce Mo-99 and other medical radioisotopes without use of any uranium material. The first path, which was approved by the US FDA in February 2018, is via neutron capture utilizing a research reactor. In this pathway, NorthStar can use either high-purity natural molybdenum discs or can use target material of enriched molybdenum-98. This pathway has successfully been producing Mo-99 and delivering to the US market for more than two years. The second path, scheduled for production start in late 2022, is the use of electron accelerators to perform photon transmutation using enriched molybdenum-100 target material. In either case, NorthStar's emissions of gaseous radioisotopes of krypton, iodine or xenon are virtually non-existent. This presentation will provide a review of the production processes and an update to current program status.

O2.4-138 – First observations of environmental ^{125}Xe, ^{127}Xe, and ^{129m}Xe

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Environmental ^{125}Xe, ^{127}Xe, and ^{129m}Xe have been observed during testing of a next-generation xenon measurement system, Xenon International. The observations of these three radioxenon isotopes occurred during routine testing at the Xenon International manufacturing facility in Knoxville, Tennessee, USA, and they are believed to be the first observation of these isotopes in environmental samples collected by automated radioxenon systems. The observations are consistent with activation of xenon in air and have been attributed to the High Flux Isotope Reactor (HFIR) located at the Oak Ridge National Laboratory, about 20 km away.
The ^{125}Xe, ^{127}Xe, and ^{129m}Xe isotopes can be detected in the beta-gamma detector of Xenon International and would interfere with the quantification of the radioxenon isotopes used for nuclear explosion monitoring. The interferences would cause elevated concentration values for the radioxenons of interest in the current analysis methodology. The ^{125}Xe was observed the most often, and it decays to ^{125}I, which can also interfere with radioxenon measurements in the beta-gamma detector. This presentation will describe the observations, production mechanisms, implications for IMS systems and possible mitigation strategies.

Promotional text: This presentation provides understanding of radioxenon background and potential interferences to the International Monitoring System radioxenon systems.

O2.4-406 – Statistical study of the Cs-137 detections at RN43 station

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This work is the result of a joint collaboration between the Italian and the Mauritanian National Data Centers. Radionuclide station RN43 in Mauritania was established in Nouakchott on 6 November 2006. The historical analysis of the occurrence of relevant radionuclides at RN43 over the past ten years showed that the main contributor was Cs-137, causing several level 3 and level 4. A descriptive statistical analysis of the Cs-137 occurrence was performed and two types of parametric process control methods were applied: the "Shewhart Control Chart" and the "Exponentially Weighted Moving Average (EWMA) Control Chart". The results of both methods were then analyzed in order to reveal seasonality, possible sources of Cs-137 and correlation with atmospheric phenomena.

Promotional text: Desert wind is blowing; Cesium fro the desert to the Ocean.

O2.4-477 – 3-D electrical imaging of mesoscale rock damage patterns from underground chemical explosions

Authors: Tim Johnson[1]; Hunter Knox[1]; Chris Strickland[1]; Justin Lowrey[1]; Christine Johnson[1]; Eric Robey[2]; Mathew Ingraham[2]; Kirsten Chojnicki[1]

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Atmospheric gas detection is a primary means for detecting and verifying underground nuclear explosions. Subsurface gas migration is governed by a complex system of unknown variables, including the interaction between geology, explosion-induced stresses and corresponding rock damage

patterns that provide primary gas flow pathways. The U.S. is conducting a series of highly instrumented mesoscale experiments that provide an opportunity to better understand the interaction between source strength and location, natural variations in rock competency, explosion-induced rock damage, and gas migration. Rock damage is imaged in 3-D using a novel combination of water injection, draining, heating and drying combined with time-lapse electrical resistivity tomography. Corresponding measurements of induced gas breakthrough times at discrete points in exterior monitoring wells are being used to understand how rock damage is influenced by local geology, and how it influences gas migration away from the source point. Results show that the influence of geologically weak zones on rock damage and gas flow are comparable to the influence of source strength and location. This result has important implications for larger scale underground explosions, and how those explosions interact with geology and alter gas migration flow paths and travel times to the surface.

Promotional text: This work discusses subsurface properties and how they interact with underground explosions to govern gas-phase breakthrough times and locations at the surface. Results provide insights that should be considered in detecting nuclear explosions through atmospheric gas sensing.

O2.4-510 – Six months of radioxenon detections by the SPALAX New Generation system near Paris in 2019

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As part of its qualification process by the PTS, the SPALAX-NG - noble gas - New Generation system was operated from October 2018 to April 2019 on the CEA/DAM premises near Paris (France). The new generation system's high performances contribute significantly to increase the number of detections and to improve the knowledge of the radioxenon background. Indeed, in this study, a major dataset including numerous isotopic ratios is established for Western Europe that enables to refine the characterization of the background sources and the discrimination criteria. In addition, a full Atmospheric Transport Modelling study has been performed from this full dataset, that allows to 1/ reconsider the radioxenon source terms of the main emitter in Western Europe (IRE, Fleurus, Belgium), and to 2/ detect for the first time some very local and non-traditional sources that can influence the categorization of a detection.

Promotional text: Major improvement in radioxenon detection capacity and background knowledge in Europe.

O2.4-709 – Statistical study of the IMS ^{133}Xe data distributions, using both a parametric and a non-parametric method

Authors: Giuseppe Ottaviano[1]; Michele Scagliarini[2]; Antonietta Rizzo[1]; Rosanna Gualdi[2]; Sofia Guernelli[2]; Claudia Sanguigni[2]; Luca Ferri[2]; Franca Padoani[1]

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The aim of this work is to apply both a parametric and a non-parametric statistical method to the ^{133}Xe activity concentrations measured at noble-gas stations of the IMS of the CTBTO, in order to investigate the atmospheric background and the anomalous values. The parametric method consists of two control charts: a single-observation chart sensitive to large variations with respect to the mean value, and an EWMA chart sensitive to small variations with respect to the mean value. The

results show that the control charts could be useful for an NDC carrying out daily monitoring to easily detect significant variations of the activity concentrations, and to perform more specific analysis of the anomalous values. The parametric method is expected to be useful to better understand the false positives. The non-parametric method is based on a Recursive Segmentation and Permutation (RS/P) algorithm, it does not require any assumption about the underlying probability distribution, and it associates a significance level to the results. The RS/P method is useful for detecting single or multiple mean shifts and/or scale shifts, and the results show that it can be useful to highlight any random oscillations of the phenomenon providing a likely better understanding of anomalous values.

Promotional text: The main contribution of the present abstract is about a better understanding of the Xe-133 background and anomalous values applying two advanced statistical methods to the activity concentration values measured at the noble gas stations of the IMS.

O2.5 Historical data from nuclear test monitoring

O2.5-173 – Using historical data to improve analysis of nuclear testing

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Films from historic nuclear testing enable new analysis of the shock propagation and buoyant cloud rise with material entrainment, furthering understanding of the time-evolution of the entrained mass. Many late cloud films were captured from at least two positions, enabling accurate characterization of the cloud development and trajectory. A generalized framework is developed to capture the similarity of nuclear debris cloud formation for detonations with similar scaled heights of burst. The nuclear debris cloud regimes are defined based on debris cloud behavior observed in a dry, dusty environment with loose, easily lofted surface material and can be used to improve dispersion models. As new information on how expected material entrainment and mixing is affected by the surrounding environment becomes available, adjustments to the regime height-of-burst ranges are easy to adopt. Both fast-running fallout codes and higher-fidelity cloud-rise and fallout codes need to be validated against existing test data. We present on the use of historical film to provide many types of data to validate and improve models of late cloud behavior. Combining such data with an understanding of buoyant cloud rise and cloud stabilization informs entrainment including the total mass of entrained materials.

Promotional text: The historic test films inform a generalized framework to understand nuclear debris clouds. New analysis of film data furthers the source characterization of nuclear detonations and provides accurate validation data sets for predictive fallout models.

O2.5-298 – Analysis Of Historical Seismograms Of Central Asia Stations To Precise The Parameters Of Nuclear Tests At Lop Nor Test Site

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The Lop Nor Test Site is located in Xinjiang Province in the Peoples Republic of China, about 600 km away of Kazakhstan. From 1964-1996, there were 47 nuclear tests, including 3 surface, 19 atmospheric, and 25 underground. During this time, the U.S. operated monitoring networks of sensitive seismic stations having both analog and digital instruments.
A seismic catalog and bulletin was created using the archived seismograms of Central Asian stations located in Kazakhstan, Kyrgyzstan, and Russia (epicentral distance 700-2500 km). In total, 800 seismograms of 41 explosions were processed. Using satellite imagery, epicenters were précised for all explosions, including atmospheric and small underground tests. The mb, regional mpv and MLV magnitudes, and energy class K were calculated. The waveforms of Lop Nor air and surface explosions were analyzed using microbarograph records from the Talgar Observatory in Kazakhstan. For several small explosions, locations were précised, dynamic parameters of seismic and infrasound records were analyzed, and origin times were calculated for the first time. As a result, the précised catalogue of nuclear explosions conducted at Lop Nor Test Site was compiled. Many of the explosions can be used as Ground Truth events to construct the regional travel-time curves and for stations calibration.

Promotional text: The precise catalogue of nuclear explosions conducted at Lop Nor Test Site was compiled.

O2.5-481 – Overview on historic atmospheric radionuclide monitoring data associated with nuclear test explosions conducted between 1964 and 1996

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A literature review is presented on historic atmospheric radionuclide monitoring data that were associated with nuclear test explosions. It covers reports related to tests conducted between 1964 and 1996. Most of these tests occured in the atmosphere but observation of nuclear debris from venting of underground nuclear tests were also found.The review is limited to off-site monitoring and many observations were done at large distances including several tests that were detected on multiple locations on the same hemisphere. This data set could be of value for validating methods based on atmospheric transport simulations with the objective of identifying the source of an event that is of relevance for atmospheric radioactivity monitoring for the Comprehensive-Nuclear-Test Ban Treaty.

Promotional text: The unlifted treasure of historic radionuclide observations associated with nuclear test explosions could be valuable for realistic case studies demonstrating the performance of methods for identifying the source of an event that is of relevance for CTBT radioactivity monitoring.

O3.1 Design of sensor systems and advanced sensor technologies

O3.1-190 – Radiation Detection for OSI – The Influence of Firmware on Detector Performance

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Radiation detection devices comprise a detection unit and a signal evaluation unit, each adapted for the specific application of the device. Traditionally, signals of radiation detectors were evaluated utilising analogue methods, such as the standardised NIM electronics. Developments towards compact, high-performance digital hardware resulted nowadays in the application of digital data evaluation methods, both especially useful in hand-held devices used for on-site inspections due to lower weight, lower power supply and lower costs.
The rise of digital data evaluation methods led to a variety of approaches and implementations, as no standardisation for digital data evaluation has been commonly agreed on so far. Therefore, it is essential to be aware of the influence of the implemented firmware on the detector performance.
Exemplarily, we will present our test results regarding the influence of firm- and hardware on the performance of the D3S, a wearable Radiation Isotope Identifier Device (RIID) from Kromek. The results have been gained utilising our QuTeSt (Qualification Test System for Radiation Detection Devices), a test environment to perform dynamic and static test measurements in accordance with international standards e.g. ANSI, IEC or ITRAP+10.
Powerful hand-held radiation detection devices with approved quality are of utmost importance for good OSI performance.

Promotional text: The success of on-site inspections relies heavily on the performance of sensor systems. The presented study will demonstrate the importance of valid firmware for reliable detector performance.

O3.1-296 – Detecting underground nuclear explosion-related dynamic phenomena using time-lapse seismic surveying

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Underground nuclear explosions produce an immense change in pressure and temperature concentrated around the source origin. This results in the formation of characteristic static and dynamic phenomena. This study highlights the potential of using time-lapse seismic to identify ground zero by monitoring post-explosion dynamic phenomena. Time-lapse seismic is successfully employed in the oil and gas industry. It involves taking more than one 2D/3D survey at different calendar times over the same reservoir and studying the difference in seismic attributes.

Dynamic changes in rock and fluid properties due to UNE are observable for a prolonged period, even up to several decades. This is prominent near to source origin and is a result of the redistribution of residual energy, such as pressure, temperature, and saturation. Frequent seismic monitoring surveys (time-lapse seismic) would enable monitoring of changes to rock and fluid properties. The characteristics of the time-lapse seismic signature in a heterogeneous medium (or heterogeneous cavity), and

the factors affecting land 4D repeatability on the 4D signature are discussed. We present a fast detection method using machine learning for the detection of explosion-related time-lapse signatures, which could be used to identify the source location or ground zero.

Promotional text: This study highlights the potential of using time-lapse seismic to identify ground zero by monitoring post-explosion dynamic phenomena. The suggested technique is envisaged for field deployment during on-site inspection to locate the zone of 4D change or source location.

O3.1-316 – Update on Xe adsorbent development at CEA/DAM

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In the context of the Comprehensive Nuclear Test Ban Treaty (CTBT), CEA/DAM developed about 20 years ago the SPALAX (Système de Prélèvement Automatique en Ligne avec l'Analyse du Xénon) system, which is used in the International Monitoring System to detect xenon releases following a nuclear explosion. This system is still under continuous improvement. In particular, CEA/DAM continues to work on the metal exchanged zeolites (such as Ag@ZSM-5) which are very relevant with regard to the Xe uptake and purification performances. CEA/DAM developed recently a new research pilot to extend its capabilities to test such materials. This presentation aims at providing an update on CEA/DAM material developments.

Promotional text: This study aims to present the results of the implementation of zeolite material in a pilot to capture xenon.

O3.1-384 – Distributed Optical Fiber Sensing and its Potential Application for IMS Hydroacoustic Stations

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Distributed optical fiber sensors (DOFSs) utilize specialized source and detection systems to convert optical fibers into linear arrays of sensors. Since early experiments in the 1980s, a range of methodologies has been developed to sense a diverse set of variables with varying sensitivities and precisions based on communication-grade as well as purpose-built optical fiber cables. Over the last decade, methods have been developed that use existing telecommunications cables to measure seismic, acoustic and temperature signals with surprising sensitivity, to sub-meter spatial resolution in some cases and with cable runs greater than 100 km in others. We review three principal techniques used to derive these measurements, together with their strengths and weaknesses, performance trade-offs, and system and environmental implementation constraints. We provide examples of existing and planned subsea implementations, and discuss the potential application of such technologies for integration into IMS hydroacoustic system sensor packages or as additional science sensors.

Promotional text: The fundamentals and applications of distributed optical fiber sensors (DOFSs) are reviewed in light of their potential for integration into IMS hydroacoustic systems.

O3.1-467 – An external calibrator system for the Hyperion Sensors

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The NCPA has developed an external calibrator system which is nearing maturity. This calibrator is attached as a replacement sensor lid for the Hyperion sensor, and injects the signal into the back volume of the Hyperion sensor. When the external calibrator is mated to the sensor, the integrated sensor-external calibrator package behaves as a self-calibrating sensor. The external calibrator allows the Hyperion to operate nominally and without significant change in response with the external calibrator installed. The calibrator is driven by an external signal generated by the digitizer (e.g., the CAL signal on a GEOTECH). This system is capable of producing signals with amplitudes greater than 20-Pa in the operational environment between 0.01-10 Hz. We report here on the performance metrics (frequency flatness, level linearity, etc.) as well as summarize the theory of operation of the device.

Promotional text: We will discuss the development of an external calibrator technology which can be used with the Hyperion sensors, which allows them to behave as self-calibrating sensors.

O3.1-579 – Innovative on-site infrasound metrology conducted in 2019 and 2020

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In order to improve the confidence in the results of measurements carried out in the field, on-site metrology is a key step. With the medium-term objective of being able to deploy a portable metrology system on different infrasound stations, CEA-DAM has tested an innovative system for calibrating its infrasound sensors. The first tests were conducted in November 2019 and September 2020 as part of the installation and certification of the IMS IS25 infrasound station in Guadeloupe. A total of 20 microbarometers were qualified on site.
We present the equipments deployed, the methods used and the results of the measurements carried out. It appears that the preliminary results show a very good correspondence between the measurements performed in the field, under particular environmental conditions, and the measurements performed in the metrology laboratory. The method will be confronted to the metrology community within the framework of the European Infra-AUV project in 2022.

Promotional text: In order to improve the confidence in the results of measurements carried out in the field, on-site metrology is a key step. CEA-DAM has tested an innovative system for calibrating its infrasound sensors.

O3.2 Laboratories including transportable and field based facilities

O3.2-218 – Long-term verification of radionuclide laboratory gain and efficiency stability

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As radioxenon samples are collected around the world at the CTBTO IMS stations, a subset of those are sent to radionuclide laboratories around the world for re-analysis. PNNL operates the U.S. Noble Gas Laboratory (US-NGL), which was certified in December of 2016. There is also an opportunity to utilize the radioxenon laboratories in a field system comparison experiment. In this presentation, we detail current and potential future methods of utilizing the radioxenon laboratories. For a laboratory system to be used for verification of continuously operating systems, it is important to routinely validate the energy and efficiency calibration of the laboratory system. We discuss long-term verification measurements made for USL16-NGL and the methods utilized to ensure stable operation. Additionally, we present the impact of the enhanced throughput on such scenarios and how to ensure that the operational role is maintained during experiments.

Promotional text: Long-term monitoring and verification of noble gas laboratories allows for improved confidence in the IMS data and analysis.

O3.2-482 – A high-resolution laboratory-based beta-gamma coincidence spectrometry system for radioxenon measurement

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GBL15, the UK's noble gas certified Comprehensive Nuclear-Test-Ban Treaty (CTBT) radionuclide laboratory supports the International Monitoring System (IMS) through measurement of environmental radioxenon samples using beta-gamma coincidence spectrometry. GBL15 currently utilises a system comprised of NaI(Tl) photon detectors and plastic scintillator electron-detectors to measure coincident emissions from the four radioxenon isotopes of interest: Xe-133, Xe-135, Xe-131m and Xe-133m. A high-resolution electron-photon coincidence detector system comprising of high-purity germanium (HPGe) detectors and a PIPSBox detector demonstrates improved discrimination between signals and less interference compared to the current system. The minimum detectable activities (MDA) and coincidence detection efficiencies for the radioxenon isotopes of interest have been quantified.

Promotional text: The UK CTBT Radionuclide Laboratory, GBL15, has configured a high-resolution beta-gamma coincidence detection system for laboratory radioxenon measurements. The system is benchmarked against the current certified capability.

O3.2-654 – Installation for the measurement of low activities of ^{37}Ar based on the detection of liquid argon scintillation

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One of the most conclusive evidences of a violation of CTBT is the presence in the subsoil air of elevated concentrations of ^{37}Ar radionuclide, which is formed in large quantities in the interaction of neutrons with calcium in rocks.
Traditionally, to measure the activity of ^{37}Ar, proportional gas counters are used, which are filled with a counting gas prepared from samples of argon with the addition of methane. Further reduction of the detection limit of ^{37}Ar is limited by the difficulty of a significant increase of argon sample volume placed in a proportional counter.
Installation for the detection of argon-37 low activities based on the liquid scintillation principle was developed at the Khlopin Radium Institute under contract with the CTBTO. The role of the scintillator in this installation is performed by the liquefied preparation of extracted from soil air argon itself. The use of liquefied argon samples allows one to multiply the volume of the measured samples without increasing the size of the measuring cell and shield elements, and allows significant reduction of detection limits of ^{37}Ar.
The presentation contains a description of the installation and the results obtained after its testing.

Promotional text: One of the main objectives of the conference is to identify opportunities and possible solutions for the continuous improvement of the control and verification of nuclear tests. The theme of our presentation is fully consistent with the achievement of this goal.

O3.3 Remote sensing, imagery and data acquisition platforms

O3.3-085 – Performance Evaluation of the Pixel-Object Fusion Algorithm for Change Detection in Use of Countering Nuclear Proliferation

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For countering nuclear proliferation, the structural changes within the suspicious area have to be carefully monitored. Due to the restriction of access to rogue states, the level of change is highly dependent on the spatial resolution of satellite imagery. As increasing the quality and quantity of the imagery, the semi-automated change detection process has been studied in support of the interpretation. Nonetheless, the availability of various methods rather focused on case studies, and the results are qualitatively discussed in general. In a practical perspective, ultimately the performance has to be reviewed quantitatively so that field users can understand usability and unusability of the semi-automated system. Further, it leads to how to supplement the state-of-art technologies for field use. With this background, this paper presents the change detection algorithm developed by Korea Institue of Nuclear Nonproliferation and Control (KINAC), which integrates pixel and object advantages in computer vision, and quantitatively evaluates the performance with accuracy indices. For the semi-automated change detection, incompatibility between the recall and false discovery rate is discussed numerically. It is concluded that effective threshold values for the semi-automated change detection can be derived from the optimisation perspective, although it must vary depending on the purpose of use.

Promotional text: The analysis techniques for satellite information for nonproliferation use have been discussed in the SnT conferences. A few states have undertaken their own R&D programme, and this is the first time to introduce the ROK programme.

O3.3-117 – Geospatial Automated Imagery Analysis tool (GAIA): incorporating time-series satellite data to detect changing site conditions

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In order to reduce uncertainties and improve confidence in analyses of potentially anomalous events, accurate event locations are required. However, event location/relocation and replicability can be difficult due to a number of factors, e.g., variability in seismic data processing and spatially sparse network coverage. By leveraging commercially available, high-fidelity satellite data as a supporting data stream, time-separated images could (1) build confidence in seismic data analyses and (2) identify specific areas where change has occurred, such as building construction/demolition or road/facilities improvements. We summarize a novel geospatial processing tool – GAIA: Geospatial Automated Imagery Analysis – that automates image orthorectification and change detection of time-separated images. GAIA is an easy-to-use, ArcGIS-based toolbox with a standardized workflow for image analyses and change detection that significantly reduces geospatial processing time (from hours to <5 minutes). We present the GAIA functionality through relevant exemplar cases with a focus on underground explosions at the Nevada National Security Site (U.S.A.). The use of GAIA in monitoring and verification applications could support event analyses through effective and consistent

use of commercially-available satellite imagery. GAIA shows promise for identifying locations of anomalous change and reducing uncertainty in event locations.

Promotional text: This proposed SnT 2021 presentation is aligned with T3.5 Data Analysis Algorithms and will demonstrate an easy-to-deploy monitoring and verification technique that augments event analyses through effective use of commercially-available satellite imagery.

O3.3-153 – Unattended Ground Sensing and In-situ Processing of Geophysical Data

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Seismic monitoring systems are typically emplaced along with a complementary infrastructure for power and data exfiltration. In some instances, it may be desirable to deploy a system in a location where it is not feasible or reasonable to provide such infrastructure. In this case there are numerous commercial options that can provide continuous recording and indefinite operation using solar power. However, these locations must still be visited on occasion to retrieve data. We have developed a system that allows for both continuous monitoring and deployment of semi-complex algorithms. Satellite and cellular communications provide a both the ability to retrieve data and command/control of the sensor platform. This platform provides for the ability to deploy complex detection and/or classification algorithms to reduce the need to send back continuous data. A system has been deployed at the Redmond Salt Mine in southwestern Utah, USA since October of 2018. A 1-D convolutional neural network (CNN) inference model has been implemented on the unit as an exemplar to demonstrate the ability to classify seismic signals from explosive blasting at the salt mine. The CNN was trained on a dataset labeled by mine level and achieved a F1 Score of 0.802 with the testing set.

O3.3-295 – Commercial UAV Based Magnetic Field Mapping Solution to OSI

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Based on the lessons learned during the past training and exercise experiences, especially IFE08 and IFE14, inspection efficiency and health & safety concerns are very important factors for conducting ground or airborne magnetic field mapping. This work would propose an UAV based magnetic mapping system, which is also the active result of joint efforts made by experts of OSI and commercial magnetic mapping application. The system is composed mainly of UAV, magnetic mapping sensor arrays as payload, ground based station subsystems. UAV platform is specially designed to minimize its own magnetic field to reduce the interference to the magnetic detection to the minimum. Quantum magnetic detector has been utilized to achieve the sensitive detection of magnetic field over 100 times more accurate than ordinary magnetic detector. Ground based station would achieve UAV flight-control and real-time magnetic mapping data visualization and analysis. The whole UAV based magnetic field mapping system would achieve mapping of 20000 m2 inspection area per hour with the flight speed of 4 m/s and detection width of 2 meter. Detection of metal anomalies with sensitivity ranging from 0.5 nT to 10 nT could be conducted with the detection depth from 3 meter to 60 meter.

Promotional text: This work would propose an UAV based magnetic field mapping system, which is more safe for inspection team, and more efficient for OSI operation.

O3.5 Data analysis algorithms

O3.5-119 – Comparing three-dimensional velocity models for seismic location accuracy using a consistent travel time framework

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Location algorithms have relied on simple, one-dimensional (1D) velocity models for fast, seismic event locations. The fast-computational speed of these models made them the preferred type of velocity model for operational needs. Higher-dimensional (2D-3D) seismic velocity models are becoming readily available and provide more accurate event locations over 1D models. The computational requirements of these 2D-3D models tend to make their operational use prohibitive. 1D are generally used as travel-time lookup tables, one for each seismic phase, with travel-times pre-calculated for event distance and depth, that are extr fast to use. Comparing location accuracy for 2D-3D seismic velocity models tends to be problematic as each model is determined using different ray-tracing algorithms. Attempting to use a different algorithm than used to develop a model usually results in poor travel-time prediction. We will demonstrate the current/updated ability to quickly create travel-time correction surfaces using an open-source framework (PCalc+GeoTess, www.sandia.gov/geotess) that easily stores 3D travel-time data. This framework overcomes the ray-tracing algorithm hurdle because the lookup tables can be generated using the exact ray-tracing algorithm that is preferred for the model. Having a common travel-time framework for a location algorithm allows individual velocity models to be compared in a fair, consistent manner.

Promotional text: Allowing for direct comparison and/or use of 3D velocity models pertains to Goal 1 for identifying opportunities/methods for improving nuclear test monitoring. Goals 4-5 are also relevant for supporting the exchange of knowledge and promoting wider application of techniques.

O3.5-343 – Impact of environmental backgrounds on atmospheric monitoring of nuclear explosions: selected results

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The International Monitoring System (IMS) was designed based on planned sensitivity estimates, such as radionuclide (RN) system minimum detectable concentration (MDC), but without knowledge of background levels. Recent background simulations and atmospheric transport modeling calculations show that for most of the Earth, using MDC values is still reasonable. However, for a number of locations, background xenon concentrations are frequently larger than the measurement equipment limitations and impose mild to severe limitations on the size of anomalous signal that can be discerned. The authors have calculated maps and statistical estimators of network capability for computed xenon background levels, using a threshold balanced between the MDC and background intensity and variability. Despite these limitations, xenon continues to be a very worthwhile monitoring method.

Promotional text: Xenon background is a key issue in the performance of the IMS. Understanding this will guide analysis from existing equipment and inform future deployment of next-generation capability.

O3.5-398 – Regional waveform-correlation detection and location, for seismic events in and near Mongolia

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We have engaged in broad-area regional monitoring for Mongolia and nearby regions, applying cross-correlation to long time windows for Lg-waves. For 2012 to 2016, using 4777 templates from a longer time-period, detections were made on searches of continuous data for a sparse network of IMS array stations, plus six long-running three-component open stations. Many candidate events were detected, for which there were too few stations in the detection network to perform locations. Fortunately a temporary PASSCAL network with many stations had been deployed in the region, which overlapped with the time period of our study. Adding windowed data from that network, based on expected arrival times for Lg-waves, we measured differential travel times to make location estimates. We have obtained pair-wise locations for 35,096 events in the detected catalog (4.7 million pairs of events). Location results are similar to those obtained in a previous study for all of China (Schaff et al, BSSA, June 2018) with average residuals of 0.0164 s; and 95% confidence ellipses with average 157 m semi-major axes. 93% of the pairs are less than 1 km apart. We are computing locations within large clusters of over 1000 events in several areas.

Promotional text: In addition to high-precision methods for locating events in an active seismic region, using continuous data from a sparse network, we have conducted large-scale searches for new seismic events. We have located them too, from open data, with quick searching methods.

O3.5-456 – Radioxenon isotopic ratios from activation of stable xenon in releases from nuclear facilities in relation to fission sources visualized in multi-isotope-ratio plots

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Evidence has shown that besides radioxenon from fission, release of activation-generated radioxenon can occasionally be observed at noble gas systems of the International Monitoring System (IMS). The literature appears to show conflicting results for the isotopic ratios from activation of stable xenon in the releases from nuclear research reactors (NRRs). This study uses ORIGEN simulations to investigate various scenarios of generating radioxenon from activation. Different neutron spectra and activation of air as well as gas dissolved in the water are studied. The main goal is to test the hypothesis that the isotopic activity ratios can be used as a discriminator for activation or fission being the dominating source of radioxenon releases from NRRs or other nuclear facilities. This is important because any source of activated xenon that can be observed in IMS samples may release other activation products as well ^{125}Xe, ^{127}Xe and ^{129m}Xe which interfere with the beta-gamma spectroscopy analysis methods which are applied by the International Data Centre (IDC). This is an important scientific foundation to decide whether interference corrections for these non-traditional radioxenon isotopes need to be introduced to the operational software.

Promotional text: A foundation for estimating the impact that radioxenon generated by neutron activation and released from nuclear facilities can have on IMS samples is presented for deciding whether interference corrections have to be introduced to the operational analysis software.

O3.5-462 – Multicomponent seismic arrays: demonstrating their potential for improved event detection and characterisation

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IMS seismic arrays are predominantly formed using multiple vertical sensors with a single three-component (3-C) seismometer co-located at one site. The deployment of fully 3-C seismic arrays, such as ARCES (PS28) and SPITS (AS72), offers the possibility to take additional advantage of the coherency on the horizontal components. For the case of S-phases, this has the potential to significantly improve their detection and characterization. Despite this, 3-C arrays are currently poorly exploited in automatic phase detection and classification algorithms.

Using events from the 2020 NORSAR regional reviewed bulletin and based on data from the ARCES and SPITS arrays, our work focuses on demonstrating the benefits of using all three components for array processing. We use the PMCC (Progressive Multi-Channel Correlation) algorithm to initially process each individual component, merging the results to form a multi-component phase detection, from which a Kurtosis phase picker is applied. For a second, more computationally intensive technique, we use all three components to rotate our data into a ray-coordinate system for a predefined set of azimuth and slowness values. Each component of the rotated data are then processed, with the resulting detections compared to both the vertical-only results and the PMCC multi-component technique

Promotional text: We investigate solutions to efficiently use horizontal components for seismic array processing. Our study aims to demonstrate how the IMS 3C-arrays can be better exploited, while also highlighting the advantages of such 3-C deployments for event detection.

O3.5-573 – Novel IDC software applications for Radionuclide data analysis

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The CTBTO International Data Centre (IDC) initiated the development of novel software applications for modernizing automatic processing and interactive analysis of radionuclide data from the International Monitoring System (IMS).
The ongoing projects aim at completing the migration to open source license free software, unifying the processing tools for particulates and noble gas, integrating new technologies and analysis methods as well as enhancing the IDC products and dissemination tools for National Data Centers (NDCs).
The presentation will provide updated status and future plans on ongoing projects:
(a) iNtegrated Software Platform for Interactive Radionuclide rEview (iNSPIRE),
(b) automatic Software Tool for RAdionuclide Data Analysis (autoSTRADA),
(c) Geant4 based RAdioNuclide Detector Simulation (GRANDSim) and
(d) new web based application (RNToolkit).

Promotional text: The contribution presents an update on novel IDC radionuclide software applications iNSPIRE, autoSTRADA, GRANDSim and RNToolkit.

O3.6 Artificial intelligence and machine learning

O3.6-118 – Emulation of seismic-phase travel times using the Deep Learning Travel Time (DeLTTa) method

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Deep Learning Travel Time (DeLTTa) is a deep-learning method and computer code for emulating seismic-phase travel times that are based on a 3-dimensional (3D) Earth model. Greater accuracy of travel time predictions using a 3D Earth model are known to reduce the bias of event location estimates and improve the process of associating detections to events. However, practical use of 3D models is challenged by slow computational speed and the unwieldiness of pre-computed lookup tables. DeLTTa trains a deep-learning network using pre-computed travel times, resulting in a compact and computationally fast way to approximate travel times based on a 3D Earth model. DeLTTa is trained using approximately 850 million P-wave travel times based on the LLNL-G3D-JPS model from randomly sampled event locations to 10,393 global seismic stations. After training, the machine-learning computer code is approximately 10 Mbytes in size and travel times are computed in approximately ten micro-seconds on a single CPU. Currently achieved prediction accuracy is approximately ½ second at the 2-sigma level, which is similar to the inherent accuracy of the 3-D model. With additional development, DeLTTa will enable easy use of 3-D models in routine seismological processing and analysis.

Promotional text: 3D Earth models can improve seismic travel-time prediction accuracy, which leads directly to more accurate event locations. Machine learning efficiently emulates travel-time calculations, opening the possibility of using state-of-the-art Earth models in the operational system.

O3.6-148 – Identification of repeating seismic events using non-linear dimensionality reduction

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In this work, we develop an algorithm for automatic identification of repeating seismic events such as aftershocks and mine explosions. Identification of such events will help to improve the quality of automatic bulletins and to lighten the analysts' burden. The algorithm constructs a low-dimensional representation of the examined data by using a variant of a non-linear dimensionality reduction algorithm named diffusion maps.

The proposed methods begin with a pre-processing stage in which a time–frequency representation is extracted from each seismogram while capturing common properties of seismic events and overcoming magnitude differences. Then diffusion maps are used in order to construct a low-dimensional model of the original data. This enables to split the data into one cluster that contains the repeating events and another cluster that holds of the other processed waveforms, which are not related to the examined events of interest.

The algorithm's performance is demonstrated on several seismic data sets that were recorded at IMS stations. In particular, at the IMS station EIL we identify arrivals that were caused by the blasts at the nearby Eshidiya mine in Jordan. Identification and masking of such arrivals should reduce the number of false associations in the automatic bulletins.

Promotional text: We develop an algorithm for automatic identification of repeating seismic events such as aftershocks and mine explosions. Identification of such events will help to improve the quality of automatic bulletins and to lighten the analysts' burden.

O3.6-205 – Using machine learning to detect and characterize long-range infrasound signals from high explosives

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The International Monitoring System (IMS) infrasound network is well positioned to record atmospheric nuclear explosions, but algorithmically classifying and characterizing these events is challenging. Difficulties stem from the variable and dynamic atmosphere that modulates acoustic transients at regional to global distances. Machine learning (ML) is well suited to classify infrasound activity but generally requires large training datasets. However, data from the relatively few large chemical explosions and sparse global infrasound network are insufficient to train a ML model given how complex and dynamic the atmosphere is at global scales. Instead, we propose a physics-based data augmentation method to produce an entirely synthetic training dataset. Realistic source time functions are generated and propagated through modeled atmospheres out to several hundred kilometers, thus producing a catalog of synthetic events. These data are then used to train a time convolutional neural network (TCN) that classifies explosions and background noise. We show the TCN not only identifies modeled events but is also effective at detecting and characterizing real world explosive transients, including those from the Humming Roadrunner experiments.

This work was supported by the Nuclear Arms Control Technology (NACT) Program at Defense Threat Reduction Agency (DTRA). Approved for public release; Distribution is unlimited.

Promotional text: We present a new infrasound based method to detect and classify nuclear blasts using machine learning. This approach will help elevate the usefulness of global infrasound deployments as a tool to monitor for atmospheric nuclear activity.

O3.6-225 – Beta-Gamma coincidence radioxenon spectra classification using the convolution neural network (CNN) technique

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In this study, using a machine learning method, in particular, a deep learning approach, we propose for the first time a model of Beta-Gamma coincidence radioxenon spectra classification. Specifically, by means of real data from the noble gas system in Charlottesville (USX75) as part of the International Monitoring System (IMS) operated by CTBTO between 2012 and 2019, we apply the convolution neural network (CNN) technique based on the absolute concentration of each radioxenon isotope. The results show that without utilizing background spectra, interference corrections, and without determining the activity concentration of each isotope, the automatic classification can be carried out with high accuracy. This implies that categorization through deep learning does not require the knowledge of screening threshold values that are applied for sample categorization after applying

the Net Count Calculation (NCC) analysis method used currently by the International Data Centre (IDC) of the CTBTO. Our results support that by synthesizing nuclear engineering and deep learning disciplines, experts can accelerate and optimize the review process of background and CTBT-relevant samples by an average accuracy of 92% and 98% respectively.

Promotional text: Classification of Beta-Gamma coincidence raw radioxenon spectra by deep learning (CNN technique) as pre-screening for CTBT relevant samples.

O3.6-400 – Markov Chain Monte Carlo Estimate of Origin Error for Seismic, Hydroacoustic, Infrasound Events in NET-VISA

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NET-VISA is a Physics-Based Generative Model of global scale seismology. The model includes a description of the generation of events which include under-water and atmospheric events, the propagation of waveform energy from the events in multiple phases, and the detection or mis-detection of these phases at the network of stations maintained by the International Monitoring System (IMS) as well as a model of noise processes at these stations. The model and its associated inference algorithm has been deployed by the International Data Center (IDC) to generate a bulletin of events known as VSEL3. This bulletin is currently being used by the analysts to generate the LEB bulletin and in future it is planned to replace the current GA-based SEL3 bulletin with VSEL3.

The current version of the inference algorithm relies on the existing IDC libraries to compute the error/coverage ellipse of events. In this work we have added a new module to directly use the NET-VISA model to estimate the 90% confidence ellipse. We describe the details of the Markov Chain Monte Carlo (MCMC) estimation and demonstrate on a study of ground truth events from the International Seismological Center (ISC) that the new confidence ellipses are more accurate.

Promotional text: MCMC estimate of origin errors added to NET-VISA.

O4.1 Performance evaluation and modelling of the full verification system and its components

O4.1-121 – Signal injection as a means to exercise the entire CTBT monitoring regime

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A nuclear explosion results in a complex combination of signals including radioactivity released to the environment, seismic, infrasound, and hydroacoustic. The International Monitoring System (IMS) was established to detect these signals and analysts around the world train in the interpretation of them. However, the unique combination of signals indicative of a nuclear explosion is only fully replicated in the IMS by an actual nuclear explosion, which is a rare event. While analysts can train with synthetic data, exercising the operational IMS hardware and process was impractical until a signal injection methodology called RaFTS (Radiation Field Training Simulator) was demonstrated by Lawrence Livermore National Laboratory. Developed for radiation detectors such as those in IMS radionuclide/noble gas (RN/NG) stations, RaFTS injects pulses directly into operational detectors which are then interpreted through their electronics in the same way as real signals. Because of the universality of the RaFTS signal injection approach, it could also work with other IMS detector types, including seismic, infrasound, and hydroacoustic, thereby enabling a system-wide exercise of all IMS operating components. This presentation describes the proposed approach to enhance training and operationally exercise the entire regime. RaFTS was recently licensed for commercialization to Argon Electronics (UK) Ltd.

Promotional text: Exercising the system represents a unique scientific opportunity and method for improving nuclear test monitoring and verification in a systems manner, including modeling/simulation of representative signatures, to their detection and interpretation.

O4.1-213 – Metrology for low-frequency sound and vibration: A introduction to the Infra-AUV project.

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Infra-AUV is a new EU project that will establish primary measurements standards for low frequency phenomena across the fields of airborne and underwater acoustics and vibration (seismology). Combining expertise from the national measurement institutes and geophysical monitoring station operators, it will develop both high-precision laboratory-based methods of calibration and methods

suitable for field use. Infra-AUV will also address requirements for reference sensors that link laboratory calibration capabilities to field requirements for measurement traceability.

To establish standards in the three technical areas, a variety of calibration principles will be employed, including extension of existing techniques such as reciprocity and optical interferometry, and development of new methods. There will also be an investigation of the potential for in-situ calibration methods, including use of both artificially generated and naturally occurring stimuli such as microseisms and microbaroms. The influence of calibration uncertainties on the determination of the measurands required by the monitoring networks will also be studied.

The project was strongly motivated by the CTBTO strategy to drive new metrology capability to underpin IMS data. The intention is to maintain interaction with stakeholders, not only in connection with the IMS, but with the broad range of users of low frequency acoustic and vibration data.

Promotional text: Our contribution describes how the metrology community is coming together to improve measurement standards that underpins data quality in CTBT monitoring activities, and aims to foster greater contact with relevant stakeholders.

O4.1-519 – Seismic Network Geometry Optimization Using a Fully Automated Stochastic Method

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One of the most important goals of any seismic network, is the ability to locate more accurately seismic events. Accordingly, accurate stations distribution, plays an important role for achieving that goal. In this study, we present a fully automated stochastic method for calculating the optimal station distribution inside a permanent/temporary seismic network. Using fuzzy self-tuned particle-swarm-optimization technique, we can do a complete search on the entire area inside the network to find the best plausible station coordinates by generating synthesized earthquakes and relocating them in a forward-inverse manner. The new stations distribution could be completely far (designing a new network) or relatively close to the current seismic network (optimizing current network). In either cases the final network pattern represents increases the accuracy of the relocated events.
We evaluated the proposed method on a data-set comprising 1562 earthquakes in Iran region (recorded by Iranian-broadband-seismic-network (BIN)) with magnitudes Mw>4.0, during 2010-2020. The maximum displacement of 25 km for each station from its initial location was considered, then the program starts to find the best coordinates. The final results showed that using the optimized seismic network, the accuracy of relocated events (based on the Hypo71 event-accuracy criteria) could be increased up to 15%.

Promotional text: Increasing the accuracy (efficiency) of seismic events (networks) has always been one of the most important goal of the CTBTO in a broad context. Here we present a fully automated stochastic-method for calculating the optimal stations distribution inside a seismic network.

O4.1-624 – Bayesian localization of infrasound events with propagation metamodels

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Infrasound has proven to be useful for localizing events, especially in the context of the CTBT. Among the usual approaches, the Bayesian inference is often favored as it provides the posterior probability density function (PDF) for source parameters. In these methodologies, propagation models are constructed by numerically propagating signals through a set of plausible atmospheric specifications so as to obtain distributions for arrival characteristics. These approaches, however, drastically increases the number of model runs and for this reason, automatic network processing is often based either on simplified stochastic models or generative models. Such models, however, do not include the current atmospheric specifications and additional analysis is often necessary to better refine the source location estimate. In this work, we combine the Bayesian framework and recent developments in metamodeling to update the posterior PDF describing the source localization. The main difference with the standard Monte Carlo method lies in the fact that the sampling is carried out over the metamodel, which is built from an experimental design of limited size. This makes such propagation metamodels more efficient than their stochastic counterparts and better suited for real-time monitoring. The performance of the method is demonstrated through reanalyzing several recent events.

Promotional text: In this work, localization is obtained using a metamodel which offers a way to compute source characteristics at a low numerical cost from the signals recorded at several IMS stations. Such a metamodel is more efficient than the stochastic models used in the BISL approach.

O4.1-636 – National Data Centre Preparedness Exercise (NPE) 2019 - Scenario Design and Expert Technical Analysis

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NDC Preparedness Exercises (NPE) are an opportunity to practice the verification procedures for the detection of nuclear explosions in the framework of CTBT monitoring. The NPE 2019 scenario was developed in close cooperation between the Italian NDC-RN (ENEA) and the German NDC (BGR). The fictitious state RAETIA announced a reactor incident with release of unspecified radionuclides into the atmosphere. Simulated concentrations of particulate and noble gas isotopes at IMS stations were given to the participants. The task was to check the consistency with the announcement and to search for waveform events in the potential source region of the radioisotopes.
During NPE2019 an Exercise Expert Technical Analysis was requested from the IDC for the first time. A fictitious state party provided within the sceario (simulated) national measurements of radionuclides and asked for assisistance in analysing the additional samples. Especially backward ATM and the search for seismic events in the possible source region was requested. In addition the overall consistency to a scenario event, a reactor incident declared by the fictitious statr Raetia was questioned. In the third and last stage of the exercise, national regional seismic data were distributed among the particpants which contained a anomaly pointing on a explosive event.

Promotional text: NPE feature monitoring expertise with scenarios of partially simulated CTBT relevant events . Highlights of NPE 2019: integration of multiple RN sources, ETA request, and synthetically manipulated seismic data.

O4.3 IT, power systems and other enabling technologies

O4.3-167 – Seismic-Hydroacoustic-Infrasound (SHI) in the Sky: benefits and pitfalls of NDC-in-a-box in the Cloud

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Capacity building efforts for National Data Centers (NDCs) commonly involve the provisioning and shipment of physical hardware systems and the training, installation, maintenance and distribution of the "National Data Centre (NDC)-in-a-Box" (NIAB) software suite. These fundamental functions (access to hardware and software) are the foundations of cloud computing. We investigate whether utilizing cloud infrastructure is feasible and beneficial to users of the IMS data and IDC software. We test using basic cloud computing and storage technologies to increase access and capacity for NDCs/users, to decrease cost and logistical burden, increase processing capabilities, and improve overall infrastructure reliability without losing the current level of local flexibility. We investigate the use of VirtualBox virtual machines (VMs), Docker containers, and Amazon Machine Images (AMIs) on elastic compute cloud (EC2) virtual hardware in the Amazon Web Services commercial cloud. Thus far we have found that AMIs offer the best balance of high configurability and low resource usage. Internal and external evaluations of AMIs containing NIAB Seismic, Hydroacoustic, and Infrasound (SHI) software and virtualized desktop environments on EC2 instances note good desktop responsiveness and adequate computing and storage capacity.

Promotional text: The study shows how the use of the NIAB software on cloud platforms could expand NDC capabilities and their use of IMS data by performing the analysis and data pulls utilizing cloud resources, reducing local bandwidth and infrastructure issues.

O4.3-266 – Next-generation IMS Power Systems: Current status and the way forward

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With a strong mandate to sustain high annual data availability throughout the IMS network, IMS/ED launched the initiative to design the next-generation IMS power systems to strengthen IMS stations' resiliency to catastrophic failures, often arising from power-related issues. Five standardized IMS power system prototypes were developed, certified, and subjected to throughout factory-acceptance testing. The developed next-generation IMS power systems are based on the open system architecture concept, utilizing ad-hoc selection and substitution of various power sources and power system components derived from the environmental demands and logistical restrictions present at the station location. These purpose-built, yet standardized power systems thus adapt to the site-specific input and output requirements, without requiring extensive redesign and cost when deployed at other stations throughout the IMS network. The high degree of standardization simplifies installation, maintenance and future upgrades as components can be freely interchanged throughout their life cycle without impacting the overall system.

The new IMS power systems are currently undergoing long-period testing in field conditions at the

FACT facility at Sandia National Laboratories, with further tests scheduled at a test site in Alaska in 2021. The drafting and release of the IMS Power System Guidelines documentation is underway.

Promotional text: The main intent of this topic's submission is to share the experience and lessons learned from the development of the power systems, which are not only specific to the IMS, but have a wider reach of applicability and interest to perhaps other attendees of the SnT conference.

O4.3-514 – Presentation of containerized solution and optimized power supply system

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The aim of this presentation is to introduce a range of new engineering systems recently developed and installed by Enviroearth and adapted to the whole IMS network. We will present a modular power supply system which allows flexibility to answer to any power supply need and configuration over the global network. These power systems are all equipped with their own state of health IT system allowing a continuous monitoring of information on the system operation via an accessible and user friendly dashboard. We will also present a series of plug and play equipment vaults and containerized system technologies that have been optimized to fit with all the topologies and technologies of the station within the IMS network. Over the past few years, we have worked on the improvement and the standardization of these systems to target more robustness and sustainability leading to better station data availability. We would like to present this knowledge and expertise on these products and introduce state-of-the-art systems adapted to the needs of the CTBTO with a focus on the verification options and assets that they are all offering.

Promotional text: Containerized Solution Technology and Power Supply are the "how know" of Enviroearth. We have designed, optimized, tested, installed, and operated a wide range of these System Solutions over each IMS Station technology and topology type and would like to present these knowledge.

O4.4 Network sustainability and systems engineering for CTBT verification

O4.4-135 – Operating temporary seismic array during modernization of IMS station

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The PS19 seismic station (GERES) is part of the IMS primary seismic network for verification of the CTBT. The station consists of 25 array elements with an aperture of about 4 km. The modernization of GERES in 2017/2018 implicated a general shutdown of the operation for 18 months, since the intra-array cabling was replaced and new equipment for power supply and data acquisition was installed. However, the absence of this station would have unacceptably decreased the network performance in Europe. Therefore, the operation of a temporary 10-element seismic array guaranteed a continuous data recording with sufficient detectability of seismic signals at this IMS location. The selected configuration has proved successful, that the high performance as is known at GERES could be sustained during the period of construction works. A crucial prerequisite was the high data availability, which was achieved due to reliable set-up of the station equipment. Robust mobile containers housing equipment for power supply, data acquisition and transmission were installed at the individual array elements nearby the vaults, where the seismometers remained at the original position. Especially, the operation of direct methanol fuel cell systems with remote monitoring has proved as technology with high operational reliability.

Promotional text: A long outage of an IMS station due to construction works decreases the network performance. A temporary array with reduced number of elements is a beneficial alternative to sustain the operation of the station. Fuel cell systems are proved to be reliable for the power supply.

O4.4-209 – Advanced algorithms and prognostics for monitoring the Radionuclide Aerosol Sampler/Analyzer (RASA)

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State of health (SOH) data from radionuclide sensors in the International Monitoring System (IMS) provides critical information about the operating status of stations. Radionuclide systems typically have many sensors that are important indicators of normal operation or system problems. Since there are many IMS stations with radionuclide systems, monitoring them all simultaneously by a single analyst is a challenge. Over the past several years Pacific Northwest National Laboratory (PNNL), in collaboration with General Dynamics, has been developing a status of health monitoring architecture for analyzing SOH data from radionuclide systems of the IMS. The architecture was originally developed to support the Swedish Automatic Unit for Noble gas Acquisition (SAUNA). Recently, the Radionuclide Aerosol Sampler/Analyzer (RASA) was added to the SOH monitoring tool. The tool uses statistical methods such as Exponential Weighted Moving Average (EWMA) and standard deviation techniques to monitor the systems. PNNL is now investigating methods to improve RASA SOH monitoring capability by using advanced algorithms capable of identifying actual failures based on sensor signatures. This research is also seeking to detect and identify the failures as early as possible using advanced prognostic approaches. The results from failure identification techniques and prognostic algorithms will be outlined and presented.

Promotional text: The SOH monitoring methods outlined in this work seek to help IMS operators identify the source of problems early and quickly. This will improve sustainability efforts of the IMS and help both the data quality and availability which are critical to monitoring and verification.

O4.4-528 – Activities to improve Data Availability by the IMS Maintenance Unit

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Maintaining and improving data availability (DA) of certified IMS stations require the joint efforts of the states hosting International Monitoring System (IMS) stations, local operators and the PTS. Activities that are being undertaken in areas of maintenance, operations, engineering, development, logistics, recapitalization and training across the PTS directly impact the DA and sustainability of the IMS. This paper provides a summary of some key activities undertaken by the IMS Maintenance Unit to improve data availability. These include; equipment standardization, improved hands on technical training, HPGe detector vacuum restoration, improved sparing, improvements to power systems, grounding and lightning protection, infrastructure improvements and equipment upgrades, monitoring HPGe detector SoH and spectral data quality to perform predictive maintenance and improvements to the station environment.

Promotional text: Technical measures undertaken to improve data availability and sustainability of the IMS stations.

O4.4-567 – [WITHDRAWN] AFTAC's Approach to Evaluating Sustainment Variance Impacting Mission Performance

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AFTAC's Center of Engineering Excellence (CoEE) understands that system variance imposes risks to both network performance and budget parameters. Left unchecked, these risks create severe consequences to AFTACs global sensor network. As a result, the CoEE has built upon previous evaluation of maintenance support strategies (O&M 2020) to identify and eliminate the largest sources of maintenance variance. The CoEE has analyzed nearly ten years of historical performance field data, process instructions, training procedures, personnel requirements, and other documentation to assess maintenance activity impacting the USAEDS Network performance and requiring additional unwarranted costs. The CoEE has made significant progress eliminating those sources of variance, improving control of network performance, and eliminating unnecessary costs. The findings resulting from this study are the cornerstone that will allow AFTAC to strategically reshape geophysical operations towards a future emphasizing agility, performance, and cost sensitivity.

Promotional text: More Mission Less Money‼

O4.5 Resilience of the CTBT monitoring regime, including lessons learned from the COVID-19 pandemic

O4.5-192 – Performance of the Global Seismographic Network (GSN) During COVID: Challenges and Opportunities

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We review the impact of the COVID-19 pandemic on Global Seismographic Network (GSN) operations. GSN stations, of which 50 also serve as IMS auxiliary Seismic Stations, have been designed to operate autonomously with very little operator intervention for long periods of time. These design goals have been strenuously tested with the advent of the COVID-19 pandemic, as travel by both local station operators and field engineers has been severely curtailed. We present examples of adaptive maintenance and repair strategies and the impact these have had on data return. Station downtimes are often limited by pre-positioned spares that may be easily swapped for damaged elements. Despite COVID-related impacts, the overall network uptime since January 2020 at 87%, while down from 88.7% in 2019, continues to exceed our funding agencies' data availability metric of 85%. Planned equipment upgrades and preventative maintenance have been postponed, which may affect future system reliability. COVID and the constraints that the disease places on travel have led to increased use of tele-consulting by remote field engineers with local operators, which we anticipate will lead to enhanced local capabilities and improved overall efficiencies.

Promotional text: network sustainment and resiliency during a global pandemic.

O4.5-385 – Maintaining Operational Capability During COVID-19

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General Dynamics Mission Systems (GDMS) overcame new challenges and implemented innovative strategies to maintain International Monitoring System (IMS) minimum requirements during the COVID-19 pandemic. GDMS focused on five areas: on-site spares, enhanced training material, refined quality assurance processes, development of remote preventive maintenance, and the health and wellbeing of team members, in order to maintain the resilience of the CTBT monitoring regime. GDMS launched remote training curricula to further local operator maintenance capabilities and implemented video procedures to enhance troubleshooting effectiveness. These remote training opportunities provided GDMS with valuable information regarding the nuances of local conditions and environments in response to the pandemic. GDMS tailored preventive maintenance plans to identify station specific needs to safeguard stations from critical failures. Efforts to secure team member safety and wellbeing in their daily operation through shift-scheduling, instant- and video-focused communication methods, and regular seminars and workshops effectively advanced inter-team knowledge and created a more efficient work structure while maintaining health and safety requirements.

These measures, while critical in the midst of the COVID-19 pandemic, revealed many lessons learned regarding efficiency, communication, and innovation. GDMS looks forward to continuing implementation after the pandemic in daily operation and unforeseen circumstances.

Promotional text: Innovative strategies and lessons learned from the GDMS COVID-19 pandemic response highlight valuable avenues of continued improvement in order to maintain operational capability during and beyond the pandemic.

O4.5-479 – Seismic Monitoring in Canada During COVID

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We describe the standard pre-COVID mode of operations for the Canadian National Seismograph Network, a large continental-scale monitoring network, and for the associated IMS stations in Canada. We examine how the operational posture has evolve and then discuss the manners in which the posture was found suitable and unsuitable to respond to the challenges and constraints of the COVID-19 situation in Canada. We find that many of the design and operations decisions that have been taken over the last several decades for seismic monitoring operations in Canada, driven largely by considerations of resilience and cost-effectiveness, and further refined after the lessons-learned of the H1N1 pandemic, resulted in a system that continued to function effectively under pandemic lockdown conditions. Specific challenges and lessons learned during the first annual cycle of the pandemic are noted.

Promotional text: We describe the specific challenges and lessons learned during the first annual cycle of the pandemic for the Canadian National
Seismograph Network, a large continental-scale monitoring network, and for the associated IMS stations in Canada.

O4.5-710 – Operation of the IMS network during the COVID-19 Pandemic - Challenges and Solutions

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The CTBTO Provisional Technical Secretariat is responsible for supervision and coordination of the IMS network operations, and for providing assistance to assure proper functioning of IMS facilities. Station Operators are responsible for the operation of the IMS facilities, in accordance with the Operational Manuals, while complying with facility specific contracts, agreements and arrangements. The global response to the COVID-19 pandemic has brought about numerous unprecedented challenges for the operation of the IMS network. Station Operators have faced challenges in accessing and operating their facilities during lockdown phases, and logistical problems such as spare parts shipments have increased during elongated periods with severe travel limitations.

This presentation will detail on those challenges, including difficulties with visits to IMS stations, RN QA/QC sample shipments, scheduled calibrations, and troubleshooting of unstable communication links. Through several monitoring tools and the COPC Operations Centre, the PTS carries out comprehensive analyses of the network to provide practical solutions to Station Operators. Continuous communication, availability and flexibility in supporting Station Operators are the key to manage such critical conditions. Further enhancements of PTS monitoring tools are under development to support IMS Station Operators in their intent to improve data availability, data quality and data surety.

Promotional text: The presentation highlights operational challenges and solutions during the COVID-19 Pandemic from the IMS/OPS view.

O5.2 Experience with and possible additional contributions to issues of global concern such as disaster risk mitigation, climate change studies and sustainable development goals

O5.2-097 – Recent Seismicity of the West African Region

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The West African region is generally considered a stable continental area with few active tectonic features. However, several earthquakes have struck the area in historic and recent times. The region has records of damaging earthquakes dating as far back as 1615. Major events which had magnitudes between 6 and 7 occurred in 1862, 1906, 1939 and 1983. The seismicity is not well known due to the sparse seismic network coverage, incomplete and inhomogeneous earthquake catalogues and poor knowledge of the ground motion parameters. However, in recent times there have been vast improvement in the deployment of seismic equipment for monitoring earthquake activity. Seismic activities with magnitudes ranging from 1.8 to 5.3 have been observed recently in Ghana, Ivory Coast, Niger, Mali, Sierra Leone among others. These events are mostly associated with the Romanche, Chain, St. Paul transform faults and the Cameroon volcanic line. Seismic data received from the International Data Centre is utilized in compiling an earthquake catalogue for the sub region.

Promotional text: Information on earthquake occurrence in the West African region which has been collated from data from the International Data Centre (IDC) is discussed. This would contribute to the public awareness creation campaign on earthquake disaster risk reduction in the sub region.

O5.2-318 – The 2015 Earthquake Swarm of Fentale Volcano: Multi-hazard Threat for Ethiopia's Access to the Coast

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The Fentale-Dofen magmatic segment was shown to be more active than other volcanic centers in the northern Mid Ethiopian Rift by a temporary seismic experiment, conducted between 2001 and 2003 (Keir et. al., 2006). However, the activity observed during the EAGLE experiment is not swarm like but randomly scattered in time. In this study, we characterize rarely observed seismicity in the Fentale volcano neighborhood that occurred in March and April 2015 using reasonably good quality seismic data. Over 1,350 earthquakes are located and the activity is clustered around "Tinish" Fentale, northeast of Fentale proper with a maximum magnitude of 3.5 ML. There are volcano-tectonic and long-period events, showing that the activity is induced by magmatic intrusion. This intrusion seems to commence at depth and migrate southwestward as it shallows, to the centre of the activity. This may imply that the magma feeding system of the Fentale-Volcanic Complex is either attributed to different sources or may all be influenced by the magma rich Afar Depression. This phenomenon is another geohazard threat, in addition to the lake level rise of Beseka, to Ethiopia's access to the active commercial route. This is a wakeup call to take precautionary measures to the concerned stakeholders.

Promotional text: The Fentale-Dofen magmatic segment is one of the active volcanic canters in Ethiopia that needs monitoring. Characterizing these volcanic sources can be used for Ground Truth events for improving crustal structure and also mitigating potential hazard for fast growing population a.

O5.2-532 – The sound of melting glaciers in Greenland in a changing climate

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The infrasound component of the IMS is not only capable of detecting nuclear-test explosions, a wide variety of natural and anthropogenic sources are continuously measured by the network.
A rich infrasonic wavefield is recorded by station I18DK, located in Northwest Greenland. I18DK is located in an unique environment far above the polar circle. Operations started in 2004, enabling long-term monitoring of its surroundings and building a statistically reliable soundscape. The infrasonic recordings reveal lots of infrasonic activity during summer, while the surroundings are infrasonically quiet in winter. The sounds are associated to glaciers around I18DK, active during the melting season. Different mechanisms like run-off and calving generate infrasound. It is found that sea and land-terminating glaciers leave a distinctly different infrasonic signature.
The simultaneous observation of sounds from different glaciers over a long time period paves the way for studying the melting behavior in the Arctic cryosphere under a changing climate. Between the years a large variability is found in infrasonic activity of the glaciers. Such activity is quantified in terms glacier dynamics by comparing it to both modeled and locally measured run-off. Sounds of the land terminating Qaanaaq glacier show an increase in activity over the years.

Promotional text: Listening to inaudible sounds, infrasound, of Arctic glaciers under a changing climate.

O5.2-539 – CTBTO to manage earthquake short-term risks

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MEMS instruments are more commonly known as inexpensive instruments to create seismic monitoring systems. As a result, independent efforts would have access to the required data stream to start analysis and applying new-generation models to continuously detecting patterns that increased creativity amid managing risks of major earthquakes. In project Earling, such data helps to distinguish high-risk seismic patterns from low risk and normal patterns. As an example, Earling issued an alert to the Icelandic Meteorological Office a few days before Iceland's largest earthquake since 2008. MEMS instruments require setup, power supply, stable connectivity, maintenance, which also are some of their constrain alongside accuracy. Utilizing accelerometers of smartphones can overcome the limitation as a mobile app would do whatever is needed to turn a smartphone into one of the nodes of a seismic network, but most of the patterns can appear in uninhabited regions with no smartphone or other instruments to record the seismic patterns. Here, the CTBTO instruments can be very useful to draw a clear viewpoint of the current risk situation in its undercover regions to detect high-risk seismic time-window when the probability of an unusual event is remarkably increased, which accurate enough especially for transferring financial risks.

Promotional text: AI, CTBO instruments and new generation of disaster modeling now can be used together to detect high-risk time-window when probability of an unusual seismic activity is remarkably increased in a specified region. CTBTO data are very useful to manage or transfer the related risks.

O5.2-620 – Role of CTBTO in strengthening preparedness for Disaster Risk Mitigation: A Study of Prospects and Challenges

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Disaster Risk Reduction is one of the most significant themes of discussion in the contemporary global debate regarding attainment of sustainable future. The CTBTO is a unique treaty which has been contributing towards Disaster Risk Mitigation with the help of its well organized verification system for years.
In 2011 when Tohoku witnessed a massive earthquake with tsunami, CTBTO monitoring stations shared critical real time information with the Japanese authority. Not only that, but after the Fukushima Daiichi nuclear disaster, the CTBTO's radionuclide network proved enormously helpful. The verification mechanisms the CTBTO posses like International Monitoring system generate critical data which can provide timely and accurate determination of earthquakes, tsunami and volcanic eruption. To improve the efficacy of Disaster Risk Mitigation, there is a need of coherent communication and coordination amongst stakeholders, in this regards CTBTO plays a significant role.
The proposed paper will evaluate the role of CTBTO as an important stakeholder in global policy oriented debate on Disaster Risk Mitigation and assess its future prospects and challenges. It will further attempt to understand the role of CTBTO monitoring stations in different South Asian nations and its potential to emerge as an important Disaster Risk Mitigation stakeholder in the region.

Promotional text: The proposed paper will provide a general outlook on the role of CTBTO as an important stakeholder in the global disaster risk mitigation framework and the paper will talk about the south asian experience of disaster risk mitigation and the role CTBTO in that context.

O5.2-674 – The Value of Open Data from Globally Distributed Geophysical Instrumentation Networks

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High-quality open data from global and regional networks such as the Global Seismographic Network and the EarthScope Transportable Array have enabled a wide range of transformative, cross-disciplinary research that has far exceeded original expectations. The networks consist of well operated and distributed stations with long-term recording histories, and were designed to facilitate studies of Earth structure and earthquake processes. However, the use of these data has been much broader, including studies of slow earthquakes, landslides, the Earth's "hum", glacial earthquakes, sea-state, climate change, induced seismicity, and wildfires. These broad discoveries have been enabled because datasets are completely open and unrestricted, and the data and metadata are easily discoverable and well documented.

Similarly, the International Monitoring System (IMS) has produced decades of valuable global geophysical observations in support of the CTBT explosion monitoring mission. The IMS, with its global distribution and high-quality can provide data for regions where no other data are available. Collectively, these various networks have contributed to capacity building, by providing data to scientists around the world, providing designs and standards for networks and stations worldwide, and engaging the public's interest in science.

Promotional text: Decade long, open, high quality data from Globally Distributed Geophysical Instrumentation Networks like the IMS can contribute to capacity building to scientists around the world, and provide data for broad discoveries far beyond the original CTBT explosion monitoring mission.

O5.3 Capacity building, education, communication and public awareness

O5.3-072 – Utilization of CTBT-NDC data in geoscience education of Bangladesh

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Bangladesh, a Comprehensive Test Ban Treaty (CTBT) signatory country since 24 October, 1996, is the 54th state to ratify CTBT on 8 March, 2000. Auxiliary Seismic Station (AS007 BRDH) in Bangladesh, accredited as an internationally certified station, receives the seismic data from International Data Center (IDC) of CTBTO. The seismic station AS007 was established to monitor the activities of nuclear testing through seismic wave propagation in the region. Geoscientists of different academic and professional institutions have been analyzing seismic travel time data from various sources. Accordingly, the objective of the present report is to find out the potential application of regional seismic travel time (RSTT) data in the geoscience researches of Bangladesh. The RSTT data can be applied to analyze this subsurface geological information with the combination of other CTBT seismic stations of the region. Besides seismic data, the IDC has other products, such as radionuclide and noble gas distribution data around the world, hydro-acoustic data for tsunami warning system, etc. Therefore, there is ample scope of introducing IDC products to the geoscience education of Bangladesh. As part of R&D activities through the CTBT-NDC, BAEC is working on this aspect by collaborating with the geology departments of several universities.

Promotional text: The proposed study is aimed to introduce the IDC products for their potential application in geoscience education in Bangladesh as well as the necessity of the capacity build up of NDC to implement the activities related to the objectives.

O5.3-103 – Role-play simulations as effective participatory learning techniques in science diplomacy education

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MEPhI Science Diplomacy Club (SDC) aims to nurture a new generation of experts who are curious about cross-cutting issues at the interface of science and international relations, who are willing to bridge diplomatic challenges & technical solutions and who are eager to learn more about current challenges including nuclear test ban, non-proliferation and disarmament.

The SDC members participate in a wealth of outreach and education activities comprising webinars with experts, presentation contests, summer seminars for pre-university students, Science Diplomacy School, career talks etc. Due to restrictions caused by the COVID-19 pandemic, we had to fully utilize evolving pedagogic methods including distance learning and videoconferencing with a view to holding SDC events in a remote format.

We'll use the occasion of the SnT21 to share our experience of incorporating simulations and role-plays, which are deemed to be one of the most effective participatory learning techniques, into multidisciplinary educational programs. Moreover, we'd like to share our main learnings from The 2020 NPT Review Conference Model which not only highlighted the NPT-CTBT nexus but also showcased the distinct role of the CYG in increasing the visibility of the CTBT.

Promotional text: Virtual simulations provide unique opportunities for students to delve into nuclear test ban and non-proliferation as they are one of the most effective participatory learning techniques in science diplomacy education. They represent a bumpy ride but very rewarding and impactful!

O5.3-413 – Knowledge Management in the Context of Comprehensive Nuclear-Test-Ban Treaty (CTBT) Science and Technology

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In support to the Comprehensive Nuclear-Test-Ban Treaty, the worldwide scientific community - via the CTBT SnT Conferences - has the opportunity to build partnerships and encourage knowledge exchange, allowing the CTBTO to remain at the forefront of the relevant technology for test-ban verification. The SnT Conferences are organized biennially by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO). This paper analyses the CTBT SnT topics presented at the Conferences from 2006-2021, capitalizing on scientific and technological applications, trends, innovations and worldwide collaborations. The goal of this work is to provide directions on the knowledge management approach for deep content analysis, strengthening the role of Knowledge Organisation Systems (KOS) as a mechanism and tool for analysing and disseminating content. This research reflects the necessity of creating a KOS-based tool for knowledge recognition and discovery that will encourage communication in a valuable way.

Promotional text: Analysing the topics from SnT Conferences 2006-2021, the paper reflects the necessity of creating a Knowledge Organisation System-KOS-based tool for deep content analysis that will encourage CTBT SnT knowledge communication and reuse on a valuable way.

O5.3-525 – Scientist and Diplomats On Site!

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In the context of the nuclear non-proliferation regime, the On-Site Inspection of the CTBTO play a mayor role for verification. OSI is when Scientists from different fields and diplomats get together with a common aim: "to identify signs from a nuclear explosion". Only a perfect match between science knowledge and diplomatic skills can assure full success for an OSI. The crucial issue is how to prepare both to be ready to go in to the field and interact properly using a common language and having the same training and motivation. For this to happen diplomats must correctly learn not only about the whole range of technologies involved in an OSI but to experiment in field exercises in order to confirm without any doubt that the data arising from scientific work are reliable, trustworthy and can be used for a proper decision at the political level.

Promotional text: Scientist and Diplomats for a successful OSI.

O5.3-639 – CTBTO Link to the ISC Database as a Tool for Capacity Building and Education

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The CTBTO Link to the database of the International Seismological Centre (ISC) is a service provided on behalf and by arrangement with IDC/CTBTO. The Link enables PTS and National Data Centres (NDC) with dedicated access to long-term definitive global datasets maintained by ISC using specially designed graphical interfaces, database queries and non-IMS waveform requests. This service gives access to the ISC Bulletins of natural seismicity of the Earth, mining induced events, nuclear and chemical explosions; the ISC-EHB dataset; the IASPEI Reference Event list (GT) and the ISC Event Bibliography.

The searches are tailored to the needs of the monitoring community and divided into four categories: Area based spatio-temporal search (based on ISC Bulletin), REB based spatio-temporal search, GT event based search and the IMS station based search (historical reporting patterns of stations close to IMS sites). We recently made several additions, for example, a service reporting suspected time periods of inverted polarities at openly available seismic stations.

The Link demonstrates one of the CTBTO efforts in capacity building for NDCs and education of new generation of seismologists working in monitoring research. The Link is regularly used by the NDCs and PTS and proved useful during recent CTBTO Exercises.

Promotional text: The CTBTO Link to ISC database supports the exchange of knowledge between CTBTO and broader scientific community, promotes the wider data used for test ban verification and contributes towards CTBTO capacity building and educational efforts.

O5.3-696 – Banning Nuclear Tests: The Role of Public Opinion Research

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In recent years, there has been a rapid increase in social scientific studies using polling techniques to better understand nuclear issues. Scholars have shown public opinion in numerous countries on subjects such as nuclear proliferation, deterrence posture, and links between civilian and military nuclear technologies. These studies are important contributions for improving decision-maker accountability and more effectively shaping policy to represent public views. We contribute to these discussions by presenting new public opinion data on nuclear explosive testing. The data come from nationally representative surveys we conducted in Belgium, France, Germany, Italy, Japan, the Netherlands, Poland, Sweden, Turkey, the United Kingdom, and the United States. The surveys demonstrate overwhelming public opposition to nuclear testing while also revealing (mis)perceptions about the effects of nuclear test explosions. Taken together, they provide useful information for policy, advocacy, and education aimed at promoting entry-into-force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

Promotional text: This e-poster shows how public opinion polling can inform policy, advocacy, and education to improve understanding of nuclear test explosions and promote entry-into-force of the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

e-Poster presentations

P1.1 The atmosphere and its dynamic

P1.1-019 – Study of Some Thermodynamic Parameters during Pre-Monsoon in Bangladesh

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An attempt has been made to calculate different thermodynamic parameters to check the severity of thunderstorms during the pre-monsoon season of 2013-2015 in Bangladesh. In this paper, 60 weak to severe thunderstorms events which were recorded by the Bangladesh Meteorological Department (BMD) are investigated. Lifted Index (LI), Showalter Index (SI), Total Total Index (TTI), Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) are calculated to find out the most reliable index for indicating the severity. It is found that the CAPE (having magnitude of 1500 J/kg or more), SI (magnitude of less than -2) and LI (magnitude of less than -3) are the most important parameters for predicting the occurrence of severe thunderstorms and these indices have a significant skill of forecasting the occurrence of severe thunderstorms.

Promotional text: Thermodynamic parameters are one of the important tools for thunderstorm forecasting. The Earth atmosphere is a complex system it is very difficult to understand the stability indices. In this research, researcher used scientific technic and atmospheric data to understand the TS.

P1.1-064 – Nyepi Day Impact on Weather Parameters Measurement at Synoptic Observation Stations in Bali

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Nyepi is a rare activity in the world that only exists in Bali, where all of human outdoor activities stop for a day. This study used Nyepi to measure its impact on changes in weather parameters measurement in Bali. The purpose of this study is to see the effect of Nyepi on the ratio of daily average temperature to duration of solar radiation as well as daily average air humidity at four synoptic stations in Bali. The data that we used are daily average air temperature, duration of solar radiation, and average air humidity from 1999-2020 on Nyepi. As a comparison, we used data from 2 days before and after Nyepi. Based on 22 years of data at the four location points, we obtained that the air temperature in the 5-day range fluctuates and shows a trend of decreasing daily average temperature during Nyepi for all stations. As for the daily average air humidity, the effect of Nyepi is only visible at the Ngurah Rai Meteorological Station as an increase. The average temperature to sunshine ratio during Nyepi, 2 days before and after Nyepi showed that the lowest ratio occurs at Denpasar Geophysical Station and Jembrana Climatology Station.

Promotional text: Nyepi Day, a day for rest the world and refresh the air quality.

P1.1-076 – Assessing convection schemes sensitivity for predict Congo Basin future drought severity

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This paper investigates the sensitivity of two cumulous convection schemes – Grell and Emmanuel – under RCP8.5 scenario drought severity over Congo Basin (CB). The analysis were conducted using a multiscalar drought indices, standardized precipitation index (SPI) for several time scale −3,6,12,24,48 months −during the decades 2021-2030 ; 2031-2040 ; 2051-2060, and 2071-2080. The results reveal that under condition "SPI < -1" Grell's model – maximum CB grid points average rate of 17.1 months per decade (mth/dec) – presents severe droughts duration trends in CB grid points coordinates different to that of Emmanuel – with maximum CB grid points average rate of 18.3 mth/dec. Thereafter, under the condition "SPI < -2", the intensification of droughts in Emmanuel's model evolves gradually with a scale of duration by grid points less stable and more extensive – 6.5 mth/ dec – towards the southern part of CB, while the Grell's model spreads randomly and less widespread over the CB area with a more stable and reduced duration in maximum average rate of 3.9 mth/ dec.

Promotional text: Good initiatives for the integration and knowledge of researchers from around the world.

P1.1-126 – Infrasound from meteorological fronts and its possible generation mechanism.

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Infrasound radiated during periods of weather changes is an almost continuous background against which infrasound monitoring of explosions in the atmosphere is carried out. In this work the results of study of temporal variations of the characteristics of infrasound (amplitudes, coherences, grazing angles, azimuths and horizontal phase speeds) detected during a passage of warm and cold fronts through the networks of microbarometers in the cities Dubna and Moscow are presented. The significant differences observed in the characteristics of infrasound from warm and cold fronts are discussed. Such differences must be taken into account when detecting infrasound precursors of atmospheric storms. A possible aerodynamic mechanism for the generation of infrasound caused by the turbulent air flow around the geometric irregularities of the surface of meteorological front is proposed.
This work was supported by RFBR grants 18-05-00576, 19-05-01008.

P1.1-133 – On the use of dense seismo-acoustic network to provide timely early warning of volcanic eruptions

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The Stromboli volcano is known for its persistent explosive activity, with hundreds of explosions every day ejecting ash and scoria up to heights of several hundreds of meters. Such a mild activity is however punctuated by lava flows and major explosions that represent a much larger hazard. On July 3 and August 28 2019, two paroxysmal explosions occurred at Stromboli, generating an eruptive column that quickly rose up to 5 km. Due to an absence of notification of the eruption, the Toulouse Volcanic Ash Advisory Center (VAAC) emitted an advisory to the civil aviation with a two-hour delay. The various processes of this event were monitored by infrasonic arrays up to distance of 3700 km and by the Italian national seismic network at range of hundreds of kilometres. Using state-of-the-art propagation modeling, we identify the various seismic and infrasound phases for precise timing of the eruptions and volcanic source characterization. Integrating national seismo-acoustic stations to the global infrasound International Monitoring System network opens new perspectives in volcano monitoring for hazard assessment by providing timely early warning of large eruptions.

Promotional text: Many volcanoes worldwide are poorly monitored. Explosive eruptions produce infrasound that are detected at thousands of kilometers. The use of dense seismo-acoustic networks could provide timely reliable source information of these eruptions to Volcanic Ash Advisory Centers.

