SnT 2021
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

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PREPARATORY COMMISSION

Seismo-acoustic characterization of the 2019 Stromboli volcano paroxysm events

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POSTER

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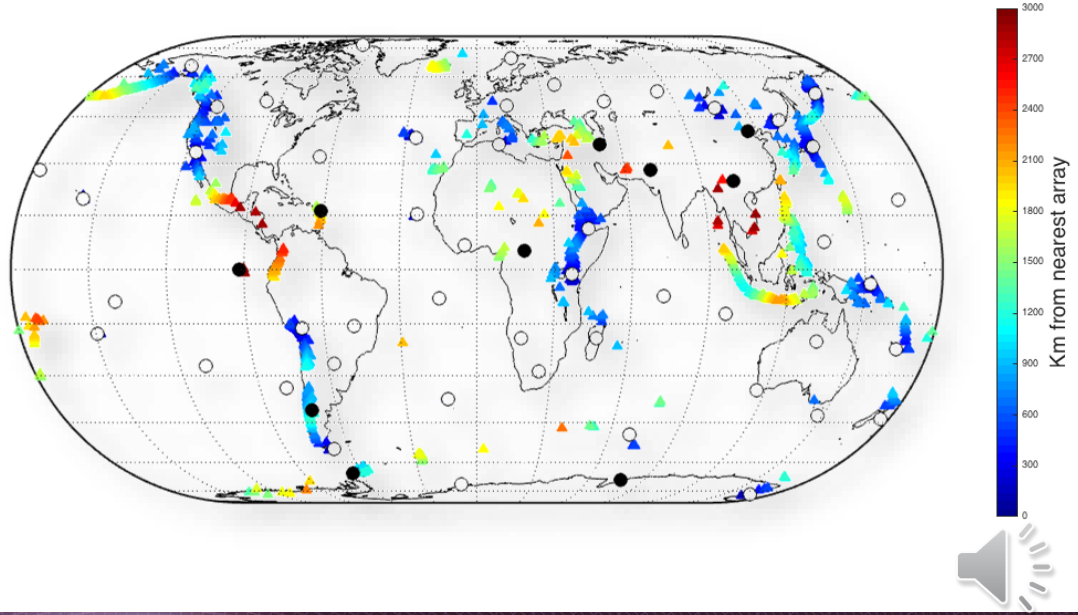
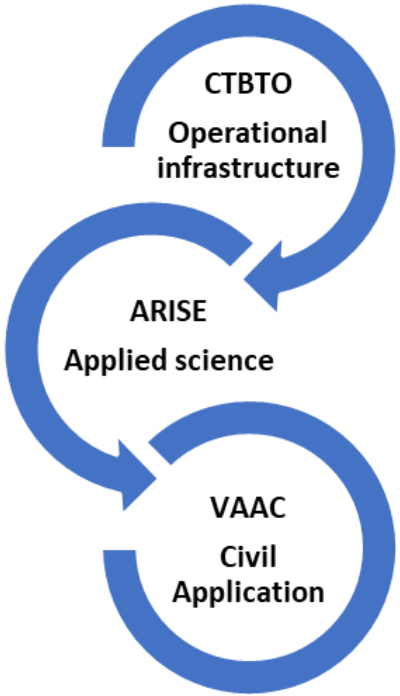
The global IMS* infrasound network

- Distribution of IMS infrasound arrays and volcanoes (triangles) that had activity during the last 10,000 years. For each volcano, the distance to the nearest IMS infrasound station is colour-coded
- Multi-year continuous quality recordings
- Global coverage: median distance from any volcano to the nearest IMS infrasound array is ~980 km
- Mean travel time of ~55 minutes assuming an isotropic propagation with a celerity of 0.3 km/s

*International Monitoring System operated by CTBTO (Comprehensive-Nuclear-Test-Ban Treaty-Organization)



From science to operations



Development of a Volcanic Information System (VIS*)

The synergy CTBTO / ARISE (**A**tmospheric dynamics **R**esearch **I**nfra**S**tructure in **E**urope, H2020 project funded by EU 2015-2018; http://arise-project.eu) offered a unique opportunity for the VIS establishment using infrasound data from a global station network

- ARISE advanced products provide valuable parametric inputs on the atmosphere dynamics that drives the infrasound wave propagation
- CTBTO brings its operational infrastructure to support dissemination of information to VAACs through the VIS
- The proposed approached is tested with **VAAC Toulouse**, mandated by the ICAO, to demonstrate the usefulness of infrasonic data to International Airways Volcano Watch

