ARISE project: Infrasound monitoring for civil applications

Elisabeth Blanc (1), Alexis Le Pichon (1), Christoph Pilger (2), Patrick Hupe (2), Lars Ceranna (2), Emanuele Marchetti (3), Nicolas Brachet (1), Pierrick Mialle (4), Philippe Hereil (5), Sven, Peter Näsholm (6), Chritopher Lee (7), Graeme Marlton (7)
(elisabeth.blanc@cea.fr)

reference number: T1.1-P5

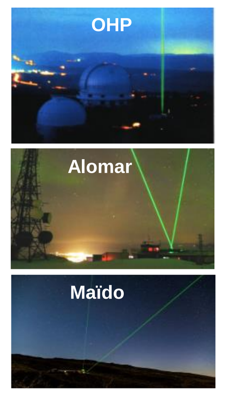
(1) CEA DAM DIF F-91297 Arpajon FR,
(2) Federal Institute for Geosciences and Natural Resources, Hannover, DE,
(3) Firenze University, IT,
(4) CTBTO,
(5) Météo - France
(6) NORSAR, NO,
(7) Reading University, UK.

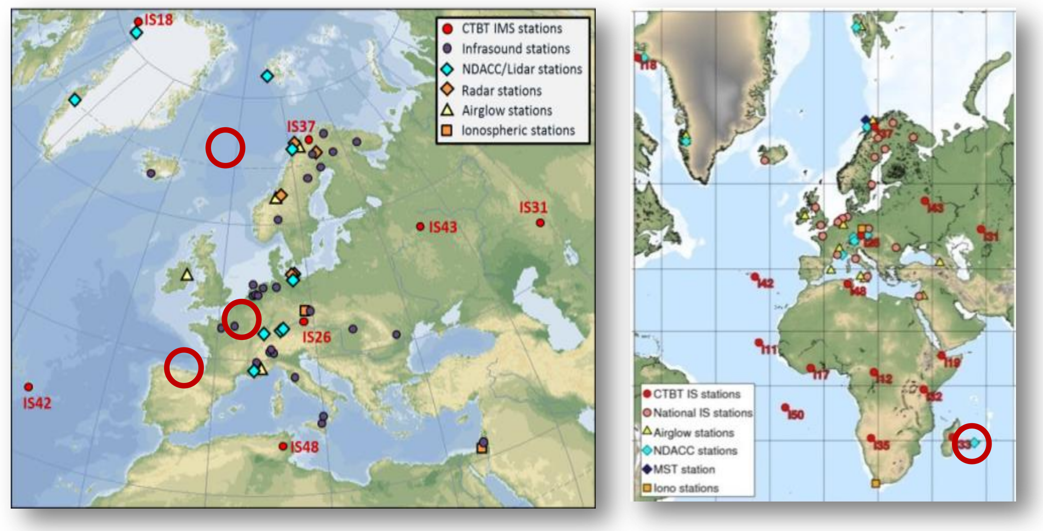
Abstract

The ARISE (Atmospheric dynamics InfraStructure in Europe) project combines the International infrasound Monitoring system developed for the verification of the Comprehensive nuclear-Test-Ban Treaty (CTBT) with lidar and radar networks and satellites for an improved description of the atmospheric dynamics. Civil applications are the following:

- Weather forecasting: It is demonstrated that a better knowledge of the stratosphere, for example at the onset of stratospheric warming events, improves forecasts at time scales of several weeks. Gravity waves observed in the lower part of the infrasound spectrum can also be parameterized for improved representation in models.
- Civil security: Infrasound remote monitoring is well adapted to automatically detect and notify volcano eruptions at global scale. The impact for civil aviation is large especially for unmonitored volcanoes. The Volcano Information System (VIS) is proposed in cooperation with CTBT organization and the Toulouse Volcano Ash Advisory Center (VAAC). A prototype is included in the ARISE data Center. Infrasound observations are also relevant for the monitoring of thunderstorms and meteors.
- Climate change: The long duration infrasound time series will be relevant to determine the evolution of disturbances with the climate change. This concerns tropical convection, lightning activity, cyclones and ice breaking in polar regions.