P1.1-137 – Infrasound analysis associated with the Beirut explosions recorded on 4 August 2020

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An explosion was reported on the 4th of October in the Port of Beirut (Lebanon), by IMS infrasound stations. News reported that the explosion was due to a large quantity of ammonium nitrate stored in the port that exploded (equivalent to around 1.1KT of TNT). The infrasonic signal was observed by several infrasound IMS stations, among them the Tunisian one (IS48). Data was processed with DTK-PMCC software to categorize the wave parameters for other infrasound stations.

Promotional text: Tunisian NDC monitor events detected by IMS stations and give a high importance to data analysis (SHI and R) in order to support the Comprehensive Nuclear test ban Treaty verification regime. Explosion happened in Beirut the 4th of October was the best challenge event on the 2020.

P1.1-147 – Graphic User Interface "Infrasound event analyzer"

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Infrasound is one of three waveform technologies of the Comprehensive Test Ban Treaty (CTBT) verification regime. The International Monitoring System (IMS) network records manmade and natural sources of infrasound signals (bolides, spaceflight activity, sonic booms, volcanic eruptions, quarry blasts, earthquakes…). To identify these sources we need to download and process data, and analysts then have to interpret results. The CTBTO provides us with the needed software, but experience and training are recommended.

Our idea is to let analysts enjoy interpreting infrasound data without being obliged to manipulate different software. For this purpose, a Graphic User Interface called "Infrasound event analyzer" is under development by NDC-TN, in which NDC-in-a-Box software (nms_client,DTK-PMCC, DTK-GPMCC) are grouped and called on a click.

Promotional text: A GUI "Infrasound event analyzer" allows the use of (nms_client, DTK-GPMC) on a click, is under development by Tunisian NDC in order to reduce the analyst workload and to promote the use of infrasound data in both: test ban verification and civil and scientific application.

P1.1-158 – Validating infrasound signal-parameter models using a global ground truth data set

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The celerity-range model used for both association and location in the standard automatic and interactive analysis at the International Data Centre (IDC) of the Comprehensive Nuclear-Test-Ban Treaty Organisation, has not been updated for over 10 years. The NET-VISA automatic association algorithm (Arora et al., 2013) currently providing additional information to IDC analysts, is based on prior probability distributions learned from previous interactive analysis results. Improving the IDC model(s) should improve interactive analysis results, and thus over time improve NET-VISA performance for seismo-acoustic events. Whilst numerical acoustic propagation modelling may be used to provide both range and time dependent priors for signal parameters, ground truth data analysis is necessary for model validation. Using software developed to consistently analyse a global ground truth database, empirical models for celerity, backazimuth and duration have been constructed from 312 detections in the 0.32 – 1.28 Hz passband. The probability distribution for backazimuth is consistent with the NET-VISA backazimuth prior derived using seismo-acoustic events. Our results do not support the IDC model increase in stratospheric signal celerity at a distance of 20°; we look to provide a range-dependent model whose uncertainties reflect the lack of observations at these longer ranges.
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Promotional text: Through validating infrasound signal-parameter models using a global ground truth data set, we aim to improve the infrasound data analysis methods used for nuclear test monitoring.
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P1.1-215 – InfraPy, InfraGA/GeoAc, and stochprop: open-source software tools for infrasound signal analysis and propagation modeling at Los Alamos National Laboratory

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Infrasound research conducted at Los Alamos National Laboratory (LANL) in recent years has included development of tools for signal analysis, propagation modeling, and uncertainty quantification. Many of these tools have been licensed as open source software, made available for download at the LANL Seismoacoustics Github page (https://github.com/LANL-Seismoacoustics), and are utilized by scientists across the globe for a variety of national security, civil, and scientific applications. The InfraPy signal analysis suite includes state-of-the-art detection, association, localization, and yield estimation algorithms accessible through Python-based scripting and notebooks, a command line interface, as well as the InfraView graphical user interface. The InfraGA/GeoAc software is a propagation modeling tool capable of simulating the propagation of infrasonic signals through the atmosphere in the limit of geometric acoustics and includes a number of unique features such as eigenray identification, weakly non-linear waveform calculation, and propagation over realistic terrain. The stochprop library is an in-development tool that includes methods enabling quantification and reduction of propagation uncertainties for infrasound analysis. The capabilities of these tools and their application to recent seismoacoustic events of interest will be presented.

Promotional text: Open-source signal analysis and propagation tools for infrasound, particularly those quantifying uncertainty, support the international explosion monitoring community, promote wider civil and scientific applications, and provide LANL researchers with feedback on algorithms.

P1.1-237 – Assessment of seasonal forecasts using North American Multimodels Ensemble (NMME) in Central Africa (CA).

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This study examines the assessment of the seasonal forecasts of the North American Multi-model Ensemble (NMME) Project in Central Africa (CA) using deterministic and categorical methods focusing on the rainfall variable. This assessment is made for the June through August, March through May, and December through February seasons at 0-5 months, lead-times which are consistent with many regional climate outlooks. The precipitation observed and predicted by the NMME models has been classified into three categories (rainy, normal and dry). It can be seen that at lead 0 that the average of the multi-model set (MME) favorably represents the average seasonal rainfall in the sub-region. The Taylor diagram shows a promising result at lead0 with significant correlation coefficients greater than 85%. At lead 3, the coefficient values are low compared to lead 0. Note that the probabilities of detection (POD) of the models are more significant for the different seasons (normal). As a result, NMME models appear to be a valuable tool that can provide some key seasonal characteristics up to 5 months in advance in the sub regions, which will allow forecasters to better take into account all the uncertainties linked to natural phenomena and the state of the atmosphere.

Promotional text: Our abstract provides information on the evaluation of a global model for making predictions. The data used are very rich and contribute to the objectives of this SnT2021. conference in the field of atmospheric physics and dynamics.

P1.1-251 – The state of the atmosphere throughout the seasons: comparison of numerical weather prediction models for infrasound observations at regional distances

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Since the year 2000 the German Aerospace Center (DLR) facility near Heilbronn, Germany, has conducted main engine tests of the European ARIANE-5 rocket.
Infrasound signals from these tests have regularly been observed during the last two decades at IMS station IS26 at a range of about 320 km in easterly direction.
While a majority of these tests produced signal observations when carried out during the winter season between October and April, there is an almost complete lack of observations during the summer season. When comparing numerical weather prediction models for summer and winter seasons, or times with detections or non-detections, then these models differ significantly in the sound speed profiles producing either a strong stratospheric duct or a lack thereof. This is also reflected by the effective sound speed ratio, mostly exceeding a value of 1 for detections and less than 1 for non-detections. However, a significant portion of profiles with non-detections, nearly a quarter or 20 out of 88 cases, show a sound speed profile that should enable infrasound signal observations. The reasons for the lack of observations are addressed in this study.

Promotional text: Infrasound signals from ARIANE-5 engine tests over two decades are investigated regarding the state of the atmosphere and the detectability at IMS infrasound station IS26.

P1.1-253 – Rapid automated detection, association, and location of remote volcanic infrasound using 3D ray-tracing and empirical climatologies

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Explosive volcanic eruptions produce powerful infrasound signals that are frequently recorded by the International Monitoring System (IMS). We are developing and testing methodologies to detect, locate, and characterize volcanic infrasound globally using data from the IMS. Challenges remain in attributing an infrasound event to a particular volcano, in part because source locations can be offset due to the effect of stratospheric crosswinds. We build on the combined association and location brute-force, grid-search, cross-bearings method of Matoza et al. [2017, 2018], here implementing backazimuth deviation predictions from 3D ray-tracing with empirical climatologies (HWM/MSISE). We are exploring the utility of climatologies rather than operational weather hindcasts for rapid first-order computation (e.g., for near-real-time monitoring, reanalysis of large data archives). With individual event case studies of two similar Volcanic Explosivity Index (VEI) 4 eruptions in Chile (Puyehue-Cordón Caulle volcanic complex on June 4, 2011; and Calbuco volcano on April 22, 2015), and stations up to ~5000 km, we obtain source location improvements of 66 to 89.6%. Here we further test our method using a multi-decadal (2003–2019) dataset of observations of moderate explosive eruptions from volcanoes Yasur, Lopevi, and Ambrym (Archipielago of Vanatu), recorded from 399 to 670 km from I22FR (New Caledonia).

Promotional text: We are building a rapid method to automatically detect, localize, and characterize volcanic infrasound using the IMS network of arrays. In this work we are centered in reducing the source misfit that atmospheric winds introduce on the location method in a robust manner.

P1.1-264 – A Synthetic Study to Determine Adequate Infrasound Network Configurations for Resolving Source Directionality

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Sources including volcanic eruptions and buried explosions have been shown to produce directional infrasound radiation. However, infrasound sensor deployments generally consist of instruments placed on the Earth's surface. Therefore, directional sampling of the radiated acoustic wavefield (especially at angles close to vertical incidence) is generally limited. This insufficient wavefield sampling may bias source size estimates, including mass flow rate for volcanic eruptions or explosion yield.

Here we conduct a synthetic study with local infrasound sensors placed around a directional acoustic explosion source to investigate the configuration of infrasound sensors required to uniquely recover a directional source mechanism estimate. We use finite-difference time-domain methods incorporating rigid topography to obtain the numerical Green's functions for each synthetic station. We invert these synthetics to determine if the prescribed directional source mechanism and source-time function can be retrieved for a variety of station configurations. We consider the influences of environmental factors (wind, temperature, noise), as well as the directionality strength and orientation. The optimal sensor configurations to best estimate acoustic directionality found in this synthetic study will help guide future deployment configurations around active volcanoes and anthropogenic explosions.

Promotional text: This study will help improve our ability to determine yield estimates for underground explosion sources, where infrasound radiation has been shown to be directional. We help bridge the gap between infrasound research on volcanic eruptions and anthropogenic explosions.

P1.1-306 – A vespagram-based approach to assess microbarom radiation and propagation models

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This study presents a vespagram-based approach for comparison between infrasound data recorded at the ground and simulated microbarom soundscapes in multiple directions simultaneously. Data recorded during 2014-2019 at the IS37 station in Bardufoss, Norway, have been processed in the framework of velocity spectrum analysis in order to generate images that present a signal power depending on time and direction (vespagrams). Calculations were performed for several frequency bands within the 0.1 - 0.6 Hz range. The modelled microbarom soundscapes were smoothed to account for the frequency-dependent array resolution. The infrasound data processed and modelled microbarom soundscapes were compared in three different aspects: i) azimuthal distribution of dominating signal, ii) signal amplitude, and iii) ability to track atmospheric changes during extreme events such as sudden stratospheric warmings (SSW). The results reveal good agreement between model and data and demonstrate the ability of vespagrams to monitor the microbarom azimuth distribution, amplitude, and frequency on a seasonal scale, as well as changes during SSWs. The presented vespagram-based approach is computationally low-cost and can uncover microbarom source variability. There is also potential for near-real-time diagnostics of the atmosphere and microbaroms,

especially when applied to multiple stations, e.g. exploiting the CTBTO International Monitoring System network.

Promotional text: Infrasound waves originating in the ocean, propagating through the atmosphere, and recorded by the CTBTO station are compared to the model via the new approach. Results show good agreement. The approach has potential for near-real-time diagnostics of the atmosphere.

P1.1-346 – Location of multi-infrasonic pulse sources based on acoustic momentum of propagation

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To solve the ambiguation in corresponding signals from same sources recorded in different arrays, a multi-infrasonic sources location method is proposed. This method is based on the conservation of acoustic momentum in audibility zone during long-range infrasonic propagation in the atmosphere. In a rocket launch observation experiment, progressive multi-channel correlation method is utilized to calculate the azimuth of each signal in both arrays. Meanwhile, the conservation of acoustic momentum of each signal is also used to match the pulse sources received by both arrays, which facilitates to obtain true locations of infra-sound sources. The propagation total reflection of a pulse signal in continuously changing medium and the acoustic momentum are analyzed. The experimental results demonstrate the effectiveness of the proposed method.

Promotional text: This method solves the ambiguation in corresponding impulse signals from same sources recorded in different arrays.

P1.1-399 – The Global and Coherent Infrasound Wavefield: Recent Advances in Reprocessing the Full International Monitoring System Infrasound Data

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We present recent advances and results of reprocessing the IMS infrasound dataset from its beginning until early 2021. A new implementation of the Progressive Multi-Channel Correlation (PMCC) algorithm enables characterization, with a single processing run, of coherent noise in log-spaced frequency with one-third octave bands from 0.01 to 5 Hz. Such an array processing algorithm enables better characterization of all received signals in their wave parameter spaces (e.g. frequency–azimuth, frequency–trace velocity). This, in turn, permits more accurate signal discrimination and source and propagation studies. The latest comprehensive reprocessing of the IMS infrasound database covers the period from January 2003 to December 2020; in the meantime, the number of stations has increased from 30 to 53. The obtained results clearly indicate a continuous spectrum of coherent signals at IMS stations within the 0.01 to 5.0 Hz frequency range, as well as the wave parameters' relation to middle atmosphere dynamics. Also, more sources are identified when comparing the recent results with those of previous reprocessing approaches or the standard IDC products.

Promotional text: Our comprehensive dataset (up to 18 years) serves as the reference for a microbarom model validation (abstract by De Carlo et al.). It also opens up avenues for further studies (abstract by Hupe et al.) presenting tailored products for atmospheric and civilian applications.

P1.1-401 – Characterization of the 4 August 2020 Beirut explosion from the infrasound component of the IMS network

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The 4 August 2020 tragic Beirut ground truth explosion is of great interest to test the infrasound component of the IMS network, especially in terms of localization accuracy and energy estimation. Although the event was detected by five infrasound IMS stations located from 2 400 km (I48TN, Tunisia) to 6200 km (I11CV, Cape Verde), the early location capability from such a sparse network remains limited. Indeed, the spatial distribution of the remote detecting stations tainted by variable background noise levels, coupled with the relatively high uncertainties associated to the atmospheric parameters in the middle atmosphere, make the accurate localization estimation of such medium size events very challenging. We will show in this presentation that even if meteorological institutes can now provide high spatial and time resolution operational products (1h in time and 0.25° in space) at a global scale up to 80 km altitude, the final localization uncertainties remain quite high using infrasound-only data. Examples of full-wave modelling performed from ECMWF analysis and forecasts products, that the IDC distributes to Member States, will be shown to illustrate that point. Such model effects on energy estimation will also be quantified and discussed.

Promotional text: Infrasound analysis of the 4 August 2020 tragic Beirut explosion.

P1.1-416 – Construction and Evaluation of a Statistical Model of Seasonal Forecasts in Cameroon.

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The objective of this study is to build and then evaluate a statistical model of seasonal forecasts in Cameroon. A study was carried out in the five agro-ecological zones of Cameroon with the test stations of Kaélé, Meiganga, Nkongsamba, Yaoundé and Kribi. This study consisted of developing statistical forecast models at each of these stations which were then evaluated first over their calibration period (1958-1987), then over an earlier period (1989-1993). It emerges from this evaluation that the sea surface temperatures so far used
during the PRESACs explain "roughly" the rainfall in Cameroon and especially in the cities of Yaoundé and Kribi where the multiple correlations between the sea surface temperature and rainfall indices are 0.70 and 0.71 respectively. It also follows that the Hit Skill Score and the rate of coincidence between forecast and observed rainfall indices vary from 65% to 85% and 76.66 % to 90% respectively. No model has false alarms. Strong connections between rainfall in Cameroon and the oceanic areas of the Atlantic coast of Africa located on the course of the African monsoon, the engine of rainfall in the region have been established. These results argue in favor of exploring other predictors to improve predictions.

Promotional text: This study then allows to know what will be the rainy season to come, through a qualitative evaluation of the seasonal accumulation of precipitations. This makes it possible to define strategies for the management of natural resources.

P1.1-458 – Observing military aircraft activity with the Romanian infrasound arrays

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Presently, National Institute for Earth Physics operates two infrasound stations deployed on the Romanian territory: IPLOR 4-element array of 0.6 km aperture, and, under cooperation with AFTAC (USA), BURARI 6-element array of 0.7 km aperture.
As many military bases are deployed across Europe and Near East region, signals from supersonic aircraft activity are detected routinely at the Romanian infrasound stations. These signals are observed from short/local ranges (140 km) to long-distance ones (2200 km). Several directions of interest were identified: NW (North Sea, Germany), NNW (Norwegian Sea, Northern Norway), NNE (NE Ukraine-NW Russia), SSE (Aegean Sea), SE (Turkey, Sinai Peninsula). Moreover, the two arrays frequently observe supersonic jets flying from military bases located in Romania.
Sonic booms generated by military aircraft could be localized by cross bearing the detections of IPLOR and BURARI arrays. The information released on military exercises and LEB bulletins is used to validate the locations. At local distances, the sonic boom appears as an infrasonic pulse dominated by high frequencies (above 1 Hz), while, for long-ranges, lower frequency drops below 1 Hz as the higher frequency components are rapidly attenuated. Statistical analysis of wave parameters (trace velocity, azimuth, frequency, amplitude) shows seasonal and daily variations.

Promotional text: As many military bases are deployed across Europe and Near East region, signals from supersonic aircraft activity are detected routinely at the Romanian infrasound stations IPLOR and BURARI. These signals are observed from short ranges (140 km) to long-distance ones (2200 km).

P1.1-464 – Detection and properties of local artillery infrasound

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Acoustic-wave detection from man-made sources like explosions and artillery is of interest both for civilian and military purposes. Infrasound propagation from surface sources is controlled by a complex interplay between source location, winds, atmospheric attenuation, and topography. The seasonal and stochastic variability of stratospheric and tropospheric winds is known to play an important role in the detectability of infrasound on the ground. In particular, large wind-intensity variations occur between summer and winter months. However, the lack of high-quality observational datasets with good temporal coverage throughout the year limits our understanding of the correlations between source characteristics, range-dependent atmospheric properties, and topography. Here, we take advantage of an extensive set of artillery exercises, conducted by the Norwegian Armed Forces in southern Norway throughout 2020, to constrain the detectability and wave properties at local distances. Up to 70 km distance, signals are generally observed when the atmospheric models include stronger lower-tropospheric winds (1-5km altitude) blowing in the direction of propagation. When cross winds dominate the wind field, low-amplitude infrasound arrivals are still observed in the acoustic shadow zone while not predicted by ray-tracing simulations, highlighting both model and propagation uncertainties introduced by small-scale wind heterogeneities and diffraction effects.

Promotional text: Artillery shots excite acoustic waves travelling over at large distances. Characterizing infrasound sources is crucial for civilian and military purposes. We perform an extensive investigation of military exercises in Norway to derive the main property of artillery infrasound.

P1.1-491 – Infrasound propagation simulations using atmospheric fields from high-resolution global models resolving gravity waves

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Small-scale atmospheric perturbations known as gravity waves (GW) are critical to infrasound propagation simulations as they alter the propagation path of the waves, causing detections at infrasound stations that remain unexplained when only large scale atmospheric features are considered. Therefore, it is important to investigate ways of accounting for these perturbations in the atmospheric fields prescribed in propagation models. Here, we use modelled atmospheric fields obtained in the framework of the Dynamics of the Atmospheric General Circulation Modeled on Nonhydrostatic Domains (DYAMOND) project. This international project, initiated by the Max Planck Institute for Meteorology (MPIM) and the University of Tokyo, describes a framework for the intercomparison of high-resolution global atmospheric models. It mainly focuses on tropospheric weather, but some models were run with a high enough top so that GW are resolved up to the stratosphere. Starting with different configurations of the Icosahedral Non-hydrostatic (ICON) model, we explore how differences in infrasound-related parameters (azimuth deviation, shadow zone, celerity) derived using a ray-tracing tool relate to differences in the resolved tropospheric and stratospheric wind and temperature fields. Lidar observations are used to assess the modelled fields and to bring ground-truth atmospheric specification for infrasound propagation simulations.

Promotional text: The verification regime of the Comprehensive Nuclear-Test-Ban Treaty requires to use the best possible tools to detect and analyse events of interest. Using infrasound observations for analysis demands very good knowledge of the middle atmosphere and its small-scale dynamics.

P1.1-522 – A novel approach for the reconstruction of microbarom soundscapes

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In this study, a comparison is made between in-situ infrasound recordings in the microbarom band and simulations using a microbarom source model. The recordings are obtained by the 'Infrasound-Logger' (IL), a miniature sensor that has been deployed as biologger near the Crozet Islands in January 2020. The sensors provide barometric and differential pressure observations that have been obtained directly above the sea surface. A method is introduced to appropriately account for all microbarom source contributions surrounding the IL, as the full field consist of multiple spatially distributed sources. In this method, range and frequency-dependent losses due to propagation in the atmosphere are accounted for. While the method relies on several assumptions, a good agreement can be observed: the reconstructed soundscape is found to be within +- 5 dB for 80% of the measurements in the frequency band of 0.1-0.3 Hz. The development of microbarom soundscapes is essential for a better understanding of the ambient infrasonic noise field. Earlier work has shown that such knowledge is useful for infrasonic remote sensing of the upper atmosphere. Moreover, insights in the ambient noise field will improve the monitoring of natural hazards and the verification of the Comprehensive Nuclear-Test-Ban Treaty.

Promotional text: In this study we propose a new method to reconstruct the microbarom sourcefield, and compared it with in-situ infrasound recordings by the 'Infrasound-Logger' (IL). The IL is a miniature biologger that has been deployed near the Crozet Islands. Such comparisons are unprecedented.

P1.1-543 – Research on infrasound location method based on wide area monitoring network

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The international monitoring system (IMS) of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) has basically completed the planned construction of 60 infrasound stations in the world. The general infrasound signal processing technology of IMS is the progressive multi-channel correlation (PMCC) method, which includes TDOA algorithm. The common limitation of location algorithm based on time delay estimation is that its basic model only considers one sound source. Under the condition of multiple sound sources, the estimation result is not very ideal, and it is a suboptimal estimation. The accuracy of time delay directly affects the positioning accuracy. The beamforming algorithm can be used to orient the position of multiple sound sources, which has good directional effect, good stability and strong anti-interference. The IMS infrasound monitoring station can be formed according to the principle of triangle positioning calculation. For multiple positioning groups, each positioning group is regarded as a subarray. The subarray adopts beamforming for orientation, and the large array adopts time delay estimation to determine the distance. Using the data monitored by the wide area infrasound monitoring network arranged by the IMS, the infrasound source is located by combining multi array and multi algorithm, so as to further improve the positioning accuracy.

Promotional text: Key words:wide spread infrasound network;infrasound localization.

P1.1-547 – Microbarometer arrays for the monitoring of extreme weather in a changing climate

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Microbarometer arrays are used for the verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) using infrasound waves. In addition, the microbarometers also measure pressure variations that are due to various meteorological phenomena with a resolution that exceeds that of typical barometers. The value of these high-resolution observations for the monitoring of extreme weather is discussed here, focusing on two recent extreme weather events in The Netherlands. Data from a dense observational network that includes lidar facilities and the Dutch microbarometer array network is compared to forecasts from global and regional weather forecast models to assess the forecast skill of the state-of-the-art weather models. The first-order agreement suggests that microbarometer arrays could provide valuable data for the development of next-generation weather forecast models. Such developments are useful for Early Warning Centers that report on severe weather outbreaks that can be disruptive for society and which are expected to occur more frequently in a changing climate.

Promotional text: This presentation demonstrates that the infrasound technology, as a civil and scientific application, could aid in the forecasting of extreme weather events that are predicted to occur more frequently in a changing climate.

P1.1-560 – I-131 and Be-7 analysis around RN22 in Guangzhou 2016-2020

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As an artificial radionuclide, I-131 rarely appears in a natural environment, while RN22 monitoring system sometimes finds I-131 each year in air samples, especially in winter. The highest I-131 activity is 3 Bq while MDC for HPGe is 0.08Bq. The Gaussian model is applied to backtrack a possible resource of Iodine near RN22. The activity of cosmogenic radionuclide Be-7 in air samples is concentrated below 50 Bq in summer while in other seasons it varies up to 200 Bq. 2016-2020 Be-7 activity varies in a similar mode. The correlation between Be-7 activity and wind speed, PM10 is analysed.

Promotional text: I-131 is detected in some air samples in RN22. A backtrack analysis using Gaussian model is used and the possible resource is analysed.
Be-7 gives a stable range in summer time than other three seasons. The correlation between Be-7 activity and wind speed, PM10 is analysed.

P1.1-588 – Long-range infrasound detections from explosions occurred in the Mediterranean area in 2020 as tools to evaluate the IMS network detection capability

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IS42 is one of International Monitoring System (IMS) infrasound stations, located in the Azores islands in the North-Atlantic Ocean.

Stromboli volcano is located in a small Italian island in the Mediterranean Sea. It is probably the world's best-known volcano due its spectacular basaltic explosions interspersed by lava fountains up to 250 m occurring every ≈10 minutes. Following the far-field characterization of its continuous explosive activity on infrasound-based analysis, we present here IS42 detections at a source-to-receiver distance of ≈3,700 km and a back-azimuth of ≈76°.

Beirut, located on the Mediterranean coast, is the capital and the largest city of Lebanon. On 4th August 2020 at 15:08 UTC, the city harbour was almost completely destroyed by an enormous explosion caused by the combustion of 2700t of ammonium nitrate. This event was detected in various IMS infrasound stations, including IS42, at source-to-receiver distances ranging from approximately 2,400 km to 8,900 km. We present here the IS42 infrasound detections from this event, as well as from other IMS infrasound stations and compare the detections obtained with the events listed in the Reviewed Event Bulletin (REB) of the CTBTO, in order to evaluate the potential of the IMS network the IMS network capability.

Promotional text: The use of ground-truth data from natural and man-made atmospheric extreme events offers the opportunity to evaluate long-range detection capabilities of the IMS infrasound network. We present here an IS42 study case for the 2020 Stromboli Volcano and Beirut Harbor explosions.

P1.1-626 – Characterisation of the coherent infrasound sources recorded by the infrasound International Monitoring System station I48TN in Tunisia (Mines & Quarries)

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The I48TN is one of the 60 International Monitoring System (IMS) stations of the Comprehensive nuclear Test Ban Treaty Organization (CTBTO) characterized by its location in the heart of the IMS Infrasound network (Figure 1.a). The ability of the IMS infrasound network to detect atmospheric nuclear explosions and other signals of interest is strongly dependent on station-specific ambient noise. This ambient noise includes both incoherent wind noise and real coherent infrasonic waves. This abstract will focus on defining and characterizing the mines and quarries in the region as the most important real coherent infrasonic noise to I48TN in order to provide the infrasound data analyst with the most important local coherent infrasound sources in the region (mines and quarries) as recorded by I48TN and also to demonstrate how useful is the synergy between Infrasound and seismic data for the characterization of the acoustic sources. DTK_GPMCC, and DIVA software are used to perform this study (Cansi, 1995; Le Pichon et al., 2010). Also, Geotool software from the International Data Centre (IDC) will be used to analyse KEST seismic data. The result of this study will allow to characterize the most important coherent local infrasound sources (mines and quarries) for I48TN.

Promotional text: I48TN and KEST stations are used to define and characterize mines and quarries in the region showing the synergies between Seismic and Infrasound technologies and the propagation of infrasound data from the coherent infrasound sources in the region.

P1.1-627 – Deep-learning for converting noise into knowledge

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While awaiting signals from a nuclear test, the International Monitoring System (IMS) routinely detects many events that are attributed to atmospheric processes and referred to as perturbators or noise. These events, known to cause false detections, are an important source of difficulty in the network processing operated at the International Data Center (IDC). Because many thousands of events are recorded per day, recent efforts have been made in developing probabilistic inference for network processing and more recently, for estimating the energy. All these approaches, however, are based on priors that are poorly constrained, and/or extremely simplified propagation models, that are known to exhibit persistent shortcomings. In this work, we introduce a new hybrid framework to derive prior probability models from waveform modeling and take advantage of events accumulated in the analyst-reviewed bulletin. This approach is based on using current state-of-the-art propagation models in combination with a data-driven machine learning tool to model the remaining residual that is hidden in data. This approach presents two significant innovations: (1) the capability of converting perturbators into information, thereby providing a physical basis for the priors and (2) the opportunity to incorporate on a daily-basis additional atmospheric data in the priors.

Promotional text: In this work, it is shown how unsupervised learning (i.e. learning without labeled training data) can be used to extract information from signals of the IMS that can be translated into knowledge for better constraining automated tasks at the IDC.

P1.1-650 – Comparison of forward and backward source-receptor sensitivities for atmospheric inverse modeling using the HYSPLIT model with the Cross-Appalachian Tracer Experiment (CAPTEX) field experiment measurements

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Based on observations from monitoring stations or other platforms, unknown atmospheric pollutant emission sources, including source location, strength, and temporal variations, can be estimated using inverse modeling techniques. In such applications, 3D-particle Lagrangian dispersion models are usually employed, and the source-receptor sensitivities are calculated in either forward or backward modes for the source term estimation. While specifics of a given application may suggest a preference for one mode over the other, both forward and backward approaches can generally be applied for the inverse modeling. However, differences are often found in the inversion results between analyses based on forward and backward methodologies. In this study, we use the Cross-Appalachian Tracer Experiment (CAPTEX) field experiment as a test case to compute the source-receptor sensitivities between the known sources and air samples collected at 84 measurement sites. The differences between the forward and backward sensitivities calculated using the HYSPLIT model will be presented. The impact of the differences between the two approaches on the source term estimation results will be discussed. In addition, the underlying causes of the sensitivity discrepancies between the forward and backward approaches will be investigated and discussed.

Promotional text: The atmospheric radionuclide observations from CTBTO IMS network are often used to estimate the sources using inverse modeling techniques. In this study, we compare forward and backward source-receptor sensitivities for atmospheric inverse modeling using the HYSPLIT model.

P1.1-663 – Characterization of diurnal cycle of rainfall over peanut basin in Senegal

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In this study, the diurnal variation of the rainfall amount, frequency and intensity, and the rainfall with different durations, as well as its intra-seasonal variability are analysed using rainfall data from 18 stations over Ndiaganiao (area located in western Senegal) during the period 2007-2015. Our results show that the mean rainfall amount and frequency peaks are observed around 1800 GMT for the whole season, while the intensity peak is observed between 1300 and 1400 GMT. It was also shown a strongest spatial variability with intensity compared to amount and frequency. Analysis of duration of rainfall events shows a higth occurence (up to 80\%) of short duration (1 – 3 hours) and these events are the main contributors (75\%) to the rainfall amount. However, the most intense events have a longer durations (4 – 5 hours). Finaly, our results show a strong intraseasonal variability of diurnal cycle in term of amount, frequency and intensity. Indeed, rainfall events occur between 1200 and 1400 GMT during the installation phase of the West African Monsoon (WAM) in June. In the height of the WAM (August-September), the amount and frequency show a similar feature with a peak observed around 1800 GMT.

Promotional text: This work can contribute to the achievement of the SnT2021 objectives.To identify how climate variability and its dynamics can impact socio activities. And help to clarify the key mechanisms influencing convection at the mesoscale, and assess their representation in atmospheric.

P1.1-672 – Unusual infrasound observations from the August 2020 Beirut explosion

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On 4 August 2020, a warehouse of ammonium nitrate exploded in Beirut, Lebanon, leading to loss of life and property. Infrasonic signals from this event have been detected across the Middle East, Europe and North-Africa. The furthest IMS station that detected the signal was IS11 (Cape Verde) at over 6000 km distance.

The features of the observed infrasonic signals were unusual for the time of year. (1) Signals with tropospheric celerities were observed at IS26 and IS48, the nearest IMS arrays to the west and northwest, as well as the national arrays in Hungary (PSZI) and Romania (IPLOR). (2) At IS26 and PSZI, curious trace velocity trends were observed, starting at high values and decreasing along the wave train, contrary to what is typically observed. (3) The fastest arrivals at IS26 and PSZI appear to have significant back azimuthal scatter.

These observations suggest that the propagation conditions were more complex than a single stratospheric duct which is typical for mid-summer conditions in the Northern Hemisphere. It is hypothesized that the tropospheric phases interacted significantly with topography. This hypothesis is supported by wind and temperature forecasts derived from numerical weather prediction models. An analysis of the propagation conditions is presented.

Promotional text: The tragic explosion that occurred in Beirut, Lebanon on 4 August 2020 generated infrasound that could be observed over 6000 km away. Our analysis of this dataset helps to further improve our knowledge of infrasound and its use in verification monitoring.

P1.2 The solid earth and its structure

P1.2-041 – Lithospheric Structure of Africa and Surrounding Regions Revealed by Earthquake and Ambient Noise Surface Wave Tomography

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To advance the understanding of the tectonic processes shaping the African continent, we construct the first continental-scale shear-wave velocity (Vs) model of the lithosphere from the joint analysis of ambient seismic noise and earthquake data recorded by ~1529 seismic stations in and around Africa. We apply the widely used ambient noise cross-correlation and earthquake two-station methods to retrieve the Rayleigh-wave group and phase velocity dispersions which are jointly inverted for a new three-dimensional Vs model. The inclusion of short-period dispersion data from ambient noise allows us to obtain a more accurate model than previous global and continental-scale studies, revealing lithospheric structures that correlate well with known tectonic features. In sparsely instrumented regions of north-central Africa, our model provides seismic evidence for the existence of cratonic remnants beneath thick sediments within the Sahara Metacraton and reveals unique mantle upwelling beneath hotspots suggesting that they may be fed by unconnected plumes. The estimated crustal thickness varies among and within tectonic provinces and shows no clear evidence for the secular variation in crustal genesis. Our new model has the potential to serve as a reference velocity model for Africa and is useful for practical applications including monitoring of the Comprehensive Nuclear-Test-Ban Treaty.

Promotional text: We present the first 3D model of the lithosphere beneath Africa and surrounding regions from joint analysis of ambient seismic noise and earthquake data. New constraints on structures in sparsely instrumented regions of North Africa makes it valuable for monitoring of the CTBT.

P1.2-044 – Triggering Mechanisms of Gayari Sector Avalanche, Pakistan

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On 7 April 2012, a massive snow avalanche occurred in the north-western mountains of Pakistan, close to the Indian and Chinese borders. To mitigate its future hazard, different triggering mechanisms have been investigated in this study. The avalanche signal was clearly recorded on both infrasound and seismic stations, located at varying distances between 300 and 450 km. The avalanche occurred within the coda of a 2.8 magnitude deeper earthquake from the Hindu Kush region, located 560 km away. Although the size and impact on the avalanche might be small, the occurrence was part of the accelerated moment release (~ 50 % seismic moment release of total 2 days) three hours before the avalanche occurred. Cumulative seismic moment and peak dynamic stress show a significant increase a month before the avalanche. This sequence was stronger and had highest daily event rate, but interestingly the avalanche occurred within the reference seismicity, rather than the aftershock relaxation phase. The secondary process might be activated or triggering clock might be advanced during this sequence. The presence of cracks within the avalanche were further weakened by extremely low temperatures and accelerated the earthquake phase during 2012.

P1.2-053 – Towards building a ground motion data base to improve the seismic hazard assessment In Bolivia (Plurinational State of)

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Seismic hazard assessment for any region in the world has become a very serious and difficult task for seismologists, civil engineers and decision makers. Probabilistic hazard studies are conducted at the Observatorio San Calixto (PSHBO-2019) to estimate the maximum peak ground acceleration integrating all available variables, however no strong motion time-series (waveform) were applied due to the limited equipment installed in the country. To solve this issue, since 2016 we started to compile and to convert the velocity frames from our IMS stations (LPAZ and SIV) and temporal seismic network installed in the country to have acceleration and displacement traces. These waveforms were pre and post treated to obtain the pseudo acceleration, velocity and displacement spectrum and they were tested with regional ground motion prediction equations in order to validate them for local use. A set of 80 earthquakes are presented that will contribute to the improvement of PSHBO-2019.

Promotional text: The new database proposed ill help to improve and to categorize the different zones with their own seismic design spectrum to improve the seismic hazard in Bolivia.

P1.2-060 – Seismic Hazard Estimates for State of Uttarakhand Himalaya in terms of Peak Ground Acceleration (PGA)

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Probabilistic Seismic Hazard Assessment (PSHA) for the state of Uttarakhand (280-320 N and 770-810 E) has been investigated considering two Next Generation Attenuation (NGA) models. Results are presented in terms of PGA for various return periods for each district. Initially, based on seismicity and seismtectonic characteristics the whole region has been defined into four seimogenic zones (UK-I, UK-II, UK-III and UK-IV. Seismic hazard computation is performed using CRISIS 2015. The study area has been divided into grid size of 0.2° x 0.2°. The input parameters are seismicity parameters and attenuation models. The estimated seismicity parameters and (NGA) models have been used to produced seismic hazard in terms of PGA for 20%, 10% and 2% probability of exceedance in 50 years which are equivalent to return periods of 225, 475 and 2475 years respectively. The hazard Contour maps have been produced for mean PGA for 2%, 10% and 20% probability of exceedance in 50 years as well as Uniform hazard spectra (U.S. at various sites for return periods of 225, 475 and 2475 years have been plotted and the rate of occurrence of earthquakes and PGA are compared in each source zone.

Promotional text: Earthquake disasters lead to the loss of life, property damage and other socio-economic disruption. These risks can be reduced by understanding complexities of the earth, dynamic and static properties; analyses and scientific interpretation of monitoring data and its application.

P1.2-094 – National network data contributions to seismic studies in the Kingdom of Saudi Arabia

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Increased urban development, occasional volcanic swarms, and large earthquakes surrounding the Kingdom of Saudi Arabia (KSA) have contributed to a renewed interest in understanding seismic hazard and risk within the Kingdom. In response, the KSA has expanded the national seismic network over the past several decades. Now, a sizable collection of local and regional data provides an opportunity to further develop KSA capabilities in seismology and seismic hazard assessment. The Lawrence Livermore National Laboratory (LLNL) and the National Center for Earthquakes and Volcanoes (NCEV) of the Saudi Geological Survey (SGS) started collaborating in 2016, with long-term goals of reducing seismic hazard and risk. We began by using time-domain full waveform moment tensor inversion and coda-envelope derived amplitude measurements to solve for earthquake source mechanism, moment magnitudes, and their source-type. We compare the moment magnitudes calculated from the two methods and publicly available earthquake catalogs and discuss the implications of the obtained source parameters. This study supports NCEV operational needs while obtaining stable and robust solutions that give quantitative information about the seismicity needed to better understand potential seismic hazards. A parallel collaborative study is focused on improving attenuation models of lithosphere for a broad frequency band using multiple-phase inversion.

P1.2-120 – Updates to the Regional Seismic Travel Time (RSTT) tomography model: tomography and path-dependent uncertainty

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A function of global monitoring of nuclear explosions is the development of Earth models for predicting seismic travel times for more accurate calculation of event locations. Most monitoring agencies rely on fast, distance-dependent one-dimensional (1D) Earth models to calculate seismic event locations quickly and in near real-time. RSTT (Regional Seismic Travel Time) is a seismic velocity model and computer software package that captures the major effects of three-dimensional crust and upper mantle structure on regional seismic travel times, while still allowing for fast prediction speed (milliseconds). We describe published updates to the RSTT model (pdu202001Du, https://www.sandia.gov/rstt) using a refined data set of regional phases (i.e., Pn, Pg, Sn, Lg). We improve on the former distance-dependent uncertainty parameterization for RSTT using a random effects model to estimate slowness uncertainty as a mean squared error for each model parameter. The random effects model separates the error between observed slowness and model predicted slowness into bias and random components. Validation of the updated RSTT model demonstrates significant reduction in median epicenter mislocation along with more appropriate error ellipses, compared to the iasp91 1D model as well as to the current station correction approach used at the Comprehensive Nuclear-Test-Ban Treaty Organization International Data Centre.

Promotional text: The inclusion of new data for RSTT from prior Workshops addresses Goals 3-5, while the update of RSTT in general applies to Goals 1 and 5 for identifying opportunities to improve nuclear test monitoring and to promote wider civil and scientific applications.

P1.2-145 – Updating seismic hazard models for Kuwait

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This research assesses the seismic hazard and deaggregation in the State of Kuwait. For this purpose, the historical and instrumental seismic catalogues of Kuwait and the active Zagros Seismic Belt were compiled, unifying the magnitudes, removing unnecessary earthquakes (seismicity declustering) and considering the completeness of the catalogues. Multi-seismotectonic models for the Kuwait region incorporate earthquake focal mechanisms, seismicity patterns, and the structural geological situation have been created to reduce epistemic uncertainty. The recurrence parameters as well as the maximum expected earthquake from each seismic source were fundamentally estimated. Appropriate ground motion attenuation relation within a logic tree formulation was mainly used in creating hazard maps. A state-of-the-art probabilistic approach is used herein to produce hazard maps at return periods of 75, 475, 975 and 2475 years (equivalent to 50%, 10%, 5% and 2%, respectively, probability of exceedance in 50 years) at periods of PGA, 0.1, 1 and 4 seconds. The computations of hazard maps were constructed using a spacing grid of 0.2° × 0.2° in the Kuwait area. Uniform hazard spectrum and deaggregation charts have been adopted for all six governorates of Kuwait.

P1.2-155 – International Data Center Magnitudes and Their Relation to International Seismological Center Magnitudes Using Data for Ethiopia and Eritrea Regions

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Various type of magnitude scales are recognized for estimating the earthquakes size. Magnitude is one of the significant factors for a unified earthquakes catalog which is needed for seismic hazard assessment and disaster management. The variation in magnitude value from seismological agency to other stimulated the researchers to study the regression relationship between the magnitudes. The study area is located between latitudes 4º- 16º and Longitudes 36 º-42º in the east Africa region. A selected number of events which has magnitudes ranges from 3 to 5.6 for the period between 2000 and 2020 were used to create the regression relations. In this research the standard least-square regression (SR) and orthogonal regression (OR) were derived to assess the relation between the international data center (IDC) magnitudes in addition to the international data center (ISC) magnitudes based on body wave magnitude (mb), surface wave magnitude (MS) and local magnitudes, these regressions were adopted to choose the best regression model. Finally, the conversion equations between magnitudes were constructed and determined for wide range about twenty years.

Promotional text: The objective of this study is to derive relation between IDC magnitudes to help when it becomes difficult to read any type of magnitude and to find relations between IDC and ISC magnitudes to solve any problem in magnitudes for the same events in case of missing or unclear data.

P1.2-171 – The use of Seismological, Geodetic and Infrasound techniques for novel integrated monitoring scheme in Nigeria

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Nigeria lies within the West African sub-region and the country is believed to be aseismic in nature. Despite this view by prominent geoscientists, the country has witnessed both historical and instrumental earthquakes since 1933. The recent recorded chains of events with moment magnitudes ranging from 3.0 to 3.4 in Nigeria, were located in Kaduna state and Abuja. Reasons which include shallow faults reactivation by hydraulic fracturing, anthropogenic causes, etc., have been adduced to the recurrent earth tremors in Nigeria. As the events are of small to medium magnitudes, their vibrations felt in different parts of the country were not recorded by the scanty existing seismic stations. This paper therefore, presents a novel integrated approach towards understanding Nigeria's seismicity, and enhanced monitoring of seismic hazard through improved recording capability of earthquakes. It outlines a detailed scheme on densification of seismographs collocated with GPS, and deployment of the advanced Infrasound equipment to strategic areas where earth vibrations are frequently observed in Nigeria but not recorded by seismic equipment, etc. The realization of the monitoring scheme would not only assist Nigeria in seismic risk mitigation and holistic planning, but will promote collaboration with the CTBTO and other key partners.

Promotional text: This study supports the wider civil and scientific applications of CTBT techniques by adopting one of its tools for verification (Infrasound), in addressing seismic hazard challenges in Nigeria and boosting awareness of the powerful technology to broader scientific community.

P1.2-188 – Analysis of foreshock sequences in the Iranian plateau

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We analyze foreshock activity in the Iranian plateau by investigating the occurrence patterns for isolated M >= 5.5 earthquakes from 1968 to 2018. Among the 165 mainshocks with M >= 5.5 (after excluding 12 aftershocks, 6 swarms and 9 doublets), 18 percent are preceded by at least one foreshock within 30 days and 20 km. However, the number of events in each foreshock sequence is significantly higher in the last ten years of the catalog. This difference is partly explained by the rapid expansion of the Iranian national seismographic network in the recent years. Based on our analysis, the completeness magnitude of the catalog is declined over years and reached to 3.4 (2008-2018) from 5.1 (1968-1998). Foreshock occurrence appears correlated with mainshock faulting type and depth; however, it is not correlated with mainshock magnitude. These results suggest that foreshock occurrence is largely controlled by the regional tectonic stress field and fault zone properties. In special cases, foreshock activity is considered as one of the most promising precursory changes for the main shock prediction in the short term; however, foreshock properties are not reliably predictive of the magnitude of the eventual mainshock.

Promotional text: In this study, we investigate foreshock activity of large earthquakes in the Iranian plateau by using available catalogs. Also, we provide a summary of expansion and modernization of the Iranian national seismic network over 50 years.

P1.2-201 – Development of Local Magnitude Scale and Determination of Station Magnitude Corrections for Northern Thailand

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In this research, a local earthquake magnitude formula (ML and MLv) was developed for measuring earthquake magnitude in northern Thailand and determined station magnitude corrections. By using data from 31 seismic stations of the Earthquake Observation Division, the Thai Meteorological

Department and CTBTO Chiang Mai seismic station, analyzed 148 earthquake events from 2009 to 2019 to find the formula. The magnitude ML was defined as ML = log A+ 0.6682 log(R/100)+ 0.0026(R-100)+ 3 and the magnitude MLv was defined as MLv = log A + 0.6002 log (R/100) + 0.0030(R-100) + 3, for hypocentral distance 25 to 500 km and depth below 60 km.
The results comparing Richter's local magnitude equation (1935) and the equation obtained from the study, found that the attenuation of earthquake magnitude in northern Thailand and southern California is quite similar. And the station magnitude corrections were between -1.1752 to 0.5393 magnitude.

Promotional text: Development of local magnitude scale and Determination of Station Magnitude Corrections for northern Thailand by Using data from Earthquake Observation Division, Thai Meteorological Department and CTBTO Chiang Mai seismic station.

P1.2-227 – Statistical assessment of seismicity level of the central part of the Baikal rift zone

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The seismicity change in time in the seismically active region around the central part of the Baikal rift zone (BRZ), the South-East of Russia, was investigated using the statistical estimate of the seismicity level (SESL'09) procedure [Saltykov, 2011]. The method is based on calculating the statistical distribution function of the decimal logarithm of the total seismic energy within a given spatial object in a certain time interval. Epicenter data taken from the International Seismological Centre [http://www.isc.ac.uk/iscbulletin/search/catalogue] and from the local catalogue from 1962 to 2019, which includes over 3.5 thousand earthquakes with an energy class equal to or higher than 8.5, were analyzed. This concept enables us to formed and defined "seismic background" for considered region. And allows us to conduct the further assessment and comparison with the seismic regimes of the other areas.
The work has supported by the Ministry of science and higher education of the Russian Federation (within the framework of state task No. 075-01304-20 and the research project IX.136.1., state number AAAA-A16-116121550016-3) and using data obtained at the unique scientific installation "Seismic and Infrasound monitoring complex of the Arctic cryolithozone and continuous seismic monitoring complex of the Russian Federation, neighboring territories and the world".

Promotional text: Qualitative seismicity assessment in the central part of the Baikal Rift Zone by using the statistical estimate of the seismicity level procedure gives important information about background seismicity for the region and allows to study variations in seismicity levels over time.

P1.2-231 – Ambient Noise Tomography (ANT) Method to Reconstruct the Subsurface of Sumatra and West Java Using the New InaTEWS Seismic Network

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Sumatra and West Java have a high potential for geological disasters, including volcanic eruptions and earthquakes. In the last two years BMKG has significantly increased the number of seismic stations in this area, by utilizing seismic waveforms recorded by the BMKG seismograph network of earthquake monitoring stations spread across the Sumatra (110 stations) and West Java (48 stations) for 5 months using the ANT method. The dispersion curve shows the subsurface information that can be imaged from a period of 1 to 50 seconds. We use subspace inversion to test the resolution to get the best parameters for inversion. Based on the results of the resolution test, subspace inversion will use a grid parameter of 100 x 100 km, and smoothing and dumping of 500 each. The resulting group velocity mapping information also corresponds to the geological information and Bouguer anomalies. To generate subsurface information in Vs against depth we use the Neighborhood Algorithm (NA) method. The subsurface information generated shows excellent results on a regional scale. Large faults that are scattered throughout Sumatra and West Java, the dimensions of the faults, as well as the existence of the basin in the western part of Sumatra can be well imaged.

Promotional text: The results of this study indicate that the subsurface areas of Sumatra and West Java have the potential for natural resources as well as deadly geological disasters. This result can be used by the local government in planning investments to build an area.

P1.2-254 – Attenuation of seismic waves in the northern Appalachians of south-eastern Canada

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We investigate seismic attenuation characteristics of the Canadian portion of the northern Appalachians. Coda Q is determined using 389 earthquakes (1.8 =< M =< 3.9) recorded on four stations of the Canadian National Seismic Network (CNSN) in New Brunswick from 1985 to 2020. For comparison, we divide the study area into northern and southern portions, each with two seismic stations and 162 and 227 events, respectively. At lapse times of 12 to 60 seconds, coda Q at 1 Hz (Q0) at the two seismic stations in the region of northern New Brunswick that is closer to the seismically active Charlevoix seismic zone (including a M7 event in 1663) is 82 +/- 5 on average. In contrast, the two stations in southern New Brunswick have an average Q0 of 114 +/- 3. The lower Q0 value in the north in comparison with the southern part of the region is in agreement with Jin and Aki's (1988) finding that Q0 is lower in the vicinity of large earthquakes. Ongoing mapping of coda Q in the area using the CNSN stations is planned in order to contribute to the ongoing development of more accurate seismic hazard models.

Promotional text: Our presentation provides an overall knowledge about coda Q in a region in south-eastern Canada which is one of the most useful parameters for the study of earth structure and seismic hazard assessments.

P1.2-272 – Probabilistic Seismic Hazard Map for Bolivia (PSHBO)

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On this research we present a probabilistic seismic hazard map for Bolivia (PSHBO-2019), this is the first map that integrated all variables available within the geo hazard for our country. We propose 13 seismic zones based on epicentral distribution, stresses and geology context, we applied the well know method for hazards assessment integration to all variables to have the maximum probable acceleration for each zone. Our results include a return period of 475 and 2475 years with five

structural periods that let us to build the uniform hazard spectrum for our country. The crustal earthquakes located at along the Eastern Cordillera, Inter Andes and part of the Sub Andes (known as Bolivian Boomerang) present peak ground accelerations up to 24% of gravity, for the subduction earthquakes show almost 34% of gravity those are located at Western Cordillera, for Altiplano the peak ground accelerations reach up to 16%, for Chaco and Beni plains accelerations of 4% of gravity.

Promotional text: The probabilistic seismic hazard map for Bolivia (PSHBO-2019), this is the first map that integrated all variables available within the geo hazard for our country, using tecnologies the International Monitoring System.

P1.2-325 – The EOS's broadband seismic network in Myanmar: installation, site classification, local seismicity reports and velocity structure studies

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To study the earthquakes and better understand the tectonics in Myanmar, Earth Observatory of Singapore (EOS) has been collaborating with local seismic monitoring authority to install (30) broadband seismic stations. With the broadband collected data, we have used them to study the site classification, earthquakes relocation and constrain the velocity structure.
We defined our EOS's broadband seismic stations site classes by using the horizontal to vertical spectral ratio (HVSR) method from ambient seismic noise. We clearly identified some of our stations on the rock site such as; EW01, M024, EW07, M027 which have resonance frequency larger than 5.0 Hz. The resonance frequency less than 1.6 Hz are defined as soft soil class such as EW05, M008, M012, M022. This kind of classification is based on the National Earthquake Hazards Reduction Program (NEHRP) site classes.
From the initial automatic location that we have selected and relocated ~1000 earthquakes which we found that all these local earthquakes well define the Indian slab beneath Myanmar region. Moreover, use selected teleseismic events located between 30 to 90 degree distance to image the Moho beneath our seismic stations using P-receiver functions (PRFs) and H-K stacking technique to get crustal thickness and Vp/Vs ratio.

Promotional text: Myanmar,
Earthquakes relocation,
Crustal thickness (Moho),
Broadband Seismic Network.

P1.2-341 – Analysis, Processing and Interpretation of the Gravity data between latitudes 15N-17N (Sudan)

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A gravity analysis and Interpretation are carried out using data collected by Sun-Oil Company in the area west of Khartoum between latitudes 15◦ -17◦ N and longitude 30◦-33◦ E. The data released in a Bouguer anomaly map at scale of 1:500,000 and a contour interval of 5mgal.The target is to analyze and interpret the gravity data in terms of surface and subsurface geology. The qualitative interpretation includes the construction of second vertical derivative map, analytical upward, downward continuation and separation of residual and regional anomalies. The operation of the second vertical derivative and analytical continuation is thought to be as a filtering operations based on the linear filter theory. Five models are used to construct a depth to the basement map. Geological sections are drawn along five profiles passing through boreholes of Elmagad, Abu Hashim and Jebel Aulia. The result revealed that the negative anomalies are associated with the existence of the Cretaceous Nubian Sandstone sediments as in the cases of BagBag, Hummar and AbuDulu basins with maximum depth of 3000, 1000, and 1900 meters respectively. These basins are considered as parts of the Blue Nile Rift Basin that has been subjected to tectonic movements which affect the central Sudan

Promotional text: New approach in this type of study can be achieved through cooperation and exchange of knowledge especially the release of new software through participation in such conferences.

P1.2-344 – Regional tectonic activity and its impact on increasing level earthquakes in Iraq

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Iraq is a country subject to seismic activity associated in a belt Zagros-Taurus which is caused by the collision of the Arab plate with the Eurasian plate. Where the Arab plate is affected by three types of tectonic boundaries: divergent boundaries, convergent boundaries, seam boundaries. The Arab plate moves north-east, leading to the expansion of the area of the Red Sea and the Gulf of Aden on one hand and increasing the collision at the mountains of Makran, Zagros and Taurus on the other hand. We note this motion from time to time being represented by light, medium and strong earthquakes. The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) provides the Member States, by the requirements of the verification regime, the data from seismological monitoring stations, one of the four techniques used by the organization to achieve its goals of making the world free from Nuclear weapons and supporting the scientific and practical side concerned with the monitoring of earthquakes and their effects. In this poster the level of seismic activity witnessed in Iraq from 2017 to 2018 and defining mb, Ml to determine Mw which was signal of increasing seismic activity is shown.

Promotional text: This poster illustrates the effectiveness of the seismic monitoring stations of CTBTO in monitoring regional seismic events.

P1.2-347 – Estimation of Mantle Transition Zone seismic discontinuities beneath northwestern South America from P-wave Receiver Function Analysis

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The present work seeks to study the seismic upper mantle discontinuities of the northwestern part of South America and report the results of the first P-to-S radial receiver function investigation of the 410 km and 660 km depth discontinuities that bound the mantle transition zone (MTZ) beneath Colombia. In order to calculate the receiver functions and generate a first-order approximation of these discontinuities' lateral depth variation and MTZ thickness. We used teleseismic information recorded in the broadband seismological stations of the National Seismological Network of Colombia between 1995 and the present year with epicentral distances in a range of 30 and 130 degrees and a magnitude greater than 6. Determining the extent of these seismic discontinuities features is the key to address several problems in region tectonics related to the structure, evolution, and mantle dynamics and study how is the behavior of the subduction processes of the Nazca and Caribbean plates beneath the South American plate.

Promotional text: The results of this on-going investigation are an important input for every researcher interested in a proper characterization of the earth´s interior for better processing, interpretation, and assessment of monitoring data and disturbances in the earth.

P1.2-357 – 3D tomography of the crustal structure of the central part of Madagascar

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Madagascar has never had a big earthquake until now. The biggest earthquake had a magnitude of 7 Richter, and not on land but in the ocean. The highest magnitude on land was below 6 Richter. The central part of the big island is the most active seismically. It can be clustered into three zones. Two of them are a Cenozoic volcanic area, which are Itasy and Ankaratra, from the north-west and the south respectively. The last seismically active zone is Alaotra, at the north-east part, and at the Alaotra-Ankay rift composed by normal faults. Many scientific articles say the volcanoes in the central part are already extinct and some say there have been recent eruptions, which means they are dormant volcanoes. The seismic map reveals that the epicenters tend to line up from the volcanic area of Ankaratra to Itasy and expand till Bongolava. A 3D tomography of this zone was done, with the permanent stations including the CTBTO station, to determine and study the structure of the crust which is thinner than the coastal areas.

Promotional text: As the CTBTO promotes the third party countries scientists, I would like and very motivated to present our work from Madagascar. No 3D study of the crustal structure of the big island has done yet, attending the SnT21 would be an opportunity to share and get experiences.

P1.2-358 – Seismic Microzonation of DKI Jakarta Indonesia Using HVSR Method

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Earthquake disaster mitigation is required to perform in DKI Jakarta which is the Capital of the State of Indonesia. To find out the geological characteristics of the study area such as soil type and rock type, an HVSR analysis was performed. The amplification value and dominant frequency can be used to estimate the level of building damage due to earthquake, damage to buildings due to the earthquake will be more severe in areas that have HVSR parameters with high amplification values and low-frequency values. We compared the amplification value between 30 temporarily installed seismic stations and one of the CTBTO seismic stations, LEM which is in the south of the study area. The LEM is in the bedrock so that it can be used as a reference to determine the amplification in this region. Based on the analysis that has been done by correlating the results of zoning maps from amplification, dominant frequency and soil vulnerability index, it is known that the area with high level of damage if an earthquake occurs is the area around Ancol in North Jakarta which is a coastal area and near the swamp.

Promotional text: we using CTBTO seismic station for HVSR analysist.

P1.2-367 – About Regularities of Seismicity of Western and Central Uzbekistan

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Space-temporal distribution of seismic activities in Western and Central Uzbekistan is considered. Four groups of strong earthquakes in the regions were analyzed. The pattern of redistribution of the accumulated tectonic energy in the form of seismic activity in the regions is revealed. In a west-east direction, an increase in the depth of earthquakes is noted. Deviations from the regularity of grouping of strong earthquakes in the seismic regime of the region is found. Periods of seismic activity of the Western Tien-Shan in the Asian part of the Mediterranean-Asian seismic belt showed their regional and planetary synchronization. Late periods of seismic activity of Western Tien-Shan had been explained by low level magnitude M=5.3 of main shocks in the group. Study of the seismic regime of the region where the triple Gazli earthquakes of 1976 and 1984 occurred, M=7.0-7.3 were probably preceded by triggers. Natural triggers: active processes of cracking (large cracks up to 100 km in length) observed in 1965; small mud volcanoes "griffons"; the absence of significant earthquakes in the Gazli region more than 40 years. Technogenic triggers: a permanent 40-year operation of "Gazly" gas fields: two nuclear explosions of 1966, 1968, which occurred near the Gazly earthquakes of 1976, 1984 that have a tectonic nature.

Promotional text: In research about influence, nuclear explosions to seismic regime on Western and Central Uzbekistan noted.

P1.2-368 – Upper crustal structure at the KTB drilling site from ambient noise tomography

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In this study, we show results from ambient noise tomography at the KTB drilling site, Germany. The Continental Deep Drilling Project, or 'Kontinentales Tiefbohrprogramm der Bundesrepublik Deutschland' (KTB) is at the northwestern edge of the Bohemian Massif and is located on the Variscan belt of Europe. During the KTB project crustal rocks have been drilled down to 9 km depth and several active seismic studies have been performed in the surrounding. The KTB area therefore presents an ideal test area for testing and verifying the potential resolution of passive seismic techniques. The aim of this study is to present a new shear-wave velocity model of the area while comparing the results to the previous velocity models. We use a unique data set composed of two years of continuous data recorded at nine 3-component temporary stations installed from July 2012 to July 2014 located on top and vicinity of the drilling site. Moreover, we included a number of permanent stations in the region in order to improve the path coverage and density. We present here a new velocity model of the upper crust of the area, which shows velocity variations at short scales that correlate well with geology in the region.

Promotional text: We use seismic ambient noise data recorded at seismic stations to image the upper crustal structure around the KTB drilling site in Germany. The results are well matched with the surface geology and improve our understanding of the complex structure of the shallow crust.

P1.2-369 – Investigating seismic radial anisotropy beneath the Zagros belt

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In this research, the difference between the velocity of Rayleigh and Love waves is used to determine radial anisotropy beneath the Zagros belt. The continuous ambient noise data are processed to image 2D tomographic dispersion maps from the period of 8 to 50 s. Then, a quasi-3D shear wave velocity and radial anisotropy model are calculated by joint inversion of the Rayleigh and Love local phase velocity dispersion curves using MCMC method. Our results imply the presence of intense radial anisotropy due to the dense minerals in the crust and uppermost mantle of the Zagros zone. Radial anisotropy changes from positive values in the crust to negative values in the upper mantle which may be evidence for the decoupling of the crust from the upper mantle beneath the Zagros.

Promotional text: Shear wave velocity and radial anisotropy model of the Iran plateau was determined using Bayesian Markov chain Monte Carlo inversions
Radial anisotropy patterns suggest ductile shear zones in the middle to the lower crust beneath the Zagros.
Radial anisotropy changes from

P1.2-390 – Beni Illmane Earthquake Of May 14, 2010 - Aftershock Sequence Location Using A Dense Seismic Network

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Algeria suffered frequently from effects of destructive moderate sized and strong earthquakes because of the seismotectonic setting on the boundary of African and Eurasian tectonic plates. On May 14th, 2010 at 13 h 29 m GMT, a moderate earthquake of magnitude Md 5.2 (CRAAG – Algeria) struck Beni-Illmane a village located about 200 km southeast of Algiers. The main shock caused substantial damage and resulted in three fatalities, 86injured, 1720out of shelter families and 6431 constructions damaged. The main shock was followed by a significant number of aftershocks for days after the earthquake. The Beni-Illmane earthquake sequence, which started on May 14th, 2010, occurred in a region of low to moderate seismic activities in north Algeria. Following the first main shock, the CGS – Algeria acted and organized a seismic survey of aftershocks using 13 temporary seismic stations installed close to the epicentral area during 30 days recording period. The data were analyzed performing single events location, relocated using MJHD method and calculated composite focal mechanism solution. The results obtained showed a distribution of aftershocks in two clusters oriented NNE-SSW and east-west. The composite focal mechanism showed a strike slip fault consistent with the global CMT solution.

Promotional text: The data were analyzed using Seisan program. Chatelain method was used for data quality control of the phase picking. Using Hypocenter program the single event localization was performed than used for the MJHD relocalization. Composite focal mechanism solution was calculed.

P1.2-500 – Effect of soft soil on frequency content of waveform and its application on seismic site selection

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Soft soil effectively changes the behaviour of seismic wave propagation and this is important for urban areas. Waveform modelling is one of the methods we can go through site effect and check how the underlying structure could amplify incoming waveform and how will affect low and high rise buildings. In this study, we have monitored a situation with and without soft soil on some existing stations and have tried to explore how much the amplification factor could change. A hybrid technique of waveform simulation is used to create near broadband signals. The method combines numerical (Finite Difference) and analytical (Modal Summation) techniques. A major earthquake (Bam, 2003) southern Iran is selected. Vp, Vs, rigidity and attenuation factors (Qp, Qs) are considered as soil condition at each site. 1D, 2D and 3D evaluation are performed to evaluate the detail effects of real source, path and site conditions. This procedure is a complementary technique to deliver clear site condition for any seismic site selection as well. Results are compared with observed data both in time and frequency domain.

Promotional text: Simulation techniques need to be considered in areas with a lack of data.

P1.2-501 – Shear wave velocity structure of upper mantle along the Zagros collision zone

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Investigation of the lithospheric shear-wave velocity as a clue helps to improve our understanding of Iranian plateau evolution. Therefore, we estimate shear wave velocity models beneath profiles perpendicular to the Zagros strike by using trans-dimensional Bayesian inversion of the Rayleigh wave group velocity dispersions at periods of 5-120 s. Our velocity models, in line with the support of the segmented slab, show that the different geodynamic processes have dominated in the northern and central-southern Zagros. In the northern Zagros, the Arabian lithosphere, near the suture, has likely experienced distributed thickening while it has underthrusted beneath central Iran in the central-southern Zagros. The presence of a high-velocity anomaly at depths 80-120 Km elongated between the low-velocity lithospheres of the UDAM and the Lut block implies that the southern slab has not flatted up to the east of Iran and the Eocene-Oligocene flare-up magmatism in the Lut block is directly independent on the Neo-Tethys subduction. Our results support the slab break-off idea along the Zagros. In the central and southern Zagros, lateral tearing might be responsible for the slab detachment so that has started from beneath the central UDMA.

Promotional text: This study is aimed at understanding the Zagros velocity and geodynamic model using a large amount of seismic data and nonlinear modeling. Due to the location of Bushehr nuclear power plant in the Zagros zone, knowing more about the velocity and geodynamics of the Zagros will be.

P1.2-503 – Occurrence And Extent of Earth Fissures: Preliminary Findings From Chikwawa District, Southern Malawi

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Although earth fissures have occurred in some parts of the country, they have not been well-documented or studied in detail. Recent field investigation into the formation and extent of earth fissures in Chikwawa District, reveal their formation due to erosion as well as tensional cracks within the affected area as a result of groundwater withdrawal from the alluvial sediments. Several sinkholes and linear fissures trending N-S and E-W, connected by horizontal conduits characterized by mud deposition and mud flow, cut through the village thereby weakening and cracking houses. Minor fissures connect orthogonally to major fissures without clear offsets. The water flow through the conduits influenced the formation of sinkholes and conduits by weakening their structural strength which caused top soil to collapse into existing voids, creating or widening the sinkholes and exposing the conduits. We used geological, airborne geophysical as well as seismic ambient noise to delineate structures and determine depth-to-bedrock. Additionally, data from local as well as international seismological monitoring networks indicate no occurrence of an earthquake in the vicinity to attribute such activity to tectonic movement or faulting.

Promotional text: Fissures, Sinkholes, Alluvium, Tectonics, Faulting.

P1.2-538 – United Arab Emirates Strong Motion Network

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UAE strong motion network consists of 62 stations distributed all over the country to construct UAE-Ground GSM "ShakeMaps" for existing urban areas and areas under strategic development. Additionally, structural design parameters will become available for verification and calibration of the seismic design code. Forty stations are equipped with shallow borehole EpiSensors and fourteen stations with surface EpiSensors installed on open ground or in small buildings and 7 stations equipped with TSA-100 and one station equipped with Titan. Stations use high dynamic range, IP aware, digitizer model Basalt, Trident or Quanterra, for data acquisition. The network telemetry topology consists of wireless GPRS backbone with data service from multiple ISPs and some station transmit data via VSAT.
A site characterization study at each site included geotechnical and geophysical analyses, microtremor testing, and soil dynamic investigations. The integral results provides estimation on the potential effects of local site conditions upon recorded ground motions. The primary operational objective is to provide input accelerations in real-time for the automatic calculation and distribution of reliable UAE-GSM "ShakeMap" immediately after a seismic event.

Promotional text: A description of the UAE Strong Motion Network as well as the various sensors that are used to provide a complete coverage of the seismic activity of the region.

P1.2-544 – Seismic and aseismic observations and self-similar theory

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The postseismic slip that follows large earthquakes is typically a few tens of percent of the coseismic moment, while the postseismic slip following small earthquakes appears to be comparable to the moment. Here I estimate the postseismic slip following intermediate-magnitude earthquakes and find that it is intermediate between the two, about 40% of the coseismic moment. The variation in postseismic slip with moment suggests that earthquakes may not be self-similar: that the properties of earthquakes or the regions that surround earthquakes vary systematically with earthquake size.if this is true, it would reveal a global fact related the physical processes of earthquakes.

Promotional text: This study is important for a better understanding of earthquake physics, which helps us in improving Earth models. if moderate earthquakes could produce large postseismic offsets which is related to aftershocks, then those postseismic values would be vital for hazard assessment.

P1.2-545 – Modern Seismological Network of Nepal

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Nepal is exposed to intense seismic activity, including devastating earthquakes. The National Earthquake Monitoring and Research Centre (NEMRC) was established under the Department of Mines and Geology (DMG) to monitor those earthquakes. It also alerts the Nepalese authorities and population about the location and magnitude of the felt earthquakes to support rescue and relief operations at the earliest. The seismological network was deployed in collaboration with the Department of Analyse, Surveillance, Environment (DASE), France, and extended to a national network covering the whole territory since 1994. 21 short period stations were tele-operated at two seismic centres, a network updated to digital between 2014 and 2016. NEMRC provides some seismic bulletins to international institutes and became the NDC of Nepal for CTBTO. The Gorkha earthquake (Mw 7.9) happened on 2015 April 25 under the network's central part. The number of stations were then increased with several international organizations (including Chinese and Japanese institutes). It now reaches a total of 41 broadband and short period instruments. These stations, exposed to low seismic noise levels, recorded more than 100,000 earthquakes, including more than 50,000 events following the Gorkha earthquake. The modern network allows improving the quality of the catalogue useful for seismological research.

Promotional text: The seismological network of Nepal has become denser following the Gorkha earthquake of 25 April 2015. Now the network with broadband and short-period seismometers allows the better location and seismological research.

P1.2-577 – How reservoir loading could change the seismic behavior and how should be managed?

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Effects of reservoir filling are studied well during past decades by increasing monitoring stations around dams. In this study, a period of more than 10 years of seismicity around Seymareh dam (a major dam Southwestern Iran) is monitored and thousands of minor earthquakes around the lake is processed and evaluated before and after reservoir filling. Various parameters of active locations and faults, depth of events, magnitude, seismicity parameters (a-value, b-value) and source migration

is explored in detail. It has been shown how lots of very shallow events are imposed on the area and how it affects by water level variations. An optimum rate for water level change is detected to minimize the induced seismicity effectively.

Promotional text: Far from dam's body, structures and living areas around dams are vulnerable when induced earthquakes happen.

P1.2-631 – Identifying suspect instrument intervals using midnight noise time histories

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Instrument response issues are common in seismology, and they can hinder research. We use large data sets to develop models that will predict high-frequency seismic amplitudes, which requires extensive quality control. To identify response and station health issues, we have collected time histories of noise measurements near (but not restricted to) midnight to eliminate diurnal variations, and have manually determined time intervals that appear inconsistent with background behavior. We assign descriptive labels, but do not attempt to diagnose causes. We currently use results to discard data. To date, we have examined 39,260 channels from 11,105 stations, heavily weighted toward Incorporated Research Institutions for Seismology (IRIS) holdings, at bands between 1 and 8 Hz, finding 24,733 anomalous time intervals that represent 13% of the total inspected time range. The majority (90%) of these intervals are constant offset shifts, often bounded by known instrument changes, likely resulting from poor response documentation at one of many stages between the field and publication. We hope these results can be of use to our colleagues, and encourage community efforts to diagnose anomalous behavior, and fix poor responses. We also hope these results will support automation efforts, including application of supervised learning techniques.

Promotional text: We demonstrate methods to improve nuclear monitoring and verification through studying noise time histories that can be used to identify issues with seismic instrumentation and calibration.

P1.2-659 – How reliable are moment tensors of small earthquakes?

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Calculation of moment tensors of weak seismic events is challenging. Quite often we face a lack of stations and inaccurate velocity models. However information on moment tensors is important for understanding origin of the events (explosions, natural and induced earthquakes) and seismotectonic regime of the area. We re-analyzed two methods of retrieving moment tensors: (i) Inversion of amplitudes of P- and S-waves, and (ii) inversion of three-component full waveforms, complemented by first-motion polarities. The methods utilize different types of waves, different frequency bands, and different methods to calculate Green's functions. We compare and discuss the methods in terms of reliability, efficiency and accuracy. The discussion is performed on examples of two weak earthquakes from Slovakian-Ukrainian border which appeared in April 2020, with local magnitudes 3.2 and 2.3.

Promotional text: To increase reliability of moment tensors of small seismic events, we analyze inversion of P- and S-wave amplitudes and three-component full waveforms. As example, we discuss two earthquakes from Slovakian-Ukrainian border from April 2020, with local magnitudes 3.2 and 2.3.

P1.2-660 – Seismicity along the seismogenic zone of Algarve region (southern Portugal)

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The present seismological study, focused around Algarve region, was carried out through a cooperation project between the Universities of Évora (Portugal), Lisbon (Portugal), Strasbourg (France) and the IPMA (Lisbon, Portugal). To locate the seismic events and find the local velocity structure of the epicentral area, the P and S arrival times at 38 stations are used (Geostar stations, telemetered network, U. Lisbon and IPMA stations). The data used in this study were obtained during the Algarve campaign, which worked, from January/2006 to July/2007. The preliminary estimate of origin times and hypocentral coordinates are determined by the Hypoinverse program. Linearized inversion procedure was applied to comprise the following two steps: 1) finding the velocity model using Velest and 2) simultaneous relocation of hypocenters and determination of local velocity structure. This work is expected to produce a more detailed knowledge of the crust structure over the region of Algarve, being able to identify seismogenic zones, potentially generators of significant seismic events and the identification of zones of active faults.

Promotional text: Build and strengthen a relationship with the broader science community by contributing with my seismological study.

P1.3 The oceans and their properties

P1.3-095 – Global hydroacoustic simulations on high-performance computers

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The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is operating and maintaining the international monitoring system of seismic, infrasound, hydroacoustic and airborne radionuclide facilities to detect a nuclear explosion over the globe. The monitoring network of CTBTO, especially with regard to infrasound and hydroacoustic, is quite unique because the network covers the globe, and the data is open to scientific use. On the other hand, global scale computer modelling of acoustic signal transmission has not been well established. In this presentation, improvements on such global acoustic transmission models will be presented with particular focus on high-performance computing.

Promotional text: Global acoustic computer simulation programs have been developed on cutting-edge computers to assist analysis of complex hydroacoustic signals.

P1.3-270 – Modular nodes: Design and development of a novel mechanism which enables the repair of individual underwater components in IMS hydrophone stations

Authors: Mario Zampolli[1]; Georgios Haralabus[1]; Jerry Stanley[1]; Geoffrey Cram[2]; Kevin Williams[2]; Michael Harrington[2]; Derek Martin[2]; Steven Schwennsen[2]

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The six hydroacoustic hydrophone stations within the CTBTO's International Monitoring System comprise a total of 11 triplets. These triplets have a 20-year design life with no scheduled underwater segment maintenance actions and are based on a linear non-modular design which offers the advantages of high reliability and efficient deployment in one continuous operation. However, a triplet employing modular components and Wet-Mate Connectors (WMC) has an advantage in that replacement of a failed component(s) in-situ becomes possible without disturbing the remaining functional system components, or requiring replacement of the entire triplet. For these reasons a modular design triplet that maintains the efficient deployment of a non-modular linear system has been investigated. A critical component that has been developed is a latch mechanism that secures the cable terminations to the node structure. This isolates the WMC plug and the cable from the deployment stress which they are otherwise unable to sustain. After deployment, the latch can be opened; should a repair then become necessary, detachment of the cable and termination can be undertaken by an ROV. The design principles, the status of fabrication and testing of the modular cable latch are presented, along with the envisaged development of a prototype.

Promotional text: A modular component was developed to enable in-situ repair of hydroacoustic underwater triplets down to component level, while at the same time preserving the advantages of the robust and efficient deployment of the legacy linear triplets.

P1.3-273 – Could short duration broadband signals identified in IMS hydrophone recordings be Right Whale vocalizations?

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The six CTBT IMS hydroacoustic hydrophone stations, comprising 11 triplets in total, record continuous data sampled at 250 Hz. Marine mammal vocalizations are frequently identified in these recordings and form an integral part of the HA stations' undersea soundscapes, as reported in numerous scientific publications. During regular IMS hydrophone data quality checks, occasional short duration broadband signals occupying the entire available bandwidth were identified, which differ from the longer duration sweeps and chirps of whale calls reported in prior studies that made use of IMS hydrophone data. When such a sound appears on more than one hydrophone of a triplet, the recordings show amplitude variations across hydrophones that are indicative of a nearby source. Furthermore, the signals do not show signs of dispersion from long-distance propagation. The hypothesis is formulated that these sounds may be the low-frequency portion of short impulsive broadband vocalizations, referred to in the literature as Right Whale "gunshots". Recordings of this endangered species are relatively rare compared to vocalizations from other whales and their study is receiving increased interest from the scientific community.

Promotional text: It is hypothesized that short duration broadband signals observed at IMS hydrophone stations may be the low frequency end of impulsive Right Whale calls. Recordings from this endangered species are relatively rare compared to vocalizations from other whales.

