# IMS infrasound data products for atmospheric studies and civilian applications – 2021 and 2022 updates

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# Abstract

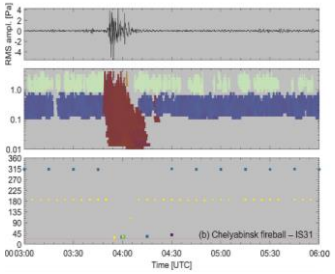
We present recent and planned updates of the infrasound data products of all certified infrasound stations of the International Monitoring System, which was established in the late 1990s for verification of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The updates extend the four data products initially published for the 2003 to 2020 period (https://doi.org/10.5194/essd-14-4201-2022, please scan QR code) by two years and thus complete a 20-year period.

Our intention for these data products is to facilitate using this unique global infrasound dataset for scientific applications. The products open up the IMS observations to user groups who do not have access to IMS data or are unfamiliar with data processing using the Progressive Multi-Channel Correlation (PMCC) method. We demonstrate the updated data products based on recent and global infrasound sources such as volcanic eruptions and ocean ambient noise and highlight the provided detection and quality parameters

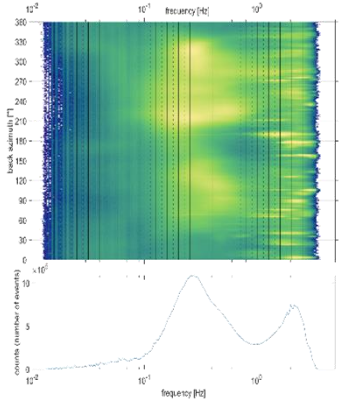
# Overview: Open-access infrasound data products

## Data & Processing

- Data base
- Station availability
- **Processing method & configuration**



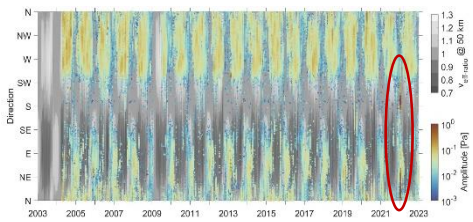

## Detections & Products




- Global infrasound detection patterns
- Definition of the four data products
- **How to download the products?**
- Product parameters

## Examples & Applications

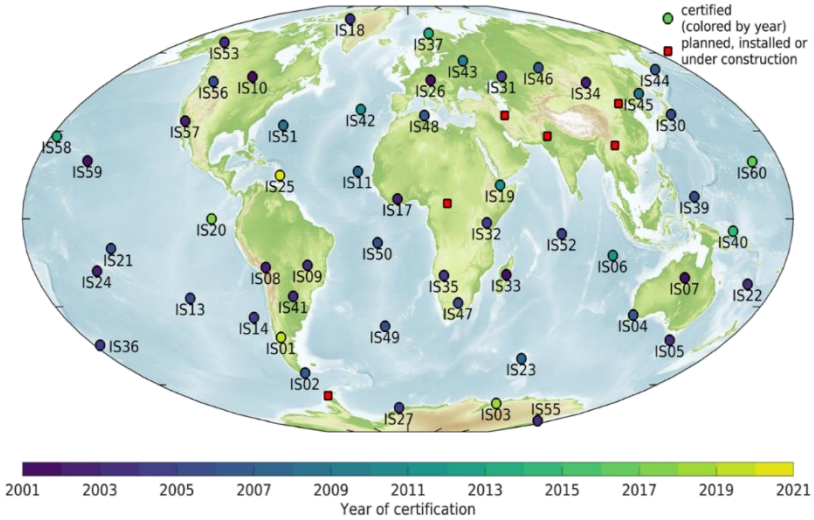
- **Examples of natural infrasound events** (volcanic eruptions, fireballs)
- Comparison between PMCC detections and product parameters
- Station example of the back-azimuth variation of the products within one year
- Multi-year multi-station variability of a microbarom product




## Conclusions & Outlook

- Summary of recent publications using the detections and products
- **Summary of the 2021 update**
- **Outlook on the 2022 update**

# Motivation: Open-access infrasound data products




**Global network of infrasound arrays** as part of the International Monitoring System (IMS) for the Comprehensive Nuclear-Test-Ban Treaty

**Surplus of IMS data for atmospheric studies and natural hazards applications has been demonstrated** (e.g., Blanc et al., 2018; Le Pichon et al., 2019), e.g. for

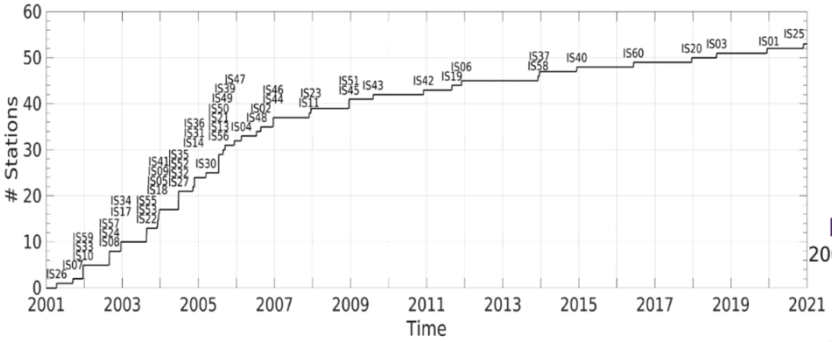
- probing the winds in the middle atmosphere (e.g., Le Pichon et al., 2015; Amezcua et al., 2020) or
- early warnings on volcanic eruptions (e.g., Marchetti et al., 2019)