ARISE project (http://arise-project.eu)



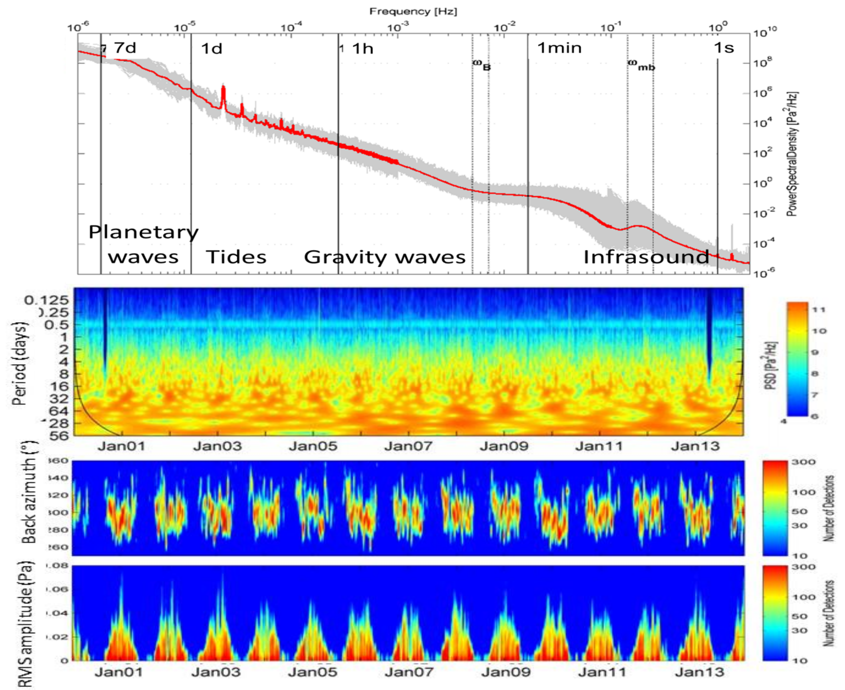


ARISE observation network

The ARISE project aims at establishing an atmospheric research and data platform in Europe. It combines a large set of complementary observations and modelling studies to better describe the dynamics of the middle and upper atmosphere.
The ARISE observation network includes:

- **The International infrasound Monitoring (IMS) System** dedicated to the verification of the Comprehensive nuclear-Test-Ban Treaty completed by the European infrasound network
- **The Network for the Detection of Atmospheric Composition Changes (NDACC dynamics) lidar network**
- **Meteor radars, wind radiometers, MST radars, ionospheric sounders and satel**lites.

Infrasound data: from transient events to planetary waves

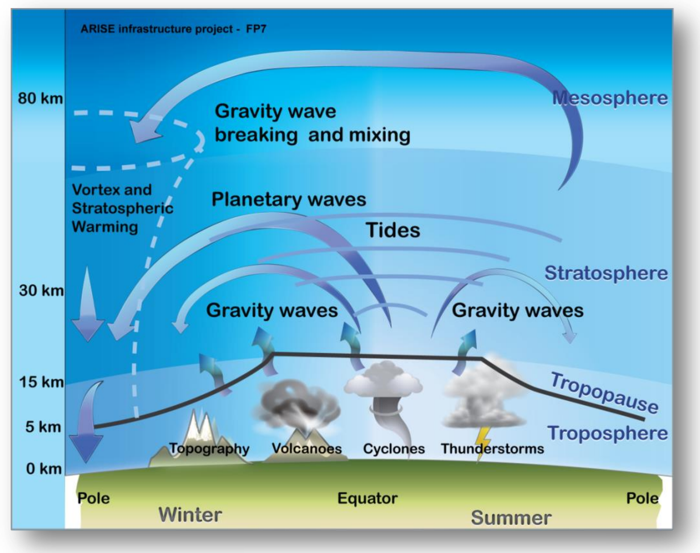


- *The IMS infrasound network frequency range is 0.01Hz - 10 Hz.*
- *Measurements are also possible at lower frequencies,*
- *The network presents a high potential for continuous observations of gravity wave and solar tides.at global scale*

