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19 TO 23 JUNE

Synergy between CTBT technologies and national technical means

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CTBTO PREPARATORY COMMISSION

INTRODUCTION

IMS uses 4 technologies - SHI and RN - in a synergistic manner to enable the detection, location, and identification of potential nuclear explosions. Each of these technologies has advantages and limitations, and overcoming these limitations is crucial for the verification regime.

METHODS/DATA

The uses of multi-technology fusion between the 4 technologies and other National Technical Means to overcome gaps and limitations. The synergy between infrasound and seismic data, and between Infrasound and Satellite imagery are good examples of synergy.

START

RESULTS

Examples of events in Tunisia (quarries and mines), where infrasound and seismic data are used to distinguish sources in areas with a low seismic network coverage. Another example of using infrasound and satellite imagery during Stromboli eruptions shows possible synergy forms.

CONCLUSION

Classic synergy and other forms of synergy between technologies can fill gaps and improve results by utilizing the strengths of each technology while overcoming its limitations

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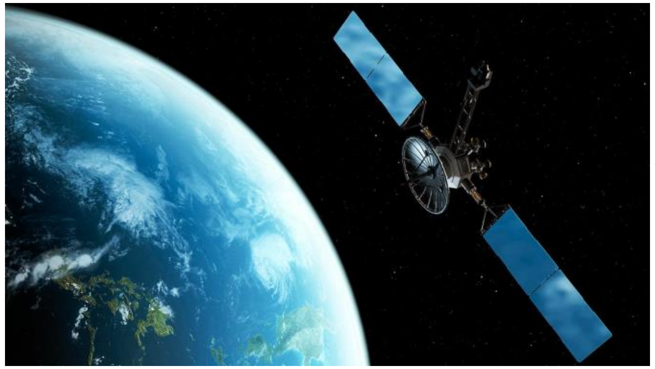
Introduction to CTBT technologies and national technical means

The International Monitoring System (IMS) consists of four verification technologies that synergistically contribute to the detection, location, and identification of potential nuclear explosions. Seismic stations detect shock waves generated by explosions through ground vibrations, while infrasound and hydroacoustic stations listen for corresponding sound waves. Additionally, radionuclide stations analyze the atmosphere to detect traces of radioactive particles and gases, which provide crucial information regarding the nuclear nature of an explosion.

Additionally, each state party possesses its own National Technical Means that can include similar technologies to the four used by the IMS, as well as other tools such as satellite imagery, thermal cameras, and more. These complementary technologies can synergistically work alongside IMS technologies to monitor nuclear tests and serve various civil and scientific applications.



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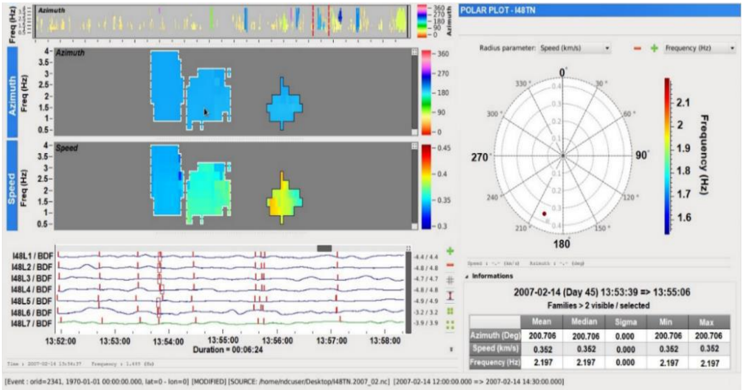
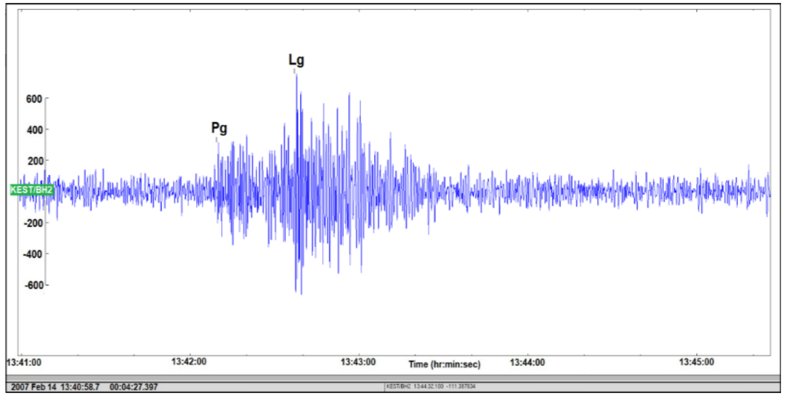
Synergy between Infrasound and Seismic data