P1.3-284 – A self-consistent estimate of the CTBT IMS hydrophone locations using scientific airgun data from the CEVICHE trial (Chile)

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The CTBT IMS hydroacoustic sensor network composed of 6 hydrophone stations and 5 T-phase is part of the global CTBT verification regime. The hydrophone stations consist of hydrophone triplets. Each hydrophone is suspended in the ocean at a depth close to the SOFAR channel axis and anchored by a riser cable to the ocean floor. The geometry of the triplets and dedicated data processing allow for estimating the direction of arrival (or back-azimuth) of an incoming signal used for localizing the event. An accurate deployment position of each hydrophone in the triplet is essential to obtain an accurate location of an event by back-azimuth estimation that may originate thousands of kilometers from the triplet. CTBTO has in the past developed an algorithm calculating re-location of hydrophones based on numerous analyst reviewed event locations obtained by the entire CTBT IMS sensor network. In this study, the algorithm is applied to the HA03 hydrophone station to estimate possible corrections to the hydrophone locations. The Progressive Multi-Channel Correlator algorithm is updated with the hydrophone re-location, and a series of signals from a scientific airgun survey recorded during the CEVICHE trial (Chile) demonstrates the improvement in back-azimuth estimates by the hydrophone re-location.

Promotional text: Verification and validation of hydrophone deployment positions are beneficial for maintaining accurate event localization using the CTBT verification technologies.

P1.3-291 – IMS hydroacoustic hydrophone station detections associated with volcanic eruptions at Kadovar Island, Papua New Guinea

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Following an eruption series at Kadovar Island, Papua New Guinea, the hydroacoustic datasets acquired by CTBT International Monitoring System (IMS) hydroacoustic (HA) hydrophone station HA11, Wake Island, were examined. HA11 is located approximately 3500 km northeast from Kadovar. Active eruptions restarted in January 2018 after a quiet period of three centuries. Cross-correlation analysis using two months of HA11 triplet data showed that the cumulative number of HA detections increased with time after commencement of the volcanic eruption series. According to local observations of Kadovar, a first eruption at the summit of the island was followed by four additional new vent spots and two vents were created near the shoreline. Our analysis suggests that the hydroacoustic signals detected by HA11 were associated with the volcanic eruptions near to the shoreline. A flank collapse resulting in erosion of the shoreline occurred on 9 February 2018. Hydroacoustic signals of long duration and small amplitude recorded at HA11 could be associated with this flank collapse. The present study demonstrates the potential contributions of the IMS HA stations data to the remote monitoring of underwater volcanic activity over large ocean areas.

Promotional text: A volcanic eruption series at Kadovar Island, Papua New Guinea, was remotely observed by IMS Hydroacoustic hydrophone station HA11, Wake Island. In addition to the eruptive events, the data also contained some small amplitude signals that associated with a flank collapse event.

P1.3-331 – Remote detection of hydroacoustic signals potentially associated with the sinking of SS El Faro using CTBT IMS hydrophone data

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On 1 October 2015, the cargo ship SS El Faro was lost approximately 120 km east of Long Island, The Bahamas, during the Hurricane Joaquin. Here, we analyze underwater sound phases potentially associated with the loss of this vessel, recorded by station HA10 of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) International Monitoring System (IMS) located at Ascension Island, Mid-Atlantic Ocean. Results from progressive multi-channel correlation and spectral analysis of broadband arrivals at both hydrophone triplets of HA10 suggest that at least one impulsive, in-water event occurred within minutes after communication with SS El Faro had ceased and emergency buoys were activated. The derived event origin notably coincides with the confirmed location of the wreckage on the seafloor. Our findings are consistent with results from 2D transmission loss modeling and further highlight the exceptional capabilities of the IMS hydroacoustic network for detecting both natural and non-natural events in the global ocean.

Promotional text: Using hydrophone data recorded at IMS station HA10, Ascension Island, we investigate underwater sound phases potentially linked to the sinking of the cargo ship SS El Faro during the 2015 Hurricane Joaquin.

P1.3-402 – Capability of the IMS hydrophone stations network to characterize low level underwater seismicity, underwater volcanism and iceberg events

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The hydroacoustic component of the IMS network consists of a series of five island-based seismic stations and six cabled hydrophone installations located in the Indian, Pacific and Atlantic Oceans. In this study, we focus only on hydrophone stations, which provide low back ground high quality data: each one of these stations hosts a set of three hydrophones deployed at a depth of the SOFAR channel, as a small-aperture (~2 km) horizontal triangular array. The direction of arrival and the apparent velocities of broadband acoustic arrivals can be determined from array processing based on correlation or beam forming techniques, therefore enhancing the detection and location capabilities of such a sparse network. Several years of data are processed with DTK-PMCC detector and global association is performed to build automatic events. The precision of estimated wavefront parameters allows to image with an unexpected accuracy the spatial locations of active seismic areas associated to ridge, subduction and volcanic seismicity, for which propagation paths are not blocked by bathymetric structures. Antarctica iceberg events are also clearly detected with season-dependent locations. Obtained seismic events are compared to LEB events, and differences are discussed in terms of location accuracy, source energy level and ground-to-water coupling.

Promotional text: This presentation demonstrates the capability of the IMS hydrophone stations network to characterize low level underwater seismicity, underwater volcanism and iceberg events.

P1.3-408 – Acoustic Energy Propagation in the Ocean Along Areas of Strong 4-Dimensional Sound Speed Variability

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The ocean is subject to complex dynamics that can produce time variant sound speed gradients with horizontal scales with potential to impact medium to high frequency acoustic propagation. Some of these features can critical grazing angles that may result in horizontal sound refraction, producing areas of stronger and weaker energy, time delays in the acoustic arrivals and changes on multi-path characteristics. The operational ocean forecast systems have skills to resolve some of these processes, but the acoustic propagation modeling solutions need to be able to handle these complex sound speed fields in order to reproduce the resulting sharp loss/gain changes along levels and directions (3D effects). These features can impact the accuracy of algorithms estimating source localization or doing ocean tomography and data assimilation. This work outlines a framework to diagnose when sound speed variability may be strong enough to trigger these 3-D effects following a risk management approach. It uses real-time ocean model forecasts, to build diagnostic variables estimating the possible acoustic impacts of ocean frontal systems and instabilities. The resulting analysis can be used to select numerical solution approaches and/or to create awareness regarding possible errors in the interpretation of acoustic signals in areas subject to strong dynamics.

Promotional text: This work includes a contribution relevant to the analysis of acoustic wave speed and attenuation, used for locating seismoacoustic disturbances in the oceans.

P1.3-425 – Recording of T-phases from the M7.4 Kermadec Trench earthquake in 2020 at the CTBT IMS HA03 hydrophone station

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On 18 June 2020, energetic underwater acoustic T-phase signals were recorded at the Comprehensive Nuclear-Test-Ban Treaty (CTBT) International Monitoring System (IMS) hydrophone station HA03, located at the Juan Fernandez Islands, Chile. In this work, we investigate the origin of these T-phases, which were associated to an M7.4 submarine earthquake with epicenter in the Kermadec Trench located at a distance of approximately 8700 km from HA03. Analysis of the recorded T-phases was performed using the Progressive Multi-Channel Correlation algorithm (DTKGPMCC) installed on the CTBTO virtual Data Exploitation Centre (vDEC). This analysis revealed a strong signal correlation between North and South HA03 hydrophone arrays, different arrivals were identified within the duration of the earthquake, and the estimated back azimuth showed variability over time. The back azimuth results suggest that T-phases could be triggered at different locations along the Trench and far from the declared earthquake epicenter. Underwater acoustic signal travel times were estimated along different propagation paths by a Normal Mode model with realistic environmental input, and possible horizontally reflected and diffracted paths were calculated by a 3D Parabolic Equation model. Future research directions for the improvement of localization T-phase excitation from submarine earthquakes will be discussed.

Promotional text: Propagation of low-frequency underwater acoustic signals (5 to 20 Hz) from the 18 June 2020 M7.4 Kermadec Trench earthquake is investigated. This analysis will provide guidance on future improvements of underwater event localization using the CTBT IMS hydroacoustic sensor network.

P1.3-490 – A theoretical formulation of a 3D acoustic propagation model for stratified oceanic media based on an indirect BEM approach.

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Despite the progress made both in hardware and numerical techniques, 3D acoustic propagation for stratified oceans in cartesian coordinates, is still a challenge. In 2019, an approach to this problem restricted to short-range distances, using the Boundary Element Method (BEM), was reported (Li et al. J. Comput. Phys. 392, (2019): 694-712.). The BEM is a widespread method that exhibits certain useful advantages for solving time-harmonic scattering problems such as the fact that only integration in 2D boundaries is required, the Sommerfeld radiation condition is automatically satisfied, there is no need to add artificial absorbing layers and the seawater-seabed interface can be managed quite easily. The main disadvantage is that a non-homogenous medium like the oceanic environment must be modelled as a multi-domain problem which makes it computationally expensive and big enough to require using of iterative solvers as the Generalized Minimal Residual Method (GMRES) in addition to techniques for accelerating the evaluation of surface integrals. Here, an indirect BEM formulation, characterized by providing a more stable solution than the direct approach adopted in the previously mentioned work, which needs preconditioners to solve the involved linear system, is developed from its theoretical foundations through numerical evaluation of some representative benchmark situations.

Promotional text: Acoustic propagation modelling in the ocean is a key component to analize and understand received signals at hydroacoustic stations. Research on new improved methods, as the one presented here, is expected to generate further and direct impact on improving nuclear test monitoring.

P1.3-494 – An inverse problem approach for acoustic Transmission Loss estimation from the analysis of signals generated by seismic air-gun arrays.

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Offshore seismic surveys with airgun array sources are currently widespread in all the oceans. They constitute one of the most powerful and systematic impulsive noise sources in marine environments. The sound pulses from large airgun arrays generate signals that contain sufficient energy in the 5-60 Hz band to propagate ocean-basin scales at ranges of hundreds to thousands of kilometres. Under favourable propagation conditions they can be received at the CTBT IMS hydroacoustic stations (HA) with high signal to noise ratio. Unlike previous work, our focus is neither to study their effects on marine species nor to investigate the stratified sedimentary structure of the seabed, but to evaluate whether these signals can be used to validate theoretical predictions of propagation models. A sample of recorded signals from seismic surveys obtained from the IMS HA historical data is exhaustively analysed through cepstral, spectral and time-based techniques. Then, based on the known characteristics of the energy source spectral density of airgun arrays below 100 Hz, as published in the literature, some underwater propagation properties are inferred.

Promotional text: Validating sound propagation models in oceans contributes to improve the nuclear test monitoring and verification. The present work is a scientific application of data used for test ban verification with the consequent feedback to the CTBTO and the broader scientific community.

P1.3-526 – Modeling of hydroacoustic propagation based on the normal mode-parabolic equation method

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Abstract: In view of the low accuracy of the far-field modeling of underwater explosion sound propagation, the normal mode-parabolic equation method is used to carry out the modeling of hydroacoustic propagation to optimize the ability of far-field propagation simulation. This method combines the advantages of the normal mode model method and the parabolic equation method, adopts local normal mode analysis in the vertical direction, and uses the parabolic equation method to solve the normal mode amplitude equation in the horizontal direction. This method can be used to simulate the sound propagation loss of underwater explosions, and combined with the sound velocity profile, the theoretical travel time of sound propagation can be calculated. This method solves the problem that the high frequency situation is hard to calculate with the parabolic equation method, and the algorithm is able to extended to three-dimensional simulation.

Promotional text: Use new method to optimize the ability of Modeling of hydroacoustic propagation.

P1.3-546 – Observed laterally reflected hydroacoustic signals generated by underwater impulsive sound sources

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The International Monitoring System (IMS) of the CTBTO includes hydroacoustic stations composed of underwater hydrophones placed at the depth of the SOFAR channel. Since the hydroacoustic component of the network is designed to detect underwater nuclear explosions, events of special interest are impulsive underwater explosions. Among these, we studied several underwater explosions detonated close to the coast of Florida in September 2016 and 4 impulsive-like events (likely also underwater sources) from the Kamchatka area recorded in August 2020. In both cases, we observe secondary arrivals on IMS station HA11 for the Kamchatka sources and HA10 for the Florida sources immediately following the direct hydroacoustic arrivals. We assume these secondary arrivals are due to coastal reflections. We identify the potential reflection points for these reflections based on their back azimuths at the recording station and the estimated location of the impulsive sources. To verify this, we used the IDC standard hydroacoustic analysis tool HART and DTK-(G)PMCC, the latter provided to CTBTO authorized users, to estimate back azimuths. Comparisons between sources in the same general area give us an idea of the consistency of these reflections between sources in the same general area.

Promotional text: From this study of reflected hydroacoustic signals generated by underwater impulsive sources it is evident that the IMS in-water hydroacoustic stations can detect signals of high relevance to CTBTO and also that the IDC processing analyst tools are applicable to define them.

P1.3-554 – Anthropogenic ocean noise: Mediterranean gateways versus open oceans

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Anthropogenic noise pollution may mask natural sounds, which are fundamental to survival and reproduction of wildlife, especially for marine cetaceans as they are highly dependent on underwater sounds for basic life functions.

In the 21st century, shipping in the ocean has increased significantly and causes low frequency (10–100 Hz) noise which affects or hinders vital communication of large baleen whales at 15 to 30 Hz. Noise in the ocean has been monitored as a byproduct by IMS monitoring stations of the CTBTO. However, elsewhere for example at ocean gateways or in marginal seas little is known about the soundscape.

Here, we report long-term and short-term low-frequency noise measurements from Gibraltar, the gateway into the Mediterranean Sea and from the Pelagos Sanctuary, a Marine Protected Area, in the Ligurian Sea, Mediterranean. Ambient noise is derived from calibrated moored ocean-bottom-hydrophones deployed for earthquake monitoring and seismic campaign work. Observations are compared to noise levels in the range of 1 to 100 Hz as revealed at CTBTO monitoring sites in the Atlantic, Indian and Pacific Ocean. Most profoundly, noise levels in the Mediterranean and near Gibraltar are significantly increase by up to 20 dB at 40 Hz when compared to the open oceans.

Promotional text: Research provides unique data on the soundscape of the oceans, documenting the global variability of the ocean noise levels, nurturing a sustainable management of our seas and oceans and protection of marine life. Observations will guide society, stakeholders, and governments.

P2.1 Characterization of treaty-relevant events

P2.1-123 – Discrimination of seismic events (2006 to 2020) in North Korea using P/Lg amplitude ratios from regional stations and a bivariate discriminant function

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Two events of magnitude (m_b) 3.6-3.8 occurred in southern North Korea (NK) on 27 June 2019 and 11 May 2020. Although these events were located about 330-400 km from the known nuclear test site, the fact that they occurred within the territory of NK, a country with a recent history of underground nuclear tests, made them events of interest. We used P/Lg ratios from regional stations to categorize seismic events that occurred in NK from 2006 to May 2020, including the two recent events, the six declared NK nuclear tests, and the cavity collapse and triggered earthquakes that followed the 3 September 2017 nuclear explosion. We were able to separate the cavity collapse from the population of nuclear explosions. However, the distinction between the earthquakes and the cavity collapse is ambiguous. We used cross-spectral Pg/Lg and Pn/Lg ratios jointly in a quadratic discriminant function and successfully categorized the six declared nuclear tests and the triggered earthquakes that followed the September 2017 explosion. Our analyses also confirm that the recent southern events are both tectonic earthquakes that occurred naturally.

Promotional text: This study aligns with the SnT2021 goal of identifying methods for improving nuclear test monitoring and verification. The performed discriminant analyses suggest that combining cross-spectral Pg/Lg and Pn/Lg results in improved discriminant power.

P2.1-162 – Improving the Resolution of the Isotropic Seismic Moment Tensor using Rotational Ground Motions

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Seismic moment tensors provide information not only about the geometry of a seismic source (tectonic – DC – part) but also with non-tectonic information such as volume changes (isotropic – ISO – part). This feature is crucial to discriminate explosive sources from others, which can hint to a nuclear test. However, that part is often not well resolved by standard methods. Measuring rotational ground motions might help to obtain more reliable results.
Six components of ground motion are needed to entirely describe the seismic wave-field, three translational and three rotational. Just recently, portable rotation sensors dedicated for seismological applications are available. In previous studies, we show that by inverting both ground motions together, the resolution of the moment tensor can be improved significantly.
In a synthetic set-up for the Korean peninsula we analysed the 2013 nuclear test of the Democratic People's Republic of Korea. Applying a Bayesian inversion method, we tested three frequency bands. We also tested the inversion with Green's functions based on one- and three-dimensional structural models. The reliability of the source mechanism benefits form both, the three-dimensional structure and rotations, even more in the higher frequency ranges. Thus, also the reliability of the ISO part is increased.

Promotional text: Rotational ground motion recordings contribute significantly to the reliable determination of moment tensors. Thus, discriminating explosive sources is better resolved. Therefore, rotational ground motions constitute an new opportunity for improving nuclear test verification.

P2.1-195 – Using publicly available non-seismic constraints to estimate the yield of a large explosion in Beirut, Lebanon

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A study of a large explosion in Beirut, Lebanon, explores the use of non-seismic constraints to supplement the seismic data yield estimates. The explosion yield is estimated by fitting overpressure to the equivalent of a 1kT overpressure curve as a function of radius from the explosion ground zero. Overpressure is estimated using explosion damage evaluations from publicly available sources such as aerial photos, movies and press articles. An equivalent yield interval of 0.7-0.9-kT is estimated.

Promotional text: A study of a large explosion in Beirut, Lebanon explores the use of non-seismic constraints from publicly available sources to supplement the seismic data yield estimates.

P2.1-241 – Lessons from OSI field tests and exercises for the development of contextualized geophysical survey strategies and methods

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The sole purpose of an OSI as specified in Article IV of the Treaty is "to clarify whether a nuclear weapon test explosion or any other nuclear explosion has been carried out" and "to gather any facts which might assist in identifying any possible violator." OSIs are to provide this clarity through the collection of information and the detection of relevant observables within the Inspection Area. For this, the inspection team may undertake visual observations and use imaging, radionuclide and geophysical OSI techniques.

This presentation demonstrates how, on the example of an OSI, the objectives of a particular field mission will determine the selection of the most appropriate geophysical survey strategies and methods. Actual data collected during several OSI field tests and exercises, which presented underground nuclear explosion scenarios, will be shown and discussed in the context of the rationale and timelines of different field mission objectives. Particular emphasis will be placed on how the integrated use of various inspection techniques may contribute to the characterisation of a site. In this context, the importance of accuracy and the inherent uncertainties of the application of geophysical techniques will be demonstrated as well.

Promotional text: This presentation demonstrates, on the example of an OSI, how to determine the selection of the most appropriate geophysical survey strategy and, thus, contributes to supporting the exchange of knowledge and ideas between the CTBTO and the broader scientific community.

P2.1-268 – Three-dimensional space analysis of radioxenon isotopic activity ratios for characterizing a nuclear event in comparison to civilian releases from fission and activation

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This study on the nuclear release timing aims analysing radioxenon isotopic activity ratios in three-dimensional space. The methodological approach and the characterization of the 3D usability threshold considered in this study were presented during SnT2019 and INGE2019. This presentation focuses on comparison to civilian sources from fission and activation.
Obviously three isotopes are less likely to be detected simultaneously than two isotopes are. However, if three isotopes are available, making use of all three together offers a much more powerful analysis mechanism than with only two isotopes. In the three-dimensional space the analysis of timing and event screening can be separated. A time-independent screening can be achieved through the projection along the decay axis and the time. In this projection, event characterization can be achieved without knowledge about the time of the release from the source. The time-independent screening is most useful for CTBT monitoring purposes since the time of origin of a remote detection is in general not known. In addition, under favourable conditions, the event origin time can also be determined irrespective of the source scenario by projecting the isotopic ratios on the decay axis and scale it in units of time.

Promotional text: The 3-dimensional analysis of radioxenon isotopes offers special opportunities for event screening and determining the event zero time. For the former, time is eliminated by projecting the data along the axis of decay, the latter by projecting the data onto this axis.

P2.1-371 – Rapid and automated full seismic source characterization: seismic monitoring application for the North Korean region

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Rapid full source characterization is strongly recommended for providing pertinent information after the occurrence of an event of interest such as a nuclear test. Full moment tensor inversion using long-period seismic waveforms recorded at regional distance has shown its relevance for confirming the isotropic component of a seismic source. In order to rapidly determine the full source parameters of events occurring in a region of interest, an automated grid-search moment tensor approach can be proposed. Here, we show that such method called GRiD MT reveals the main parameters of any events with magnitude above 3.5 within a few minutes: detection, origin time, location, moment magnitude and mechanism. We demonstrate its interest for seismic monitoring when implemented over the North Korean region using only a limited number of seismic stations. Correct identification of all past North Korean nuclear tests (including the smallest one in 2006) is rapidly obtained within an easy-to-use algorithm for a seismic analyst. Lastly, GRiD MT can be used for the monitoring of small to larger tectonic events, and is currently being tested and implemented for multiple objectives at the French National Data Center: nuclear test monitoring, earthquake monitoring, and tsunami warning.

Promotional text: This presentation shows the substantial interest for a national data center to develop and implement full source inversions in near-realtime for seismic event characterization.

P2.1-472 – Event Analysis of CTBT Relevant Radionuclides Detected in the Nordic Region 2020

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A series of measurements of multiple anomalous treaty relevant radionuclides at several measurement stations in Sweden and Finland, including the Stockholm aerosol sampler (SEP63) in the International Monitoring System (**IMS**), occurred in the summer of 2020. The cause and source of these radionuclides is still unknown. The laboratory re-measurement of the split **IMS** sample revealed that one-half of the split sample contained the entirety of the anthropogenic radioactivity - a high degree of sample inhomogeneity due to hot aerosol particles. Using the **IMS** results and by performing some advanced laboratory coincident measurement techniques, an international, multidisciplinary team started to unravel the details on the nature of this event while also demonstrating the verification benefits of adopting new sample analysis techniques.

Promotional text: Detections of multiple treaty relevant radionuclides by the IMS and national monitoring networks in June 2020 initiated an event analysis. An international, multi-disciplinary team employed multiple techniques including an advanced laboratory system to characterize this event.

P2.1-474 – Simulations of the long-term evolution of Ar-39 produced in an underground nuclear explosion

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Measurements of gas collected from locations surrounding historic underground nuclear tests have identified that Ar-39 produced during a nuclear explosion can remain in the subsurface decades after the event occurred. As an activation product produced by the interaction of neutrons with geologic potassium, Ar-39 is produced in significant quantities in almost any underground nuclear explosion. With a half-life of 269 years, the primary loss mechanism for Ar-39 over time is dilution in the atmosphere or the geology surrounding the event. In order to better understand how the transport of Ar-39 affects its viability as a long-lived underground nuclear explosion signature, a series of simulations were performed of an initially pressure-driven Ar-39 source with varying depth and geology type surrounding the source. The evolution of both Ar-37 and Ar-39 was modeled over 30 years and the loss to the atmosphere or to dilution in the surroundings was tracked.

Promotional text: This work discusses further evaluation of the viability of Ar-39 as a potential long-term indicator of underground nuclear explosions as it compares to Ar-37, with simulations demonstrating persistently detectable subsurface Ar-39 concentrations even decades after events.

P2.1-486 – Data-based kernel density equations for probability distributions of CTBT-relevant radioxenon isotopes at IMS stations in normal background from nuclear facilities and as simulated from underground nuclear explosions

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The objective of this study is to apply the kernel density (KD) approach to generate and investigate probability distributions of isotopic ratios for radioxenon releases from certain types of sources. KD equations for nuclear facility releases are derived from the data set of the radioxenon emission inventory of all nuclear power plants and all nuclear research reactors, as well as selected medical isotope production facilities in the calendar year 2014. Analytical equations for the releases from assumed underground nuclear explosions are obtained using Bateman equations for simple scenarios of prompt and delayed releases from underground nuclear explosions with in-growth and decay or alternatively with complete fractionation at time zero after the nuclear fission event. For both types of sources, KD equations will be linked with isotopic ratio calculations that connect source and receiver. The goal is to create probability density functions that could be applied e.g. with a Bayesian method to determine the probability whether an IMS observation could possibly be caused by a nuclear explosion.

Promotional text: This study presents data-based kernel density equations for possible nuclear test signatures and normal background. These can be used e.g. in a Bayesian method to determine the probability whether an IMS observation could possibly be caused by a nuclear explosion.

P2.1-487 – UK National Data Centre: Radionuclide Event Analysis

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The UK National Data Centre (NDC) operates a series of custom-developed software tools for the automatic processing, analysis, archiving and interpretation of radionuclide (RN) data from the International Monitoring System (IMS). The tools include an RN Pipeline for the analysis of radionuclide data (noble gas and particulate), and a series of simulation pipelines to provide accompanying atmospheric transport modelling (ATM) data. The ATM products are triggered on the identification of an 'RN detection event', which can include radioxenon plumes or 'high-priority' detections. An overview of the toolset is presented, along with case-studies using interesting RN detections from recent years, such as particulate detections at SEP63 and RUP61 during 2020.

Promotional text: The UK National Data Centre (NDC) has developed methods for the analysis and interpretation of radionuclide events. Here they are used to present results from the analysis of radionuclide detections on the IMS.

P2.1-540 – Forensic Event Analyses at the Turkish NDC

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During the year 2020, apart from the global pandemic, there have been several global incidents that were recorded by IMS stations. As Turkish NDC, we have selected three of these events to be analyzed. The first event is the fragmentation of a meteorite/bolide on 27 May 2020 that was observed by many cities over the Northeastern part of Turkey, the second event is the Fireworks factory explosion at the outskirts of Sakarya city of Turkey occurred on July, 3rd and the last event that was analyzed is the explosion of 2.7 kT Ammonium Nitrate at the harbor of Beirut, Lebanon on 4 August 2020. Since all of these events occurred on the surface or the atmosphere, several IMS infrasound stations detected the acoustic pressure changes over great distances. In addition to the IMS infrasound stations, local seismic stations in Turkey recorded the ground vibrations caused by the shock waves of these events. Therefore, we were able to make an event analysis using fusion of both technologies to test not only our NDC's capabilities but also the products and tools that were provided by CTBTO. Our final analysis results will be presented at SnT 2021.

Promotional text: This work just shows the mutual benefits between CTBTO and NDCs. Characterization of an interesting event can be achieved through data fusion. NDCs can access to various global data through IDC to conduct in-depth analyses.

P2.1-572 – Nuclear Debris Characterization by Fission Isotope Assessment

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Radionuclide isotopic composition analysis is an important and reliable tool for determination of the artificial radionuclide source. As each anthropogenic emission could be characterized by its own unique radionuclide composition, these „fingerprints" make it possible to determine the evidence of radionuclide contamination source. Gamma spectrometric measurements were performed with the state-of-the-art "Ortec" alpha spectrometer and gamma spectra were recorded by SILENA gamma-spectrometric system with an HPGe coaxial detector. Radionuclide isotopic ratios were measured by a high resolution sector field mass spectrometer combined with a high sensitivity APEX sample introduction system. Elevated ^{137}Cs/^{239,240}Pu, ^{238}Pu/^{239,240}Pu, ^{240}Pu/^{239}Pu isotopic "finger print" values reliably reveal a nuclear event and assess its source by fusing these values with atmospheric transport modelling. The report discusses the areas of uneven "hot" particle deposition and large, vast "hot" spots.

Promotional text: The report discusses the formation of uneven nuclear debris "hot" particle deposition areas and covers large, vast "hot" spots assessment accomplished during radionuclide monitoring.

P2.1-601 – Connecting underground nuclear explosion gas-release ranges as aggregated from a set of scenarios with IMS radioxenon observations for evaluating isotopic activity ratios as indicators of a nuclear test

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Isotopic activity ratios of radioxenon measured in IMS noble gas samples are routinely obtained that might indicate a gas release from an underground nuclear test, although actually caused by atmospheric emissions from nuclear facilities. A robust method is required that tests the isotopic activity ratios of samples of special interest against a set of all relevant release scenarios that could possibly explain the source. This presentation treats nuclear explosions as the source. The method presented here combines the two ends of the lifetime of radioxenon isotopes and their activity ratios. One end is the radioisotope generation by a nuclear explosion, the other end is their measurement in IMS samples. Mathematical modelling is used to create the relationship between both ends. Recent research results on the source mechanisms including in-growth and decay, cavity-melt fractionation and seepage of cavity gases are used to develop best-estimate input source terms as well as minimum and maximum activity ratio boundaries as a function of time. The ratios in the IMS sample are reconstructed as a function of the time of release into the atmosphere and the sampling time. The output is a score for the consistency of a set of scenarios with the observation.

Promotional text: Investigating IMS noble gas samples for possible nuclear test signatures requires all possible underground nuclear test scenarios to be considered. This presentation shows how the aggregated signature of all scenarios can be connected with IMS observations of a specific event.

P2.1-643 – Atmospheric Transport Modelling for potential releases and detections possibly connected with announced DPRK nuclear tests

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Various techniques of Atmospheric Transport Modelling were applied after announced DPRK nuclear tests in order to support the analysis of potentially connected radionuclide detections. Forward dispersion forecasts from the test-site predicted potentially affected IMS stations; forward ATM for known background sources assessed their potential contribution to measured concentrations.
In case of detections, backward ATM has shown consistency with certain emitter locations and identified coincident source regions for multiple detections.
As we think that DPRK test 2017 could and must have been the last nuclear test at all, the presentation gives a comprehensive overview how ATM supported the analysis of the National Data Centre. Special focus is how potential interference with known background sources had an impact on the assessment. In several cases measurements of releases from nuclear facilities caused ambiguous radioxenon detections in the aftermath of DPRK tests.
Finally, for two DPRK tests (2009 and 2016-Sep) it was not possible to identify potentially related radioxenon detections, for two tests there were consistent but not conclusive detections of Xe-133 only (2016-Jan, 2017) and for two tests there were matching isotopic ratios and fitting atmospheric conditions (2006, 2013).

Promotional text: The application of Atmospheric Transport Modelling in the aftermath of DPRK events gave crucial information and increased usefulness of potentially connected radioxenon detections and non-detections.

P2.1-683 – An array of noble gas samplers suspended at various heights from light gas-filled balloons hard wired to the ground to bolster the efforts of an On-Site Inspection team

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The On-Site Inspection (OSI) Team shall converge to the possible test location applying various permitted inspection techniques using approved equipment within /set timeframe (technical & political significance). OSI relevant noble gases such as Argon and Xenon from the potential test(s) (underground) may reach the atmosphere through venting and/or atmospheric pumping (depending upon local geology). These gases are denser than the earth's atmosphere at sea level and are terrain hugging in nature. The lift (elevation) & movement (horizon) are primarily caused by wind. An array of portable noble gas samplers covering elevation(vertical) and azimuth(horizon) may be used to increase the probability of detection. The array design for sampling of OSI relevant noble gases depends upon :
• Properties of OSI relevant noble gases(Known)
• The distance between point of release (vent) and sampler (Unknown)
• The Meteorological Data (Probabilistic weather forecasting)
This paper discusses the design of an array (no of elements, distance between elements) and the placement.
Probabilistic assessment of 8760 hourly sampled/historical weather data involving atmospheric weather modelling (like Gaussian puff-plume and Lagrangian particle model) to understand the design and performance optimization (of arrays) is considered.

Promotional text: Nobel gas detectors can be used in an array suspended from various balloons which are hard wired to the ground and whose altitude can be adjusted. This array may be placed at a suitable place/ area and at a particular height depending on the air flow pattern to detect & zero-in.

P2.2 Challenges of on-site inspection

P2.2-027 – Radiation hardened RFID solution to OSI samples Chain-of-Custody

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CTBT treaty clarifies that "The DG shall have the primary responsibility for the security, integrity and preservation of samples. The DG shall, in any case, establish a stringent regime governing the collection, handling, transport and analysis of samples". This work is dedicated to the engineering application of IOT/RFID technology to the CTBT technical framework and real OSI scenarios and to provide practical engineering solution. Radiation hardened design was utilized for the first time to develop OSI scenario oriented RFID chips to meet with normal function requirements under nuclear radiation environment while handling OSI samples. Dual-RFID-label mechanism was invented for the first time to realize both tamper evident and Chain-of-Custody solution to OSI samples. Customized containers design of different shapes and materials was also utilized to meet with the requirements of collection, handling, transportation and analysis of all forms of samples including water, soil, vegetation, noble gas. Suggested application solution of global coverage IOT Nano-satellite constellation could be utilized to strengthen the overall Chain-of-Custody concept and in-real-time tracking of OSI samples during transportation and off-site analysis.

Promotional text: This work would fill in the gaps of OSI samples Chain-of-Custody concept. It would contribute to the security and tamper-proof of OSI samples, which could also contribute to the IMS samples COC management.

P2.2-030 – Combined Ground Magnetic and Very Low Frequency Electromagnetic (VLF-EM) Investigations for Gold Exploration around Ihale in Bunnu-Kabba Area of Kogi, north-central Nigeria

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This study combines ground magnetic and Very Low Frequency Electromagnetic (VLF-EM) geophysical investigation techniques to evaluate the economic potential of mineralized pegmatite veins for gold and associated metallic deposits. Twenty five carefully planned magnetic and VLF-EM profiles, each, were occupied east and west of a reference profile purposively established on an identified mineralized pegmatite vein around Ihale in Bunnu – Kabba area of Kogi, north-central Nigeria. The acquired magnetic data were filtered and transformed to remove regional field effect, cultural noise as well as focus magnetic anomaly peaks over corresponding sources. The measured raw real and raw imaginary components of the EM fields were subjected to Fraser and Karous Hjelt filtering to remove harmonic noise, make anomaly amplitudes relate directly to the causative conductors and also generate current density for charactering the subsurface. Seven zones of relatively high current density with matching high residual positive magnetic anomalies present closely correlate-able signatures with subsurface response of the reference profile established where local mining activities indicate evidence of gold and associated metallic mineralization. The applied geophysical techniques in this study demonstrate the efficacy of geophysical tools for delineating natural/induced earth structures and artefacts whose identification are valuable in test ban verification.

Promotional text: Magnetic and VLF Electromagnetic techniques for mapping the occurrence of gold deposits within the subsurface demonstrate the use of geophysical tools for delineating natural/induced earth structures and artefacts whose identification are valuable in test ban verification.

P2.2-036 – Commercially used ground penetrating radar's customized application to OSI

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According to CTBT treaty, Ground Penetrating Radar (GPR), together with magnetic and gravitational field mapping and electrical conductivity measurements, are non-destructive geophysical detection technology which can achieve effective detection of OSI anomalies or artifacts underground. As a matter of fact, GPRs have been commercially widely used for decades to conduct safety inspection of underground gas pipelines of cities and towns. It has also been commercially widely used to detect caves under the paved roads to avoid any unexpected land subsidence accident. This work is the active result of joint efforts made by experts of OSI and experts of commercial GPR application. Based on the rich experience and data accumulation of underground pipelines and caves detection, customized radar detector design and data processing mechanism suitable for CTBT OSI scenarios has been put forward. According to the requirements of different geological environment, working frequency of radar ranging from 50MHz to 1GHz can be customarily designed, so as to make the GPRs meet with practical requirements of real OSI scenarios. Moreover, the GPRs would be made user-friendly based on Android operating system, with touch screens and blue tooth data communication capability, etc.

Promotional text: This work would bring GPRs' commercial application together with CTBT OSI practical requirements, which could provide another optional choice for OSI essential equipment development.

P2.2-074 – A Compact Portable Cognitive Satellite Communication System for OSI

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In principle, OSI could be conducted anywhere on the earth. Communication is mission critical for OSI. 10 years have passed since the last Directed Exercises of OSI communication in Jordan. Some of the communication equipment suggested by the exercise, mostly old fashioned radio communication, would find its restrictions for meeting the practical requirements of OSI. Based on cognitive satellite communication and ad hoc communication networking technologies, this work carried out a study of cognitive satellite communication system for OSI. A compact portable satellite communication prototype VSAT has been developed with high reliable capability achieved by advanced cognitive communication technology. The main specifications are the following: Weight is less than 7 kg including lithium battery, which is suitable for inspectors to carry. Size is 310mm×460mm×60mm with antenna and receiver in an integrated design. Working time is up to 5 hours. Communication speed is up to 256Kbps. By means of working with ad hoc hubs (deployment depending on IA terrains, individual terminals, and commercial encryption, it would provide a reliable communication working environment for IT and IT members, supporting secured communication among IT members, ISP representatives, BoO, CTBTO headquarters and other possible parties.

Promotional text: This work carried out a study on compact portable cognitive satellite communication system for OSI, which would provide an option for OSI communication equipment development, so as to meet the urgent need of OSI communication equipment support requirements.

P2.2-220 – Operations Support Centre during Preparations for an On-Site Inspection

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The Operations Support Centre (OSC) is a crucial element for effective preparation for an on-site inspection (OSI); its organization and proper functioning directly impact the degree of inspection team preparedness before departing for the inspected State Party. The OSC will be activated within a couple of hours after the DG has received a request for an OSI, and it must immediately become operational. That requires a sound concept, a tested organizational approach, adequate infrastructure, clear and user-friendly procedures, and trained staff from all units of the Technical Secretariat. The OSC concept and related operating procedures have evolved over the time. The most recent update reflected the experience from the 2014 integrated field exercise and the commissioning of the new CTBT Operations Centre (COPC) at the PTS headquarters (Ref. SnT2019-T4.4-P13), which is a potential deployment location for an ad hoc OSI OSC at the Vienna International Centre. It was tested during the Build-Up Exercise on the OSI launch phase (BUE-L) in November 2019.
This poster explains the updated concept and organization of the OSI OSC as an ad hoc part of the COPC, illustrates the infrastructure, and summarizes relevant aspects of BUE-L.

Promotional text: The poster explains the updated concept and organization of the OSI OSC as an ad hoc part of the COPC, illustrates the infrastructure, and summarizes relevant aspects of BUE-L.

P2.2-230 – OSI Hybrid Power Integration for Base of Operations

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One challenge of On-Site Inspection (T2.2) is preparing for deployment to unknown locations with unknown resources. A critical element of a functional Base of Operations is stable and reliable electricity. The current diesel generators and UPS system has been enhanced with a hybrid power system that adds the ability to accept power from other generation sources, such as solar. An increased battery bank allows for more quiet time without the diesel generators reducing fuel usage and CO2 production.
Compact, foldable 100w solar panels have been designed to fit the air transportation containers connecting to inverter hubs that assist the hybrid power unit to supply power to the BOO. Excess energy is stored in battery banks for later use and the design of the system allows for immediate use of solar power anywhere alone the distribution network. The smart controller and control screen allow for efficient management of available power, auto-starting generators as a last resort if required.
Deployable solar units for smaller field equipment such as samplers or pumps complement smaller fuel generators, and small solar mats and converters that clip directly to existing battery terminals provide trickle charge to remotely deployed field equipment (such as SAMs) during sunlight hours.

Promotional text: Stable and reliable electricity is critical for a functional OSI. The integration of solar power into the OSI field power distribution is an opportunity to enhance flexibility in the field and harness renewable energy at the Base of Operations and to deployed field equipment.

P2.2-313 – Radioactive signs at tunnel portals after underground nuclear tests at Semipalatinsk Test Site

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One of the possible manners to conduct a clandestine, unannounced underground nuclear explosion may be a test in a tunnel under a mountain. At the Semipalatinsk test site (STS) of the Soviet Union, 209 underground nuclear tests were conducted in the tunnels. Radioactive noble gas (RNG) release of various intensities occurred at ~40% of the tests. In 1996, the Khlopin Radium Institute conducted a survey at the former STS of about 40 tunnels portals before their final closure. The radiation background was measured, gamma spectra were recorded, rock and soil were sampled for radiochemical analyses. The report will present data on contamination of the surveyed tunnel portal areas by radionuclides Cs-137, Sr-90 and others, and compare them with data on the radiation situation during nuclear tests (RNG release). Remaining radioactive traces are the most important sign during on-site inspection.

Promotional text: Report is content the information about radioactive contamination of area near tunnel portal as consequences underground nuclear test. This information is needed for elaboration OSI method.

P2.2-348 – Application of visualized 3-D simulation platform to OSI operation management and decision making support

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An OSI could be conducted anywhere. Due to the concept of the comprehensive nuclear test ban, an OSI inspection area could be in an extremely challenging environment. A simulation platform could be a solution both from the perspective of health and safety and mission efficiency. This work would propose a compact transportable visualized 3-D simulation platform to provide decision making and management support to OSI operations. Based on personal and environmental interactive virtual reality technology, it would quickly create a virtual reality inspection area environment utilizing treaty-agreed commercial remote sensing images and terrain data. Different terrains and environments could be simulated and visualized, such as mountainous areas, the Gobi Desert, water-based areas and inhabited towns under different lighting and weather conditions. The base of operations setup and routine management, health and safety management, contamination area marking, managed access area marking, mission estimation, sub-team daily mission planning, inspection routes planning, search area management, ground inspection and overflight simulation could be achieved. Holographic visualization could also be achieved through holographic goggles to realize immersive visualization. The system is compatible with popular international GIS platforms. During overflight simulations, an external joystick can be used to achieve a more vivid simulation effect. A touch screen has been used for better handling.

Promotional text: This work would propose a commercial compact transportable visualized 3D simulation platform to provide decision making and management support to OSI operations.

P2.2-387 – Improving environmental radioactivity monitoring by the use of shielded portable HPGe detector

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The ENEA Traceability Laboratory in Bologna utilizes a portable HPGe gamma spectrometer TransSPEC-DX-100T for in situ monitoring campaigns and to evaluate the possible presence of radioisotopes in the environment (e.g. waste assay measurements, emergency response, nuclear safeguards inspection).
The instrument is also used in the laboratory to characterize radioisotope concentrations in samples from different sources: ie contaminated environmental soils, food with different radioisotopes absorption rates, nuclear materials.
The gamma monitoring technique is allowed to be used during an On-Site Inspection by the Treaty. The specific instrumentation to be used has to be included in the draft list of the equipment for OSI. A good characterization of the monitored site needs the capability to observe a small variation on the activity concentrations and the capacity to lower the background contribution.
In order to use the instrument to its full capacity and potential, a transportable shielding has been designed and built-in collaboration with the University of Ferrara, taking into account a good balance between transportability and performance of the system.
The results of a monitoring campaign with and without shielding will be shown and the need to include shielding in the draft list of auxiliary equipment will be discussed.

Promotional text: How to cope with mobility and transportability of on-site monitoring and instrumentation performance.

P2.2-465 – COVID-19 Protocols, preventive measures, and recommendations for On-Site Inspection.

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COVID-19 is an infectious disease caused by the new coronavirus SARS-CoV2, recently discovered and for which there was no history of human pathologies. Currently COVID-19 is a pandemic that affects many countries around the world.
The objective of this presentation is to apply safe work protocols to protect people from any situation that implies a potential risk of contagion with COVID-19, during an On-Site Inspection or Exercise. Ensure the health and psychophysical integrity of the OSI Inspection team, representatives of the Inspected State Party and third parties linked to the services provided to the On-site inspection through the implementation of preventive measures and recommendations that guarantee safe work procedures.

Promotional text: The objective of this presentation is to apply safe work protocols to protect people from any situation that implies a potential risk of contagion with COVID-19, during an On-Site Inspection or Exercise.

P2.2-568 – Update on the OSI airborne techniques simulator

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The development of an airborne physical simulator to support the development and testing of airborne OSI equipment configurations as well as facilitating ground-based training for airborne operations was reported at SnT2019. This paper provides an update to the project, summarises the difficulties of transforming a dilapidated airframe into a multi-purpose structure and describes its commissioning. The interior of an Mi-2 helicopter has been completely transformed and now provides a realistic and flexible configuration enabling simulations of different airframe types. All original cabling and unnecessary elements have been removed while the cockpit, windows and interior lining have been enhanced but still retain the feel of a military helicopter. The exterior of the airframe has been repaired and repainted with hardpoints added to mimic a range of different airframes. These hardpoints allow training on the installation of external equipment such as laser range finders and radar altimeters. Real life scale 3D printed versions of airborne equipment are now available for use in the simulator allowing testing and training on realistic alternatives to the real items.

Promotional text: Airborne operations are a technically demanding aspect of an OSI, this paper reports on a tool to expedite testing and development of airborne equipment and facilitate training on airborne equipment and procedures in a realistic simulator.

P2.2-575 – EIMO - the equipment and instrumentation management system for OSI

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At SnT 2019 the development of an On-Site Inspection system for managing OSI equipment and software was reported. The system, now called, EIMO – the equipment and instrumentation management system for OSI – has been further expanded and rolled out as a production system. The custom browser-based system is used for recording and tracking both OSI inspection gathering and support equipment. This encompasses the key task of setting maintenance plans and recording all maintenance activities undertaken at an item or system level. EIMO holds definitive information on OSI inspection and support equipment. As well as facilitating work at the TeST Centre, EIMO was also used during the Launch Phase element of the OSI Build-up Exercise in November 2019 to generate the equipment list for the OSI mandate.
EIMO has been expanded for use during an OSI. Modified versions of EIMO are available for use at the point of entry to support equipment checking and also in the working and receiving areas at the base of operations to support the management of equipment configurations. EIMO is available to the relevant versions of GIMO to facilitate the planning of missions and field teams as part of the Inspection Team Functionality cycle.

Promotional text: Certifying that OSI equipment has been calibrated, maintained and protected is a fundamental prerequisite of an on-site inspection. To this end a system has been developed to facilitate the management of OSI equipment at the TeST Centre and also during an OSI.

P2.2-619 – Unfolding Directional Aerial Radiation Survey Maps to enable Extrapolation and Improved Precision

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Gamma spectroscopy measurements are a key component of an on-site inspection conducted under the Comprehensive-Nuclear-Test-Ban-Treaty. Radiometric aerial survey has proven to be an efficient way to cover large areas, however the spatial distributions of features smaller than the survey altitude are smeared out and their radioactivity concentration is underestimated. Moreover, the inspected state party may declare multiple restricted access sites over which the aerial survey may not be able to fly. In previous work presented in this conference series we have shown how multi-crystal direction-capable or imaging gamma detectors can reconstruct radioactivity distributions in a restricted access site from vantage points on its perimeter. In this work, we present a new method to unfold the measurement making use of Monte Carlo generated response functions in an iterative minimization to extract the true underlying radioactivity distribution within uncertainties. By requiring the solution be consistent with the measurement from every crystal sub-detector involved in the survey simultaneously, this method greatly improves spatial precision and the distance over which extrapolation is valid. Most importantly, the method provides the significance of the observation of radioactivity in certain areas, and gives an upper limit on the amount of allowed radioactivity in other areas.

Promotional text: A method to unfold the measurement system response from radioactivity maps made with multi-crystal spectrometers improves spatial precision, permits extrapolation, and determines the significance of the presence of radioactivity in some areas and its absence in others.

P2.2-704 – Geophysical Characterizations of Unconsolidated Sediments for Geotechnical Studies at Bhadrapur Municipality Area of South-east Nepal

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Geophysical characterizations of unconsolidated sediments can be correlated with the invasive geotechnical investigations considered as a scientific basis for land use planning and development. In this study, Centerless Circular Array (CCA) having 2 Hz frequency (short period with a circumscribed radius of 2 m) seismometers were used to estimate the subsurface velocity profile, whereas Vertical Electrical Sounding (VES) used to estimate the resistivity of individual layers. Standard Penetration Test (SPT) were used to conduct the field survey for estimating N values. Soil samples were taken for laboratory testing to understand the soil type, water saturation, texture etc. Preliminary result showed that the sediments in Bhadrapur Municipality area which has shear wave (Vs) velocity ranges from 100 to 500 m/s, whereas the resistivity ranges from 20 to 400 ohm-m. Corrected N value for the gravelly sand ranges from 7 to 25 blows whereas for silty sand it ranges from 4 to 10 blows. The shear wave velocity, resistivity and the N value map were prepared. Shear wave velocity and its correlation with N value would be helpful in seismic micro-zonation of the areas where ground motion is considered as an important parameter.

Promotional text: Our department has engaged in using various surface geophysical techniques such as seismic, geoelectric, GPR, geo-magnetics to solve the problems underneath the ground. Those techniques have greater relevance in on-site inspection of the Nuclear Test sites.

P2.3 Seismoacoustic sources in theory and practice

P2.3-079 – Air and ground vibrations from explosions on the Earth's surface

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Most equations used to predict the ground motion produced by explosions were developed using confined blasts that were detonated with the intention of breaking rock for mining or tunnelling. Ground motion is usually recorded by geophones or seismometers. The air blast produced by open-pit blasts and explosions on the surface can pose a significant risk, thus microphones and pressure gauges are often also used to monitor the effects of the explosion. The aim is to determine whether or not the predictive equations developed for confined explosions can be used to predict the effects from explosions placed on the surface, with appropriate adjustments to the various coefficients.

Three predictive equations developed for buried explosions were tested and it was shown that the United States Bureau of Mines peak particle velocity (PPV) predictive equation is the most reliable. In addition, a predictive equation using the secondary atmospheric shock wave phenomenon also produced good results and is easier to measure. These equations may be utilised both for demolition sites, where old and potentially unstable explosives and obsolete equipment are destroyed on the surface of the ground, and for assisting in forensic seismology to determine the details of an unexpected and unknown explosion.

Promotional text: The study focused on seismoacoustic signals produced by surface explosions at distances further than what is normally monitored. Although the explosions were not on the same scale as those monitored by the IMS, the study provides interesting insight into forensic seismology.

P2.3-081 – Characteristics Review for Underwater Explosions based on Depth and Source Types

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Most of underwater explosions show characteristics of bubble pulse and reverberation effects. Therefore it is most important to find these two phenomena in order to identify an underwater explosion for any sinking and/or missing a ship or a submarine. The best known studies to find bubble pulse and propagation effects are spectral analysis and cepstral analysis. The review technologies for underwater explosion includes Kursk submarine disaster, ARA San Juan Missing, some Russian underwater nuclear explosion as well as the ROKS Cheonan Sinking which is the main topic in this study. Seismologically it is also the most important to find a positive polarity of the first P-wave arrival from the vertical component record whether or not it is an underwater explosion. Nonetheless it is not always clear to find the upward (compression) of the first P-wave onsets in case of an underwater explosion inside a submarine. This paper is stressed on a shallow underwater explosion near the surface like the ROKS Cheonan Sinking showing a bubble jet characteristic resulting in splitting the ship into two pieces . The phenomena of a bubble jet and a toroidal bubble are highlighted in high resolution spectral analysis for a shallow underwater explosion.

P2.3-116 – Discrimination of quarry blasts using a complex of seismic and infrasound data in Kazakhstan

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The monitoring system of NNC RoK comprises five seismic arrays, eight 3-component stations, and three infrasound arrays. Every year, the network in Central Asia registers and processes some 20,000 seismic events. Among the total bulk of such processed events, about 5,000 events are blasts of different characters. Mainly, they are industrial quarry blasts. The technique has been developed and technology has been generated for recognition of the character of the event based on the set of seismic and infrasound data, which can also increase the accuracy of blast localization significantly on account of reliable reference to the specific quarry. For twelve quarries, template seismic waveforms have been produced. It has been shown that a record of the Lg phase at every quarry at a specific station has a specific form; notably, record forms of this phase from different blasts registered by the same station at the same component for the same quarry are very similar. This feature is used as a criterion for recognition. This technique has been tested with data from the Aqbastau quarry. The findings of this research proved that this method is feasible and highly efficient.

Promotional text: Discrimination of quarry blasts applying correlation techniques with a combination of seismic and infrasound data can support national needs, and to improve nuclear test monitoring and verification.

P2.3-149 – Seismo-acoustic analysis of Mw 4.2 mining induced earthquake nearby Kiruna, Sweden

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An earthquake happened in 18 May 2020 early morning in the Kiruna underground iron ore mine (Northern Sweden) having a magnitude Mw 4.2. Following the earthquake, the mine was immediately evacuated because of the risk of aftershocks. This event is the largest mining-induced earthquake that has ever taken place in Scandinavia and it produced signals recorded by three infrasound arrays at distances of 7 km (KRIS, Sweden), 155 km (IS37, Norway) and 286 km (ARCI, Norway). We explore seismo-acoustic features of this event recorded in near and far-field focusing on how the signal propagated in the atmosphere and in the solid earth. Our study provides a detailed comparison between observed and predicted wave front characteristics at the arrays. We also conduct a comparison of amplitude corrected for propagation effect versus magnitude and ground shaking amplitude. These results show that infrasound recorded up to ~300 km from a shallow moderate-magnitude earthquake can provide ground shaking information as well as local amplification caused by topographic and geological features.

Promotional text: Infrasound waves are inaudible low frequency sound waves that can be generated during earthquakes. A minequake happened in Kiruna generated infrasound and recorded up to 300 km distance. We investigate waves from different stations and explore what has happened during this quake.

P2.3-156 – QSDA (Quality Seismic Data Assessment): On line Web Base of Power Spectral Density for Seismic Noise Quantification

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The development of the seismograph network in Indonesia has been massive in the last two years. As more and more seismographs are installed, it is hoped that continuous data and high-quality data will be obtained. The presence of noise in seismic waveforms greatly disrupts the identification of earthquake events. Various potential sources of seismic noise exist, such as: ocean waves, meteorological effects and human activities. Choosing a location for a sensor that has a low noise level is very important to get a high quality earthquake data recording. Therefore, we developed a power spectral density application to identify and to quantify seismic noise. This web-based Power Spectral Density (PSD) application operates online and flexible time window. The principle of seismic quantification used in this method is the Peterson Noise Model. This application can be used to determine the quality of data from all seismograph stations on a regular weekly or monthly basis.

Keywords: seismic noise, waveform, PSD

Promotional text: To get the accurate result of hypocenter location, focal mechanisme, stress drop, amd other analysis we need high quality seismic waveform data. Seismic waveform data usually content noise. Seismic noise came from environmental and electrical noise. We need to quantify the noise.

P2.3-232 – Infrasonic Signatures of 1001 Rocket Launches for Space Missions

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In the present study we analyze infrasound signatures of 1001 rocket launches for space missions recorded at stations of the International Monitoring System between 2009 and mid-2020. We include all surface- or ocean-based launches within this period with known launch time, location, rocket type, and mission name; whereas launches of sounding rockets and ballistic missiles for scientific and military purposes, respectively, are excluded from our study. We characterize the infrasonic signatures of over 70 different types of rockets launched at 27 different globally distributed spaceports to estimate the general detectability of rocket infrasound, to evaluate the individual station performance, to quantify propagation and attenuation effects and, finally, to derive a relation between rocket thrust and acoustic energy. Results from the infrasound analysis of the launches will be provided as a DOI referenced dataset for supporting future research on infrasound topics as well as on atmospheric dynamics.

Promotional text: Infrasonic signatures of 1001 rocket launches for space missions are analyzed to provide a DOI referenced dataset to support future research on infrasound topics as well as on atmosphere dynamics.

P2.3-233 – Infrasound at Costa Rica

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The NDC-CR has promoted the use of the infrasound methodology in Costa Rica and in the LAC region with the installation of permanent (IVTCR) and temporary (I069CR) stations in the country, as well as with the organization of regional workshop in the field (Infrasound workshop 2019 jointly by CTBTO and NDC-CR).

The I069CR and IVTCR identified different infrasound sources. Among the most relevant is the fall of the Agua Zarcas meteorite in Central Costa Rica, on April 23, 2019, 21:07 local time, meteorite from which more than 30 kg were recovered by locals and which has had a great impact on the national and international scientific community.

OVSICORI-UNA permanent stations have recorded specific events; for example, the landslide of ~25e+06 m3 on August 26, 2020, 04:00 am local time on the Irazú volcano; recorded by JTS (AS025), which is located ~125km from the source.

Although infrasound instrument had been operating since 2007 at the JTS site and the OVSICORI-UNA seismic network had installed instruments near volcanic sources, it is until recently that the community had shown interest in this methodology and the CTBTO jointly with the NDC-LAC could play an important role to build capacity in the field.

Promotional text: Temporary and permanent infrasound stations had been installed by OVSICORi-UNA (NDC-CR) to characterized acoustic source in the zone, with great impact to help in the determination of volcano explosions. Data also used to study meteorite fall in April 23, 2019.

P2.3-240 – Understanding mb Variations: The Implications of a Global IMS

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When complete, the International Monitoring System (IMS) will include 170 seismometer stations. These stations consist of various seismometer types, and are located in a range of geological and tectonic settings. The data recorded can be used to determine the body-wave magnitude (mb) of a seismic event, which is used in the mb:Ms event screening criterion applied at the International Data Centre (IDC). Event screening being the rejection of the null hypothesis that an event is a single point underground explosion. Initial development of the mb magnitude scale (and the mb:Ms criterion) was mainly based on body-wave data recorded by standard short-period instruments. Today, the IMS consists of a range of short-period and broadband instruments with a variety of responses.

Our work seeks to understand the implications of varying instrumentation and the potential impact on the mb values measured, as well as investigating the effect of variations in attenuation. Initial results suggest that a combination of these variables has the potential to affect the consistency of event mb magnitudes using the current IDC mb measurement method. We consider alternative methods which could prove more robust.
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Promotional text: This research aims to improve event screening by enhancing our understanding of variations in mb measurements and determining if current IDC mb measurement methods are optimal.

P2.3-246 – The 7th July 2011 Abadan, Turkmenistan explosions: A seismoacoustic analysis

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At 11:40 (UTC) on 7th July 2011, a series of accidental explosions occurred in the town of Abadan, Turkmenistan. The Turkmenistan government listed the cause of the accident as the ignition of

pyrotechnic matter intended for fireworks, which then spread to military storage areas, where an estimated 5,000 - 50,000 tons of ammunition was stored (Boggs et al., 2013).

The explosions are clearly observed ~11 km away at the International Monitoring System (IMS) seismometer array GEYT (Turkmenistan). A total of 30 individual events can be identified. Yields are estimated using P-wave (Koper et al., 2002) and Rg amplitude (Bonner and Russell, 2013) and range between 0.5 – 45 tonnes (TNT equivalent).

IMS infrasound arrays in Kazakhstan, Russia, and Germany observed these explosions. A yield for the largest explosion(s) (4 – 90 tonnes) is determined using the dominant period of these infrasonic signals (Whitaker, 2006), and is consistent with the yield determined using seismic observations.

Air-to-ground coupled waves at GEYT exhibit downward first motions, consistent with an initial positive blast overpressure. We measure the period and peak-to-peak amplitude of the air-to-ground coupled waves and find amplitude varies with yield but not period.

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Promotional text: We analyse the 7th July 2011 Abadan, Turkmenistan accidental explosions through utilising both seismic and infrasound IMS data.

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P2.3-286 – Infrasound Bulletin from local and regional sources by the NDC of Costa Rica between 2018 and 2020 and integration of data from I20EC, I51GB, I08BR, I09BR (IMS) infrasound stations with local volcanic infrasound monitoring networks and portable array I69CR (CTBTO)

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Since 2018, the inclusion of infrasound monitoring in active volcanoes in Costa Rica with local networks has been implemented by OVSICORI-UNA. In addition, at the end of 2018, two portable infrasound arrays were installed, such as I69CR and IVTCR in cooperation with CTBTO and UNIFI. The NDC-CR includes the integration of IMS stations such as I20EC, I51GB, I08BR, I09BR, thus making it possible to use the event location option through back-azimuth triangulation for relevant local and regional events in the region of Central America and the Caribbean. Among the relevant events from local and regional infrasound sources analyzed for the Infrasound bulletin are the following. Volcanic events: small volcanic explosions (Rincón de la Vieja Volcano, Turrialba Volcano, Poas Volcano between 2018 and 2020). Events of fireballs or meteorites detected in the I69CR portable station and IMS stations: Fireball over Bering Sea 2018-12-18, Cuba Meteorite 2019-02-01, Haiti Meteorite 2019-04-14, Costa Rica Aguas Zarcas Meteorite 2019-04-24, Meteorite South East New Orleans 2019-05-04, Fireball over Caribbean South Puerto Rico 2019-06-22, Meteorite North Puerto Rico 2020-01-17. Seismic events: Earthquake between Costa Rica and Panama of 2019-06-26. Irazú Volcano landslide event August 26, 2020.

Promotional text: With this infrasound bulletin, it is possible to have a characterization and knowledge of the different sources of infrasound in the Central American and Caribbean region.

P2.3-292 – Infrasound Records And Data Analysis For The South Indian Ocean Fireball On March 4, 2020

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On March 4, 2020 the Infrasound Stations I03AU, I05AU and I47ZA detected the South Indian Ocean event at 20:26:40 UTC. This detection belonged to a fireball that had a TNT yield equivalent of 1 kiloton (Kt). The infrasonic signals were observed by the three infrasound arrays that are part of the International Monitoring System (IMS) located in Australia and South Africa. The PMCC method was used to estimate the wave parameters at the three infrasound arrays, and the source location (52.11S, 91.15E) was determined by the back azimuth intersection, which is only 100 kilometers away from NASA's location (53.3S, 90.8E).

Promotional text: The poster is contributes to learn about how we used the IMS data and IDC products for estimated the wave parameters and bolide event location.

P2.3-356 – Finding repeating mining events using waveform cross correlation at seismic and infrasound IMS stations

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Mine blasts are an example of repeating seismic/infrasound events with very close epicenters. In some areas, hundreds of mining blasts per year are measured by the IMS and built by the IDC. Waveform cross-correlation is a natural method to detect repeating signals. The IDC has been testing a prototype WCC-based pipeline to find repeating mining events matching the event definition criteria (EDC) for the Reviewed Event Bulletin (REB). The REB is used as a source of master events with seismic and infrasound waveform templates. Several open-pit mines create intensive acoustic waves detected by the IMS infrasound network and these detections are used to build seismic-infrasound events matching the EDC. The prototype pipeline is processing seismic and infrasound data continuously and we systematically compare the cross-correlation bulletin (XSEL) with the automatic bulletin (SEL3) and the REB. This comparison is used to tune the defining parameters of data processing. Here, we present the overall statistics of the continuous processing in the first half of 2021 and the results of offline testing of several mines in Eurasia and USA and two specific time intervals.

Promotional text: Waveform cross-correlation is a natural method to detect repeating signals. Mine blasts are an example of repeating seismic/infrasound events with very close epicenters. In some areas, hundreds of mining blasts per year are measured by the IMS and built by the IDC.

P2.3-366 – Near ground explosion - monitoring with a mobile infrasound array and seismic sensors

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The project ABC-MAUS is a collaboration between the Austrian Ministry of Defense, Joanneum Research, the Austrian national weather and geophysical service Zentralanstalt für Meteorologie und Geodynamik (ZAMG), including the Austrian National Data Center (NDC), as well as the private company GIHMM. The aim is to develop a strategy of protection for chemical, biological, radiological and nuclear threads (CBRN) for the Austrian armed forces.

In the frame of the project, a mobile infrasound array was deployed together with seismic sensors to monitor the military training ground Allentsteig in Lower Austria. During one week a series of controlled explosions, originating from different sources, was recorded.

The Austrian NDC developed a tabletop exercise based on a hypothetical explosion. The collected waveform data was analyzed and used to locate the explosion. Once the explosion had been verified by infrasound data, forward modeling assuming a hazardous release was undertaken to understand which areas might have been affected by a resulting toxic plume (reference to contribution by Hieden et al.).

Promotional text: In the frame of the project, a mobile infrasoundarray was deployed together with seismic sensors to monitor the military training ground Allentsteig in Lower Austria. During one week a series of controlled explosions, originating from different sources, was recorded.

P2.3-372 – ThunderSeis: Seismic analysis of thunder signals recorded at the Gaisberg mountain, Austria

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Lightning strokes create powerful wavefields of seismoacoustic nature, which we refer to as thunder. Unfortunately, even though bolts of lightning received much attention in such fields as physics of plasma and meteorology, less research was conducted to investigate the thunder itself.

A radio tower on the top of the Gaisberg mountain in Salzburg is permanently instrumented with electrical sensors able to record the current of lightning strokes hitting the tower's top. In October 2020, observations of 5 thunder signals have been made using several one-component seismic sensors. At the same time, this tower is instrumented with a meteorological station, which allows us to model precisely the propagation of seismo-acoustic thunder signals from the above-mentioned lightnings.

These observations and modeling give insight into how thunder is created during the lightning stroke, which is an important milestone for seismo-acoustic observations of atmospheric events.

Promotional text: We measure the seismic signal as well as electrical parameters produced by the lightning. We were able to model precisely such thunder signals for each lightning event and therefore were able to gain some insights into the mechanism of thunder.

P2.3-376 – Bulletin of Iraqi NDC events analysis

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Through the International Monitoring System (IMS) of the Comprehensive Nuclear Test Ban Treaty (CTBT) and through their continuous work despite COVID-19, we still benefit from IMS data and the International Data Center (IDC) products. We analyzed many events that occurred and detected via infrasound stations. As the meteor in Turkey on 27 May 2020 which was analyzed with software DTK-(G)PMCC and located with the Geotool and compared results with the catalog reference of analyzed events of NASA. As well as the explosion that occurred in Russia near Achinsk on 5 August 2019, which generated intense infrasound signals including both seismic and acoustic arrivals from infrasound and seismic stations of IMS, and also took the opportunity to analyze and locate event

via both the DTK-(G)PMCC and the Geotool.
Through SeisComp3 software already installed in our Iraqi NDC an acquisition system to process the real-time data. We will display an earthquake that occurred On 3 June 2020 at the Iraq-Iran border, which was monitored by the Iraqi seismic stations and detected by SeisComp3 and our local stations not belonging to IMS stations and Geotool for analysis and comparing results.

Promotional text: Analysis of seismo-acoustic data for IMS by NDC Iraq using NDC -in- a -Box tools.

P2.3-403 – Generation of S-waves by scattering and conversion revealed by large-N array data

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We investigate the origins of seismic S-waves generated by the Source Physics Experiment (SPE), which was conducted near the north end of Yucca Flat at the Nevada National Security Site (NNSS), United States. Understanding the generation of S-waves from underground chemical explosive sources provides physical understanding of regional event screening methods that rely on P-wave and S-wave amplitude ratios. SPE explosions were recorded on a two-dimensional seismic array, enabling us to study the evolution of the near-source wavefield. First, the earth model used for simulations was adjusted until the decay rate of waveform cross-correlation coefficient as a function of inter-station distance matched observations. These comparisons validate the statistical properties of wave scattering in the numerical simulations. We found that adding depth-dependent stochastic variability to the geology-based velocity model improves simulations up to 10 Hz. After model refinement, we used high-frequency simulations and a beaming method to identify the origin of observed wave phases. In addition to waves generated at the source, conversions of Rg to S waves, basin-induced waves, and wave scattering in sedimentary layers were found to be the main mechanisms of shear-motion generation for the SPE-5 explosion source for frequencies below 10 Hz.

Promotional text: Validated simulations of SPE explosions show that near source scattering is the dominant source of S-waves. These results are applicable to event screening based on regional-distance P-wave and S-wave ratios.

P2.3-415 – Negative isotropic seismic moment tensors, migrating and cyclic seismicity during the 2018 summit collapse at Kilauea caldera

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The 2018 rift zone eruption of Kilauea volcano was accompanied by a remarkable and episodic collapse of its summit. Between May-August the eruption and collapse sequence included over 70,000 earthquakes (M≥0) and 54 major earthquakes (M≥5). We analyzed the seismicity in the Kilauea summit region and estimated seismic full moment tensors with their uncertainties for the 54 M≥5 events. These events occurred at almost daily intervals and were accompanied by intense seismicity which was concentrated between 0-3 km depths beneath the Halemaʻumaʻu pit crater. The hypocenters

reveal partial elliptical patterns (map view) that migrated downward by ~200 m. The moment tensors reveal remarkably consistent mechanisms, with negative isotropic source types and localized uncertainties, and vertical P-axis orientations. From the moment tensors we derived Poisson's ratios which are variable (ν=0.1–0.3) for the first half of the collapse events and converged to ν~0.28 from June 26 onward.

Promotional text: We analyzed 54 earthquakes from the 2018 eruption at Kilauea caldera. Their mechanisms reveal collapses similar to events following nuclear explosions in North Korea and the Nevada Test Site. The mechanisms at Kilauea appear related to evacuation-collapse of its magma reservoir.

P2.3-423 – High frequency events detected by I33MG

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High Frequency infrasound are produced generally by explosion, aircraft, storm or lightning…(Campus and Christie, 2010). High frequency infrasound signals are detected by I33MG at the azimuth around 39°. To perform the study, IMS infrasound data from I33MG and I19DJ are processed by mean of PMCC method. After investigation these events are correlated with oceanic storms in the Indian Ocean. In this area, lightning flashes, halo and sprite happen frequently (Christian et al., 2003, Chen et al., 2008) as well as surf events. These events are located at far as 3000 km from I33MG. Frequency of I33MG detections are less than 4 Hz and less than 2 Hz for I19DJ detections. Sources of these events would be strong for having high frequency signal detected for a long distance.

Promotional text: Characterize unknown events in order to better identify potential CTBTO relevant event and enhance infrasound station detectability.

P2.3-441 – Examples from data analysis integrating IMS/IDC data with local seismic data in SEISAN

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We demonstrate here the advantages of combining data from local seismographs with IMS data in the analysis of both local and distant events. The implementation of new IMS to SEISAN and IDC to SEISAN links makes the integration much easier than before. These links are the results of a project funded by the EU (CELEX 02018D0298-20200423) to facilitate the use of IMS and IDC data at NDCs using the SEISAN package for routine seismic analysis. In this presentation we show how to import parametric data in Nordic format and waveform data in SEED format for a combined analysis of three events: a) an earthquake in West Greenland on 2020-09-27. The regional seismograph network in Greenland is very sparse, and the addition of extra data is extremely valuable. b) an earthquake in Denmark on 2018-09-16 where distant phases can add extra information about the event, and finally c) the DPRK nuclear test on 2017-09-03 which was recorded on both seismographs in Denmark and Greenland. All three events are relocated using the data integration.

Promotional text: Demonstrate how the new SEISAN link can improve the ability of NDCs to use IMS/IDC data and participate in verification.

P2.3-448 – Events Location Using Spectrum From Seismoacoustic Data Of Teleseismic Stations

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A series of earthquakes occurred within the year 2020. These earthquakes were felt both on land and sea. IMS stations in Africa, Europe, and North America that were at teleseismic distances from the epicentre recorded these events. The earthquakes of 3 June & 1 September for Chile and 18 June for New Zealand were analysed using data from seismic and hydroacoustic stations at teleseismic distances as well as Infrasound data from local and regional distances. The waves were extracted and studied by methods of spectrum and azimuth. Results from the analysis showed that the spectrum studies could be used to clear pick the shocks and aftershocks of the earthquakes from stations that are at teleseismic distances from the epicentre. The azimuth from the analysed data was consistent with the known azimuth for the events.

Promotional text: Spectral Analysis is a less complex and useful tool to study and record events at teleseismic distances if the background noise is reduced. Understanding spectrum will ease the understanding of the earth complex system.

P2.3-504 – Seismoacoustic observations using a seismic array on an ice floe

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We present the results of seismoacoustic wavefield geophysical measurements carried out at Lake Baikal in the winter of 2020. A system of six special autonomous geo-hydroacoustic buoys, capable of continuously functioning at least for a week, was used as measuring equipment. Each individual buoy consists of a recording system, a seismometer-velocimeter, a hydrophone and wireless data transmission facilities. The measuring system was placed on an ice surface of the lake, forming a seismic antenna system. Lake depth at the locations of some buoys reached 400 m, the ice thickness was 1 m. As a result of experimental data processing, the arrival times of several local earthquakes were identified on ice seismograms. This allows one to study the process of seismic energy transformation into hydroacoustic and back. In addition, a hydroacoustic signal generated by the operation of a distant 100-ton seismic vibrator was recorded in deep water under ice conditions. It can be concluded that geohydroacoustic buoys have demonstrated the convenience and high reliability of use in severe winter conditions. Thus, the possibility of placing seismic arrays on drifting ice floes in the Arctic for solving problems of seismoacoustic monitoring can be considered confirmed.

Promotional text: The possibility of application ice monted seismic arrays for seismoacostic monitoring is demonstrated.

P2.3-585 – Identifying and tracking regional storms with infrasound data

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The infrasound array at Piszkés-tető, Hungary (PSZI) has been operational since May, 2017. Since then PSZI has collected hundreds of thousands detections. These include detections both from known and unknown sources. The categorization of the detections would be important for future automation. The objective of this study is to identify and collect those detections that belong to local and regional storms and lightnings. We present a methodology to identify storms by correlating lightning data from the Blitzortung database we consider as ground truth with the PMCC infrasound detections at PSZI. We also analyze the seasonal variations in the directions and distances of the detected storms.

Promotional text: We build a ground truth database of regional storms and lighting detected by the PSZI infrasound array that in the future allow us to apply machine learning technologies for the automatic screening of storms and lightnings in infrasound records.

P2.3-591 – An Integrated Study of Seismic and Infrasound for Detecting Non-Tectonic Earthquakes in Indonesia

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Indonesia is in an earthquake prone area, not only tectonic earthquakes but also non-tectonic earthquakes. Non-tectonic earthquakes are unique, because they rarely happen. However, in the last decade there have been many non-tectonic earthquakes recorded by seismic sensors due to volcanic activity. Therefore, we need to validate the earthquakes, whether they are caused by tectonic or non-tectonic activity. To distinguish between these earthquakes, we need to integrate parameters between seismic and non-seismic (infrasound) measurement. Tectonic and non-tectonic earthquakes have different frequencies. Non-tectonic earthquakes are dominated by a low frequency and well detected by infrasound measurement, because Infrasound is an acoustic wave with very low frequency less than 20 Hz (~0.01 – 20 Hz).

Promotional text: Seismic and non-seismic (Infrasound) measurement is a good combination to detect and validate non-tectonic earthquake. By studying these parameters, we want to learn specific characteristic of non-tectonic earthquake to give early warning to the society.

P2.3-630 – Stromboli volcano eruption 2019-07-03 and atmospheric influence on the detection capability on the infrasound stations.

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The International Monitoring System (IMS) is part of the verification regime of the CTBT; in addition, civil and scientific applications are a possible additional benefit that State Signatories could gain from participation in the Treaty verification regime. One of the four technologies used in the IMS is the infrasound network composed of 60 array stations when the network is complete and which is effective for tracking and quantifying volcano eruptions phenomena. In this paper we will focus on one of the most violent eruptions of Stromboli volcano which is one of the most active volcanoes in Italy and on the earth, occurred on 03 July 2019 using data from four IMS Infrasound stations situated in different distance from the Stromboli volcano to observe the detection capability of the Infrasound network in the IMS and the influemce of zonal wind on the infrasound stations detectability as the infrasound propagate in different layer of the atmosphere and depends also on the wind field. The analysis of infrasonic pressure waves generated by Stromboli volcano is essential to the understanding of volcanic explosion. DTK_GPMCC and DIVA software are used to perform this study (Cansi, 1995; Le Pichon, Matoza, Brachet and Cansi, 2010).

Promotional text: A study of a violent eruptions of Stromboli volcano, occurred on 03_07_2019 using data from four IMS Infrasound stations situated in different distance from Stromboli volcano to observe the detection capability of the IMS Infrasound station and the influence of the atmosphere.

P2.3-635 – Source Detection and Risk Evaluation of Ru-106 Event of 2017 in Europe

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Considerably high levels of Ru-106 were measured by some air monitoring stations in Europe at the end of September and beginning of the October in 2017. Routine measurements revealed Ru-106 levels that vary between 10 to 100 mBq/m3 with maximum values reaching as high as 150 mBq/m3 during this period. Based on this motivation, a mathematical modeling study for the atmospheric transport of Ru-106 was performed to locate possible sources of this radionuclide. Using inverse modelling methods, potential Ru-106 source were analysed via FLEXPART, a Lagrangian particle dispersion model. The model was used in backward mode to locate possible sources of Ru-106 event of 2017. The model was later used in forward mode to simulate atmospheric dispersion and ground level deposition of Ru-106 in Europe considering the possible identified sources. The backward and forward simulations performed in this study used ECMWF datasets. Concentration and deposition results were compared with available data recorded by the European environmental radiological monitoring networks. In addition, possible transport routes and deposition of Ru-106 in Turkey were also estimated to identify potentially contaminated regions in Turkey. Finally, various dose values were estimated using model outputs for health and environmental risk evaluation purposes.

Promotional text: It is a study made to enlighten the source of the Ru-106 event in 2017. Inverse atmospheric dispersion modeling method were used and dose values were estimated to reveal health effect.