*Prototype system has been developed within ARISE H2020 EU project

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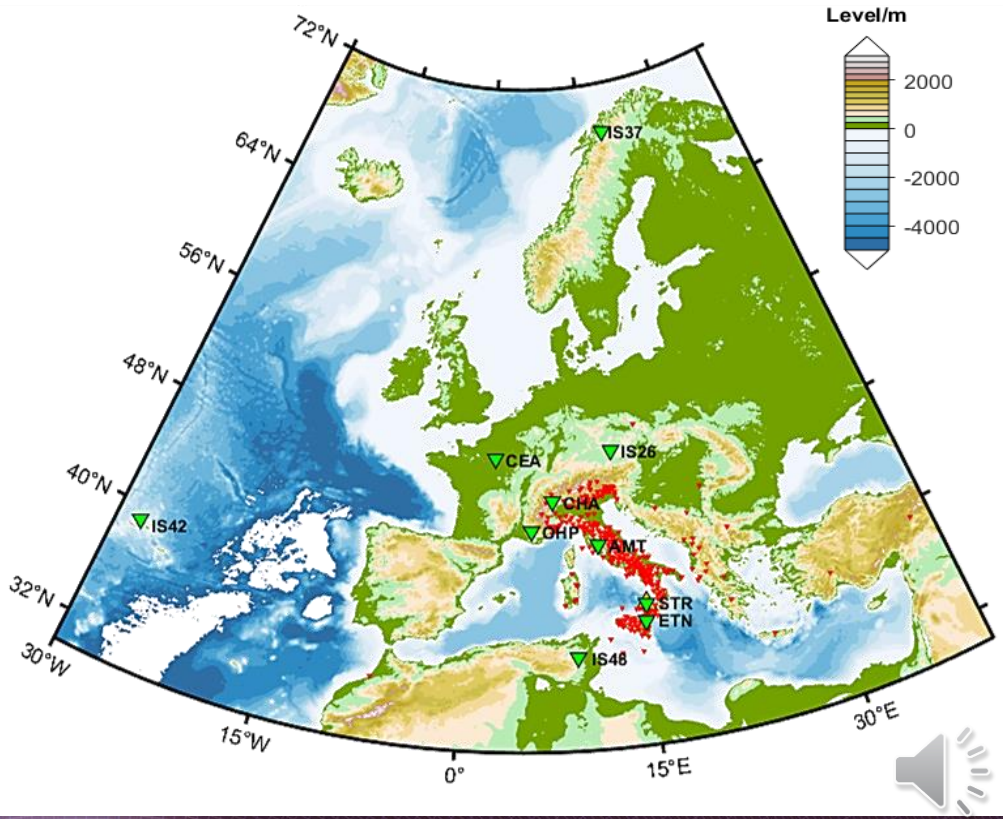
- On July 3rd and August 28th, two paroxysms with significant volcanic ash emission
- More infrasound station operating (4 IMS + national arrays, up to 3700 km) ▼
- Broadband seismic stations part of the Italian National Seismic Network (INGV) ●

Main objectives

- Added-value of dense seismo-acoustic network for source location and characterization
- Assess atmospheric / propagation models
- Potential benefit to improve operational monitoring methods / societal impact



