O5.1-448

The Volcanic Information System (VIS)

Long-Range Infrasound Monitoring of Volcanic Eruptions

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Sep 9, 2025 — SnT2025 — Vienna, Austria — **Presents: R. De Negri** (`rodrigo.denegri@uca.fr`)

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Outline

Volcanoes and infrasound

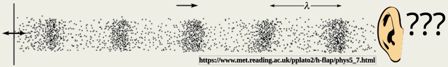
The Volcanic Information System

Challenges

Past/Current/Future work

Volcanoes and infrasound

Infrasound: acoustic waves below hearing frequency threshold ($<$ 20 Hz)



Volcanoes and infrasound

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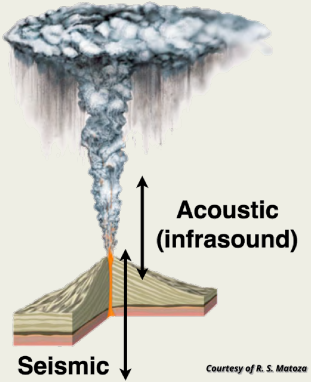
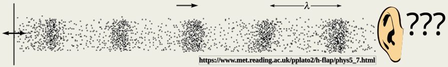
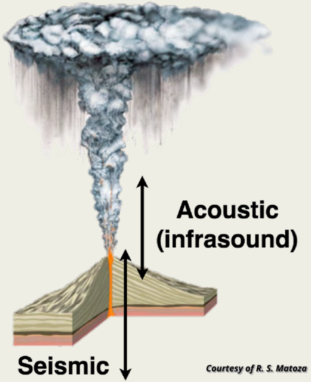
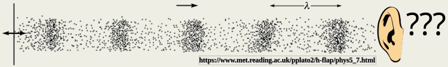




Volcanoes and infrasound

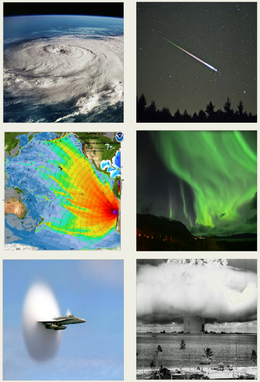


Infrasound: acoustic waves below hearing frequency threshold (< 20 Hz)



Other sources:

- Natural: microbaroms, ocean surf, mountains, meteorites, auroras, earthquakes, big waterfalls, etc.
- Anthropogenic: wind turbines, dams, airplanes, chemical explosions, etc.



From 1883 Krakatau to 2022 Hunga

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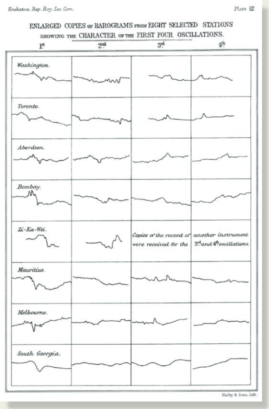
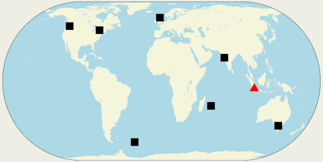
Krakatau erupting on May 27, 1883





Very low frequency acoustic waves detected in barographs multiple times worldwide

Figures from [Symons, 1888]

From 1883 Krakatau to 2022 Hunga

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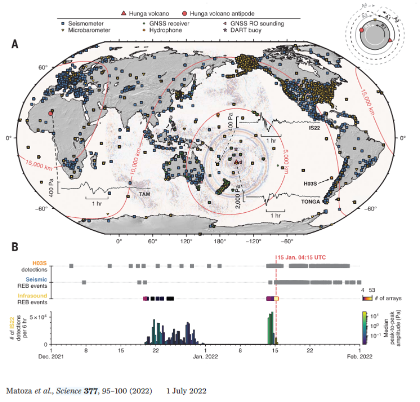