Infrasound and seismic are waveform technologies employed by the International Monitoring System (IMS). In the following example, we will showcase the synergy between seismic and infrasound data, illustrating how they can be combined to determine the source location and origin time of a blast in a phosphate mine located in Mdhilla, Tunisia:



Infrasound detection information from the I48TN station regarding the Mdhilla mine on February 14, 2007.



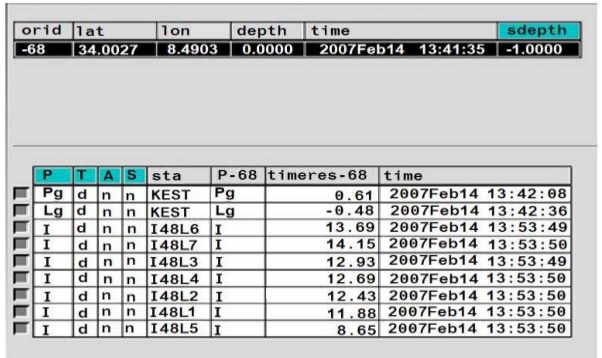
Seismic detection information from the KEST station regarding the Mdhilla mine on February 14, 2007.

The analysis of IMS data from the infrasound station I48TN on February 14, 2007, using DTK-GPMCC software as shown above, yielded the following findings regarding the characteristics of the infrasound source emanating from a Back Azimuth of approximately 200°

Station	Time	Phase	BackAz	Speed (m/s)	Frequency
I48TN	2007-02-14 13:53:29	I	**200°.706**	352	2.197

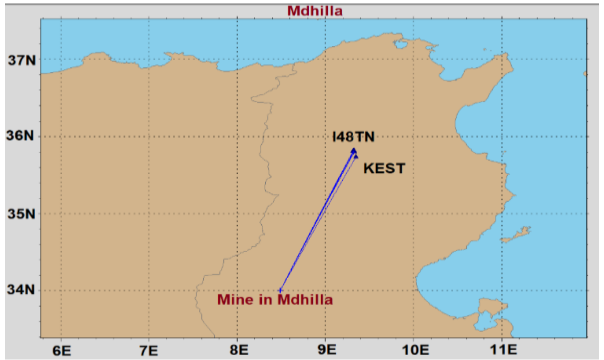
By analyzing the seismic data from the IMS station (KEST) in Tunisia for the same period of time by using the Geotool, Pg and Lg arrivals were added, and the origin time was defined “13:41:35” as shown below:

Origin Time			2007-02-14 13:41:35		
Station	Time	Phase	Latitude	Longitude	Depth (km)
KEST	2007-02-14 13:42:08	Pg			
KEST	2007-02-14 13:42:36	Lg	34°.0027	8°.4903	0



orid	lat	lon	depth	time	sdepth
-68	34.0027	8.4903	0.0000	2007Feb14 13:41:35	-1.0000

