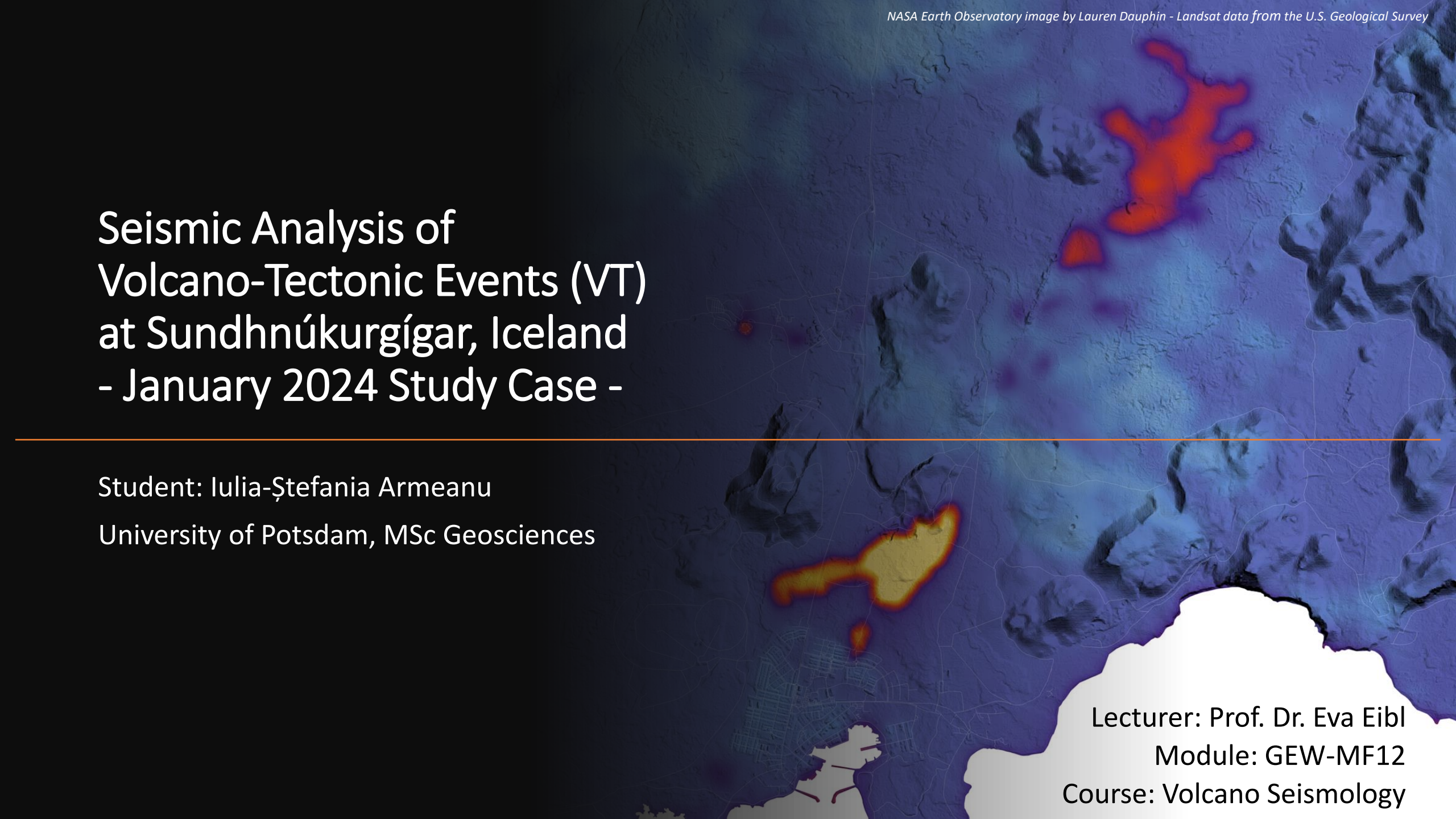

Seismic Analysis of Volcano-Tectonic Events (VT) at Sundhnúkurgígar, Iceland - January 2024 Study Case -

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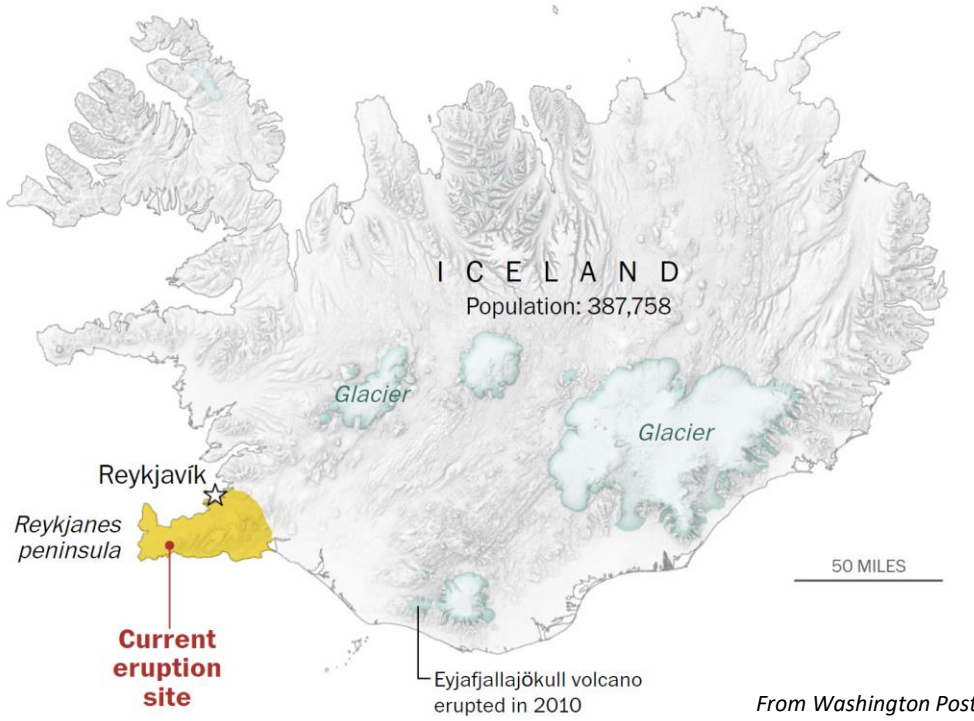
University of Potsdam, MSc Geosciences