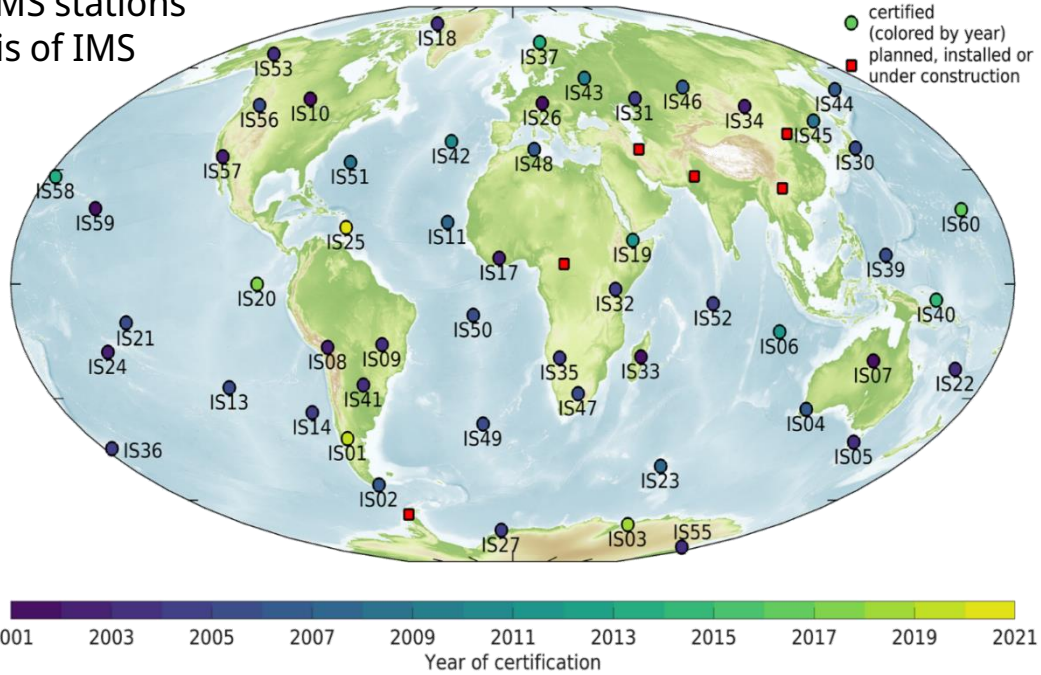
*But*: access to IMS infrasound waveform data is restricted (e.g., vDEC contract)

Idea: tailored **open-access data products** of broadband detection lists (“product of a product”) – neither providing raw data nor the comprehensive detection lists, thus not replacing the privileges of a vDEC access or IDC-registered users (e.g., Reviewed Event Bulletin)

# IMS infrasound data

- More than 20 years of infrasound data from IMS stations
- First systematic broadband (0.01-5 Hz) analysis of IMS infrasound data by Matoza et al. (2013)
- The full and increasing IMS infrasound data set is regularly reprocessed at the German NDC (Ceranna et al., 2019)
- DTK-PMCC software (Cansi, 1995) developed by CEA is used for the data processing

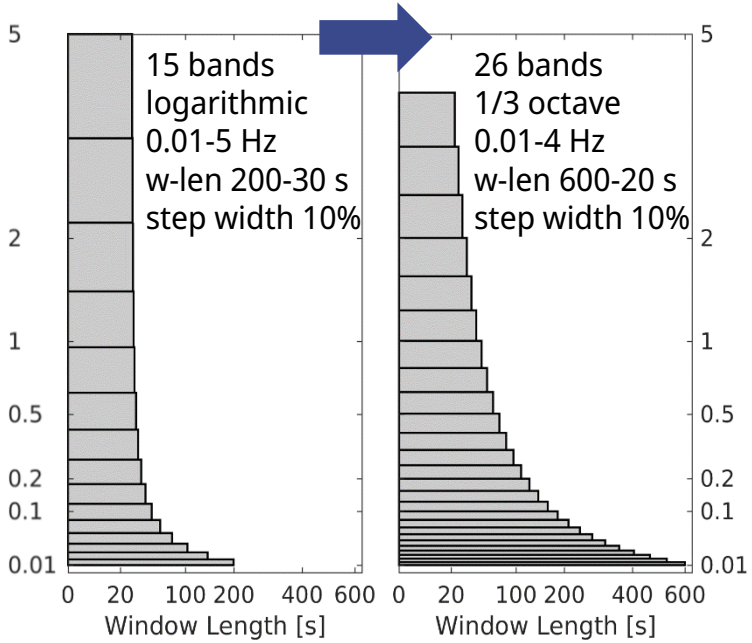


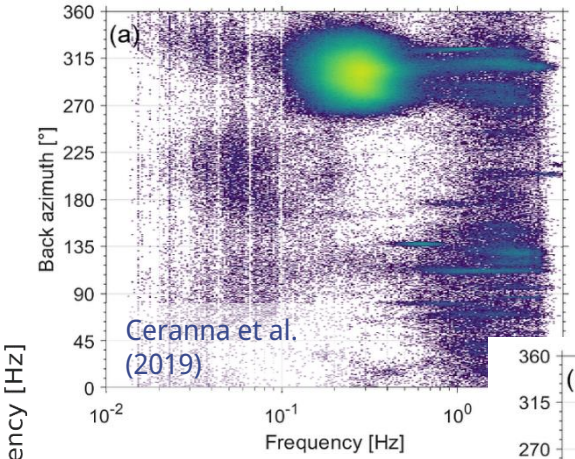



# New configuration for PMCC processing

Matoza et al. (2013)
Ceranna et al. (2019)

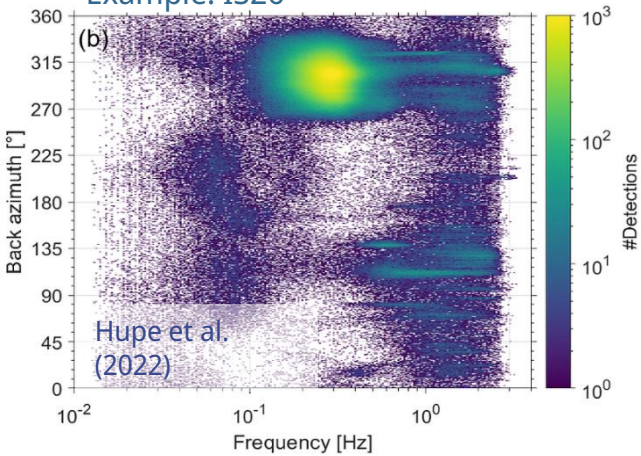
Hupe et al. (2022)




- more detections
- new sources resolved
- better discrimination between interfering signals