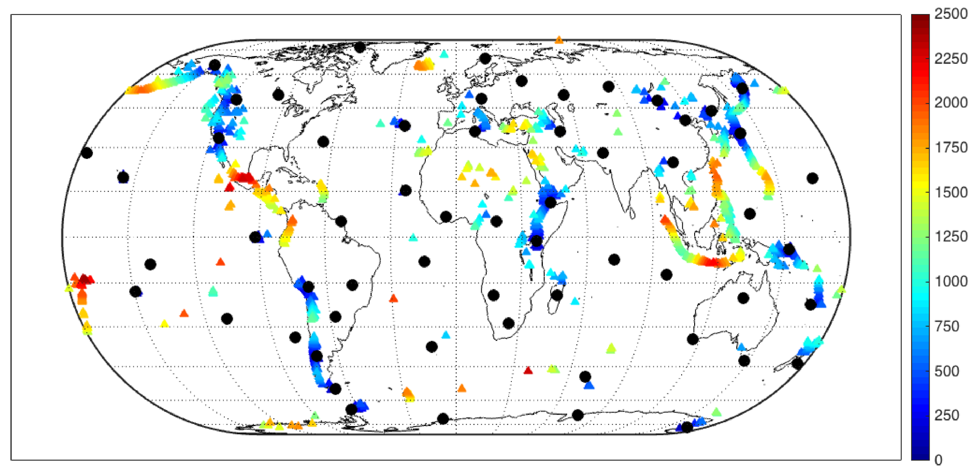
Civil security and atmospheric dynamics

The main ARISE objective is to provide new data sets

- **to better describe the middle atmospheric disturbances and wave systems**
- **to improve their representation in climate and medium range weather forecasting models**
- **for extreme event monitoring (volcanoes, thunderstorms,, cyclones …)**
- **to predict the evolution af wave systems and disturnances with climate change**



Civil security: Remote volcano monitoring



IMS infrasound station map and volcano active areas

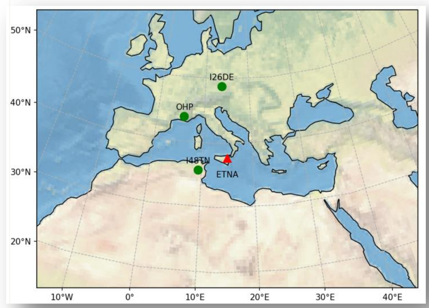
The IMS infrasound network: coverage is well adapted to remote volcano monitoring . Volcanoes are color-coded according to the distance from the closest certified IMS infrasound array.

Median distance from any volcano to the nearest IMS infrasound array is ~890 km

➔ mean travel time of ~50 min assuming an isotropic propagation with a celerity of 0.3 km/s

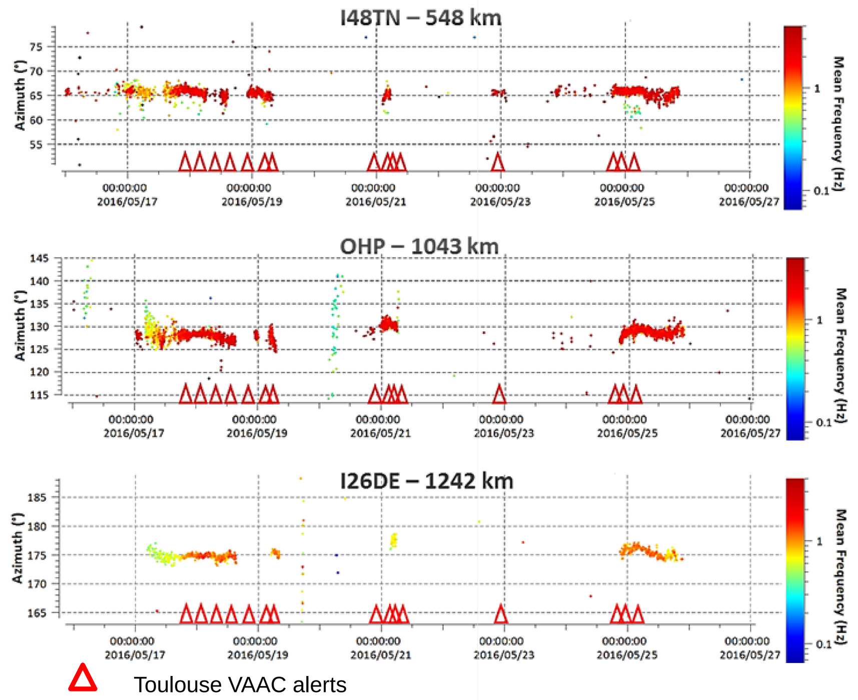
Ceranna et al., 2018

Comparison between infrasound detections from local and regional arrays and VAAC advisories