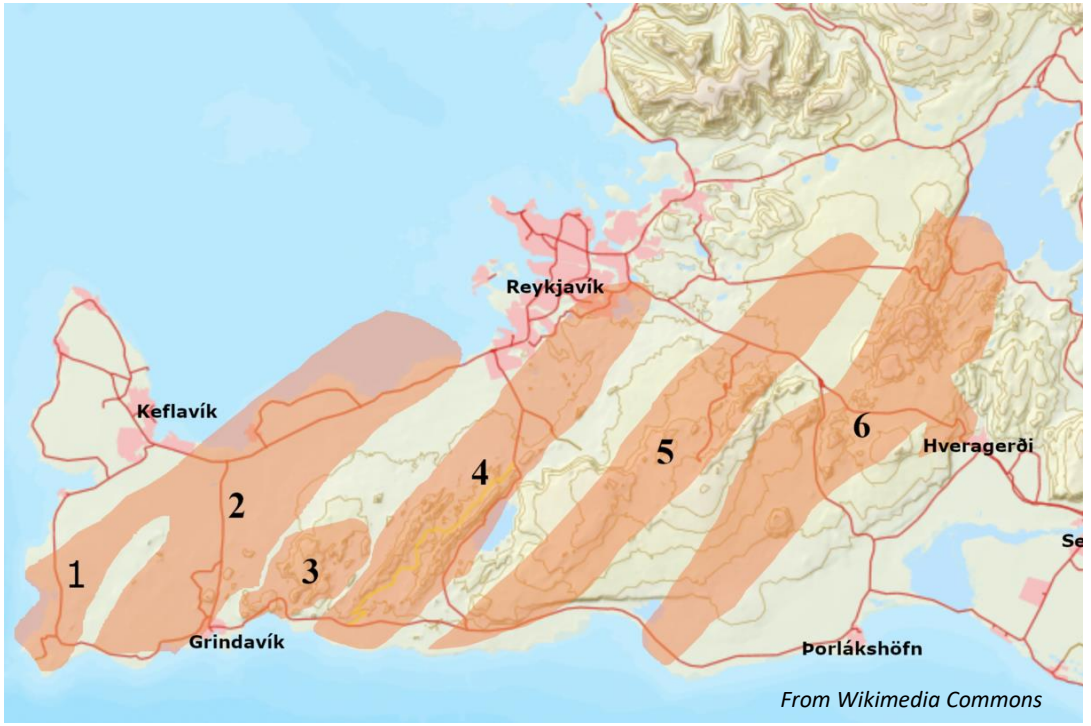
Lecturer: Prof. Dr. Eva Eibl

Module: GEW-MF12

Course: Volcano Seismology



From Washington Post



From Wikimedia Commons

Volcanism along the Reykjanes Peninsula (RP)

Basaltic eruptions – common in Iceland

Eruption occurrence time: 3-5 years

- At central volcanoes: days to weeks
- Basaltic fissure eruptions: can last for years

RP hosts the RVB:

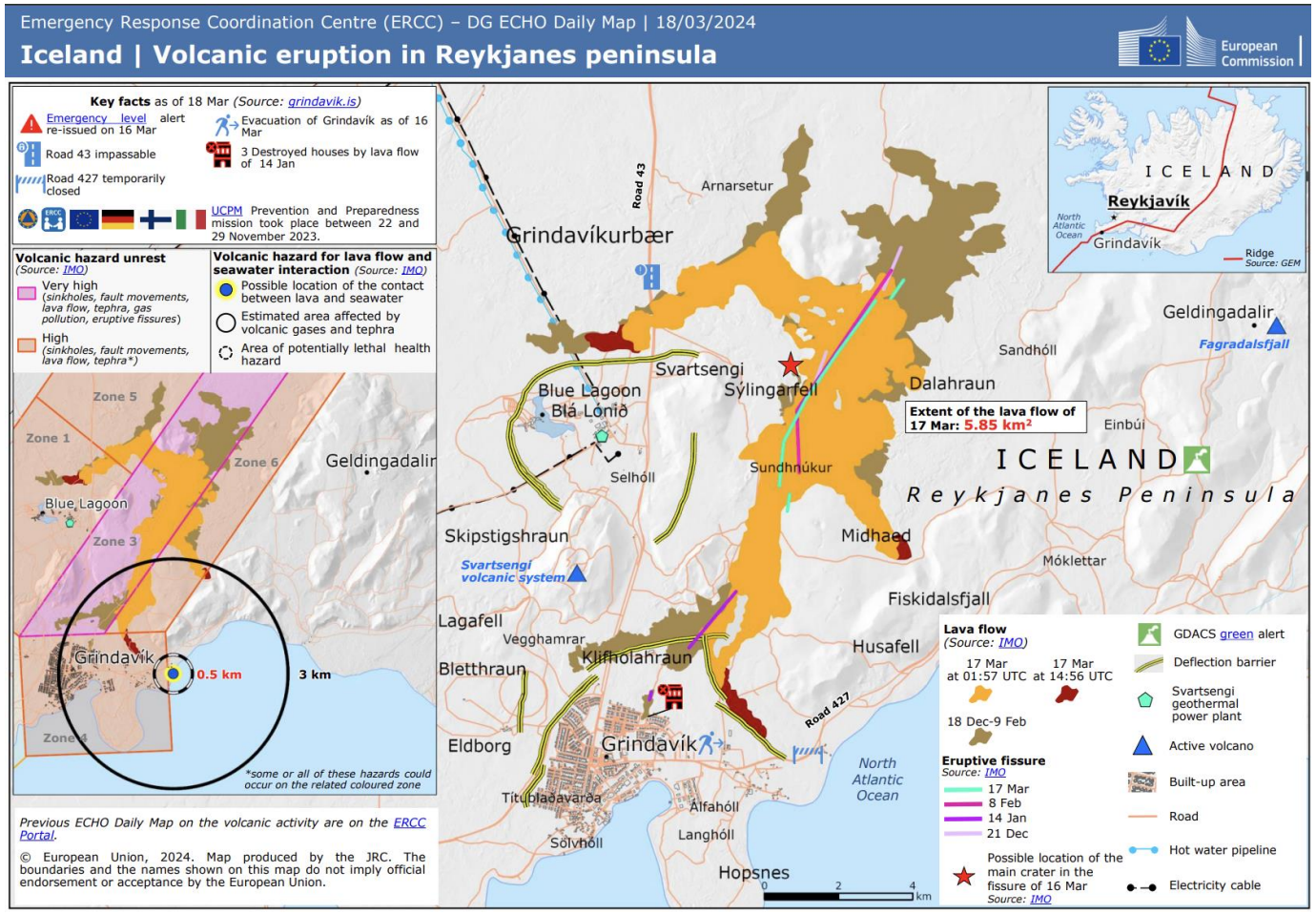
- major volcanic lineaments
- periodically active over the last 4000 years
- 2021 eruption on the (FVL) marked renewed eruptive activity after 781 years of dormancy - 8 individual eruptions have taken place over the last 3 years

2023-24 Sundhnúkur fires

- 20-26 October 2023: magma accumulation at 4–5 km depth beneath Svartsengi
- 10 November 2023: major earthquake swarm
- 18-21 December 2023: 1st eruption

  lava field covering 3.4 km^2
- 14 (7:57 a.m. local time) -16 January 2024: 2nd eruption started (southern segment of the SVL and ~ 1–2 km north of Grindavík)