Example: IS26

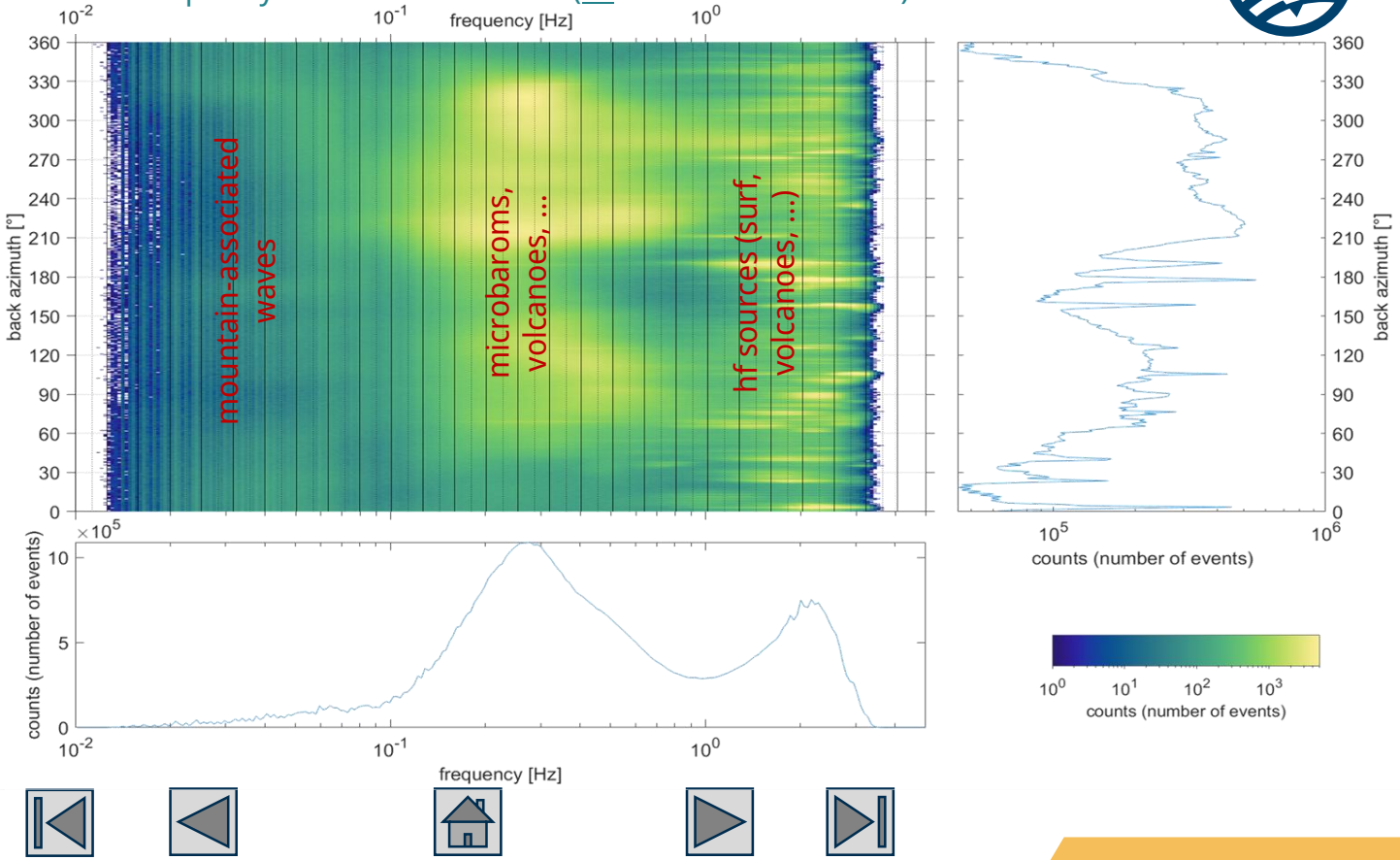



- more accurate estimates of signal parameters
- artefacts reduced

# Detections

- Low frequencies <0.1 Hz: rare but far-field sources
- Frequencies around 0.25 Hz: global detection patterns of the dominant microbaroms
- High frequencies >0.6 Hz: local (near-field) sources
- Data products shall reflect the different groups of sources

Frequency-azimuth distribution (all 53 certified stations!)