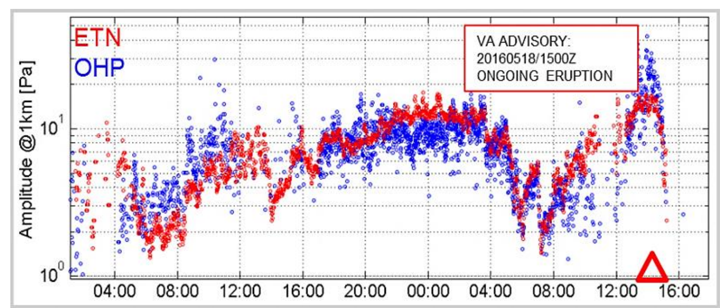


Example of infrasound data from Etna eruption, recorded at IS48 (Tunisia), OHP (France) and IS26 (Germany) arrays for the period between May 15 and May 27, 2016.

Le Pichon, Brachet, 2018, Mialle, Hereil (2018), Ceranna, (2018), Marchetti, (2018)



Eruption signature identified up to 1000 km from eruption

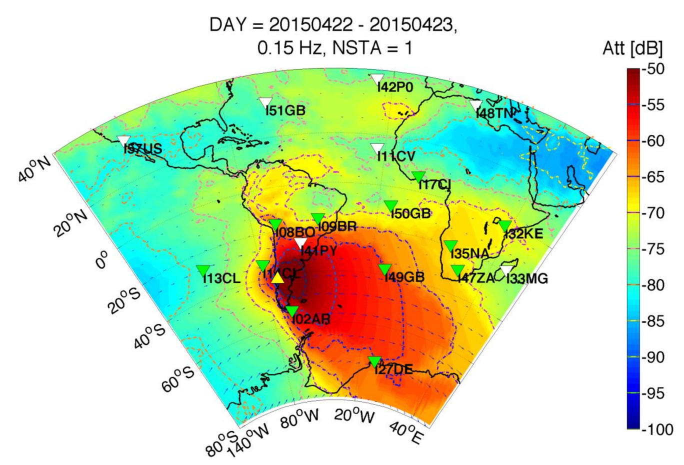


The eruption signature is similar at Etna and OHP stations, between May, 17th, 2016, 00:00 UTC and May 18th, 2016, 18:00 UTC which shows the possibility to retrieve source characteristics at large distances.

Comparison of infrasound amplitudes recorded at the local ETN array (red dots) with data recorded OHP array (blue, @ 1040 km) and corrected for propagation effects

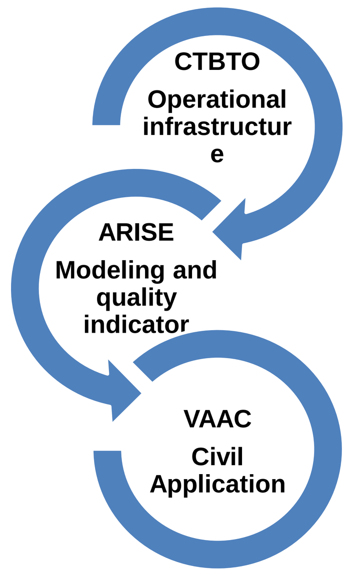
The VIS (Volcano Information System) is based on remote monitoring using the IMS CTBTO system. Infrasound notifications from remote infrasound arrays would be of great interest for the Volcano Ash Advisory Centers (VAACs) when volcanoes are not instrumented.
The VIEW (Volcano Infrasound Early-Warning) system uses infrasound stations near active volcanoes and provides useful calibration data.