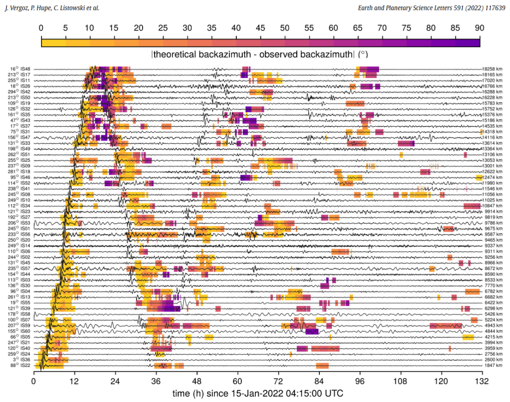

Seismic, hydroacustic, satellite and infrasound characterization of January 2022 Hunga eruption, Tonga

Figure from [Matoza et al., 2022].

Infrasound waves circunavigating the Earth (up to 16 passes)

Figure from [Vergoz et al., 2022].

The International Monitoring System (IMS)

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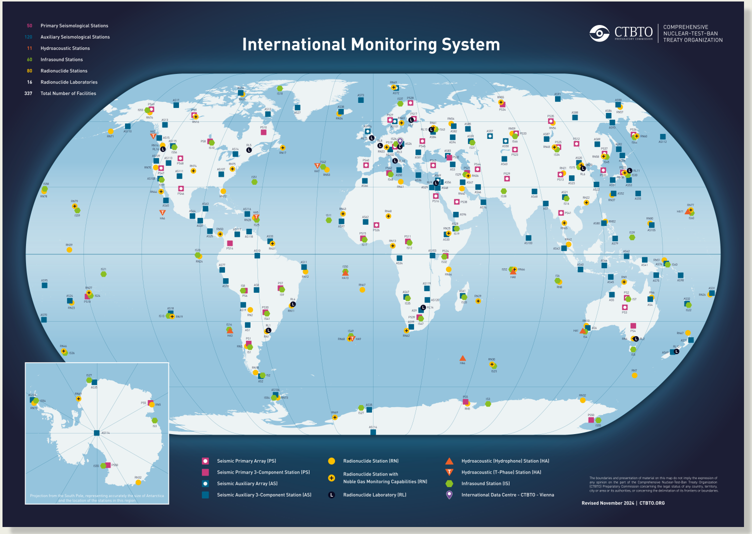
The Comprehensive Nucear Test-ban-Treaty Organization (CTBTO).

Seimic, hydroacustic, radionuclide, and infrasound.

(map from www.ctbto.org/map)



The IMS infrasound network

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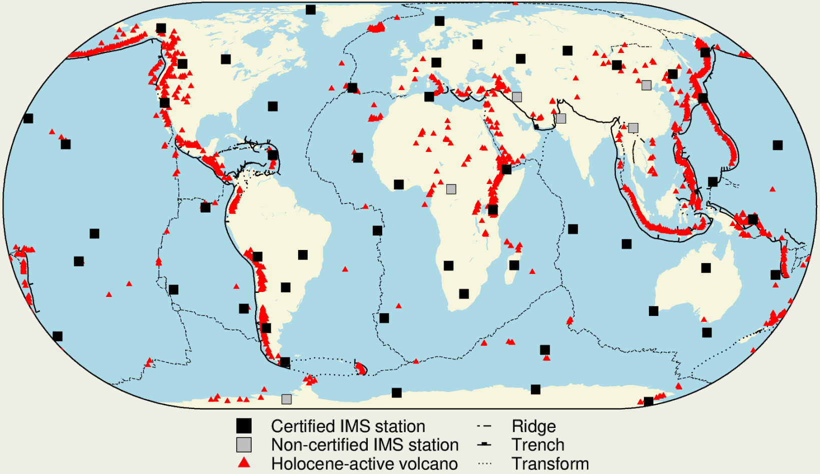


Infrasound-based monitoring methodology (and tool) for remote detection of volcanic eruptions.

Infrasound-based monitoring methodology (and tool) for remote detection of volcanic eruptions.

Why?