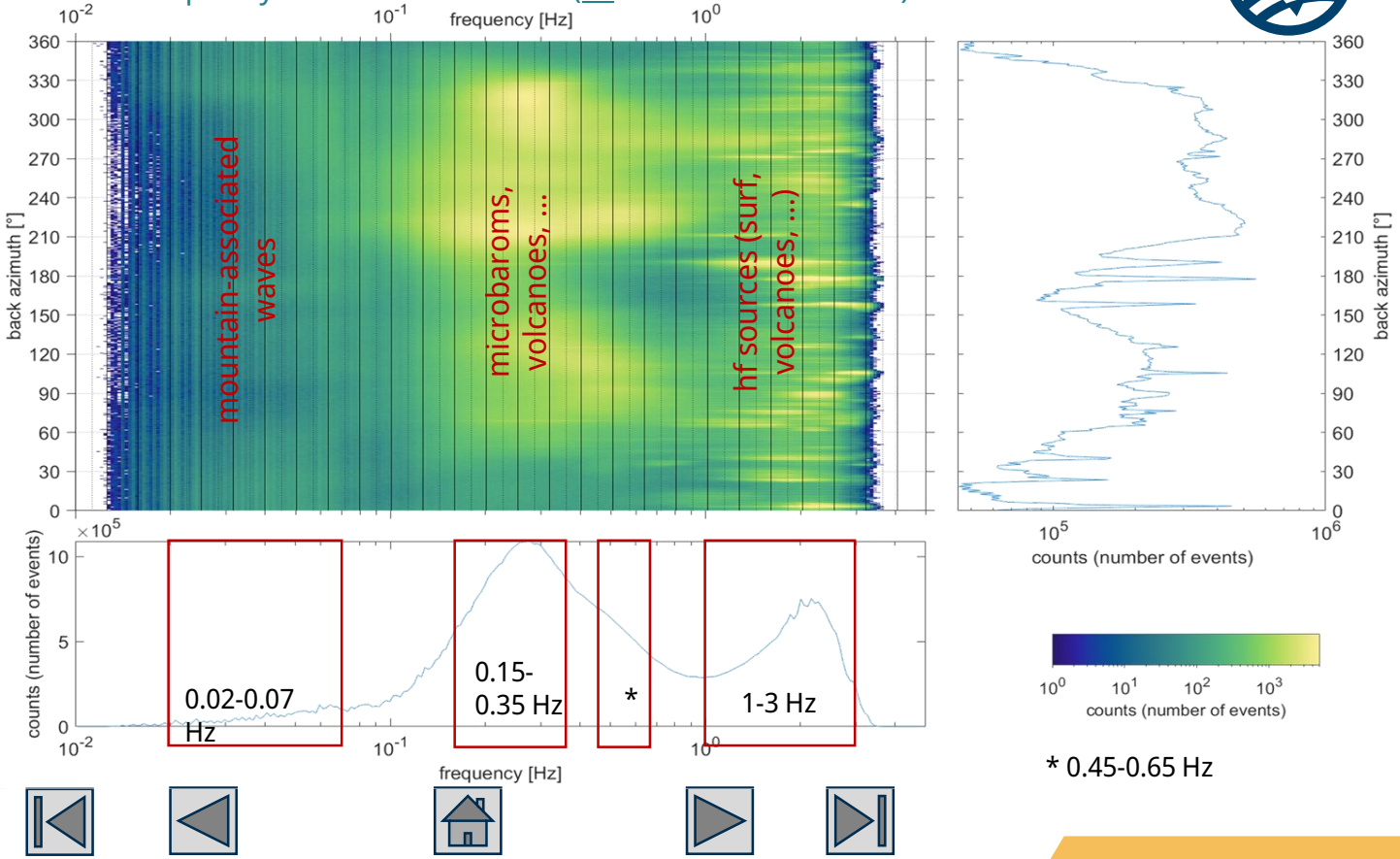


# Data products

- Low-frequency product
- “Microbarom” products, both
  - lower and
  - higher frequency range
- High-frequency product

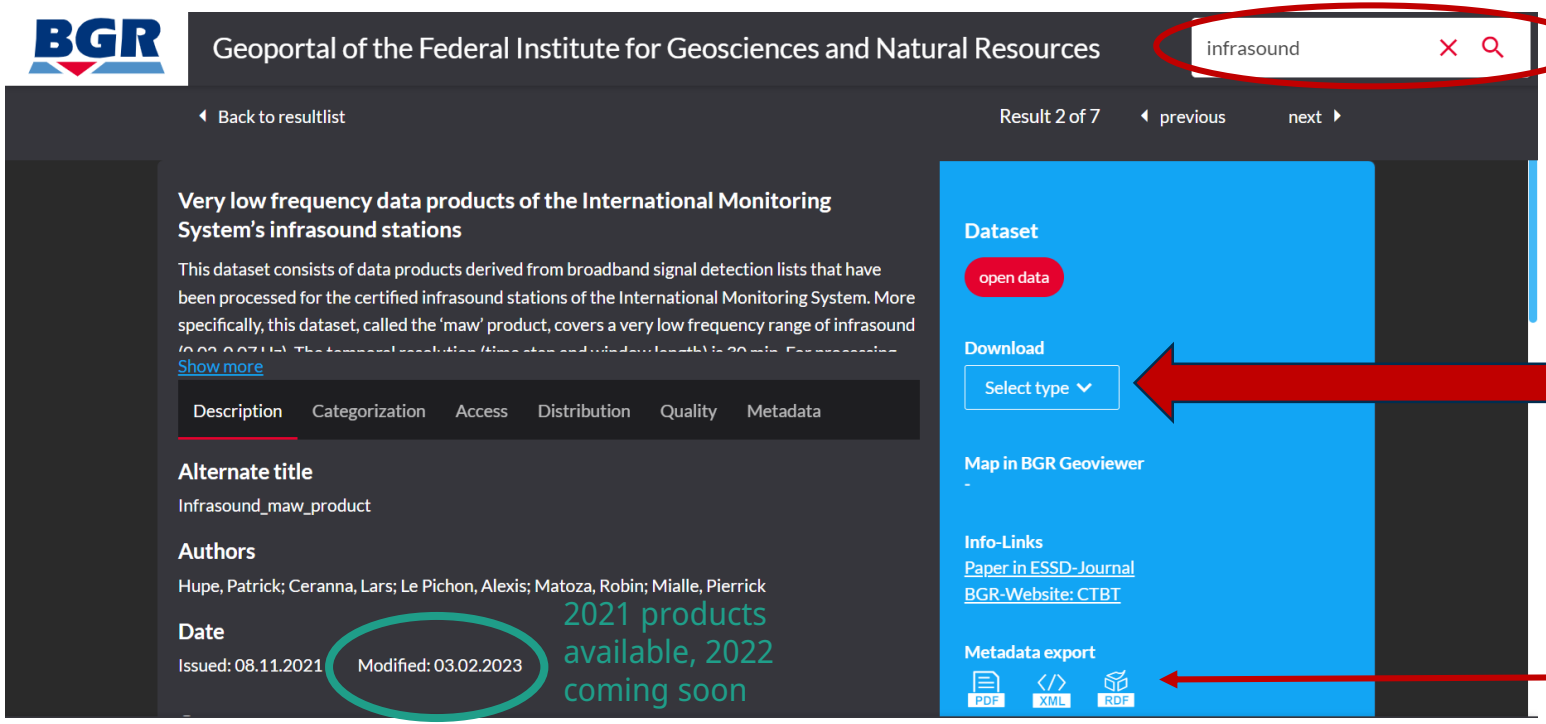
- Temporal resolution 30, 15, and 5 min
- Products reflect dominant detections within time window
- Detection and quality parameters provided

Frequency-azimuth distribution (all 53 certified stations!)



# Easy, open access: Geoportal of BGR

Product download: single .zip file with annual subdirectories comprising one file per station