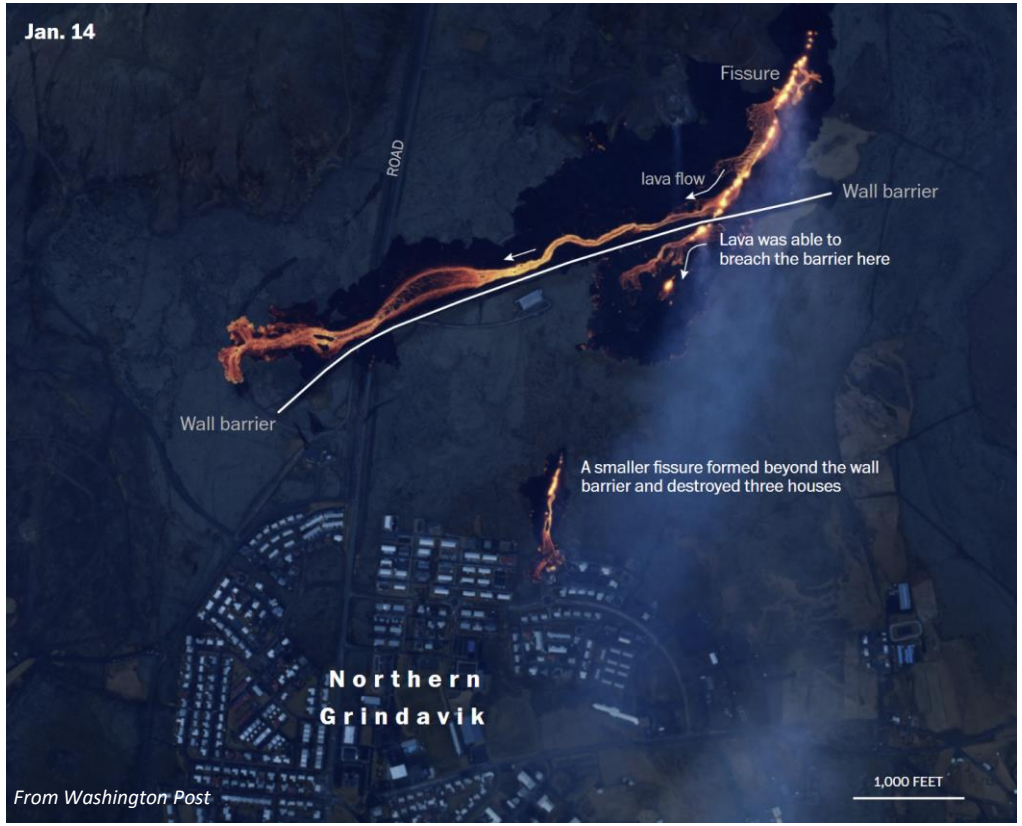
  lava field covering 0.7 km^2
- 8 February 2024: 3nd eruption along the SVL
- 16 March 2024: 4nd eruption



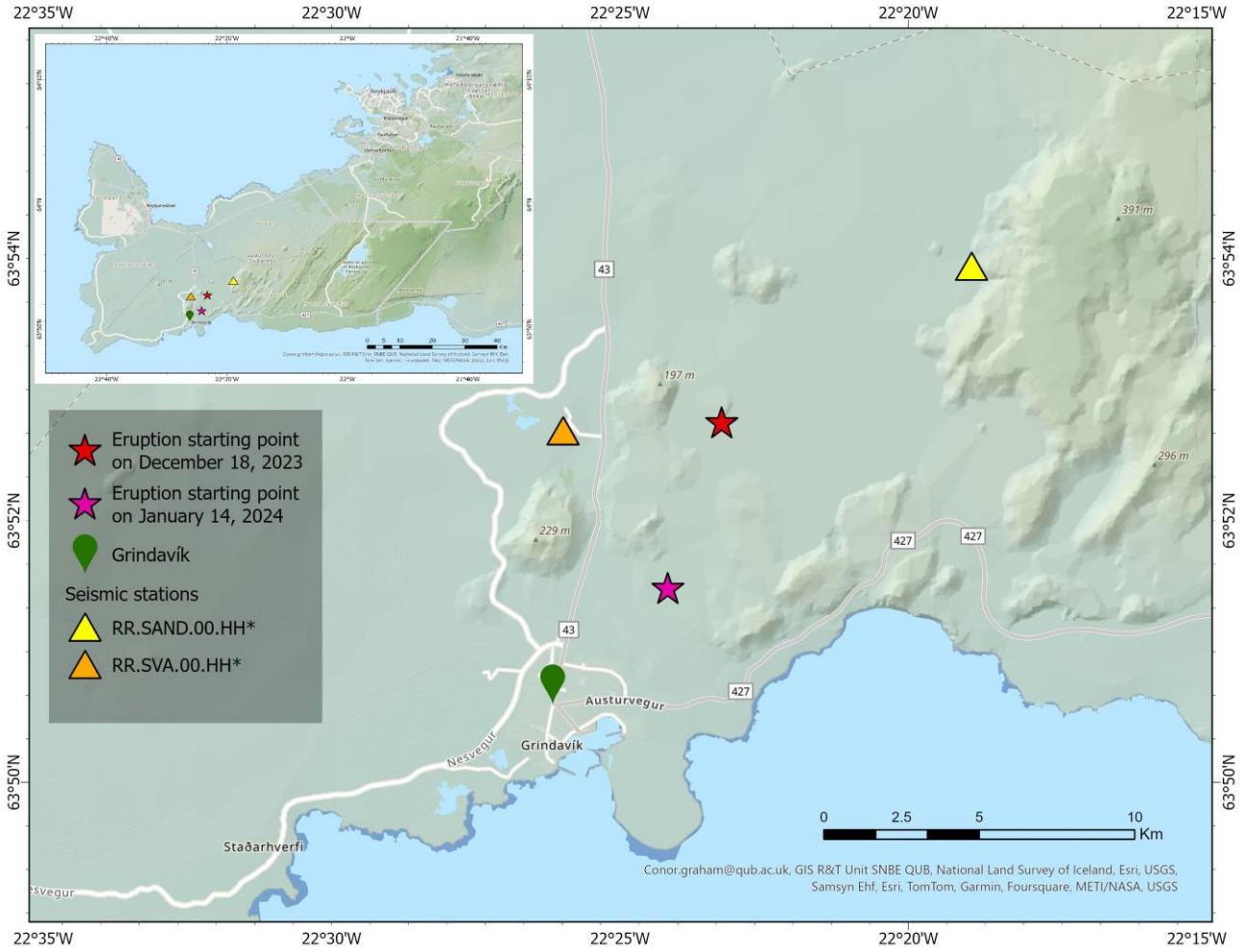
From ECHO

Study case – January 2024

An eruption began at 7:57 UTC southeast of Hagafell mountain, 900 m from Grindavík. Lava flowed towards the town, south of the new deflection barriers.