CALBUCO VOLCANO, CHILE (22-23/04/2015)



Confidence criteria: detection capability map of the IMS stations depending on the atmospheric condition

The eruptions can be automatically detected. ARISE advanced products provide notifications and confidence criteria in support of the civil aviation (VAACs) in relation with the CTBTO (operational monitoring)



Le Pichon, Arnal, Brachet, Hereil, Mialle (2016, 2018) Marchetti (2018)

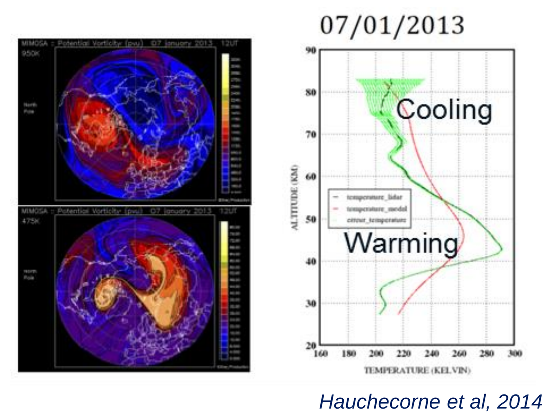
New recommandations of the International Airways Volcano Watch (IAVW) set up by the International Civil Aviation Organization (ICAO) to develop monitoring systems

Action Agreed 8/10: Use of Infrasound Data in Support of IAVW

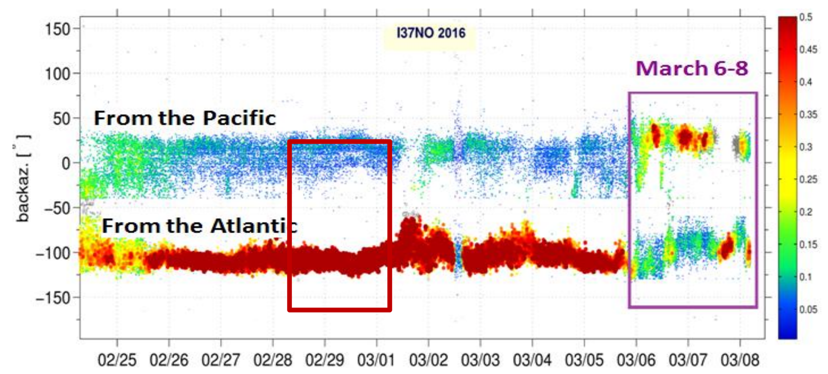
Numerical Weather Predictions

Sudden Stratospheric Warming events(SSW): large disturbances which affects weather forecasting during several weeks, characterized by:

- polar vortex breaking,
- stratospheric warming, mesospheric cooling,
- inversion of the zonal stratospheric wind and of the infrasound propagation direction

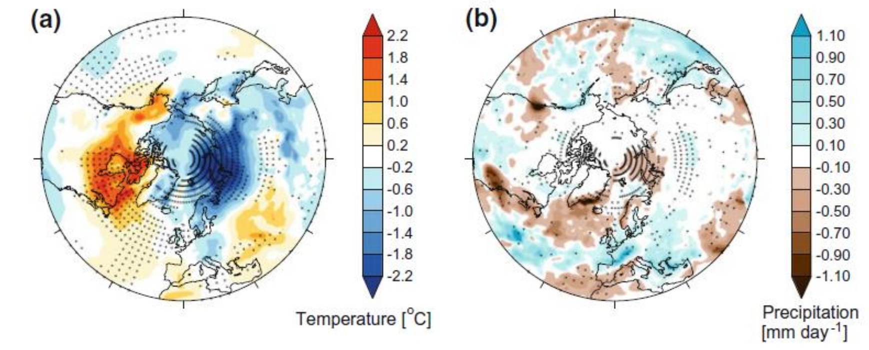


Comparison between lidar observations and models during the 2013 SSW



Processed NORSAR infrasound data recorded at the IS37 station during the SSW event in March 2016. (Näsholm et al., 2017)

New data sets for Numerical Weather Predictions



Major SSW events can be followed by cold weather that can affect Europe for several weeks