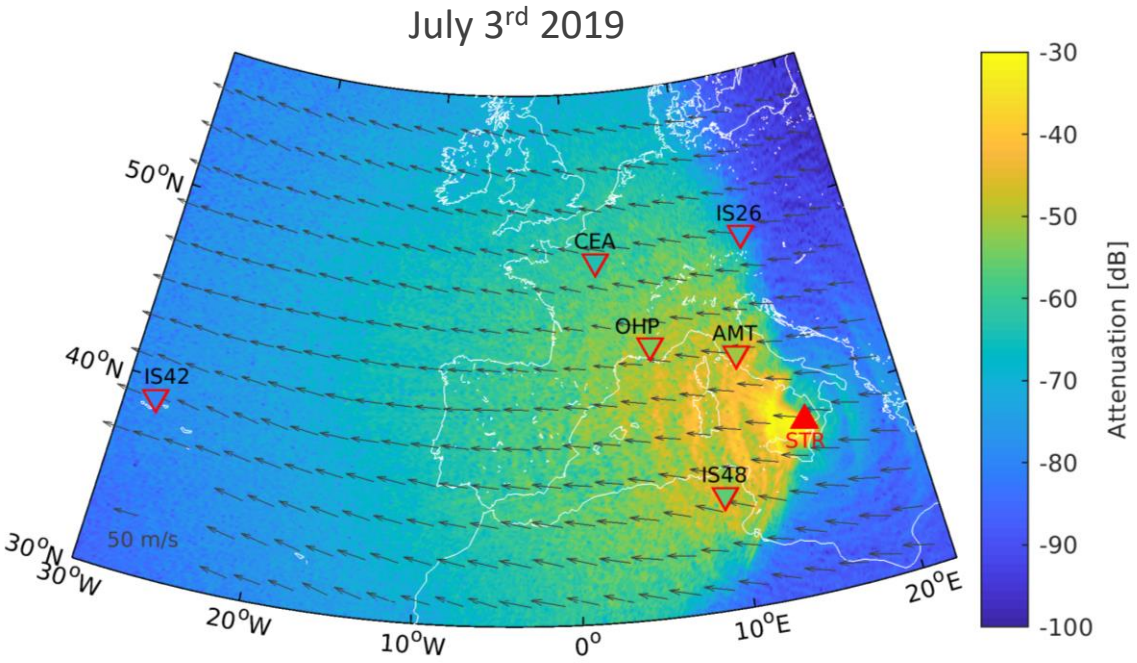
Volcanic Ash Advisories (VAAs)

STROMBOLI - 2019-07-03 17:00 utc

VA ADVISORY
DTG: 20190703/1700Z
VAAC: TOULOUSE
VOLCANO: STROMBOLI 211040
PSN: N3847 E01512
AREA: ITALY
SUMMIT ELEV: 924M
ADVISORY NR: 2019/01
INFO SOURCE: INGV WEBCAM, SAT IMAGERY
AVIATION COLOUR CODE: NIL
ERUPTION DETAILS: EXPLOSIVE ERUPTION OCCURED AT 1448Z
OBS VA DTG: 03/1700Z

- The explosive episode released an eruptive column that reached ~5 km height
- Alert sent to the Civil Protection
- For the July eruption (14:45:43), first VAA issued at 17 UTC
- Remote arrays would have been delivered ~45 minutes after the eruption