From Washington Post



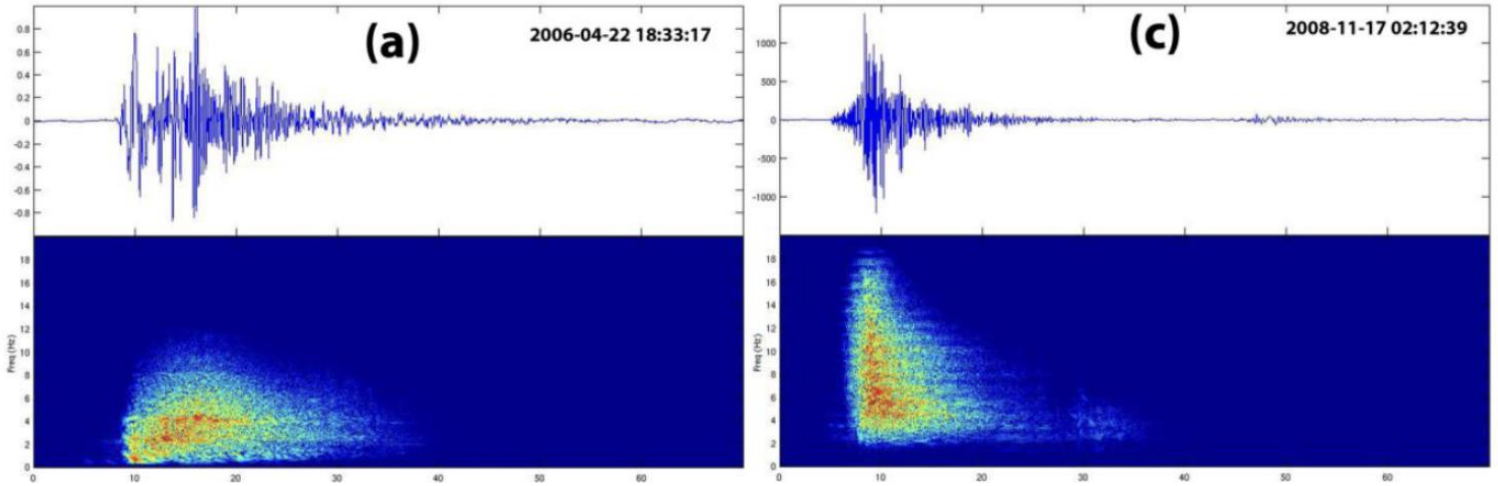
Eruption locations (midpoints) near Grindavík with dates: December 18, 2023, and January 14, 2024, and the seismic stations used in data analysis of VT events

Volcano Tectonic Events (VT)

Definition: Seismic activity caused by the movement of magma or volcanic fluids within the Earth's crust.

Significance

- Indicates volcanic activity or potential eruption
- Essential for monitoring volcanic behaviour



O. Macedo et al., 2019

- **Type A Volcano-Tectonic Events**
- **Characteristics**:
  - Higher frequency (>5Hz)
  - Sharp, well-defined seismic waves – clear P- and S- onset
  - Short signal duration
  - Depth: 1-10km

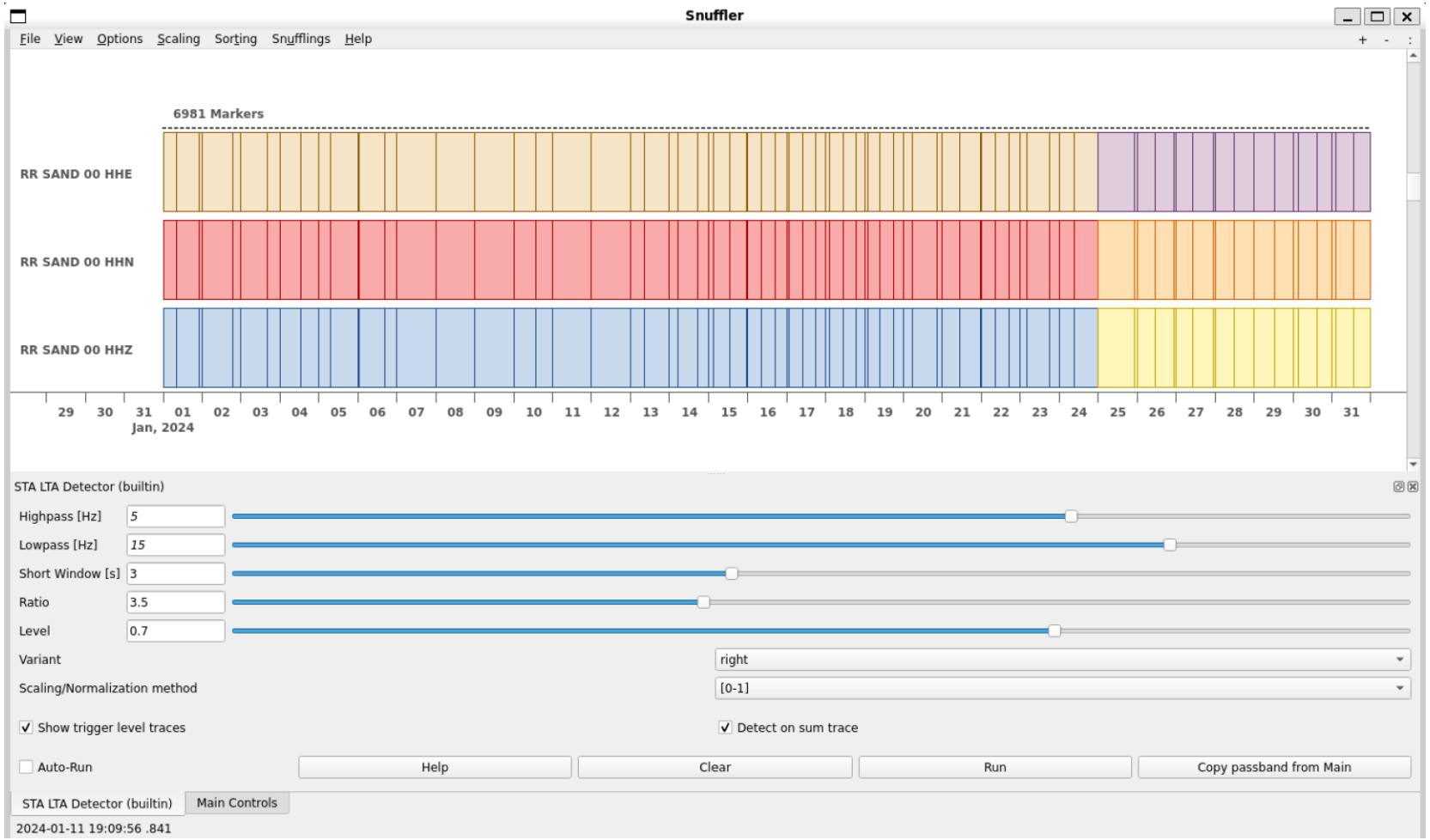
- **Type B Volcano-Tectonic Events**
- **Characteristics**:
  - Lower frequency(1-5Hz)
  - Long-duration, less-defined seismic waves – emergent P- and no S- onset
  - Linked to fluid movement and gas pressure
  - Depth: <1km

