Seismo-acoustic characterization of the 2019 Stromboli volcano paroxysm events

A. Le Pichon, V. Souty, B. Hernandez, J. Vergoz, C. Listowski (CEA, DAM, DIF)
E. Marchetti (Università di Firenze, Italy)
E. Pilger, L. Ceranna (BGR, Germany)

Poster No. P1.1-133

Vienna Institute for CTBT Science and Technology
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)
**Development of a Volcanic Information System (VIS*)**

The synergy CTBTO / ARISE (Atmospheric dynamics Research InfraStructure in Europe, H2020 project funded by EU 2015-2018; [http://arise-project.eu](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 approach 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.*
Seismo-acoustic characterization of the Stromboli volcano paroxysm events

- 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)

- 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 \(~1500\ \text{Pa}\)

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO.
Long-range propagation modeling

- Seismic waveforms recorded at INGV stations (0.5-2 Hz)
- Simulations accurately predict ground footprint of stratospheric arrivals ($\Delta t < 5$ 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)
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.
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 (Δt<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