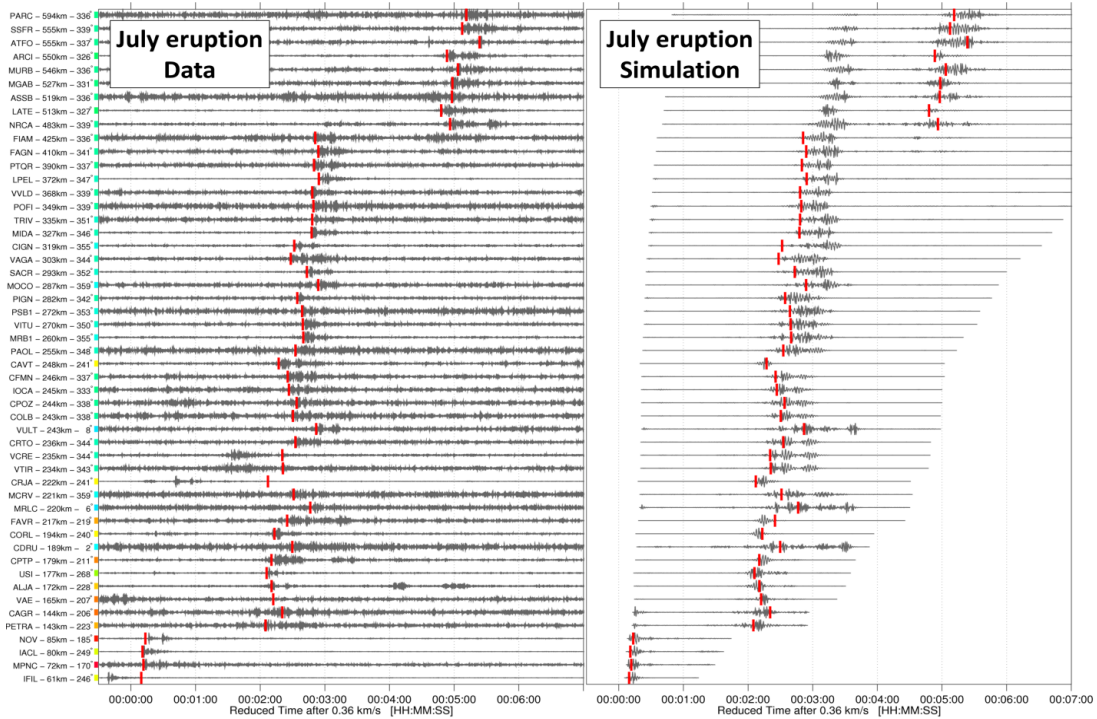
Long-range propagation modeling



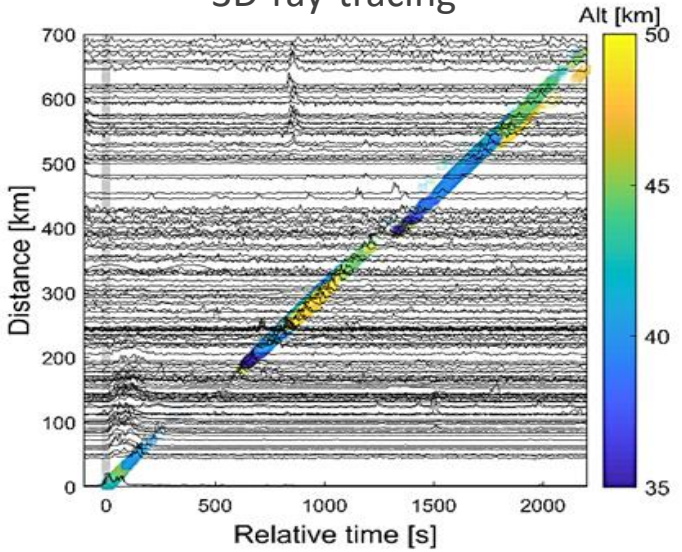
- 2D-PE simulations are run in a 360° circular pattern with a step of 0.1° to identify multi-directional ducting
- ECMWF HRES IFS cycle 38r2 + Gardner gravity wave model (1993) to account for unresolved atmospheric perturbations
- Favorable stratospheric ducting westward
- Least square fit between modeled and observed attenuation values
- The minimized quadratic difference occurs for a source amplitude of ~**1500 Pa**