Data processing

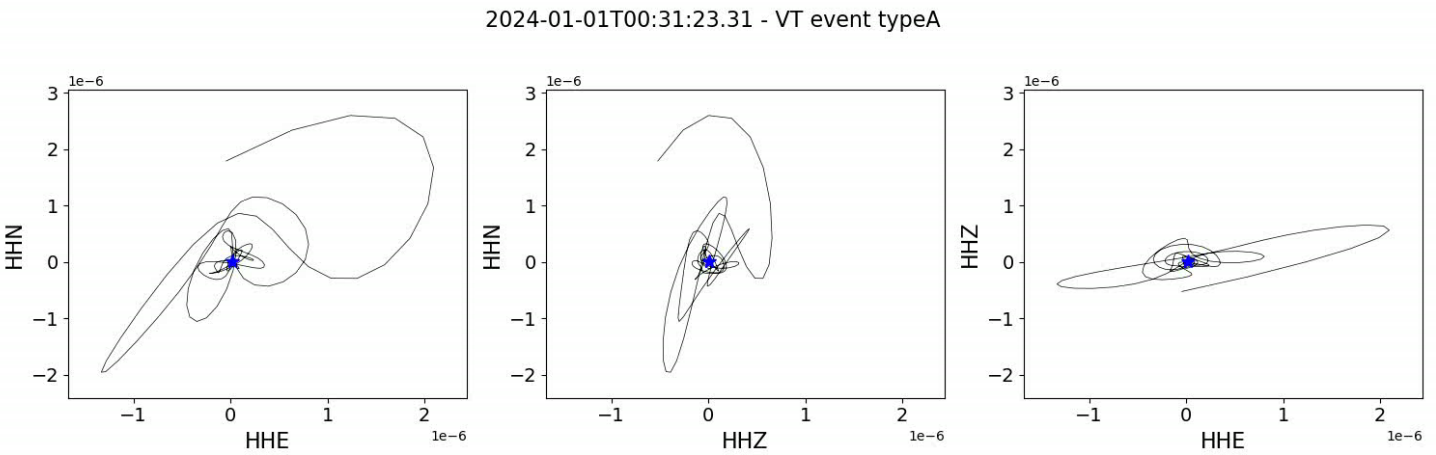
- Data span: 01-31 January 2024
- Data from a high broad band station – 200Hz sampling rate
- Automatic detections – STA LTA Detector (snuffler): 6981 events
- Manual checking: 1172 events (type A - 890 & type B - 282)

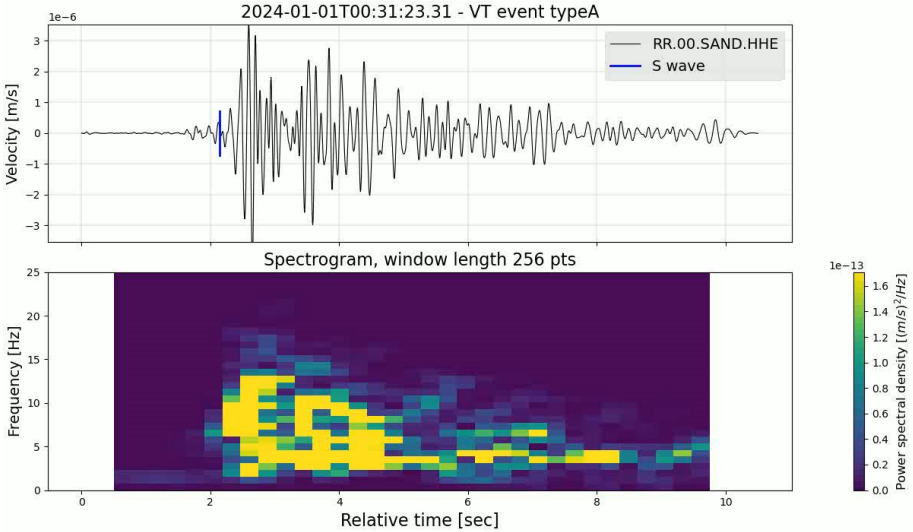
➢ MSEED data pre-processing:

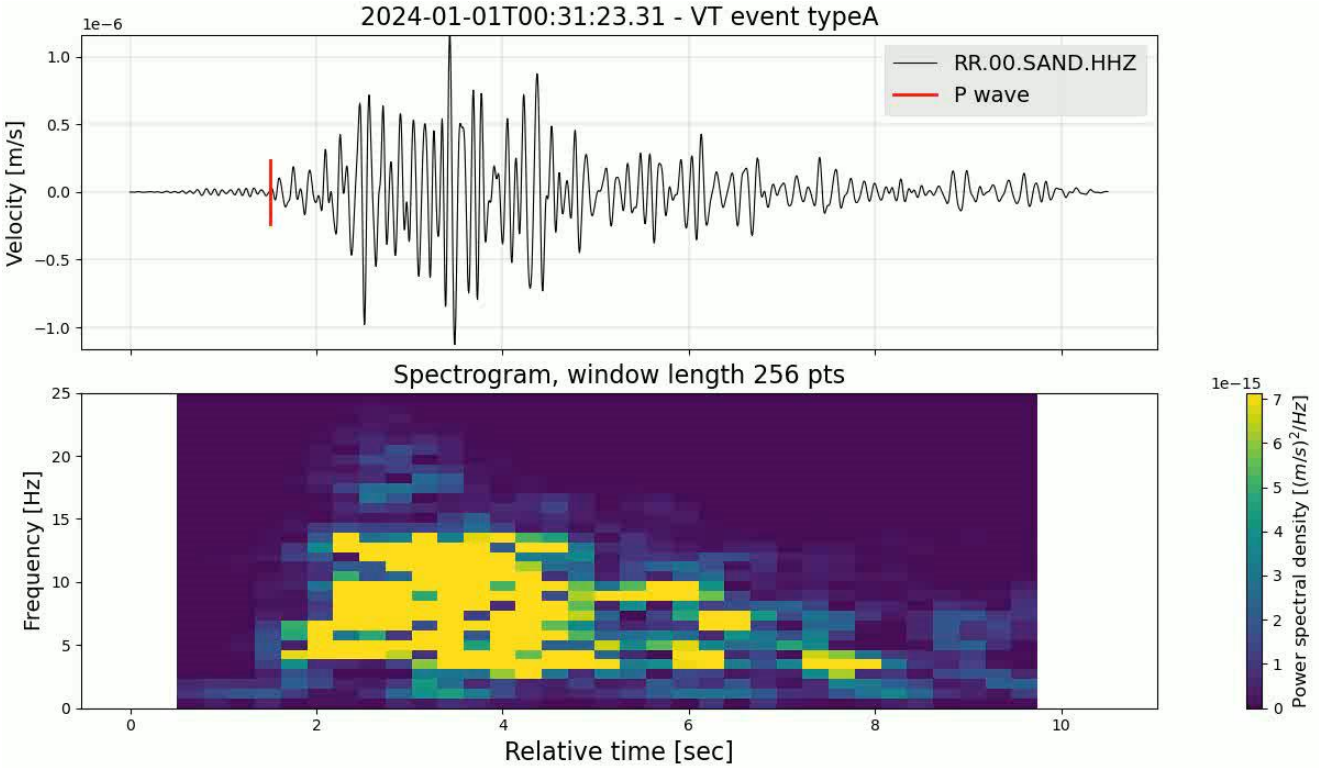
- Trimming (-1.5s before P arrival and + 9.0s after P arrival)
- Detrending (‘demean’ and ‘linear’)
- Tapering (0.1)
- Instrument Response Correction (using XML file and ‘Velocity’ as output)
- Filtering (type A: 5-15Hz & type B: 1-5Hz)