Search infrasound datasets

Download zip file

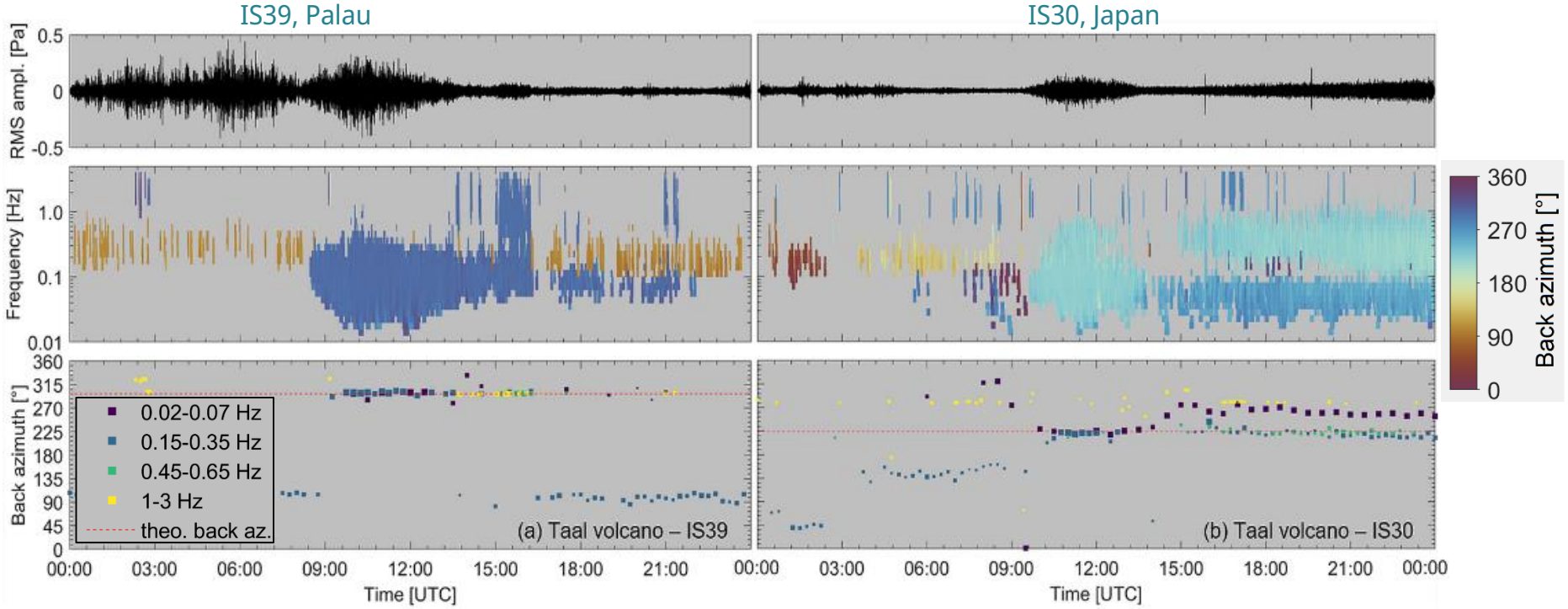
Metadata at a glance

https://geoportal.bgr.de

# Data product parameters

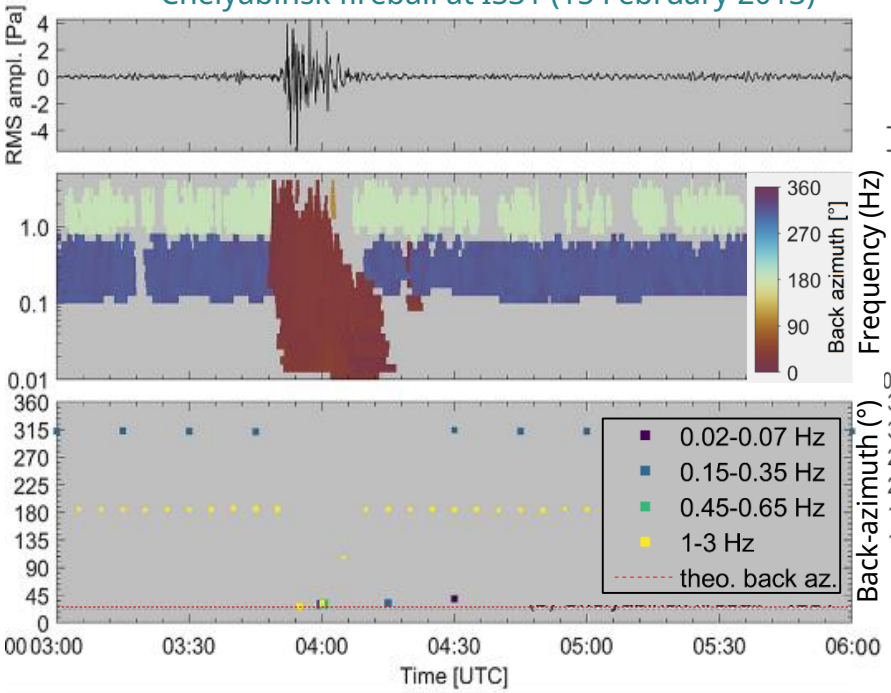
| Parameter | Unit | Variable name | Type | Size | Description |
|---|---|---|---|---|---|
| Time (all time steps) | | time | Char | $N_{\text{time}} \times 15$ | yyyymmddTHHMMSS (ISO 8601) |
| Time (product available) | | $\text{time}_{\text{p}}$ | Char | $N_{\text{avail}} \times 15$ | yyyymmddTHHMMSS (ISO 8601) (where num > 0) |
| Duration | s | $t_{\text{dur}}$ | Double | $N_{\text{avail}} \times 1$ | Sum |
| Back azimuth | ° | azim | Double | $N_{\text{avail}} \times 2$ | Mean, SD |
| Apparent velocity | $\text{m s}^{-1}$ | vapp | Double | $N_{\text{avail}} \times 2$ | Mean, SD |
| RMS amplitude | Pa | $a_{\text{rms}}$ | Double | $N_{\text{avail}} \times 3$ | Mean, SD, max |
| Frequency | Hz | freq | Double | $N_{\text{avail}} \times 2$ | Mean, SD |
| Family size | | $f_{\text{size}}$ | Double | $N_{\text{avail}} \times 3$ | Mean, SD, sum |
| Correlation | | corr | Double | $N_{\text{avail}} \times 3$ | Mean, min, max |
| Fisher ratio | | fish | Double | $N_{\text{avail}} \times 3$ | Mean, min, max |
| Peak-to-peak amplitude | Pa | $a_{\text{p2p}}$ | Double | $N_{\text{avail}} \times 1$ | Max |
| Period at max amplitude | s | $p_{\text{max}}$ | Double | $N_{\text{avail}} \times 3$ | Mean, min, max |
| Number of detections | | num | Double | $N_{\text{time}} \times 2$ | At dominant azimuth $\pm 5°$\| within time window |
| Quality parameter | | $Q$ | Double | $N_{\text{avail}} \times 1$ | Max – quality parameter accounting for sensor (data) availability, Fisher ratio, and mean correlation (Eq. 1) |
| Sensor flag | | flag | Double | $N_{\text{time}} \times 1$ | Flag for daily sensor availability, where 1 is all sensors available, 2 is fewer sensors available but at least three, and 3 is fewer than three sensors where no PMCC detection is possible |
| Sensor statistics | | sens | Double | $N_{\text{avail}} \times 2$ | Array size \| max no. of sensors contributing to PMCC detections |