P2.3-645 – Armenian Seismic Network and Earthquake Catalogue

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Seismic networks are a source of valuable data for seismological research. For a few years in cooperation with the French CEA/DASE broadband seismic network in Armenia has been upgraded. Among various tasks in seismological research, the modern network allows improving the quality of the catalog.
The seismicity of the Armenian Upland relates to the Arabian-Eurasian plate collision, which is characterized by the diffusive distribution of shallow earthquakes of various magnitudes. The strong shallow earthquakes are expressed by well-pronounced active surface faulting. Comparison of seismicity of Armenia and the Caucasus with tectonic setting shows that all the strong earthquakes are associated with the active blocks, their edges, and junctions. The analysis of the focal mechanisms of earthquakes with various magnitudes shows the presence of all fault types in Armenia: strike-slip, normal, reverse, thrust, oblique, normal faulting with various components, and with prevailing strike-slip faulting. The combinations of exposure depend on the relatively neighboring block movements. The quality of the Armenian National Catalogue is discussed and the representativeness is described. A unified and homogeneous earthquake catalog is a base for analysis—determination of catalog completeness, recurrence and activity rates, etc., which are the key input parameters for probabilistic seismic hazard assessment.

Promotional text: A sub-network of 6 stations has been deployed in 2018 and 2019 on the Armenian territory thanks to a technical and scientific collaboration between the RSSP and the CEA/DASE aimed at improving the completeness magnitude of the catalog.

P2.3-647 – Microseismic Activity in Armenian Upland

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Seismic networks are a source of valuable data for seismological research. Since 2010 in cooperation with the French CEA/DASE, the broadband seismic network in Armenia has been upgraded. Digital seismological stations were deployed in the territory of Armenia and they are providing data that enabled to conduct of various research activities, including the study of microseismicity and active tectonics in the region.
The seismicity of the Armenian Upland relates to the collision of Arabian and Eurasian plates, which is characterized by a diffusive distribution of shallow earthquakes of various magnitudes.
The strong shallow earthquakes as well as microearthquakes are expressed by well-pronounced active surface faulting. The microearthquake pattern observed over the past few years is consistent with the tectonic pattern of the study area including historical seismicity. In general, the seismicity in the Armenian Upland correlates with the known geologic structures. The microseismic activity also was studied from the point of view of large crustal earthquakes preceding.

Promotional text: A sub-network of 6 stations has been deployed in 2018 and 2019 on the Armenian territory thanks to a technical and scientific collaboration between the RSSP and the CEA/DASE aimed at improving the completeness magnitude, quality and representativeness of the catalog.

P2.3-671 – Use of small-aperture, near-source seismoacoustic arrays in characterizing low-yield chemical explosive sources

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Ground-truth (GT) recordings of low-yield quarry blasts at near-source distances provide a means of assessing the accuracy of seismoacoustic arrays in detecting and characterising explosive events. Infrasonic recordings from surface explosions generally show superior signal-to-noise (SNR) ratios compared to seismic detections, however dynamic atmospheric conditions introduce uncertainty. For detection of low-yield explosions in urban environments, small-aperture arrays of collocated seismic and acoustic sensors should perform well in a greater variety of conditions. We deployed two six-node, small-aperture seismoacoustic arrays in near Labrador City and Ottawa, Canada, over month-long periods. Using an empirical approach, we develop amplitude and period scaling relationships for estimating yield at distances 3-70 km using GT event details (timing, location, explosive yield) provided by mine and quarry operators. The sources are ripple-fire detonations spaced milliseconds apart. The blast durations are ~10-30 seconds, and origin times are generally accurate to within seconds. Blast yields are 3-1000 T of TNT equivalent and associated seismic magnitudes are approximately 1.3-2.9 MW. We show that seismoacoustic data are complementary and, when combined, result in more accurate blast characterisation.

Promotional text: This study focuses on improving our understanding of seismoacoustic characteristics of low-yield explosions at near-source distances, with applications to urban seismoacoustic monitoring arrays.

P2.3-688 – Seismoacoustic measurements of surface explosions in Sweden

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Seismoacoustic measurements of surface explosions in Sweden are presented. In northern Sweden, near Kiruna, three explosions at one tone each were carried out in August 2020. Further, during 2019, a single considerably larger explosion took place in mid Sweden. For all explosions, seismic and infrasound measurements were made with both temporary and permanent stations in IMS as well as national networks.
Scalings were successfully made for sound pressure level as a function of yield and distance together with local magnitude as a function of yield. The combined measurements allow for a characterization of the explosions both in terms of yield as well as type of detonation (underground, surface or airburst).
Finally, we also present a calibration of a local magnitude scale for northern Sweden that was needed in order to correctly characterize the explosions near Kiruna.

Promotional text: Seismoacoustic measurements were made from four large surface explosions in Sweden.

P2.3-708 – Remote hydroacoustic and infrasonic detection and characterization of eruptive activity leading to, during, and following the December 2018 major flank collapse and tsunami at Anak Krakatau

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A climactic eruption phase on December 22, 2018 triggered the collapse of the southwest flank and summit of Anak Krakatau stratovolcano, generating a tsunami which struck Sumatra and Java. We employ a selection of remote moored hydroacoustic (H08S, 3,307 km; H01W, 3,720 km) and infrasonic (IS06, 1,156 km; IS07, 3,475 km; IS52, 3,638 km) stations of the International Monitoring System (IMS) to investigate eruptive activity preceding, during, and after the climactic eruption phase. We observe 6 months of co-eruptive intermittent infrasound at IS06, and powerful infrasound from the climactic eruption on IS06 and IS52. The climactic eruption phase was not detected hydroacoustically, but we observe a ~12-day swarm of hydroacoustic signals beginning 24 days before the flank collapse event that we attribute to sustained submarine eruptive activity at Anak Krakatau. We perform waveform multiplet analysis to assess similarity of infrasound and hydroacoustic events. Impulsive infrasonic events recorded during the main infrasound-generating eruption are similar, indicating repetitive explosions at Anak Krakatau. Hydroacoustic event families at H08S are less similar, indicating a possible range of submarine eruption processes and signal types. This study further underscores the potential of remote acoustic technology for detecting and characterizing eruptions at submarine or partially submerged volcanoes.

Promotional text: We conduct a multi-technology analysis using infrasonic and hydroacoustic stations of the International Monitoring System (IMS) to remotely detect volcanic signals leading up to, during, and after the 2018 major flank collapse eruption of Anak Krakatau.

P2.4 Atmospheric and subsurface radionuclide background and dispersion

P2.4-037 – Comparison of modelled atmospheric radionuclides from the Fukushima Dai-ichi nuclear accident with CTBTO station measurements.

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The global atmospheric dispersion and deposition of radionuclides released from the Fukushima Dai-ichi nuclear power plant accident was modelled using the EMAC atmospheric chemistry – general circulation model at different esolutions (equivalent to ~50 km and ~110 km Gaussian grid). The model accounts for emissions and transport of the radioactive isotopes ^{131}I and ^{137}Cs, and removal processes through precipitation, particle sedimentation and dry deposition. In addition, we simulated the release of ^{133}Xe, a noble gas that can be regarded as a passive transport tracer of contaminated air. Modeled surface concentrations were compared to station observations by the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO) global monitoring network for a number of stations through the CTBTO Virtual Data Exploitation Centre.

Promotional text: We present a scientific application of the data used for test ban verification, by comparing modeled surface concentrations to station observations by the CTBTO global monitoring network after the Fukushima NPP accident, to evaluate model performance and investigate impacts.

P2.4-075 – Radionuclides Cs137 and Sr90 in mussel population from Rio de Janeiro, Brazil.

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The most common mussel species in Rio de Janeiro State is Perna perna. It is an edible Mylilidae that has been cultivated in many places at Brazilian coast from Espirito Santo to Rio Grande do Sul States. Ten kilograms of flesh of mussels with a size of 5 to 8 cm were collected annually in the town of Arraial do Cabo, Rio de Janeiro State (23o S and 42o W) from 2002 to 2009. These organisms are distributed on rocky shores from the intertidal zone to 5 meters deep. The results of the analyses are in a database at the Admiral Paulo Moreira Marine Research Institute. The concentration of Cs 137 in the mussels was very low varying from 0,003 to 0,21 Bq.kg-1. The concentration of Sr 90 was also very low, varying from 0,006 to 0,03 Bq.kg-1. The results show that the radionuclides found in mussel of Arraial do Cabo are in very low concentrations and do not cause any harm to the health of the local human population. The only source known of these radionuclides is from the nuclear atmospheric tests made in the past.

Promotional text: This is the first study on artificial radionuclides in mussels of Arraial do Cabo at Rio de Janeiro State, Brazil. The concentrations are very low and do not represent any harm for the local human population.

P2.4-078 – First results with INVAP STAX monitor

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A general description of INVAP STAX monitor final status is shown, including calibration and software/hardware configuration.

First measurements results obtained in a real Noble Gas emission environment (MIPF plant at Ezeiza Atomic Center, CNEA, Buenos Aires, Argentina) are presented. Equipment measurement ranges, mainly focused to low flow rate and high activity concentration emissions, are discussed.

Promotional text: Radioxenon accurately detection of high concentration emissions at MIPF such as EZEIZA (CAE, CNEA, ARGENTINA) is improved with the new STAX monitor manufactured by INVAP.

P2.4-080 – Atmospheric Transport Model Applied to the Design of Nuclear Facilities

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Xenon emissions from medical isotope production facilities (MIPFs) and other nuclear installations affect the verification capability of the International Monitoring System (IMS) of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO). In an effort to minimize the impact of this radioxenon and in order to mitigate, in general, the radionuclide emission, Atmospheric Transport Models are applied at INVAP on different stages of the design and development of type of facilities. The design includes safety protection radiological analyses, either inside or outside the installations, and monitoring of gaseous effluent release into the atmosphere considering both normal operation as well as accidental cases.
In this work, examples of different capabilities and results for different cases are shown. The safety analyses are based on conservative Gaussian Plume models, which include the evaluation of systems performance, operational cases, atmospheric dispersion and transport of radionuclides, meteorological conditions, emission parameters and site characteristics.

Promotional text: This work done by INVAP contributes to the global effort and commitment promoted by the CTBTO to minimize the impact of radioxenon and in general of radionuclides emissions through the development and application of ATM on different stages of the design in nuclear facilities.

P2.4-088 – Applications in CFD in nuclear emergency response decisions

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The atmospheric dispersion modeling of radionuclides is used to obtain responses to emergencies by estimating radiation effects, associated with the atmospheric release of radioactive materials. Nowadays, almost all software used for these purposes, is based on the Gaussian model, which provides fast and conservative means that consider regions free of obstructions and simple weather conditions.

However, when it comes to calculate radiological impacts from radionuclide transport to recover the affected area in complex regions close to the event, considering the physical or physico-chemical phenomena of the flow, the radioactive-cloud spreading time, the concentration and effective dose levels, and both time and environmental impact on the reached area, we need to use more robust tools to assist us in decision making. Hence, this work aims to address the use of computational fluid dynamics as a differentiated and complementary tool to support decisions related to nuclear emergencies, involving the atmospheric dispersion of radionuclides, and to analyze a possible underground nuclear explosion, based on the calculation of radioxenon surface flow regarding yields, detonation depths and distinct permeabilities.

Promotional text: The objective of the work is to show the application of CFD, as a differentiated and complementary tool for data analysis and characterization of relevant events to the Treaty. Being able to contribute in the exchange of knowledge between CTBTO and the scientific community.

P2.4-090 – Comparative study of the transient and steady state thermal hydraulics analysis of the Low Enriched Uranium (LEU) core of Ghana Research Reactor-1 (GHARR-1)

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Countries seeking a quick bomb or would-be nuclear terrorists have eyes on poorly secured sites that contain significant quantities of high enriched uranium, (HEU). HEU is the material of choice for states or terrorists that seek to proliferate stealthily without testing their weapons. It is therefore critical to make current stocks of HEU as inaccessible as possible. One of the most effective long term approach is to eliminate it from as many locations as possible and convert the HEU cores to low-enriched uranium (LEU) core. The high enriched uranium core of the Ghana Research Reactor-1 has been converted to a low enriched uranium core. The transient and steady state thermal hydraulic analysis of the LEU core of Ghana Research Reactor -1 is presented in this work. The Monte Carlo N Particle code (MCNP-5) was used in obtaining neutronic parameters for the transient and steady state simulations. PARET/ANL was used in simulating transient responses of the GHARR-1 LEU core and PLTEMP/ANL was also used for the steady state simulations. Results obtained in both transient and steady state compared well with the experimental data.

Promotional text: The global concern on Nuclear Non-Proliferation has been heralded by a core conversion of HEU cores of Research Reactors to LEU cores, this paper focuses on thermal hydraulic evaluation of Ghana's LEU core after the core conversion.

P2.4-099 – Development of New Methods for Measuring Concentration Activities I-131 Using Direct and Indirect Methods in Radioisotope Production Stacks, in the Environment and in Settlements (Indoor and Outdoor)

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Radioisotope Production Facility in Serpong, has produced and processed I-131 which can be dispersed to residential areas and the environment around the Serpong Nuclear Zone (SNZ). Measurement of the air release dispersion I-131 using an old analogue tool is not functioning, and only a

charcoal filter is functioning in the stack of the isotope production facility. Measurement of the I-131 dispersion to the environment and houses around SNZ has not been carried out. Therefore, it is necessary to develop a new method of measuring the release of I-131 concentration in the stack combined with equipment from the CTBTO and I-131 measurement in the environment and settlements (indoor and outdoor) around the SNZ. Direct measurements using a portable in-situ NaI(Tl) detector were carried out in the house, environment, and using the LaBr3 detector in the stack. Indirect measurements using charcoal filters and vacuum pumps were carried out in the stack and outdoors. The newly developed I-131 discharge measurement method can be used to replace the I-131 analog method, because the new measuring system can be operated rapidly and continuously. The concentration of I-131 during rain and high humidity tends to increase, while the presence of sunlight reduces the concentration of I-131.

Promotional text: I hope our abstract can be received.

P2.4-125 – Characterizing the background variability of radionuclides at International Monitoring System stations

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A variety of factors influence the atmospheric background of ubiquitous radionuclide signatures, like xenon-133, measured at International Monitoring System (IMS) stations. Variability in the radionuclide background obscures the categorization and discrimination of signals from nuclear weapons testing and civilian and industrial activities tied to medical radioisotope production and nuclear power reactors. The radionuclide background fluctuates due to synoptic weather events, temporal changes in background sources, and site-specific details related to the placement of IMS stations. To better characterize the radionuclide background, we have statistically analyzed a set of factors that may be associated with background variability. These factors include historical IMS measurements, weather reanalysis products, high-resolution spatial topographic and land-use data, and a large collection of atmospheric transport modeling simulations. We use this dataset to assess the relationships between potential background sources, site-specific characteristics, and signals at IMS stations, including an assessment of stations susceptible to large variations in background. This assessment may improve our understanding of the radionuclide background and may aid event characterization and analysis of data at the International Data Centre.

Promotional text: A statistical analysis of variability in background radioxenon reveals important factors associated with fluctuations in radioxenon at IMS stations. This analysis is useful for characterizing and understanding the radionuclide background.

P2.4-144 – Modeling of atmospheric dispersion and radiation dose for a hypothetical accident in a radioisotope production facility

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Atmospheric dispersion modeling and radiological safety analysis is performed for the public outside a radioisotope production facility (RPF) in case of hypothetical radioactive Iodine spilling and leakage from a hot cell. Potential human error is expected and the column that holds iodine may be broken causing it to spill on the radioactive cell floor. The ventilation exhaust system is dedicated

to extract dispersed material through dedicated filters before gases are expelled outside the facility. Two scenarios are performed in this paper, the first one is predicting the dispersion with filtration from the extraction ventilation system, while the other is with loss of efficiency of the filtration components. Spilled radioiodine is the source term, and the HotSpot 3.1 is used to provide the required calculation tool to assess and evaluate an emergency situation, including radioactive nuclides release, to illustrate the transport modeling which is then applied to estimate the total effective dose equivalent (TEDE) in different Pasquill stability classes. It would be transferred to a human body depending on downwind distance and radionuclide activity. The adopted methodology uses dominant site-general meteorological data and theories of dispersion models to study the impact of hypothetical dispersion and release to the environment from the selected radionuclide and assess how such a dispersion may have a bad radiological impact on the public.

P2.4-169 – Search for small temporal modulations of half-lives of radionuclides in the IMS Quality Control data

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Half-lives of radioisotopes are thought of as absolute constants of Nature. However, since the 1980s several experiments indicated that small percent or sub-percent level temporal modulations may exist, potentially correlated to variations of the solar neutrino flux. The issue has been debated by the nuclear theory community, since it would imply some new mechanism influencing weak decays, and of fundamental importance for nuclear physics. One problem is that high quality data collected over extensive period of time are scarce.
As regular part of their operation, the IMS monitoring stations take so-called quality control data daily, measuring a source of known isotopes for 30 minutes. The stations are at diverse geographic locations and using standardized equipment and sources. Such data are ideal to investigate long-term, small modulations of the half-lives due to an external influence, like solar neutrinos.
We obtained and analyzed 15 years' worth of quality control data from 11 IMS stations for annual and higher frequency modulations. We will present the results of this analysis, including an upper limit of the amplitude of the modulations and suggestions for the design of a future high-sensitivity experiment, dedicated to settle the issue of temporal modulations of half-lives due to solar influence.

Promotional text: Eighteen years of International Monitoring System was analyzed for evidence of time variance of nuclear decay contents. Additional, special experiments on the equipment were analyzed to asses the effects of periodic sample movement.

P2.4-206 – XENAH: Xenon Environmental Nuclide Analysis at Hartlepool

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Scientists from the U.K. and the U.S. are collaborating to perform measurements involving three different radionuclide monitoring techniques with the collective goal of better characterizing radionuclide emissions of a nuclear power reactor and how those might affect the International Monitoring

System. The Xenon Environmental Nuclide Analysis at Hartlepool (XENAH) collaboration will perform these measurements at the Hartlepool Power Reactor in northeast England with cooperation of the reactor operator, EDF Energy. The three radionuclide monitoring techniques are: stack monitoring of radioxenon emissions at the source, stand-off measurements of radioxenon after atmospheric transport of several kilometers utilizing sensitive air sampler/analyzers, and ultralow background measurements of relevant environmental samples collected at and near the reactor. Measurements began this year and will take place over 1 – 2 years. The measurement effort and techniques will be described, along with the scientific questions we plan to address.

Promotional text: Utilizing a stack monitor, stand-off detection via sensitive radioxenon sampler/analyzers, and ultralow background sample measurements at a nuclear reactor, U.K. and U.S. scientists are increasing understanding of radioxenon sources that may affect the IMS.

P2.4-211 – STAX Project – Data data analysis and interactive data access

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The STAX (Source Term Analysis of Xenon) project aims at the development of a worldwide network to measure radioxenon isotopes released from medical isotope production facilities. A software package has been developed to fully process STAX data from secure data acquisition at the back end, to interactively viewing data at the front end. This presentation focusses on the analysis of data and on the viewing options of the software. An overall dashboard displays the STAX network state of operation and issues at specific stations can be diagnosed through a State-of-Health data viewing interface. In order to increase the confidence in analysis results, stack release data are analyzed in two parallel pipelines: at the STAX systems data are automatically analyzed using analysis software from the monitoring system manufacturers and on the central STAX server, data are analyzed using the autosaint software. Time series of both data sets can be viewed either individually or together and significant discrepancies between the two analysis pipelines can be displayed. User configurable time windows can be set to calculate emission values for specific time intervals. For each individual sample, the raw data as well as a spectrum chart can be accessed via the time series chart.

Promotional text: This works aims at improving the understanding of the contribution of Xenon background sources to the measured concentrations at IMS stations.

P2.4-217 – Isotopic transport variation as a function of environmental conditions

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As gaseous and particulate signatures are produced during an underground nuclear explosion, it is important to understand their transport to the surface for subsequent atmospheric transport and detection. By understanding the transport throughout the subsurface, the atmospheric measurements have the potential to allow for a better understanding of the fractionation and total release fraction of radionuclides from a nuclear explosion. We have performed microscale studies of formation of particulate and transport of gaseous species within a variety of geologic media. In this presentation,

we discuss the use of exploding wires to simulate the formulation of particulate and the use of inverse gas chromatography to characterize gas transport parameters for a variety of geologic media.

Promotional text: Understanding material transport in the subsurface through microscale laboratory experiments allows for a better understanding of the signals available for detection within the IMS.

P2.4-258 – Atmospheric and Subsurface Radionuclide Background and Dispersion

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A general code has been developed to describe two phase flow, tracer transport and thermal effects through a fractured porous medium on the Darcy scale under the action of constant or time dependent pressure fluctuations. The fractures are modeled as surfaces with specific properties. The fluid properties can depend on pressure and temperature.
The equations for flow, tracer concentration and temperature are discretized by the finite volume method on triangular and tetrahedral meshes.
The three modules which compose the code, namely flow/energy/tracer transport are parallelized by the OpenMP technique and shown to function satisfactorily separately and in interaction.
Applications of this code are made to a typical situation of interest with an underground cavity and a potential chimney. The dimensions of the geological medium above are 100x100x400m; it contains 147 fractures of radius 20 m and of equivalent aperture 1 mm. The fracture network is percolating from the cavity up to the surface. The initial pressure is 200 bars and the temperature 1000 K. All these characteristics can be modified at will.
Pressure, temperature, and concentration evolutions as well as surface fluxes will be presented and discussed.

Promotional text: A code is developed for two phase flow, tracer transport and thermal effects through a fractured porous medium under the action of pressure fluctuations. The fractures are modeled as surfaces with specific properties.The fluid properties can depend on pressure and temperature.

P2.4-260 – Parametric study of the radioxenon data distribution, measured at the noble gas stations of the International Monitoring System of the CTBTO

Authors: Giuseppe Ottaviano[1]; Michele Scagliarini[2]; Antonietta Rizzo[1]; Sofia Guernelli[2]; Luca Ferri[2]; Claudia Sanguigni[2]; Franca Padoani[1]; Angelica Ciocca[2]

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The aim of this work is to apply a parametric statistical methodology to the radioxenon activity concentrations measured at noble gas stations of the International Monitoring System of the CTBTO, in order to investigate the radioxenon atmospheric background and the radioxenon anomalous values.
The proposed parametric statistical methodology is based on the "Statistical Process Control" method and it consists of using two "Control Charts". The "Single Observation Control" Chart, sensitive to large variation of the measured values, could be useful for periodic monitoring of the phenomenon

at the noble gas stations; the "Exponentially Weighted Moving Average" Chart, sensitive to small variations of the measured values, could be used to perform specific studies on the atmospheric background and on the anomalies of radioxenon activity concentrations.

Promotional text: Radioxenon is useful to potentially reveal underground nuclear explosions (UNEs) but it is also emitted by civil sources. To discriminate signals, advanced statistical methods are used to understand the background and the anomalous values that could be reasonably related to UNEs.

P2.4-261 – Non-parametric study of the radioxenon data distribution, measured at the noble gas stations of the International Monitoring System of the CTBTO

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The aim of this work is to apply a non-parametric statistical methodology to the radioxenon activity concentrations measured at noble gas stations of the International Monitoring System of the CTBTO, in order to investigate the radioxenon atmospheric background and the radioxenon anomalous values. The proposed non-parametric statistical methodology does not require any assumption on the underlying probability distribution of the raw data. The suggested method, based on Recursive Segmentation and Permutation (RS/P), allows to detect single or multiple mean and/or scale shifts.

Promotional text: Radioxenon is useful to potentially reveal underground nuclear explosions (UNEs) but it is also emitted by civil sources. To discriminate signals, advanced statistical methods are used to understand the background and the anomalous values that could be reasonably related to UNEs.

P2.4-274 – Shielding of radiation from atmospheric dispersion resulting from a radiological accident

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This work describes the determination of the shielding against ionizing radiation from atmospheric dispersion arising from a radiological accident in a small nuclear reactor (SMR). Among the radionuclides from the inventory of this reactor, the contribution of Cs-137 was considered for simulation in HotSpot (analytical modeling) and ANSYS (numerical modeling), of the concentration and total effective doses (TEDE) received, both depending on the distance of the event. The analytical solution, based on the hypotheses of the Gaussian approach, aims to validate the numerical solution brought by the CFD techniques, in a simplified computational scenario, taking into account the set of partial differential equations that govern the physical phenomenon of the transport of this material radioactive. Additionally, for the analysis of shielding, Taylor's formulations were used to perform simple shielding calculations, considering only shelters, based on ordinary concrete, possibly existing in the contaminated area, and Broder, in multilaminated cases, with adding a layer of lead to the front of the wall. The relevance of this investigation shows the importance of planning responses in an emergency situation, considering the data assumed in the simulations.

Promotional text: The present work can contribute to multilateral scientific cooperation, since the computational tools of this study can still be used in civil applications, such as the release of radionuclides from medical facilities, for example, and which use radioactive sources.

P2.4-307 – Spatial and Temporal Variation of the Anthropogenic Radionuclides Cs-137 and Cs-134 in Ground-Level Air Samples by IMS Stations Located on the African Continent

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Anthropogenic radionuclides of fission and activation products are frequently detected by most IMS stations located on the African continent with varying concentrations in the years 2011 to 2020. This study assesses the spatial and temporal variation of Cs-134 and Cs-137 in ground-level air at IMS stations located on the African continent from 2011 to 2020. Spatial and temporal base analysis will be performed to discern various patterns of these radionuclides. The study provides insight into the connection of anthropogenic radionuclide concentration levels in ground-level air with meteorological phenomena over the areas under investigations. It also discusses the results in view of the very few possible sources of anthropogenic radioactivity located in Africa, because for effective nuclear explosion monitoring it is important to understand the observed background. The African continent is rarely studied for this purpose and this presentation intends to fills that gap.

Promotional text: For effective nuclear explosion monitoring it is important to understand the observed background of CTBT-relevant radionuclides. This presentation fills a gap by investigating the observations of Cs-137 and Cs-134 on the African continent.

P2.4-308 – Ultra-sensitive gamma-spectrometry measurements of environmental samples from the Hartlepool Nuclear Power Station

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Two ultra-sensitive gamma-spectrometry systems are being used to measure environmental samples collected from the Hartlepool Nuclear Power Station in the United Kingdom. The work is being performed as part of the Xenon Environmental Nuclide Analysis at Hartlepool (XENAH) collaboration between Pacific Northwest National Laboratory (PNNL, USA), the Atomic Weapons Establishment (AWE, UK) and EDF Energy (UK). The coincidence-based gamma-spectrometry systems are located at the Shallow Underground Laboratory (USA) and Boulby Underground Laboratory (UK), and they are being used to measure radionuclides that are relevant for nuclear explosion monitoring purposes. Stack filters for particulate fission and activation products, charcoal cartridges for gaseous iodine, and other environmental samples are being collected and measured. The advanced systems have detection sensitivities some orders of magnitude better than standard laboratory systems (e.g., for ^{106}Ru/^{106}Rh, ^{134}Cs, ^{144}Ce), and they shall improve the understanding of the trace-level radionuclide emissions of the Advanced Gas-cooled Reactor (AGR) at Hartlepool. This is important for interpreting the radionuclide measurements performed at International Monitoring System (IMS) stations and determining whether detections are attributable to civilian nuclear sources or nuclear explosive tests.

Promotional text: These next-generation ultra-sensitive gamma-spectrometry systems are advancing the capabilities of the radionuclide laboratories and the understanding of background source terms, such as the Advanced Gas-cooled Reactor at Hartlepool, UK.

P2.4-321 – Baseline assessment of radionuclides and heavy metals in groundwater, surface water and soil along with their potential human health risk in the vicinity of Rooppur nuclear power plant, Bangladesh

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The concentrations and distributions of natural and anthropogenic radionuclides and heavy metals in surface water, groundwater, and soil samples of the site of Rooppur Nuclear Power Plant which is being constructed were investigated with the aim of evaluating the environmental radioactivity and radiation hazard and associated health risk assessment. Water and soil samples were collected and analyzed the levels of radionuclides and heavy metals using ICP-MS, Gamma-ray Spectrometry together with AAS. The heavy metal evaluation index (HEI), Nemerrow pollution index (NI) were applied to identify how different heavy metals pollute the groundwater in the studied sampling sites. According to USEPA 1999, HQ and HI value for adults through oral exposure pathway in groundwater shows the medium level of chronic risk and in surface water shows a low level of chronic risk. The estimated effective dose, as well as annual effective dose due to intake of different radionuclides, are significantly lower than both the World Health Organization (WHO) and the International Commission on Radiological Protection limits. The concentrations of ^{226}Ra, ^{232}Th, and 40K in soil samples, radium equivalent activity for soil, absorbed dose rates, external hazard (Hex) values were determined. No artificial radioactivity (^{137}Cs) was found in these samples.

Promotional text: One of the objectives of this conference is to identify how scientific developments and cooperation can support national needs and frame policy objectives. Participating in thi conference, there is a great chance to share radionuclides from subsurface in Nuclear Power Plant site.

P2.4-335 – Effect of 2020 Chernobyl Exclusion Zone Wildfires on the IMS Radionuclide Stations Network

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Wildfires broke out on the 3rd of April 2020 in the Chernobyl exclusion zone, and the fires lasted for several weeks. As a consequence, measurable amounts of Cs-137 were re-suspended into the atmosphere and observed through the IMS network. Over the period of April - May 2020, the International Data Centre reported a significant increase in the number of Cs-137 detections compared to the same period in the previous years.
In this poster, all the stations from the IMS network that reported Cs-137 over the period into consideration are first given. Based on Atmospheric Transport Modelling (ATM) simulations, stations impacted by the plumes from Chernobyl were determined, and the effects of the wildfires were assessed through (1) measured activity concentrations of Cs-137 and (2) Cs-137-to-K-40 ratios. Finally, the impact of such natural events on the categorization of IDC products is also illustrated through the evolution of relevant discrimination thresholds.

Promotional text: This study demonstrates the capability of the CTBTO IMS network to track even very low activities of radionuclides in a large geographical area, which can provide opportunities and methods for improving nuclear test monitoring and verification.

P2.4-352 – An investigation on the IMS noble gas stations network coverage: 2015-2019

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This paper evaluates the desirability of noble gas stations network coverage in the International Monitoring System of the CTBTO for the detection of 1 kt nuclear explosions. It was assumed all the 39 noble gas stations become active, the annual average of MDC was used for each certified station and the MDC of Non-Operational Stations was considered 0.24 mBq/m3. In this regard, the daily network coverage of IMS noble gas stations was analysed using SRS fields based on the 14 days backward modeling from 2015 to 2019. The daily, monthly, and annual average of network coverage were calculated and investigated in the form of image pattern and the numerical value corresponding to the global latitude/longitude grid. The results indicated that using the mean coverage over space and time makes some misconceptions, hence the network coverage was evaluated based on an event spatial distribution which provides a real understanding to assess the network coverage for the state parties.

Promotional text: The daily network coverage of IMS noble gas stations was analysis using SRS fields based on the 14 days backward modeling from 2015 to 2019.

P2.4-360 – NPE19 source term reconstruction based on radionuclide monitoring result

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NDC Preparedness Exercises (NPE) are regularly performed to practice the verification procedures for the detections of nuclear explosions in the framework of CTBT monitoring. In the event of NPE-2019, a fictitious state RAETIA announced that a reactor had an incident and some radionuclides were released into the atmosphere. Both the IMS data and data from a fictitious neighbour state, EASTRIA, were provided to participants, and EASTRIA requested assistance from the IDC, called Expert Technical Analysis (ETA). The work we have done is radionuclide detections data analysis, ATM in backward mode by flexpart, source reconstruction in bayesian method.

Promotional text: In the event of NPE2019,some IMS radionulide stations measured some abnormal nuclides. Based on these results,the work we have done is radionuclide detections data analysis, ATM in backward mode by flexpart, source reconstruction in bayesian method.

P2.4-373 – How can we determine the origin of radionuclide observations? Presenting the Bayesian source reconstruction algorithm ”FREAR”

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Radionuclide observations made by the International Monitoring System are an important part of the CTBT verification regime, as it allows to discriminate between conventional and nuclear explosions. Atmospheric transport and dispersion modelling can link known sources with such observations. However, sometimes observations are made for which the source parameters (such as the release amount, release period and release location) are unknown. In that case, inverse atmospheric transport modelling can be used to determine the source parameters. In this talk, the Bayesian source reconstruction tool FREAR will be presented. The FREAR tool allows to determine source parameters based on radionuclide observations and source-receptor-sensitivities; the latter can be calculated by an atmospheric transport model and are routinely provided by the CTBTO. Detections and instrumental non-detections are taken into account, and the possibility of false alarms and misses is considered too. The Bayesian approach inherently takes into account uncertainties. Furthermore, a method to determine model uncertainties, based on an ensemble, will be presented.

Promotional text: An algorithm will be presented that determines the release location and other source parameters by making use of radionuclide observations (both detections and non-detections can be used) and atmospheric transport modelling. Uncertainties are rigorously taken into account.

P2.4-405 – Devices to reduce the emission of radioactive noble gases into the environment

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The Fission Radioisotope Production Plant of Argentina, located at the Ezeiza Atomic Center, produces ^{99}Mo since 1985 irradiating targets with High Enrichment Uranium. In 2002 the targets have been changed by Low Enrichment Uranium.
Facilities that produce radioisotopes by fission increase the background of noble gases in the environment, especially radioactive xenon.
This background could interfere with the CTBTO assessments of nuclear explosions.
The work will show the production method for ^{99}Mo and ^{131}I that is carried out in Argentina, the emission levels and production during the last years. The current measurement system will also be described.
Finally, different mechanisms for the reduction of noble gas emissions and a comparative study of the advantages and disadvantages of each of them will be presented.

Promotional text: The objective of the poster is to show which are the different alternatives for reducing noble gas emissions to the environment due to the production of radioisotopes by fission.

P2.4-421 – Characterization of radioxenon global background between 2015 and 2020

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Worldwide monitoring of radioxenon is a necessary component of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The current IMS design foresees

40 radioxenon stations around the world to provide a 90 % detectability of a 1 kt nuclear explosions within 14 days. Radioxenon stations have the capability to measure four radioxenon isotopes; ^{131m}Xe, ^{133}Xe, ^{133m}Xe, and ^{135}Xe. The discrimination between radioxenon emission from civil sources and xenon released from a nuclear explosion is achieved by analyzing different ratios between the four xenon isotopes. In the present work, we systematically study the development of the four Xe isotopes background between 2015 and 2020, and its geographical distribution according to the measurements from the IMS stations.

Promotional text: The Evolution of the four Xe isotopes background between 2015 and 2020 is analyzed, and its geographical distribution according to the measurements from the IMS stations is described.

P2.4-427 – Source-Term Estimation of the CTBT relevant radionuclides using EgNDC-SRC and Webgrape Software.

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The source-term estimation of the radionuclides detected at IMS stations by using adjoint atmospheric transport modeling (ATM) is a vital part in the CTBTO monitoring and verification Regime. Webgrape software was developed by CTBTO International data center to assist the state signatories in the verification purposes of radionuclides detections. However, the source determination of an event and its nature is the state signatory's responsibility. Therefore, National Data Center of Egypt recently developed its own software for inverse modeling and source determination (EgNDC-SRC). The current work compares the source estimation algorithms of Webgrape and EgNDC-SRC by using some atmospheric transport modeling (ATM) synthetic experiments and some real events that have detections at IMS stations.

Promotional text: This work compares the source estimation of two software; the Webgrape and EgNDC-SRC, by using some ATM synthetic experiments and some real events that have radionuclide detections at IMS stations.

P2.4-461 – Modeling plume dispersion for near ground explosion scenarios in the framework of a decision support system

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The project ABC-MAUS is undertaken by a collaboration of the Austrian Ministry of Defense, Joanneum Research, the Austrian national weather and geophysical service Zentralanstalt für Meteorologie und Geodynamik (ZAMG), including the Austrian National Data Center (NDC), as well as the private company GIHMM. The aim is to develop a strategy of protection for chemical, biological, radiological and nuclear threads (CBRN) for the Austrian armed forces.
Once the explosion is identified from infrasound and seismic measurements (reference to contribution by Mitterbauer et al.), forward modeling assuming a predefined release term is undertaken to understand which area might be contaminated. As soon as radiological measurements are available, the source term is adjusted.
Tabletop-Exercises are developed and tested based on hypothetical near-ground explosion scenarios (ordinance, accidental or terror attack).

Promotional text: Atmospheric dispersion events with respect to radiological, biological and/or chemical materials.

P2.4-480 – Analysis of Atmospheric Radioxenon Detections in the UK

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An IMS-like noble gas system is in operation at AWE (Aldermaston, UK) and can collect and measure the radioxenon content in environmental air samples. When operated in this mode, data produced is analysed at the UK National Data Centre (NDC) as part of the in-house radionuclide (RN) analysis pipeline. This work discusses a number of significant detection events analysed using the operational system deployed at the UK NDC, which includes atmospheric transport simulations and a real-time stack-monitoring data feed from a nearby medical isotope production facility in Belgium. A comparison of the expected radionuclide contributions with measured detections is presented, including a comparison of the isotopic ratios for the radioxenon isotopes of interest (Xe-133, Xe-131m, Xe-133m, Xe-135).

Promotional text: Radioxenon detections on an IMS-like SAUNA system operated at GBL15, the UK CTBT Radionuclide Laboratory, have been correlated with a medical isotope production facility in Europe.

P2.4-523 – Source reconstruction from dry and wet deposition measurements

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Measuring airborne radioactivity typically requires large, static installations, limited in number and geographical distribution. By measuring the activity of matter deposited to the ground (by dry settling or wet scavenging), one can complement detections of airborne activity and improve overall data availability.

Many ways exist to detect deposited activity, such as using rain basins which capture precipitation for a known span of time, or directly sampling soil or bodies of water. The latter have certain drawbacks (e.g. ambiguity as to what timeframe of atmospheric activity is actually covered by the sample) leading to large uncertainties, but have the advantage that data can be gathered anywhere and at any time (including days or weeks after a plume of interest has already come and gone), without requiring any preexisting infrastructure.

This presentation compares between atmospheric- and deposition-based detection as practical techniques by treating a series of cases simulating individual 'puff' releases. In every case, we determine how sensitive the existing network of International Monitoring System (IMS) stations would be to the release, and subsequently the surface area which a hypothetical rain collection basin would require at every location to match the sensitivity to the release that is achieved by the IMS stations.

Promotional text: Since radioactive particulates are subject to wet deposition and gravitational settling, we perform a modelling study to test whether deposition measurements can complement existing airborne measurements for source reconstruction purposes.

P2.4-551 – A study of the radioxenon background and potential sources at the IMS station SEX63, Sweden

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Understanding the radioxenon background at the radionuclide stations in the IMS network is important to improve the verification capability of the network. The background at the IMS station SEX63 in Stockholm Sweden has been studied in the time period between 2012 to 2019 using data from the IMS SAUNA II system. From 2017 data have also been evaluated from the co-located SAUNA III system. Xenon detections have been studied to understand potential sources and their contributions to the detections at the station. Detections have been characterized with respect to concentrations, isotopes detected and wind direction. ATM has been used to try to identify specific sources in a few case studies.

Promotional text: Understanding the radioxenon background at the radionuclide stations in the IMS network is important to improve the verification capability of the network.The background at the IMS station SEX63 has been studied between 2012 and 2019 and the results will be reported.

P2.4-552 – Preliminary analysis results of ongoing temporary radioxenon background measurement campaign in Japan

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In 2017, the Government of Japan has decided to make a voluntary contribution to further enhance the capabilities of the CTBTO verification regime. In that framework, two transportable noble gas systems were deployed in Horonobe and Mutsu. They respectively started operating in February 2018 and March 2018. Continued operation of the two systems is now financially supported with funding from European Union Council Decisions.

Together with the IMS station RN38 in Takasaki, this forms a temporary high-density configuration network enabling observation of the same event release at different locations at distances of about 500 km from each other.

As of today, few thousands of samples were already collected and measured in Mutsu and Horonobe, and this number is still increasing daily. Resulting spectra are automatically sent to the IDC and processed in a non-operational database. They are routinely reviewed, and the concentrations of the four xenon isotopes of interest for the CTBTO (^{131m}Xe, ^{133m}Xe, ^{133}Xe and ^{135}Xe) are calculated. Analysis results are made available (together with raw data) to State Signatories through a Secure Web Portal.

In this work, preliminary analysis results of ongoing temporary background measurement campaigns are presented.

Promotional text: Preliminary analysis results of ongoing temporary background measurement campaigns in Japan are presented in this e-poster.

P2.4-553 – Sub soil measurements in Sweden of radioxenon and radioargon

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The most important indicators for an underground nuclear explosion during a CTBT on-site inspection are the radioactive xenon isotopes ^{131m}Xe, ^{133}Xe and ^{133m}Xe and the radioactive argon isotope ^{37}Ar. Knowledge of how these isotopes vary and potentially correlate in different types of soil is essential to be able to discriminate between the natural background and a signal from a nuclear explosion.
A series of measurements has been performed at different depths within a limited area in the region of Kvarntorp (Sweden), a location with known elevated uranium content in the ground. To investigate variations of the naturally occurring noble gas concentration in sub soil gas over time and at different depths sub soil sample collection was carried out over a period of two weeks. The analytical results from the collected samples will be discussed in relation to radon levels, soil uranium content and environmental parameters such as the meteorological conditions.

Promotional text: Radioactive noble gases are important indicators of a underground nuclear explosion. To investigate variations of the naturally occurring noble gas concentration in sub soil gas over time sub soil sample collection was carried out over a period of two weeks.

P2.4-563 – Simulating Xe-133 concentrations at IMS noble-gas-stations, using operational stack emission data from the medical isotope production facility of Fleurus

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The National Institute For Radioelements (IRE), located at Fleurus in Belgium, is an important emitter of radioactive xenon into the atmosphere. These emissions are not harmful to the environment, but can interfere with the very sensitive noble gas detection stations that are part of the verification regime of the Comprehensive Nuclear-Test-Ban Treaty Organization. Radioxenon stack emission data from civilian nuclear facilities, combined with atmospheric transport modelling, can help to discriminate real events (radioactive xenon detections that originate from a nuclear explosion) from false alarms (radioactive xenon detections that originate from a civilian nuclear facility).In this presentation, we will present the additive value of using the STAX data from the Fleurus site in near real time xenon forecasts in order to show its capability to model the radioactive xenon background on the CTBTO noble gas stations. We will use the Lagrangian particle dispersion model Flexpart to calculate the transport and dispersion of Xe-133, using numerical weather prediction data from the European Centre for Medium-Range Weather Forecasts. Radioxenon activity concentration time series will be presented. The results will be compared with observations of the International Monitoring System and statistical scores will be calculated.

Promotional text: The simulation of Xenon-133 in near real-time, using STAX data, will improve our understanding of the xenon background in an operational context.

P2.4-590 – Evaluating the added value of multi-input atmospheric transport ensemble modeling for applications of the Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO)

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The potential benefit of ensemble dispersion modeling for CTBTO applications was investigated using input data from the ECMWF-Ensemble Prediction System (EPS). Five different test cases - among which are the ETEX-I experiment and the Fukushima accident - were run. For those test cases run in backward mode and based on a puff release it became evident that Probable Source Regions (PSRs) can be reduced in size compared to results based solely on the deterministic run by applying minimum and probability of exceedance ensemble metrics. It was further demonstrated that a given puff release can be reproduced within the meteorological uncertainty range. For the test cases run in forward mode it was found that the control run, 10- and 51-member medians exhibit similar performance in time series evaluation. The main added value of the forward ensemble lies in producing meteorologically induced concentration uncertainties and thus explaining observed measurements at specific sites. It can be concluded that meteorological uncertainty to a large degree is covered by the 10-member subset because forecast uncertainty is largely suppressed due to concatenating analyses and short term forecasts, as required in the operational CTBTO procedure, and because members from different analyses times are on average unrelated.

Promotional text: enhance the capabilities of the Treaty's verification regime via ensemble dispersion modeling.

P2.4-606 – Global radioxenon emission inventory 2014 from all types of nuclear facilities

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The goal of the third ATM challenge is to perform atmospheric transport modelling in order to estimate radioxenon observations at selected IMS stations in the northern hemisphere for an extended period in the year 2014 (June to November). This estimation is needed for calibration and performance assessment of the verification system as described in the Treaty. The best estimates for Xe-133 emissions from known sources is used as input data for this exercise. This presentation summarizes the global radioxenon emissions inventory for the whole year 2014. It comprises all relevant nuclear facilities. For the two strong sources IRE (Belgium) and CRL (Canada) stack release data with a high time resolution are available. For nuclear power plants (NPP) in Europe and the USA the reported release for the whole year are applied in combination with information about their operational schedule. For all other NPPs and for the strongest research reactors sources the best estimates are used. The estimated release of the strongest nuclear research reactors sources is included as well as the annual emissions from the Mallinckrodt facility (The Netherlands), the NIIAR facility (Russia) and the Karpov Institute (Russia).

Promotional text: This presentation summarizes the best estimates of radioxenon emissions from all nuclear facilities in the year 2014. It is a unique data set to be used in studies to enhance data analysis from the noble gas component of the International Monitoring System.

P2.4-607 – Investigation of Xe-135 observations at IMS noble gas systems generated by neutron activation and its relevance for nuclear explosion monitoring

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Strong neutron sources may generate significant amounts of radioxenon by activation of stable xenon. Radioxenon emission from some nuclear research reactors and from spallation neutron sources are dominated by neutron activation as the production process. The isotopic ratios are different from fission gases. Activation generates Xe-135 to Xe-133 activity ratios like fission but the activated gases may escape from the facility faster than fission products that are initially contained within fuel cladding. Therefore, less Xe-135 has decayed and a comparatively higher activity is emitted. When detected at an IMS station, the Xe-135 to Xe-133 activity ratio can even exceed the threshold for raising the screening flag that indicates it appears like a prompt release from a nuclear explosion. It may also happen that Xe-135 is observed without simultaneous detection of Xe-133 in the same sample. This presentation investigates activation sources that could possibly be observed at IMS sites. These include the HFIR reactor and strong spallation neutron sources. The conclusions of this study have important implications for assisting States in identifying the source of a specific event and for the decision whether interference corrections for non-traditional radioxenon isotopes generated by activation needs to be introduced to the operational software.

Promotional text: This presentation investigates whether radioxenon generated by activation may be observed by IMS noble gas systems. This is important for Expert Technical Analysis and possibly for making IDC software robust against interference from non-traditional radioxenon isotopes.

P2.4-637 – How to Use the FLEXPART Model in Atmospheric Transport Modelling Challenges

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The "Flexible Lagrangian particle dispersion model" FLEXPART is used in the IDC as well as by many of the participants in the Atmospheric Transport Modelling Challenges. As a truly flexible model, it may be used in forward and backward mode and it has many other parameters that can be set by users. All of these options influence the CPU and memory requirements as well as the accuracy of the output. For example, if we consider only a small number of stations and daily or half-daily samples, but are interested in a large number of of possible emitters and/or emission time slots, backward simulations will usually be more efficient. There is also the option of using gridded output or a point receptor with a sampling kernel. Number of particles and model time steps also influence both the resources required and the results. For the ATM Challenge 3, certain modifications have been implemented in FLEXPART version 10 to make full use of possible combinations of options. Pertinent findings and recommendations will be reported.

Promotional text: FLEXPART users will be assisted to better understand the options for organising and setting up simulations for complex or compute-intensive tasks. ATM challenge 3 will be used to compare options, derive recommendations, and make trade-offs involved more transparent.

P2.5 Historical data from nuclear test monitoring

P2.5-086 – A comprehensive earthquake catalog in Central Asia

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The Lawrence Livermore National Laboratory (LLNL), Michigan State University (MSU), and national data centers in Central Asia (Kazakhstan, Kyrgyzstan and Tajikistan) digitized analog seismic bulletins in order to produce a new, unified seismic catalog. The main objective of the project is to provide a reliable seismicity map for new probabilistic seismic hazard analysis of Central Asia. The national network bulletin data are supplemented by data from the International Seismological Centre (ISC) bulletin.

We present the preliminary relocation results of more than 350,000 events recorded by hundreds of seismic stations in the region. Digitized bulletins extend to the early 1950s, providing millions of amplitude and phase arrival data. We relocated each event with iLoc, a single event location algorithm, using both ak135 and Regional Seismic Travel Time (RSTT) predictions to improve locations and to measure the performance of the RSTT model. The results show significant improvements in the understanding of regional seismicity in Central Asia. When data ingestion and relocation are finalized, the result will provide a basis for many other studies (e.g., travel-time tomography, seismicity) that have not been previously possible.

Promotional text: Strengthen the engagement of the scientific communities working in test ban monitoring. As a result of exchange of data from diverse institutions we improve the earthquake locations and earth models in Central Asia.

P2.5-089 – A Unified Seismic Bulletin of Central Asia Using Legacy Data

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We have created a unified seismic bulletin of Central Asia to improve event locations and knowledge of seismic hazards. The national data centers and seismic networks of Kazakhstan, Kyrgyzstan,

and Tajikistan have digitized paper historic bulletins of earthquakes with mb3.0 and greater from this region of Eurasia for 1949-2009. Soviet-era data covering portions of Uzbekistan, Turkmenistan, and Russia are included for completeness. Data from the International Seismological Centre (ISC) for all years, and local digital seismic bulletins since 1993, were collected and merged with the digitized bulletins. The unified bulletin contains over 10 million arrivals. To obtain regional magnitude conversion relationships from small events with traditional magnitudes (ML, mb, and Ms), we use a coda calibration technique that allows direct calculation of Mw from source spectra obtained using the Coda Calibration Tool (CCT), which was developed at Lawrence Livermore National Laboratory (LLNL). After merging all available information and relocations, the unified seismic bulletin was created. This is the first comprehensive bulletin developed for this region.

This project fills in a considerable portion of a gap for the region, increases the accuracy of event parameters, preserves unique, perishable archival data, and supplements ISC bulletins with new data for the region.

Promotional text: Strengthen the engagement of the scientific communities working in test ban monitoring. As a result of exchange of data from multi-country institutions we improve the earthquake source parameters and locations and earth models in Central Asia.

P2.5-092 – Seismicity of the Caucasus region: a comprehensive, revised catalog for 1951-2019

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The Lawrence Livermore National Laboratory (LLNL) and the Institute of Earth Sciences (IES), Ilia State University developed a project to generate a new seismic catalog for Georgia. The main objective of the project was to provide a reliable seismicity map that can be effectively used in a new probabilistic seismic hazard analysis for Georgia. Monitoring centers in Armenia and Turkey have also contributed bulletins from their own archives and provided picks for selected events. A subset of events from the IES bulletin was used as an input for the seismic hazard analysis. This data set is combined with the seismological bulletins of the Republic Seismic Survey Center (RSSC) and the International Seismological Centre (ISC) bulletin.
We present the relocation results of more than 20,000 events in the bulletin. We relocated each event with iLoc, a single event location algorithm, using Regional Seismic Travel Time (RSTT) predictions to improve locations. Using the iLoc results as initial locations, we then applied Bayesloc, a multiple event location algorithm, to simultaneously relocate the entire seismicity of the Caucasus region. The results show significant improvements in the understanding of regional seismicity.

Promotional text: Strengthen the engagement of the scientific communities working in test ban monitoring. As a result of the contribution of this large dataset, regional earth models will be improved which will reduce the uncertainties in regional discrimination studies.

P2.5-176 – Large chemical explosions of the Soviet period on the territory of Kazakhstan as ground truth events

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In Soviet times, large chemical explosions were conducted on the territory of Kazakhstan with different purposes (industrial, investigative, military). The parameters of these explosions are quite well known, but can be further elaborated by special investigations using contemporary methods. Furthermore, these explosions can be used as ground-truth events for the calibration of regional seismic networks in Central Asia.
These explosions are: 1 – investigative explosions in the south of Kazakhstan, Arys 19.12.1957, yield 1000t; 2 – double explosions for construction of a mud dam near Almaty: Medeo 21.10.1966, (1689t and 3604t) and Medeo 14.04.1967 (3940 and 1944t); 3 – investigative explosion "Massa" near Almaty, 28.11.1981 (251t); 4 – investigative explosions in Central Kazakhstan of 9 ton yield Chemex-1 2.09.1987, Chemex-2 3.09.1987. In addition, on the territory of Semipalatinsk Test Site there were 175 chemical explosions conducted for military and scientific purposes; the parameters are known for ~30 explosions. For these explosions, using the archive and published data, the source parameters were specified, the catalogue and seismic bulletin were compiled. The kinematic and dynamic parameters of records were investigated, regional travel-time curves were constructed. The seismic effect of the investigated explosions was compared with that of other large chemical explosions conducted in Central Asia.

Promotional text: We collected information about large chemical explosions were conducted on the territory of Kazakhstan. These explosions can be used as ground-truth events for the calibration of regional seismic networks in Central Asia.

P2.5-181 – 70-years contribution of "Borovoye" Geophysical Observatory into nuclear explosions monitoring

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2021 is 70-years from the day when nuclear explosion of 38 Kt yield was conducted at STS and recorded at Borovoye area. Following first successful experiment and field works, the Special Division of IPE U.S. decided to establish "Borovoye" geophysical observatory. In 1961, it recorded UNE of 2.6 Kt from Nevada Test Site at ~10 thousand km distance.
"Borovoye" Observatory is one of the most known global stations for nuclear explosions monitoring. Its uniqueness is determined by good seismological-geological settings for seismic signals recording, the most continuous history of digital recording started in 1966.
In 1974, Vostochnoye, Chkalovo, and Zerenda seismic stations were installed near the Observatory, and formed a so-called large-aperture "Triangle" array with the central station on the Observatory territory. In different years, the magnetotelluric and infrasound stations were used here for monitoring.
In the post-Soviet period, BVAR seismic array of the IMS was constructed at the Observatory area and certified in 2002; in addition, BORK seismic station of IRIS IDA was installed here.
The report presents the history of Borovoye Observatory, shows the examples of recorded nuclear explosions conducted at different world Test Sites, and investigates the spectral density of seismic noise in different periods of time.

Promotional text: The report shows the history of establishing of "Borovoye" Geophysical Observatory that this year celebrates its 70-years of operation and invaluable contribution into the nuclear explosions monitoring. In addition, the station has the longest period of digital observations.

P2.5-297 – The Travel-Time Curve For The Region Of The East Tien Shan By The Records Of Historical Seismograms Of UNE From The Lop Nor Test Site Area

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We constructed travel-time curves for eastern Tien-Shan using historical seismograms of underground nuclear explosions from the Lop Nor test site in the Peoples Republic of China. We measured the arrival times of the main seismic phases on seismograms from 1969-1996 stored in the analog archives of Kazakhstan as well as digital stations from Kazakhstan and Kyrgyzstan. In total, more than 500 seismograms were processed. The data were used to construct travel-time curves for regional phases Pn, Pg, Sn, Sg, and LR at distances ranging from 700 to 2500 km. Individual travel-time curves were constructed for each event for which the nature of each wave group was précised; a joint averaged travel-time curve for east Tien-Shan using all events was also constructed. The construction of the travel-time curve is used for such tasks as precision of the main parameters of explosions at Lop Nor, improvement of location accuracy of seismic events sources from the east Tien-Shan region (including Lop Nor Test Site area), and other tasks.
The travel-time curve for the eastern Tien-Shan was compared to one in routine use for Central Kazakhstan that was calculated using regional chemical calibration and nuclear explosions conducted on the territory of Semipalatinsk Test Site.

Promotional text: We constructed travel-time curves for eastern Tien-Shan using historical seismograms of underground nuclear explosions from the Lop Nor test site.

P2.5-397 – Applying calibrations to digitized historical analog seismograms of nuclear explosions and other important events

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Digitization of analog seismograms from past nuclear tests are critical for monitoring because many historical tests occur within unique geologic environments. To utilize this digitized data, it is important to know the frequency characteristics of the seismic channel that generated the seismogram to accurately correct for instrument response and recover ground motion. Calibrations can vary significantly with time and location, thus a single generic calibration for a station or instrument type is insufficient. Focusing on stations and instrumentation from the former Soviet Union, we developed software to accurately translate the original published yearly station calibration parameters into modern dataless SEED files. We compare Power Spectral Density (PSD) measurements of digitized SKM short-period analog records against co-located digital broadband instruments to demonstrate that the process yields an accurate picture of ground motion from 0.3-5 Hz. The resulting transformation of the digitized analog seismogram into a faithful digital rendering of ground motion can be used for advanced seismic analysis, including waveform transformation between displacement to velocity domains, frequency-based discrimination studies, and more. We are now applying the correct station calibrations to several seismogram recovery and digitization projects in northern Eurasia.

Promotional text: Historical seismograms, when accurately digitized, also require a modern description of channel response. We have developed techniques to translate historical calibration parameters and metadata into modern response files that correct for channel response to yield ground motion.

P2.5-443 – Producing High Quality Digitizations from Historical Analog Seismograms of Nuclear Explosions

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The recovery and digitization of legacy seismogram waveforms is critical for research of historical events in nuclear monitoring. We are improving the digitization process by applying an interpolation algorithm and examining the frequency recovery of the potential records. The implementation of a Piecewise Cubic Hermite Interpolating Polynomial (PCHIP) interpolation algorithm improves the quality of the digitization and minimizes the amount of distortion. We quantify the effectiveness of scan density by the ease of digitization and waveform accuracy. Low scan resolutions adversely affect waveform accuracy and ultimately the frequency recovery. This is demonstrated in a synthetic 'white noise' seismogram that emulates an analog record. The synthetic signal is converted to numerous scan resolutions then digitized. After digitization, the digital seismograms are compared back to the original synthetic seismogram. Preliminary results indicate that a 200 DPI image can recover signals up to about 2.5 Hz whereas a 600 DPI image can recover up to about 8 Hz, assuming an original recording speed of 60 mm/s and a short period sensor. Additional analog seismogram parameters such as line width, signal contrast, and signal amplitude all factor into the overall quality and waveform accuracy of digitized data.

Promotional text: We have improved the digitization process for analog seismograms representing historical nuclear explosions and quantified the effects of variables such as scan resolution, contrast, and line thickness and how they impact waveform accuracy, and ultimately frequency recovery.

P2.5-499 – Quantitative research using digitized historic short-period nuclear explosion seismograms

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The recovery and digitization of Peaceful Nuclear Explosions (PNEs) from the Soviet Era provides a unique opportunity to study the geology and geophysics of seismically quiescent regions. Due to the improved digitization and excellent recovery of the analog signals, these now-digital seismograms can be used with modern seismic modeling techniques. PNEs can be modeled as point sources and since the source characteristics are known, they serve as ground truth events. However, regional geology heavily affects the ability to distinguish between nuclear explosions and tectonic earthquakes, such as in the Siberian Platform. We are using regional full moment tensor inversions of the digitized PNE data to see if it can be used to compare competing Earth models of these regions, since we know the nature of the source of the events. We also evaluate amplitude data in multiple frequency bands to find phase-based discrimination criteria in relation to the local geology in regions of northern Eurasia. Furthermore, the moment tensors and phase ratios can be researched with respect to how the emplacement geology, regional stress, depth, and yield affect the seismic signal. Other abstracts describe the data set and digitization process.

Promotional text: The applicability of short-period digitized seismic data from Soviet Era Peaceful Nuclear Explosions are tested through evaluation of source characteristics and event discrimination.

P2.5-594 – Digitization of Soviet Peaceful Nuclear Explosion Seismograms

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The Geophysical Survey of the Russian Academy of Sciences and Michigan State University are working to recover, preserve, scan, and digitize the historic seismograms of Soviet Peaceful Nuclear Explosions (PNEs). The Soviet Union detonated 122 PNEs from the mid-1960s through the late 1980s. The PNEs were conducted in a wide range of geologic settings and geographic locations, thus representing a unique data set for geophysical studies. These explosions were well recorded by the regional seismic networks, where thousands of seismograms are still retained. We are working to index these irreplaceable legacy analog seismograms and preserve them against loss for future generations. In the process, we are also generating high resolution scans of the seismograms and digitizing them for analysis. Most seismograms are from short period instruments, and when combined with the correct station calibration information, the digitization process accurately recovers ground motion signals to at least 5 Hz.

Promotional text: Thousands of seismograms from Peaceful Nuclear Explosions remain within the vaults of the regional seismic networks of the former Soviet Union. We are indexing, scanning, and accurately digitizing them to preserve these irreplaceable records for future geophysical research.

P2.5-712 – Reconstructing nuclear events from annually laminated lake sediments in Northern Finland

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The annually laminated sediments deposited in Lake Kevojärvi (69°45N, 27°00'E) in the municipality of Utsjoki in Northern Finland were investigated for radioactivity. A freeze cores recovered from the 35-m deep basin preserve a distinct succession of annual laminations deposited between 1909 and 2015. The basic varve structure was composed of a detrital snowmelt layer and an organic-rich post-snowmelt layer lying on top of the snowmelt layer. A total of 53 annual laminations were taken for gamma spectroscopic measurements using low-background gamma spectroscopy. This allowed a reconstruction of ^{137}Cs, ^{241}Am and ^{210}Pb fallout history in the Lake Kevojärvi region. This highly resolved profile revealed a detailed record of anthropogenic radioactive fallout from atmospheric nuclear testing conducted in the 1950s and 1960s and the Chernobyl accident in 1986. The ^{137}Cs concentrations in sediment varves were first found to increase in 1956 while the peak years occurred in 1964, 1970 and 1986 varves. The ^{241}Am concentrations peaked in slightly different years in 1960-1962, 1964 and 1970 varves. Each peak was found to correspond to different nuclear testing campaigns. A two-year time delay between years of intensive nuclear weapons testing and peaks in the sediment records was observed due to sedimentation from the stratosphere.

Promotional text: Analysis of gamma-emitting radionuclides in annually laminated lake sediments are presented focusing on the anthropogenic ^{137}Cs and ^{241}Am which are also products of nuclear weapons testing.

P3.1 Design of sensor systems and advanced sensor technologies

P3.1-101 – A new damping system for seismic sensors based on the eddy currents

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This research describes a new damping system for optical seismic sensors that, is based on eddy currents. In the last decade, scientists have been considered optical approaches for readout systems of seismic sensors. So, the use of reliable and high-performance damping systems in this category of seismometers is very important. This has led us to build a damping system based on the eddy currents for a spring-suspended mass whose position is monitored by the moiré technique. To demonstrate this approach, a conventional oscillation system has been used. Also, the proposed damping system consists of a neodymium magnet which is fixed to the suspended mass, and a conductive plate which is fixed to the frame of the oscillator. The magnet and the conductive plate are facing each other with a distance of 0.5 mm. By relative motion between the magnet and the nearby conductive plate, eddy currents have been produced in a way that opposes its creator. Experiments to test this approach have been performed, and the evaluations of the results show that the proposed damping system for optical sensors is quite reliable.

Promotional text: The present study describes a new approach to building a reliable damping system for optical seismic sensors, that is based on eddy currents. The evaluations of the results show that the proposed damping system is quite practical and efficient.

P3.1-102 – An approach for determination of suspended mass displacements in seismometry

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In this research, a new approach based on the moiré technique is presented to calculate the displacement of the suspended mass in seismometers. The oscillating system consists of a spring-suspended mass whose position is monitored using the moiré technique. To form the moiré pattern, two similar Ronchi grating are used so that they are facing each other without physical contact. One of the gratings is fixed to the oscillating mass and the other to the body of the oscillating system. An arrangement consisting of a laser diode, a narrow slit, and a photodiode was also used to detect and record the signal from the displacement of the moiré fringes due to the oscillation of the suspended mass. Also, an algorithm for calculations and conversion of the electrical signal into the displacement signal is presented. To validate the equations and the proposed algorithm, simulated and real data were evaluated and the results were compared. The results show the high capability and accuracy of the moiré technique and proposed algorithm in determining the oscillating mass displacement.

Promotional text: This research demonstrates a novel method to calculate the displacement of the suspended mass in seismometers that is very important in seismometry. This method is based on the moiré technique and an algorithm to process the recorded signals.

P3.1-104 – FSUE VNIIA contribution to the development of CTBT related technologies

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VNIIA is the premier ROSATOM organization in implementing the CTBT and is currently performing a cluster of research activities:
- provides scientific methodological support and develops hardware and software solutions to ensure the CTBT OSI activities, carries out a comprehensive assessment and foresee of technical abilities within the verification regime for compliance with the CTBT, analyzes the effectiveness of control means and the level of information of IDC data;
- participates in the analysis of events, indicating possible non-compliance with the Treaty by States Parties; gathers geophysical and radionuclide data based on IDC products;
-improves the information and analytical system in order to use it in the applied research for the activities of Rosatom within the CTBT verification regime;
- explores and refines capacities of complex-analytic techniques usage in determination the nature of the suspicious event with IMS data;
- develops and implements modernization of the E-Training System Software for training of surrogate inspectors in OSI methods and procedures;
- develops short-period vertical and three-component broadband seismic receivers for seismic monitoring systems;
- develops a microbarometer for infrasound monitoring systems;
- VNIIA specialists proceed with the preparations for certification of NG monitoring equipment of domestic development–Xenon Isotopes Monitoring System (MIKS).

Promotional text: VNIIA is the leading organization of the "Rosatom" regard to the CTBT regime.VNIIA strives to develop scientific research and international cooperation that can serve national needs, achieve political objectives in support of the CTBT.

P3.1-109 – Investigation of the sorption and separation characteristics of materials for argon extraction and processing

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A method for detecting radioactive argon ^{37}Ar produced in the soil by the nuclear reaction between ^{40}Ca and fission neutrons is used for monitoring and detection of underground nuclear tests. In this regard, a relevant problem is to extract argon from soil gas with the elimination of impurities and conduct radioactive analysis. An industrial technology of low-temperature air rectification allows argon extraction in large quantities. However, this technology is prohibited by the CTBTO for on-site inspection purposes. This work is devoted to the study of materials for argon extraction and processing using the adsorption method and, in particular, the pressure swing adsorption (PSA) method. Traditional noble gas sorbents are used as materials, as well as high-silicon zeolites modified with transition metal nanoparticles (of the Y and ZSM-5 types), which feature an increased selectivity for argon. The study is carried out on a setup for examining the sorption and separation characteristics of sorbents. The technique for determining the characteristics of argon sorbents is based on the volumetric method (in the high-pressure range) and the preparative gas chromatography method.

Promotional text: The study of materials for argon extraction and processing allows to determine the sorbents with the highest selectivity for argon and to provide the possibility to conduct analysis of its radioactivity with the aim of underground nuclear test monitoring and verification.

P3.1-115 – Major Upgrade of the I31KZ: Learning the Lessons of the Past and Keeping up with the State of the Art

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I31KZ, Kazakhstan, has been in operation for almost twenty (20) years. Over this period, the specific experience was gained of operating the array in hard-to-reach areas in harsh environmental conditions such as strong winds, low temperature in winter months and flooding in springtime. This experience and lessons learned allowed to minimize the risks of potential damage and loss of detectability. All critical systems, which became obsolete over the long operating period, were renovated and the most advanced available technical solutions were implemented. The station was brought to the state-of-the-art for infrasound installations. Calibration capability was added, namely site-by-site and electrical calibration of MB3a via digitizer, which became a breakthrough in station operation control. The possibility of remote array control is of prime importance for hard-to-access areas. This additional element and commonality of wind noise suppression systems improve station robustness and increases array performance, which is critical for the area with high wind noise levels. Upgrade of the power system and application of several up-to-date solutions, such as Low-noise power supplies and switch to Ethernet fiber optic from serial radios resulted in significantly higher accessibility and data quality, as evidenced by the attached statistical graphs and PSD plots.

Promotional text: A major upgrade of the I31KZ infrasound array considering the experience of array operation in a remote location and under harsh climate conditions using up-to-date equipment and techniques improved the station's ability for nuclear test monitoring and verification.

P3.1-128 – Thermal equilibration of Hyperion infrasound sensors

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An evaluation of several Hyperion 5313A infrasound sensors was performed in order to determine the length of time it takes for the sensors to thermally equilibrate under a variety of environmental conditions. The motivation for performing these tests was to aid in determining suitable procedures for station operators to follow when installing these sensors. Thermal equilibration occurs when the temperature of the component materials of a sensor are equalizing with its environment. This can occur when the sensor is exposed to an environment with a different ambient temperature or when the sensor is first powered on, both of which typically occur during the installation of a sensor. During the equilibration period, the measured noise on the sensor output can be considerably higher than when it has thermally stabilized.

P3.1-180 – Metrology of rotational seismometry

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Rotational seismometry is an emerging perspective area of science for further developing of seismic monitoring. The quality of manufacturing measuring devices is improving. New instruments are being developed. Accuracy of measurements is increasing. Data processing algorithms are being improved. However, the absence of standardized metrological schemes for developers, manufacturers and users creates problems in data dissociation. The data can't be compared. Metrological characteristics of devices should be standardized. All the necessary characteristics must be clearly defined for each type of device. Then we can trust and analyze all monitoring data. This paper presents the model of the estimation of errors of measurements collected by the rotational seismometer.

Promotional text: The quality of the IMS seismic network of the CTBT can be improved by using rotation sensors. There is still a lot of work to be done in this field. The paper presents overview of the metrological problems in rotational seismometry, which require further improvement.

P3.1-187 – Low-level ^{140}Ba measurements on high-volume air filters using gamma coincidence systems

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It has been proposed that the use of gamma-gamma coincidence methods could lower the detection limit for the detection of certain relevant radionuclides, such as ^{140}Ba. Gamma coincidence measurements have the advantage of significantly lowering the background at the cost of lower overall efficiency. Modelling efforts indicate that a net gain in detection limit can be achieved. Several experiments were designed where small amounts of ^{140}Ba was spiked at 70 mBq and 150 mBq onto high-volume air filters (RASA and Cinderella). These filters were measured on several gamma singles and coincidence systems, both on the surface and in shallow underground laboratories. Initial results show a benefit of coincidence systems over gamma singles when measured in the typical IMS process (24 hours collect, 24 hours decay, 24 hours count). Gamma coincidence methods were able to detect the presence of ^{140}Ba after 24 hours of counting, whereas singles required several days of counting to detect ^{140}Ba. Accurate ^{140}Ba/^{140}La separation time was also able to be accurately calculated using coincidence methods.

Promotional text: Utilizing advanced gamma spectroscopy methods such as gamma coincidence measurements can increase the sensitivity of the IMS for relevant radionuclides that have decay schemes that emit coincidence gamma rays.

P3.1-203 – Commercial Automatic Weather Station Solution to IMS/OSI

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Weather forecast is essential for precision measurements involving meteorology related CTBT scenarios. Weather parameters recording is also very critical for routine maintenance of IMS stations. Looking at the IMS network all over the globe, it would be very important to get to know the local weather situation to support the normal operation of the four categories of IMS stations in the middle of nowhere. For OSI operations, mission critical sampling operation, especially radioactive noble gas sampling, relies heavily on the accurate forecasting of wind directions with time. Even the proper selection of base of operations out of the concerns of health and safety, also relies on the proper study of weather conditions of the inspection area. This work would propose a commercial automatic weather station solution, which is not only quite suitable for CTBT OSI mission requirements, but also for IMS station operation support. This automatic weather station is self-sufficient with solar-panel power supply. It also has a built-in compact design, which could provide all basic parameters of meteorology, such as temperature, humidity, wind direction and speed, air pressure, rain gauge, et cetera. The system could be connected through wire or wireless communication to other CTBT equipment through RS232/GPRS/4G.

Promotional text: This work would provide a practical automatic weather station solution to IMS/OSI support, which provides meteorology data, such as temperature, wind speed, wind direction, humidity, air pressure, rainfall to support IMS station maintenance, OSI sampling, overflight, and IT H&S.

P3.1-216 – Development of a radioxenon detector with a high-resolution beta detector

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Beta-gamma detectors are utilized extensively for the detection of radioxenon, but the beta detection is primarily performed with a plastic scintillator cell. Two areas of improvement for plastic scintillators are the sample carry-over ("memory effect") and energy resolution. While the scintillator can be coated to remove the memory effect, the energy resolution must be improved with a different detector material. Silicon is the current leading candidate for the future beta cell material due to the much-improved energy resolution compared to plastic scintillators (factor of ~3x). PNNL is developing a silicon beta cell for use as a potential modular replacement within Xenon International (a next-generation radioxenon detection system currently undergoing acceptance testing for potential inclusion in the International Monitoring System). The beta cell utilizes four different silicon detectors to create an active volume for the radioxenon within an outer gas cell. Since there are four separate beta signals (compared to one for plastic scintillators), data acquisition modifications are required. In this presentation, we detail the design, efficiency measurements, and long-term testing of the silicon beta cell and potential improvements in isotopic discrimination. Additionally, we discuss the required data acquisition and analysis updates needed to best utilize the silicon improvements.

Promotional text: Improving identification of nuclear explosions in a sea of anthropogenic backgrounds with the improved isotopic discrimination available with a silicon beta cell.

P3.1-221 – Current PTS Activities Related to Low-Cost Infrasound Sensors

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Infrasound sensors deployed in the IMS Infrasound Network are of high performance so they can meet the strict IMS minimum requirements. The PTS in its effort to deploy state-of-the-art infrasound sensors has been performing continuous technology watch for the last 11 years on high quality infrasound sensors. More recently, the PTS also started monitoring developments in the field of low-cost infrasound sensors. The objective is to stay on the pulse of infrasound sensors development and also to spot new infrasound sensing technologies, with great potential for the future, at an early stage. In recent years an increasing number of low-cost infrasound sensors have been developed. The PTS has made a concerted attempt to explore and test those low-cost infrasound sensors. Sensors such as the Raspberry Shake and Boom, the iTem Prs0025a and the Gem Infrasound Logger v1.01 has been tested. This poster present the testing observations made of those types of sensors.

Promotional text: More recently, the PTS also started monitoring developments in the field of low-cost infrasound sensors. The objective is to stay on the pulse of infrasound sensors development and also to spot new infrasound sensing technologies, with great potential for the future.

P3.1-243 – CalxPy: a software for the calibration of geophysical systems against a reference

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The IMS Operational Manuals for waveform stations require that IMS stations be calibrated regularly. Since 2012, the PTS had relied mostly on electrical calibration to meet that requirement.
However electrical calibration comes with some challenges (no traceability, integration and sustainment issues, high operating costs…).
A part of the geophysical community, including Station Operators, has started performing regular calibrations by comparison against a co-located reference. This method allows a more systematic and centralized approach to calibration. Over the past few years it has been gradually more used at IMS stations, particularly infrasound. In this context, the PTS is developing tools to support this alternative approach.

Here we present CalxPy, a web-application developed at the PTS for the calibration of geophysical systems by comparison. With CalxPy, one can calculate, store and display the response of a system for a given period, or track the evolution of the response against time or environmental variables. CalxPy also allows the refinement and evaluation of the measured response against a baseline, and the reporting of IMS2.0 calibration results.
CalxPy supports the Initial calibration and On-site yearly calibration processes, as well as Data Quality Control.
CalxPy can be deployed in the IDC pipeline and in NDC-in-a-box.

Promotional text: CalxPy is a versatile software solution that supports the implementation of a passive and traceable calibration method based on the principle of comparison against a reference. This method can be applied across all IMS waveform technologies.

P3.1-256 – Technology For Disaster Resilience: Low-Cost Weather Station

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Despite the prudent importance of monitoring weather and climatic trends, the cost of setting up weather monitoring experiments and devices prove to be costly and even with available costly solutions, they are without standardization rendering the data collected from them unusable for scientific enquiries or examinations. The objective of the work described in this paper is detail the activities done to create mass producible weather monitoring station with low starting and maintenance cost that is capable of generating scientifically usable data of good precision and accuracy and equip weather scientist, world over, with such technology to fight against hydro-meteorological disasters. To achieve these objectives a prototype of embedded micro processor system was developed and iteratively improving it at field tests for thermal capabilities, power consumption, data delivery systems and processing modes. The improved device was setup according to the guidelines of World Meteorological Organization and then generated data was compared to standard meteorological station for data validation. The data fit was performed by time-stamp comparison and functional compensation of the biases and non-linearity. The developed prototype was designed in to a Printed Circuit Board for commercial production into consumer off the shelf form factor.

Promotional text: Low cost weather station is design and developed in Nepal for the measurement of temperature, realtive humidity, air pressure, wind direction, wind speed, light intensity and precipitation. These parameters are very essential for observing any types of disaster on earth.

P3.1-265 – Added value of low-cost seismic and infrasound sensors to local monitoring

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In the framework of a tabletop-exercise of the Austrian NDC scheduled ground detonations within a week in November 2020 were monitored. Therefore, a local network was deployed. Additional to the permanent seismic station ABNA in the vicinity, the NDC deployed two seismic broadband stations with co-located low-cost seismic and infrasound sensors as well as a mobile infrasound array.

After the location of the scheduled ground explosions further analysis of the waveform data was performed: we reviewed the quality of the different seismic sensors as well as the added value of the low-cost infrasound sensor. Additionally, we looked into the background noise at the newest permanent station ABNA of the Austrian Seismic network.

Promotional text: In the framework of a tabletop-exercise of the Austrian NDC scheduled ground detonations within a week in November 2020 were monitored. Therefore, a local network was deployed. Additional to the permanent seismic station ABNA in the vicinity, the NDC deployed two seismic broadban.