P	T	A	S	sta	P-68	timeres-68	time
Pg	d	n	n	KEST	Pg	0.61	2007Feb14 13:42:08
Lg	d	n	n	KEST	Lg	-0.48	2007Feb14 13:42:36
I	d	n	n	I48L6	I	13.69	2007Feb14 13:53:49
I	d	n	n	I48L7	I	14.15	2007Feb14 13:53:50
I	d	n	n	I48L3	I	12.93	2007Feb14 13:53:49
I	d	n	n	I48L4	I	12.69	2007Feb14 13:53:50
I	d	n	n	I48L2	I	12.43	2007Feb14 13:53:50
I	d	n	n	I48L1	I	11.88	2007Feb14 13:53:50
I	d	n	n	I48L5	I	8.65	2007Feb14 13:53:50



The map and event location shown above are the outcomes of using Geotool software to pick the Pg and Lg seismic phases from the data gathered at the KEST seismic station. Additionally, the infrasound I phases observed with DTK_GPMCC were incorporated from the infrasound data obtained from the I48TN station.

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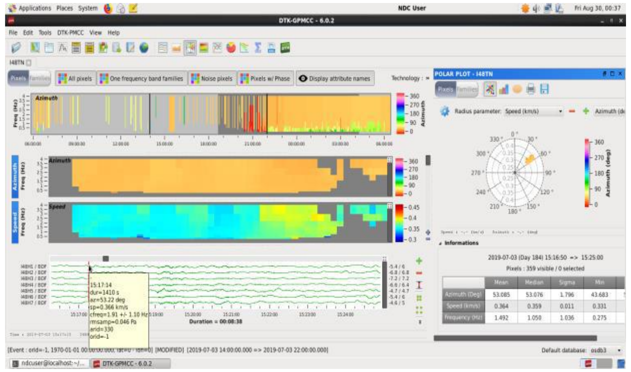
Synergy between Infrasound and Other National Technical Means

This is another example of synergy between Infrasound and Thermal Cameras or Satellite imagery for monitoring volcano eruption.

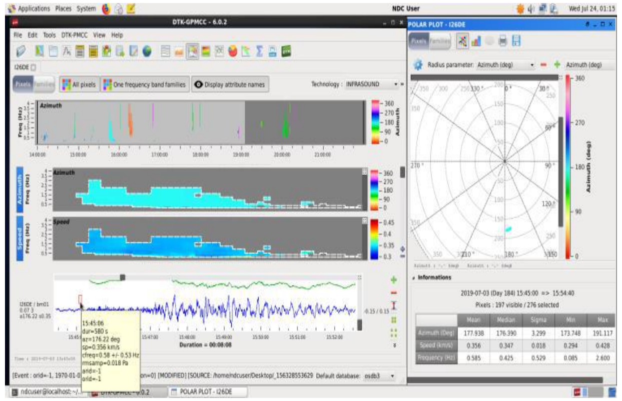
Infrasound data analysis for Stromboli volcano eruption on 3rd of July 2019

One of the most recent eruptions of Stromboli volcano occurred on July 3, 2019. Four IMS infrasound stations were used to analyze and characterize the eruption, namely: I48TN in Tunisia, I26DE in Germany, I37NO in Norway, and I42PT in Portugal using DTK-GPMCC software:

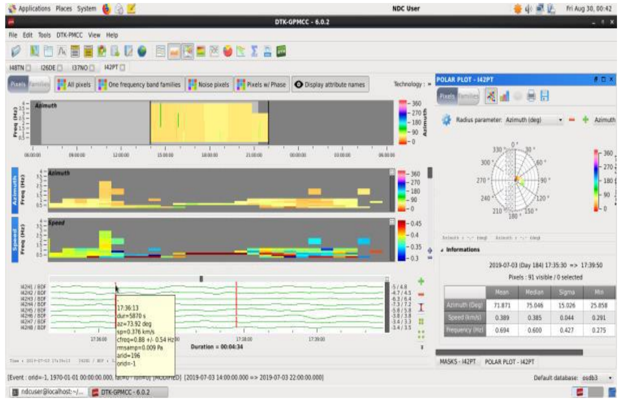
Event parameter at I48TN



Event parameter at I26DE

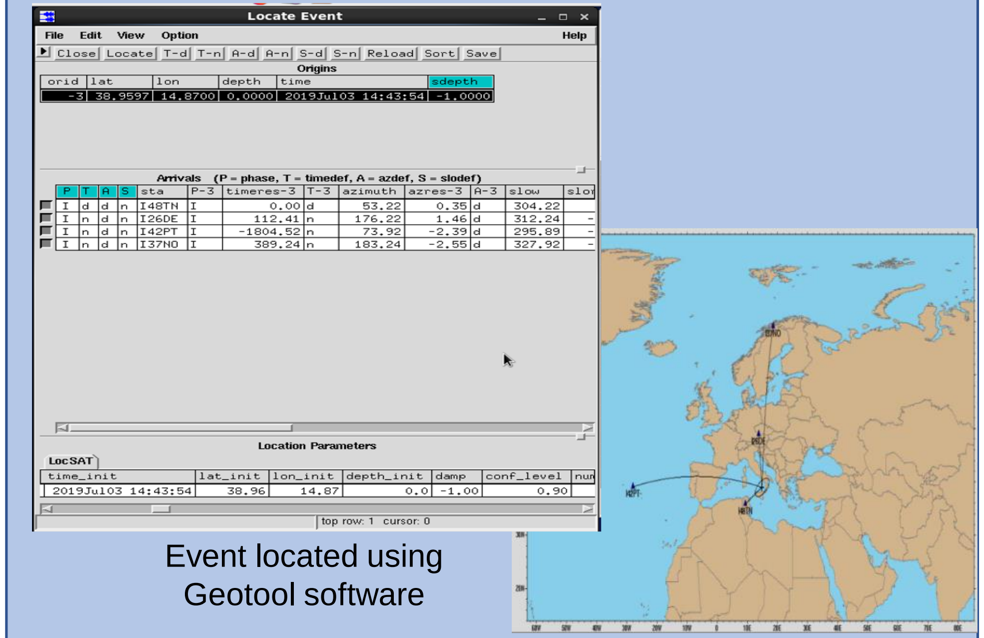


Event parameter at I42PT



Event parameter at I37NO

By adding the results from the four IMS Infrasound stations I48TN, I26DE, I42PT and I37NO to Geotool Software which is part of the NDC-in-A-Box package and used by the National Data Centres as shown below, the location of the event was defined : ***Lat: 38°.9597, Lon: 14°.8700, Depth: 0.0 and the Origin Time: 14:43:54*** which correspond to the Stromboli eruption on 3rd July 2019.



Event located using Geotool software

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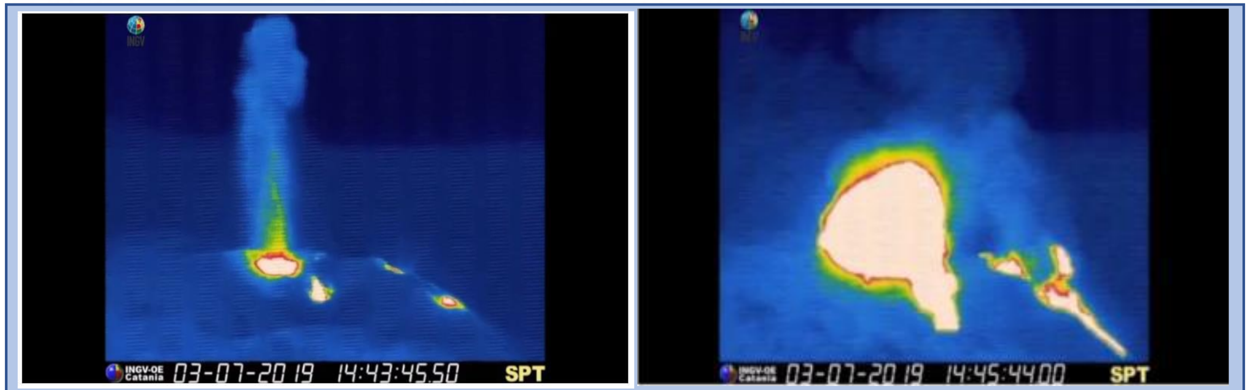
Stromboli Volcano eruption recorded by a thermal camera