Long-range propagation modeling

Normal mode

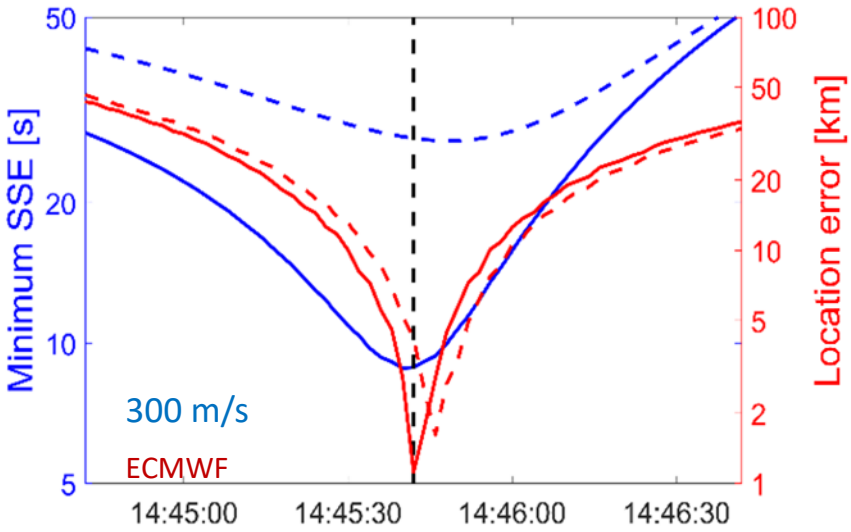


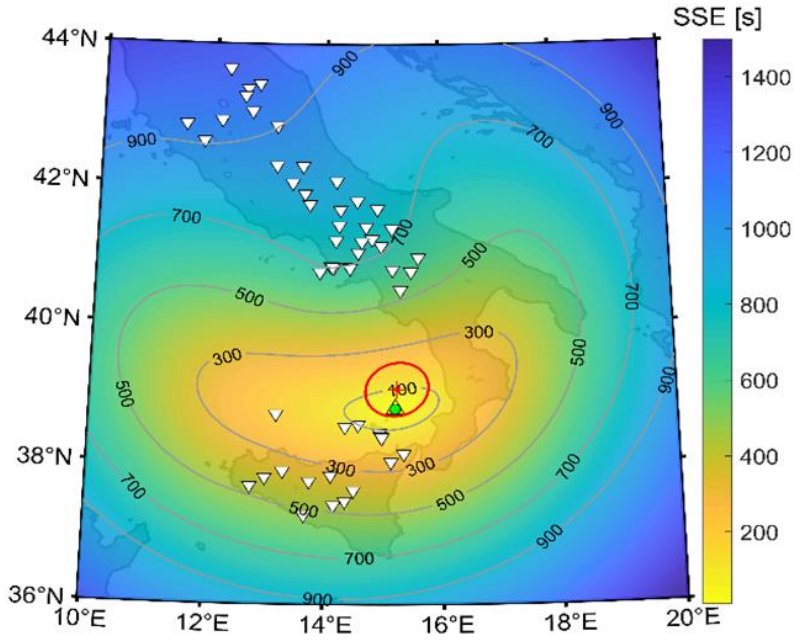
3D-ray-tracing



- Seismic waveforms recorded at INGV stations (0.5-2 Hz)
- Simulations accurately predict ground footprint of stratospheric arrivals (Δt<5 s)

Grid search source location

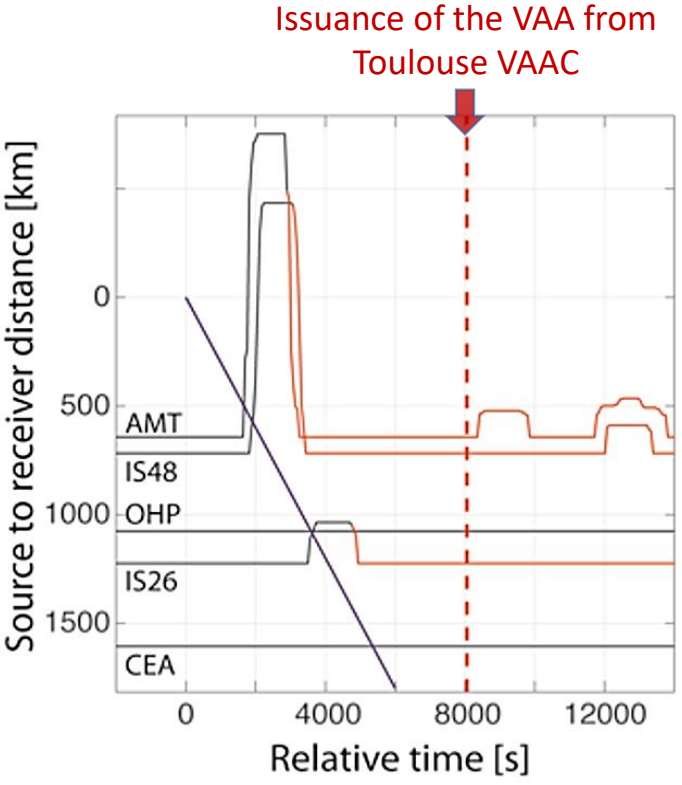




- Reverse Time Migration method (Walker et al, 2013)
- Sum squared errors (SSE) < 5 s
- Location errors: **~30 km using IMS stations / ~1.5 km with INGV network**

Ellipse error using 6 IMS stations (cross-bearing)

Volcano notification to VAAC



- Infrasound Parameter (IP) used to characterize the eruption persistency and magnitude.

  $IP = N_{det} \times A_m$ *(Marchetti et al, 2019)*

  N_{det} *: ratio of detections duration over time interval*

  A_m *: pressure amplitude @1 km of the source, inferred from far field observations;* discard strongly attenuated signals (>110 dB)

  (Le Pichon et al., 2012)

- For the July 3rd eruption , a notification based on infrasound observations at IS48 precedes the VAA by 105 minutes

Summary

Outcomes

- Integrating data from dense regional infrasound arrays and seismic network lower response time and improve location: location error is ~30 km using IMS station only and reduces to ~1 km using the Italian seismic network ($\Delta t<3$ s in origin time)
- Exploiting the synergy between complementary networks is useful to develop at a low-cost efficient monitoring systems for disaster prevention or mitigation
- VIS notifications often raised before VAAC alerts: collaboration on VIS is an asset for ARISE (research) and ICAO/WMO (civil application, safety) communities

Future work

- Best design of dense array to improve infrasound monitoring methods (location, characterization)
- Calculate the source magnitude from local/regional seismic measurements (air-to-ground coupling) to estimate the acoustic energy
- Evolve from prototype system to near real-time alert system: improve the reliability of the notifications, reduce false alarms rate