P3.1-293 – Hydroacoustic observations using Distributed Acoustic Sensing technology on a fiber-optic submarine cable

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A ship-based air-gun survey was conducted contemporarily with distributed acoustic sensing (DAS) observations using an abandoned submarine cable. Measurements were compared between DAS and co-located hydrophones on the seafloor. DAS measures the Rayleigh back-scattering variations along a fiber-optic cable, of the same kind as the IMS HA hydrophone stations' trunk cables, using incident laser light from the cable terminal. From this measurement, strain or strain rate are obtained. It is known that both spatially- and temporally-dense measurements are achieved with DAS technology, and therefore 50-km length DAS was performed with 10-m resolution and 500-samples per second (SPS). The submarine cable was on the seafloor, except for a 2-km buried section, and reaching 1000 m depth. Broadband frequency signals associated with the air-gun shots recorded by DAS agreed with recordings from co-located hydrophones. The amplitude of DAS strain rate is correlated to pressure at a frequency range above 2 Hz. We also investigated the capability of DAS to measure ocean microseismics (peak frequency ~0.1 Hz), which were identified along the entire submarine cable up to 50 km. Since DAS is performed along a fiber-optic cable of several tens of kilometers length, it can be used also for array observations.

Promotional text: Hydroacoustic observations of air-gun shots by distributed acoustic sensing (DAS) using a fiber-optic submarine cable, and comparison with data from co-located hydrophones, show that DAS can detect hydroacoustic signals. Our data suggests DAS can be used for array observations.

P3.1-299 – Maintaining IMS particulate radioactivity measurement capabilities – integration of a next generation automated air sampler – Cinderella G2

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The international monitoring network of radionuclide stations of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has been built up for the last 20 years. This mature monitoring network has now reached a phase where a technology upgrade for some systems has become necessary. The Cinderella G2 is a commercial automated particulate air sampling system, due to replace the first generation Cinderella air sampler. This sampler is currently used at ~7% of radionuclide IMS stations, with some operating for over 15 years. Deployment of the second generation systems requires an integration of the commercial system into the IMS hardware and software environment. This PTS project aims to achieve this integration, simplifying and standardizing the technology for future deployments.

Promotional text: The new generation of automatized samplers.

P3.1-302 – 4-Mode GNSS Solution to OSI

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Positioning and navigation are essential for inspectors in the Inspection Area, which is probably a place of nowhere in the world.They would lead the inspectors to the potential Ground Zero together

with the guidance of OSI search logic.They are also very important for most of the OSI measurements, which are normally geo-referenced, such as SAMS, CPT, multispectral imaging. With the development of global satellite navigation system, including GPS, GLONASS, GALILEO, BEIDOU, GNSS has already been a technical solution, which makes it possible to take advantages of all the existing major satellite navigation systems. This work would propose a 4-mode GNSS solution to OSI, which is compatible with all the existing satellite navigation systems and more reliable. It would also keep the balance of mission sufficiency and political awareness. Any of the GNSS system receiving channel could be blinded according to the ISP requirement out of the negotiation between IT and ISP during the future OSI. This system is designed to meet with field mission. Android system based hand-held tablet has a user-friendly interface, which would integrate more software applications meeting with inspectors' customized requirements. It would also be very easily to be connected through network with OSI IIMS system.

Promotional text: This work carried out a study on 4-mode GNSS solution for OSI, which would provide an option for OSI positioning and navigation while keeping the balance of mission sufficiency and political awareness.

P3.1-303 – Coincidence Detector System Configurations for Particulate Stations of the IMS Network

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Coincidence Detector Systems have the potential to increase IMS network sensitivity for Treaty Verification purposes. The study presents the first test implementation of a coincidence detector system for measurement of particulate samples at the CTBTO Test Station VIP00, located on rooftop of Vienna International Centre in Vienna – Austria. The prototype dual/coincidence system setup and its configuration are built upon previous coincidence systems developed at GBL15 (AWE, Aldermaston, United Kingdom), and are part of an ongoing collaboration between the Commission and AWE investigating the potential of these systems to enhance the quality and sensitivity of measurements performed at Radionuclide Stations within the IMS network.

Promotional text: Advanced (operational) coincidence systems for particulate monitoring are in use at several CTBTO laboratories. These systems have the potential to greatly improve the sensitivity of measurements and are being evaluated for deployment on the IMS.

P3.1-309 – Development of a first-look cadmium zinc telluride detector for the Radionuclide Aerosol Sampler Analyzer

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A novel first-look cadmium zinc telluride (CZT) detector is being developed by Pacific Northwest National Laboratory (PNNL, USA) in collaboration with General Dynamics – Mission Systems (GD-MS, USA). The compact gamma-spectrometer is designed to be installed within the air intake plenum of the Radionuclide Aerosol Sampler Analyzer (RASA) design of International Monitoring System (IMS) radionuclide stations. It provides real-time measurements of the radionuclides collecting on the filters in advance of the standard High-Purity Germanium (HPGe) measurement made 48 – 72 h after sample collection. These measurements are made every 15 minutes, and may provide an

early indication of radionuclides relevant for Treaty monitoring purposes, supporting nuclear event discrimination and atmospheric transport modelling (ATM) projections. During the high-activity conditions that might be expected during a nuclear accident, it would also provide a measurement of dose rate useful for protecting the station operator and other personnel (including the dose expected from activity collected on the filters). The first-look detector would also safeguard against contamination of the RASA, and may be used to trigger reduced air flow and collection time, to limit the activity being collected onto the filters, and measured by the HPGe.

Promotional text: The first-look CZT detector aims to advance the capabilities of the radionuclide monitoring stations of the IMS. It is aligned to Theme 3: Verification Technologies and Technique Application – Design of Sensor Systems and Advanced Sensor Technologies (T3.1).

P3.1-312 – Development of an ultra-sensitive gamma-gamma coincidence system for radionuclide measurements at International Monitoring System stations

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Next-generation gamma-gamma coincidence measurements have the potential to significantly improve the confidence of detection of particulate radionuclides relevant for nuclear explosion monitoring purposes. Sophisticated laboratory systems have demonstrated order-of-magnitude improvements for radionuclides such as Ru-106/Rh-106, Cs-134 and Ce-144. However, the implementation of these systems at IMS particulate stations has been limited by the complexity of acquisition hardware, data processing and analysis techniques required. At Pacific Northwest National Laboratory (PNNL, USA), in collaboration with Mirion Technologies (USA), a prototype system suitable for station deployment is being developed. Designed for practical implementation and operation, the system consists of acquisition electronics that are compatible with the existing station hardware and streamlined software capable of calculating the activity of relevant radionuclides using coincidence algorithms. This presentation discusses the design, validation and performance of the system, and compares the detection sensitivity with standard IMS stations.

Promotional text: The next-generation gamma-gamma coincidence system aims to advance the capabilities of IMS radionuclide monitoring stations. It is aligned to Theme 3: Verification Technologies and Technique Application – Design of Sensor Systems and Advanced Sensor Technologies (T3.1).

P3.1-361 – Microbarometer for infrasound monitoring systems

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The microbarometer for infrasound monitoring systems was developed by FSUE VNIIA, the leading organization of the State Atomic Energy Corporation Rosatom for the implementation of the CTBT. The microbarometer is used to receive infrasonic vibrations of atmospheric pressure and is intended for use in facilities of the CTBT International Monitoring System.
Compared to existing analogues, the developed microbarometer provides a low level of intrinsic noise, high long-term stability of -10 years' characteristics and has a built-in system for monitoring performance.

Main characteristics:
- operating frequency range, Hz from 0.01 to 20;
- maximum amplitude of infrasounds oscillations, Pa 150;
- SKZ of own noise in frequency band 0.02-4.0 Hz, mPa less than 1;
- Range of operating temperatures from minus 40 to 50 °C;
- operable after exposure:
– Maximum reduced (minus 55 °C) and increased (60 °C) temperatures;
– after immersion in water at a depth of 1m;
– after falling from a height of 0.75m.

Promotional text: Compared to existing analogues, the developed microbarometer provides a low level of intrinsic noise, high long-term stability of -10 years' characteristics and has a built-in system for monitoring performance.

P3.1-362 – Making the best use of pixel silicon detector for radioxenon traces measurement: a simulation study

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Noble gas stations installed on the IMS are designed to detect low level concentrations of radioxenon in the atmosphere. In order to improve sensitivity, one can either increase the volume of air sampled or lower the minimum detectable activity. Designing new detectors allows noble gas station developer to play on both grounds.
After 5 years of research and development, high resolution electron detector, the PIPSBox, based on silicon technology was created and implemented on the new generation of SPALAX system. Recently, work was conducted on designing a higher volume cell using pixelized silicon detectors. From this, a new sample cell, double sided by four 3 cm x 3 cm silicon pixels, was designed: the PIXELBox detector. Nevertheless, other silicon pixels configurations can also be considered in order to design well-type sample cells.
Simulation work regarding achievable efficiencies for such designs will be presented. Discussions on designs regarding their mechanical feasibility and extra features will be provided.

Promotional text: Investigation for future detection systems desgined for radioxenon measurement.

P3.1-375 – The Swedish Radioxenon CUBE Array – operational experience and first data

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The worlds first radioxenon array was installed in Sweden during 2020-2021. The array consists of five so called SAUNA CUBE units, placed with 200 – 500 km inter-distance. Each CUBE unit has a measurement sensitivity for 12-hour samples comparable to the SAUNA II systems presently used in the IMS, but to a fraction of the cost. Array design, experiences from installation, and first months of operation of the array will be reported, as well as analysis of array data compared to data collected by a next generation SAUNA III system simultaneously running in Stockholm.

Promotional text: This is the first test of a new, unique concept in radioxenon detection, that has the potential to advance the field of radioxenon verification substantially.

P3.1-393 – The second generation of precision small-sized temperature sensors: measurement and take in account the internal temperature of seismic instruments

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One of the main noise-causing factors in precise long-period seismometry is temperature fluctuations of mechanical elements of devices and sensitive sensors, as well as temperature oscillations in their interior space. To reduce such noise level it is possible to apply adaptive filtering of seismic signal based on elements temperature acquisition. However, to date, this way it was not possible to achieve significant results since there were no small systems capable of recording temperature changes with sufficient accuracy. The developed precision small-sized temperature sensors are capable of simultaneously monitoring the temperature at several of the most important points of many seismic device with an accuracy of at least about 0.001 Celsius degrees.

Promotional text: One of the main noise-causing factors in precise long-period seismometry is temperature fluctuations of mechanical elements of devices and sensitive sensors. To reduce such noise level we promise to use our precision small-sized temperature sensors.

P3.1-394 – The second generation of precision small-sized temperature sensors: investigation of thermal fields near the Elbrus volcano on the basis of the North Caucasus Geophysical Observatory

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The Baksan Neutrino Observatory of the Institute for Nuclear Research of the Russian Academy of Sciences is a unique engineering facility, which is a system of underground mine workings in the Andyrchi mountain massif (at a depth of 2 km from the surface and 4 km from mine enter) located twenty kilometers from the Elbrus volcano down the Baksan gorge in the Neutrino village. The unique location of the laboratory allows for a comprehensive analysis of various geophysical fields recorded in an almost complete absence of interference. Precision temperature measurement provides quantitative information about the heat flow from the interior of the Earth, which is fundamental for a deeper understanding of the relationship between fluid-magmatic and geodynamic processes. It allows obtaining unique data on the structure and dynamics of the thermal field of the Elbrus volcano. This study is a particularly important task from the point of view of obtaining new fundamental knowledge about the structure of magmatic structures, and from the point of view of assessing the volcanic hazard caused by the presence of liquid magmatic melt in the interior of the volcano, which in turn will provide new data on the potential hazard of the Elbrus volcanic center.

Promotional text: The system of precision temperature measurements, developed at the IPE RAS, is a part of the North Caucasus Geophysical Observatory of the IPE RAS. It allows obtaining unique data on the structure and dynamics of the thermal field of the Elbrus volcano.

P3.1-396 – Ice geo-hydroacoustic buoy: first field test results

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In recent years, a new prototype of a geo-hydroacoustic buoy has been created at the IPE RAS. The buoy is designed to collect acoustic, hydroacoustic or seismoacoustic data in various environmental conditions. It can be installed in onshore and offshore wells. The main purpose of the buoy development was its use for operations in the Arctic latitudes as an element of distributed drifting ice-class antennas. These buoys can be suitable for IMS station in Polar conditions. The buoy is built on a modular structure and can include a combination of sensors: a vector scalar hydroacoustic accelerometer, a broadband molecular electronic velocimeter, and additional hydrophones. A significant advantage of the buoys is their robust case, which allows them to be used on ice fields and under water at depths of up to 300 meters. They can be moving without special handling, which is especially important when transporting by such special means as boats, helicopters, etc. The advantage of the buoy is its low power consumption, which ensures stable autonomous operation for at least one week. Recently, several field tests of buoys have been carried out, during which it was confirmed that they fully meet the high standards of modern seismological instruments.

Promotional text: In recent years, a new prototype of a geo-hydroacoustic buoy has been created at the IPE RAS. The main purpose of the buoy development was its use for operations in the Arctic latitudes as an element of distributed drifting ice-class antennas.

P3.1-434 – Upgrading the Detection System of the MIKS (TKAS6) Xenon Isotope Monitoring Complex during Preparation for the International Certification

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The initial version of the beta-gamma coincidence detector of the MIKS complex failed to meet the requirements specified by the PTS of the CTBTO Preparatory Commission for the energy resolution of the beta channel and the memory effect. After the substantial upgrading, the energy resolution of the beta channel of the redesigned detectors is 37–38 keV for the 129 keV line and the memory effect does not exceed 3%, which meets the PTS requirements. The container of the QC source has been replaced with a container that is more transparent for gamma rays.
The tests of the upgraded detection system of the MIKS complex prototype, the analysis of the data files transferred by VNIIA to the IDC based on the test results, and the prompt implementation of the PTS recommendations by VNIIA confirm the readiness of the MIKS (TKAS6) xenon isotope monitoring complex for its certification in the International Monitoring System.
In order to successfully certify the MIKS complex taking the remoteness of its location (IMS RN58 Station near Ussuriysk, Primorsky krai of the Russian Federation) into account, VNIIA will provide prompt response to any undesirable event during the certification operation of the MIKS complex.

Promotional text: The process of development and modernization of a detection device for a radioactive xenon detection system based on the beta-gamma coincidence method is described.

P3.1-444 – Combination of “Open source architecture” and “Compress Sensing” makes next generation of geophysical equipment

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Aliasing is caused by discrete sampling below the Nyquist frequency. In order to recover the harmonics of shape in a signal, it is necessary to use a sampling rate at least twice the highest waveform frequency (Shannon Theorem). This means more volume of storage or more bandwidth for transmission. If we could overcome this limitation, we can reduce the sampling rate by less than twice the maximum frequency and the cost of storage media and bandwidth for data transmission would be reduced. It could also have an impact on reducing energy consumption.
The latest method to reduce the sampling rate is the Compress Sensing method to digitize analog data, which allows us to work with a sampling rate less than the number of maximum frequency.
On the other hand, manufacturing companies generally use arm or x86 architecture to develop their systems. Because software support is discontinued from a specific architecture within ten years, hardware manufacturers are also losing support for their systems, and the ultimate customer is paying the cost of this technology change.
A combination of open source architecture and compression sensing could start a revolution in the new generation of geophysical equipment.

Promotional text: Combination of “Open source architecture” and “Compress Sensing” makes next generation of geophysical equipment.

P3.1-473 – Design and production of Shaking Table for testing velocity meter and accelerometer in Iran

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Iran’s economic sanctions, along with the ever-increasing advances in digital technology and the presence of high-level experts, have made Iran one of the pillars of producing high-tech geophysical equipment in the Middle East, and will close the competition with the products of major corporations such as nanometrics and guralp. At present, high-precision digital recording equipment with velocity meter and accelerometer are produced in Iran. The production of this equipment requires testing and calibration equipment, and since many of the testing and calibration equipment are dual-use, their sale to Iran is prohibited, so it was necessary to manufacture the equipment in the country.

After studying a wide range of shaking table manufacturing experience in the world, the researchers of GeoPersian Co developed an affordable structure with facilities in the country using the best equipment available to us. One of the remarkable features of this shaking table is the possibility of creating high acceleration at low frequencies. The calculations required to determine the maximum course required for the round trip, the maps, and the test results are the material that we covered in this poster.

Promotional text: Design and production of Shaking Table for testing velocity meter and accelerometer in Iran.

P3.1-485 – Measurement of gaseous fission products on an electron-photon coincidence detector system

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Gaseous fission products have been produced via neutron irradiation of a uranium target and extracted using a custom gas processing system for measurement on a high-resolution beta-gamma coincidence detection system. The gas was extracted and measured in two stages in order to measure the prompt and delayed fission products. This poster presents an overview of the system used to extract gaseous products, and the results of the advanced coincidence techniques used to identify and quantify the radionuclides present. This work demonstrates the capability to produce gaseous radionuclides for quality assurance and calibration purposes in Radionuclide Laboratories supporting the Comprehensive Nuclear-Test-Ban Treaty (CTBT) as well as for the calibration of equipment used for criticality monitoring.

Promotional text: Fission product gases have been produced, processed and measured on a high-resolution beta-gamma coincidence spectrometry system. Results from the measurements are presented.

P3.1-495 – Analysis and Design of Wide Spectral Imaging Spectrometer for CTBT OSI

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According to scenarios of Comprehensive Nuclear-Test-Ban Treaty On Site Inspection (CTBT OSI), a kind of wide spectral imaging spectrometer based on aviation platform (including UAV) is proposed. The methods of detecting and recognizing nuclear test based on optical remote sensing are summarized, and several application fields using hyper spectral data are analyzed, such as detecting the changes of geography, landform and its spectrum, as well as plant stress. Aiming at the analyzed features, single grating is adopted to realize highly compact design of the spectrometer, which has wide spectrum range from VIS to MWIR (0.4μm -5μm) with high SNR (1000). Based on the further study and comprehensive discussion with the experts in the field of nuclear test inspection, we expect to upgrade the spectrometer for a better application.

Promotional text: According to scenarios of CTBT OSI, a kind of wide spectral imaging spectrometer based on aviation platform (including UAV) is proposed in this paper which can be used for detecting and recognizing nuclear test, expanding methods of CTBT OSI.

P3.1-506 – Large Surface Detector System for the Contamination Evaluation of Air Filters

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The system is an alpha/beta detector able to determine the independently alpha and beta contaminations based on PSD (pulse shape discrimination) capabilities of the scintillator and the real time digital pulse processing of fast electronic readout. The detector is designed for measuring alpha and beta emitter contamination on large air sampling filters and to complement the high-resolution spectrometry of gamma radiation.
The detector is based on a ZnS scintillator with a sensitive surface of 576 cm2 and an active area of more than 97%, that can be customizable. It is embedded in a shielding structure to reduce the external background and radiological content coming from other filters located nearby.
The system was laboratory tested with the procedure used for contamination monitors based on large area radioactive sources to verify its functionality and the uniformity for both alpha and beta sources. Results demonstrate a good response to the different source energies and over the full area. The signal discrimination analysis used, electronics, software, test procedure and measurements performed will be described.

Promotional text: The system exploits digital pulse processing to identify beta and alpha radiation with large surface detectors and rejects cosmic radiation background. This detection system could be integrated in the CTBTO gamma monitoring stations, for an additional assay of the air filters.

P3.1-512 – Past and future developments of noble gas detection systems at CEA/DAM

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For several decades, CEA/DAM is developing noble gas detection systems for nuclear test detections. In particular, CEA/DAM developed the SPALAX system which started to integrate the CTBTO IMS network in Tahiti in 2002. In 2015, CEA/DAM started the conception and realization of the SPALAX New Generation (SPALAX-NG) integrating the results of several years of R&D on material adsorbents and electron/photon detectors. The first industrial system has been released in 2017 and is currently finalizing its qualification by PTS. In its continuous effort of R&D, CEA/DAM is already prospecting for the next generation technologies. This presentation aims to provide an overview on the past, recent and future developments for noble gas detections at CEA/DAM.

Promotional text: Past and future development in radioxenon detection at CEA/DAM.

P3.1-520 – Design of Wind Noise Reduction System and Technique Application

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Enviroearth has developed over the past few years Wind Noise Reduction System (WNRS) of advanced technologies that meet all the requirement and configuration for each of the infrasound

stations topology over the whole IMS Network. Among the continuous improvements made to the design of these systems systematically associated with micro barometer sensors, we will mainly present the possibility of verifying the correct installation of our WNRS by carrying out a pressure test regardless of the WNRS model installed. In addition, we will introduce the reference system technology developed by Enviroearth. The objective being to compare the signal received by a sensor connected to a standard WNRS in parallel to a sensor connected to a reference system and thus to make analysis and verification on the corresponding signals received. The studies carried out on the comparison of these 2 signals provide rich information in terms of verification method as well as analysis of spectra and events.

Promotional text: Over several years Enviroearth has been working on optimizing its WNRS by supplying and deploying systems on IMS infrasound sites. Therefore, we continuously improve the design of our products to best suit the CTBTO needs and would like to share all our corresponding knowledge.

P3.1-524 – Timing Board: a new module for very low-consumption timing applications

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CEA/DAM, in partnership with the startup Fullscale, has developed a compact board, targetted to easily integrate any equipment with accurate dating needs.
Based on GNSS reception to get an absolute time reference anywhere in the world, the Timing Board provides standard PPS signal and NMEA frames, and optionnally a stabilized 4 MHz clock. Its extra-small size and very low consumption (<40 mW) allow it to be embedded in any kind of device, such as compact digitizers or digital sensors.
The Timing Board module offers a very high stability without GNSS reception: the maximum drift is +/- 20 ppb over a wide temperature range [-20℃; +70℃].
This module meets the PTS requirements in terms of timing and will be integrated in SMAD and MB3d digitizers soon.

Promotional text: Timing Board: a new module for very low-consumption timing applications with very high accuracy.

P3.1-527 – Tests and Performances of a Special Identifier of Nuclear Threats and SNM in Realistic Scenarios

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This paper presents the results of extensive tests conducted for more than 4 years, towards the realization of a portable backpack systems for the measurement and identification of radioactive material and at the same time determine in real time, without the support from experts, presence of SNM isotopes: U, Pu-239, PuWG, UWG, Am-Be, Am-Li, or their combination with masking sources and shielding. The performances of the device are exceeding the reference standards in sensitivity and furthermore for its capability SNM identification. The exclusive feature of this instrument is the capability to discriminate between fission sources (like Californium ^{252}Cf) and alpha-n type sources (like Americium Beryllium Am-Be) from Plutonium and Uranium through an innovative dedicated

parallelized algorithm. The neutron source detection has also been proved in a gamma ray field up to 100-300 µSv/h.
This device, based on an organic liquid scintillator with excellent Pulse Shape Discrimination (PSD) proprieties for the simultaneous detection of gamma rays and neutrons, detects radioactive source as SNM, medical, industrial and Naturally Occurring Radioactive Material. An additional inorganic scintillator is also embedded, giving the capability of calculating Pu and U enrichment grade through characteristic gamma emission lines.

Promotional text: The system presented can perform the characterization of nuclear and other radioactive materials using a combined detection of fast neutrons and gamma radiation that can help to determine the origin and history of the materials under assay.

P3.1-616 – Xenon International Acceptance Test Phase 1

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Xenon International is a next generation radioxenon monitoring system that was developed at PNNL and being manufactured at Teledyne Brown Engineering (TBE) to strengthen nuclear test monitoring and has recently completed phase-1 testing for acceptance as a qualified system for the International Monitoring System (IMS). Xenon International processes samples every 6 hours generating over 2.5 cc of xenon gas that is counted in a beta-gamma coincidence detector for 12 hours resulting in unprecedented detection limits for radioxenon isotopes. Phase 1 testing was conducted at TBE and consisted of a PTS acceptance visit, radioxenon spikes processed on Xenon International, and 6 months of uninterrupted automated sampling and analysis. Radioxenon analysis data was automatically sent to the PTS after the finish of each count. Xenon International completed phase 1 testing with >98% uptime, and routinely detected never-before seen radioxenon isotopes in an IMS station including ^{125}Xe, ^{127}Xe, and ^{129m}Xe. This talk will discuss Xenon International performance during phase-1 testing and will discuss the impact of unexpected radioxenon isotopes on detection of treaty verification radioxenon radionuclides.

Promotional text: The work cited in this presentation fosters strengthening nuclear test monitoring though development of advanced radionuclide detection systems. Phase 1 testing also strengthens remote monitoring of nuclear explosion, data interpretation, and data availability of complex systems.

P3.1-618 – Ukrainian infrasound network - current state and short-term perspective

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Until recently, the infrasound network in Ukraine consisted of two infrasonic arrays with a small aperture. However, the situation changed when we managed to create our own inexpensive digital condenser microbarograph (DCM). It has a frequency range of 0.05 to 15 Hz, a sensitivity of 40

mV/Pa, and an amplitude range of 200 Pa. Now, the array in the Kamenets-Podilsky region consists of 8 microbarographs. The array near Malin consists of 3 elements. The infrasound array near Radomyshl was created from 4 microbarographs in 2020. A site has been prepared for placing a three-element array in the Luhansk region (next Odesa region). The tests of microbarographs on the PS45 seismic station elements have also been successfully carried out and the installation of 7 microbarographs is planned. For research purposes, a 3-element mobile array is available. The infrasonic microbarograph at Vernadsky station (Antarctica) is supplemented with a set of 4 Chaparral Model 64 microbarographs. All data in miniSEED format are collected at the NDC. A cloud service has been created for remote work with infrasonic data. The modernized network is a big step towards ensuring the implementation of the CTBT Treaty by national means. It is also a good tool for regional observations.

Promotional text: Infrasound technologies, which are developing at the national level, are an important part of the provisions of the CTBTO Treaty. By developing the national network, Ukraine contributes to the improvement of monitoring.

P3.1-642 – Levels of background seismic noise in Venezuela with an emphasis in the AS117 and AS118 IMS stations

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The background seismic noise in Venezuela has been studied using broadband stations of the Red Sismológica Satelital Nacional (RSSN) (Netcode VE), including stations AS117 and AS118 of the auxiliary network of the IMS. To calculate the most representative values of noise at a given period, the method proposed by McNamara and Buland (2004) has been applied.
For periods lower than 1 s, the AS118 station shows values of -131.5 dB, while AS117 shows values of -121.5 dB. This 10 dB difference is attributed to the continuous discharge of water from the dam where AS117 is installed. For periods longer than 30 s, the vertical component of AS117 presents noise values close to the NLNM proposed by Peterson (1993), while the horizontal components present a sharp increase in noise values. The exact opposite behavior occurs in station AS118.
An interpolation of the noise values was generated in the range 4 - 8 s (double frequency peak) where high noise values were observed in basins and low values in mountain ranges.
The results obtained are important for studying the behaviour of the stations and detecting equipment failures. In addition, we show the behaviour of noise sources in Venezuela.

Promotional text: The results obtained in this study are important to understand the behavior of the IMS seismic stations in Venezuela. This study uncovers important information for the analysis of background noise collected by this auxiliary sensors.

P3.1-644 – A comparison of gamma spectrometry detectors for analysis of IMS samples.

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The South African radionuclide laboratory (ZAL14) supporting the Comprehensive Test Ban Treaty's International Monitoring System (IMS) is situated at the South African Nuclear Energy Corporation.

The laboratory is equipped with two ultra-low background HPGe detectors gamma-spectrometry systems (Canberra BEGe5030 and BEGe65) of which the BEGE5030 has been certified for analysis of IMS samples. To ensure sustainable analytical service for IMS operations, the ZAL14 laboratory aims to commission the BEGe6530 detector as a backup for the current certified detector. The purpose of this study is to verify that the detector complies to the technical requirements for certification listed in table1 of CTBT/PTS/INF.96/Rev.9. Additionally, the performance of the detector will be evaluated by analysis of IMS proficiency test samples and comparing results against the certified detector.

Promotional text: This work is aimed at improving on nuclear test verification methods for testing IMS samples.

P3.1-646 – Infrasound and electromagnetic sensor array in several configurations for monitoring active volcanoes in Ecuador

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The scope of the prototype presented in this work was to create a compact and flexible sensor array, reliable enough to be used in volcanic monitoring. In order to achieve this objective, we used an Spartan-6 L X 45 FPGA as the base of the embedded system, getting the capability of continuous acquisition at a configurable velocity up to 50 ksps. In addition, the equipment has some features as 12 24-bit ADC channels available and expansible to 24 channels, USB and SD-card data storage, Ethernet communication port, LCD display for basic information and time synchronizing via external GPS. As a direct application of this prototype, a mathematical model based on the solution of Maxwell's equations was implemented to obtain a comparison pattern that was verified with the results obtained by field tests in the Chiles and Cerro Negro volcanoes and the processing of signals by software specialized in arrays.

Promotional text: It is a new technique that is being applied in volcanic monitoring, in Latin America it has not been applied yet and Ecuador is a pioneer in applying it and compared to other techniques, good results are being obtained.

P3.1-665 – Resolving complex infrasound wavefields using a dense array

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Complex infrasound wavefields (containing multiple simultaneous waves with different slowness vectors) pose a challenge for traditional array analysis. We approach this problem using a dense array (22 sensors) as a field method, and secondary infrasound from earthquakes as a research target. Secondary infrasound from earthquakes contains potentially useful information on ground shaking, but the presence of many interfering waves from different radiators complicates source analyses. Using both direct waves from a local earthquake (M3.5, 10 km) and refracted waves from a regional event (M6.5, 720 km), we show that the detail and resolving power provided by array analyses can be improved dramatically by increasing the number of sensors in the array.

Many routine applications of infrasound face the challenge of distinguishing wave sources of interest from superposed waves from many sources, and single-channel rapid-deploy instrumentation suitable for "large-N" recording is increasingly available (e.g., the Gem infrasound logger used in this work). Consequently, we expect our methods and findings to be broadly applicable beyond our specific problem of earthquake infrasound.

Promotional text: Adding more sensors to infrasound arrays increases their resolving power, facilitating detection of weak signals and identification of multiple simultaneous waves from different directions.

P3.1-666 – Fiber-optic gyroscope to catch ground motion: a short review of blueSeis use

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For the past 3 years, rotation of ground motion can be measured with a portable broadband instrument. Thanks to its expertise in fiber-optic gyroscope learn into navigation market, iXblue have been able to offer a product line called blueSeis to bring the unmatched performance of this technology from submarines to seismic field.
However, not everything has been straightforward, and there is still margin for improvement. So, in this presentation the most important failures that occurred during this short story will be described. Indeed, shortcomings are usually the best way to get to know someone or something better.
Early adopters are also discoverers, and the main papers and results from the use of blueSeis sensors will be summarized here to give a broad overview of what can be done with this brand new sensor.
Finally, the next steps for the development of the blueSeis product line will be revealed with the very first experimental test results of our upcoming product, which will have improved sensitivity.

Promotional text: Rotation of the ground can be measured now thanks to the fiber-optic gyroscope. This poster will share the story of the use of this brand-new instrument offered by iXblue, and share some information about future development.

P3.1-667 – Design Scientist

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All broadband, low noise velocity borehole sensors manufactured have limited high frequency response. In this paper, results from the 89 mm diameter measuring only 600 mm long VBB very low noise sensor with 250 Hz High frequency corner (-3 dB points at 360 seconds and 250 Hz) is presented.
The high loop gain feedback sensor modules are based on mechanical long period suspension system. The modules are stacked 90 degrees to each other and the complete package with hole-lock weighs less than 22.5 Kg
Methods used to test the three borehole sensors is described. The test results are provided from triplet collocated borehole sensors with identical frequency responses.
The borehole sensor clamping mechanism is described. The topology of single jaw hole lock resonances is beyond 300 Hz providing resonant free sensor installation exceeding 300 Hz.

Promotional text: This abstract is describing a new technology for instrumentation of Borehole sensor systems for detecting underground manmade explosions. The described sensor system unifies high frequency and broad band long period sensor systems which currently does not exist.

P3.1-669 – Electrostatic Precipitator Integration into RASA 2.0 for Radionuclide Particle Collection

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Creare has previously designed an electrostatic precipitator (ESP) collection system as a drop-in enhancement and replacement for the current RASA, the U.S. built Radionuclide Monitoring Station, as presented at S&T2019. This current work incorporates a full new design for the next generation of monitoring stations, RASA 2.0, with several significant improvements including advanced detectors, increased particle collection efficiency, lower power consumption, and potentially shorter collection times. The ESP incorporates a new form factor, potential for new collection material, and improved integration into advanced detectors. Our advanced two stage ESP has shown greater than 90% particle collection efficiency at both 0.2–0.3 µm and 10 µm particle sizes for 2000 m3/hr flow rates using 1443 W of ESP and blower power. The power consumption is almost 10x lower than the current impact filter RASA system at that same nominal flow rate of 1000 m3/hr, and also consumes less power at 2000 m3/hr than the current system at 1000 m3/hr—approximately 25% lower. The ESP can be dynamically and remotely controlled to change the particle collection efficiency within seconds from less than 50% to greater than 95% efficiency depending on the conditions and needs of the users.

Promotional text: This work advances the radionuclide particle collection and detection by developing an electrostatic precipitator for the next generation of monitoring stations that will directly benefit CTBTO's radionuclide stations in the International Monitoring System.

P3.1-670 – Study of materials for improved adsorption of xenon at IMS radionuclide stations

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Xenon monitoring systems are a crucial component of the verification system of the CTBT. As part of the IMS, these systems are monitoring the atmosphere for potential xenon releases originating from nuclear explosions. The efficient adsorption and desorption of the xenon isotopes in adsorbent materials is essential for their detection.

Recent studies on xenon adsorption in porous materials have shown promising results for possible use in the IMS noble gas systems. In the framework of the two previous EU Joint Action programs, SCK CEN developed a laboratory set-up to perform breakthrough experiments on different adsorbent materials and developed a model for the simulation of the adsorption process. Although this research was performed in a different context, it was obvious that the studies performed and the methods developed could be beneficial also for xenon monitoring purposes.

The SCK CEN has been contracted by the CTBTO under the EU JA VII program to perform a fundamental comparative study of xenon adsorption materials which, depending on the results, may be used for future alternatives for noble gas monitoring at IMS stations with the aim of higher detection capability. The project was completed end of 2020 and the results will be presented.

Promotional text: During this project, new Xe adsorption materials were investigated for potentially improving or providing future alternatives to current IMS noble gas systems with the aim to enhance the detection capability of the noble gas component of the IMS.

P3.1-713 – A coherent gas-combustion infrasound source

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An invaluable tool in characterization of any receiver, propagation path, or detection system, is a source with known and repeatable signal characteristics. This talk will discuss engineering development and evaluation of a coherent (non-explosive, periodic, with controlled duration) infrasound source with frequency capabilities in the sub-hertz to several hertz band. Design of a sound source within this band is a difficult engineering challenge. The simple source equation, which will govern any portable human-fabricated infrasound source due to the long wavelengths, shows this fundamental difficulty. As frequency decreases volume displacement must increase by the squared inverse factor of frequency in order to maintain an equal pressure amplitude at equal range. For this reason, the authors evaluate utilizing the high energy density available in gas combustion to periodically displace large volumes of air within the open atmosphere. Prototype testing has verified the capability of generating continuous signals at a fundamental frequency of 0.25 Hz at ranges >1 km in low wind conditions. Generation of harmonics of this fundamental throughout the 0.25-4.0 Hz band with reasonable signal-to-noise ratio was also demonstrated. These results will be reviewed, and efforts to increase useful source range will be discussed.

Promotional text: Development of a cost effective and transportable non-explosive infrasound source to aid in verification of infrasound monitoring sites.

P3.2 Laboratories including transportable and field based facilities

P3.2-279 – Proficiency Test Exercises (PTE) : Bringing Certainty into Uncertainty

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The international monitoring network of radionuclide stations of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is supported by 16 radionuclide laboratories. As part of a continuing performance evaluation programme for these laboratories PTEs have been organised for the particulate and noble gas measurement capabilities of the IMS laboratories. PTS has been evaluating additional tools to the standard PTE grading scheme to assist laboratories with improving quality of results. This includes the statistical evaluation of zeta test scores and evaluation of measurement data including interferences. One of the critical steps in analysing a gamma spectrum includes the decision on which nuclides are present in the sample. Statistical methods employed in standard commercial software for evaluating whether the measurement signal is consistent with background noise ignore complications that may arise from interfering radionuclides. We present results for extracting information on uncertainties from zeta statistics and of applying a modified method for determining characteristic limits based on ISO11929:3 (2019) to experimental spectra.

Promotional text: Proficiency Test Exercises not only provide performance evaluation of IMS laboratories, but can also provide additional tools for laboratories to improve the quality of their analysis.

P3.2-424 – Modification of OSI radioxenon processing system

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In order to play a more important role in the OSI activities organized by CTBTO, such as inspector training, the single technique test or exercise, build-up exercises (BUEs) and the OSI integrated filed exercise (IFE), et cetera, the Northwest Institute of Nuclear Technology (NINT) manufactured one brand new OSI radioxenon processing system (or XESPM-III Mark II). Comparing with the XESPM-III Mark I, four aspects of modifications have been made. First, sufficient amounts of switchable parts installed before each running can fulfill the aim of automatic processing without an attendant. Second, the refrigerating temperature has been lowered further to increase the sampling volume per trap due to the enlarged adsorption efficiency. Third, the processing volume is doubled to the amount of 8m3, consequently the least minimum detectable activity concentration (MDC) can be halved. Fourth, the processing time is shortened, so the daily processing throughput can be further increased. The technical specifications of XESPM-III Mark II has obviously been improved, such as more sensitive, faster in processing and more adaptable for field use, et cetera.

Promotional text: Three-generation OSI radioxenon systems have developed, and participated in some activities organized by PTS since 2002. In order to play more important role in the build-up exercise, one modified XESPM-III was manufactured, whose specifications have been improved a lot.

P3.2-518 – Introducing Mobile SPALAX NG version

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In the context of the Comprehensive Nuclear Test Ban Treaty (CTBT), the CEA/DAM developed the SPALAX (Système de Prélèvement Automatique en Ligne avec l'Analyse du Xénon) about 20 years ago which is used in the International Monitoring System to detect xenon releases following a nuclear explosion. The new generation of the system has been successfully developed by the CEA and CEGELEC Défense. It is now fully operational. For the second system, CEGLEC integrated the SPALAX NG modules in a shelter. This way, it can be deployed easily anywhere in the world. It is energy self-sufficient (generator) and can be supplied by different electricity networks. CEGELEC climate chamber reproduces extreme weather conditions and the tests of the SPALAX-NG shelter were very satisfying. It is now in service in France for the CEA experimentations.

Promotional text: The Spalax NG should be part of the IMS stations in the future. We wish we introduce the shelter version of the product.

P3.2-691 – Design considerations and layout of the new OSI Field Laboratory

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According to paragraph 69(d) of Part II of the Protocol to the CTBT, future OSI inspectors are permitted to analyse environmental samples from above, at and below the surface to detect anomalies. These analyses shall take place at the OSI field laboratory which must be designed for ready deployability, set-up and in-field operation.

The OSI action plan for 2016-2019 aimed at improving and testing the design of the OSI field laboratory in general and the set-up and in-field operations for radionuclide noble gas sample processing and analysis in particular. The configurations of the field laboratory with due regard to the specific requirements for measuring OSI relevant xenon and argon isotopes were assessed. The approach taken comprised the preparation of a draft layout and design of the next generation OSI field laboratory from the perspective of the requirements for radionuclide noble gas sampling and analysis.

This poster provides a summary of the layout and design of the next generation OSI field laboratory. It highlights the requirements, the current status and future improvements of the OSI field laboratory for the development of OSI capabilities.

Promotional text: The poster addresses the configuration requirements of the next generation OSI field laboratory, their status and future development and therefore contributes to the objective of identifying opportunities for improving verification.

P3.3 Remote sensing, imagery and data acquisition platforms

P3.3-023 – Extending the infrasonic array from the stratosphere with multi-member ensemble, long duration, high altitude balloon constellation

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Stratodynamics proposes to deploy its NASA designed infrasound sensor aboard a constellation of long duration, high altitude balloons in collaboration with Project Loon.

By leveraging Project Loon's distributed data centre computation and blended Analogue Ensemble (AnEn) machine learning techniques, a balloon deployed infrasound sensor could enable revolutionary observations from around the world in real time.

The constellation could extend coverage of nuclear blast detection across the ocean and benefit from atmospheric attenuation/amplification effects of a stratospheric flight envelope.

Furthermore, sensor calibration could occur from a centralized recovery location with the infrasound instrument suite returned to the ground station on an automated trajectory. This would optimize resources for in-field calibration.

A secondary goal of the collaboration leverages these integrated technologies for early detection of Tsunami and earthquake events.

P3.3-059 – Commercial Nano Satellite Constellation's application to Multilateral Arms Control Verification

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Multilateral arms control and disarmament treaties would require, instead of National Technical Means (NTM), International Technical Means (ITM) as verification solution, due to its efficiency and transparency characteristics. With the rapid development of commercial space technology, space based remote sensing and communication technologies are no longer dominated only by a few states or organizations, consequently, they could be utilized by future multilateral arms control and disarmament regime as verification option, like CTBT. Nano satellite constellation, as a new trend of space technology, has raised attention for modular design, easy production, rapid deployment and cost efficiency. This work would explore Nano satellites' potential application to verification infrastructure. A Nano satellite would cost around several million dollars depending on different payload configurations. A constellation of Nano satellites could be produced and launched within a short period of time. A constellation of Nano remote sensing satellites (resolution up to sub-meter level) would achieve continuous monitoring over a certain inspection area. A constellation of Nano communication satellites would achieve in-real-time communication among inspectors in inspection area or providing communication link for IMS stations, which would provide practical support to the mission like OSI and IMS of CTBT in a place of nowhere.

Promotional text: This work would envisage the potential application of commercial Nano satellite constellation to multilateral arms control and disarmament treaties' verification. This would suggest a practical solution to future space based international verification technology.

P3.3-073 – Study of Ionospheric Total Electron Content (TEC) Variations before The 2019 M 6.9 Sunda Strait Earthquake in Indonesia

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Researchers around the globe have been carrying out studies related to short-term earthquake predictions. The studies use various approaches of observation methods to find the early signs of anomalies, both physically or chemically changes before the occurrence of earthquakes, as known as precursors. One of the precursors is the emergence of total electron content (TEC) anomaly within the ionosphere. Stress accumulation in the lithosphere can cause microfractures resulting in charged particles possibly release from those microfractures around the earthquake preparation zone toward the atmosphere and disturb the TEC variations. Therefore, this research aims to find the anomaly of TEC before M 6.9 of the 2019 Sunda Strait earthquake which hit several provinces in Indonesia around the Sunda Strait that caused 6 casualties and hundreds of injured. Moreover, this study implements the correlation technique with a threshold and obtains the TEC data from Global Ionospheric Maps (GIM) of the Center for Orbit Determination in Europe (CODE). As a result, it shows that an anomaly of TEC was recorded 22 days before the earthquake occurrence. Also, the Disturbance storm time (Dst) index is utilized to validate that the recorded anomaly is not caused by the geomagnetic storm.

Keywords: Earthquake, TEC, Ionosphere, Precursor.

Promotional text: I am very enthusiastic to participate in the CTBT Science and Technology 2021 Conference for improving my capacities and capabilities as a geophysicist. In addition, I also want to expand my network with other researchers, scientists, and professional careers around the globe.

P3.3-110 – Commercial Cost-Efficiency UAV for OSI Trainings and Exercises

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In CTBT treaty and OSI Operation Manual, Initial Overflight and Additional Overflight would be arranged to provide IT opportunities to understand the overall situation of Inspection Area and conduct specific inspections such as visual observation and multispectral imaging. In the past exercises and training, manned helicopters have been used for a long period of time. With the development of unmanned aerial vehicles (UAV), and also the practical health and safety concerns for inspectors to be onboard the manned airplanes or helicopters in real OSI, the potential application of UAV to OSI trainings and exercises has its practical meaning. This work would propose a commercial cost-efficiency unmanned helicopter system, which could be designed to meet the requirements of OSI. The UAV flight height could be restricted within the scope of 1000 meters, the flight boundary could also be restricted within the inspection area taking into consideration of the managed access requirement proposed by the ISP. The flight routes, through programing the flight control software of the UAV, could be jointly worked out by the IT/ISP field teams every day to keep the balance of inspection sufficiency and intrusiveness. The UAV could carry both commercial optical or multispectral payloads.

Promotional text: This work carried out a study on commercial cost-efficiency UAV for OSI, which would provide an option for OSI training and exercises, taking into consideration of health and safety concerns and also the balance keeping for mission efficiency and intrusiveness.

P3.3-112 – Remote sensing monitoring of earthquakes in Sudan with Land Surface Temperature

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Remote sensing plays a critical role in seismotectonics monitoring of active fault systems. In quest of finding the main geophysical parameters to be surveyed by geospatial and in situ measurements in an integrated monitoring system, this study is focused on the analysis of some earthquake activities recorded in the study area. Specific precursors can be reliably detected using satellite sensors through the capability of thermal remote sensing in the identification of seismically active areas. The behaviour of Land Surface Temperature (LST) is characterized by changes before earthquakes. The objective of this study is to find the relationship between earthquake active areas and thermal properties of earth surface. To this end, LST of MODIS sensor on Terra platform and Sentinel 3 images and some earthquake events from USGS and SRI Catalogues have been used as the material of the study. The study has found that the areas characterized by higher LST for long period have more seismic activity most probably represent major faults.

P3.3-132 – Deformation Identification Using DinSAR Multi Temporal Analysis and Gravity Method in Supporting Infrastructure Development

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The lack of information regarding land structures that are prone to deformation can have an impact on the failure of infrastructure development in the New Capital City Region. Therefore, it is necessary to conduct a study on the deformation that occurred in the area, as initial information in determining the location for safer infrastructure development based of the soil structure. This study uses the DinSAR (Differential Interferometry Synthetic Aperture Radar) method which will be analyzed multi-temporally, and combined with the gravity method to estimate the value of Simple Bouguer Anomaly (SBA) to determine the subsurface structure in the study area. The data used are SAR image of Sentinel 1A type SLC C band for the period 2015-2019 and the gravity anomaly model data Free Air Anomaly (FAA). The results obtained indicate that deformation has been identified in several areas with the maximum decrease is 12.97 cm and the maximum increase is 10.01 cm. Areas identified with land subsidence generally have relatively lower SBA values and thus have weaker soil structures. Areas that experience uplifting generally have a relatively higher SBA value than the surrounding area, and can also become areas for deposition of sedimentary material deposits.

Promotional text: I conducted research to map areas that are prone to deformation in the Indonesian New Capital City . By using the DinSAR remote sensing method and the gravity method.

P3.3-488 – Detecting nuclear activities using geospatial systems platforms

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Nuclear activity is a significant threat to the world peace. Monitoring such activities is important but in many cases it cannot be done in real time. Remote sensing and geospatial analysis play an important role in detecting the signatures resulting from these activities. These events leave impressive or disguised deep or superficial signatures on the environment, such as changes in the water table or in the surface water. Changes in the surface water can be monitored using data from multispectral imaging platforms. Image processing of non-homogeneity data, for instance, may result in errors caused by noise coming from surface signals and the error introduced by atmospheric effects can results in incorrect interpretation. Detecting water changes in satellite imagery is not an easy process because it depends on the human ability to accurately delineate water bodies. It can be achieved by digitizing manually or by extracting features automatically using a number of computational algorithms. Automatic feature extraction can produce faster results but it may mislead the interpretation because some features may occur naturally and not as the result of nuclear activity. Although image processing can provide some accurate results, it needs to be validated using other techniques to detect nuclear signatures.

Promotional text: It aims to discern how RS can contribute to the monitoring nuclear activity. Understand how effective and efficient some techniques perform is crucial for the response process. The quality of the data and the equipment available are important to assess and monitor such events.

P3.3-586 – Change Detection in Satellite Image using the Pixel Subtraction Method for Event Verification

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Remote sensing satellite data provide opportunity to obtain information about the surface of the earth at different spatial and spectral resolution. Satellite imagery has been used since the 1960s for reconnaissance studies and has since had large number of applications including, disaster mitigation planning, agricultural development, resource monitoring and surveillance purposes. A large number of change detection techniques has been developed to utilize satellite images and while there's no general recommendation on the choice of change detection method, new methods and technologies keep emerging. A satellite image does not only show the graphical presentation but also the quantitative description of the pixels obtained from the value of the reflected solar radiation from the surface. This paper is prepared to show the advantages and the promising use of satellite imagery for the detection of new activities using the pixel subtraction method in change detection technique.

Promotional text: This technology could be vital in remotely obtaining information about clandestine activities.

P3.3-692 – Use of Remote Sensing Technologies for Strengthening Verification Regime

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Micro satellites are cost effective, environmentally friendly and enjoy extended operational life in space. These can be equipped with smart state of the art remote sensors for acquisition of optical,

environmental and other data with all the possibilities of detecting related impacts remotely. Success primarily depending upon resolution and other related factors. These acquired data sets can be used to determine surface and subsurface tectonic and other manmade activities to include nuclear detonations. Subsurface activities both deep and shallow leave definite signatures on the surface conditions though depending upon time and other conditions. Speed of S-Wave travelling across the crust depends on the shear modulus and the density expressed by relation B= √(u/p). Therefore a correlation of data acquired from ground stations revealing direction and magnitude with intensity obtained from observations can be correlated with the spontaneous and long terms change detections by the remote sensing platforms. This correlation can yield more authentic scientific evidence towards establishing anthropogenic nuclear activity or detonations in particular. Deep detonations however may take more time and closer observations beside higher resolution of sensors present on board. Launching of a constellation to cover possible end points of body wave impact zones can yield useful results.

Promotional text: Use of Remote Sensing Techologies can be cost effective, more sustainable and more authentic beside being an additional source of data acquisition.

P3.5 Data analysis algorithms

P3.5-026 – Automatic Classification of Particulate Radionuclide Spectra

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This poster describes progress in 2020 of classifying IMS particulate radionuclide spectra into "likely normal" (Cat. 1,2) and "requires scrutiny" (Cat.3,4,5).The aim is to assist IDC radionuclide analysts by reducing their workload of "normal" spectra, which are the majority of IMS spectra.
The method described here is **entirely ignorant** of radionuclide science. The point of these efforts was to find how close to a correct classification one could get without using any radionuclide science. Accuracy of over 94% has been achieved. It is likely that injecting radionuclide science into the method will improve the results.

P3.5-114 – A new automatic first arrival picking algorithm based on a mathematical approach with considering the fractal dimension

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This research demonstrates a new accurate automated method for seismic first arrival picking that is based on a mathematical approach with considering the fractal dimension of seismic traces. Reliable and accurate detection of the first arrival is a key step for the determination of seismic parameters. In this work, we introduce an adaptive mathematical triggering algorithm by considering the fractal dimension variations along the seismic records. The results show that our proposed algorithm is quite reliable and it is less susceptible to false-positive detection errors. This suggests adaptive mathematical fractal dimension algorithm may be less sensitive to analyst parameter choices than other methods. Our proposed algorithm was verified using seismic records and synthesized seismic records with different noise levels. Also, we showed the performance and the results of the mathematical fractal dimension method on seismic records. The results emphasize that our proposed algorithm is quite practical and reliable for noisy and bad seismic records, and as well as, it is computationally efficient and easy to apply.

Promotional text: This research presents a new accurate automated method for seismic first arrival picking that is based on a mathematical approach with considering the fractal dimension of seismic traces. Our proposed method is quite viable and efficient for the determination of first arrivals.

P3.5-127 – Distributed detection and fusion of multi-signature explosion-sourced waveforms: predictive capability, quantitative performance, and experimental demonstration

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Quantitative methods that enable multi-physics waveform fusion support explosion monitoring and general research in geophysical processes that comprises background emissions for explosion monitoring. We offer a constructive method to fuse statistics that we derive from multi-physics waveforms and improve our capability to detect small, above-ground explosions over methods that consume single waveforms. Our method advances Fisher's Method to operate under both hypotheses of a binary test on noisy data and provides density functions required to forecast our ability to screen fused explosion signatures from noise. We apply this method against 12-day, multi-signature chemical explosion and noise records to illustrate three primary results. We show that: (1) a fused multi-physics statistic that combines radio, acoustic, and seismic waveforms can identify explosions roughly 0.8 magnitude units lower than an acoustic emission, STA/LTA detector for the same detection probability; (2) we can quantitatively predict how this fused, multi-physics statistic performs with Fisher's Method; and (3) that this data stream method competes well with lower fidelity, decentralized detection approaches. We additionally present our preliminary, but more general work that addresses multi-signature association of data streams to a common source.

Promotional text: This work supports the objective of improving nuclear test monitoring and verification by using chemical explosion test data to develop better methods of signal detection.

P3.5-178 – Classification of seismic events using a time-frequency based approach

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The automatic classification of seismic events is an absolute necessity when dealing with an important amount of data. Moreover, the classificationneeds to be achieved almost in real time. Due to the importance of an automatic task, various approaches have been proposed in the literature. Numerous approachesare based on features related to time domain, when othersexploit the frequency characteristics of the signal.
In this study, we propose a novel approach combining both frequency and time features to construct a robust classifier of the seismic events. To do this, seismic signals are presented in the time-frequency domain. It is shown that in this domain, the seismic signals of the same event source class reveal a degree of similarity. A tool is then developed to quantify this similarity and differentiate among the different classes. The performance of this approach is demonstrated using real seismic data of four classes. The results achieved were promising.

Promotional text: Improve nuclear test monitoring and verification by exchanging of knowledge and ideas between the CTBTO and the broader scientific community.

P3.5-183 – Using waveform correlation and template event metadata to reduce analyst workload

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Waveform cross correlation uses template waveforms from historical seismic events to detect recurring events from the same seismic source. Waveform cross correlation works well for dense regional networks, so research challenges arise when applying similar techniques to a sparse network such as the International Monitoring System (IMS). Effective waveform cross correlation requires templates

with broad frequency content to produce reliable single-station detections over a broad area, but because high-frequency information attenuates strongly over distance, such high-quality templates with broad frequency content only exist for stations at local to near-regional distances from the target seismic sources. Our research seeks to improve the effectiveness of waveform cross correlation detections through use of template event metadata and network analysis of corroborating stations. We seek patterns of multiple station corroboration of seismic arrivals to generate a more effective collection of template waveforms for a network of stations. A network-focused perspective of recurring events improves the credibility of detections, since the number of stations that detected the template event originally, in combination with the relative amplitude of recurring detection, enables estimation of how many stations are likely to detect the subsequent event; thus, we select waveform correlation detections to reduce analyst workload.

Promotional text: Identify opportunities and methods for improving nuclear test monitoring and verification by improving IDC automated pipeline with waveform correlation techniques to reduce analyst effort on routine recurring events such as mining blasts.

P3.5-185 – An envelope-based approach for seismic signal discrimination

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Seismic event source identification is one of the vital and primordial tasks in seismic signal processing. Indeed, the first goal of seismic signal analyst is to recognize the source of each recorded seismogram. For example, one of the main goals of CTBTO is to identify nuclear explosion from natural seismic events. Several complex methods have been studied in the previous researches.
The aim of the present research study is to investigate the capability of signal envelop, both in time and frequency domain, to classify seismic seismograms of different classes. To do so, a large database of real seismic seismogram was used. An algorithm is developed to extract the envelope of each seismogram in time and frequency domain and combine them to determine the corresponding seismogram class. The experimental results showed that, in addition to the simplicity of this approach, it achieves good accuracy. The algorithm is explained in details so that it can be reproduced in other seismic networks all over the world.

Promotional text: The aim of this work is to develop more simple and efficient seismic signal classification algorithms to help CTBT in recognizing nuclear explosions from other seismic events.

P3.5-194 – A semi-automatic cepstral method for seismic event depth estimation

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Seismic event depth is used for event characterization and location and is estimated using the vertical component of the velocity at the source and half the time interval between a direct P seismic phase and a similar shape echo, reflected from the surface, named depth phase or pP. The signal-echo separation can be estimated with cepstral methods designed for shallow-event cases when the P and pP seismic phases are not well-separated.
Our cepstral analysis method named CWAM1.0 used homomorphic deconvolution to retrieve the signal and echo, and proposed fifteen metrics to estimate the solution credibility. Because CWAM1.0 involves long and tedious trial-and-error analysis to find the best input analysis window parameters, the objective of this study was to design and test a semi-automatic depth estimation set of algorithms

named CAT1.0, with the ultimate goal of building an automatic cepstral analysis tool to be applied on events with depth less than 3 km. The tool is tested in this study on seismic waveforms from a series of well-located Nevada Test Site explosions.

Promotional text: The objective of this study was to design and test a semi-automatic depth estimation set of algorithms, with the ultimate goal of building an automatic cepstral analysis tool to be applied on events with depth less than 3 km.

P3.5-198 – The application of a dynamic correlation processor for IMS detection screening

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The vast majority of International Monitoring System (IMS) seismic detections are associated with small events that are detected by only one station. Large numbers of small-event detections at each IMS station increases the probability of the International Data Centre (IDC) automatic system building false events. We test whether detections of small, repeating local events (e.g., mines) can be identified and screened prior to the IDC association process. We use a dynamic correlation processor (DCP) (Harris and Dodge, 2011) to form groups of similar waveforms, and we then manually associate these groups to known mines and other sources. We first test screening at the Norwegian Arctic ARCES IMS array by applying the IDC beam recipe to the incoming data steam, then using the DCP software to group events. Preliminary results on this array show that for two beams, 80% and 74% of automated detections are found by DCP and may be screened before IDC preprocessing. These promising results suggest that the DCP screening method may be used to identify and screen detections that are not of interest to monitoring before they are passed to the IDC automatic system. Detection screening may significantly reduce analyst effort to produce the Reviewed Event Bulletin.

Promotional text: Small, repeating events that are detected by one IMS seismic station may be identified and screened prior to the event association process. Detection screening may reduce analyst burden by decreasing the number of false events that are formed by the IDC automatic system.

P3.5-234 – Performance monitoring of beta-gamma detectors using quality control data

Authors: Michael Mayer[1]; Matthew Cooper[1]; James Ely[1]; Justin McIntyre[1]; Johnathan Slack[1]

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Quality Control (QC) measurements are taken to monitor and correct for gain drifts in radioxenon nuclear detectors. The measurement is performed by placing a ^{137}Cs source near the detector and measuring the position of the 662-keV photoelectric peak in the NaI detector and determining the endpoint for the Compton scatter distribution, but there is much more information that can be gleaned from the collected spectra, which PNNL is now leveraging. This QC data set is being utilized to additionally monitor the health and performance of the nuclear detectors over time by determining the relative efficiency, resolutions, and gains with respect to the check source. Baseline determination of these detector characteristics and placement of quality control limits enables an operator to determine if an issue is happening or has happened with the detectors. This presentation will go over how we determine these QC detector characteristics and how they can be used to infer the health of the detectors.

Promotional text: This presentation provides new opportunities and methods for improving nuclear test monitoring and verification by leveraging existing data to monitor the nuclear detectors' health.

P3.5-235 – Method for calculating radon activity and radon rejection

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Radioxenon detection systems chemically separate and purify xenon from the collected atmospheric sample. These systems reject radon to a high degree during this processing step. On occasion, radon will make it to the nuclear detectors and its progeny will interfere with the radioxenon measurement. The minimum-detectable-concentration values of an atmospheric monitoring system will also be negatively impacted by the presence of this radon. To minimize these consequences, it is important to understand how much radon made it to the nuclear detectors and its effect. We have developed a way to calculate the activity of radon in the nuclear detectors using the coincidence beta-gamma spectrum and to determine the impact to the minimum-detectable-concentrations. This presentation will discuss the method to calculate the radon rejection levels needed to maintain optimal radioxenon detection sensitivity and the impact of radon on radioxenon uncertainties.

Promotional text: This presentation provides new opportunities and methods for improving nuclear test monitoring and verification by allowing radon activity and rejection levels of a system to be determined.

P3.5-236 – Technique to mitigate effects of detector gain drifts through use of larger regions of interest

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Radioxenon measurements use the net-count method to determine the activity for the radioxenon isotopes of interest. Detected decay events are plotted on a beta-gamma coincidence histogram and events are tallied inside regions-of-interest specific to a given radioxenon isotope. The boundaries of these regions are based on both the resolution of the detector and the physics of the emitted radiation of the radioisotope. Nuclear detector gain drifts can cause the energy calibration of the detector to be incorrect and the decay events to fall outside the region, causing inaccurate activity measurements if the detector gain drifts too much. One possible method to mitigate the effect of gain drifts is to increase the size of the regions-of-interest. This presentation will demonstrate the effect gain shifts have on activity calculations, how larger regions decrease this effect, and the impact larger regions have on the sensitivity of the measurement.

Promotional text: This presentation provides new methods for improving nuclear test monitoring and verification by providing alternative activity measurement analysis techniques.

P3.5-245 – A data visualisation tool for radionuclide detection events

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The United Kingdom National Data Centre (UK NDC) has developed a novel tool for the analysis of radionuclide (RN) detection events on the International Monitoring System (IMS). An automated process for the fusion of RN and atmospheric transport modelling (ATM) data streams has been produced which efficiently compiles a wealth of information in a single source and puts interactive virtual maps at an analyst's disposal for rapid data interrogation. A specially dedicated, automated radionuclide analysis pipeline periodically identifies 'plumes' of Xe-133 and high-priority RN detection events at IMS stations and these are compared with simulated station contributions from possible radionuclide emitters. For a given detection event, features such as wind direction vectors, station history and 2D representations of emission contributions are all available for visualisation and interaction within the new tool.

Promotional text: This poster outlines recent developments to the United Kingdom NDC radionuclide detection event analysis capabilities. An interactive data visualisation tool allows for the rapid interrogation of potential source locations.

P3.5-250 – Automatic quality checks of the Calibration files for RN Particulate Stations

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The International Monitoring System Division (IMS) of the CTBTO aims to maximize the data availability from the radionuclide monitoring systems. The detectors at the radionuclide stations require a calibration whenever a new detector is installed or the geometry is changed.

The maintenance unit of the IMS division is responsible for assisting the Station operator during calibration, ensuring that the data quality meets the requirements and that calibration and geometry files are submitted to the PTS in a timely manner. A ROOT based software program has been developed to automatically process the spectrum, compare it against the requirements and to the calibration pairs generated at the station. Discrepancies are then flagged for correction.

The process is the following. First the certificate block is retrieved from the calibration (CALIBPHD) file. Then the peaks at the energies from the certificate block are found and fitted. The results from the fits are compared against the requirements and data pairs from the station. The peak fits as well as both efficiency and FWHM curves are plotted and tabulated.

The results displayed allow one to assess the calibration spectrum swiftly and as a result to take immediate actions as needed.

Promotional text: A ROOT based software program has been developed to automatically process the spectrum, compare it against the requirements and to the calibration pairs generated at the station. Discrepancies are then flagged for correction resulting in a swift assessment of the calibration.

P3.5-278 – Accounting for radioxenon interferences

Authors: Matthew Cooper[1]; Brittany Abromeit[1]; James Ely[1]; Daniel Keller[1]; Michael Mayer[1]; Justin McIntyre[1]; Johnathan Slack[1]; Thomas Suckow[1]; Ryan Wilson[1]

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Radioxenon analysis is a critical part of monitoring for underground nuclear explosions. Algorithms that determine the activity concentration of a sample were developed over many years and continue to be updated as lessons are learned from automated radioxenon analysis systems. During Xenon International testing in the U.S., a large activity ^{133}Xe spike caused false positive hits for ^{133m}Xe and ^{131m}Xe, with similar false positive hits are expected when the metastable isotopes are present. The U.S. is developing algorithms that include interference terms for the four radioxenon isotopes and the radon daughters to reduce the biasing and false positives that are caused by large interference radioxenon spikes. The algorithms will use matrix inversion to solve the correlated interference terms simultaneously. The additional interference terms will provide radioxenon analysis that is more accurate under more conditions and will reduce the number of false positive results.

Promotional text: This work discusses a method that will improve nuclear test monitoring and verification by improving the accuracy of radioxenon analysis and is intended to disseminate the concepts to the broader monitoring community.

P3.5-280 – Quality Control source analysis using a rotating frame of reference

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Development of methods to track beta-gamma detector gains is important to the accuracy of radioxenon system measurements. Typical gain monitoring and correction is done using a mixed ^{137}Cs/^{154}Eu source, which results in several gamma-ray lines that can be fit by Gaussian distributions, and gain adjustments made to bring the peaks into the expected channel. The beta detector on the other hand does not produce clear peaks, so peaks are made by taking slices from the 2-D Compton scatter line and then analyzed. The method developed at PNNL takes a different approach; it uses the 2-D Compton scatter line and rotates the frame of reference until the projection of the Compton scatter line forms a peak. This method optimizes the use of counting statistics available from the Compton scatter and gives reliable results even with relatively short measurement times.

Promotional text: This work discusses a method under development that will improve nuclear test monitoring and verification by improving the accuracy of radioxenon analysis and will disseminate alternative detector gain stability check that performs well even with low counting statistics.

P3.5-282 – Automatic radioxenon data validation for increased measurement reliability

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Radionuclide event formation needs reliable detections. Because of the relatively large uncertainty in atmospheric transport modelling, which radionuclide event formation relies on, radionuclide event formation benefits from higher quality measurement analysis, specifically minimizing the number of false positive and false negative detections. This work proposes a quality scale that algorithmically assesses measurement reliability by examining measurement metadata and spectrum values to generate a reliability index for each measurement. Individual measurements used to form an event

can be weighted such that lower reliability measurements have less influence on the final event and higher reliability measurements have more influence on the final event. In addition to being useful for automatic event formation screening, it is anticipated that this work will help prioritize samples for analyst review and shorten time needed to review samples. When used to complement the radioxenon Noble Gas Categorization scheme this algorithm reduced the number of samples brought to analyst attention, samples categorized as level C, by 12%.

Promotional text: This project provides an automated method to improve nuclear test monitoring and verification by increasing the reliability of measurements.

P3.5-300 – Recent algorithm developments on methods for the analysis of radioxenon beta/gamma coincidence spectrum

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The evolution of the SPALAX systems, now equipped with a high resolution beta/gamma detection equipement (PIPSBox/HPge), led CEA/DAM to develop dedicated spectrum analysis algorithms. The first developments were presented to CTBTO noble gas experts during the “Paris equation” meeting in March 2018.
Lately, CEA/DAM conducted a computer-based study to evaluate those algorithms. A large low count rate spectra database was generated by Monte-Carlo simulations for several detector configurations. It permitted the production of counts statistical distributions and the proper evaluation of associated uncertainties, the critical and detection limits.
The discrepancies between algorithms and detector configurations will be presented.

Promotional text: Come, see, and discuss!

P3.5-345 – ARMD-a suite of Analysis System for CTBT Radionuclide Monitoring Data

Authors: Xinjun Zhang[1]; Shiian Wang[1]; Qi Li[1]; Yanqing Fan[1]; Huaimao Jia[1]; Yungang Zhao[1]; JianFang Shi[1]

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The analysis system for CTBT radionuclide monitoring data is developed by the CNNDC. The system realizes the functions of automatic acquisition, database storage, automatic processing, interactive analysis and statistical query of IMS radionuclide monitoring data. A comprehensive assessment is carried out. The results show that the data analysis system has the capability of detection and quantitative analysis of weak peaks on the high ambient background baseline.

Promotional text: ARMD system realizes the functions of automatic acquisition, database storage, automatic processing, interactive analysis and statistical query of IMS radionuclide. ARMD system shows the technical ability of CNNDC in the comprehensive analysis and processing of radionuclide data.

P3.5-354 – Recovery of the largest aftershock sequences using waveform cross correlation

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Shallow earthquakes with Mw>8-9 usually create extensive aftershock activity with thousands of events with mb>3.5. This is a tremendous challenge for IDC automatic and interactive processing, with the Tohoku-2011 earthquake being a prime example. The SHI IDC processing is fine-tuned to find the smallest events (with fixed human resources), and thousands of similar events within a very short time stresses the system. The waveform cross-correlation (WCC) method - based on the similarity of neighboring seismic sources and using a fixed station set - is an alternative method well suited to the nature of the aftershock sequences, i.e. similar repeating events within a confined area measured by seismic stations of the International Monitoring System. The IDC has been testing the performance of a prototype WCC-based processing pipeline. There is a feature very specific to the IDC: the resulting cross-correlation bulletin (XSEL) contains only the events matching the full set of event definition criteria applied to the Reviewed Event Bulletin. Here we present the testing results as obtained from four different aftershocks sequences. For these sequences we show the effect of varying defining parameters of the prototype WCC pipeline and two sets of master events – the REB and automatic SEL3.

Promotional text: The waveform cross-correlation (WCC) method - based on the similarity of neighboring seismic sources and using a fixed station set - is an alternative method well suited to the nature of the aftershock sequences, i.e. similar repeating events.

P3.5-355 – Spot check of seismic and infrasound data and products at the IDC using waveform cross correlation and the REB historical events

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The Reviewed Event Bulletin (REB) of the IDC is the final product of interactive analysis, but also represents a set of seismic (S), infrasound (I), and SI events, which can be used for the analysis of the REB consistency. Continuous comparison of the event hypotheses obtained in routine automatic and interactive analysis with these historical events also helps to improve the REB completeness. More than 600,000 REB events have been converted into master events (MEs) with waveform templates at IMS seismic and infrasound stations. We use the method of waveform cross-correlation (WCC) to assess the similarity between event hypotheses and the MEs at a station-by-station basis. For the hypotheses built in automatic processing (SEL1 to SEL3), only the MEs within 8 degrees from a given event hypothesis are used. For checking the REB, the best MEs within 4 degrees are used. In addition to checking the IDC bulletins, we process continuous SI data for missed events using a global set of ME selected as the most efficient in WCC detection of the historic REB events. All events obtained in the WCC processing are subject to the same spot check procedure as the SEL3 events.

Promotional text: Continuous comparison of the event hypotheses obtained in routine automatic and interactive analysis with historical events helps to improve the REB completeness.

P3.5-377 – Improving the sensitivity for radioxenon beta-gamma measurements by optimizing the ROI limits for each sample

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Current techniques used for analyzing beta-gamma spectra measured by radioxenon systems are based on Regions-of-Interest (ROIs) covering relevant decay modes. The ROIs are set in the detector calibration procedure, and the same ROIs are used for all samples. However, the optimal ROI limits generally will be different for each sample. We present at new method where the optimal ROI settings are calculated for each sample by minimizing the MDA using differential evolution (DE), which is an optimization method used for real-valued multi-dimensional functions, not necessarily differentiable. For some detectors, we find that the MDA is decreased by up to 50%. Possible consequences for the standard analysis procedure used for radioxenon systems will be discussed.

Promotional text: This analysis method will improve the measurement sensitivity of radioxenon beta-gamma systems. For some systems, the improvement is very large, up to 50%.

P3.5-386 – An algorithm for determining the moment of occurrence of changes in the environment that are non-linear and / or non-Gaussian in nature

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This paper analyzes the possibility of applying higher - order statistics - third - order cumulants for isolation and autonomous determination of the moment of physical change in the observed environment. The proposed methods and algorithm make it possible to analyze all those phenomena: sound, infra sound, seismic and others that are essentially non-linear and non-Gaussian. As a result of the application of the algorithm, information was obtained about the occurrence of a given change, as well as the time when it happened precisely in an autonomous way. The application of the algorithm is important in all cases when the occurrence of events is stochastic and when it is necessary to provide constant monitoring and control without a man in the loop. The algorithm is especially important in all cases where it is necessary to register characteristic events that occur at relatively large distances from measuring sensors and when the information about the phenomenon is significantly distorted due to the processes that occur during transmission through medium: attenuation, multi path transmission and others.

Promotional text: When monitoring various phenomena that can occur in the natural environment, we pay special attention and interest to stochastic phenomena, which by their nature can be natural and/or artificial explosions, earthquakes, waves and the like. To monitor these processes, different se.

P3.5-392 – Combining IMS and non-IMS seismic stations using CTBTO distributed software (NDC-in-a-Box)

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NDC-in-a-Box is an independent software package developed, distributed, and supported by PTS, which is intended for NDCs to establish a verification regime with a number of functions including receiving, archiving, processing and analysing data from IMS stations. To simplify installation and configuration of NDC-in-a-Box package, most software tools and applications are provided via a distributed virtual machine. SeisComP3, which has a large installed base, has been integrated into NDC-in-a-Box since 2016. Automatic data processing is now possible in addition to interactive data analysis.

The standard way to configure non-IMS seismic stations is to use SeisComp3 scripts. Station parameters are imported into the OSDB database or saved as data files within the NDC-in-a-Box virtual machine. An alternative method is introduced here for configuration of non-IMS seismic stations. Based on basic parameters and instrument response file of non-IMS seismic stations, a program developed in Matlab is used to process stations parameters including calculation of instrument response parameters and export them into the database. Standard data files of non-IMS seismic stations can be accessed by NDC-in-a-Box via the shared folder of virtual machines, which simplifies the management of parameters for non-IMS seismic stations parameters and data exchange.

Promotional text: Based on basic parameters and instrument response file of non-IMS seismic stations, a program developed in Matlab is used to process stations parameters including calculation of instrument response parameters and export them into the database.

P3.5-404 – Phases Analysis of the Las Gonzalez Mérida, seismicity burst 2015-16, implementing SeisComp3 tool

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An extensive phase identification (i.e. Pg,Pn,Sg,Sn,Lg) and analysis is still pending in order to better precise the location and nature of the main seismic events (5.1 and 4.8 Mw) that took place within the two branches of the Boconó fault in Las Gonzalez sector in Western Venezuela. Along with these two events (Nov 14th and 11th) in 2015, an intense aftershock sequence of almost one thousand events took place until March 31th in 2016. During this time period, FUNVISIS, the Venezuelan Foundation for Seismological Research, had deployed the GIAME project (Integrated Geoscience of the Andes) with a significant number additional receivers covering the area; this dataset is still available for extensive work, and a tool as SeisComP3 could exploit their full potential and contribute to our better understanding of this stress release process and the geometry of the faulted area. We expect that our proposed phase analysis, with an increased number and more consistent time readings, will provide a better constraint for the locations of the events; also, when used with on-going efforts with relative location strategies (Waldhauser, 2001), we expect that dipping fault will be better captured with a better determined velocity model for the region.

Promotional text: This research put into practice the NDC capacities developed in the training course Seiscomp3. in order to solve and apply CTBT developments into a broad dataset and can provided insites for the Venezuela NDC.

P3.5-407 – Testing the Forensic Radionuclide Event Analysis and Reconstruction Tool (FREAR)

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The recently developed open source **FREAR** tool improves nuclear event analysis by using Bayesian inference principles to estimate key source term parameters using measurements from distant radionuclide monitoring equipment in combination with Atmospheric Transport and Dispersion Models (**ATDM**). Trials on real world reconstructions have demonstrated clear and dramatic improvements over standard correlation techniques, such as the Possible Source Region (**PSR**) algorithm. The improvements in source characterization are a result of implementing a statistical non-detection model that accurately represents the performance of the radionuclide detection equipment and by using a full **ATDM** uncertainty model in the reconstruction process. To further test the performance and capabilities of this tool, two blind tests are conducted with synthetic source terms with short- and long-range transport. The test scenarios and the results of the reconstruction are described and assessed to further demonstrate the compelling benefits of using the FREAR statistical tool in event analysis.

Promotional text: The Forensic Radionuclide Event Analysis and Reconstruction Tool is a new method to improve nuclear test monitoring and verification by applying statistical inference methods to reconstruct the emission source by fusion of radionuclide data and atmospheric transport modelling.

P3.5-442 – A new algorithm for processing beta-gamma coincidence spectra based on the maximum likelihood estimation

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A new algorithm for processing beta-gamma coincidence spectra based on the maximum likelihood and non-negative least squares (NNLS) methods is presented. The algorithm allows simultaneous processing of the signal in all regions of interest (ROI). This approach has a number of advantages over the net count calculation (NCC) algorithm and provides a solution to the problem of processing beta-gamma spectra in its most general form. The use of regions of interest (ROI) with simultaneous NNLS fitting allows efficient and noise-resistant estimation of the activity of relevant xenon isotopes.

The presented method also makes it possible to process measurement errors in a more general and correct form. A linear regression solution is used to calculate the errors, which makes it possible to take into account the correlations of obtained activity estimates.

A program was developed for processing beta-gamma spectra using a new algorithm, and the activities and volumetric activities of xenon were calculated using the data obtained by the Monitoring System of Xenon Isotopes MIKS in 2020. The results of the new measurement processing algorithm and other algorithms are compared.