- Eruptions with a Volcanic Explosivity Index (VEI) $\geq$3 create large ash plumes [Newhall and Self, 1982].
- This is expected to happen yearly [Papale and Marzocchi, 2019], but only a fraction are monitored in real-time [Webley and Mastin, 2009, Pallister and McNutt, 2015, Ripepe et al., 2018].
- The ash plume poses a great risk to commercial planes [Webley and Mastin, 2009].
- There is a global infrasound network!

How does the VIS work?

Detections
Stations at less than 2740 km of stations

Volcano azimuth filter
$\phi_i \in [\phi_0 - \triangle\phi,\ \phi_0 + \triangle\phi]$
keep signals within $\pm \triangle\phi$ (3°)
of the real source back-azimuth (ϕ_0)

Propagation effects correction
$A_P(f, V_{\text{eff-ratio}}) \longrightarrow p_s = p_a / A_P$
Attenuation (*Le Pichon et al., 2012*) — pressure at 1 km from source

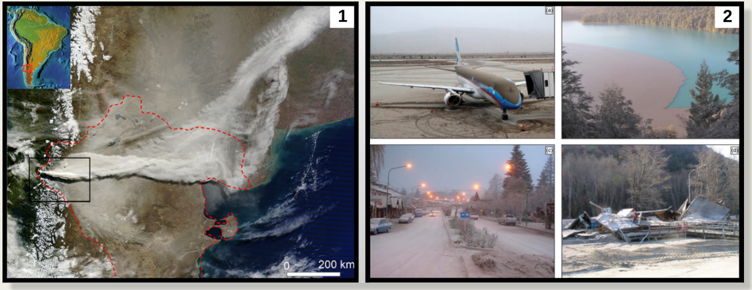
Pressure filter
$p_s < 500$ Pa
keep signals smaller than 500 Pa
at 1 km from source

Persistency filter
$\frac{t_{\text{det}}}{W} > 0.33$
keep signals with more than 33%
of persistency in time window W

Infrasound parameter filter
$\text{IP} = \frac{t_{\text{det}}}{W} \times 100 \times \frac{p_a}{A_P}$
keep signals with an IP value above 100
(*Marchetti et al.,2019*)

VIS notification
Start time (adjusted), Code,
Mean Amplitude at 1 km (Pa),
Level, ...

Example: June 2011 Cordón Caulle eruption, Chile

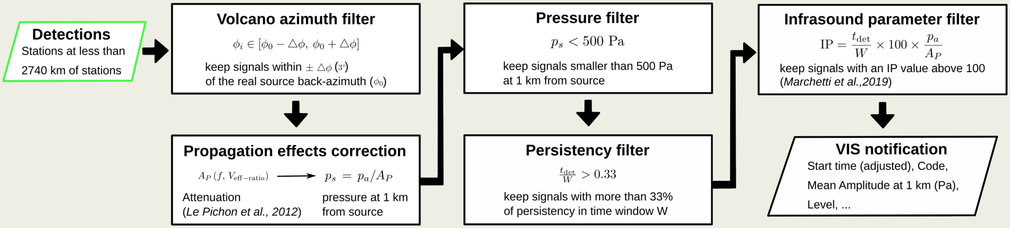


(1) NASA image on 13 of June 2011. (2) Ash fall effects on Villa la Angostura, Bariloche, and Paso Samoré (Argentina).

Figures modified from [Elissondo et al., 2016]

- Explosive phase starts on June 4, 18:45 UTC
- VEI 4
- Sustained plume 10-12 km height several days
- Ash plume affected large areas

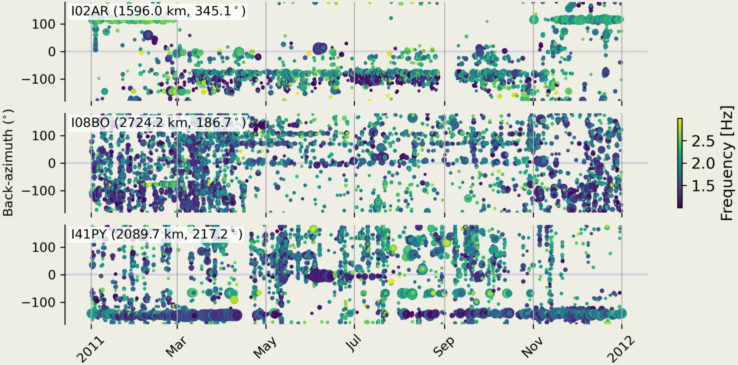
Step 1 - Detections



Modified from Poster presented at AGU 2024

Step 1 - Detections

- Open access (OA) data from [Hupe et al., 2022].
- “High-frequency” (1–3 Hz), sampled every 5 minutes.