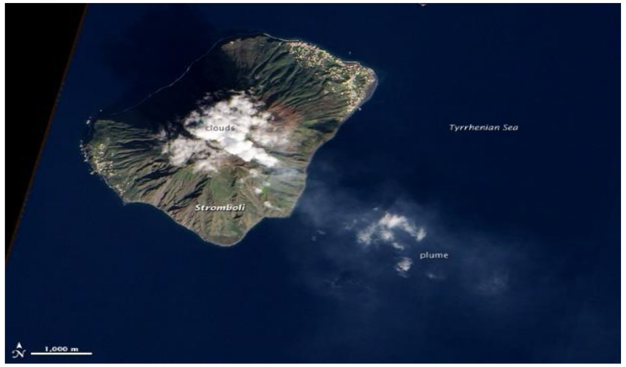


Stromboli eruption 2019-07-03 (©INGV-OE, 2019)

The above screenshots are from a thermal camera (INGV-OE, 2019) capturing the start time of the major eruption on July 3, 2019. The first screenshot indicates the recorded start time of 14:43:45, followed by the second screenshot depicting the eruption occurring at 14:45:45, approximately 2 minutes later.

When comparing the results to the ground truth information recorded by the thermal camera on July 3, 2019, it can be observed that the recorded Lat/Lon correspond to Stromboli volcano with a notable ellipse error. Additionally, the event time aligns with the eruption time, as indicated in the table below.

Study results from four Infrasound IMS stations		Stromboli location and eruption time (Ground truth)
Latitude	38°.9597 N	38°.789 N,
Longitude	14°.8700 E	15°.213 E
Time	14:43:54	14:43:45 followed by a big eruption on 14:45:45



Cloud cover on Stromboli volcano (NASA, 2011)

The natural-color satellite image displayed above depicts the island of Stromboli, with its cloud-covered summit and a narrow volcanic plume, as captured on January 13, 2011 (NASA, 2011).

Observing Stromboli's eruptions from space has been made possible through the utilization of Sentinel satellites from the European Earth Observation Program Copernicus. These satellites provide a vast amount of geospatial data that is openly accessible and usable for various applications, such as environmental monitoring, territorial control, and natural and civil security risk studies. Specifically, the Sentinel 2A/2B satellites, equipped with the MSI (Multispectral Instrument) sensor, offer high spatial resolution optical band data (including infrared bands) with a resolution of up to 20 meters. These satellites play a crucial role in the study of volcanic activity, as highlighted by Marchese et al. (2019).

The combination of visual, infrared (IR), and ultraviolet (UV) imaging synchronized with acoustic instrumentation has contributed to a deeper understanding of the sources of volcano infrasound. However, it should be noted that satellite data can be hindered by cloud cover, making it more challenging to detect weak explosions occurring at lower altitudes (Matoza et al., 2019).

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Conclusion on the Synergy between CTBT technologies and national technical means

The synergy between infrasound and seismic data is very important to distinguish the correct infrasound source from a couple of sources in the same region, especially when there is a low Seismic network coverage. The synergy between infrasound and space observation for volcanic eruptions showed us that the infrasound monitoring of volcanoes provides relevant information about ash injection in the atmosphere when satellite information is not available because of cloud coverage.

In the two examples presented in this study, we demonstrated the importance of synergy between CTBT technologies, as well as the utilization of other national technical means such as thermal cameras and satellite imagery. This highlights the significance of integrating multiple technologies to enhance our understanding and analysis capabilities.

However, there are a software limitation in data fusion between different technologies which need to be addressed by software engineering and technology experts to work more on the existing tools to address this limitation.

References

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