Promotional text: A new algorithm for processing beta-gamma coincidence spectra based on the maximum likelihood method is presented. The calculation of the activity of xenon was carried out according to the data obtained from the MIKS system.

P3.5-452 – The algorithm of infrasound signals network selection efficiency estimation

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The materials relative to impulse source detection from SnT 2015, 2017 and 2019 were summarized using methods of maximal likelihood ratio according on information collected at the infrasonic IMS stations.
New criteria of infrasound IMS station efficiency were defined according on priority areas of network selection method control.
The present work reveals the influence of the signal propagation rate on likelihood ratio, the relation of frequency and probability of false alarm during CTBT monitoring process.
The application procedure of the detection algorithm, selection algorithm and algorithm of preliminary identification were proposed.
Using obtained results the algorithm was enhanced and also specified an efficiency probability of infrasound IMS subsystem based on determination of detection operating parameters of impulse sources in atmosphere.

Promotional text: The materials relative to impulse source detection from SnT 2015, 2017 and 2019 were summarized using methods of maximal likelihood ratio according on information collected at the infrasonic IMS stations.

P3.5-453 – The Coda Calibration and Processing Tool: Java-based Freeware for the Geophysical Community

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The coda magnitude method of Mayeda and Walter (1996) provides stable source spectra and moment magnitudes (Mw) for local to regional events from as few as one station that are virtually insensitive to source and path heterogeneity. The method allows for a consistent measure of Mw over a broad range of event sizes rather than relying on empirical magnitude relationships that attempt to tie various narrowband relative magnitudes (e.g., ML, MD, mb, etc.) to absolute Mw derived from long-period waveform modeling. The Coda Calibration Tool (CCT) stems from a multi-year collaboration between the US NDC and LLNL scientists with the goal of developing a fast and easy Java-based, platform independent coda envelope calibration and processing tool. We present an overview of the tool and advantages of the method along with several calibration examples, all of which are freely available to the public via GitHub (https://github.com/LLNL/coda-calibration-tool). Once a region is calibrated, the tool can then be used in routine processing to obtain stable source spectra and associated source information (e.g., Mw, radiated seismic energy, apparent stress, corner frequency, source discrimination on event type and/or depth). We welcome future collaboration, testing and suggestions by the geophysical community.

Promotional text: CCT provides a fast and efficient means of calibrating and processing local and regional coda envelopes to estimate stable source spectra, Mw, and apparent stress, that are roughly 3-to-4 times less variable than estimates derived from traditional direct wave estimates.

P3.5-459 – The on-site inspection area coordinate determination method

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This method allows us to determine the most reliable OSI area coordinates and the probability of the infrasound source occurrence by using the signal detection results, time of signal event and an azimuth of the signal according to information from IMS stations.
The method is based on the construction of the complex probability map and furthers its analysis according to CTBT OSI area limits. In the present research work, the chosen coordinate pitch, the pitch of source event time and its addition, and also a possibility of elimination from processing of associated but not identified signals are explained.

Promotional text: This method allows to determinate the most reliable OSI area coordinates and the probability of the infrasound source occurrence by using the signal detection results, time of signal event and an azimuth of the signal according on information from IMS stations.

P3.5-476 – IMS Data Fusion and the Possibilities of Dempster-Schafer Theory

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The International Monitoring System (**IMS**) is comprised of multiple types of sensors that provide verification information. While each piece of information is useful for verification, the full benefit of multi-technology measurements has not been fully taken advantage of. Data Fusion is an approach that seeks to integrate disparate sources of data into a unified and comprehensive event analysis. Several approaches (*e.g.* cost-function analysis, Bayesian inference) have demonstrated the power and benefit of data fusion approaches for Treaty verification. However, an important problem in the data fusion process arises when not all information is consistent, or believable. Dempster-Schafer theory provides a statistical means to reconcile evidentiary beliefs in the data fusion process. This poster will describe how inconsistent evidence may arise within the **IMS**, and show how Dempster-Schafer theory can help to reconcile evidence in a data fusion process and support the event analysis process for National Data Centres.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This abstract is LLNL-ABS-817217-DRAFT.

Promotional text: Uncertainty characterization is crucial in data fusion processes (e.g. inference techniques) that combine evidence from multiple sources. When pieces of evidence are inconsistent, applying Dempster-Schafer theory reconciles the inconsistencies and improves the inference process.

P3.5-483 – Method for assessing ^{37}Ar emissions from nuclear reactors

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^{37}Ar is an indicator of an underground nuclear explosion. This radioisotope is produced via ^{40}Ca (n, α) ^{37}Ar reaction through neutron activation of ^{40}Ca included in the rocks near to the nuclear

explosion location. The relatively long half-life of 35 days compared to CTBT-relevant radioxenon isotopes results into ^{37}Ar activity becoming stronger than radioxenon activity approximately 50 days after detonation. Normal operational releases of ^{37}Ar from nuclear facilities contributes to the atmospheric background. It can be produced via neutron activation of air or of gas dissolved in water. The emissions of this isotope are not regularly measured and very few release data are available. Therefore, the two-step method presented here is more complex than the method the authors had applied previously for assessing ^{37}Ar releases from nuclear research reactors. As the first step, simulations with ORIGEN determine isotopic ratios of ^{37}Ar and an appropriate proxy like ^{41}Ar for which stack release data are available. These ratios are depending on the duration of the irridiation and the intensity of the neutron flux. As second step, the retention time is used to account for the decay between escaping the neutron flux and getting released through the stack.

Promotional text: ^{37}Ar is important as indicator of an underground nuclear explosion. Nuclear power plant emissions contribute to the ambient background and needs to be assessed. This presentation describes a method how to achieve this.

P3.5-507 – Is there a potential for further enhancing IDC spectrum analysis methods of CTBT radionuclide measurements after 25 years of progressive development?

Authors: Boxue Liu[1]; Martin B. Kalinowski[1]

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This presentation is an overview on radionuclide analysis procedures at the IDC. There are three sets of approaches currently, the single channel analyser curve for particulate, the least squares regression on gamma- and X-rays peaks of xenon isotopes for high resolution spectra and the net count calculation method for beta-gamma coincidence spectra for noble gas, which are based on conventional frequentist statistics. Most daily IMS spectra have low counts close to background level. Decision thresholds by Currie's definition have been found to tend being underestimated, resulting in false positive detections. Enhancements on current methods could apply optimization regression analyses of standard spectra, 3-D fitting and gross counts, or machine learning which all are consistent with ISO standards on estimation of measurement uncertainty and characterization limits based on Bayesian statistics. Probability distributions of measurands, e.g. activity, concentration and isotopic ratio, could be obtained by the Monte-Carlo method, directly based on distributions of inputs of measurement spectra, calibration data and related parameters, resulting in realistic estimates for measurands, their uncertainties and associated limits of the coverage interval with a given probability. IDC radionuclide analysis reports could be enhanced by reporting not only results and their uncertainties but also associated characterization limits.

Promotional text: The overview on past achievements and potential developments of radionuclide analysis procedures at the IDC reveals the challenge to enhance estimation of measurement uncertainty and characterization limits, improving analysis reliability.

P3.5-508 – Monte-Carlo Calculations of Isotopic Ratios of Fission Products Detected at IMS Radionuclide Stations

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Activity ratios of paired isotopes detected at IMS radionuclide stations can be used to not only discriminate a nuclear test from civil nuclear releases, but also determine the explosion time under assumed scenarios. A function of the isotopic ratio with time from the explosion time up to the stop of collection can be derived, based on Bateman equations of given decay chains. It is not a linear relationship between activities collected in the sample and concentrations in the plume. Activities in the sample are determined by spectra analysis. Non-linear relationships of isotopic ratios can also be caused by the division algorithm when denominators have larger measurement uncertainties. Covariances between isotope concentrations might be another reason for non-linearity. Correlations of two concentrations could be caused by decay corrections of parent-daughter chain, interference corrections between two isotopes and subtractions of the same detector background measurement. This presentation demonstrates Monte-Carlo procedures estimating the probability distributions of isotopic ratios, based on input distributions related to spectrum measurements and decay chains. Then the isotopic ratio, associated uncertainty and limits of the coverage interval can be estimated accordingly. Furthermore, the explosion time can be estimated in the same way, if applicable.

Promotional text: This presentation is about calculation procedures of isotopic ratios by the Monte-Carlo method. It is a simple and direct way to perform uncertainty estimation for numerical solutions of the isotopic ratio and explosion time.

P3.5-511 – An Alternative Proposal for Estimation of Body Wave Magnitude Taking Account of Noise Magnitudes

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Magnitude measures the strength of an earthquake and is an important parameter for earthquake / underground test discrimination.
The IDC computes body magnitudes from the amplitude to period ratio recorded at network stations. Radzyner et al. (2017) showed that there was superior consistency of magnitudes across stations when the magnitude is computed as a linear function of the ratio, but with a slope that could differ from 1. The slopes and intercepts that describe these lines were found to be station-specific.
We extend the method by also including noise magnitude measurements in determining the station corrections. This follows the maximum likelihood (ML) magnitude estimation approach of Ringdal (1976), later applied to offset estimation for IDC data by Zaslavsky-Paltiel and Steinberg (2008).
We develop an optimization algorithm that finds joint ML estimates for the station-specific parameters that link observed seismic signals to event magnitude, taking account of noise magnitudes, as well as computing the event magnitudes themselves.
The procedure is applied to a large database of IDC events and to primary stations. We find strong support for the general, but station-specific, linear relationship proposed by Radzyner et al. for computing body wave magnitude from the amplitude to period ratio.

Promotional text: This work presents an alternative algorithm for computing body wave magnitudes which incorporates both recorded magnitudes and noise magnitudes. There is extensive analysis of IDC data.

P3.5-550 – Development of a processing toolkit for in-depth radionuclide data analysis: Case study for the period of 2017-2020 IMS detections

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IMS radionuclide concentration data is accessible through the CRTooL. It contains detected concentrations for all kinds of radionuclides, categorized as noble gas (Xenon) and particulates, standing for natural, activation and fission-products.
The ultimate role of these data is to find and then identify any event that is related to the verification regime of the CTBT. Identification of events demands data visualization to look for different aspects of data.
Here, we obtained offline CSV files for the period of 2017-2020 taken from CRTool, with appropriate tags declaring detection location, country, region and the kind of radionuclide. Then, a toolkit has been developed for parametric study of these data. There are several types of graphics produced for the in-depth analysis of data: a bar chart to show the concentration of all radionuclides for any single station and a bar chart to show the concentration of a radionuclide for all stations, probably within a region/country. It also is possible to produce animated graphics, for a daily, weekly or monthly variation of concentrations. This may be displayed by bubble chart graphics over a geographic map for any single radionuclide.

Promotional text: Currently, CRTool is limited to very simple data visualization and graphics capabilities. This work helps to renew the design of CRTool data analysis and visualization graphics, and brings several ideas for still and animated graphical representations of data.

P3.5-561 – Massive earthquake detection techniques: Matched filter and fingerprinting

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Seismology data analysis is becoming a challenge due to the exponential growth of continuous data being stored. In this study we present and compare two methods to massive detect earthquakes: the matched filter and fingerprinting. We have tested matched filter over several study zones of interest: in the Western part of Mexico to study general seismic activity, in the Isthmus of Tehuantepec in Southern Mexico to track aftershocks from the September, 2018 Mw8.2 earthquake, and in the North Pole to study seismic activity mainly caused by ice cracking, or ice-quakes. We have demonstrated the accuracy of this technique especially detecting low amplitude signals hidden in the noise and coming out when we stack the resulting correlation coefficients over multiple stations. We are now testing fingerprinting, a technique much more efficient computationally, where we focus on extracting a fingerprint of the waveform for several templates in the time-frequency domain by compressing the resulting scalogram at different time steps. The information for each time step for every template is stored. We then perform a similarity search computing the Jaccard similarity and the probability for each query signal to every template, so that we can classify similar events automatically.

Promotional text: Seismology data analysis is becoming a challenge due to the exponential growth of continuous data being stored. In this study we present and compare two methods to massive detect earthquakes: the matched filter and fingerprinting techniques.

P3.5-584 – Integration of a Generalized-F Detector at the IDC and US NDC

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Selby, (2008, 2011) developed a Generalized-F method, (Gen-F), to enable application of an F-statistic detector to small-aperture arrays where correlated background noise would otherwise degrade performance; and in 2013, he introduced an innovative time-frequency approach that further enabled application of Gen-F to arrays independent of aperture. Tests of the method on the IMS arrays have shown that the Gen-F detector out-performs the current detector in use at the IDC for many of the arrays, both increasing valid detections, while decreasing their overall number. The UK NDC contributed software based on Selby's 2013 method, and the US NDC integrated it into the DFX detection framework in use at the IDC and US NDC. The Gen-F detector is implemented as a module fully compatible with the input and output of the existing DFX framework and is compatible with the subsequent down-stream station and network processing, (StaPro, GA, NetVISA). The US NDC is tuning the Gen-F parameters that frame an isotropic noise model to suppress correlated noise at regional, small-aperture arrays. Using a multi-day, analyst-reviewed set of detections as ground-truth, and the observed interstation correlation, the US NDC will demonstrate the impact of tuning these Gen-F parameters at one (1) regional array.

Promotional text: The abstract denotes a potential improvement in seismic signal detection processing applied within the constructs of the DFX detection framework.

P3.5-610 – On the requirements for validation data sets in potential future scientific projects for enhancing and developing methods to highlight possible nuclear explosion signatures in radionuclide monitoring

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The discrimination between the highly variable radioxenon background caused by normal operations of nuclear facilities and CTBT-relevant events is a challenging but crucial task. For this reason, the radioxenon background at IMS noble gas systems must be sufficiently characterized and understood. The scientific methods and software tools to do this can still be significantly enhanced. This presentation summarizes relevant scientific project line-outs that would serve this purpose and make use of atmospheric transport modelling (ATM). These include methods for associating multiple samples to the same release event, provision of higher source location estimates, developing of the screening flag "ATM backtracking to known sources", corrections to ATM in case of systematic discrepancies between observed and simulated concentrations from a known source due to complex terrain, land sea breeze, and mountains, as well as the use of isotopic ratio measurements for screening. For each of these possible projects, the atmospheric radioxenon measurement data required for developing and validating the methods and tools is described. These build on IMS noble gas measurements possibly supplemented by data from temporary experiments with transportable noble gas measurement systems.

Promotional text: This presentation describes possible scientific projects to develop among others methods for asociating multiple samples to the same radionuclide release event, for backtracking to known sources. It describes what radioxenon measurement data are required to validate the results.

P3.5-680 – A new method of denoising seismic signals using blind source separation

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Seismic signal processing aimed at extracting relevant information is often faced with the problem of the presence of disturbing signals, which can be generated by different sources of noise. This problem is all the more glaring when the seismic event of interest is so weak that it is drowned in noise, and can therefore pass without being noticed. We propose in this paper a new method which allows to solve this problem by using a Blind Source Separation (BSS) approach. Based on Independent Component Analysis (ICA), our method makes it possible to estimate the contributions of each of the noise sources, then to subtract them from the seismic signal supplied by each sensor. For this, we model each seismic signal as a linear mixture of all the sources present, and we assume that the number of sensors is greater than the total number of these sources. In our processing, we focus on the slices of the observed signals where only the noise sources are present, assuming that the latter are stationary and independent.
Our new denoising method has been statistically validated on mixtures of artificial sources. The results of tests carried out on some real seismic signals are very encouraging.

Promotional text: In this paper, we propose a new solution to the familiar problem of noise that can interfere with the extraction of relevant information from a seismic signal. This solution which uses a Blind Source Separation approach is based on Independent Component Analysis.

P3.5-687 – Multivariate analysis of fission product ratios to determine the history of nuclear fuel

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Multivariate analyses of fission product activities have previously been successfully used to determine the history of spent nuclear fuel from gamma measurements. A high dimensional data-set is projected to a one- or two-dimensional space using e.g. Partial Least Squares (PLS) regression to the parameters of interest, such as reactor type, burnup, initial enrichment and cooling time. Previous work was focused on well controlled measurements of intact fuel assemblies where all non-volatile fission products could be compared together. This work extends the concept to measurements of dispersed traces in the atmosphere, where a direct comparison of activities from different elements is not possible. Instead, ratios of fission products from the same elements are used as input to the multivariate analysis. A feasibility study is presented, using synthetic data, where the sensitivity of the method is investigated together with a discussion of the way different isotopes contribute to the measurements.

Promotional text: A multivariate analysis of radio isotope measurements is used to project high-dimensional data sets to one or two dimensions. This substantially simplifies the regression to parameters of interest, such as reactor type, burnup, initial enrichment or cooling time.

P3.5-699 – Event Simulation using Augmented Reality and Progressive Data Fusions

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Nuclear test event data as acquired by the sensors at the terminal ends can be used to create multiple possible simulations of the event using any basic model. Alternatively, events can be created in an simulation environment generating stimuli producing data as of the recorded event. This can

be done by adjusting input variables like yield, surface condition coefficients, depth variations, S-Wave attenuation and other factors. Depending upon maturity of the basic model and maximum possible correlation with the known actual parameters, process can give a fairly good simulation of the event. These parameters can thereafter be further adjusted using additional data from other sources using statistical techniques of upscaling, downscaling or interpolation as required to improve related boundary and other conditions and getting near real simulation. This iteratively improved simulation can be used to create augmented reality presenting a visual view of the actual event, impacts, surrounding physical conditions, device structure estimation and resultant geo and thermal activity for research and other purposes. The technique will also help in finding gaps in existing acquisition methods beside others. The technique can help in perfecting the estimates and detecting events in cost effective manner with increased viability and acceptance.

Promotional text: Speaking futuristic more cost effective as well as improved simulations of the events may be required. Augmented reality can help in creating better simulations and will required additional possible data from other sources. For the same iteratively improved models are best.

P3.6 Artificial intelligence and machine learning

P3.6-096 – AI Enabled System for OSI IT/ISP Living/Working Area Management

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According to OSI Operation Manual, IT/ISP living and working areas should be well-protected. Scenarios like the management of the different living and working areas for IT and ISP, require entry permission granted separately to either IT or ISP members. This work would provide a customized management supporting system solution to the above mentioned scenario. The system is based on Artificial Intelligence (AI) related hardware learning and self-deep learning. System functionality involves personnel detection, image classification and recognition. The whole system combines thermal, daylight/CCTV and laser lighting/range-finding with application software. It also supports dynamic and static targets detection and recognition including human, animal, vehicle, smoke, fire and high-temperature items, with AI functions of detection, recognition, classifications, and reactions like alarm, denied access. IT/ISP members' image could be pre-loaded into the system, which would grant permission to IT/ISP individuals or deny their access. The system could be compatible with OSI IIMS and other third-party systems. The system also supports area intrusion/leave/behavior analysis. In order to achieve high level image recognition, the deep-learning software could work under harsh environment by intelligence function such as defog, background analysis and area shield. Individual privacy issues would be jointly and legally solved together with the PTS.

Promotional text: This work carried out a system solution to OSI IT/ISP living and working areas management supporting system, based on Artificial Intelligence (AI) related hardware learning and self-deep learning.

P3.6-111 – Machine learning based earthquakes-explosion discrimination for Sea of Galilee seismic events of July 2018

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Discrimination between earthquakes and explosions is an essential component of nuclear test monitoring. Discrimination methods currently used by the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) are often ineffective for regional events, particularly in Israel's region.
For instance, five seismic events whose epicenters lie near the Sea of Galilee (Lake Kinneret) were reported by the CTBTO in July of 2018. Those were relatively strong regional events, which were observed by stations hundreds of kilometers from the epicenter. Notably, three out of those five events were not screened out by the CTBTO as natural events, though they were a part of a swarm of earthquakes.
In this work, the diffusion maps-based discrimination method is configured and applied for discrimination of the July 2018 Sea of Galilee seismic events. Utilizing waveforms of the Israel Cooperating National Facility (CNF) station HRFI, we show that this machine learning method correctly classifies as earthquakes all July 2018 Sea of Galilee seismic events with durational magnitude Md > 2.3.

Promotional text: In this work, the diffusion maps-based discrimination method is configured and applied for discrimination of the July 2018 Sea of Galilee seismic events. .

P3.6-124 – Deep learning denoising applied to regional distance seismic data in Utah

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Seismic waveform data are generally contaminated by noise from various sources. To date, the most common noise suppression methods have been based on frequency filtering. These methods, however, are less effective when the signal of interest and noise share similar frequency bands. We implemented a seismic denoising method that uses a trained deep convolutional neural network (CNN) model. In our approach, the CNN provides a signal mask and a noise mask for an input signal. The Short-Time Fourier Transform (STFT) of the estimated signal is obtained by multiplying the signal mask with the STFT of the input signal. To build and test the denoiser, we used compiled signal and noise datasets of seismograms recorded by the University of Utah Seismograph Stations network (United States). Results of test runs involving more than 9,000 constructed waveforms suggest that on average the denoiser improves the SNRs by ~5 dB and that most of the recovered waveforms have high similarity with respect to the target waveforms and suffer little distortion. Application to real data suggests that our denoiser achieves on average a factor of up to ~2-5 improvement in SNR over bandpass filtering and can suppress many types of noise that bandpass filtering cannot.

Promotional text: This study aligns with the SnT2021 goal of identifying methods for improving nuclear test monitoring and verification. In fact, the implemented deep learning denoiser could provide a valuable addition to the existing data processing pipelines.

P3.6-131 – Domain Informed - a better approach to regularization and semi-supervised learning for seismic event analysis

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Typically, data-driven learning works best when we can exploit expectations from our data domain. For example, the development of recurrent neural network architectures to deal with the temporal dependence in language, geometric deep learning for 3-D problems, and physics-constrained Bayesian learning for more interpretable dependencies. Yet it can be unclear how to interject expectations, and which specific expectations will result in better outcomes for a given domain. In seismic event processing, enforcing consistency over disparate observations for an individual event has a long history of empirical value. For example, we almost always use magnitude estimates from many individual stations, drop outliers, and average to arrive at a final event magnitude. Similarly, we can leverage the expectation that stations provide consistent predictions for any event-level attributes, such as event type, when we develop deep learning based predictive models. In this work we show how to formulate this expectation as a loss term during model training and give several examples of how this expectation can result in better model regularization, which can reduce overfitting while still outperforming other methods, give us more trustworthy decision confidence, and allows us to leverage data where no ground truth is available.

Promotional text: The primary conference goal this work addresses is improving nuclear test monitoring by advancing algorithms for event discrimination. A second goal, with implications beyond event discrimination, is in advancing our ability to use deep neural networks for actionable decision sup.

P3.6-143 – Application of a Paired Neural Network to Aftershock Identification

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Large aftershock sequences cause problems for the International Data Centre (IDC) because the seismic event rate increases dramatically during an aftershock sequence, making correct association of arrivals difficult for the automated pipeline. Aftershock sequences can continue for days or even months after a large earthquake and although aftershocks aren't events of interest for treaty monitoring purposes, they must be reviewed and eliminated by analysts, resulting in delayed release of the IDC bulletins. We turn to machine learning to automatically identify aftershock events and improve automated pipeline performance. In our research, we train a paired neural network (PNN) to automatically perform aftershock identification based on waveform similarity, even when only a few datapoints are available for training. This allows the model to be applied to classes outside of the original training dataset. We analyze the ability of our PNN to classify aftershock data constructed from signals recorded by the IMS network and several open IRIS networks added to real noises from the STanford Earthquake Dataset (STEAD) or the University of Utah network. We apply the trained model and waveform cross-correlation on the constructed test dataset and compare the performance of the two approaches.

Promotional text: This study aligns with the SnT2021 goal of improving nuclear test monitoring and verification. This research aims to provide a method to automatically identify nuisance aftershocks that could potentially be used to improve the IDC automated data processing pipeline.

P3.6-184 – Application of Deep Neural Networks to seismic signal recognition

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Automatic recognition of seismic event source has been a primordial task since the introduction of digital seismic networks. Nowadays, this task becomes more important due to the huge quantity of data recorded continually and the need for real time results. Different approaches have been addressed in the literature. Currently, artificial intelligence techniques have attracted increasing attentions among scientists owing to their efficiency to handle complex non-linear real world problems.

The purpose of this study is to seek a Deep Neural Network (DNN) architecture for a more reliable seismic signal recognition. The main advantage of this approach is its strong ability to extract automatically complex features that express the seismogram in much more detail. Thus, it might be much more efficient than other neural network based classifiers which require manual feature extraction. To convert the seismogram to image, the time-frequency representation is exploited. Several set of experiments were conducted to analyze different DNN architectures and compare their relative performances. To do so, a large seismic database was used. The results confirmed the ability of this approach to recognize events with a good accuracy.

Promotional text: The aim of this research is to investigate the ability of deep neural network in seismic signal classification. The goal is to discuss the proposed approach with other researches and scientist, so that it can be improved and extended to help CTBT in identifying nuclear explosions.

P3.6-197 – Discrimination between Earthquakes and Quarries Blasts Using Committee Machine

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In this work, a committee machine was used to combine supervised and unsupervised artificial neural networks to discriminate between Earthquakes and quarries blasts. The unsupervised network is used as a measure of accuracy for the results of the supervised neural network. The unsupervised Self-Organized Map (SOM) and the k-means clustering algorithms are used to estimate support and confidence measures for the results. Meanwhile, the supervised neural network is used to discriminate between Earthquakes and explosions. Using data from the Egyptian National Seismological Network (ENSN).
The artificial neural networks are trained using different input parameters which are the P wave spectrum corner frequency (PcF), S wave corner frequency (ScF), and the ratio (Rcf) of PcF to Scf.
The combined approach succeeds to discriminate between Earthquakes and quarry blasts in Northern Egypt. The method provides the results with a measure of confidence which eliminates false discrimination.

Promotional text: The current paper represents an idea to implement the artificial intelligent to assist experts in decision-making situations. Committee machine could Identify the nature of a particular event using the aid of several discrimination methods.

P3.6-224 – Understand the vulnerabilities of machine learning systems in adversarial settings

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Machine learning has advanced radically over the past 10 years, and machine learning algorithms now achieve human-level performance or better on a number of tasks. Machine learning techniques have been extensively deployed for a variety of applications in different areas of life. The success of machine learning algorithms has led to an explosion in demand.
Machine learning models are also subject to attacks at both training and testing phases. Attackers can break current machine learning systems, such as by poisoning the data used by the learning algorithm or crafting adversarial examples to directly force models to make erroneous predictions
The main threat during testing is evasion attack, in which the attacker subtly operates by making small perturbations to the test set and modifies input data so that a human observer would perceive the original content but the model generates different outputs. Such inputs, known as adversarial examples, has been used to attack voice interfaces, face-recognition systems, image and video and text-classifiers.
This presentation will explain adversarial attacks examples in current machine learning models and its future trends as well as answering what can be done to defend models against adversarial manipulation.

Promotional text: Attacking Real-World Machine Learning Systems,
Understand Machine Learning security,
Adversial ML,
Data poisoning

P3.6-269 – Unsupervised deep learning for identifying seismic event classes in signal-rich records for environmental monitoring

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Manual identification of seismic events in long and signal-rich records is a challenging and time-consuming task. Power detectors for single stations or array beams are widely just but often provide a vast number of ungrouped events. The need for screening these events arises for example when no a priori information about expected events is available, precise locations cannot be obtained, or location alone is not sufficient for event classification. Unsupervised machine learning allows grouping of seismic signals without using class labels. For our approach, we adapt state-of-the-art, pre-trained convolutional neural networks (CNN) for image recognition. Spectrograms of three-component seismic data are combined as RGB images and fed into the CNN for clustering. The output layer is intuitively visualized to evaluate the obtained grouping. We test two different approaches: grouping pre-detected events and sliding window processing combing the detection and clustering step. We apply the methods to typical data sets in environmental seismology: seismic data recorded at glaciers in Svalbard (icequakes) and at an unstable rock slope in Southern Norway. In both cases, expert-labeled events are available to evaluate the results. We find the unsupervised deep neural network to be a powerful tool to analyze and differentiate between the seismic events.

Promotional text: We present a method for automatic identification of seismic events using machine learning and its application for environmental monitoring. Our contribution addresses the need for new verification technologies as well as issues in a global context such as climate change.

P3.6-326 – A neural network architecture for detecting repeating events using seismic arrays

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Recent advances in convolutional neural networks (CNNs) have brought impressive detection capabilities to one- and three-component seismic stations. Still, the highest sensitivity to repeating events is obtained by beamforming signals over a seismic array. We propose a new neural network architecture that combines the two, by introducing a two-dimensional convolutional layer that encodes the propagation time delays between array stations. This results in a purely empirical model, which does not rely on the plane-wave approximation of traditional beamforming. We demonstrate the model by detecting and classifying repeating blasts from multiple mining sites in northern Fennoscandia. Results are compared to those obtained by empirical matched field processing, a highly sensitive method which, similarly, does not require signals to be coherent under the plane-wave model.

Promotional text: We present a machine learning method for seismic arrays, which aims to improve verification capabilities through higher detection sensitivity and better identification of repeating sources.

P3.6-428 – The Optimised Local Renyi Entropy-Based Shrinkage Algorithm for Sparse TFD Reconstruction

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Time-frequency distributions (TFDs) are useful tools for nonstationary signals analysis. Due to the presence of unwanted cross-terms, useful information extraction from TFDs has proven to be a challenging task, in particular when analysing noisy real-life signals.
One way to suppress the cross-terms is by employing compressive sensing methods that enforce sparsity in the resulting TFD. In this work, we have developed a sparse algorithm that reconstructs a TFD from a small sub-set of signal samples in the ambiguity domain. The algorithm utilises the information from both the short-term and the narrow-band Renyi time-frequency entropies, while its parameters are optimised using evolutionary meta-heuristic methods.
Results are presented for synthetic and real-life signals in noise, and compared to the state-of-the-art sparse reconstruction algorithms.

Promotional text: We have proposed a novel algorithm for sparse representation of nonstationary signals. The algorithm utilises Renyi time-frequency entropy information, and it's optimised using evolutionary methods.

P3.6-439 – AI/ML vision technology application to OSI search logic supporting

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Advancements in AI/ML are creating a paradigm shift in virtually every sector of the tech industry. Among the endless applications, AI vision technology based on Deep Neural Network, finds its strength at image processing, pattern recognition and image interpretation, which can be utilized for manufacturing, medical diagnosis, and OSI. Current OSI search logic relies on finding and identifying nuclear test signatures and anomalies by means of inspectors' visual observation and test results of OSI equipment. Normally visual observation could be the first breakthrough to initiate the OSI search logic. OSI visual observation is based on nuclear experts' scientific knowledge of nuclear tests experience. Judgement bias exists as a result of inspector individual difference and human errors. For this case, AI vision could be utilized as supporting strength to assist OSI operations. This work would carry out the preliminary study over the principles of AI vision technology's potential application to OSI mission support. It would also identify the advantages and possible disadvantages of AI/ML for OSI application. For example, AI vision is relied on large amount of data base for model training, this would cause the concern of keeping the balance of OSI operation efficiency and intrusiveness.

Promotional text: This work carried out a preliminary study of AI/ML vision technology application to OSI search logic supporting.

P3.6-509 – Analyzing radioxenon spectra with machine learning algorithms to predict Activity Concentration of Each Isotope

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In this study, we aim to develop a new approach using machine learning and data mining algorithms to estimate the activity concentration of radioxenon isotopes of any unknown sample without extensive mathematical calculations from calibrated raw spectra. So far, several methods have been applied such as the region-of-interest (ROI) and the simultaneous decomposition analysis tool (SDAT) to estimate net counts for each isotope. By means of machine learning methods, we specifically analyze Beta–Gamma coincidence spectra without the availability of processing parameters that are currently used by the CTBTO such as successive subtractions of background interferences (i.e., radon and its daughters), which can reduce errors and human workload of analysis. Thus, our purpose is to improve MDC in the detection of low-level activity concentration of radioxenon isotopes.

Promotional text: Machine learning for 2D radioxenon beta-gamma coincidence raw radioxenon spectra analysis.

P3.6-516 – Automatic Radionuclide Detection Using Deep Neural Networks

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One of the implementations to support the CTBT instrument measurement is radionuclide identification. An automatic real-time identification radionuclide can be an option for some applications, including monitoring of environmental contamination and prevention of nuclear terrorism. This research is about the automatic algorithms that provide feedback about the presence of any radiations anomaly. In addition to designing better hardware, a sophisticated computer algorithm is also a needed for automatic detection of radioactive materials by developing a method for supervised learning model from identified gamma spectrum using deep learning. The gamma-ray detector data for this study was obtained from public data from ORNL for research and development purposes.
For the simulations, OpenMC and Geant4 is used to generate data files in a time-series manner and modeling standard NaI(Tl) detector resolution at 661keV. The data set contains six different types of source combinations: High enriched uranium (HEU), Cesium 137, Iodine 131, Cobalt 60 , Technetium, and LEU, in total 10000 data files with ground truth were provided in the dataset. Experiments on simulated spectra suggest that deep learning methods (RNN + LSTM) can achieve a higher F1 score at difficult testing conditions compared to the best performing traditional machine learning models, obtaining a 91.11% score during evaluation.

Promotional text: This research can be used for radionuclides identification in any various fields, including in the difficult areas. Besides, it also can be used for environmental monitoring system. By doing this research, the author also might open any collaborations from another participants.

P3.6-541 – Research on Local Event Detection Method Based on Deep Convolutional Neural Network

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An event detection method based on deep neural network combined with the average wave speed ratio of multiple stations is proposed for detecting local events under the global sparse seismic network. Firstly, the method uses multi-task convolution neural network to detect and identify the direct P and S phases, as well as estimate their arrival time. Then a joint network of GAN and LSTM is used to identify and eliminate the noise signals in detections. Finally according to the principle that the P and S wave velocity ratios of local earthquakes in the regional network are consistent, the association of seismic phases from multiple stations are realized. The P and S phases arrival time and wave velocity ratio are used to estimate the preliminary origin time. The hyperbolic method based on station pairs is used to estimate the preliminary event location. Using the preliminary origin time and location of the event as the initial value of the conventional iterative inversion location method, and finally the exact event location and time are obtained

Promotional text: This paper proposed a local event detection method based on the deep convolution neural network. The test results verify the effectiveness of the deep learning method in seismic monitoring data processing.

P3.6-615 – On using self-sustained events for stochastic waveform modelling with deep neural networks

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The International Monitoring System (IMS) includes waveform sensor stations connected to a centralized processing system in the International Data Center (IDC) in Vienna. While the performance of the IMS is known to be related to atmospheric properties, the usual approach at the IDC still relies on expert judgments and simple models to incorporate the environmental knowledge. In this work, we develop a deep neural network (NN) that takes advantage of basic physical laws to learn a model for the stochastic component involved in wave propagation, and predict some statistics of the recorded time series. A neural network architecture is proposed which uses additional layers to embed some properties on the stochastic parameterization used to represent the atmospheric randomness, given appropriate context information on the medium (mean, standard deviation, …). The NN model is trained on data emanating from individual stations of the IMS, using far-field self-sustained natural events such as microbaroms and high-fidelity simulation data. Finally, it is shown how this neural network architecture can be used in combination with probabilistic Bayesian models to improve network processing (detection, association) as well as our understanding of atmospheric variability.

Promotional text: We develop a new generation of deep neural network that takes advantage of basic universal laws to predict the background infrasound noise. In combination with Bayesian approaches such as NET-VISA, we believe that the neural network can enhance the association process.

P3.6-622 – On filtering regional turbulence noise in infrasound data with interpretable neural networks

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The environment of infrasound stations is characterized by mesoscale wind speed and temperature fluctuations that affect the temporal variability of the Atmospheric Boundary Layer (ABL). While the statistical characteristics of turbulence are poorly constrained, modeling such statistics appears to be crucial since each sensor of infrasound stations is subject to this local noise that may mask

true signals and cause false detections. In this work, we propose to improve the station processing by characterizing the noise due to turbulence in the ABL using neural networks. Assuming that the turbulence is governed by a parametric nonlinear dynamical system which involves known dimensionless numbers, a neural network architecture is proposed to infer the turbulent noise in the data. For this task, we design a custom deep autoencoder network to obtain a coordinate transformation into a reduced space where the dynamics of the ABL can be sparsely represented. The resulting modeling framework combines the strengths of deep neural networks for flexible representation and sparse identification of nonlinear dynamics for parsimonious models. The performance of our approach is assessed using real-world signals recorded at several infrasound stations of the International Monitoring System, over days and nights, and for different seasons.

Promotional text: We introduce a new strategy to reduce the wind noise in the recorded signals of the IMS stations. This strategy is based on using machine learning to extract turbulence noise from data than can be translated into knowledge about the underlying fluid mechanics.

P3.6-651 – Simulation of operational results of NET-VISA on a three-month historical data set

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NET-VISA has benefitted tremendously from the interaction between its developers and CTBT State Signatories experts. One way that this interaction has taken place is through the delivery of data sets processed with successively enhanced versions of the software, with feedback from the experts. We present the results of a full simulation of operational results conducted offline with a recent version of NET-VISA (December 2020). The processing includes the complete three-pipeline configuration. The data set covers August-October 2016, includes an announced nuclear test, and is intended to be delivered to the State Signatories experts. The analysis will cover the essential comparison criteria of overlap and inconsistency between the automatic results and reviewed results, but will also go deeper into the comparison of the NET-VISA results with the SEL3 automatic bulletin for that period, taking into account location accuracy and completeness of the automatic events.

Promotional text: The physics-based Machine Learning operational software NET-VISA is being continuously improved. We present the most recent offline results on a three-month historical data set to be distributed to State Signatories.

P3.6-703 – Global Scale Discrimination of Explosions and Earthquakes with Deep Learning

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Discriminating between explosions and earthquakes is necessary for building hazard maps and monitoring applications. Previous studies have used classical ML techniques based on the amplitudes of

various phases. More recent methods based on Deep Learning use the full seismic waveform; however, they rely on detections made by nearby stations. These methods are inapplicable for global-scale networks such as those maintained by the International Monitoring System (IMS).
In our work, we perform a study using seismic waveforms of explosions and earthquakes as classified by the International Seismological Center (ISC) for events detected by the International Data Center (IDC). We show a comparison of various Deep Learning techniques on this task and our experiments demonstrate that the discrimination capabilities for events with magnitude between 3-4 mb degrade smoothly with distance between the event and the nearest station.

Promotional text: We present a study of Deep Learning applied to the explosions/earthquakes discrimination problem at a global scale.

P3.6-706 – BazNet: A Deep Neural Network for Confident Three-component Backazimuth Prediction

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Three-component stations traditionally rely on polarization analysis to estimate the backazimuth of each arriving wave. Unfortunately, these polarization estimates suffer from both high error and low confidence, and contribute very little to the downstream association algorithms at the IDC. Here, we present BazNet, a deep neural-network-based backazimuth predictor for three-component stations. For existing stations with ample historical training data, the technique achieves an overall median absolute error of around 14◦, a modest improvement over polarization. More importantly, each estimate is accompanied by a robust certainty measure, which is highly covariant with the error. By integrating the BazNet predictions and certainties into NETVISA, we demonstrate the potential of this algorithm to enhance global association at the IDC.

Promotional text: This work explores the use of a temporal convolutional neural network architecture for improved three-component backazimuth estimation, potentially enhancing the seismic signal processing pipeline used at the IDC for nuclear test monitoring and verification.

P3.6-707 – ArrNet: A Deep Neural Network for Confident Arrival Time Estimation

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Phase arrival time estimation for tele-seismic signals is a critical and fundamental step in the detection and localization of nuclear explosions and seismic study in general. Typically, this process involves heavy human interaction with more than half of all automatically detected arrivals being manually re-timed by a human analyst. Developments in Artificial Intelligence and specifically in the field of Deep Learning have produced architectures capable of tackling this task to minimize human involvement and improve the overall data processing pipeline. To this end, we introduce ArrNet, a deep Temporal convolutional Network (TCN) capable of reducing the mean residuals from automatic processing by more than 50%. ArrNet has been trained to be transportable by including data from all available IDC stations. It is capable of providing accurate arrival time estimates for any new station and across a wide range of signal to noise ratios. Additionally, ArrNet has been trained

to produce measurements for the 94%, 80% and 50% confidence intervals by implementing quantile loss functions in addition to regressing the arrival time estimate. These margins are covariant with the observed errors and work as a confidence metric for the estimated arrival time in order to refine downstream location and association estimates.

Promotional text: This work explores the use of a temporal convolutional neural network architecture for improved three-component arrival time estimation, potentially enhancing the seismic signal processing pipeline used at the IDC for nuclear test monitoring and verification.

P4.1 Performance evaluation and modelling of the full verification system and its components

P4.1-113 – Updating the "IDC Processing of SHI Data" user guide

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National Data Centre (NDC) staff need to interpret International Data Centre (IDC) seismic, hydroacoustic, and infrasonic (SHI) data processing results, which requires detailed knowledge of IDC SHI data processing. Similar understanding is needed by those that want to propose new IDC SHI data processing algorithms. To find the required information, NDC staff access the "IDC Processing of SHI Data" document, a comprehensive, detailed and accurate (at the time when it was written in 2002) user guide. Unfortunately, this document is currently outdated as many techniques recently adopted by the IDC are not described in it. Furthermore, not all technologies and techniques are described at the same depth and there are some inevitable errata. To significantly update this lengthy user guide and maintain the high overall quality is no trivial endeavor. Hence, in January 2019 a platform to note problems with the document and propose fixes was made available as an NDC Forum Topic, to take advantage of the considerable collective technical expertise of the NDC staffs. In this presentation we will provide an introduction to the platform, review results that have been entered so far, and discuss the path forward to producing an updated version of the document.

Promotional text: This presentation supports the conference goal to identify opportunities and methods for improving nuclear test monitoring and verification. Our NDC Forum platform allows States Parties experts to assist the IDC by noting issues with the IDC waveform data processing document.

P4.1-159 – The SSI calibration module

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The SSI calibration module is a tool that extends the Standard Station Interface (SSI) for intuitive execution of instrumental calibrations and review of calibration results. It aims to support the complex planning, technical execution, evaluation and reporting of the calibration of IMS seismic and T-phase stations. The SSI calibration module also provides a single and standard interface that masks the heterogeneity of the hardware/software used at different IMS stations. Finally, the SSI calibration module helps to standardize the communication through the full implementation of IMS2.0 format to dramatically ease the exchange, parsing and review of calibration messages, for both the Station Operator and PTS staff. The module has been deployed at a number of stations and the PTS currently continues its deployment at other stations. This poster presents the SSI calibration module and focuses on the functionalities supporting Station Operators during calibration activities.

P4.1-196 – Combined quality control check source for improved gain tracking and calibration

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Quality control (QC) in beta-gamma coincidence systems that are used for radioxenon measurement is currently performed using a Cs-137 check source. Compton scattering in the scintillating plastic (polyvinyl-toluene) of the beta detector creates a line of activity from the 667 keV gamma captured by the sodium iodide (NaI) across the beta dynamic range. Fitting the Compton scatter line provides a beta endpoint energy. The beta endpoint is used in combination with the 662 keV gamma peak to track the gain drift in the system before and after a sample measurement to ensure system stability during the count. Periodic QC checks are performed as well to monitor the long-term health of the system. By introducing another isotope to the check source, Ba-133, a second Compton scatter line can be generated in the coincidence counts that is well separated from the first. This would provide improved gain tracking, efficiency monitoring, and potential data on detector degradation. The multiple low-energy gamma lines of Ba-133, as compared to the 662 keV of Cs-137, would provide additional peaks for the energy and efficiency calibrations.

Promotional text: This presentation provides a new method for improving the reliability and accuracy of nuclear test monitoring systems.

P4.1-248 – The Italian CTBTO CNF: readiness status

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The CTBTO PrepCom and the Government of Italy agreed that the seismic station located in Cludinico (CLUD) may participate as a prototype Cooperating National Facility (CNF) in experiment conducted by the Commission. The Government of Italy designed the National Institute of Oceanography and Applied Geophysics – OGS (Italy) as responsible for the management of the station. This station can contribute to further refine the CTBTO location capabilities in the Europe/Middle East area of about 21% as shown in Pesaresi and Horn (2015).
In this presentation, we will illustrate the technical details of the solutions adopted to incorporate the Italian CNF into the CTBTO International Monitoring System (IMS). We considered a CTBTO specific seismic data acquisition system, but we then opted to keep the available standard one with the addition of the CTBTO Standard Station Interface (SSI). For the SSI we had to go through hardware and software procurement: we then experienced some difficulties in installing the SSI software and its required Operating System, solved with the help of the PTS. We will also illustrate the other required technicalities like the upgrade of the U.S. the anti-tamper device operations, the establishment of data communication link and the security measures adopted.

Promotional text: The CTBT verification system includes the possible use of other data for expert technical analysis. PrepCom and Italy agreed to designate OGS seismic station CLUD as a CNF. This can contribute to refine CTBTO locations in the Europe/Middle East of about 21%.

P4.1-294 – Australian NDC testing of the NET-VISA application integrated with SeisComP3

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The results of testing, at the Australian NDC, of the NDC-in-a-Box (NIAB) release containing the NET-VISA associator integrated with SeisComp3 (SC3) are presented. The aim of this work was

twofold: First to test how well the NIAB release was able to reproduce the VSEL3 bulletin produced by the International Data Centre (IDC) using data from the IMS network of stations. Second, to use an updated version of the NET-VISA software that allowed integration of non-IMS stations within NIAB to examine if performance improved in areas of interest to the NDC. In both cases the scdfx detector was used.

Testing showed that the NIAB release emulated the VSEL3 bulletin to a satisfactory extent. The improvement in monitoring threshold gained using NET-VISA integrated with non-IMS stations is reported for the Australian and another region. In Australia the earthquake catalogue was the ground-truth to test the performance of the automatically generated NET-VISA bulletin. The automatic bulletin from NIAB contained a similar number of earthquakes to the Australian catalogue and the automatic events had locations within 2 degrees of the reviewed locations. In some parts of Australia, the NET-VISA associator built more mining related explosions than the automatic bulletin used for the reviewed bulletin.

Promotional text: Evaluation of NET_VISA with non-IMS stations.

P4.1-324 – IDC SHI Reengineering Alpha Tester Group

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The PTS is leading the IDC SHI Reengineering project since 2014 with the goal of creating modernized, open-source software for SHI processing, and improving maintainability and extensibility to the system. Starting 2019, the project entered the Implementation phase and is currently under active development. The future system is based on the Geophysical Monitoring System (GMS) being developed for the US NDC. The aim of the Alpha Tester Group (ATG) is to enhance the engagement of the NDC community towards the IDC Reengineering project. It allows low-barrier access for State Signatories and NDCs to the current state of the reengineered system. The role of the ATG is to validate the results of the system, provide feedbacks on the system design and usability. This presentation highlights the challenges and technical solutions to provide and monitor test instances to our users around the world using cloud technologies.

Promotional text: In the context of the Alpha Tester Group on IDC SHI Reengineering, the PTS is providing test instances of the SHI data processing system being developed to participating NDCs. This presentation highlights the main challenges and chosen technical solutions.

P4.1-330 – Comparing the performance of a Bayesian automatic waveform event associator (NET-VISA) with the current operational approach (Global Association) at CTBTO. Minimum detectability maps for simulated explosions.

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The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has been developing and testing NET-VISA, Bayesian automatic waveform event detector, whilst a conventional detector, Global Association (GA), is in operation. In the context of CTBT verification regime, knowing the location dependency of the minimum detectable magnitude of those two event detectors is of interest. In the presentation, the geographical distribution of the minimum detectable magnitude of those detectors will be examined using a synthetic event generator simulating

expected arrivals from hypothetical explosions embedded in an actual data day. Two different data days are used for the simulations. One is chosen as representative of normal seismicity while the other is representative of particularly high seismic activity.

Promotional text: The presentation shows the performance of the currently operational waveform event detector and newly developed machine-learning event detector over synthetic seismic events.

P4.1-336 – Quality Control of Heterogeneous IMS Stations

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The Wilson Alaska Technical Center (WATC) at the University of Alaska Fairbanks operates a worldwide set of primary seismic, auxiliary seismic, and infrasound stations for the US Nuclear Arms Control Technology (NACT) Program and CTBTO. While WATC has long employed tools focused on data integrity, this project has expanded the quality control scheme to include data quality metrics that quantify noise performance, detect transient noise events, and identify metadata issues. The heterogeneous nature of WATC waveforms, which include broadband, short-period, and infrasound, presents challenges for established tools such as IRIS MUSTANG/ISPAQ. We have developed scripts that extend the capabilities of existing tools beyond conventional seismic channels, allowing us to generate comprehensive network intelligence that informs upstream quality assurance efforts. This presentation describes the system, demonstrates examples of data defects that have been identified, and outlines general spatio-temporal network performance indicated by almost a year of metrics. Finally, we demonstrate the results of applying aspects of the system to evaluate the data quality effects of deploying a small wind turbine in the vicinity of a colocated broadband and infrasound station.

This work was supported by the NACT Program at Defense Threat Reduction Agency. Approved for public release; Distribution is unlimited.

Promotional text: High quality data is crucial for nuclear test monitoring and verification. This presentation will outline a system that is employed for identifying data defects and generating metrics that can then be used to improve network performance, contributing to enhanced test monitoring.

P4.1-339 – Controlled underwater explosions of WW2 ordnances

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World War 2 (WW2) devastated Europe between 1939 and 1945. Unexploded ordnances remaining from this conflict are still found in European harbours. These recovered ordnances are moved to remote locations and destroyed in a controlled way. Some underwater detonations were large enough to be recorded by the International Monitoring System (IMS). Related events were included in the International Data Centre (IDC) bulletins. Position and charge size of WW2 ordnances are well documented in the press as they are of interest to the residents of affected areas. This information may be used to assess location accuracy and estimated magnitude of events recorded by the IMS network. This presentation will show recordings of events linked to controlled underwater explosions of WW2 ordnances in 2020. Examined events were triggered by devices of different charge size and took place in several locations. There were also other, previously detected WW2 ordnance underwater explosions which could be compared to events in 2020. We present how accurately these relatively small

explosions are located by the IMS network. We also relate charge size of explosive material to event magnitude in this special case of well-coupled underwater explosion.

Promotional text: Events triggered by controlled explosions of ordnances remaining from armed conflicts may be used to assess the location accuracy and magnitude estimates provided by the IMS network.

P4.1-365 – Participation of the Austrian NDC in the NPE2019-Exercise

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Following the statement of the state of Raetia regarding an accident at a TRIGA reactor facility, the Austrian NDC started investigating a possible violation of the Test-Ban Treaty. Based on a list of IMS radionuclide detections a forward run was performed and Possible Source Regions were determined. However, the detections could not be traced back unambiguously to the location of the reactor. Especially, the forward simulation supported the hypothesis that radioxenon measurements from IMS station Schauinsland were not related to the TRIGA reactor.In agreement with atmospheric transport modeling (ATM) results radionuclide analysis revealed the possibility of two overlapping incidents. Possibly, a second event took place around three days before the announced reactor release.

Additional data was released over a three months period. The second release contained radionuclide records from the national station in Vienna. ATM in combination with radionuclide analysis supported the hypothesis of a second event.

The last data released, was seismic data from local non-IMS-networks. With the data and public available bulletins, analysis of the waveforms was started. Finally, a suspicious source, an explosion,was localized and identified.However, it was not possible to relate this event to the radionuclide measurements at Schauinsland and at Vienna via ATM.

Promotional text: Participation of the Austrian NDC in the NPE2019-Exercise.

P4.1-431 – Research of Modeling and Applications on Amplitude-Magnitude-Distance-Depth of Teleseism and Ultra-Teleseism Phases

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The consistency of phases is an important method to estimate the relationship between the event and signal in the detection of seismic event. The consistency of amplitude can be used to determine the association, through the comparison of amplitude residuals, of numerous signal features on time and frequency domain. Different phases comply with the different propagation and attenuation laws of amplitude-distance-depth. The distribution of sample size along with the distance of teleseism and ultra-teleseism phases, such as P, PcP, PKP, PKPab and PKPbc based on the IDC is calculated. The model of amplitude-magnitude-distance-depth is constructed by iterative regression based on the residual statistics. The accuracy of model is estimated through the standard deviation and mean of magnitude. The application of the model is verified through examples.

Promotional text: In routine analysis, automatic seismic signal processing usually results in large amount of false events, which are caused by improper phase association. The consistency of amplitude can be used for determination of association through the comparison of amplitude residual.

P4.1-446 – Twenty years of IDC Reviewed Event Bulletin (REB) statistics using data from a sparse IMS network to one reaching near completion

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As of 14 December 2020, almost 90% of the IMS facilities (including radionuclide laboratories) were installed and certified, data is transmitted in either real time or on request from IMS stations to IDC for processing and analyzing. IDC analysts review automatic bulletins generated continuously and release the Reviewed Event Bulletin (REB) on a daily basis since February 2000. We present the statistics of mostly natural seismicity waveform events processed and analyzed over the past 20 years, as the network grew in size and became established. In particular, multiple parameters including magnitude for those events associated with detections from seismic, hydroacoustic and infrasonic stations are analyzed. Techniques and rules related to waveform data analysis and the need to correct the automatic bulletin are discussed. This discussion should be beneficial for analysts work and data processing system optimization.

Promotional text: We present the statistics of mostly natural seismicity waveform events processed and analyzed over the past 20 years, multiple parameters including magnitude for those events associated with detections from seismic, hydroacoustic and infrasonic stations are analyzed.

P4.1-455 – Tuning the IMS seismic stations by optimizing their detection thresholds

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Two principal performance measures of the International Monitoring System (IMS) stations detection capability are the rate of automatic detections associated with events in the Reviewed Event Bulletin (REB) or precision of the REB and the rate of detections manually added to the REB or miss rate of the REB. These two metrics are significantly influenced by prespecified slowness-, frequency- and azimuth- dependent detection thresholds used in the short-term average over long-term average ratio detection scheme of the IMS stations. The thresholds should be set at optimal values that a) the miss rate is as low as possible since no nuclear explosion should go unnoticed by the IMS and b) the precision is as high as possible as low precision compromises the quality of the automatically generated event lists and adds heavy and unnecessary workload to the seismic analysts during the interactive processing stage. In this abstract we present the procedure for optimizing the STA/LTA detection thresholds and how these new values are expected to impact the associated phases and added phases rates and other performance measures.

Promotional text: Optimization of STA/LTA detection thresholds at the IMS seismic stations and its expected impact on the association (or hit) rate and added phases (or miss) rate.

P4.1-592 – Probability of Detecting Seismic Events in IMS seismic network

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In the verification regime of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), nuclear tests must be detected and identified with high confidence. Seismic monitoring is particularly well suited for detecting and locating an underground nuclear explosion and determining its magnitude. The detection capability of a seismic network depends on the density of the network and distribution of stations, their site conditions, their recording characteristics, their data link to the processing center, and the post-processing methods of recorded seismic data.
In this study, previous studies of determination coverage of IMS seismic network is reviewed. Furthermore, the probability of detecting a seismic event is determined using the methodology proposed by Schorlemmer and Woessner (2008). This method is based on past seismicity detected by a seismic network. Accordingly, the detection probability for each seismic station is determined as a function of magnitude and hypocentre distance, using data from past seismicity.
After more than 20 years of performance of IMS seismic network, in this paper, the detection capability of this network is estimated based on past performance of the network. A comparison is made between the results of this study and the seismic coverage maps provided by the IDC.

Promotional text: One of the main concerns in CTBTO is the coverage map of seismic network of IMS. The coverage map is a tool to ensure the proper performance of the IMS seismic network in relation with the Treaty objectives. This paper address the evaluation of performance of IMS seismic network.

P4.1-593 – Methods to Assess the Value of High Input Resolution in Atmospheric Transport Models

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The question of whether the increased cost of implementing higher input resolutions in atmospheric transport models is difficult to address, and any answer is typically qualified with an "it depends." Attempts to study the effects of high resolution are frequently performed with a small set of case studies, making it difficult to generalise the findings to other cases that may vary in a number of attributes.

Our group has developed a methodology to run hundreds to thousands of paired ATM (FLEXPART) simulations in which only the resolution is varied, evaluating metrics such as plume arrival time and concentration, and then looking for "signatures" over many simulations that may reveal significant differences due to resolution alone. We suggest that if there are general improvements due to higher resolution, they must exhibit such signatures, and once they are detected they are further scrutinised. The methods have been used to explore paired FLEXPART simulations driven by 0.5 vs 1.0 degree ECMWF and GFS meteorological inputs every 36 hours over periods of eight to twelve months.

Promotional text: This work describes a framework that facilitates rigorous comparison of model parameters to determine whether differences affect simulations in significant ways.

P4.1-595 – Investigation of improvement possibilities for source localization using high-resolution atmospheric transport modelling within the framework of the CTBT - Application to Xe-133 observations at IMS station DEX33 in Germany

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The IDC investigates the utilization of High-Resolution Atmospheric Transport Modelling (HRATM) in the CTBTO's aim to locate possible source regions after detections of radioactive substances through the International Monitoring System (IMS). Supporting the decision process, the IDC accomplished a case study with two approaches; using the current operational atmospheric transport model FLEXPART on a regional domain with 0.1 degree horizontal and 1 hourly temporal resolution, and the Weather Research and Forecasting Model (WRF) which serves as an interface between the driving meteorological data and the HRATM FLEXPART-WRF to further increase the resolution. Optimizations of settings were done by a WRF sensitivity study. The performance was evaluated by using ATM backward simulations and their comparison with observational data which are comprised of seven episodes of elevated Xe-133 concentrations from the IMS noble gas system DEX33, located in Germany. Each episode consists of 6 to 11 subsequent samples with each sample being taken over 24 hours. Both FLEXPART models used the source terms from a medical isotope production facility in Belgium to simulate the resulting concentration time series at the DEX33 station. Statistical metrics are used for comparison.

Promotional text: This presentation describes the results from a case study which was conducted to support the decision process on applying HRATM at the CTBT. Simulation results from two HRATM approaches were compared to measurements from the IMS station DEX33.

P4.1-613 – Seismological investigation of the NPE2019

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The NDC Preparedness Exercises (NPE) are regularly performed dealing with fictitious treaty violations to practice the combined analysis of CTBT verification technologies. These exercises should help to evaluate the effectiveness of analysis procedures applied at NDCs and the quality, completeness and usefulness of IDC products. The NPE2019 is a combined radionuclide-waveform scenario. The source region and time domain of a possible treaty violation activity was determined from ATM in backtracking mode with input data from fictitious particulate radionuclide and radioxenon measurements at stations of the IMS of the CTBTO. The seismicity of the determined source region was investigated in detail to identify events which cannot be classified as natural. An earthquake sequence could be identified within the specified source region and time frame from ATM analysis. The unusual shallow source depth of about 3 km and no mining activities in this region could classified these events as a possible treaty violation. Results were used to decide about the need of an OSI to answer this question.

Promotional text: Investigation of seismic events within the NDC Preparedness Exercises 2019 (NPE-2019) target area to identify the nature of these events and decide about a potential treaty violation.

P4.3 IT, power systems and other enabling technologies

P4.3-058 – Optimal energy storage system for remote seismic nodes

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It is well known that remote seismic nodes fail frequently due to uncertainties of energy storage deployed at the node. The classical energy storage at the node is a lead-acid battery powered by a photovoltaic module, which exhibits irregularities and prompts increased running cost. This paper intends to integrate the battery and ultracapacitor, to reduce stress on the battery, extend its lifecycle, and meet the electrical energy demand of the node. In this solution, the ultracapacitor complements the electrical energy requirements of the lead-acid battery to energize the node continuously with its excellent power density. This novel integration of energy storages at the remote seismic nodes could aid the battery to complete its journey of lifespan and afterward enable relatively long-term acquisitions of seismic data. This will facilitate predictions and near real-time seismicity monitoring of areas. PSIM and Simulink environments were employed for the simulations and the results were promising and efficient. A Photovoltaic System with Buck converter and Maximum Power Point Tracking algorithm was implemented to optimize the constraints for the energy conversion.

Promotional text: Remote Seismic Nodes fail frequently, lead-acid battery is commonly used as energy storage at the nodes. But the battery is constrained with a reduced lifecycle for the required lifespan. MPPT algorithm and integration of supercapacitor and battery enhance the power at the node.

P4.3-066 – Methodology of good practices in databases management at CATAC to guarantee issuance of earthquakes products in real time

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Due to the large amount of information that is created with a new event and its relocation, the SeisComP3 (SC3) Database size tends to increase and the backup process becomes increasingly time-consuming.

At CATAC (Central American Tsunami Advisory Center) we created a data import mechanism, to send the information referred of every event from the main database to three other real-time servers, which represent the front-end to disseminate products such as Hypocenter location, Focal Mechanism and Moment Tensor in the webpage and two SC-Processing Backups.

We also implement this procedure to import solutions from the Earthquake Early Warning (EEW) Server to the main Server.

Thanks to these good practices, we keep data protected and available into the main database, servers, and backups avoiding unnecessary traffic that overloads the network.

In every server, queries are made directly at the localhost level so there's no network traffic and the main server is not saturated at all. Additionally, in case of IT chaos in our datacenter provoked by a natural disaster or another, there will be no data loss.

Promotional text: Methodology of Good Practices in SeisComP3 Databases Management at CATAC to Guarantee Issuance of Earthquakes Products in Real Time for Making-decision, Hazard Assessment and

Risk Mitigation.

P4.3-140 – Transition to Seiscomp on OVSICORI

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OVSICORI is the institute in charge of earthquake and volcanoes monitoring in Costa Rica. Similar to other countries in Central America, we have limited economical resources. Thanks to an important government investment in 2010 we chose Antelope by BRTT as our main monitoring computational system. Antelope worked well for us at the beginning, but over the following years we found out that most of the countries around us were using Seiscomp. In some ways, this prevented us from sharing data and knowledge with our neighbours. Seiscomp has developed faster than Antelope and we have therefore found some procedures easier on Seiscomp than on our system.
In 2018 CTBTO invited us to the Basic Seiscomp Training which helped us understand the system. This course was the beginning of the transition for us. In 2020, COVID-19 affected the national economy and so we were unable to afford Antelope's license. At the end of 2020, the transition to Seiscomp began.

Promotional text: Transition to Seiscomp on OVSICORI. Our institute decide to explire Seiscomp3 system after CTBTO course.

P4.3-160 – IMS Guidelines: Minimum Standard for Grounding and Lightning Protection System at the IMS Stations. Standard content, implementation and its influence on data availability statistics

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Based on statistics and experience in station installation and operations, IMS/ED in cooperation with OVE developed a comprehensive guidelines/company standards for a grounding and lightning protection system at IMS stations. The document's first edition was issued in 2010 and then revised in 2018-2019.
The document provides comprehensive information for the design and implementation of the grounding and lightning protection system for all four IMS technologies. The guidelines steadily became an integrated part of all terms of references for IMS stations' installations and upgrades. The standard has been implemented at over 20 IMS stations, which lead to significant reduction of damages caused by lightning strikes and power surges in the IMS network and, consequently, to increased data availability in the IMS network.
The poster presents the main parts of the standard, statistics of standard implementation and associated data availability changes at affected stations.

P4.3-267 – Safeguarding data availability at IMS Hydroacoustic hydrophone stations by improving on-shore digital data handling equipment

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The IMS hydroacoustic (HA) network monitors continuously the world's oceans with only six hydrophone stations (11 triplets). The acoustic signals acquired by the hydrophones are digitized underwater and transmitted via fibre-optic cable to an on-shore Digital Data Formatting Interface (DDFI). The DDFI builds data packets and sends these to the Commission's Standard Station Interface (SSI), where CD1.1 data frames are formed and forwarded to Vienna via satellite. Loss of data from even a single triplet has a high impact on the network's overall coverage and is often associated with the following root causes: SSI malfunction, local DDFI-SSI network or satellite transmission issues. An engineering effort was undertaken to mitigate the impact of such data-loss scenarios by adding to the DDFI a local disk buffer storing hydrophone and diagnostic data. This buffer is accessible through newly developed SSI functionalities, which allow backfilling of user-specified data segments and retrieval of diagnostic data logs by remote user request. The enhanced backfilling makes it possible to recover from the above described data-loss situations, whereas remote retrieval of DDFI diagnostic data leads to more efficient station troubleshooting. Rollout of these new capabilities to HA01, HA03 and HA04 is being planned for the period 2021-2022.

Promotional text: Newly developed shore equipment features make it possible to reduce data loss and improve the remote troubleshooting of IMS Hydroacoustic hydrophone stations. Roll-out to HA01, HA03 and HA04 is being planned.

P4.3-329 – A solution for the continuous power supply of the AS043 station

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The CTBTO site station in Parapat (AS043), North Sumatra has been losing data since 2020. This has resulted in the loss of important data for analysis. Data analysis from SQLX shows the seismometer in good condition and noise spectrum still within HNM / LNM limits. The site station has used solar panels but this is not enough. Solar panel energy cannot supply battery power effectively. The solar panels work for about 4 hours. Due to the Parapat climate it is almost cloudy every day. The LDR (lightning detector relay) is designed to regulate the supply of power sources from the consumption of solar power and the main generator. This way, the battery can always be fully charged. Therefore, data can be sent continuously. The LDR is intended for automatic switching between the generator and solar panels coupled with a contactor type relay. This is not a new technology, just a simple solution to ensure continuous data availability without interruption. Noise studies have not been carried out, but the converter can be located outside the seismograph area. The generator power supply is used because only that device may be available in the vicinity of the site.

Promotional text: Transfer power supply from solar panel to main generator.for AS043.

P4.3-334 – The SSI new Configurator

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The Station Standard Interface (SSI) is a modular software, consisting of a set of executable programs, application programming interfaces (API) and libraries. The main purpose of SSI is to collect, sign, buffer, reformat and transmit data using IDC format. SSI is used at more than 150 IMS stations in all waveform technologies as well as at several NDCs. The Web configurator has been the main interface for operators to configure SSI, however this web interface can appear as complex and sometimes not so user-friendly. One of the major issues of this configurator is that it's challenging to configure SSI over a low bandwidth link. A new configurator was then developed to fill the gaps and difficulties of the previous interface and compatible with CTBTO network infrastructure. This new configurator is a fat client developed in Python running on both Linux and Windows. The backend compresses the entire configuration in one file before sending it to the frontend. The file is then read by the frontend which will display information in a user-friendly way for reading or modification. When a change is done in the configuration, the frontend will zip the configuration in one file before sending it to the backend.

Promotional text: The management of continuous and efficient station data acquisition and data forwarding to the IDC is a key functionality of IMS stations with deficiencies impacting directly the station performance.

P4.3-414 – The Expert Communications System

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The Expert Communications System (ECS) is a secure internet-accessible application, sharing and strengthening the intersessional work of the Commission and its subsidiary bodies, that enables registered users from States Signatories, the Provisional Technical Secretariat (PTS) and a restricted observers' number to the Preparatory Commission (PC) to access to official documents.
Users can launch or participate in discussions related to the ongoing and forthcoming meetings of the Commission and its subsidiary bodies or access documents' drafts.
Live streaming and on-demand videos of meetings and as well as related information are also available on ECS.
Recently work has begun to redesign ECS by adding a new user interface and to adhere to the corporate identity standards, referenced in the CTBTO Style Manual, and to re-organize all available information in a more user-friendly way to support needs, comments and feedback collected from registered members and observers.
Moreover, ECS is undergoing a process to refactor its source code in a more robust way, removing old legacy dependencies, and introducing the principles of CD/CI as well as moving deployment to a Docker environment.
The proposed e-poster will showcase the main design changes in ECS, and the software architecture enhancements and solutions applied to the system.

Promotional text: The ECS is an important tool for sharing and strengthening the intersessional work of the Commission and its subsidiary bodies.

P4.3-418 – Development of Alert Monitoring System for the Malaysian Radionuclide Monitoring Station (RN42)

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Among the monitoring stations include the RN42 which is located in Cameron Highlands, Pahang, Malaysia. Generally, the task to monitor the status and result of the radioactivity spectrum is quite a tedious job. The radionuclide analyst at the International Data Centre (IDC) in Vienna, Austria analyzed around 21 to 25 spectrum data every day. Automatic products help the analyst to perform subsequent interactive analysis. However, from the National Data Centre (NDC) point of view, the task of monitoring the result is only part of their other routine task. Consequently, they could miss important events that happened at their stations that require immediate response. This paper aims at discussing the development of a simple alert system for monitoring the health of the RN42 station. The preliminary data (PREL) which is collected and received every two hours are chosen in this study as the parameter of interest, including the existence of natural radionuclides such as Beryllium-7 (Be-7) and Sodium-24 (Na-24) as indicator. The alert system has been developed using Python and integrated with existing client email software. Alert will be sent to the authorized recipient to their smartphone using Telegram Bot and could be displayed in a simple webpage.

Promotional text: A simple but effective method to alert NDC staff and stakeholders about what is happening on their stations as well as important alerts about any important detection which answering the first objective of this conference.

P4.3-445 – Segregation of the verification email flow in the CTBTO

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The PTS uses email (SMTP) as a transport mechanism for a portion of the verification data received from the IMS stations and laboratories and for data transmitted to States Signatories. Currently the PTS uses the email domain @ctbto.org for both its verification and non-verification email systems, forcing the sharing of resources and making it difficult to segregate the email flows and systems.

Starting in 2017, the PTS built a new structure for its email systems that allows for the full segregation of the verification and non-verification email flows. The domain @ctbto.int was chosen for the verification systems. The basic infrastructure was assembled and made available to PTS teams. Software solutions are being developed to allow the use of the new email domain.

This presentation will describe the high-level architecture design and the solutions developed for the new email domain. It will also highlight the challenges to implement the new design, such as the need to change the configuration of the IMS stations.

Promotional text: The PTS uses email as a transport mechanism for verification and non-verification systems and identified the need to segregate verification email flows. This presentation describes the project to create a new email domain for verification data on a segregated infrastructure.

P4.3-470 – GDMS US-IMS Cloud Migrations

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General Dynamics Mission Systems (GDMS) is seeking ways to improve the maintainability and scalability of its applications and IT infrastructure by leveraging emerging cloud technology and

best practices. The cloud offers many advantages over traditional IT infrastructures including greater flexibility, reduced cost, improved backup solutions and faster deployment cycles.

GDMS cloud migration consist of moving new and existing application to a cloud-ready architecture, creating new cloud infrastructure and services and incorporating cloud solutions in backup plans. Cloud applications are developed as a collection of smaller services which are deployed as containerized services. Legacy monolith applications are refactored into a design that allows for containerization of individual services. Applications are then deployed and managed using container orchestration services. Kubernetes was chosen as the orchestration tool because of its maturity and flexibility. Finally, data and artifacts are stored in cloud databases and other cloud backup solutions for persistent, off-site and unlimited data storage capability.

Promotional text: GDMS migrates IT infrastructure to Cloud solutions to improve maintainability and scalability of applications and services. The migration consist of developing applications for the clouds, managing deployed applications using Kubernetes and leveraging cloud backup solutions.

P4.3-533 – CTBTO Equipment Smart Management Solution Based on RFID

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Equipment is mission critical for CTBTO verification pillars. Within the 3 Divisions of CTBTO, IMS, IDC and OSI, the categories and volumes of equipment are increasing with the non-stop and quick development of the verification infrastructure. Equipment management could be either an efficiency improving factor or bottle neck for the functioning of CTBT verification engines, like a double-edge sword. Take the OSI as an example, effective equipment management is crucial for current OSI exercises and operations after the EIF. During OSI operations, according to OSI operation concept and search logic, VO, SAMS, RN, CPT, LA teams would be mixed together to form Field Teams for every day mission, equipment would also be mixed together, this would greatly increase the scale of complexity of OSI equipment housekeeping effort, which has been already a practical challenge for IT and IT members. This work would carry out a system solution to CTBTO equipment solution based on recent RFID technology. Varieties of sticker RFID, anti-metal RFID, High-frequency and Ultra-high frequency RFID labels, and auxiliary devices would be utilized to meet the practical scenarios of CTBTO requirements. This practical solution has already been applied to CTBT Beijing NDC and Beijing RL for daily equipment management.

Promotional text: This work would provide a practical equipment management solution to CTBTO based on RFID, which has already been applied to Beijing National Data Center and Beijing Radionuclide Laboratory for daily equipment management.

P4.3-558 – Challenges in using RF link for intra-site communication at IMS waveform stations

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Radio frequency (RF) systems are used at large number of IMS waveform stations for transmitting data and State-of-Health parameters from the array elements to the Central Recording facility. Main operation and maintenance challenges experienced over time are related to equipment obsolescence, aging, material deterioration or harsh environmental conditions. RF equipment must receive regular preventive inspections and maintenance in order to ensure stable radio links and to achieve expected reliability over years of operation. Unnecessary downtime can be avoided by implementing efficient technical solutions and by having regular maintenance of RF transmission equipment, by performing appropriate monitoring of critical parameters and by having recourse of qualified RF engineers for design, implementation and training of station operators. This paper describes the challenges faced with RF systems used at IMS waveform stations and focusses on the successes with operation and maintenance and on the solutions to mitigate the radio communication problems.

Promotional text: This paper describes the challenges faced with RF systems used at IMS waveform stations and focusses on the successes with operation and maintenance and on the solutions to mitigate the radio communication problems.

P4.3-570 – GCI, Station and NDC Infrastructure Resilience Optimisation

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Since the migration to GCI – III it has been observed that there are multiple instances of failure of data transmission when there is an operational GCI-link. Elements for significant consideration in the analysis phase examined why, when the GCI link is available, data transmission stops but subsequently backfills indicating that there is some element in the overall data path that is temporarily failing. Ensure that the GCI equipment is connected to the appropriate power source at the stations. As the backup GCI-link has a lower overall consumption than the primary it may be appropriate to connect it to the data acquisition same power source if it, in conjunction with the reliability of the recharging capability is considered to have sufficient capacity that data acquisition is not put at risk. Due to complexities in the data acquisition path, particularly when the station is run by, in effect a separate entity there is a firewall or other network elements between the actual acquisition equipment and the PTS SSI machine, understanding the actual full data flows and improving automated monitoring and alerting could improve data availability.

Promotional text: Use on Network Monitoring Data to analyse and rectify configuration issue, improve availability and predict potential issues to be rectified by preventative action leading to increased data availability.

P4.3-571 – Challenges and improvements to DC power systems at IMS waveform stations

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Most waveform stations in the IMS network are now 10-20 years old. Problems with power and communication systems often relate to cables, circuit breakers, connectors and/or surge protection becoming corroded or deteriorated to a point where good connections and functionality can be compromised. Many stations are located near the sea, in high humidity and salty environments, which

inevitably provokes corrosion over time, almost regardless of precautions during installation to protect the electrical installations. In addition, DC power installations are prone to create a constant ion flow that can create electrolysis and could damage metals in the installation. Examples of corrosion has been observed on cables, connectors and surge protection devices and shows the importance of proper installation, timely inspection and periodic maintenance of the power and communication systems, to ensure sustainable operation and high data availability of IMS stations. Installation methods to simplify inspection and maintenance can help the station operators during troubleshooting and to report power issues before they become problems. This paper describes some of the power systems installed at IMS waveform stations and focusses on the operation and maintenance of these power systems.

Promotional text: DC power systems maintenance and repair, degradation due to time, humidity, etc. State of the art components for DC power and surge protection.

P4.3-652 – Implementation of a tool for recording and consulting the most frequent problems in a station

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This study proposes the development and implementation of a tool for recording and consulting the problems that occur at the station. The application to be implemented internally in the station, which can be mobile, would record the incident and once the event has been added, a group of contacts would be notified about the problem that occurred and its solution. In turn, the application would allow the query of previous similar events in order to apply a similar solution, reducing maintenance time. This knowledge base must be able to store multimedia files, such as images and videos, in order to facilitate maintenance. These multimedia files will be used to implement augmented reality technology, further facilitating the access and location of the station components. The application will have an external navigation mode that allows the location of the infrasound sensors and the distance between all its components and an internal navigation mode, virtual tour type, dynamically optimizing the location of parts or modules of any type of station, which seeks to perform a more efficient maintenance of station components.

Promotional text: The station staff changes each 1 or 2 years, which causes difficulty in the transmission of knowledge and loss of traceability about the problems that the equipment has had and how to solve them.

P4.3-653 – Power Energy Model to Improve Data Availability of IMS, adapted to South America Seismic Stations site conditions.

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Remote places, away from crowded areas, where anthropic noise cannot affect the quality of the measurement characterize the site of installation of a seismological station. However, these sites are generally difficult to access, located in places where there are no traditional energy and communication systems, or the access to maintenance facilities affects its operability. This condition could for long periods affect the availability of the data generated by seismological stations connected to traditional energy systems, due to failures in the traditional electricity service. From this approach, the incorporation of autonomous energy systems is an alternative solution. However, in South America given the diversity of climates, with the presence of cloud forests, high vegetation and average precipitation levels between 350 and 2500 mm per year, the incorporation of autonomous energy systems to ensure the data availability of the seismic stations of the IMS - and therefore mission capable - represent a challenge. The purpose of this research is present a model for the incorporation of a stronger energy power system for IMS stations, adapting to South American region conditions. The results shared a contribution to improve IMS seismic station data availability, using an alternative system energy and considerations for its implementation.