Problem: too many detections, i.e., *clutter*.

To get the data, go to `https://geoportal.bgr.de` and download from “Geophysics”→“High frequency data products”

Step 2 - Back-azimuth filter

Detections
Stations at less than 2740 km of stations

→

Volcano azimuth filter

$\phi_i \in [\phi_0 - \Delta\phi,\ \phi_0 + \Delta\phi]$

keep signals within $\pm\,\Delta\phi$ ($3°$)
of the real source back-azimuth (ϕ_0)

↓

Propagation effects correction

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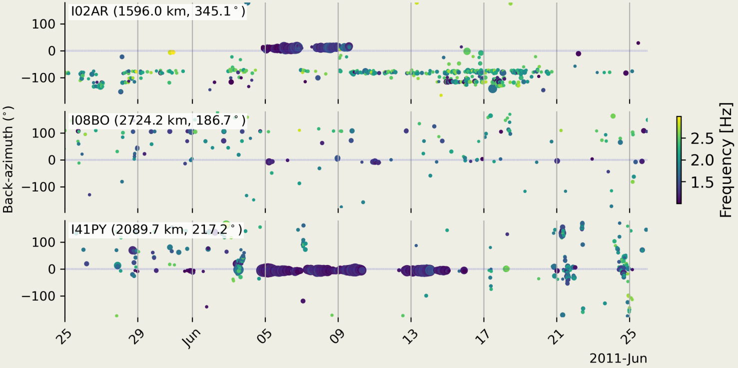
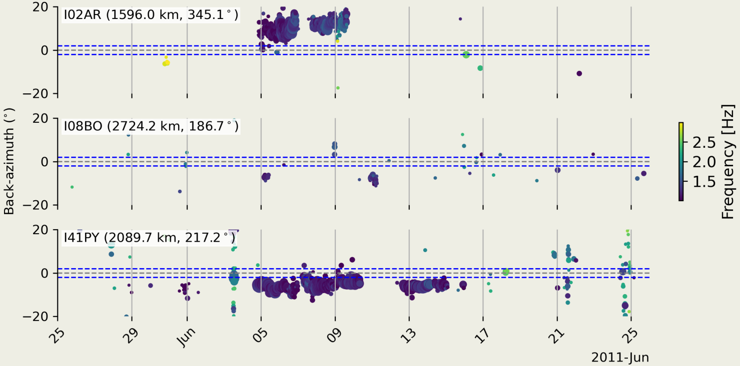
Step 2 - Back-azimuth filter



Zoom into 25 May to 25 June 2011

Step 2 - Back-azimuth filter



Zoom into detections within $\pm 20^\circ$ of true back-azimuth

Problem: Most detections don't fall within $\pm 3^\circ$ of true back-azimuth...

Step 2 - Back-azimuth filter

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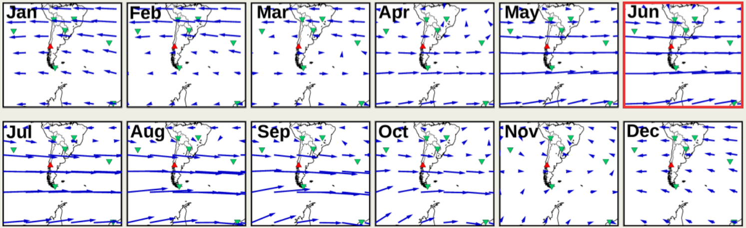
Average winds per month around ∼40 km altitude.