# Eruption (VEI 4) of Taal, Philippines, 12-Jan-2020

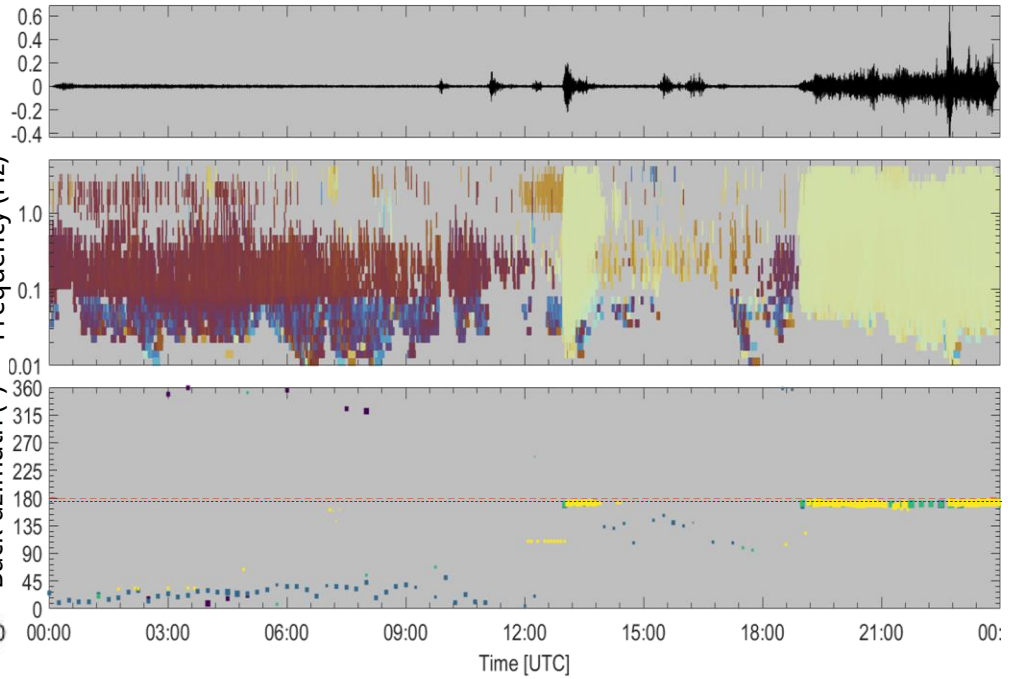


# 2013 Chelyabinsk Fireball & 2021 La Soufriere eruption

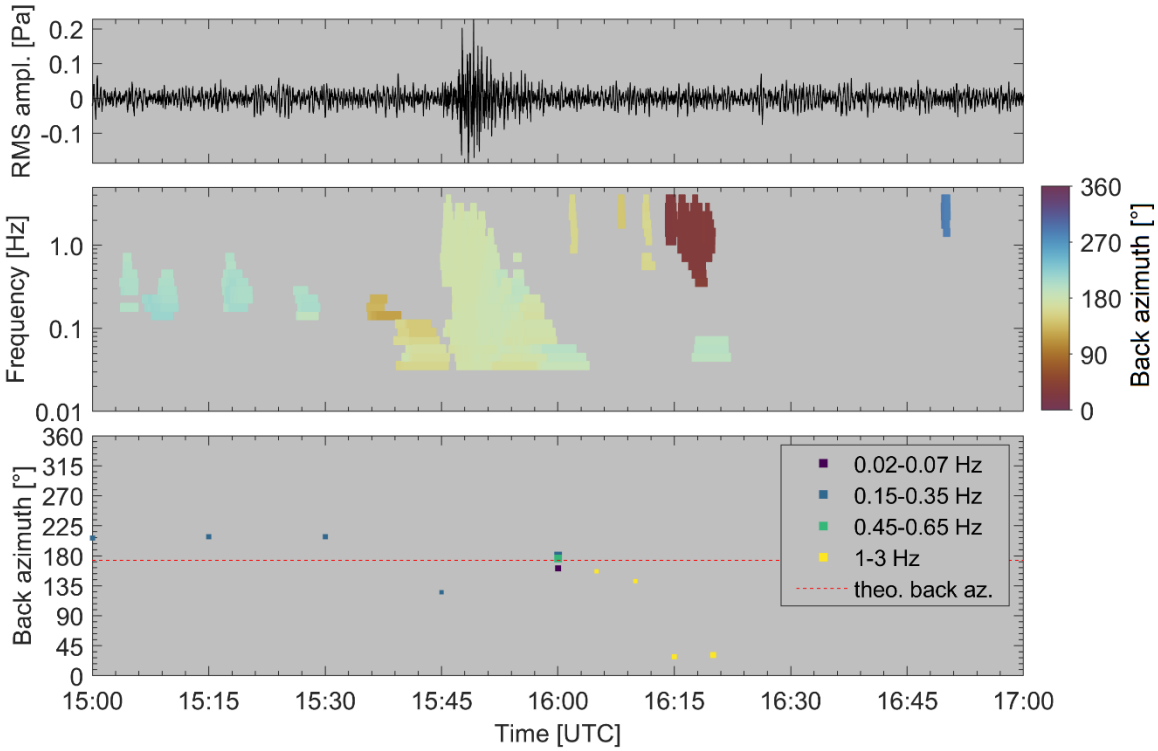
Chelyabinsk fireball at IS31 (15 February 2013)