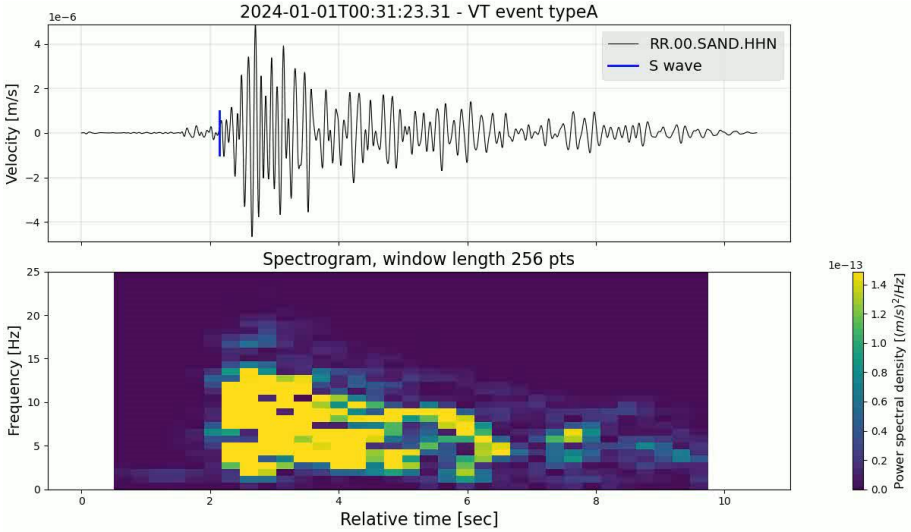


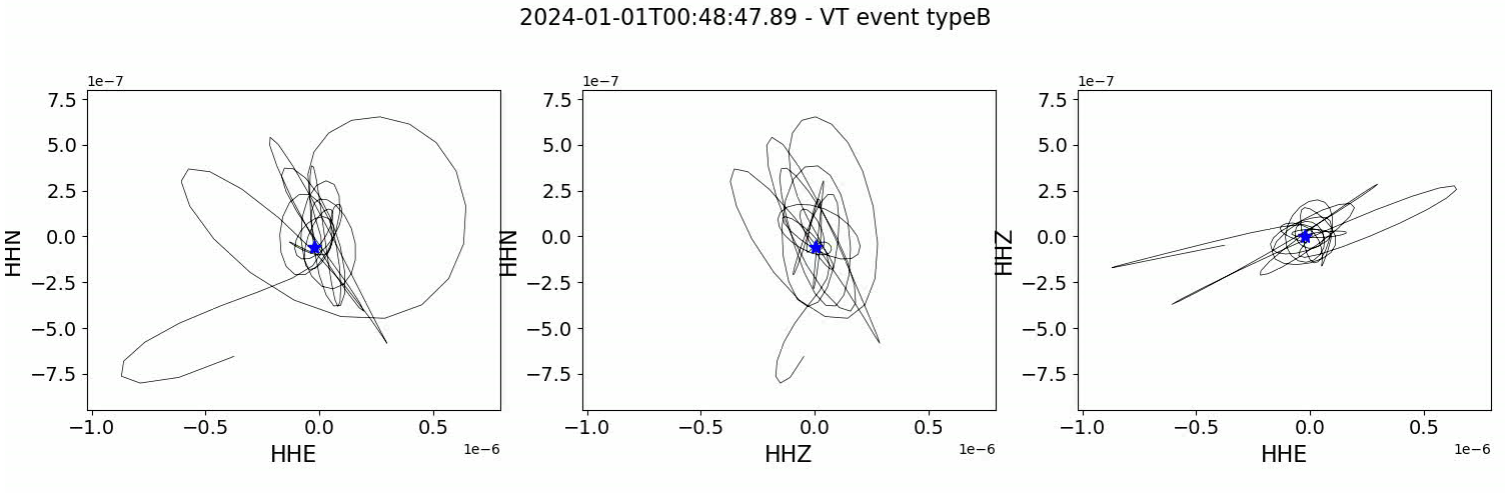
Data visualisation in Snuffler (January 2024) – STA LTA Detector tool