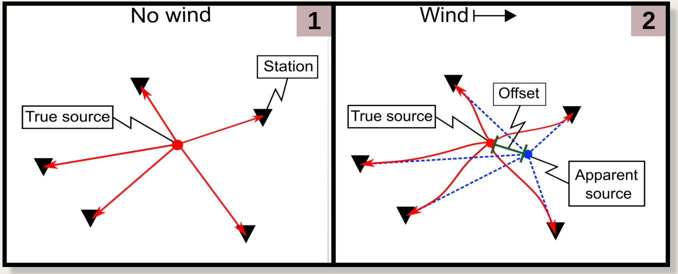


Wind direction, 50 m/s

We forgot about the winds!

There are strong seasonal winds at stratospheric (∼40 km) altitudes, i.e., zonal winds.

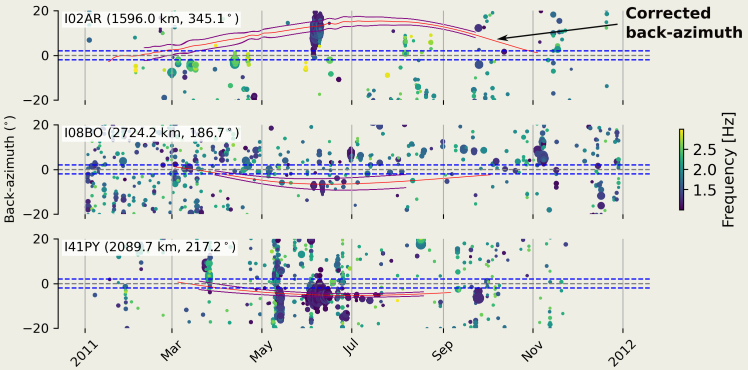
Step 2 - Back-azimuth filter



The winds deviate the trayectory of the infrasound waves.

Figure modified from [De Negri and Matoza, 2023]

Step 2 - Back-azimuth filter



Considering *corrected* back-azimuth deviations

[De Negri and Matoza, 2023,

De Negri et al., 2025].

Problem: other sources (local) can still be present at the corrected back-azimuths.

Step 3 & 4 - Propagation effects and pressure filter

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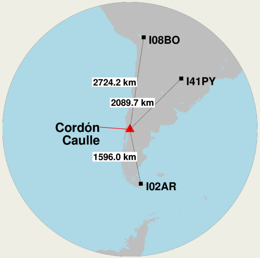
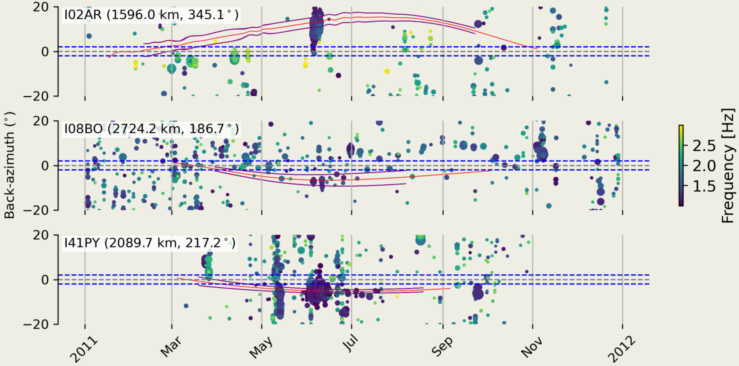


Whole year (2011)



Use only detections with "corrected" amplitude <500 Pa

[Le Pichon et al., 2012,

Marchetti et al., 2019].