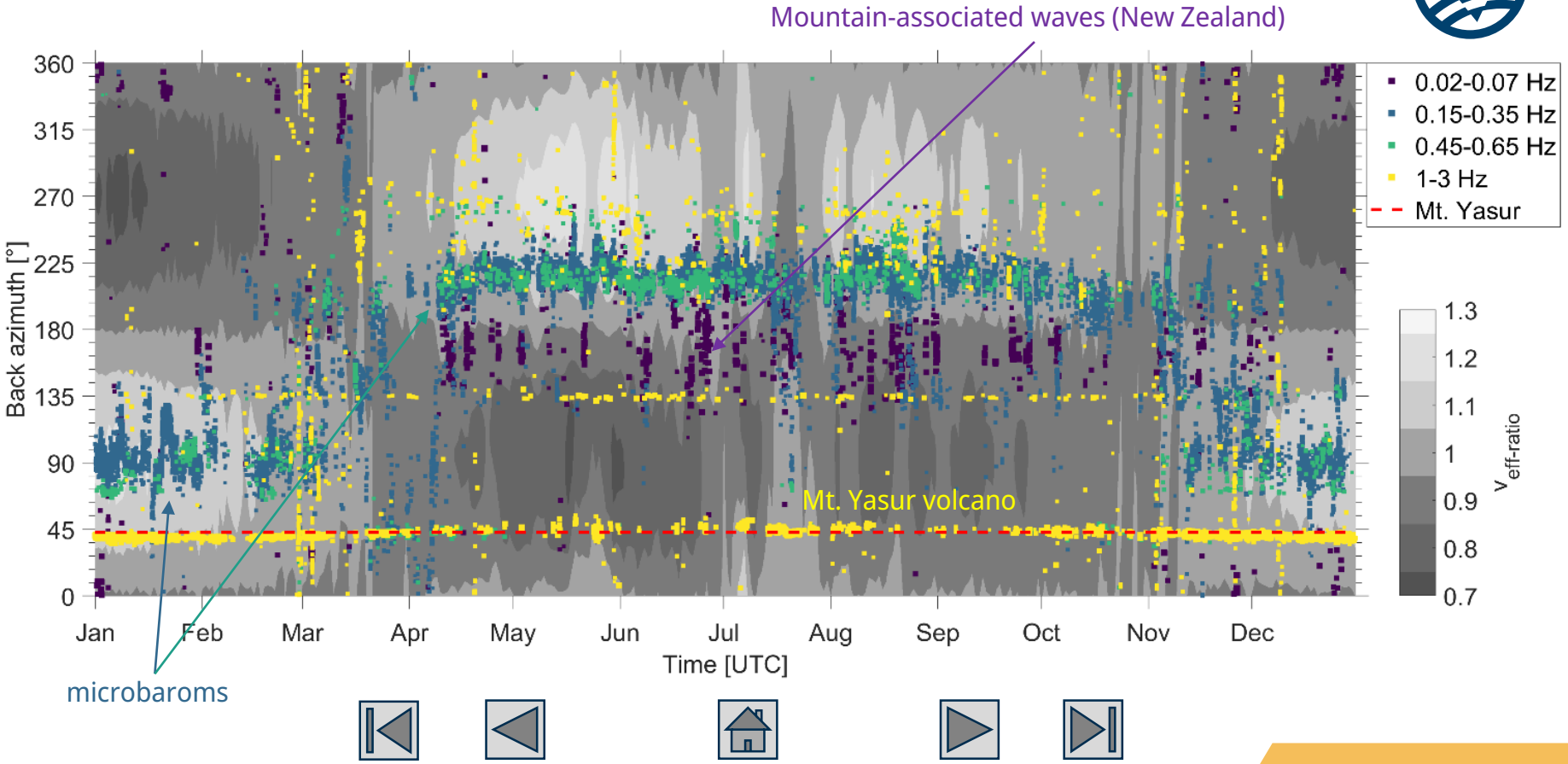

La Soufriere eruption at IS25 (April 2021)



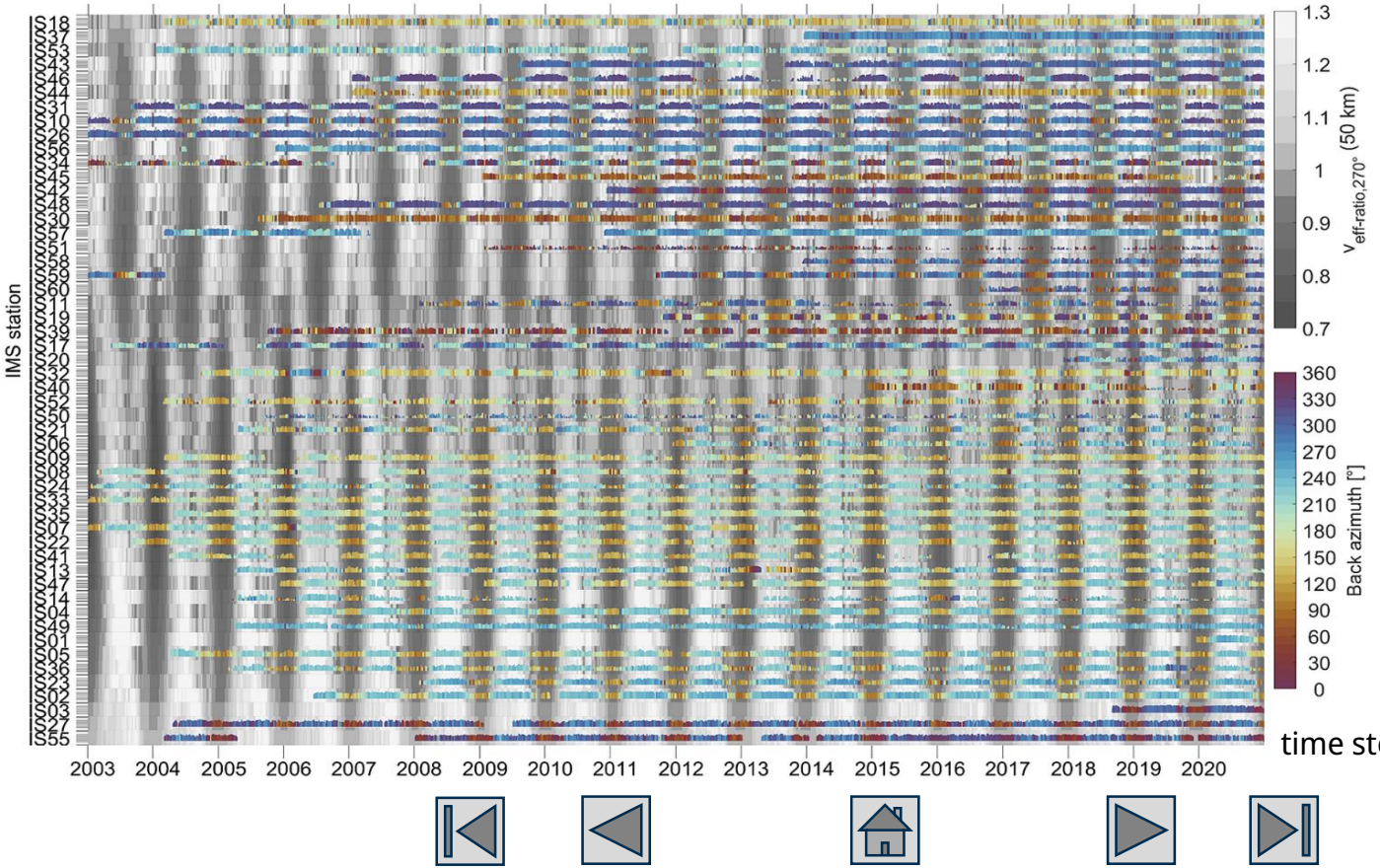
# Stromboli eruption detected at IS26 on 3 July 2019