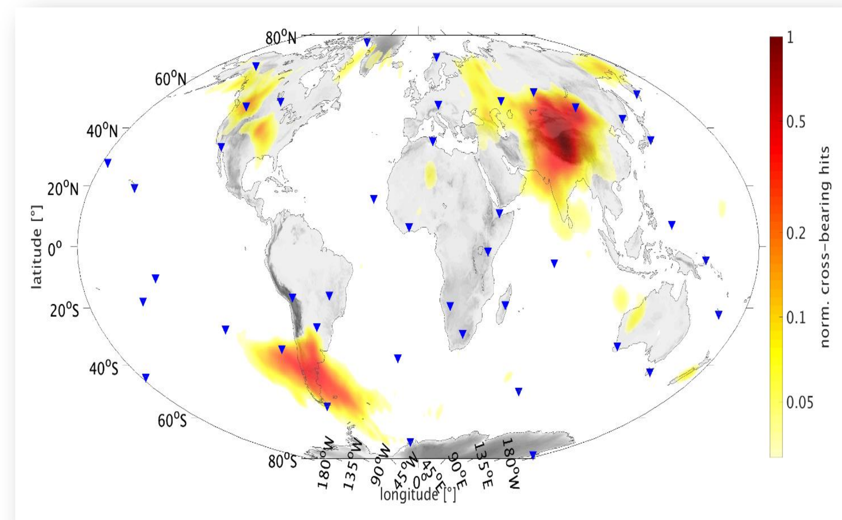
Lee et al., 2019

Average anomalies of surface temperature (a) and precipitation (b) over 15-30 days after the onset for 15 SSW

Mountain Acoustic waves as observed by the IMS network

- ❑ New atmospheric imaging using the infrasound system
- ❑ Mountain gravity waves disturb the general atmospheric circulation in all atmospheric layers
- ❑ The identification of the wave origin is more difficult with other technologies

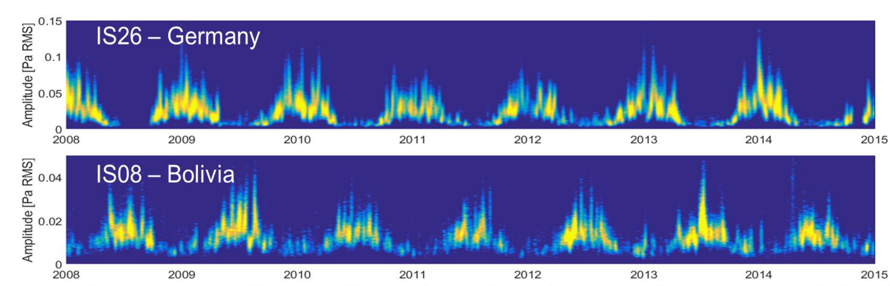
Hupe, PhD manuscript, 2019



Example of global stacked view of mountain waves observed by the infrasound technology, using a cross bearing approach.

Uncertainties at larger scales related to planetary wave activity

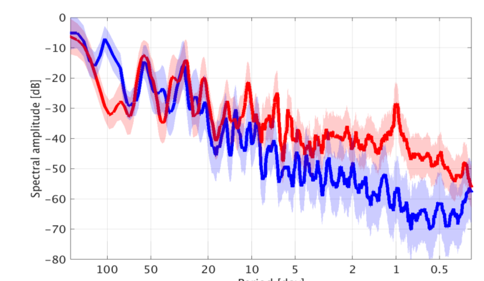
Planetary wave signature in infrasound data



Fluctuations of microbarom amplitudes, observed by the IMS network represent planetary wave activity in winter. Such data could help to represent this activity in models

Le Pichon et al., 2009

Comparison of Power Spectral Density Lidar observations and models



The Coral lidar in Argentina during one year showed that planetary wave activity is larger than predicted by ECMWH at periods smaller than several days

Perspectives

- Infrasound monitoring of extreme events (volcanes, meteors ,weather related events)
- Identification of the uncertainty origin in the numerical weather prediction models at sub seasonal scales
- New data products for future data assimilations in weather and climate models and infrasound monitoring simulations
- Monitoring of middle atmosphere disturbances and relation with climate change

References

- *ARISE review paper: Blanc et al., Toward an improved representation of the middle atmospheric dynamics thanks to the ARISE project, Surv. Geophy. 2018, http://link.springer.com/article/10.1007/s10712-017-9444-0 (open access)*
- *Springer © 2018: Infrasound Monitoring for Atmospheric Studies Challenges in middle-atmosphere dynamics and societal benefits Editors: Le Pichon A., Blanc, E., Hauchecorne, A.*