Step 3 & 4 - Propagation effects and pressure filter

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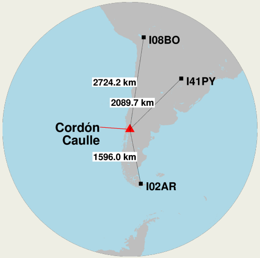
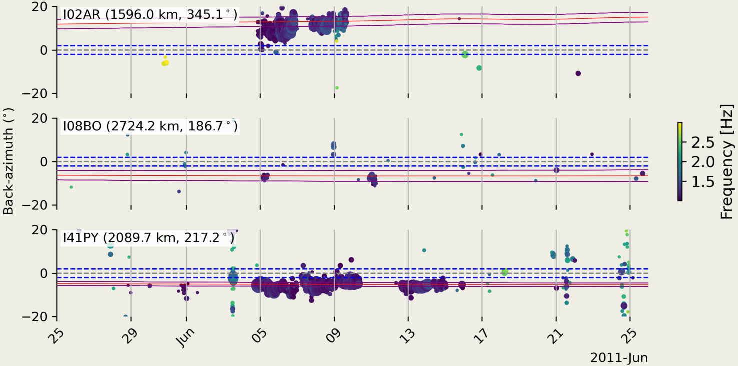


From 25 April to 25 June



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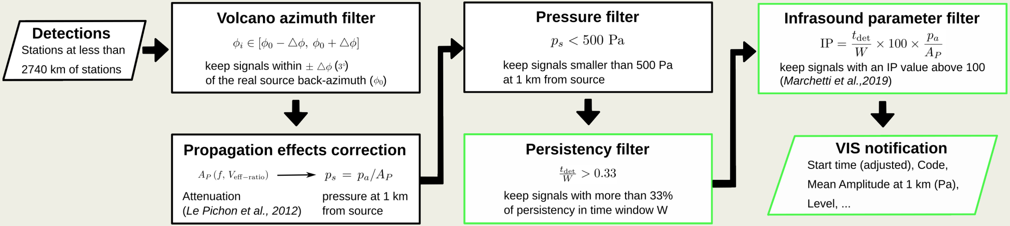
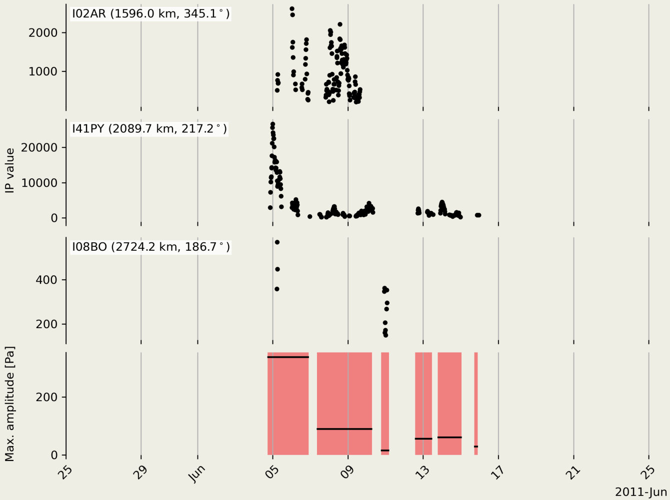
[Le Pichon et al., 2012,

Marchetti et al., 2019].

Step 5 to 7 - Persistency, IP, and VIS results



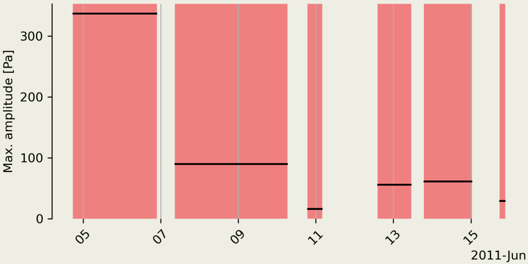
Step 5 to 7 - Persistency, IP, and VIS eruptions



- Filter by persistency (33%) and calculate IP.
- If IP>threshold (100), create a notification.