Promotional text: Through the research, we can identify a potential and adaptive solution to improve the performance of the IMS seismic stations contributing to verification regime. Present this proposed in the Snt scenery is an opportunity to adjust and improve the research through the exchange.

P4.3-677 – Secure and Reliable Office IT architecture for an efficient Secretariat

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The Provisional Technical Secretariat (PTS) is the entity assisting the Preparatory Commission in the establishment of a global verification regime to monitor compliance with the comprehensive ban on explosive nuclear testing.
In this digital era, efficient, secure, and pervasive IT services are key enablers allowing the PTS to fulfill its core technical mandate.
To modernize its office IT environment the PTS has embarked on an IT transformation and is relying on cloud services.
In this e-Poster, we present the office IT architecture that is being deployed to support the high strategic goals of the PTS.
The document further presents how this architecture has served the PTS in times of COVID-19 and will serve it in the eventuality of a disaster.
By the end of the transformation, the anticipated benefits include mobility, security, improved collaboration, unified identity and access management, and disaster recovery.
Year on year worldwide, we observe more sophistication and a rise in cyber threats. There were twice as many confirmed breaches in 2020 as in 2019. Hence, the PTS transformation is considered a key investment in IT security, in a bid to guaranty the CIA triad. Without disclosing confidential details, the e-Poster provides insight into how the architecture is secured.

Promotional text: The Poster presents the architecture of a modern office IT environment. Cloud services are used at the core of the architecture.

P4.4 Network sustainability and systems engineering for CTBT verification

P4.4-049 – Upgrade and recapitalization of seismic station AKASG

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The seismic station AKASG (PS45) is located at the territory of Ukraine. From 2000 to 2002, the station had been being upgraded according to the CTBTO requirements. From 2003 to 2010, the station was operating within IMS, the most important problem in the station data presence during that period was the radio link system, used at the station. From 2010 to 2011, the new modernization project of the station was being developed, which was implemented from 2013 to 2016. In the course of its implementation, the following works were performed:
-the existed data transferring system from the station elements, which was constructed of both the copper lines and the radio link tools, was replaced into the new one, fiber optic communication lines;
- all the equipment, installed by SAIC, except of the sensors, was replaced into the new ones;
-both the power supply system and the lighting protection system were upgraded.
The station modernization allowed to increase the data presence from the station elements from 86% in 2015 to 99,9% in 2020.
Nowadays, the process of the fiber lines installation at the 8 sites and a new alarm and video surveillance system is being developed.

Promotional text: This annotation is dedicated to the achievements that were obtained during the recapetalization and modernization of the AKASG station in 2013-2020.

P4.4-057 – Decentralized maintenance at Colombian Geological Survey – National Seismological Network

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The Colombian Geological Survey (SGC) has its headquarters in Bogota, Colombia, where most of the technical and administrative personnel are located. However, its main activities are in the field. The National Seismological Network has monitoring stations countrywide. Due to this centralized scheme, preventive and corrective maintenance takes up to 45 days after planning, This is not a good stats indicator as it is greater than 12% outage in a year. The National Seismological Network has moved a maintenance engineer to the Cali city, where SGC has a regional office. He was moved in order to carry out a test about responding in better time for near stations and improving the outage time. It was also a budgetary decision as he does not need flight tickets and uses free days to return to Bogota.
In addition, COVID-19 restrictions allowed us to carry out maintenance of the stations located in the region. As the airports were closed, the furthest station took eight hours to reach by car.
Due to the improved outage stats using this new maintenance scheme, the seismological network is evaluating whether to move maintenance engineers to the Medellin and Bucaramanga SGC regional offices.

Promotional text: The centralised maintenance activities have not efficient way to keep good seismologies station country wide operating with the best stats, all activities run from Bogota. Then, the SGC has move technical personnel to Cali to attend Pacific and south Colombian areas.

P4.4-134 – Modernization of the PS19 seismic station

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After 25 years of reliable operation, PS19 (GERES) was modernized in 2017/2018. It was the first major upgrade since the station was certified as primary seismic IMS station in 2002. The German NDC operates PS19 remotely. The required data availability is ensured by preventive maintenance twice a year. The station consists of 25 array elements within an aperture of about 4 km. During the modernization, a total of 200 km cables for power supply and data transmission, connecting the array elements with the central facility, were replaced and the infrastructure was refurbished. A new system for overvoltage protection was installed in order to reliably operate the array in future. The GCI between the central facility and the IDC was changed from satellite connection to internet based VPN routing. All GERES GS13 seismometers underwent on-site reference calibration against a set of GS13s tested at CEA, France and SNL, USA in order to validate each seismometer's response against the values configured in the IDC. Data authentication has been successfully transitioned from DSA to ECDSA on both CD1.1 frame and sub-frame level. An additional broadband seismometer was installed for increasing the station's mission capability. PS19 was successfully revalidated in its new configuration.

Promotional text: IMS stations need to be refurbished at the end of physical life of the equipment. The modernization of PS19 represent the complexity of this task for a 25-elements seismic array. State-of-the-art power supply and overvoltage protection guarantees reliable operation in future.

P4.4-139 – Using data science for predictive maintenance of noble gas systems within the IMS

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Analysis of state of health (SOH) data from radionuclide systems can provide information beyond alerts and system diagnostics. Careful analysis of the data can help detect degradation of sensors that may help predict when a failure may occur or the remaining useful life (RUL) of components. In some early work performed by Pacific Northwest National Laboratory (PNNL; US), high-resolution SOH data from the Swedish Automatic Unit for Noble gas Acquisition (SAUNA) and Système de Prélèvement Atmosphérique en Ligne avec l' Ánalyse du Xénon (SPALAX) was analyzed using data-driven approaches with a goal of developing predictive maintenance techniques. This work investigates a hybrid methodology that combines both data-driven and physics-based approaches to more accurately predict system failures. This work also investigates the feasibility of using current available IMS SOH data for predictive analytics as well identification of possible gaps in the data.

Promotional text: The predictive maintenance techniques outlined in this effort will seek to improve sustainability of the IMS network. This aligns with the conference goals of identifying methods to improve monitoring and verification as well as community scientific knowledge exchange of ideas.

P4.4-152 – Station state-of-health monitoring with the Geophysical Monitoring System (GMS)

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Sandia National Laboratories is developing the Geophysical Monitoring System (GMS) for modernization of the United States National Data Center waveform processing system, including data acquisition, automated processing, and interactive analysis. The United States is providing the common architecture and processing components of GMS as a contribution-in-kind to accelerate progress on International Data Centre (IDC) Re-engineering. Open source releases of GMS have been made annually since 2018. Recently the GMS project has focused on developing an operational-quality Station State-of-Health (SOH) Monitoring capability, to enhance the ability of system operators to quickly recognize and address station availability and quality issues. This capability was provided to the IDC in the 2020 GMS open source release. The Station SOH Monitoring application has been designed to receive, process, and display SOH information from at least 300 stations using the CD-1.1 protocol, and to meet operational performance, deployment, and reliability specifications. System improvements include using a message-based, reactive software architecture, a Kubernetes containerized deployment platform, and automated system testing capabilities. This presentation describes the GMS Station SOH Monitoring capability, system architecture and design, and deployment and operations.

Promotional text: A new Station SOH Monitoring capability is available in the latest GMS software release provided to the IDC Re-engineering project. This presentation describes this operational capability and improvements to system architecture, design, and deployment.

P4.4-189 – Deployment of Portable Infrasound Sites to Assess Feasibility of Additional Elements, I51GB, Bermuda, UK

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IMS infrasound station I51GB, located on the island of Bermuda in the Atlantic Ocean, was certified in December 2008. The original installation presented many design challenges driven by land availability, island topography and proximity to populous zones. These challenges not only dictated the amount of elements that could be installed, but also the geometry of the station. The array geometry of I51GB is atypical for an IMS infrasound station, comprising of a large-aperture, rectangular four-element array. To add to the uniqueness of the site locations, is the large lagoon that lies directly between all elements. In late 2018, after several incidents of vandalism rendered elements inoperable, the PTS was approached about the feasibility of relocating existing elements to more secure locations, which had become available since the original installation. In September 2019, with cooperation of the Station Operator, the PTS installed two portable infrasound stations in parallel with the existing I51GB elements. Data was collected for roughly 10 months to allow for IMS station site survey requirements and to assess, whether the additional elements benefit station infrasound event detection capabilities. Results from the successful site survey are summarized in this poster.

Promotional text: In 2019, the PTS installed two portable infrasound stations in parallel with the existing I51GB elements. Data was collected for 10 months to allow to assess whether the additional elements benefit station infrasound event detection capabilities.

P4.4-257 – Structure of Testing Technology Program for On-Site Inspections equipment

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The Preparatory Commission is tasked to make all necessary preparations, in fulfilling the requirements of the Treaty and its Protocol, for the support of on-site inspections (OSIs) from the entry into force of the Treaty. The OSI Technology Testing Program (TTP) is meant to support these preparations. The specific challenges and the unique nature of an inspection is making the synergy between equipment, infrastructure, human resources and procedures very important. The TTP is addressing this synergy through the implementation of a continuous and interrelated development process. Also, the structure of the program has been designed to formalize the processes in place by describing expected inputs and outputs. From the definition of user requirements, functional design, prototyping to field testing, and propositions of new technical specifications for the list of equipment, the poster will present the different development phases. The iterative and incremental approach will be exposed with concrete examples. They also show that the OSI capabilities must remain suitable and fit for purpose as technology evolves and innovations emerge. Hence, they must be subject to ongoing review with constant attention to their availability and appropriateness which is being considered in the OSI TTP.

Promotional text: The poster intends to support the exchange of knowledge and ideas between the CTBTO and the broader scientific community. Systems Engineering methods are here used in a nuclear test monitoring and verification improvement context.

P4.4-276 – The sustainment of the IMS Hydrophone Hydroacoustic Network of the CTBT

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Hydroacoustics is the only verification technology of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) to be fully certified. Five T-phase stations and six hydrophone-based hydroacoustic stations monitor the world oceans 24/7 for signs of nuclear explosions. Hydrophone stations comprise triplets of underwater microphones, called hydrophones, suspended hundreds of meters below the sea surface and cabled to shore with electro-optical cables, providing near real-time hydroacoustic data to the International Data Centre in Vienna, Austria. Installing the six hydrophone-based hydroacoustic stations in some of the most remote places on the planet constituted a major engineering accomplishment – sustaining or repairing them turns out to be equally, if not more, challenging.

Failure causes include natural phenomena, such as underwater landslides which damage underwater segments of cables, degradation of cable protective material in the near-shore areas, and obsolescence or malfunctioning of shore equipment. This poster summarizes the on-going sustainment projects of the IMS hydrophone hydroacoustic network though re-establishment solutions of damaged sections, risk mitigation studies and external aggression protective measures, innovative modular solutions for easy of repair of underwater components and enhanced resilience together with protective measures for onshore electronics.

Promotional text: The certification of all the IMS hydroacoustic stations constitutes a major engineering accomplishment. The sustainment of this network turns out to be equally, if not more, challenging. This poster summarizes all the on-going projects to achieve resilience in hydroacoustics.

P4.4-382 – RASA Revalidation Improvements using the Rig for Automated Flow Testing (RAFT) System

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Expanding upon flow analysis efforts presented in SnT 2019, General Dynamics Mission Systems (GDMS) has developed a field deployable system to validate the performance of mass flow meters at International Monitoring System (IMS) radionuclide stations with Radionuclide Aerosol Sampler/Analyzer (RASA) systems. The Rig for Automated Flow Testing (RAFT) system can validate the factory calibrations of the Sierra 620S mass flow meters, characterize the RASA ductwork's impacts to flow-rate measurements at various operating ranges, and perform flow validation measurements in line with CTBT certification/re-validation procedures for particulate systems. The RAFT system collects and compares measurements from the Sierra 620S flow meter, the RASA system, and the Senya VM700 flow meter in near real-time, minimizing testing errors from manual data acquisition. Using the RAFT system, GDMS can characterize station specific duct work configurations to minimize air volume measurement deviations between the RASA and the Senya VM700 flow meter.

Promotional text: The RAFT system is designed to optimize the flow rate certification efforts for RASA systems. In addition, the RAFT system allows users to field validate existing flow meter installations to ensure they continue to meet CTBT requirements. This effort aligns with Theme 4.2.

P4.4-664 – NORSAR Station Operations and State of Health Monitoring

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NORSAR is the Norwegian National Data Centre (NDC) and operates six stations of the International Monitoring System. These are the primary seismic arrays NOA/PS27, ARCES/PS28, the auxiliary seismic array SPITS/AS72, the auxiliary single seismic station JMIC/AS73, the infrasound array IS37 and the radionuclide station RN49. It is crucial to have a good overview of the state of the various components of the stations. NORSAR has since fall 2018 been developing and using a system based on Nagios, PostgreSQL and Grafana to monitor and log uptime and state of health of our installations and processes.

Promotional text: This presentation will give an overview of NORSARs field installations and station operation. Emphasis will be on the how we have set up the new SoH monitoring system and lessons learned so far.

P4.4-686 – Successful operation and maintenance of the Botswana Seismological Network (BSN) stations including Lessons learned from the COVID-19 pandemic crisis.

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Botswana Seismological Network(BSN) have deployed a countrywide state-of-the-art network of 21 autonomously recording broadband stations. The sensors deployed in the BSN are the Streckeisen and the Nanometrics Trillium 120. A relatively low cost in-house developed NARS Dataloggers developed by the seismology group and the Instrumental group of the Physics department of Utrecht University is used in the BSN together with the new de facto standard Centaur Digital Recorders developed by Nanometrics. For timing the NARS Datalogger uses the Trimble Acutime Gold GPS smart antenna. The BSN is powered by solar energy with the use of a smart charge controller that regulates power. Mobile network communication systems are used to provide continuous remote access. This communication system allows us to connect to the stations remotely via SSH, SFTP and VNC to do remote maintenance, upgrades and to check for the state of health of the stations(SOH). Remote Access to the stations and the use of automated scripts is our new norm of getting the SOH, downloading data and managing most of the routine processes during this Covid-19 crisis. The BSN stations are integrated by Seiscomp3 with the IMS and regional stations to improve location of local and regional earthquakes.

Promotional text: The Abstracts shares ideas with other NDC's how we operate and maintain our network stations. The Abstract is also open to improvements and changes after learning from other Institutions.

P4.5 Resilience of the CTBT monitoring regime, including lessons learned from the COVID-19 pandemic

P4.5-038 – Influence of the reduction of human activity due to the pandemic in the identification of infrasonic events by I09BR Station

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The analysis of infrasonic data from the I09BR station, installed in the vicinity of the city of Brasilia, Brazil, indicated a significant reduction in the level of local noise during the COVID-19 pandemic, allowing us to identify other sources of signals previously masked by cultural noise. Most infrasound signals recorded at the I09BR array are originated from sources located close to the surface due to mainly urban activity (airport, factories) and also by quarry blasts that can be recorded in two IMS technologies: seismology and infrasound. Government decrees to control the movement of people in cities to contain COVID-19 considerably reduced the noise produced by the city, improving the performance of the infrasonic station in detecting distant mine blasts. In this work, data from the infrasound station I09BR were analyzed, to observe the variation in the pattern of infrasonic detection caused by changes in people's routine due to social distancing measures decreed by the Government.

Promotional text: Due to the continuous analysis of the infrasonic station I09BR data, several detection patterns can be observed. With the social isolation measures on account of the Covid-19 pandemic, there was a variation of these patterns.

P4.5-069 – Importance of information exchange and out-of-box thinking towards high degree of system resilience

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A resilience of a system is a measure how the same behaves in disruptive conditions and potentially unforeseen scenarios managing the situation appropriately. The CTBT monitoring regime is built on relevant information acquisition protocol, globalized data sharing platform via IMS, GCI and IDC tools with a mechanism to investigate suspicious events, through OSI, while having a process for confidence building. As the CTBT monitoring regime forethought the events with standardized responses and run by pre-trained professionals, the system remains robust. Lack of information exchange among nations and incoherent global response towards the COVID-19 deepened the health crisis to a global pandemic demanding a common platform towards collective decisions with collaborative efforts. The most valuable lesson learnt from the COVID-19 crisis, towards the CTBT monitoring regime, is the importance of openness and information sharing among the nations across boundaries extending beyond political and regional confinements. Though the strength of the CTBT monitoring regime remains strong, particularly due to extended information exchange platform, the resilience of the same is arguable as almost all components of the system are well-tuned towards predefined scenarios limiting its ability to adopt for anomalous and unforeseen circumstances.

Promotional text: Contemporary global issues are discussed and shared in common platforms for speedy and effective solutions. However, unforeseen scenarios test the resilience of such systems and COVID-19 emphasizes the importance of information exchange towards effective solutions.

P4.5-193 – Resilience Of The CTBTO Seismological Monitering Around The Dead Sea Transform Region And Around

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The Dead Sea Transform fault system (DST) is responsible for the earthquake activities in the region. Seismicity information including historical and instrumental data indicate that many destructive earthquakes occurred in and around the DST. Realtime monitoring systems around seismogenic zone are important for early detection of earthquake, seismic hazard and seismic risk assessments. Since the last damaging earthquake 90 years ago, the population's awareness of such threats has decreased from generation to generation.
The COVID-19 pandemic has affected the seismological monitoring and other monitoring technologies, duties and tasks. Additionally, technological Monitoring institutions should consider establishing pandemic-specific policies and procedures, capabilities for employee communications, telecommuting and personal leave to minimize disruptions. Due to their duration, impacts on personnel in the regions that absorb additional work cannot be overstated, from the start of the pandemic to several weeks in, when contractor resources can start to meaningfully contribute. Scale can vary, and to date it has been regionally concentrated with some global impacts; we have not seen a fully global crippling pandemic yet, although this remains a possibility.
Focus on lessons learned from the COVID-19 pandemic for enhancing duties and tasks in the seismological monitoring in the DST region and around.

Promotional text: Contribution lessons learned from the COVID-19 pandemic crisis.

P4.5-202 – Operation of Kazakhstan National Data Center (KNDC) under COVID-19 pandemic

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In Kazakhstan, for two months of 2020 there was an emergency rule over the whole country. For Almaty, where the KNDC is located, the urban office for coronavirus prohibited the operation of all offices, including the KNDC, movement of people and transport inside the city was limited. During 1-2 days it was necessary to re-arrange the operation of the Center, avoid the suspension of data acquisition and transmission processes, and continue data processing and seismic bulletins compilation. This became possible owing to gradual transfer of KNDC to the technology of virtual operation of servers and work machines started in 2018. By 2020, almost all servers and work machines operated through the Proxmox Virtual Environment with a web-interface. This helped to quickly arrange remote operation of analysts, and control data arrival and the operation of equipment and software. For two months, only one person had access to the office - not a specialist - who was responsible for heating and communications. He communicated with KNDC staff through the WhatsApp application, received instructions and eliminated problems if it was necessary. For two months of this operation with no people, thanks to the well-arranged computer-communication infrastructure there were no failures in work, and all obligations were implemented properly and on time.

Promotional text: The report shows an example of Kazakhstan National Data Center operation during the pandemic period. The uninterrupted operation of the Data Center is the contribution of the country into the non-proliferation regime and control for nuclear tests.

P4.5-204 – Changes in seismic levels in Thailand COVID-19 Epidemic Period: Case Study of BKSI Earthquake Monitoring Station.

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The COVID-19 outbreak began to emerge in late 2019 at the Wuhan mine in China, with a dramatic increase in the number of people diagnosed with the novel coronavirus. This was until March 2020, when a few other countries started to report massive cases. In a world where people interact with each other at work and elsewhere, this resulted in a marked increase in the number of cases due to human-to-human transmission of this virus. Reducing the transmission of the virus is done by maintaining social distance. As the number of people infected with the virus increased, the Thai government had to declare an emergency situation, causing department stores, schools, et cetera to close. Buses and even planes were disrupted to reduce mass gatherings. Except for pharmacies and other basic needs, workshops and heavy equipment usage were also reduced. There was more working from home. The effect of this lockdown has greatly reduced human-induced ground vibration. After the Thai government announced the removal of the lockdown, the ground shake from June 2020 returned to normal. The man-made seismic signals are clear in approximately 0.1 second intervals and can be observed from characteristics of the seismic signal surrounding the seismic monitoring station with PSDPDF.

Promotional text: Changes in seismic levels in Thailand COVID-19 Epidemic Period: Case Study of BKSI Earthquake Monitoring Station.

P4.5-244 – Station Operator and Impact of the COVID-19

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Costa Rica has been impacted by the COVID-19 pandemic during 2019, which has led to the Universidad Nacional de Costa Rica closing its facilities since March and much of the daily work being done virtually. With Costa Rica's NDC located at UNA, the primary work has been done through phone calls, email, whatsapp and videoconferences and rarely in person. Among the work carried out electronically are the procedures for clearing customs equipment sent by GCI international supplier, calls with local GCI provider, conversations with JTS's site housekeeper and videoconference with participants of the 2019 CTBTO Infrasound Workshop in Costa Rica. From the videoconference, was requested a continuation of training courses and perhaps creation of video clips by CTBTO.
During the pandemic, a CTBTO video producer was attended personally and pandemic protocols was followed and there was no setback. Trips were also made to the JTS site to review technical problems in it, using for transportation to the site a vehicle donated by CTBTO and therefore avoiding virus transmission using dedicated transport for the work. All the measures taken until now have made the work efficient and smooth and seismic data from JTS continues to flow to the IDC.

Promotional text: How the pandemic caused by COVID-19 had the station operator's work at Costa Rica and how we continue to give the service to JTS station making the data to continue a smooth flow to IDC.

P4.5-252 – Operation And Maintenenance Of KMBO Primary IMS Seismic Station In The Wake Of Covid-19 Pandemic

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In the wake of Covid-19 pandemic in Kenya, which apparently coincided with the long rain season, KMBO seismic station experienced rampant mains power outages and/or voltage fluctuations. Rainwater dripped into the tunnel and caused short-circuiting and burning of electrical sockets. Compounded with this problem was the fact that GCI UPS and batteries were not supplying back-up power to the GCI equipment as required until the mains power was either back or stable. Additionally, the GCI UPS batteries had been set to very high threshold such that connection is lost whenever the GCI UPS battery capacity drops to 96%. This rather high threshold in the GCI UPS battery capacity led to numerous communication and data outages and gaps with subsequent IRS and outage tickets from PTS and Hughes Network Systems LLC (the PTS GCI contractor) respectively. Operation and Maintenance was worsened by cessation of movement in and out of Nairobi Metropolitan area imposed by the President of the Republic of Kenya on April 6, 2020.
During SnT2021, we will present steps taken to ensure operation and maintenance activities for optimal station performance, demonstrate with, case examples, performance of GCI UPS causing the rampant communication outages and how this problem was resolved.

Promotional text: This paper presents the challenges in O&M of the remote IMS KMBO seismic station in the wake Covid-19 pandemic and the steps taken to ensure O&M activities for optimal performance of the seismic station.

P4.5-285 – NDC-JO and ASF056 Seismic Auxiliary station in COVID-19 crisis and NDC-HOME in the future

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To cope with the effects resulting from the COVID-19 crisis on normal duties and tasks for the NDC-JO, we have done our daily work from home using different technology, such as remote desktop connection, accessing IMS data and IDC product from the secure web portal using the Internet and installing NDC in a box software on personal computers. This will lead to a new idea for the NDC: NDC-HOME .
This presentation explores the operating methods and maintenance tasks for ASF056 during the COVID-19 crisis that are aimed at sustaining the functionality of station. It also sheds light on the problems, difficulties and challenges faced particularly when visiting the station. The laws imposed to prevent movement between regions have prompted us to take a set of necessary procedures through cooperation with the Crisis Management Center to solve the technical issues for the station, ensure the uninterrupted functioning of the ASF056 Seismic Auxiliary Station and maintain the general safety of people.
The presentation will address new practical experiences and lessons learned through the crisis that will surely develop more robust operation, maintenance, and sustainment plans and practices in the future.

Promotional text: NDC-JO and ASF056 Seismic Auxiliary station in COVID-19 crisis and NDC-HOME in the future.

P4.5-305 – Lessons learned from the COVID-19 Pandemic crisis in Cameroon

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This poster will illustrate how the COVID-19 pandemic arrived in Cameroon, rules that were implemented by the government to avoid the pandemic, how the population lives (working and studying) with COVID-19, protocol of Government, self-prevention solutions and statistics of the population (tested, affected, safe) after a month and to date. During the pandemic, we lost our main power transformer at the IMS radionuclide station in Cameroon. Given the barrier measures, the challenge was to able to replace this power transformer in order to maintain the normal operation of the station while respecting barrier measures prescribed by the World Health Organization with regards to the number of people that must install the transformer.

Promotional text: he power transformer of our mid-voltage line was damaged during the period of the covid19 pandemic. Given the barrier measures, the challenge was to be able to replace this power transformer in order to maintain the normal operation of the station but while respecting the barrier.

P4.5-328 – A simple web-scraping tool for state of health monitoring within Covid19 times

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The COVID-19 quarantine accelerated remote work (teleworking), especially in terms of operations and maintenance and the state of health (SoH) for critical systems, such as the real time data acquisition, the authentication, the energy supply and transmission. These were the main variables to monitor from home. Being connected 24 hours to Grafana from our houses was not possible, therefore we coded a small web-scraping tool ensembled with optical character recognition to write simple log files sent by email to be reviewed by Station Operator in near real time. After testing the code during the most critical times (May to September, 2020) we decided to preserve as a main tool for our routine, for the future a graphical interface will be designed.

Promotional text: The remote working speed up the digital migration, however in some regional context the homes were not ready having a laptop for each member of family, Revieing the SoH at certain hours automatically helped us a lot.

P4.5-333 – State of Health Monitoring of the IMS Network

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The IDC Operations Section makes daily use of six key operation tools to oversee and manage the Operation of the IMS network and the communications between the PTS and station operators. Some tools and their features are already available to station operators through Single-Sign-On (SSO). As part of the COVID-19 resilience enhancement, new features and functionalities are under development to facilitate station operators with notifications, monitoring, and troubleshooting of IMS station incidents and communication between PTS and station operators. Different monitoring tools,

including the PTS centralized monitoring tools, the monitoring capabilities for station operators with a large number of stations, station operator tools for a single or a small number of stations, and the Station Standard Interface (SSI) at IMS stations, will complement each other. All these tools will make the monitoring of the IMS network more reliable and incident identification and resolution more efficient and thus contribute to achieve as the highest possible overall IMS network data availability, data quality, and data surety.

Promotional text: Improvements on monitoring tools will facilitate IMS station operator in operating and maintaining the IMS stations in a more reliable and efficient manner and thus contribute to achieve as highest possible IMS network data availability, data quality and data surety.

P4.5-342 – Ensuring the operation of Russian IMS stations in the context of a pandemic of COVID-19

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The Russian segment of the International Monitoring System includes more than 20 objects and started functioning more than 10 years ago. Currently, 97% of the stations identified by the CTBT are certified. Maintaining such an extensive network often requires complex decisions and effective planning.
For more than a year, the world community has been continuously fighting the new COVID-19 virus. The pandemic affected many people, intervened in all areas of the economy and industries without exception. Despite the widespread changes in global processes, the task of maintaining the verification regime not only does not become less relevant, but on the contrary requires the consolidation of additional forces.
In 2020, the specialists of the Special monitoring service (SMS) ensured the certification of the RN55 Norilsk radionuclide station, which became the last of the eight radionuclide stations provided for by the Treaty in the Russian Federation. The joint effective work of the specialists of the PTS and the SMS allowed us to solve the emerging problems in a short time.
In addition, at the moment, the SMS provides a number of other infrastructure projects, performs tasks to maintain a high level of data availability, and guarantees the continuous operation of equipment.

Promotional text: The unique experience gained in performing these tasks can be successfully applied by other IMS station operators and participating countries.Within the designated topic, the work of the SMS staff to ensure the functioning of the Russian segment of the IMS will be evaluated.

P4.5-349 – Operation of seismic, infrasound and hydro-acoustic stations in Australia and Antarctica during the COVID-19 Pandemic.

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Robust station design, good working relationships with local operators and remote access to station equipment are key factors that allowed Geoscience Australia (GA) to continue operating CTBTO stations in Australia and Antarctica with minimal downtime during the COVID-19 pandemic.

Travel restrictions within Australia due to the pandemic resulted in station maintenance only undertaken for one out of five Australian stations between December 2019 and November 2020.

Although Australian stations were minimally impacted, GA encountered problems with single elements at two Infrasound arrays. We were able to identify the outages, troubleshoot and determine the cause, and in one case rectify the problem and return the element to operation.

This was due to our ability to monitor station performance remotely to identify the outage, and remotely access station equipment to identify and troubleshoot the issue. We were able to engage with the local operator nearby the station with knowledge of the equipment and systems who could assist with equipment exchange and perform tests.

With travel restrictions lifting in Australia we are now able to reinstate regular maintenance visits of stations. However good planning, practices and remote technologies assisted in ensuring stations remained operational in Australia during the crisis.

Promotional text: Detailed are challenges encountered in operating CTBTO stations during the COVID-19 Pandemic in Australia and Antarctica. Effective methods of station operation, monitoring and remote access to ensure availability of seismic, infrasound and hydro-acoustic are described.

P4.5-378 – Development of Remote Station Infrastructure Monitoring Tools

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General Dynamics Mission Systems' (GDMS) concept of operations for US International Monitoring System (IMS) stations focuses on robust state of health and remote-control capabilities of the particulate and noble gas systems, paired with local operators to monitor the station infrastructure. However, with COVID-19 limiting travel for engineers to IMS stations, GDMS is improving our remote monitoring capabilities for the station infrastructure to assist our local operators. This monitoring includes automated alerting for station environmental and power issues, remote-control of station equipment (HVAC units, generators, etc.), and stationary and portable cameras to monitor key equipment. Through this effort GDMS looks to provide early warning alerts on infrastructure issues, preventing future station outages. Furthermore, by increasing these remote monitoring capabilities, GDMS can reduce the time needed to diagnose station issues, shortening outage durations. Finally, with video cameras onsite, GDMS looks to augment the capabilities of local operators by providing real-time remote support during repair efforts.

Promotional text: The development of remote station infrastructure monitoring highlights the ways GDMS is adapting to and overcoming the challenges posed by the COVID-19 pandemic. This effort aligns with Theme 4.5 "Resilience of the CTBT Monitoring Regime, Including Lessons Learned from the COVID-.

P4.5-379 – INPRES seismic monitoring during the COVID-19 pandemic crisis

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The National Institute for Seismic Prevention (INPRES) was able to continue providing its essential services during the COVID-19 pandemic and the subsequent quarantine thanks to remote operations.
INPRES' primary mandate is the development of the earthquake-resistant construction regulations

and its continuous updating as well as seismic monitoring.
During the period of preventive and compulsory social isolation, called ASPO, duties carried out using remote and/or virtual platforms. All of them were managed by the use of the Electronic Document Management System (GDE), an integrated system for labeling, numbering, monitoring and recording of all actions and records of the Public Administration, based on Remote Digital Signature or PKI Cloud, with the database in the Arsat National Data Center.
The physical maintenance of the seismic stations during the ASPO period was on standby.
Once ASPO is finished and in return to face-to-face activities, preventive measures were followed, such as: personnel temperature monitoring upon entering the Institute, biometric sensing on entry / exit, use of the face mask, the reduction of working hours, avoiding sharing offices and official vehicles for transportation, in addition to those already imposed by government about distancing, PCR test requirements and the closure of the country's borders.

Promotional text: Procedures to carry out the seismic monitoring by the National Institute for Seismic Prevention of Argentina, INPRES, during the COVID-19 pandemic based on Remote Digital Signature, with database in a secure National Data Center.

P4.5-409 – The Importance of Blockchain in Nuclear Verification as a Solution to Reporting Hardships in Times of Crises

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The COVID-19 pandemic illustrated how the world could shut down overnight and how adaptations need to occur immediately in order to continue the functionality of imperative operations such as those of the CTBTO. Because of the issues brought to light in the COVID-19 pandemic, it is imperative to learn how technology can be used to mitigate the challenges highlighted during the COVID-19 pandemic specifically ensuring nuclear nonproliferation practices remain in place. Utilizing secondary analysis comparison was made on benefits blockchain has in maintaining continuous reporting in a time of crisis. Blockchain is a technology that helps mitigate some of the challenges that arose and became apparent during the COVID-19 crisis by ensuring uninterrupted reporting because it does not require human to human contact, paper records, or access to specific locations. Blockchain technology is not something that is only useful in a pandemic but can be extrapolated to times of war and severe weather or climate crises.

Promotional text: Covid-19 outlined various challenges that can arise in a time of crisis illustrating the importance of having technologies in place that can overcome and operate through those challenges.

P4.5-411 – "Alternative" Approach To Operation Nd Maintenance Activities

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The station PS24, herein referred to as the "station" is a three channel broadband seismic station located in a 40 meter tunnel about 80 km west of the capital city Nairobi, inside Oldonyo Sabuk National Park.
Seismic data from the above station are transmitted directly to the IDC from the work stations via the V-sat link antenna outside the tunnel. Since commencement of operations, the station has continued to fulfill its obligation to the verification regime of the CTBTO. Despite this exemplary performance, the station continued to experience operational as well as logistical challenges, some of which were compounded by restrictions during the pandemic. These included sensor failure, GCI problems,

frequent power outages among others.
In view of the above we will highlight the various measure we undertook together with the geological society of Kenya to address and maintain this remote station to its near real time transmission status, navigating through health safety protocols and government restrictions provide vital lessons for future operation and management practices.

Promotional text: Exploiting limited opportunities provided for during a crisis.

P4.5-432 – RN Particulate Network QA/QC Program 2020: Challenges and lessons learned during the global COVID-19 pandemic crisis

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Since 2004, the PTS requests, on a quarterly basis, a random sample from a certified station to be sent to an IMS-certified laboratory for re-analysis as part of its IMS Radionuclide Network QA/QC Program. The global response to contain the SARS-CoV-2 (COVID-19) pandemic in 2020 has brought numerous unprecedented challenges in the implementation of the RN QA/QC Program. This presentation will discuss the challenges experienced by all stakeholders throughout the sample chain-of-custody and the lessons learned during the COVID-19 crisis. Continuous collaboration and timely communication between Station Operators, Laboratory Operators, and the PTS are key factors in the continuous implementation of the QA/QC Program amidst current and similar crises in the future.

Promotional text: This presentation will discuss the challenges experienced by all stakeholders throughout the sample chain-of-custody and the lessons learned during implementation of the IMS RN Particulate QA/QC Program 2020 amidst the COVID-19 crisis.

P4.5-437 – The collapse and return to mission capability of the I35NA infrasound station.

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The I35NA infrasound station located in Tsumeb, Namibia was certified in 2005. Gradual improvement in skills development through CTBTO training programs and the introduction of the operation and maintenance plans improved the general operations and understanding of the infrasound station. However, the health of the station was in for a rude awaking when a change in senior management in 2017, aging and obsolete equipment in 2018, staff morale in 2019, the weather and COVID restrictions in 2020 lead to the collapse and inability to remain mission capable of the I35NA station. Inexperience on a senior management level frustrated and clashed with a well trained and experienced operational staff. Failing equipment. above average rainfall flooded vaults and the COVID lockdowns complicated response and support. A committed group of people, thousands of kilometres apart, locked up in their homes, worked together to bring the I35NA station back to life and return it to mission capability. It is safeguarding the verification regime. Lessons are shared when things go wrong and what is required to motivate and encourage people to still give their best. The I35NA station is one of the casualties in 2020, but the experiences must be shared.

Promotional text: Failures produces lessons learned and improves overall system management and performance.

P4.5-537 – Experiences from the CTBTO online capacity building activities during Covid-19 lockdown

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The CTBT mandated the PTS to equip State Parties with the prerequisite capacity to monitor compliance to the Treaty. The advent of Covid-19 and its associated lockdown disrupted the capacity building activities of the PTS. To minimize the perceived disruption of training activities, the capacity building team of the CTBTO adopted an online training method. Two online NDC Waveform Training Courses on using SeisComP3 were conducted by the capacity building team on 2-6 November and 23-27 November via the WebEx platform. The two courses had about 27 participants. A SWOT test of the two online training courses was done using a structure questionnaire that was administered randomly to selected participants. An analysis of the results from the study identified timeliness, excellent knowledge and topic delivery as some of the identified strengths while internet interruptions, lack of physical presence and time zone differences were perceived weakness of the online training courses. The experiences gained by the State Parties that participated in the online training will strengthen the deployment of the CTBT verification technologies for civil and scientific purposes. Further funding of the capacity building activities will enhance the ability of more State Parties in the monitoring of compliance with the Treaty.

Promotional text: The use of cutting edge technology in training activities will enhance the promotion of CTBT verification technology.

P4.5-542 – Difficulties and obstacles to keeping a radionuclide station in operation in Brazil during 2020

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The RN11 radionuclide station is located at the Institute of Radioprotection and Dosimetry, in the city of Rio de Janeiro, Brazil. The country has been severely affected by the pandemic, with millions of people infected and more than 185,000 dead. The different spheres of government sought to manage the effects of this tragic event in different ways, such as instituting rules for social engagement, remote work, blockades, among other initiatives. Many of these laws and regulations have had adverse effects on the management and functioning of the RN11 station, such as the difficulty of access of team members to the RN11 station building, or the inability to send or receive shipments and also the cancellation or postponement of technical visits to maintenance of station equipment. On the other hand, as the pandemic evolved, the team had to take measures to protect itself from the danger and at the same time try to keep the RN11 station running. The station underwent several events that year, such as the replacement of the X-cooler and various other maintenance. An analysis of these events identifying the positive and negative points and the opportunities for improvement are presented in this article.

Promotional text: To overcome the difficulties during the pandemic, several initiatives were taken and these experiences, when analyzed, should contribute to improve the performance of activities at the station and serve as inspiration for other teams in stations with similar dynamics.

P4.5-565 – Adoption of new ways of working during the Pandemic.

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One of the great challenges during the pandemic crisis caused by COVID-19 was to adapt the way of working during the quarantine. Communication, organization and planning were fundamental pillars to manage the activities involving the research and analysis of the IMS data and IDC products. One thing is certain, the tools of organization, management, communication and planning, contributed so that the activities could happen. Thus, facilitating the challenges of working in the home office since it is necessary to divide the time focused on work activities with the distractions of the house. Children who are in homeschooling, the presence of their parents, husband or wife, and even day-to-day functions, such as cooking and washing clothes.
This work aims to address the measures adopted by IDQBRN and OBSIS / (their department) for the continuity of activities during the global pandemic caused by COVID-19.

Promotional text: The work aims to contribute presenting the measures adopted by IDQBRN and OBSIS during quarantine in Brazil.

P4.5-574 – Increasing International Monitoring System (IMS) Supply Chain Resilience During COVID-19

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The sustainment of the IMS encompasses a global supply chain from sourcing to delivery of equipment. The supply chain is exposed to disruptions caused by the COVID-19 pandemic and measures adopted by countries, resulting in border closures, restrictions in the movement of goods and other logistical constraints. Inevitably the establishment and sustainment of the IMS network is affected.

From the outset the PTS recognized the need for higher redundancy to ensure a functioning supply chain to minimize the loss of station data due to lack of consumables or missing spare parts. Levels of critical spare parts at stations were reviewed combining station operator input, known supply chain disruptions, PTS' own experience and knowledge and analytical results from sparing optimization. Where indicated, additional equipment was sent to depots and stations. The availability of transportation possibilities was explored and monitored continuously developing and applying contingency plans to have more than one shipping alternative available.

Experience showed the importance of cross-functional contingency plans developed, tested and ready to implement before a supply chain disruption occurs as it is too late to develop, test and implement such plans at the same time.

Promotional text: The COVID-19 pandemic has implications on all global supply chains - the IMS network is no exception. The PTS is addressing these disruptions in various ways to ensure continued establishment and sustainment of the verification system.

P4.5-583 – Remote analysis: empowering analysts to work from home

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Due to the COVID-19 crisis of 2020, most organizations had to re-adapt their working routines, permitting their employees to work remotely instead of at the office. The CTBTO was no exception, in March 2020 and again in November 2020, all CTBTO employees including waveform (SHI) and radionuclide (RN) analysts were mandated to work from home. The challenge that arose for us in IMS/NSS, was preparing a setup fit for SHI and RN analysts to securely work remotely and reliably, without compromising on efficiency. At the office, each analyst is equipped with a Linux workstation, and due to the nature of the analysis software that requires a dual monitor setup, two monitors with a 1920 X 1200 resolution. To meet the reported challenge, this setup had to be replicated at home. This presentation describes the complete solution that was deployed and its dependencies, and the influence it had on the analysts' working routines.

Promotional text: This presentation describes the solution and its dependencies that was deployed by IMS/NSS to enable waveform and radionuclide analysts to securely work from home as a result of the COVID-19 crisis of 2020.

P4.5-587 – IS42: COVID-19 breakdown Operation and Maintenance constrains in the Azores Islands

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Located on the island of Graciosa, Azores, the infrasound station's (IS42) operation and management (O&M) activities are carried out by two station operators, a local operator and IVAR technical staff. The operation is carried out remotely from the IVAR facilities, located on the São Miguel Island. Inspection and preventive maintenance are carried out at 15-day intervals by the local operator and bimonthly by a station operator. This is performed annually by both operators, IVAR staff and subcontracted companies. Air travel between São Miguel and Graciosa last two hours, including Terceira island.
The first COVID-19 active case occurred in the Azores on March 15. On the nine islands with 243 000 inhabitants and initially only one with a limited yet COVID-19 capable health care infrastructure, the Government of the Azores implemented restrictive measures to mitigate the virus propagation and monitored the related epidemiology. The IVAR also implemented restrictive actions in its contingency plan. Those constraints included, among others, closure of public and private services; confinement of visitors and residents; establishment of sanitary fences; suspension of air links, etc. We present here a timeline of the active cases, the related constraints and O&M actions taken, with the PTS support, to guarantee the mission capability of the station.

Promotional text: In a remote archipelago, with limited health system response to the COVID-19, where regional authorities have taken very restrictive measures to mobility and access to IS42 station infrastructures, a timeline shows how O&M activities have been adapted to keep Mission Capability.

P4.5-609 – Scheduled Calibration of IMS Seismic and T-phase Stations: challenges and solutions within the COVID-19 pandemic scenario.

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Station calibration activities at IMS Seismic and T-phase IMS Stations aim at fulfilling the requirements defined in the Operational Manual for Seismological and Hydroacoustic Monitoring and the International Exchange of Seismological and Hydroacoustic Data.
The 2020 Scheduled Calibration activities have been merged in the unprecedented scenario of the COVID-19 pandemic.
The PTS Calibration Team has adopted a high level of flexibility and adaptation during the pandemic, in order to assure the necessary support to Station Operators and achieve the successful completion of the Scheduled Calibration 2020. Examples of the encountered challenges and adopted solutions within the COVID-19 scenario will be provided.
The experience has paved the way for preparing a new level of readiness to perform Scheduled Calibration activities under very critical conditions.

Promotional text: Station Operators and the PTS faced new challenges for maintaining the operational standards, including scheduled calibrations, at IMS Stations during the COVID-19 pandemic. This Abstract provides an example of resilience of the CTBT monitoring regime.

P4.5-611 – IS01 – Pilcaniyeu, Argentina - Initial Testing management during the COVID-19 Pandemic

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The challenging situation brought about by the new corona virus (COVID-19) required radical actions from governments worldwide in an attempt to slow down the spreading of the virus until a vaccine became available. Lockdowns became a de facto practice to prevent the virus from spreading further by reducing people's circulation. However, such practice had extremely negative effects on people's lives, essential services and the economy. In this context, it would be reasonable to expect that the operation of the IMS network was also impacted.
Station IS01-Pilcaniyeu in Argentina is an unmanned station composed of 8 elements. It was built in 2018/2019 and was certified in December 2019. It is currently running under the Initial Testing Agreement. During the pandemic, our team faced several challenges to ensure it remained operational. Overall, the station proved to be robust and did not present any signs of deterioration that required repairs, changes or upgrades. Thus far, it has been operational for almost 100% of Mission Capability during the period.
During this presentation, we will discuss the challenges and lessons learned from the management of the IS01-Pilcaniyeu station during the pandemic.

Promotional text: The challenging situation brought about by the new corona virus (COVID-19) required radical actions from governments worldwide to slow down the spreading of the virus. In this context, it would be reasonable to expect that the operation of the IMS network was also impacted.

P4.5-623 – Daily challenges at the IDC Operation Center to address Station issues during the COVID-19 pandemic and maintain the IMS network at a high level of performance.

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Daily challenges at the IDC Operation Center to address Station issues during the COVID-19 pandemic and maintain the IMS network at a high level of performance.
The COVID-19 pandemic and the associated public health interventions undertaken to contain it have resulted in widespread and unprecedented social disruption.
Station operators are responsible for the operation of the individual International Monitoring System facilities in accordance with the IMS Operational Manual. In this context, station operators faced the new challenge of operating stations during a lockdown or in periods of severe travel restrictions.
The restrictions imposed by Governments created limitations to perform the on-site troubleshooting, which forced station operators to maximize their capability to perform remote troubleshooting.
The PTS has developed a comprehensive analysis of station issues through several monitoring tools, thus providing solutions that can be implemented by station operators to handle such issues in a timely manner.
Continuous communication and flexibility to support station operators is also key to making progress in troubleshooting under critical conditions.
The presented results show that this approach can minimize station downtimes and keep the IMS network at a high level of performance, even during a pandemic.

Promotional text: Station Operators and the PTS faced new challenges to handle the incidents to keep the IMS network at a high level of performance during the COVID-19 pandemic. This Abstract provides an example of the resilience of the CTBT monitoring regime.

P4.5-668 – Flexibility of work in the Jordan-NDC during the COVID-19 pandemic crisis

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Jordan recorded the first cases of COVID 19 in March and did a great job at dealing with pandemic in many ways, such as having a full lockdown and partial lockdown, and switching to online working and teaching. The JO-NDC took the necessary measures to ensure the continuity of work through reducing the number of employees, creating a clean work environment (social distancing, using sterilization tools and wearing masks) and working remotely (online from home) by dealing with the local seismic system and network (integrating, processing and analysis data), using the software package (NDC in a box) for regional and teleseismic events and requesting data from IMS data and IDC product .In this poster, I will present and evaluate the online working techniques in the JO-NDC during the COVID-19 pandemic and the resilience of the CTBT monitoring regime.

Promotional text: The poster is contributes to learn about how the Jo-NDC worked during the COVID-19 pandemic crisis.

P4.5-675 – Impact Of COVID-19 On The Operations And Activities At The Developing NDCs Like Nigeria And Ghana

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The global pandemic took the world by surprise with most countries unprepared for the consequences that came with it. With the understanding that different National Data Centres operate at different levels, it became important to determine some of the strategies that should be adopted by the Nigerian National Data Centre (NDC) and the Ghana NDC in order to ensure sustainability of activities at the NDC sites.
We focus on the extent of data requests from the International Data Centre (IDC), power supply, et cetera.
Ghana and Nigeria are looking at the level of the resilience of the Ghana NDC and the Nigeria NDC with a view to some improvements towards the enhancement of resiliency of the NDCs to enable them contribute significantly in the verification processes of the CTBT, despite all the challenges. The work compares power outages at the sites, data downloads, data analysis and the lessons learned over the period.

Promotional text: The project will ensure that lessons learned in the use of the CTBTO system during the COVID-19 pandemic are shared in a way that the work will ensure the sharing of ideas and adoption of best practices in the utilization of the National Data Centres during a pandemic of this mag.

P5.1 Science in policy discussions and scientific lessons learned from other arms control agreements and arrangements

P5.1-055 – Resiliency and the OPCW Scientific Advisory Board: Tales of Providing Scientific Advice During a Pandemic

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Decision makers serving in policymaking organs of international arms control, disarmament and non-proliferation instruments often consider and review information with significant scientific underpinning. Engagement with scientific communities helps to ensure that an organisation remains abreast of developments in science and technology, and can continue to adapt to emerging challenges and develop capabilities that enhance operational effectiveness. The Organisation for the Prohibition of Chemical Weapons utilizes its Scientific Advisory Board (SAB) to monitor science and technology development of importance to the Chemical Weapons Convention, States Parties, and the OPCW. The SAB has recently, as everyone else, had to adapt to a challenging and changing working environment – one where travel is restricted and communication taxed. We will discuss the SAB's important role in providing scientific advice to the OPCW, States Parties and policymakers and how the SAB has continued its work during the recent Covid-19 pandemic. Necessary adaptations, success stories and lessons learned to providing scientific advice during uncertain times will be shared. The current challenge has given us an opportunity to test our fortitude and build resiliency into our processes, guaranteeing the SAB's efforts and effectiveness moving forward.

Promotional text: Science underpins treaty implementation. Ensuring that science advice is available to policymakers even during challenging and uncertain times, such as during the recent Covid-19 pandemic, requires forethought and remains critical to proper treaty implementation.

P5.1-067 – A New Threat to the CTBT

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The CTBT is under a new threat. The 2020 U.S. Compliance Report charges that "Russia has conducted nuclear weapons experiments that have created nuclear yield and are not consistent with the U.S. 'zero-yield' standard," and may also be guilty of a violation of the 1990 Threshold Test Ban Treaty. The Report claims that China may be guilty of similar activities. Similar charges have been circulating in the U.S. for years, but this is the first time a "finding" has been made by the U.S. Intelligence Community. The fact that U.S. charges of non-compliance by Russia resulted in the Trump administration's withdrawal from both the INF Treaty and the Open Skies Treaty indicates that this situation needs to be resolved urgently. No evidence is presented for these charges and the International Monitoring System has not reported any relevant evidence of such activities. This problem has at least three aspects. These are the treaty obligation found in Article I, the obligation found in the Vienna Convention on the Law of Treaties and the voluntary testing moratoria being undertaken by many countries. This issue may recede a bit under President Biden, but still must be cleaned up.

Promotional text: This oral presentation discusses the charge in the 2020 U.S. Compliance Report that Russia, and perhaps China, are violating obligations related to the CTBT. This poses a serious threat to the CTBT itself. The relevant obligations are discussed, along with possible solutions.

P5.1-107 – Four Ways that the Biden Administration Can Make CTBT Ratification Possible

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Joe Biden's election victory offers a potentially historic opportunity for test-ban advocates to push for US Ratification of the Comprehensive Test Ban Treaty (CTBT). This paper makes a case that President-elect Biden, a prominent advocate of the treaty over the past two decades, can accomplish this goal by following these four specific policy recommendations: (a) the President should pitch nuclear testing ban as an issue of national security in the US, which can help prevent it from becoming a victim of partisan politics; (b) the President can help spread scientific knowledge about the security benefits of this treaty in order to sway public opinion in favor of ratification; (c) the President can work to build bipartisan support in US Senate, addressing the concerns of the treaty's opponents from the Republican party. And once the US ratifies the treaty, (d) President Biden can help set in motion a good domino effect, pushing many other states – including China, India, and Pakistan – to ratify the treaty. Building on knowledge from other arms control agreements, this paper shows how taking these steps will pave the way for the treaty's entry into force.

Promotional text: This paper contributes to the SnT 2021 objectives by showing how a combination of scientific knowledge and political cooperation can help make US ratification of the CTBT possible in the next four years.

P5.1-168 – The Disarmament and Development Nexus and the CTBTO

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The CTBTO is recognized as a crucial disarmament and non-proliferation organization, and its monitoring technology and analysis methods are essential also for other key players like the IAEA and NPT, but its influence is not limited to security policy.
Economic and social development is dependent on a peaceful and secure environment, and on availability of resources, which instead of being spent on arms could be used for development. Therefore, there is a linkage between disarmament efforts and financing of development. Here, the Goals listed in the 2030 UN Agenda for Sustainable Development illustrate what the world's resources should rather be spent on Actually, economic development will strengthen most 2030 Goals and thereby also reduce the risk of armed conflicts. Disarmament is good for development, and development is good for disarmament.
Scientific expertise is essential for disarmament control mechanisms and the corresponding political organs, and it should be discussed where a dialogue between them,i.e.science diplomacy, can best take place. Besides e.g. the CTBTO and IAEA, the UN is a natural forum, as it covers all relevant aspects.

Promotional text: The abstract suggests ways and forums for science diplomacy, to strengthen the role of CTBTO and other disarmament organizations, in support also of achieving the UN 2030 Sustainable Development Goals.

P5.1-263 – Technology transfer for a relevant presence worldwide

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Definitions differ when examining "spin-offs" and technology transfers in non-profit organisations and NGO's (Goodman & Lawless, 1994). Weick and others (2003) have shown that the scientific community have been agreeing on the fact that a spin-off is a technology, originally developed to meet an organisation mission needs, that can be transferred to other uses and could potentially provides benefits as products or services. These spin-offs are transferred to other stakeholders through various types of partnerships including licensing, funding agreements, assistance from experts, use of facilities, and other collaborations between organisation, private industry, other governmental and non-governmental agencies, as well as academia. Rather than using the word spin-off, some other organisations tent to use the expression "technology transfer" to share the benefits of their research and development, strengthening industries at large without "technology astigmatisms". This paper provides a detailed technology map of CTBTO assets (tangible and intangible) collating them to a finite prioritised list of industrial needs world-wide enabling new applications and business opportunities. The findings are presented in a threefold: industries, universities and the CTBTO itself, taking into consideration successful previous experiences in other NGO's that might allow a sustancial and more relevant presence of the CTBTO in the World.

Promotional text: This paper provides a detailed technology map of CTBTO assets (tangible and intangible) collating them to a finite prioritised list of industrial needs world-wide enabling new applications and business opportunities that would help to enhance the presence of this important agency.

P5.1-317 – Future of Comprehensive Test Ban Treaty and its impact on the Non-Proliferation Regime

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The Comprehensive Test Ban Treaty (CTBT) has not entered into force, due to the non-ratification of 44 specific states. It is still not on the top priority of NWS, especially the US; therefore one should not expect it to enter into force in the near future. It still needs to be signed and ratified by all major powers. The Treaty has been called a 'dead horse' by several international scholars as well as the community worldwide. The prospects of the remaining states signing the CTBT have been fading constantly due to the consideration that the US will not ratify it even it endorsed in its US Nuclear Posture Review 2018. However, this paper also highlights how most of the world's advance technological stockpiles were developed with the assistance of computer models simulation nuclear tests. Likewise, it has tried to review the positions held by the two nuclear South Asian countries on the CTBT as well.

Promotional text: Since none of the theme's sub-topics has mentioned its impact on other arms control and non proliferation regime, the paper will outline its future standings in the complex environment where no other state is taking any substantial measures for its ratification.

P5.1-322 – CTBT: An important Piece of The Puzzle

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The aim of this paper is to present the CTBT as part of the whole Non-proliferation regime. It focuses on the different pieces of the "Global non-proliferation regime" highlighting how the CTBT is an essential part of the whole picture. The paper aims at analyzing the interaction and overlap among the different pillars of the regime such as the NPT, Safeguards agreements, Free Zone Treaties, and

the TPNW. The paper argues that even that the CTBT has not entered into force yet it has already set up norms and has influenced the whole complex of non-proliferation.

Promotional text: The paper focuses on the different pieces of the "Global non-proliferation regime" highlighting how the CTBT is an essential part of the whole picture.

P5.1-422 – 25 years of CTBTO: progress with verification technologies and looking towards the future 25 years and beyond

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A total of 10 nuclear tests have been conducted since the organization of the CTBTO in 1996 and the International Monitoring System (IMS) has played a key role in the detection of 6 of these tests, all of which were conducted by the Democratic People's Republic of Korea (DPRK). The first one was on October 9 2006 which was detected by 22 stations and had a recorded local magnitude 4.1. The second test, conducted on May 25 2009 was detected by 61 stations with magnitude 4.52. The third test conducted on February 12, 2013, with magnitude 4.9 was detected by 96 stations, two of them infrasound. Radioactivity consistent with this test was later detected at radionuclide stations in Japan and Russia. The fourth test conducted on January 16 2016 was initially detected by 27 stations and the fifth test conducted on September 9 later that year was detected by over 100 stations with a magnitude 5.1. 38 stations contributed to the technical analysis of the September 3 2017 test whose magnitude was determined to be 6.1.This serves as evidence that the IMS has been effective in the detection of nuclear tests conducted during this period.

Promotional text: The presentation aims to celebrate the achievements made by the IMS in the last 25 years as well as highlight some of the goals of the verification regime looking into the future.

P5.1-426 – Is weakening of arms-control norms, treaties and regimes a challenge to the CTBT?

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The ongoing trajectory of the nuclear arms race threatens the CTBT: resurgence of global competition between great powers; the existing nature of regional competition compounded by security dilemmas; the breakdown of existing arms control treaties between erstwhile Cold-War powers; and the pursuit of disruptive technologies, such as hypersonic missiles, and artificial intelligence enabled conventional and nuclear capable delivery systems, all pose substantive challenges. Erosion of different arms control treaties and confidence building measures, such as the Intermediate Range Nuclear Forces Treaty; Open Skies Treaty; lack of consensus on New START, withdrawn or lingering pipedreams, such as the Strategic Restraint Regime between Pakistan and India also threaten CTBT's efficacy. Rising tensions between nuclear armed states may cause triggers which undo voluntary moratorium on nuclear testing and cause resumption of nuclear tests for "deterrence". These may inflict a blow on existing or proposed arrangements between states to reach consensus on nuclear arms control arrangements, including the CTBT or voluntary testing moratorium. This paper examines the relationship between breakdowns of bilateral nuclear arms control treaties, consensus, multilateral arrangements and confidence building measures between nuclear armed states, such as US, Russia, China, India, Pakistan and others (JCPOA, Iran and North Korea) as well as the resurgence of disruptive arms race that threaten CTBTs norms and global peace.

Promotional text: This abstract will seek to undertake an explanatory analysis of different factors: eroding arms-control treaties; threat of arms-race; and rising tensions between nuclear armed states, that threaten CTBT, associated norms, and especially, voluntary nuclear testing.

P5.1-440 – CTBT and Computer Simulations: Is it a Plausible Alternative to Nuclear Testing?

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Nuclear explosion tests are seen as primary source of testing the behavior and performance of nuclear weapon systems since nuclear test is the only credible source of validating the actual performance of a weapon system. Comprehensive Nuclear-Test Ban Treaty (CTBT) propagates all-inclusive ban on nuclear testing, but cold test or computer simulations are not banned under the provisions of CTBT. With extraordinary advances in the field of computing, data sciences, artificial intelligence and quantum computing, many countries have gained the expertise and experience to combine computer systems and military and weapon technologies (including nuclear weapons) together to get optimum outputs. This paper will examine whether the cold testing or computer simulations are a substitute or plausible alternative for nuclear testing in order to study, predict and evaluate the behavior and accuracy of nuclear explosions in absence of nuclear testing.

Promotional text: Given advances in quantum computing, data sciences, artificial intelligence, nuclear testing behavior can be analyzed short of nuclear tests. It is imperative that these disruptive technological changes be analyzed to map out its possible impact on CTBT's norms.

P5.1-460 – Implementing Knowledge Transfer Processes: Lessons learned from an application in the OPCW

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The Chemical Weapons Convention is an international disarmament treaty intended to exclude completely the possibility of the use of chemical weapons. The Convention prohibits the development, production, acquisition, stockpiling, retention, transfer or use of chemical weapons, and provides for the destruction of existing stockpiles. The Verification division (VER) provides support to the States Parties by technically assess compliance with their obligations and by implementing a credible verification regime. VER has done a project to identify improvements on its knowledge transfer processes. The project evaluate VER knowledge transfer activities and tools, identify gaps and propose corrective actions. The study presents lesson learned from knowledge transfer exercises and practical cases where the implementation of knowledge transfer processes results in improvement of operational processes efficiency. This is fundamental for the sustainability of the operational processes in organization with high turnover of expertise.

Promotional text: The project highlight the importance of knowledge transfer processes and how a good implementation improve the efficiency of the operational process. This is fundamental for the sustainability of the operational processes in organization with high turnover of expertise.

P5.1-492 – The need for the Comprehensive Nuclear-Test-Ban Treaty to enter into force and its relationship with the Treaty on the Prohibition of Nuclear Weapons.

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The risk of deliberate or accidental use of nuclear weapons has increased in a global context that is in itself challenging for multilateralism. The Comprehensive Nuclear-Test-Ban Treaty (CTBT) and its verification regime, despite not having entered into force, have contributed significantly to protecting humanity from the profoundly damaging environment and health consequences of nuclear tests and will continue to be a fundamental pillar in the nuclear disarmament and non-proliferation regime. The entry into force of the Treaty on the Prohibition of Nuclear Weapons (TPNW) in January 2021, highlights the need for the Annex 2 States to ratify the CTBT. The TPNW recognizes the relevance of CTBT and contains commitments to assist victims of the testing or use of nuclear weapons or other nuclear explosive devices, a new type of obligation that relies in part on the CTBTO international monitoring system.

Therefore, based on a review of the relevant literature and interviews with experts, the main objective of this review is to identify and characterize the potential areas of cooperation between the CTBT and the TPNW.

Promotional text: This proposal seeks to emphasize the importance of the entry into force of the CTBT, and the relevance of the international verification system, for compliance with some of the provisions of the TPAN and other instruments of the nuclear disarmament and non-proliferation regime.

P5.1-515 – Strengthening Nonproliferation Norms in South Asia

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The emerging trends in South Asia's nuclear politics are running contrary to global non-proliferation norms. The developing trends not only have the tendency to make the nuclear norms more vulnerable, but also undermine the security of the region as a whole. The emerging trends include preferential treatment of India in civil nuclear agreements and its potential membership in the NSG, growing nuclear material stockpiles and the consistent opposition of Pakistan and India to a Fissile Material Cut-off Treaty (FMCT) and to the CTBT.
Historically, India and Pakistan have developed some confidence building measures and despite hostilities have honored those norms. Likewise, India and Pakistan have honored their unilateral moratorium on nuclear testing till date, notwithstanding nuclear developments. While efforts should be made for a formal ratification of the CTBT by India and Pakistan, it is important to strengthen the norm by encouraging any step in that direction, such as a bilateral test ban treaty.

Promotional text: Mitigating nuclear risks in South Asia through a normative approach.

P5.1-549 – Exploring Science and Technology Reviews under the Biological Weapons Convention

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The Implementation Support Unit (ISU) of the Biological Weapons Convention (BWC) and the United Nations Institute for Disarmament Research (UNIDIR) are undertaking a joint project on exploring possibilities for a science and technology review mechanism for the BWC. This project involves a background review of existing review mechanisms, a survey of BWC States Parties views around possible mechanisms and a series of workshops to sustain dialogue around such a mechanism in the run up to the Ninth BWC Review Conference. The oral presentation, which would be delivered jointly by the ISU and UNIDIR, would be designed to present provisional findings from the background research and survey and stimulate discussion amongst participants around the requirements for effective science and technology reviews in the context of an international disarmament agreement. Particular attention would be paid to key issues around participation, independence, leadership and the mandate of such mechanisms.

Promotional text: This contribution is intended to explore issues related to the provision of scientific advice in arms control and disarmament agreements. The contribution will cover issues including participation, independence, leadership and mandate.

P5.1-603 – Measures Required Of CTBTO To Be Considered

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The measures required to be taken 'consistent with international law' to facilitate 'the early entry into force' of CTBT have already been exhausted. It may also be said that CTBTO has not on its part done the requisite homework to bring its operationalization. The 'Conference of Parties' is fully authorized to bring about, another set of measures which may bring it into force. There are number of issues that the CTBTO must work on to avoid the 'Fizzling fervency' (shaper:2007) of CTBT a landmark Treaty in International Law.

Promotional text: Fizzling Fervency of CTBT.

P5.1-661 – Science and Policy: Bangkok Treaty From a Scientific Point of View

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Legally-binding nuclear-test ban is essential to ensure peace and security for all. Throughout the years, we have witnessed international agreements on nuclear arms control that have come into force. Nevertheless, we still lack a comprehensive treaty that could prevent catastrophic impacts caused by nuclear testing. Putting a halt to nuclear testing is one of the most intense battles in arms control history. Thus, it is vital that we must start incorporating science and technology elements into our discussions. This study aim to analyzes science and technology elements in the Southeast Asian Nuclear-Weapon-Free Zone Treaty or the Bangkok Treaty. The analysis will include evaluating radionuclides released into the environment due to the nuclear explosion and nuclear fallout effect from a biological and environmental point of view and whether or not the Bangkok Treaty had considered the health and ecological impacts of nuclear weapon detonation. Involvement of science in the policy-making process would ensure that the policy remains intact with the rapid developments of science and technology, and subsequently could continue to enhance operational capability. The results of this study, including lessons learned and best practices in the Bangkok

Treaty, are expected to influence decision-makers in determining policies regarding nuclear testing.

Promotional text: Our study aims to open a dialogue between scientific groups and policymakers. We have broadened our knowledge of nuclear weapons bans by collaborating with various parties to conduct this research. At the same time, we are leaving a trail of awareness on our way.

P5.1-693 – Future of CTBTO – Looking at Next 25 Years

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The world is rapidly changing and this pace of change will be accelerated over the next decades in an unprecedented manner. Changes will be holistic and shall impact both human lives and behaviours in a profound manner. Technologies will change in their form and structures. Sources of energy for powering new found technologies will also change with renewable ones replacing the non-renewable ones. International political systems will also transform with changed system of wars. 'Short, smart and swift' war like actions using technology will emerge leading to the redefinition of war methodologies. This may bring about a major shift from weapons of mass destruction to the weapons of smart destruction. The scenario therefore may not have space for nuclear weapons in terms of their form and type as they exist today. Smart munitions and micro nuclear weapons may however be there to act as deterrents. Nuclear testing will therefore change its form in essence and will call for new instruments ensuring peace, non-proliferation, testing and banning. Verification regime will therefore experience a major shift in days to come. A plethora of new avenues and options are therefore on their way to include major modifications of existing arrangements.

Promotional text: A wholesome change is inevitable over the next two decades. Internatoinal Political System will undergo a major shift and so do the instruments of war. Next 25 years of the CTBTO are therefore absolutely different in terms of both structure, verification technologies and others.

P5.1-694 – Science and Technology as Major Policy Determinant of the Future

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Today, the world has started relying on science more than ever before. Scientific data is becoming a predominant factor in reaching collective global and individual national decisions. Human social needs and individualistic behaviour vis-à-vis lifestyles are also changing with more and more dependency on technology. This all is hinting at science and technology predominantly deciding the future of this world. Technological developments across the globe will define the policy of States and thereby global policy towards major issues concerning humans. No other consideration than the scientifically determined facts through scientifically acquired data and thereby statistically projected trends will convince the decision makers. All international instruments of policy and mutual agreements between states have to align themselves with related technological sources. The need for the acquisition of more and more related technologies to be developed will also emerge out of the fast paced technological race between existing and newly emerging global powers. Technology is therefore likely to bring about massive policy changes whereby the whole global system will get redefined to fall in line with the existing and new technologies. The need therefore is to orient our global systems accordingly. All agreements without sound technological support will cease to exist in days to come.

Promotional text: Technologies of the future will define future of the global system. Virtuals are likely to dominate actuals at least in the foreseeable range of time.

P5.1-701 – CTBTO and Science diplomacy

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The CTBTO is developing a global verification network through its International Monitoring System (IMS) generating data managed by International Data Centre (IDC). IMS and IDC can be used as tools for nuclear and radiological applications and emergency preparedness. Locally, in States Signatories, CTBTO ensures a science-policy interface for wide dissemination of scientific knowledge to both decision-makers and the general public in general.
As the current COVID-19 pandemic is questioning the global preparedness and discrepancies between countries, it appears that an emergency plan and science are more important than ever for our societies.
The CTBTO can fill the gaps through its global network and data by acting as a leader organization promoting wider scientific engagement locally and reinforcing the multilateral cooperation globally.

Promotional text: As the multilateral cooperation is more critical than ever, It is urgent to mobilize all the countries in CTBTO for dealing with science and policies at the international level.

P5.2 Experience with and possible additional contributions to issues of global concern such as disaster risk mitigation, climate change studies and sustainable development goals

P5.2-016 – Characteristic multi-sphere interaction in the coastal and marine environment inferred from infrasound observation at Terra Nova Bay, Antarctica

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Characteristic features of infrasound waves observed in the Antarctic reveal physical interaction involving surface environments around the continent and Southern Ocean. An infrasound array (100 m spacing) by using three sensors (Chaparral Physics Model 25, with a detectable frequency range of 0.1-200 Hz), together with a broadband barometer (Digiquartz Nano-Resolution Model 6000-16B Barometer, with a detectable frequency range of 0-22 Hz) were installed at Jang Bogo Staion, Tera Nova Bay, West Antarctica in December 2015 by the Korea Arctic and Antarctic Research Program (KAARP). The initial data recorded by the broadband barometer include several signals originated surrounding surface environment, in addition to the local wind noises such as katabatic signals. Clear signals from background oceanic origin (the "microbaroms") are continuously recorded at the austral summer on mid-December with predominant frequency around 5 s. Variations of their frequency context and strength appeared in Power Spectral Density are affected by evolution of the sea-ice surrounding the Tera Nova Bay. In this presentation, more than two years data is demonstrated by its variations in frequency content and amplitude with time.

P5.2-017 – Seismic harmonic tremors and their origins from cryosphere dynamics in the Lützow-Holm Bay, East Antarctica

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Characteristics of seismic tremors in April 2015 were investigated at Syowa Station, in the Lützow-Holm Bay (LHB), East Antarctica. To examine the relationship between surface environment in a particular cryosphere variation, MODIS satellite images were utilized for comparison with the tremor events. Since a large volume of sea ice was discharged in April 2015, along with large icebergs passed through the northern edge of the fast sea ice of LHB, it was supposed to detect seismic tremors involving cryosphere dynamics in the region. Throughout the month, a total number of 49 tremor events were identified (Kanao et al., 2017). The majority of the events had a duration of over 15 minutes, which were divided into both tremors and ice shocks. Cryospheric sources recorded by seismic tremors were classified by their origins. In particular, strong amplitude tremors with harmonic overtones (Tanaka et al., 2019) were assumed to have occurred independently from meteorological condition. The most plausible candidate of the origins could be collisions between the bottom of drifting icebergs with the top of seabed sediments/crystalline rocks in places where the northern edges of continental shelf of LHB. Here the depths of the ocean floor can be less than 300 m from mean the sea level.

P5.2-021 – Arctic region as an example of mutual and beneficial cooperation on combating the problem of radioactive pollution between states

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Today with growing processes of globalization geopolitical and economic role of Arctic region in the world is also constantly growing. The Arctic region is becoming the center of building a new system of global and regional security, which also contributes to the growing interest of States in the development of this region, and leads to the expansion of active economic activity.The increasing development of the Arctic raises concerns among States about the preservation of its fragile Arctic ecosystems. According to the results of a detailed diagnostic analysis of the current state and forecast of possible environmental changes in the Arctic region radioactive pollution and deterioration of surface and underground water quality in the coastal territories of Arctic were identified as priority environmental problems.

In my work, I would like to talk about the current state of the Arctic region (Russia), as well as about international projects to combat radioactive pollution, and promising areas of cooperation in this area. I also want to show that even in the current crisis in Russia's relations with the West, international cooperation in the field of environmental protection and research on the main causes of environmental challenges continues today in the Arctic region.

Promotional text: Arctic is a unique region of our planet and which has a great impact on every country of our planet: The north and south poles play a vital role in regulating the Earth's climate — acting as our cooling system and the Arctic Ocean, We must protect it now.

P5.2-025 – Trending Discussion on Indonesian Tsunami of September 28, 2018

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This report presents on the recent tsunami that hit coasts of the Indonesian Island of Central Sulawesi. Indonesia, due to its location has experienced numerous tsunamis in recent times. The 2004 Indian Ocean tsunami is one of the most devastating among them. The latest one on 28th September 2018, at 18:02:44 a strong tsunami accompanied an earthquake of Mw 7.5 and left the state of Central Sulawesi worst affected. The tsunami was quite unprecedented as the quake was spawned by a strike-slip fault (Palu-Koro fault); usually, strike-slip faults displace land horizontally and not vertically and hence do not lead to a tsunami. This suggests that the geological, geographical and tectonic details of the island country are responsible in understanding the causes and mechanisms of earthquakes and tsunamis in the region. Foreshocks (Mw 6.1) and aftershocks (more than 150 in number) activities have also been analyzed. Satellite images of the region shot before and after the event highlight the devastation caused. The details of casualties and other associated damages have been collected from various sources. Various tsunami catalogues from 1500 to date estimates are assembled by causes, maximum magnitudes and water heights observed during the tsunamis as well as total fatalities.

Promotional text: The most disastrous hazards accompanying the earthquake is tsunami. It has often caused widespread devastations leading to serious human, environmental and economic losses. I strongly believe these devastation and losses can be reduced by building resilience.

P5.2-033 – Seismicity And Seismic Hazard Assessment In West Africa

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Lack of in-depth seismic hazard studies (SHS) for West Africa (WA) has negatively impacted planning and disaster risk management. Using modern techniques for SHS, this study aims to address such challenges. WA's earthquake catalogue was updated from various data sources including CTBTO. The seismotectonic setting of WA is assumed to be either, a stable continental crust or a shallow crustal seismicity. Therefore, we investigated both scenarios and compared results. For each, three different ground-motion models (GMMs) were applied and combined to produce each hazard map using logic tree formalism with equal weights. Earthquake recurrence parameters were computed for the entire WA region and five created seismic source zones within WA. The computed b-value, activity rates λ, regional maximum possible magnitudes mmax for the five zones and those for the entire region ranged from 0.84 to 1.0, 0.3–2.1, 5.2–7.0; and 0.77, 4.1, 7.2, respectively. The b-value of 0.77 falls within the generally accepted range for tectonic seismicity. The confirmation from our study that WA is actually characterised by stable continental crust is a monumental contribution. The highest hazard levels were observed in parts of Ghana, Guinea, and the Cameroon Volcanic Line region, ranging between 0.02 g and 0.03 g.

Promotional text: CTBT promotes civil and scientific applications of its techniques and data. Our study engendered revolution in West Africa by contributing in supporting exchange of knowledge, data and promotion of healthy collaboration with larger scientific community in line with CTBT's goals.

P5.2-035 – Climate Adaptation – Developing A Geospatial Technique For Quantifying Wind Hazards Using A Case Study In Bogor City, West Java - Indonesia

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Increasing windstorm occurrences significantly affect human lives, especially communities living in densely populated areas. However, windstorms commonly occur in a short period, with unexpected timing and at random places. Therefore, wind hazard maps must be developed to build resilience actions within communities. Bogor City area is used as a sample study and this research utilised GIS in developing wind hazard map. Further, this research develops a new methodology using parameters (slope-angle, land-cover/land-use, rainfall-intensity, and maximum wind-speed) to produce wind hazard map accurately that could be used to develop preventative action.

As a result, it is evident that potential wind hazards are a high hazard category during the rainy season with around 73% of previous accidents happened at this category. It can be concluded that the generated maps can thus be used to describe the wind hazard of Bogor City region.

According to the sample study, it should be noted that a developed map could describe the effectiveness of the methodology related to input parameters, pre-and -processing data, and producing a map. In general, the application of four critical parameters demonstrates that a developed methodology can be a new paradigm in GIS modelling for wind hazard mapping.

Keywords: Wind, Hazard, Mapping.

Promotional text: This research was conducted as part of in Partial Fulfilment of the Requirement for the Master of Engineering in Disaster Management and should be published in international conference and journal.

P5.2-045 – High Resolution Satellite Study Of Multiple Stressors In Arctic Marine Systems & Correlation Of Ocean-Atmosphere-Cryosphere Interactions With Climate Variability To Develop Arctic-Ocean Climate Predicting Models (AOCPM)

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The impacts of multiple stressors on the ocean and the associated risks of abrupt state shifts can be explored through ocean system interactions, risks, instabilities, synergies and Arctic Ocean climate predicting models.
The draining of pools underneath the glacier and glacier retreat is attributed to increased carbon dioxide and green house gases.
Hence, efforts are made on the co-evolution of climate and marine life in the Arctic Sea through the correlation of ocean-atmosphere-cryosphere interactions with climate variability i.e. to evaluate the correlation between the impacts of multiple stressors on the ocean and the associated risks of abrupt state shift, rising of sea levels, melting of the glaciers, vis-à-vis climate variability.
The kinematic features of the mesoscale convective systems over the Arctic Ocean regions would be correlated with ocean-atmosphere-cryosphere variability on time and space scales and at local, regional and global levels through the extracted sea surface temperature (SSTs) over the grid box, attributing the regional change to natural and anthropogenic radiative forcing agents and bringing out a few optimum values of these to develop ocean systems interactions, risks, instabilities, and synergies and Arctic Ocean climate predicting models by using high resolution satellite imageries, data access, assimilation, HPC and cloud computing for real-time analysis.