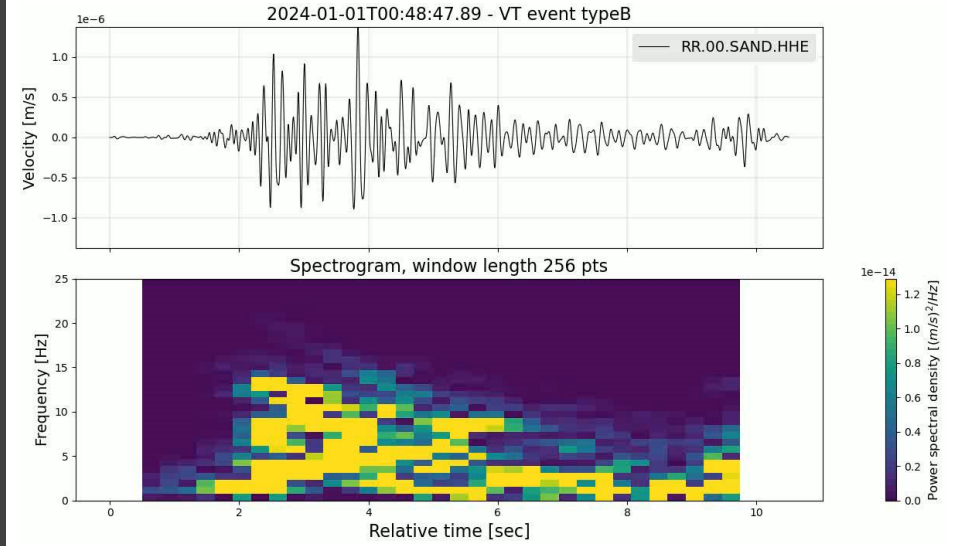

2024-01-01T00:31:23.31 - VT event typeA
HHN
HHE
HHN
HHZ
HHZ
HHE
1e−6

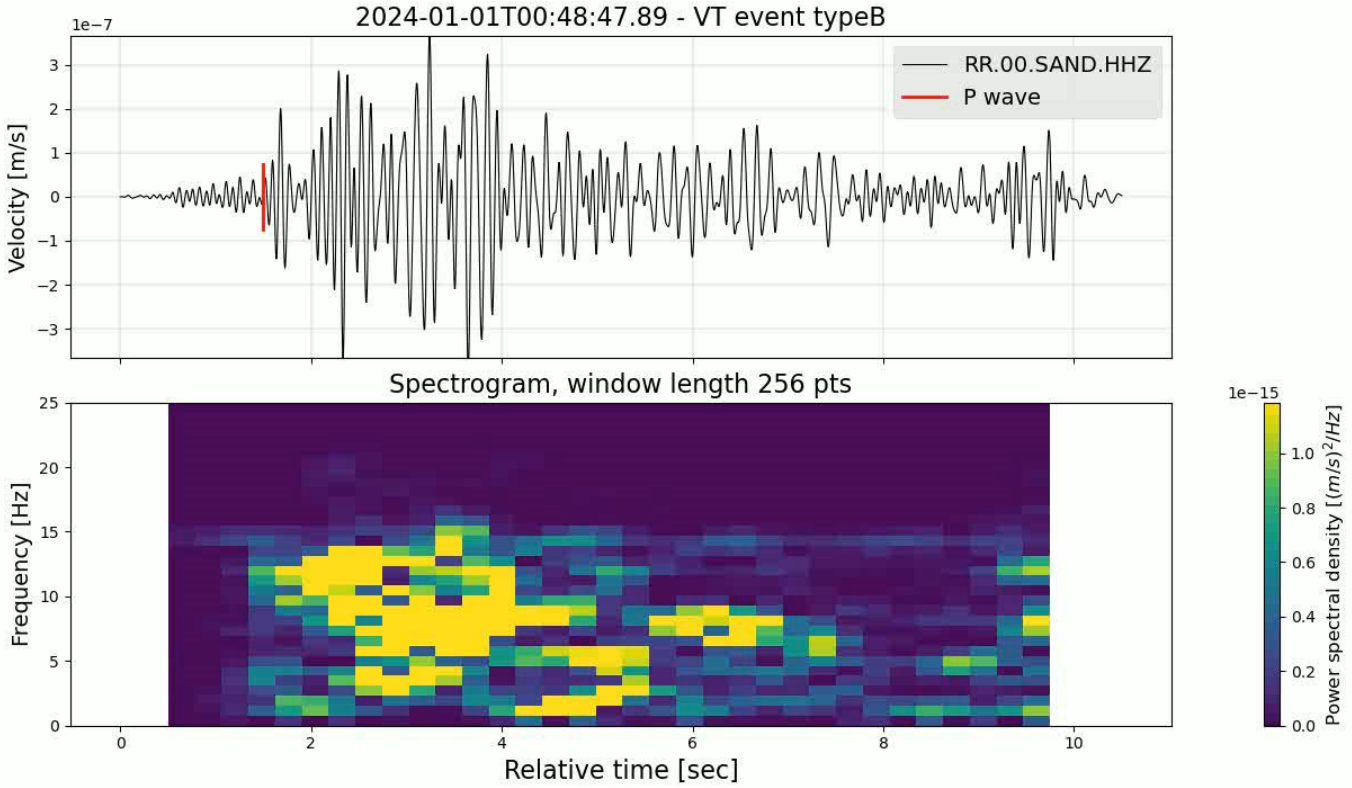

2024-01-01T00:31:23.31 - VT event typeA
RR.00.SAND.HHE
S wave
Velocity [m/s]
Spectrogram, window length 256 pts
Frequency [Hz]
Relative time [sec]
Power spectral density [(m/s)²/Hz]
1e−6
1e−13

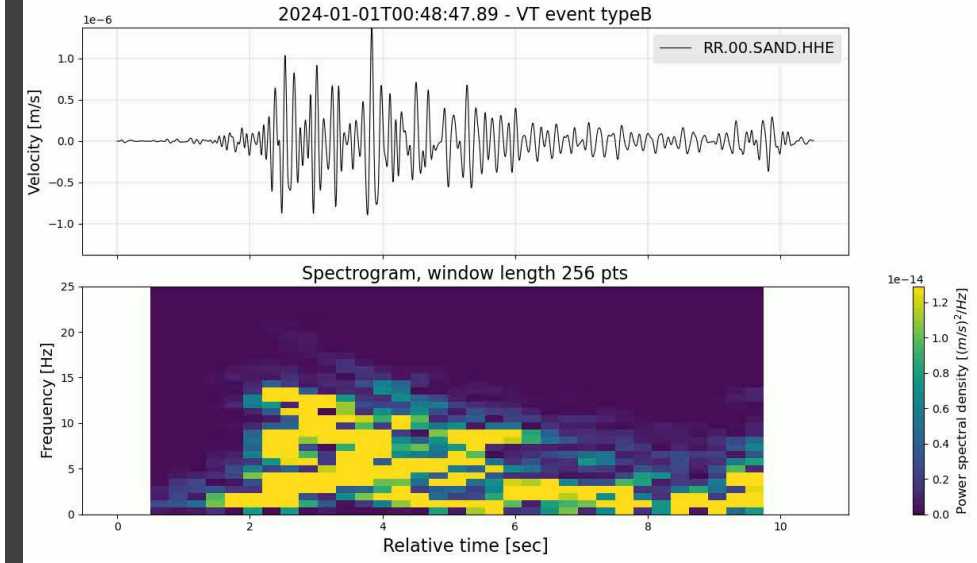

2024-01-01T00:31:23.31 - VT event typeA
RR.00.SAND.HHZ
P wave
Velocity [m/s]
Spectrogram, window length 256 pts
Frequency [Hz]
Relative time [sec]
Power spectral density [(m/s)²/Hz]
1e−6
1e−15


2024-01-01T00:31:23.31 - VT event typeA
RR.00.SAND.HHN
S wave
Velocity [m/s]
Spectrogram, window length 256 pts
Frequency [Hz]
Relative time [sec]
Power spectral density [(m/s)²/Hz]
1e−6
1e−13