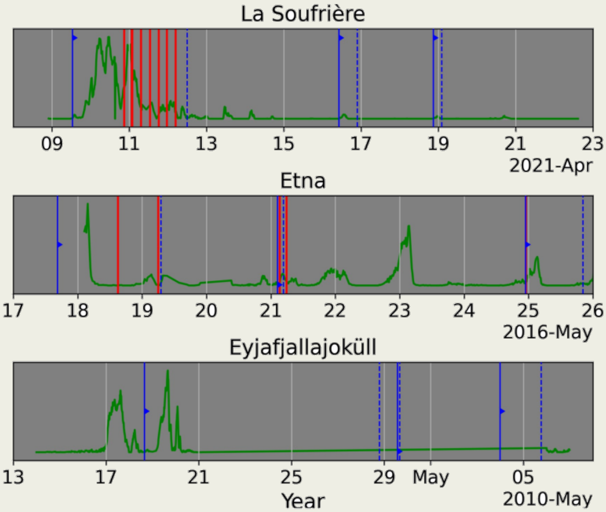
June 2011 Cordón Caulle VIS results

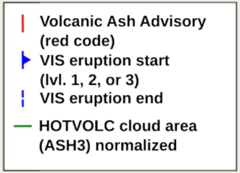
#	Time (UTC)	Duration	A. [Pa]
1	Jun 04 18:03	2d 3h15m	337
2	Jun 07 09:13	2d 20h50m	90
3	Jun 10 19:08	8h30m	16
4	Jun 12 14:38	20h05m	56
5	Jun 13 19:18	1d 4h50m	61
6	Jun 15 18:03	2h50m	29



Problem: time delays are about 1h per 1000 km...

Comparing VIS results with other methodologies



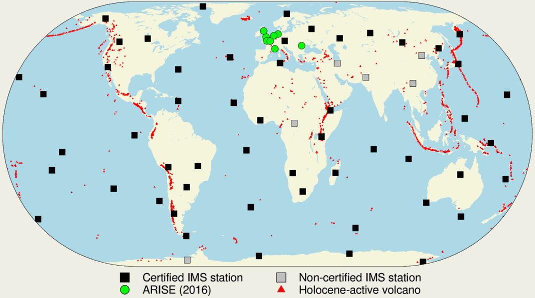


Challenges

1. Atmospheric variability (winds, temperatures, chaotic events, etc.) ✓
2. Clutter infrasound (non-volcanic sources) ✓
3. Data availability
4. Volcanic complexity & methodological shortcomings

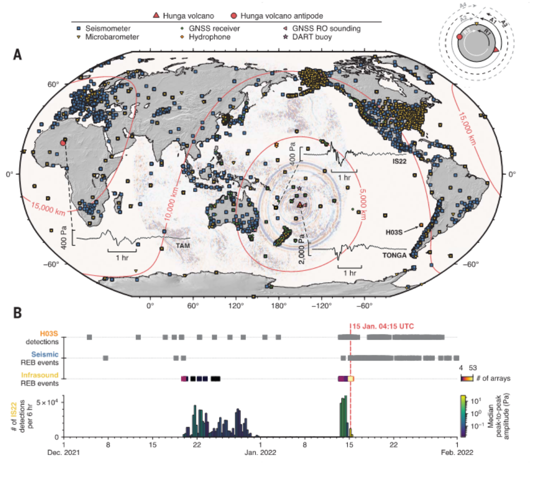
Challenges - Data availability

- IMS infrasound network
  - near-real-time data available for research with delay of three months
  - derived Open Access data from BGR could be used instead [Hupe et al., 2022]
- Local arrays
  - near-real-time data could be available (e.g., AMIATA, Firenze, Italy)
  - ARISE-like stable network of arrays?



Challenges - Shortcomings

- Infrasound: surface (syn-eruptive)
- Prior/Syn/Post eruptive characterization: multi-technology



Matoza *et al.*, *Science* **377**, 95–100 (2022) 1 July 2022

Past/Current/Future work

- 28–29 August 2025 — VIS Workshop at Deparment of Earth Sciences, University of Firenze, Firenze, Italy (`https://www.geo-inquire.eu/dissemination/workshops/volcanic-information-system`).
- Open source project: will be released soon (check `github.com/rodrum` for “openVIS”)
- Near-real time tests, plume height, reliability & web interface [Perttu et al., 2020, Gheri et al., 2023, Gheri et al., 2025]

Interested?

Contact me at `rodrigo.denegri@uca.fr`!

Check `github.com/rodrum`!

Thanks :)!

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