# IS22 products in 2020



# Atmospheric dynamics




- Microbarom low-frequency product (0.15-0.35 Hz)
- Background: Propagation conditions from west to east
- Seasonal variation of the dominant (mean) back azimuth reflects the stratospheric wind conditions
- Useful for atmospheric circulation models?

time step: 4 days, time window: 8 days

# Summary & Conclusions

- The reprocessing and the data products (2003-2020) are described in an **open-access paper**, Earth System Science Data (https://doi.org/10.5194/essd-14-4201-2022)
- Regular product updates planned (additional data and bug fixing, if any)
  - **2021 products available since February 2023** (see next slide)
  - **2022 products upcoming (May/June 2023)**
  - Near-real time for dedicated applications in the future?!

- The detection lists have already been used for different applications, for example:
  - *De Carlo et al. 2021: microbarom model validation (Geophys. Res. Lett.)*
  - *Pilger et al. 2021: Rocket infrasound signatures (Geophys. Res. Lett.)*
  - *De Negri et al. 2022: Volcanic eruptions of Mt. Michael (South Sandwich Islands) detected at IS27 (Geophys. Res. Lett.)*
  - *Kristoffersen et al. 2022: Updated global reference models of the broadband infrasound wavefield and PMCC metrics (Earth and Space Science)*
- The data products are accessible via **BGR's „Geoportal" – open access, DOI-assigned** (CC BY 4.0)
  - Microbarom product used by *Eggen et al. 2023: Using a machine learning and stochastics-founded model to provide near real-time stratospheric polar vortex diagnostics based on high-latitude infrasound data* (EGU23-11977)

# Updates overview

**2021 products available since February 2023**

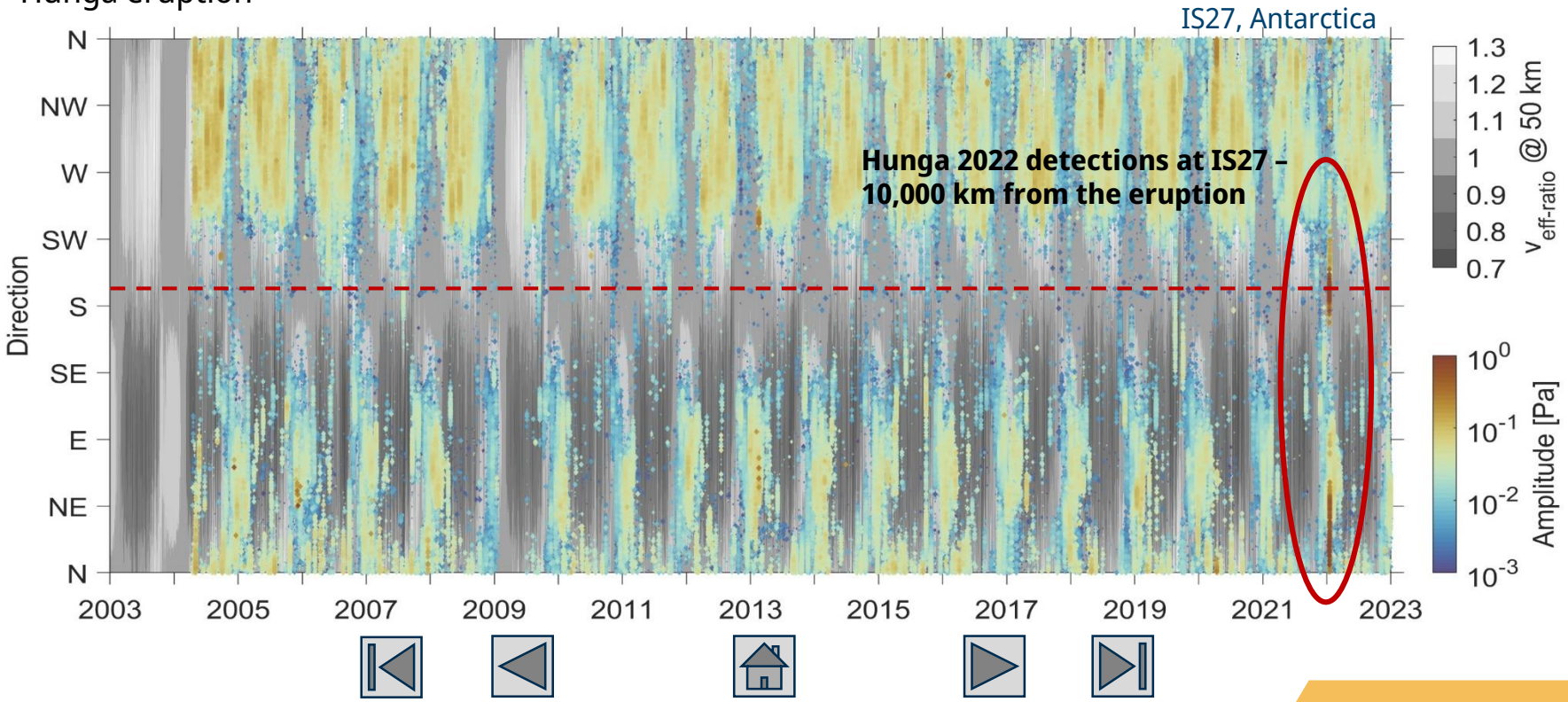
- Products of all 53 certified IMS infrasound stations added
- Quality parameter *Q* fixed for IS56 in 2006
- Previous (unfixed) data remain in the dataset marked as archived
- Versioning introduced for updated (fixed) data products

**2022 products upcoming (May/June 2023)**

- Products of all 53 certified IMS infrasound stations will be added
- Products contain signatures of the Hunga eruption, with exceptionally large amplitudes

# Outlook

Next update will comprise the products for the year 2022, including **global detections** of the Hunga eruption



## Thank you!

# Open-access products from IMS infrasound bulletins for scientific applications

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*Earth System Science Data*

*The CTBTO PrepCom is acknowledged for providing vDEC access to the IMS infrasound network data, which enabled us to undertake this study.* *The views expressed herein are those of the authors and do not necessarily reflect the views of the CTBTO Preparatory Commission.*