Promotional text: Let us put efforts into the Co-evolution of climate and marine life in the Arctic-Sea through the Correlation of Ocean-atmosphere-cryosphere interactions with Climate Variability and save mother Earth from Environmental Pollution for the present and future generations.

P5.2-050 – Identification of Palu-Koro Fault mechanism based on Fault slip and earthquake focal mechanism data

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The identification of the Palu-Koro Fault has been conducted. The study method used is a merging scientific discipline of geology and geophysics. Field data acquisition, processing, analysis and modeling in the laboratory using geological and geophysical techniques became the main framework in this study.
Acquisition of geological investigation including fault-slip at 19 points and 30 historical earthquakes data were used to verify the dominant fault type of the earthquake focal mechanism.
The earthquake focal mechanism analysis shows the type of fault that predominantly controls through the Palu area and its surroundings is strike-slip or horizontal fault mechanism.

Promotional text: The focal mechanism parameter of the earthquake provides critical information for vulnerability analysis earthquake and local study tectonic, regional, and global. The focal mechanism is geometric representation shifting fractures at the time when the earthquake happens.

P5.2-068 – Costa Rica Tsunami Preparedness

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The SINAMOT (Sistema Nacional de Monitoreo de Tsunamis), is responsible for increasing Costa Rica tsunami preparedness, by characterizing the threat, increasing community preparedness and strengthening the existing tsunami warning standards of practice.
The National Tsunami Warning Center (NTWC), SINAMOT evaluates tsunami hazard models including near and far field scenarios. We use several numerical models, which incorporate data such as bathymetry and LIDAR topography to adequately assess potential run up at the coast, from a wide range of possible tsunami scenarios. This information is also used to generate tsunami inundation maps and for some communities, tsunami evacuation maps as well.
The results are presented to different stakeholders and decision makers such as national and local government, emergency managers and emergency committees. Currently, we have guided more than 40 communities in the designing of their own tsunami evacuation map, and about 15 of them also in their tsunami evacuation plan. Two communities have been awarded as Tsunami Ready by IOC/UNESCO.
However, there are still more than a hundred coastal communities that have not received training in tsunami hazard. In addition, we should further explore non-seismic tsunami sources, such as nuclear test, landslides and perform tsunami inundation modeling at more locations.

P5.2-093 – CTBTO data for the achievement of the UN Development Goals in the central Sahel (Burkina Faso, Mali and Niger).

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The Sustainable Development Goals were approved by the United Nations to lead the way for a better world. Designed to respond to global challenges, the SDGs are answers to questions related to poverty, climate, prosperity, environment, peace, justice, et cetera.
Unfortunately, only a decade away from achieving these SDGs, the countries of the central Sahel (Burkina Faso, Mali and Niger) are facing insecurity that is exacerbating the effects of climate change, the massive displacement of populations with their corollaries of multidimensional crises, such as food shortages, malnutrition, school dropout, et cetera.
None of these SDGs is achievable in the absence of peace. These peace-loving Sahel countries have already signed the CTBT, advocated for nuclear technology for peaceful purposes and supported nuclear non-proliferation through several instruments they have ratified.
The missions of the CTBTO data centers should be strengthened in order to take account of certain security concerns, such as control of the movement of unauthorized weapons and the interception of suspicious communications.
This initiative will help restore peace and security in this zone. The success of this experiment can be extended to other areas of the world in the grip of similar crises.

Promotional text: Without peace and security, no development activity is possible.

P5.2-098 – Monitoring Tsunami Treat for Suriname?

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In the last 500 years, more than 75 tsunamis have been documented in the Caribbean and the adjacent regions. Since 1842, 3446 deaths associated with tsunamis have been reported. On August 21 2018, a magnitude 7.3 earthquake occurred just off the northern coast of Venezuela and caused tremors in several nearby countries. A tsunami was not expected, nonetheless the Pacific Tsunami Warning Center issued an Tsunami wave alert along coastlines. Disaster mitigation is a top priority and the CTBTO is currently contributing data from almost 40 of its monitoring stations to regional and national tsunami warning centers. The data can enhance the ability of the centers to identify potential tsunami-generated earthquakes and provide vulnerable communities with faster warnings so that they can evacuate. The Suriname NDC is receiving seismic data from the CTBT International Data Center and is using these data and other information to monitor earthquakes that can generate a tsunami in our region. The SnT conferences is therefore a highly appreciated and important event for the NDCs. The conferences also provide an essential contribution to the CTBT treaty verification monitoring activities.

P5.2-129 – Integrated management of natural disasters and resilience to climate change

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Natural disasters are a serious disruption to the functioning of a community involving significant damage and loss of human life that the community cannot overcome with its own resources. The effects are often cumulative and felt over time and space. Thus, it is imperative to put in place a good prevention and risk management system that makes it possible to optimize actions, especially when resources are limited. This optimization necessarily requires a combination of the efforts and resources of the actors involved in the system. That is to say through close collaboration and coordination between the state, communities and partners. Aware of this need, Niger has created structures and put in place tools for early warning, assessment and emergency response. This paper gives a brief overview of Niger's experience in risk and disaster assessment techniques and the prospects in terms of capacity building in this area.

Promotional text: Natural hazards and their impacts on populations can vary over time and space. They can arise suddenly or evolve slowly but in either case they can be devastating for a community, country or region. The awareness by stakeholders of the impacts of dangerous phenomena (natural and.

P5.2-161 – Integrating the CTBTO IMS and NDC into the NNREP as a tool for enhancing radiological emergency response and preparedness in Nigeria

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The National Nuclear and Radiological Emergency Plan (NNREP) provides the basis for a national level response to a radiation emergency in Nigeria that is effectively integrated with an accompanying international, national and local response plan to establish a timely, organized and coordinated emergency response by the Nigerian Authorities to promptly and adequately determine and take actions to protect members of the public and emergency workers. The NNREP describes the capabilities, responsibilities and authorities of government and international agencies. The CTBTO verification technologies, together with the data, technologies and products of the International Data

Centre, have potential civil and scientific applications which can provide significant benefits to States and the international scientific community. These applications would be integrated into the NNREP in collaboration with the National Data Center. The National Disaster Management Plan (NDRP) describes the structure for organizing, coordinating, and mobilizing Federal resources to augment State and local response efforts. The NDRP may also be used in conjunction with Federal agency emergency operations' plans, developed under other statutory authorities, amongst the various Federal agencies and international organizations. If these capabilities are enhanced and integrated into the NNREP it would go a long way to protect public health and safety.

P5.2-175 – CTBTO IMS Contribution to SDG:14 Life Below Water "Extended"

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During SnT19 we presented our work on defining the sources of hydroacoustic signals in the Indian ocean and looked at how the IMS can contribute to SDG 14. During the analysis we only managed to process three months of data from IMS HA04, HA08 and HA01. This time, we processed more than 12 months of non-stop data from those same stations. Data processing was performed using PMCC method with standard parameters for hydroacoustic signal detections. For each station we separated the detections into two main categories. The first category is the detections which remains present during the entire processing period. The second category is detections that requires further investigations, such as volcanos, land slide, breaking ice, cyclones and life below water. Constant detection was observed at stations H01W, H08S, H04N, respectively, between azimuth 140 and 250; azimuth 27 to 35 and 150 to 200; azimuth 0 to 100. We observed that those signals may come from tectonic events and ice breaking. For life below water it is still hard to say if we have detected any but this is included in NDC Madagascar's perspective.

Promotional text: This work is the fruit of researches and recommendations following the SnT2019. We brought updates and new approach especially for detection association.

P5.2-177 – Application of Kazakhstan monitoring network data for the safety of nuclear facilities

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Since 1994, the Kazakh NNC RK has operated the contemporary monitoring system that includes seismic and infrasound stations. Five stations are included in the IMS: PS23, AS57, AS58, AS59, IS31. The main goal of the NNC RK network is monitoring of nuclear explosions in support of the CTBT. The data of NNC RK network are actively used in civil tasks, for example, to estimate the seismic hazard of places where the nuclear critical facilities are located.
Kazakhstan possesses the research nuclear reactors, LEU bank, tailing facilities, Tokamak and the infrastructure of the Semipalatinsk Test Site. A nuclear power plant is planned to be constructed in the future. All these facilities are located in tectonically different regions of Kazakhstan. The seismic hazard of many Kazakh regions was poorly investigated and, as a result, underestimated. The contemporary data of NNC RK network and archive materials were analyzed and generalized, the earthquake catalogues were created for the regions where nuclear facilities of RK are located. The tectonic structure was studied, the database of strong motions was created, and the seismic hazard of the regions was estimated. The necessity to create the early warning system for earthquakes at the regions of the research nuclear reactors location is shown.

Promotional text: The NNC RK operates the contemporary monitoring system since 1994, 5 stations are included into the IMS: PS23, AS57, AS58, AS59, IS31. Data of the NNC RK network are used in civil tasks, to estimate the seismic hazard of places where the nuclear critical facilities are located.

P5.2-182 – CTBT in Changing Global Context

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We see that the process of globalization approaches its virtual pick. However, the key drivers for risk assets are still in place. One of those risk assets is nuclear assets.
Now, when world community is facing global concerns, such as disaster risk mitigation, climate change studies, the Sustainable Development Goals and lockdown policies. Governments forced to implement radical strategic changes. The CTBT makes it very difficult for countries to develop a nuclear sphere, or for countries that already have a nuclear sphere, to make its arsenals more powerful. It more than ever prevents the huge damage caused by nuclear assets to humans, animals and plants.
In this presentation we consider the possible impact of a changing global agenda to the CTBT that can bring the benefit of swift global action in different areas. On the other hand, we can suggest that the CTBT could play a more consolidating role, helping countries to reach more safe and sustainable development.
We conclude that the Treaty possesses huge potential to reinforce a joint call for its prompt entry into force, and to increase its role in a new global policy context.

Promotional text: This presentation highlights studies on possible impact of a changing global agenda to the CTBT that can reap benefits of swift global action in different areas. As a result, we conclude that the CTBT should play more consolidating role, helping countries to reach more safe.

P5.2-229 – Anomaly of Radon Gas Concentration Before The Deadly Earthquake on 28 September 2018 In The Central Sulawesi Region

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An Earthquake with a magnitude of 7.4 Mw with a depth of 10 Km that occurred in the Central Sulawesi province on Sept. 28, 2018, at 18:02 (WITA) triggered a Tsunami with a height of up to 5 meters and Liquefactions in Palu City. Based on the results of radon gas monitoring at Tadulako station, which is ~71 Km from the earthquake epicenter shows before the earthquake occurred indicating an increase concentration radon gas since August 13 2018 until the maximum increase which was quite significant when the earthquake occurred. Monitoring of the water level at the radon borehole also showed a drastic decrease and increase within two days, precisely on August 20, 2018. Ground water temperature data show that there has been a slow decline since July 20, 2018 and began to rise again after the earthquake occurred. At the Palolo station, which has a distance of 107 Km from the earthquake epicenter, there was no anomaly of gas radon concentrations, water level and ground water temperature. Based on these results, monitoring of radon gas concentration is very promising to be carried out in active fault areas that are scattered throughout to improve the Earthquake precursor results.

Promotional text: This research can provide information on how promising monitoring of radon gas concentrations, geotemperature and water levels in monitor fault activity a few days before an earthquake occurs.

P5.2-301 – Seismic Vulnerability assessment of building structures.(A case study at Nyanyano, Ghana).

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This paper focuses on assessing the vulnerability of buildings at Nyanyano (Ghana) in case there are future earthquakes. Seismic data(local and CTBTO) was used as basis to forecast the occurrence of future earthquakes. Thirty buildings were sampled throughout the area and grouped into the different types according to European Macroseismic Scale (EMS-98) based on what was used for their construction. Fifteen classified as adobe structures, thirteen classified as unreinforced units and two classified as reinforced/confined.
The EM scale aims to classify the vulnerability of buildings explicitly based on the type of structure. Six classes of decreasing weakness (A-F) are therefore proposed, A to C which reflect the strength of "typical" adobe building, brick construction and reinforced concrete structure. According to the vulnerability classification, adobe buildings are one of the most vulnerable structures which has its vulnerability spanning from A to B. Unreinforced units mostly has its vulnerability at B and in few case scenarios a range between A and C depending on the state of the structure and reinforced or confined structures have their vulnerability at D, when reinforcements are low, its vulnerability falls to C and in some special cases of well-designed structures, the vulnerability may extend to E.

Promotional text: This abstract will contribute to issues of global issues of concern such as disaster risk mitigation during earthquake occurrence by helping people know best their structures will react during an earthquake therefore retrofitting their buildings or adopting proper building code.

P5.2-340 – Change mitigation and nuclear weapon testing/Explosion reduction: steps towards achieving sustainable development goals

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The fast-pace developments in scientific innovations introduced many new challenges for man-kind. The 21st century is facing many non-traditional security threats like climate change, pandemics, refugees' crises, resource scarcity etc. Both security and non-traditional security threats pose hinderance in the process of sustainable development and disaster risk mitigation efforts.
On one hand climate disasters are putting human lives into danger by creating issues like health problems, financial crises, food insecurity and human rights issues. Similarly, nuclear weapon testing and explosions are also cause of many socio-economic and environmental disasters for mankind. Huge budgets are being spent for development of weapon of mass destruction which can be utilized to achieve various sustainable development goals.
One important problem to combat these issues is lack of responsibility on part of various nations. We need to develop mass awareness on issues like climate change and nuclear testing and explosion at grass root level through development of curriculum and media engagement.

We need to understand the link of many socio-economic problems with climate change and nuclear weapons development. In order to have an effective disaster risk management system we need to develop and implement policies which can mitigate climate change and prohibit nuclear weapon testing/explosion.

Promotional text: Climate Change/environmental and nuclear testing have common, political and socio-economic negative impacts for mankind. Both problems require collective efforts at all levels to develop effective policies and create mass awareness to mitigate disasters impacts.

P5.2-395 – The 2020 Taal Volcano (Philippines) Eruption as Recorded by the International Monitoring System

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On 12 January 2020, Taal Volcano (Philippines) had a strong phreatomagmatic eruption producing a 10-15 km ash column and ashfall reaching as far as Quezon City (~80 km). Taal is one of the most dangerous volcanoes known, with 34 eruptions since 1572, and eruptions being phreatic, phreatomagmatic, strombolian or plinian (e.g. 1954). Increased volcanic activity has been observed for a year but rapid intensification on 12 January prompted PHIVOLCS, the Philippine volcano warning agency, to raise the alert from level 1 to level 4 (hazardous eruption imminent), requiring immediate evacuation of thousands of people. The crisis lasted for 2 weeks with fissuring, ground deformation and high seismicity attributed to magma and gas intrusions. The decline in seismicity helped in lowering the alert level on 26 Jan. This eruption history was very well recorded by the CTBTO IMS as the 3-component auxiliary station AS80 (TGY) was situated only 11.8 km away from the volcano. In addition, two REB infrasound events related to the most powerful eruptive activities were also recorded by the IMS infrasound network. Such close seismo-acoustic activities are not often observed on the IMS network. This poster will present the seismicity and infrasound events as seen by the IMS.

Promotional text: One of the areas of interest of the CTBTO is the disaster early warning, The CTBTO's Member States and international and national institutions responsible, receive this information to perform on time an effective exercise of evacuation.

P5.2-410 – Carbon Dating. Ruined by Nuclear Testing?

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Following the spike of above ground nuclear testing in the 50s, carbon dating has become very difficult to perform and most scientists have started to move to other dating methods if they wished to date anything from the 50s to the this day. We look at how the fission products Carbon-14 and Cesium-137 have affected our environment and why it is important to ratify CTBT to prevent damage like this.

Promotional text: We examine how nuclear testing has permanently affected how we study our past.

P5.2-435 – Hypocenter Determinations Of Volcanic Earthquakes Prior To The 2006 And 2011 Eruptions At Volcano Nyamuragira, Virunga Volcanic Area

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Earthquake swarms observed before the 2006 and 2011 Nyamulagira eruptions were analysed. The activities and hypocenter distributions of these earthquake swarms were mainly examined.
The former swarm was characterised by a higher seismic activity than the later. Although the two swarms accompanied eruptions, most of the swarms observed in 2006 and 2011 were not followed by any eruptions. These swarms probably represent an intrusion of magma at a shallow depth.
Hypocenters of these earthquake swarms show that most of the events are located in and around the crater of Nyamulagira summit at a shallow depth less than 5km. Some of events were located at a deep depth around 20-25km.
Numerical examinations of the hypocenter determination indicate that some small errors in arrival times make the hypocenters not re-located or relocated at a depth of 0km. This suggests that to obtain more reliable hypocenter distribution, it is necessary to deploy seismic stations on and around Volcano Nyamulagira. Such a dense seismic network will enable us to discuss more in detail the swarm activity preceding eruptions and differences between the swarms preceding eruptions and those caused only by magma intrusion at a shallow depth.

Promotional text: with this presentation, my contribution to the SnT2021 objectives is to explain to the participants the Nyamulagira volcano activity and in particular the 2006 and 2011 eruptions of this volcano. Indeed, this volcano is the very african active, one eruption every 2 or 3 years.

P5.2-451 – Analysis on earthquake databases of the Sabah region and its application for seismic hazard assessment using the IMS data of the CTBTO

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Sabah is the most seismically active state in Malaysia where it has recorded higher number of moderate seismological activities for the past decades. The seismicity record of Sabah shows the presence of two distinctive seismic zones, which are Ranau in Kota Kinabalu and Lahad Datu in the southeast of the region. The IMS network setup by the CTBTO has successfully detected seismic events occurred in the region for the past decades. In this study, we present the results of data analysis of earthquake events occurred around Sabah region, distributed over 19 years' periods, from 2002 to 2020. The results represent the preliminary findings of seismic hazard assessment (SHA) in Sabah using the IMS data, where the results have enabled the quantification of seismic hazard in the region in terms of recurrence periods and probabilities of occurrence of earthquake at any given magnitude. This study demonstrates that other than for nuclear explosion monitoring, the IMS data can also be used for civil and scientific applications and can make significant contribution in seismological research. Consequently, the findings could be used to assess the impact of seismic events in Sabah as well as assisting relevant entities in development planning and disaster management.

Promotional text: The IMS monitoring capability of seismicity leads as well to the estimation of the seismic hazard posed by earthquakes in many different localities, on which one of the many potential civil applications of IMS data. In addition to many other proven studies that had been performed.

P5.2-471 – Use of the seismic moment tensor to recognize the genesis of seismic events in the East Baltic region

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Energy facilities and natural resource development are potential sources of anthropogenic impact on tectonic stresses in the earth's crust. The consequence of this can be provoked seismicity, which can be divided into induced seismicity and trigger seismicity. Provoked seismicity can be dangerous for the above-mentioned objects. However, signs of difference between tectonic and provoked earthquakes continue to remain relevant. The seismic moment tensor (SMT) based on waveform inversion is considered as a potential feature. The object of research is the sources of tectonic earthquakes and the alleged induced earthquake 2015/06/12 in the East Baltic region, located on the East European platform. The region is characterized by low seismic activity, a large number of quarry blasts and the presence of environmentally hazardous energy facilities. An induced earthquake of 2015/06/13 ("Red-light") ML 4.4 on the North American platform is also used as a test sample. The complex of analyzed parameters is supplemented by other characteristics of the earthquake source (seismic moment, moment magnitude, stress drop, source radius). The advantage of the method is the ability to assess the SMT for single stations. An estimate of the duration of the seismic process in the source can be a potential diagnostic feature.

Promotional text: The main contribution of the presentation is to search for perspective signs to distinguish between tectonic earthquakes and provoked earthquakes (induced and triggered) at East-European craton. One of the promising parameters of the SMT may be the duration of the seismic process.

P5.2-502 – Seismic monitoring and IMS collaboration

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Seismic monitoring and observation is a vital and main function of the Seismological Observatory Section of the Solomon Islands. The Solomon Islands are formed from part of a complex of Melanesian island arcs and are located on the South West Pacific Region NW of Papua New Guinea and SE of Vanuatu Islands. Due to tectonic settings of a complex plate of convergent zone, the seismicity of the Solomon Islands are relatively high. Thus Seismological Observatory Section is focusing on developing more on earthquake monitoring.

Solomon Islands had signed the verification with CTBTO in 1996 and then collaborated through the Seismological Observatory Section which then certified its HNR Station in 2005 as an auxiliary seismic station AS098 to carry out seismic monitoring for nuclear explosion monitoring. From then, it had continued engagement with the observatory and carried out sending seismic data to IDC on request. It is currently working towards becoming a National Data Center.

With its aims and obligations, the observatory had recently integrated a seismic and tsunami early warning monitoring and is working towards solving current challenges faced with the National Seismic Network.

Promotional text: The Seismological Observatory Section of the Solomon Islands had its main role and obligation to develop and maintain a national network of seismic stations to monitor seismic and volcanic activity and to fulfill national obligations with the Global Seismic Network and CTBTO.

P5.2-534 – The 2010 Haiti earthquake revisited: an acoustic intensity map from remote atmospheric infrasound observations

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Following the January 12, 2010 Mw 7 Haiti earthquake, the shaking intensity near the epicenter was overestimated and the spatial extent of the potentially damaging shaking was underestimated. This was due to the lack of seismometers in the near-source region at the time of the earthquake.

Besides seismic-waves, earthquakes generate infrasound, i.e., inaudible acoustic-waves in the atmosphere. Here we show that infrasound signals, detected at distant ground-based stations, can be used to map the acoustic intensity, which is proportional to the shaking intensity. This is demonstrated with infrasound from the 2010 Haiti earthquake detected in Bermuda, 1738 km away. Wavefront parameters retrieved in a beamforming process are backprojected to map the measured acoustic intensity to the source region. Furthermore, we resolve the polarity in the epicentral region.

Infrasound measurements are conducted globally for the verification of the Comprehensive Nuclear-Test-Ban Treaty and although the network was designed to provide global coverage for nuclear explosions in the atmosphere, we show that there is also global coverage for the estimation of acoustic shaking intensity. In this study, we lay the groundwork that can potentially make infrasound-based ShakeMaps a unique operational IDC product alongside conventional ShakeMaps for earthquake disaster mitigation in sparsely monitored regions.

Promotional text: Remote infrasound detections can complement earthquake near-source seismic measurements. This can potentially make infrasound-based ShakeMaps a unique operational IDC product alongside conventional ShakeMaps for earthquake disaster mitigation in sparsely monitored regions.

P5.2-555 – CTBTO's contribution in improving education and research quality, and mitigating climate change

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The International Data Centre (IDC), which is present in Vienna, receives information from the International Monitoring System (IMS). The IMS has radionuclide, seismic, and hydroacoustic stations around the globe which gather data about air quality, land and oceans respectively. This regularly updated scientific data can be used by the "students of Environmental Science and Global Environmental Politics" for the research and assessment of environmental problems such as climate change. Most of today's research in these fields is based upon assumptions and theoretical scenarios which is inadequate to solve the environmental issues properly. The availability of the data provided by IDC to the students will equip them to perform better and precise research. This study illustrates how the availability of the scientific developments achieved by CTBTO to the students will improve the education and research quality in the member states and how the use of updated scientific data in research will help in finding proper solutions for environmental problems.

Promotional text: The study illustrates the usefulness of the CTBTO's scientific developments and data in improving education and research quality in the member states, and mitigating the climate change.

P5.2-576 – Tsunami Hazard Map for Cilacap District, Indonesia based on Numerical Modelling Data

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District of Cilacap is located on the southern coast of Java island, in the area near to the subduction zone between the Indo-Australian Plate and the Sunda plate which has high earthquake activity. One of the biggest tsunami events ever recorded in the past is the tsunami event known as the Pangandaran tsunami. The July 17, 2006 tsunami originated from the Mw 7.8 earthquake on Pangandaran Beach, West Java. The tsunami impacted the tourist area of Cilacap, the water level reached 5 m and caused the destruction of 64 houses, 98 people died, and 7 others injured (Cousins et al, 2006).
As an area with vital economic infrastructure, it is necessary for the district of Cilacap to anticipate the incoming tsunami disaster, especially to the coastal communities. An important key to ensuring an appropriate community response is developing a tsunami evacuation plan and procedure. We conduct several tsunami simulations based on numerical modeling using historical data (Mw 7.8 Pangandaran earthquake, 2006) and also Mw 8.9 worst-case scenario earthquake (PUSGEN 2007).
Using simulation data results, we provide more detailed tsunami evacuation hazard maps that can be used as a reference for local governments to prepare and updating the tsunami contingency plans.

Promotional text: updating tsunami contingency plans for the district of Cilacap, Indonesia using a detailed tsunami hazard map based on numerical modeling.

P5.2-582 – Current status and perspectives of the French Tsunami Service Provider operated in France since 2012

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The CENALT (CEntre National d'ALerte aux Tsunamis) has been operating as the French TSP (Tsunami Service Provider) since 2012. Its objective is to disseminate warning messages towards the French national civil protection agency and the international subscribers, in less than 15 min following a tsunamigenic earthquake in the Western Mediterranean Sea and the North-East Atlantic Ocean. Early localization and characterization of the source event are made possible through the interpretation of geophysical data received from several networks, including those available from national and international cooperations. Seismic data and sea level variations are monitored in real time by the on-duty operator.
We present here the events monitored by the CENALT since 2012 and the main information messages that have been disseminated. The contribution of the CTBTO IMS seismic stations is underlined, especially concerning the watch in the Atlantic Ocean. To ensure its reliability, the CENALT also participates to national and international exercises. An overview shows how they contribute to the robustness of the system. Finally, numerical modeling plays a growing role in the warning, and preliminary results are presented on the capacity of CENALT to deliver accurate forecast products in the future.

Promotional text: Communication exercises allow the validation of the transmission modes latencies. A focus is presented on the international Neamwave21 exercise. High performance computing offers the perspective to deliver foreseen water heights in less than real time.

P5.2-599 – Strengthening of Indonesian Earthquake Information and Tsunami Warning Centre

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Indonesia Tsunami Early Warning System (InaTEWS) as National Tsunami Warning Centre (NTWC) and Tsunami Service Provider (TSP) for the Indian Ocean region countries, as well as ASEAN Earthquake Information Center (AEIC). In InaTEWS operational, BMKG is responsible for monitoring, analyzing, and disseminating earthquake information and tsunami early warning. Based on BMKG's master Plan up to 2045, it will be achieved by strengthening the system of monitoring, processing, and dissemination

Promotional text: To information for other institutions about the strengthening and development of Indonesia Tsunami Early Warning (InaTEWS).

P5.3 Capacity building, education, communication and public awareness

P5.3-020 – Analysis of the CTBTO scientific communication using network visualizations

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The CTBTO Library has created an extensive analysis of the CTBTO scientific communication. This was possible using bibliometric and scientometric techniques, through key network visualizations to represent its contribution to the global scientific community during the last 25 years of international collaboration.
In the context of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) verification system, this analysis includes the content of more than 2,500 documents such as scientific articles, conference proceedings, reports, books, book chapters, expert reports, and dissertations (1996-2021) where experts in nuclear test detection from different backgrounds and types of institutions interact and contribute with innovative solutions to improve the verification regime.
In this framework, the network visualizations offer an innovative approach to represent the complexity of this universe. With this technique, it has been possible to determine all the variety and diversity characterizing all the connections between experts, subjects of interest in common, institutions, and countries.
This work was possible with the following software: a) Mendeley (free software), and b) VoSviewer (open software). The role of the Metadata was crucial, especially to standardize of author's names, keywords, institutions, and countries. These representations express how clusters are interconnected, their co-occurrence, and relatedness based on the frequency of publications.

Promotional text: CTBTO 25 years of Scientific Communication.

P5.3-034 – Summer School in old Nuclear Test site

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Humanity may be destroyed by its very own progress of successfully harvesting or releasing atomic energy. For my country and for me personally, this is not a concern: Kazakhstan was the first country who joined and signed for NWFZ in 2008. Our country learned an important lesson from the tragedy of Semei.
Nuclear weapons are not just short time weapons. They are long lasting guns, which will effect the environment for centuries. Kazakhstan tested around 456 nuclear bombs from 1949 until 1989. Most of them were tested close to the different villages to see the effects to humans, cattle and animal products, buildings and so on. This is only place where a population still lives in the territory of a nuclear test site. They are coping with extremely high rates of cancer and infant mortality. Furthermore, many mutilated children are born. It is very important to teach students the real facts related to nuclear test effects. The universities of Kazakhstan can teach unique courses on nuclear weapons and arms control, and visit the nuclear test sites and talk with the local people, study their cases and help them to overcome their fear and disease.

Promotional text: The aim of this project is to illustrate or present the results of nuclear explosions to world young speakers who is against to any nuclear test. By motivating them, they can be full of emotion and thirst after real experience in Semey Nuclear Test Site.

P5.3-043 – ESD, DRR and SDGs: Finding synergies, creating opportunities

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In the midst of the Covid-19 pandemic, a need has arisen to rethink our way of working. As Disaster Risk Reduction and Mitigation is increasingly taking the spotlight so are education for Sustainable Development and the overarching framework of the SDGs. An important aspect that needs to be (re)considered to address future risks is the role education and life-long learning play.
In this article we will analyse the risks of fake news and disinformation and its effects on effective interventions in emergencies, specifically for the CTBT this will also look at the importance of factual information and the added value of its seismometer network in ensuring quick and up to date information.

P5.3-054 – Converging Knowledge and Technology Role on University's Non-Proliferation Culture

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University, indispensable for research, is one of the pillars of the prosperity and security of future generations. The diversification of research impose new ethical rigor hanging in the dissemination of the results. Responsible management of research in universities requires active commitments from relevant institutions.
The progress in free access to information on the internet shows an increase role of security in scientific and innovative databases, especially of unclassified information for various reasons for dual use materials and technologies. Research is most vulnerable to unethical use because it generates and provides knowledge, materials, methods and technologies that could be channeled into crime or terrorism. However, scientific researchers and engineers play a key and responsible role in non-proliferation. Researchers are the most knowledgeable and best placed professionally to assess the nature and seriousness of the potential for misuse of knowledge, products or technologies. In this way, they should be the most responsible for evaluating and reporting on these findings within the research institution and to relevant national bodies. It is imperative to implement an optional discipline related to engineering and non-proliferation for students specializing in research. Such an alternative or optional course is currently under development at the mentioned technical university center.

Promotional text: Convergence of engineering education, Research and Non-proliferation, Research Ethics.

P5.3-122 – Building effective awareness networks in XXI Century.

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The CTBTO mission has been linked since the beginning of the Treaty to cooperation models between diverse stakeholders in science, technology and policies areas in order to make its task more

effective and comprehensive.
Nevertheless, there is still a long way to go in this regard and many actors must be incorporated on the effort to build a real awareness, to ensure joint initiatives can be spread out as far as possible and achieve the deepest penetration, both in general public as well as at all political levels - the decision makers on this matter. Several NGOs could contribute weaving a massive network to spread out related issues.
The aims of this work are about how alliances built between some sectors related to CTBTO initiatives, through resources such as training, media communication and lessons learned from areas of similar complexity, could optimize the communication about disarmament and non-proliferation issues. This could become relevant topics of discussion that encompass the whole of society.

Promotional text: Will present some ideas on network capacity building and strategies aplied in similar fields, also propose education and training on nuclear issues in order to create social awareness,highlighting the peaceful uses of nuclear energy and benefits that results from its.

P5.3-136 – 15 years achievements as NDC-TN

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From 2006, when Tunisian IMS station (PS42 and IS48) started sending data, the NDC-TN has made a concerted effort to effectively participate in the verification regime of the Treaty and to implement obtained knowledge and capacities at the national, regional and international levels.
This poster will give you an idea on how the NDC-TN:
• Ensures the smooth functioning of the stations and the maintenance at the first level as well as its participation in various exercises relating to the updating of the hardware and software of stations, such as IS48 and SSI upgrades, calibration, et cetera;
• Places a large importance on the development of national capacity building and the establishment of a methodology of work;
• Prioritizes data analysis (SHI and R) and contributes to the promotion of civil and scientific applications.

Promotional text: Tunisian NDC is making efforts to establish a methodology of work to implement capacity building methods and ensure the good functioning of the IMS stations in order to improve nuclear test monitoring and verification.

P5.3-157 – Joint Seismic Monitoring Activities In Central Asia

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Central Asia is tectonically complicated with high seismic activity. Over the past 150 years four great earthquakes occurred with magnitudes exceeding 8. Seismic monitoring is one of the most important problems of the region, having both scientific and social significance. Since many years, NORSAR (Norway), the Institute of Geophysical Research (Kazakhstan), and the Institute of Seismology (Kyrgyzstan) are cooperating to solve this problem. A joint scientific program is focusing on capacity building in Central Asia, in relation to technical verification of compliance with the

CTBT, as well as research on improved seismic monitoring. Under this cooperation, seismic stations and the National Data Centres (NDC) in Kyrgyzstan and Kazakhstan were upgraded and Central Asian seismologists were trained at the Training Centre, established at Kazakhstan's NDC. In 2018, joint work started on compiling a new seismic bulletin for Central Asia, based on data from 51 stations and 5 arrays. Observed magnitude and energy class discrepancies were studied with respect to systematic station and network effects. Aftershock sequences of 80 earthquakes with different magnitudes were analysed. The induced, anthropogenic and natural seismicity from different regions with mining activities in Kyrgyzstan and Kazakhstan as well as icequakes in the Tien Shan glaciers were analysed.

P5.3-172 – The Impact of Capacity Building Project on Jordan NDC

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The CTBTO capacity building project includes a capacity building system (CBS), training courses, technical visits, et cetera. The CBS that has been established in Jordan is helpful in integrating data acquisition, processing and analysis using the NDC in a box, which was developed by the IDC. The training courses and technical visits helped on how to use the CBS and software package (NDC in Box), and how to access to the IMS data and IDC products by requesting the data from IDC product then analysing this data by using different software (GeoTool, SeisComP 3, et cetera). In this poster we describe how the capacity building project has improved the Jordan NDC and developed the staff's experience, knowledge and skills.

Promotional text: in this poster you will be Know how the CTBTO activities are very useful for improve and develop the NDCs staff experience, Knowledge and skills.

P5.3-222 – Scientific Promotion Programme for IMS data in Chile

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The National Data Center in Chile is established at the Chilean Nuclear Energy Commission. Its principal mandate is to verify the compliance of the treaty and the storage of the data we receive. For this very reason, the NDC has a large amount of data available to be used by the scientific community. The problem is that this is not very well known today. To solve this issue, it started the Scientific Promotion Programme (SPP), whose objective is to develop data processing capabilities to promote their use in scientific research and to promote the diffusion of the CTBT and its benefits to our community. It offers opportunities to sign agreements with scientific institutions and ensure that this data is being used for pacific and civil purposes and not let its potential be neglected, because around the world, the potential of the IMS data to the promotion of science has been proven .This paper is about the steps followed to develop the SPP and the obstacles encountered during the process (for example: COVID-19) and the aspects that were identified and improved due to this programme at the Chilean NDC.

Promotional text: The main objective of this abstract is the scientific development through data availability for test ban verification and also cooperation with the scientific community to support national needs, exchange of knowledge and ideas between the National Data Center and this community.

P5.3-288 – Improvements of data analysis and capacity building by NDC - Costa Rica using IMS stations and advances in updating NDC-in-box programs

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In recent years with the installation of the NDC-Costa Rica since 2010, improvements have been made in advances in data analysis by CTBTO tools to the states party of the treaty. On the part of the NDC-Costa Rica, the real-time inclusion of IMS seismic stations and OVSICORI local seismic stations for monitoring local, regional, global seismic and infrasonic events automatically through SeisComp 3 acquisition system included in the NDC-in-a box. With the different trainings by CTBTO, some analysis of events data has been carried out, such as: explosion in the Port of Beirut (2020-08-04 15:08 UTC) where IMS stations were used: I26DE, I42PT, I11CV, I17CI, I48TN (infrasound), BRTR, IDI, ASF, EIL, MMAI (seismic) and Stromboli Volcano eruption event in Italy (2019-07-03 14:45 UTC) through infrasound stations: I26DE, I37NO, I42PT, I48TN. In addition, in recent years all data analysis programs such as Geotool, DTK-GPMCC, DIVA, Webgrape, SeisComP 3 have been updated to be accessible to NDC-Costa Rica users for data analysis.

Promotional text: Increased infrastructure and data analysis capabilities at NDC Costa Rica.

P5.3-310 – CTBT 2026: Scaling up Youth Initiatives

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2026 marks the 30th anniversary of the adoption of the CTBT and the establishment of the CTBTO. One of the most powerful tools that can help the CTBT enter into force is the young generation. We hope that the CTBT Youth Group could break this vicious circle.
We are aiming to establish a project to raise awareness for the young generation and to educate them. We have already assembled a team of activists and arranged sessions of 30-minute interactive seminars with NRNU MEPhI pre-university students. The target is to explain technical terms in simple words, plunge into history, briefly describe future possibilities, and to motivate them to join the CTBTO Youth Group. It can serve as a springboard for considerable actions relating to the CTBT.
We are deeply convinced that our generation is a generation that can change the world. We see that the future of the Organization and of the Treaty is youth. Our generation is full of strength and energy, we have a lot of opportunities and tools for implementation. Our world is changing rapidly, and we would like organizations to keep pace with these changes.

Promotional text: The proposals made by the authors can elevate the role of the CTBT among the young generation, meanwhile can serve as a springboard for considerable actions related to the CTBT's entry into force and lay the groundwork for closer contacts with the youth around the world.

P5.3-314 – Seismic Hydraulic Diffusivity a tool for Geothermal Exploration

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The seismic hydraulic diffusivity is investigated to examine the implications fluid circulation has on the seismic activity at a geothermal prospect. The effect that fluid circulation has on the seismic activity is achieved by estimating the seismic hydraulic diffusivity from a source that originates from a point where the pore pressure propagates from for a distance (r) and time (t) from a single source

that initiated the seismic swarms to each earthquake in the swarm.
To achieve this aim the following objectives are satisfied; The location of hypocentral locations to outline the seismic event location and correlate them with the causative faults, determining the focal mechanisms to establish the style of faulting and fault plane orientation and to estimate the seismic hydraulic diffusivity to establish the source properties in the causative faults using the following formula; r^2= 4*3.14*D*t where D is the seismic hydraulic diffusivity.
To achieve this a dense seismic network is required, in most cases due to the cost limitations just a few stations are set-up. The data from the seismic IMS stations can be used to improve the quality of data as it adds up to the seismic network and also improves results accuracy.

Promotional text: Geothermal Prospecting using the Seismic Hydraulic Diffusivity and IMS seismic data usefulness.

P5.3-319 – Communication and Public Awareness

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This presentation will examine the extensive efforts of the CTBTO Technical Secretariat to advance public awareness of the Treaty, and will explore what NGOs have done to further this effort. Most important, it will investigate the avenues that academics, NGOs, and scientific experts can pursue, in particular in cooperation with each other and with respective governments. The CTBTO has established an impressive Group of Eminent Persons and Youth Group; outside, in civilian society, more must be done. Academics, NGOs, and scientific groups can pursue through Coalitions (such as one formed by this author) educational panels, workshops, speaking engagements, at meetings and major international conferences. Their efforts can help exert pressure on governments to ratify the treaty. For example, a U.S.-China symposium organized by specialized, highly recognized thinktanks, NGOs and academics in both countries, would attract considerable attention and could find a receptive audience among government policymakers regarding the reasons for ratification. Although ratification in the U.S. depends on the U.S. Senate, the Biden Administration likely will have a more positive view of the CTBT than the previous administration. Also, while the G7 has supported entry into force of the CTBT, the Treaty is not expected to be a central point of discussion at the NPT Review Conference as it used to be.

Promotional text: How scientific experts and academics can promote the CTBT.

P5.3-337 – Nuclear Education and Training of Young Professionals with CTBTO Content.

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Education and training of young professionals in the nuclear industry are one of the Nuclear University primary objectives. In achieving this goal, it is vital that attention must be paid to all aspects of the development and use of nuclear power and nuclear technology. Future generations must understand and share the responsibility for the stability and safety of our entire world. CTBTO has made great efforts to ban all nuclear weapon tests. This is a crucial issue and this work definitely makes our world safer and our life more secure. The significance of education and research activities in this field cannot be overstated. We started from the participation in the CTBT Public Policy Courses and then CTBT Science Diplomacy Symposiums and CTBT Science and Technology Conferences have led us to including of the CTBT-related topics in the student's curriculum. It is very important that CTBTO offers excellent e-learning resources such as the CTBTO Knowledge and Training Portal

(KTP) and CTBTO channel on iTunes. The survey shows grooving of the student's interest to the CTBT and CTBTO educational resources. In addition, the majority of respondents said that they would like to take part in the CTBTO activities.

Promotional text: The approaches to educating the younger generation of nuclear industry professionals through the use of CTBTO educational resources which are also promoting and raise awareness and understanding of the CTBT through educational initiatives and science communication have presented.

P5.3-359 – Study of Perception of Pacific Islander's students at Otago University New Zealand about CTBTO

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Pacific Island member countries have a combined population of about 2.3 million people. Nuclear tests in these islands significantly impacted humans and environment. More than 300 nuclear tests were carried out in the Pacific from 1946 to 1996 in the atmosphere, underground and underwater. Recently Prime Minster of Fiji, made a statement on behalf of 12 Pacific countries to UNGA and presented vision that "the blue Pacific Ocean will become an ocean of peace and prosperity for our people and the world and it could only become an ocean of peace if it was nuclear-free". To reflect his statement, we have conducted a study among pacific islander students enrolled at University of Otago, Dunedin New Zealand about their perception about Comprehensive Test Ban Treaty (CTBTO). We have received response from total 80 students (35 male, 43.75% and 45 females, 56.25%). Only 45% (36) students have knowledge about CTBTO and only 70% (56) knows about nuclear testing. This shows there is still lack of awareness about young generation of pacific islanders about ban on nuclear testing and it require special education and online awareness campaign is required to build momentum against nuclear testing among young generation.

Promotional text: over 300 nuclear tests has been conducted in pacific islands and they significantly impacted human and environment. We have conducted a study to check perception of young generation of pacific islanders about CTBTO.

P5.3-447 – Nepal in the arena of the CTBT

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Nepal is a peace loving country and signed Nuclear Non-Proliferation Treaty (NPT) in 1970. Nepal became a Signatory of Comprehensive Test Ban Treaty (CTBT) in 1996 with the commitment of using nuclear energy in improving human health, world peace and prosperity and security - not for military purposes. The Nepalese Government has recently passed a law on Radioactive Material (usage and regulation) Act 2020. It has now opened the door for the peaceful use of nuclear applications for the benefit of the country under guidelines of International Atomic Energy Agency (IAEA) as being a Member State of the IAEA. Next, Nepal is surrounded by several nuclear installations of neighboring countries and is always at the risk of nuclear threats that may occur in its neighborhood. In this context, Nepal can benefit from IMS Laboratories under CTBTO's network especially in monitoring seismic activities and radionuclide monitoring. In this run, after being motivated through participation in the conferences of National Youth Council (NYC) under the Ministry of Youth and Sports, Government of Nepal. It is the right time for the government to engage youths in the activities of the CTBT. It is necessary to link NYC with the CTBT to carry out CTBTO's mission.

Promotional text: Nepal is a signatory of both NPT and CTBT. Nepal Government has recently passed the Radioactive Material Act 2020. Nepal is surrounded by several nuclear installations of neighboring countries and is at the risk of nuclear threats that may occur and needs assistance of CTBT.

P5.3-450 – Determinants of Public Support for Nuclear Proliferation

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What are the determinants of public support for nuclear proliferation? Fielding two survey experiments to nationally representative samples in a non-nuclear weapon state, we provide micro-level foundations for the acquisition of nuclear weapons. We find individual support for proliferation augments as existential threats loom large and it diminishes when external security is plentiful. Results also show that the presence of a powerful security guarantor tempers popular support for nuclear-weapon acquisition. But we also find that when it comes to issues of nuclear proliferation, psychology matters in a specific way: individuals who rank high on conservation values express preferences that align with rationalist incentives for and against proliferation more intensely than other members of the public.

Promotional text: Our results show that assessments of the external security environment drive proliferation preferences. The public in a non-nuclear weapons state offers or withdraws support for proliferation policies within a set-up involving a potential proliferator, her allies, and her enemies.

P5.3-463 – MEPhI Science Diplomacy Club: Building Bridges

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A central tenet of MEPhI Science Diplomacy Club (SDC) activities is building bridges in the field of scientific and technological cooperation. The Club aims to construct an intergenerational dialogue by cultivating good working relations with high-profile experts in the field of non-proliferation, disarmament and nuclear test ban. The cornerstone of SDC policy is building educational and scientific bridges by providing a platform for youth from all over the world. The Science Diplomacy School "The NPT: Preserving the Legacy", the II UN Security Council Model and Presentation Contest "My vision of the CTBT 2026" are prime examples of bringing students and experts from different profiles and raising awareness about current problems and pressing challenges.

In addition, SDC maintains close ties with pre-university students by actively participating in summer practical seminars. It also attaches great significance to engaging female students with proactive attitude in its activities. It's time to make a difference and empower women to get to grips with science diplomacy issues.

So, MEPhI Science Diplomacy Club opens up great opportunities for youth to network, share knowledge and exchange experiences.

Promotional text: MEPhI Science Diplomacy Club is a deep dive into intermeshing of science and diplomacy, a chance to raise cross-discipline awareness and a great opportunity to network, share knowledge and exchange experiences!

P5.3-498 – Comparisons between the interactive seismological analysis softwares SEISAN and Geotool: advantages and disadvantages from the Venezuelan NDC perspective

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The interactive seismological analysis system used by default at the Venezuelan NDC (Funvisis) is the SEISAN, which offers a complete package of programs for seismological analysis and for research purposes. Geotool, although it does not have a seismological research program package, is a software with a graphical interface that allows to display and analyze seismic events interactively. Both softwares can be customised and exteded, which is considered an advantage in these times of technological developments. SEISAN is used, commonly, through commands in the terminal, or command window, in the operating system in which it has been installed, in addition, the way to mark the seismic phases in the seismograms requires a lot of practice, making it prone to errors. On the other hand, Geotool has a friendly graphical interface that allows access to functions quickly and intuitively, such as observing statistics, errors and location parameters in a window within the interface and not in an uncomfortable terminal window. The advantage of SEISAN, regarding nuclear explosions and CTBTO's main aim, is its ability of making focal mechanisms, a procedure which is fundamental regarding the differentiation of a natural event from an artificial one.

Promotional text: Is fundamental, for the CTBTO Training Team and the NDCs around the world, to understand the capabilities of the different softwares developed to fullfill their main task: keep the world monitore and safe from the threat of a nuclear explosion. This is the main aim of this work.

P5.3-530 – Integrating realtime CTBTO and local seismic data using SEISAN

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This presentation gives examples on how to process and analyse data obtained in realtime from the IMS through the newly developed SeedLink service available on the Global Communications Infrastructure (GCI), using the seismic analysis software package SEISAN. Furthermore, we show how to integrate sensor data and metadata and event parametric data from the CTBTO with locally collected data. SEISAN is used in more than 30 countries mainly at smaller seismic networks or by students or researchers, for processing data from permanent or temporary seismic networks and at a number of NDCs. SEISAN runs on both Windows and Linux and is freely available and open sources (see http://seisan.info). The examples include guides for: 1. Simple configuration of IRIS slarchive software for handling the SeedLink connection and local storage of the realtime data feeds from the IMS in SDS or BUD format. 2. Configuration of SEISAN for analysing data from the SDS in automatic and manual modes. 3. Merge IMS sensor metadata with the SEISAN database. 4. Create local versions of the IDC REB, SEB, SEL, etc. bulletins in SEISAN databases. Signals from teleseismic and local/regional events are used in the examples using the SEISAN virtual network functionality to include IMS data.

Promotional text: We present methods to integrate CTBTO seismic realtime data with local data, which will enable NDCs to improve nuclear test monitoring, using the newly developed SeedLink service available on the GCI and IDC bulletins.

P5.3-535 – Baseline studies of environmental radioactivity in Nigeria to improve on-site inspection capabilities in regions with elevated radiation levels

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Nigeria joined the international community to welcome the adoption of the Comprehensive Test Ban Treaty (CTBT) by the United Nations General Assembly on 10th September 1996, as a veritable tool to prohibit "any nuclear weapon test explosion or any other nuclear explosion" anywhere in the world. Nigeria signed and ratified the CTBT in September 2000 and September 2001 respectively. Baseline studies of environmental radioactivity and radiation mapping was conducted in Nigeria, to enable quick detection of elevated radiation levels due to cross boundary radiation from possible nuclear tests. Such data can be used to extrapolate activity at the test site, thus ameliorating the challenges of on-site inspection because of high radiation field, or where the test site is not within the jurisdiction of Nigeria.

Nigeria, in her effort to ensure adequate and safe environment, carried out Environmental Impact Assessment in and around all its high risk facilities, Research Reactor in CERT, Zaria,GIF, Shada and medical facilities using Cobalt-60.

Promotional text: The abstract will enable SnT2021 objectives to be achieved. The abstract indicate the efforts and the work done by the regulatory body in Nigeria to ascertain the environmental impact of research reactor in the country and its environs.

P5.3-562 – Challenges toward building a nuclear power plant in Kazakhstan

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The first round of consideration of the construction of a nuclear power plant in Kazakhstan began in the mid-90s. The second time, with serious intentions, talking about construction of a nuclear power plant started in the mid-2000s. And for the third round, activity in the construction of a nuclear power plant in Kazakhstan dates back to 2013-2014 with government commission recommending two construction areas. No final construction decisions were made due to surplus of electricity. However with country's electricity demand growing it is expected to have electricity shortage by 2030.

Energy demand and economical sides of the project considered as reasons for delay of construction; however, there are far more reasons explaining why it would be challenging to progress with nuclear power plant construction in Kazakhstan. One of the main obstacles would be social rejection of the project due to trauma after nuclear weapon testing in Semipalatinsk area, with people still suffering from its consequences with growing rates of cancer and birth defects in area. All the tragedy and horror of the past left its deep wounds to Kazakh people. Also, lack of nuclear knowledge, communication to public, cultural security, and public awareness would be addition to the project delay.

Promotional text: In my presentation I would like analyze how development of nuclear knowledge among citizens, communication to public would raise public awareness and cultural security, and have direct impact in social acceptance of nuclear power plant contraction project.

P5.3-569 – A book showing the importance of an NDC in Brazil for its better participation in the verification regime of the CTBT

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Brazil does not have its NDC yet, but its creation has recently been discussed and, to contribute to these discussions, we have written the book The Brazilian Participation in the verification of CTBT, which presents the importance of an NDC, the advantages obtained with the its creation and demonstrated importance of CTBT in the control of nuclear weapons and in the construction of a solid social scientific knowledge base, through applications of the IMS data.
Brazil participates in CTBT with three technologies (seismic, infrasound and Radionuclide). The book presents the locations of the last nuclear test carried out by RPDK and the accidental explosion in Beirut.
There are several benefits for Member Countries with an NDC: access to raw and/or processed data; access to training and capacity building; access to software and technical support; access to a protected website that offers a platform for discussions and exchange of confidential information. By accessing the data of this worldwide network, Brazilian scientists will be able to develop studies and research in all areas of knowledge related to natural and man-made phenomena observable and measured by this worldwide IMS network. In this work we present the main subjects treated in the book.

Promotional text: The book was written to show the importance o an NDC in Brazil in order to better comprise with the CTBT.

P5.3-578 – CTBTO Youth Academy of Sciences

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This is the research and educational project for CYG members, which involves them in the CTBT research. The participants will work in groups of 4-5 people. Their research topic may include Verification Issues, Article XIV, CTBTO in the context of the nonproliferation regime, Science diplomacy, CTBTO and climate change, non-nuclear related applications of the IMS, et cetera. Each group will have a scientific supervisor from the GEM to bridge the younger and more experienced generation. The resulting papers are to be published in the Newsroom magazine, CTBTO web site and other platforms to revitalize discussion around the CTBT in the scholar's community be the voices of the young generation.
Steps:
1) Pre-orientation online lectures on advanced issues related to the CTBT;
2) One-week online seminars on the CTBT key challenges to determine what kind of research is currently relevant and necessary to be conducted. The GEM members are involved in these seminars as speakers and mentors as they are to become research advisors of research teams;
3) One and a half to two months of research work of the research groups;
4) Publishing the results. Presentation of the results during the SNT or SDS in the presentation or poster sessions.
The project intends to be an annual initiative.

Promotional text: The CTBTO Youth Academy of Sciences aims at developing and boosting the research in the fields related to the CTBT by being a convenient framework for young researchers. The results will bring back the CTBT on academic and research plate at local, regional, international levels.

P5.3-580 – Pathways Forward: Positioning the CTBT Among Other Arms Control Treaties

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Due to stringent entry into force provisions, the Comprehensive Test Ban Treaty (CTBT) has yet to enter into force, despite a provenly effective comprehensive verification regime and widespread support. Meanwhile, the Treaty on the Prohibition of Nuclear Weapons (TPNW)–a more aspirational treaty with a broader scope and lower entry into force requirements–received enough ratifications to enter into force on October 24, 2020. Among other provisions, the TPNW prohibits the development or testing of nuclear weapons: language reminiscent of, though not identical to, prohibitions contained in the CTBT.

This e-poster presentation explores how the current landscape of arms control treaties, including the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the TNPW, affect the CTBT. It assesses: what are the legal obligations related to nuclear weapons testing under various arms control treaties? In what ways do the treaties reinforce one another? If one treaty poses a risk of undermining the CTBT, how can that risk be addressed, resolved, and transformed into an opportunity?

In seeking to answer these questions, the presentation will incorporate the author's legal interpretation of treaty text, the results of expert interviews, and comparisons drawn from other areas of international law with complicated treaty landscapes.

Promotional text: As the global conversation on arms control continues to evolve, reflecting new developments in treaty regimes, the CTBT must remain relevant. This presentation contributes to the SnT2021 objectives of education, communication, and public awareness of that relevance.

P5.3-581 – OSI Exercises and Training – an Effective Way to Enhance Global Nonproliferation Efforts

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OSI is the ultimate pillar of the CTBT verification regime. Available only after the Treaty's EIF, it implies rapid deployment of a large amount of equipment and personnel. To maintain the operational readiness of the OSI segment, the CTBTO develops a network of exercises of different type and scale.

Hosting an IFE, a BUE or an OSI Regional course is a process that requires a lot of resources – financial, human, administrative, political. What motivates a country to offer doing that?

In this oral history project interviews were conducted with representatives of host countries and the PTS staff involved in IFEs (Kazakhstan 2008, Jordan 2014), BUEs (Austria & Hungary 2012-2013, Slovakia 2019-2021), Regional courses (Sri-Lanka, Argentina, South Africa).

Further work requires defining the group of interviewees, specially from host countries around the following themes: determining the host country process; motivation for a country to host large-scale exercises; impact for a country (prestige, attempt to raise profile/role in global nonproliferation and disarmament efforts, contribution to science etc.) and domestic process of approving hosting of OSI exercises.

The results of the study will be shared in this presentation.

Promotional text: Hosting a large-scale OSI-related exercise, such as IFE or a BUE is a process that requires a lot of resources – financial, human, administrative, political. What motivates a country to offer its territory for such exercises - from the perspective of both PTS and host country?

P5.3-608 – Nuclear Harms & Slow Violence: Storytelling as Tool for Change

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Storytelling can be a powerful tool for change and social activism. This essay proposes a storytelling blog as a platform to raise awareness and engagement with the goals of the CTBTO, namely, bringing the CTBT into force and working toward global deproliferation of nuclear weapons. Embracing Shampa Biswas's broader conception of nuclear harms, such a project could work to make the harms of nuclear testing and other nuclear activities, such as uranium mining, intelligible and moving for a broad audience. This would align with Rob Nixon's imperative to make slow violence – "violence that occurs gradually and out of sight, a violence of delayed destruction that is dispersed across time and space" – visible and arresting. Such a project could also make connections with the geographical concept of sacrifice zones, areas where environmental damage and economic disinvestment devalue life and wellbeing. Finally, a blog of this kind could make links to global environmental justice movements, which often focus on the location of sacrifice zones in marginalized, racialized communities; this project could therefore serve to connect the goals of the CTBTO to broader environmental movements and mobilize activists, organizers, and concerned citizens to pressure governments to bring the treaty into force.

Promotional text: This project would serve as an outreach initiative to engage the public with the goals of the CTBTO, and thus falls under Topic 5.3 of the SnT themes. As an undergraduate student, I also believe this project would appeal to youth and connect the CTBTO to less engaged audiences.

P5.3-617 – Importance of the National Data Centers (NDC) in the ratification of the CTBTO treaty.

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Some countries have signed the CTBTO nuclear test ban treaty but are reluctant to ratify it. This can have several causes: Either their selfish aspect which can lead them to do not accept a total control by the preparatory commission of CTBTO, or the diplomatic relations are not very well strengthened between CTBTO and these countries.
We believe that the installation of National Data Centers (NDC) in these countries can be a necessary tool to gradually bring them to the ratification of the treaty.
The National Data Center promotes:
 Continuous exchanges between the signatory country of the treaty and CTBTO
 Strengthening diplomatic relations between CTBTO and the country
With the National Data Center, CTBTO has the possibility of organizing scientific trainings and capacity building activities in these countries in relation with the verification regime. The delegates of CTBTO will therefore be able to go to these countries and meet there scientific and political figures who are in the position of decision-making.
Such continuous exchanges can lead to very strong diplomatic relations that can push these countries to ratify the treaty.

Promotional text: Since the ratification of the treaty is a crucial element for it to enter into force, it is essential to seek the various diplomatic strategies which can help CTBTO to bring certain important countries to this ratification. This abstract helps to increase ideas for CTBTO.

P5.3-641 – Environmental consequences of nuclear disaster: 10 years of Fukushima Daiichi meltdown and the role of CTBTO in nuclear emergency response

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Nuclear accidents are capable of exponential damage, and in particular can be the reason for acute environmental degradation. Radioactive contamination can occur for multiple reasons like damage in the nuclear reactors, from nuclear waste and also from the temporary storage of spent radioactive fuel. Radioactive emissions are fundamentally airborne and guarantees contamination for the next hundred years.
In 2011, massive earthquake with tsunamis in Japan caused by the Fukushima Daiichi nuclear accident. Implications of the Fukushima Daiichi meltdown were not only regional but global at the same time. After the accident, an immense amount of radioactive materials was released into the atmosphere through varied meteorological conditions like wind and precipitation. CTBTO and its monitoring stations played significant role after the disaster to study the radioactive fallout and its consequences.
The proposed paper is divided into two parts. Firstly, it will assess the environmental consequences of nuclear disaster in general. Secondly it will study the Fukushima Daiichi nuclear disaster and its implications on environmental degradation over the last 10 years. The paper will further evaluate the role of CTBTO to lay out a potential nuclear emergency response mechanism in the context of the disaster.

Promotional text: The proposed paper will assess the environmental consequences of nuclear disaster in general and will also reflect on the Fukushima Daiichi nuclear disaster and its implications on climate change since the last 10 years.

P5.3-655 – Open Day at IMS stations PS19 GERES and IS26 in the Bavarian Forest

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The Primary Seismic Array PS19 GERES and the Infrasound Array IS26 are located in the Bavarian Forest and are operated by the Federal Institute for Geosciences and Natural Resources (BGR). From 2017 to 2019 extensive GERES refurbishment and recapitalization construction works were performed in the area which also had an impact for local population and tourists as cabling exchange disrupted hiking trails. After completion BGR organized an Open Day for the local population and tourists on 25 August 2019. Besides the chance to see the station elements, a comprehensive exhibition with information kiosks about CTBT monitoring, seismicity, infrasound sources and many other topics BGR is engaged with was provided. In front of the facility building a little folk festival with regional food and drinks as well as traditional brass music took place. During the day around 600 people visited the site at a remote place which seems kind of mysterious for the normal population. But after the open day they knew more about the purpose of the facility and the whole IMS an how monitoring works.
Parts of the exhibition were also shown several weeks later when Vienna based diplomats were invited to visit the station site and facilities.

Promotional text: Station visits for the public or diplomats enriched with an information programme about the CTBT and its monitoring regime give a extrremely valuable hands-on experience!

P5.3-679 – Teaching Humanitarian Impacts of Nuclear Weapons as Part of CTBT Education: Case of Kazakhstan

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There is a growing understanding in the international community of the catastrophic humanitarian consequences of the use of nuclear weapons on individuals, society, the economy and the environment. However, recent efforts by non-nuclear weapons states and civil society to encourage nuclear powers to prioritize nuclear disarmament that culminated in the adoption of the Treaty on the Prohibition of Nuclear Weapons have not been successful. There is a clear need to revitalize the humanitarian impacts agenda, which will also help promote the CTBT's entry into force. One of the ways is to educate the young generation by incorporating humanitarian aspects of nuclear weapon detonations in academic curricula of relevant higher education institutions. In Kazakhstan, a country that housed a major nuclear test site and is now home to five International Monitoring System stations, a number of universities offer non-proliferation and disarmament courses that comprehensively cover, among other topics, nuclear test-ban issues, including CTBT's political and legal aspects, as well as health and environmental consequences of nuclear testing. This experience demonstrates that educated youth equipped with necessary knowledge can be instrumental in achieving progress towards a world free from nuclear weapons.

Promotional text: Promoting CTBT Goals through Youth Education.

P5.3-681 – Outreach and Education through Museums and Cultural Centers

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The creation of the CTBTO Youth Group is just one example of successful outreach and education being made accessible for individuals not already involved in nuclear/security circles. The entry into force of the Treaty is not just dependent on high-level talks but also influenced by civil-society. This is where museums, cultural, historical, and scientific centers are necessary for the communication of the CTBTO, the Treaty, etc. into the public consciousness. Such examples already exist to talk about nuclear testing and climate change (i.e "Godzilla: A Living Atomic Bomb" & "Nuclear Contamination and Climate Change" by Natural History Museum of Los Angeles County x The Los Angeles Times) and natural radiation (i.e. "Radioactivity in the Natural World" by Naturhistoriche Museum Wien). It would be in the organization and the treaty's best interest to explore new avenues for awareness and promotion as these learning centers are inclusive and non-discriminatory; possibilities of collaboration include but are not limited to: side events/panels, youth programs, exhibits (temporary and permanent).

Promotional text: The idea is to connect with other educative platforms for promoting CTBTO in non-nuclear civil society areas (i.e. Climate) and provide a new avenue for possible collaboration and awareness; this is a new innovative way to tackle the lack of awareness and promotion.

P5.3-682 – CTBTO Youth Group as a prime model of track 2 diplomacy: united in science

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CTBTO Youth Group represents a unique platform of almost 1000 members from diverse backgrounds,connecting science and policy in an interdisciplinary way. The platform provides opportunities through nuclear disarmament and non-proliferation education to involve its members in various track 2 diplomacy channels creating a safe space for active engagement, learning and exchange between peers coming from nuclear- and non-nuclear weapon states. This special type of interaction is possible through different dialogue possibilities available for the members, such as citizen diplomacy, science diplomacy, intergenerational cooperation and citizen journalism - fostering peace and collaborative atmosphere. Technological aspects of the CYG include the website with e-learning resources, connection via webinars and social media. These tools help to expand the network outside of nuclear field and attract more interest in the importance of banning nuclear testing, demonstrating support using a variety of means and contributing for the entry into force of the CTBT, highlighting its verification regime along with the scientific benefits.

Promotional text: CTBTO Youth Group: Citizen diplomacy in action with the use of technologies. Explore more on how CYG acts as a track 2 diplomacy channel which fosters more peacebuilding and security initiatives within and beyond the network.

P5.3-684 – Introduce nuclear to the common people culturally by keris

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Introducing the concept of nuclear non-proliferation can be done with various approaches, including cultural approaches. Through the cultural approach, the introduction can be done by understanding the cultural products of a society, one of which is the Javanese society: a keris.

As a cultural product, Javanese people use keris as weapons or accessories or collections. For the Javanese indigenous people, the keris is not just an object, it is also believed to have spiritual or mystical values. The keris is believed to provide strength to its owner. People who hold a keris or are near a keris may feel different sensations.

Many researchers have found that the energy emitted by the keris produced by the constituent material which is a combination of iron, steel, nickel, cobalt, uranium and meteorite is the cause of the various sensations felt by the holder and the people around the keris. Various forms and phenomena surrounding the keris make it easier for the Javanese indigenous people to understand nuclear and radiation.

Keris is an example of a cultural object that we can use to introduce nuclear to the common people through a cultural approach. CTBTO can increase awareness about nuclear to the wider community through cooperation with several local cultures.

Promotional text: CTBTO can raise awareness about nuclear by means of culture through keris.

P5.3-685 – CTBTO Youth Group Communications Model

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The CTBTO Youth Group (CYG) was launched in 2016 and since then has around 1000 members. But this membership would not have been possible without effective and proper communication among members and with the CTBTO staff. The objective of the paper is to share successful communications model of the CTBTO Youth Group. The results suggest that this experience could be helpful for other youth organizations and further development of the CYG. Initially, the Group has a Coordination Team that represents the interests of the members and serves as the contact point between the CTBTO representatives (CYG Task Force) and all CYG members. Secondly, it has a CYG portal and social media accounts with the latest news and updates. Likewise, the CYG has a Newsletter that provides its members with information on recent and upcoming events and opportunities, as well as the articles on the CTBT-related topics. Next, Coordination Team members have a regular call with CTBTO staff to discuss strategies and events organization. Moreover, SnT and SDS serve as the platform for CYG members to meet in person and come up with the ideas on the CTBT's and CYG's promotion.

Promotional text: The paper highlights the CTBTO Youth Group's successful communication model thanks to which CYG successfull grows and therefore broadens the engagement of young scientists in working in test ban monitoring as well as young diplomats promoting science diplomacy.

Side events

CTBTO Youth Group

SE1 – Evolution of the SnT Conference: CTBTO Youth Group dialogue with Executive Secretary Lassina Zerbo

Since we only see the slow emergence from the COVID pandemic, SnT 2021 has gone mostly virtual. The new format aims to stimulate rich discussions and to create the space for wider and more diverse participation, especially by the next generation of experts. This year's conference is the sixth conference in the SnT series and coincides with the 25th anniversary of the CTBT since it opened for signature. The principal goal of the conference series remains unchanged – to create a multidisciplinary scientific platform attracting scientists and experts from the broad range of the CTBTO's underpinning technologies. For an entire week over multiple sessions, they will review scientific and technological advances and anticipate which innovative technologies would further strengthen the Treaty and its verification regime.
Since 2015, CTBTO Youth Group (CYG) members have participated in the SnT as speakers, citizen journalists, poster presenters and attendees. To highlight the importance of multi-disciplinary youth engagement, Dr Lassina Zerbo, Executive Secretary of the CTBTO, will engage in an interactive dialogue with the CYGs. Participants will be able to discuss the evolution of the SnT series, the role of youth and learn about the main highlights of the conference.

CTBTO Youth Group

SE2 – Group of Eminent Persons - CTBTO Youth Group Mentoring Session

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Intergenerational dialogue and mentoring are key in building the next generation of STEM and nuclear non-proliferation experts. In fields that are considered highly technical and difficult to enter, such as STEM and arms control, good mentors that provide guidance for both career and personal growth can encourage young professionals to break barriers and create lasting change. To inspire and encourage our next generation of experts to pursue their career goals, the CTBTO Youth Group (CYG) is partnering with internationally renowned leaders in STEM and disarmament from the CTBTO Group of Eminent Persons (GEM) for a virtual mentoring event.
During the session, GEM members will act as mentors and engage with students and young professionals from the CTBTO Youth Group for two rounds of short, focused conversations held under Chatham House rules. Participants will meet in Webex breakout rooms for 25 minutes on a rotating basis.
This unique opportunity will further the CYG members' knowledge of the nuclear non-proliferation sphere, answer their most pressing professional questions and build their confidence their pursuing their interests and breaking silos in fields that require more diversity and emerging voices.

Educational Initiative for Young Professionals with Technical Background

SE3 – OSI Educational Initiative for Young Professionals with a Technical Background

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For over a month, students of Russia's National Research Nuclear Institute – Moscow Engineering Physics Institute (NRNU - MEPhI) have been working on case studies developed for them by the On-Site Inspection (OSI) Division. These cases cover a wide range of OSI-specific topics driven by the need to ensure its operationalization at the CTBT entry into force. At this side-event students will present their ideas and technical solutions on how to further increase the OSI capability.
For participants, it has been a unique opportunity to interact with the PTS staff and OSI experts, get a sense of what the work of the CTBTO is like and offer their take on how to address the actual challenges to one of the elements of the CTBT verification regime.
The event is organized jointly by the OSI Division, the CTBTO Youth Group Task Force and NRNU–MEPhI, that the CTBTO has traditionally close ties with, and that has been spearheading efforts to promote and enhance CTBT-related expertise and youth involvement among Russian universities and worldwide.

Educational Initiative for Young Professionals with Technical Background

SE4 – International Gender Champions and Youth - Collaboration for Successful Outcomes

Two International Gender Champions (IGC) from the Vienna Hub will come together with members of the CTBT Youth Group to discuss effective ways for meaningful youth involvement in the current world agenda.

It has been proven that increasing youth participation and nurturing youth leadership in shaping today's societies is an effective method to combat complex challenges such as poverty, hunger, gender equality, environmental issues, and migration, just to name a few, and to build more thriving, inclusive, prosperous and peaceful communities . This panel will centre on the role of youth empowerment in the context of the future of work, address hurdles that young people are facing in starting their career paths and discuss best practices in supporting them.

In this discussion, the Vienna-based International Gender Champions, a network of 40 leaders who foster gender equality and push the gender agenda in Vienna, will open the conversation on the venues for common action needed to best prepare the younger generation with members of CTBT Youth Group, an assembly of over 1070 prominent young women and men who strive for a better future and accelerate positive societal changes. Both groups represent indispensable allies in the quest for sustainability.

Moderator: Mr. Sahil Shah, Policy Fellow at the European Leadership Network, member of CTBT Youth Group

Participants:
• Mr. Alejandro Solano Ortiz, Ambassador and Permanent Representative of Costa Rica to International Organizations in Vienna, International Gender Champion
• Ms. Elena Sokova, Executive Director of Vienna Center for Disarmament and Non-Proliferation, International Gender Champion
• Ms. Mingqi Xie, Junior Associate at International Conflict and Security Consulting Ltd, 2022 Schwarzman Scholar, member of CTBT Youth Group
• Ms. Naledi Daka, Masters Student at Charles University in Prague, member of CTBT Youth Group

NDC Session

SE5 – NDC Session

Co-authors: Andry Ramanantsoa[1]; Daniela Veronica Ghica[2]; Gonzalo Antonio Fernandez[3]

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NDCs (National Data Centres) are the national technical organizations competent to advise their governments on the verification of the Comprehensive Nuclear-Test-Ban Treaty. The objective of this session is to allow NDC experts to share experience in fulfilling their verification responsibilities. During presentations and discussions, special emphasis will be put on:
• use of IMS data and IDC products for verification purposes as well as civil or scientific applications,
• use of NDC-in-a-box or specific tools in operation in NDCs,
• collaboration and interactions between NDCs.

Speakers: Several speaker interventions
The duration of each presentation is 10 minutes, following by 5 minutes of QA.

Abstracts:
1) From the isolated seismic / infrasound acquisition systems to a research and development system
Author: G. A. Fernandez, Observatorio San Calixto, BOLIVIA

The Observatorio San Calixto (OSC) is a Jesuit nonprofit private research institution from Bolivia (Plurinational State of) stablished on 1913 since then is on charge of the seismic and infrasound monitoring at local, regional levels, actually in charge of seismic hazard studies along the country. On behalf of science OSC has made scientific agreement with "Commissariat à l'Energie Atomique et aux énergies alternatives, France" (CEA) and "Air Force technical Application Center" (AFTAC) with both institutions we certified the Primary Seismic Station PS06-LPAZ, Auxiliary Seismic Station AS08-SIV and Infrasound Array IS08-Peñas. Since then a set of three different acquisition software were implemented at our National Data Center (NDC), somehow was complicated to merge the earthquake localization solutions, but since 2016 and within the NDC – Capacity Building we were benefited with the Capacity Building System (CBS), which is composed by a server, workstations and backup system, after that our NDC started to have all data from our certified stations and some from the open seismic network from the neighborhood countries and as result the OSC – NDC is performing efficient monitoring and new studies.

2) 20 YEARS OF MADAGASCAR NDC ACTIVITIES

Authors: A. H. Ramanantsoa, F. Randrianarinosy, J.B. Andrianaivoarisoa, A.T. Rakotoarisoa, from Institute and Observatory of Geophysics of Antananarivo, MADAGASCAR

At the end of 2001, NDC Madagascar has operated after infrasound and seismic stations were installed. Data availability of 99% is the result of rigorous maintenance. IMS data are used as verification regime and for civil applications. Data are processed using NDC in a box packages. All of these activities are not possible without different trainings (maintenance, data processing…) followed by the staff of NDC Madagascar. Participations in Science and Technology conference or Infrasound Technology Workshop allow the NDC to present research results to the community.

3) Infrasound processing at Romanian NDC using NDC-in-a-Box
Author: Daniela Ghica, National Institute for Earth Physics, ROMANIA

At Romanian NDC, the infrasound data processing capabilities of NDC-in-a-Box are used since 2016, when the duo of infrasound detection-oriented software – DTK-GPMCC and DTK-DIVA – has been packaged into the system.
Starting with 2009, three infrasound stations have been deployed on the Romanian territory by the National Institute for Earth Physics (NIEP): (1) IPLOR (in the central Romania), (2) BURARI (in the northern Romania), under the cooperation with Air Force Technical Application Center AFTAC (USA), and (3) I67RO temporary PTS portable array (in western Romania) as two-year experiment (2016-2018), within a collaboration project with PTS/CTBTO.
Data recorded with the Romanian infrasound stations are automatically processed at Romanian NDC

by running PMCC detector (DTK-PMCC). DTK-GPMCC is applied to study in detail the detected signals, including the capacity of fusing them into approximate source location by cross bearing. DTK-DIVA is used to investigate the array monitoring performance. i.e., detection capability, types of sources observed, ambient noise conditions etc.
In addition to the data recorded with the local stations, data from IMS infrasound network are processed at Romanian NDC, in order to jointly characterize large events (bolides, explosions). Furthermore, IDC products such as LEB bulletins proved to be very useful to identify the detections observed with the Romanian infrasound stations.
Infrasound processing at Romanian NDC benefited from the technical assistance kindly provided by PTS/CTBTO and consisting of NDC-in-a-Box SHI Software Package, trainings (Intermediate Level Infrasound Data Analysis Training, July 2019, Bucharest, Romania; NDC Advanced Training on Infrasound Data Analysis, October 2019, Bruyères-le-Châtel, France), as well as of valuable advices from the PTS staff.

CTBTO Youth Group

SE8 – CTBTO Youth Group SnT 2021 Fireside Chats 1

Building on the successful practice of the #CYGWebinars, the virtual format of SnT 2021 will benefit from interactive engagement opportunities between CTBTO Youth Group (CYG) members and SnT speakers and high-level guests. These two half-hour virtual Fireside Chats will feature brief presentations on global topics of interest by prominent SnT speakers and high-level guests, followed by an informal interactive discussion with CYGs. These webinars will encourage young people to engage with experts and generate interest in the wide variety of topics and presentations featured at the Conference.

The first Fireside Chat will be moderated by Mr Marius Jano (CTBTO Preparatory Commission, Vienna, Austria). The second Fireside Chat will be moderated by Ms Sneha Nair (CTBTO Preparatory Commission, Vienna, Austria).

Speakers:
• Professor Tracey Rogers, Marine Ecologist, University of New South Wales Sydney
• Ms. Zainab Azim, Co-Founder of G.I.V.E and Youngest Member of Virgin Galactic's Future Astronaut Program

CTBTO Youth Group

SE9 – CTBTO Youth Group SnT 2021 Fireside Chats 2

The Korean peninsula is the only region in the world to have seen a nuclear weapons tests in the 21st century. The latest such test was conducted in 2017. In 2018, Pyongyang announced a moratorium on nuclear tests, which it has continued to observe to this day. Around the same time in 2018 the DPRK announced the closure of the Punggye-ri nuclear test site and the tunnel entrances were collapsed in the presence of foreign journalist (but no international inspectors) a few week later. Can we expect further progress towards a comprehensive nuclear test ban in the region? And what specific steps could be made in that direction?
These and other questions will be discussed during the SnT Fireside chat with Anton Khlopkov, Director of the Center for Energy and Security Studies.

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