2024-01-01T00:48:47.89 - VT event typeB
HHN
HHE
HHZ
1e−7
1e−6

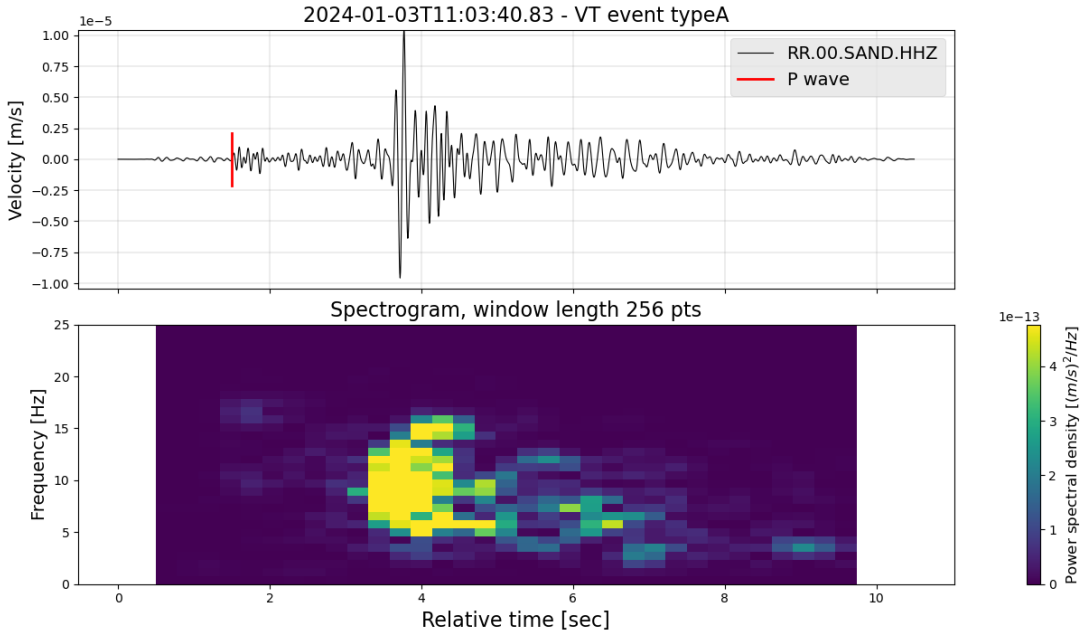

2024-01-01T00:48:47.89 - VT event typeB
RR.00.SAND.HHE
Velocity [m/s]
Spectrogram, window length 256 pts
Frequency [Hz]
Relative time [sec]
Power spectral density [(m/s)²/Hz]
1e−6
1e−14

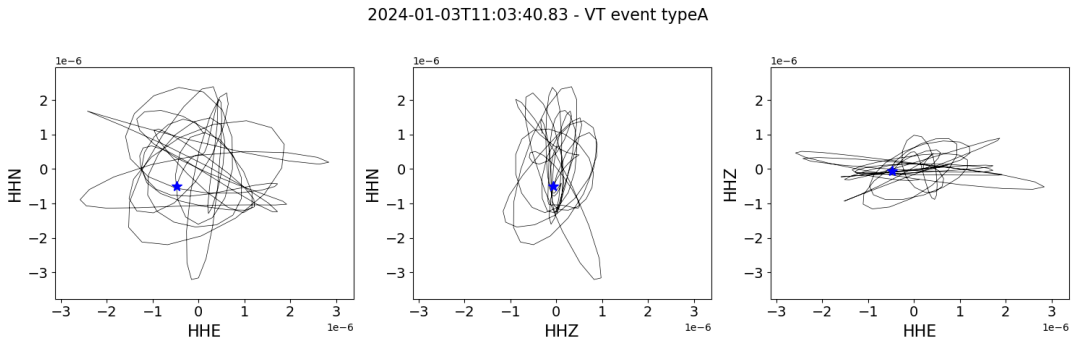

2024-01-01T00:48:47.89 - VT event typeB
RR.00.SAND.HHZ
P wave
Velocity [m/s]
Spectrogram, window length 256 pts
Frequency [Hz]
Relative time [sec]
Power spectral density [(m/s)²/Hz]
1e−7
1e−15


2024-01-01T00:48:47.89 - VT event typeB
RR.00.SAND.HHE
Velocity [m/s]
Spectrogram, window length 256 pts
Frequency [Hz]
Relative time [sec]
Power spectral density [(m/s)²/Hz]
1e−6
1e−14

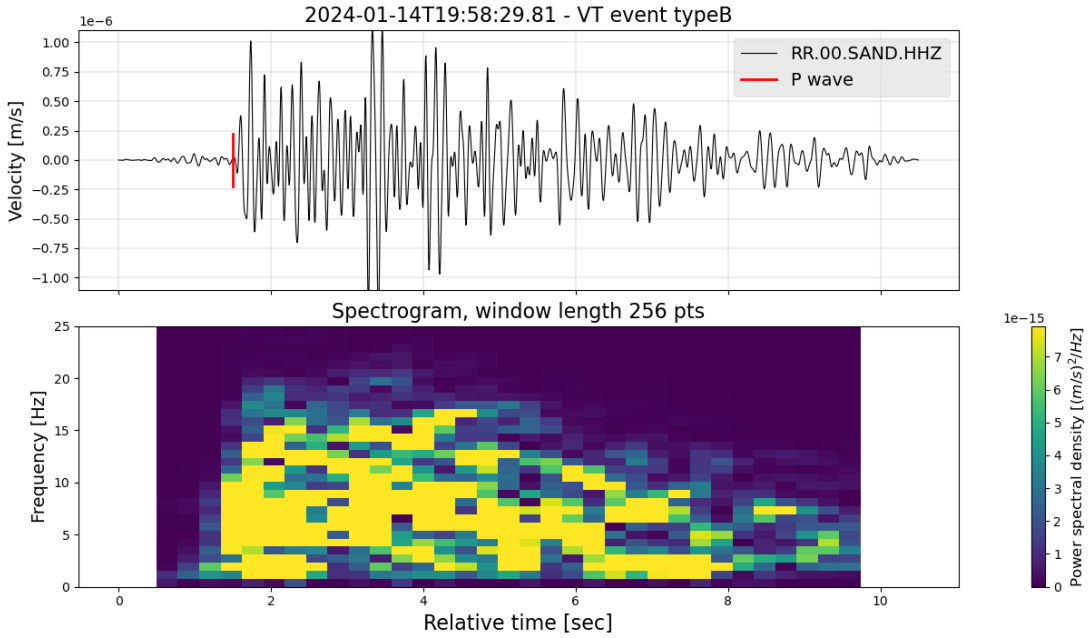
Comparison of VT events types

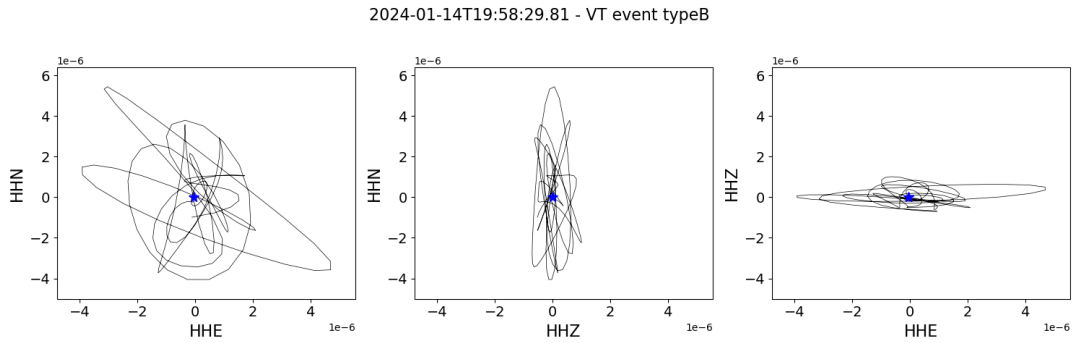
Type A



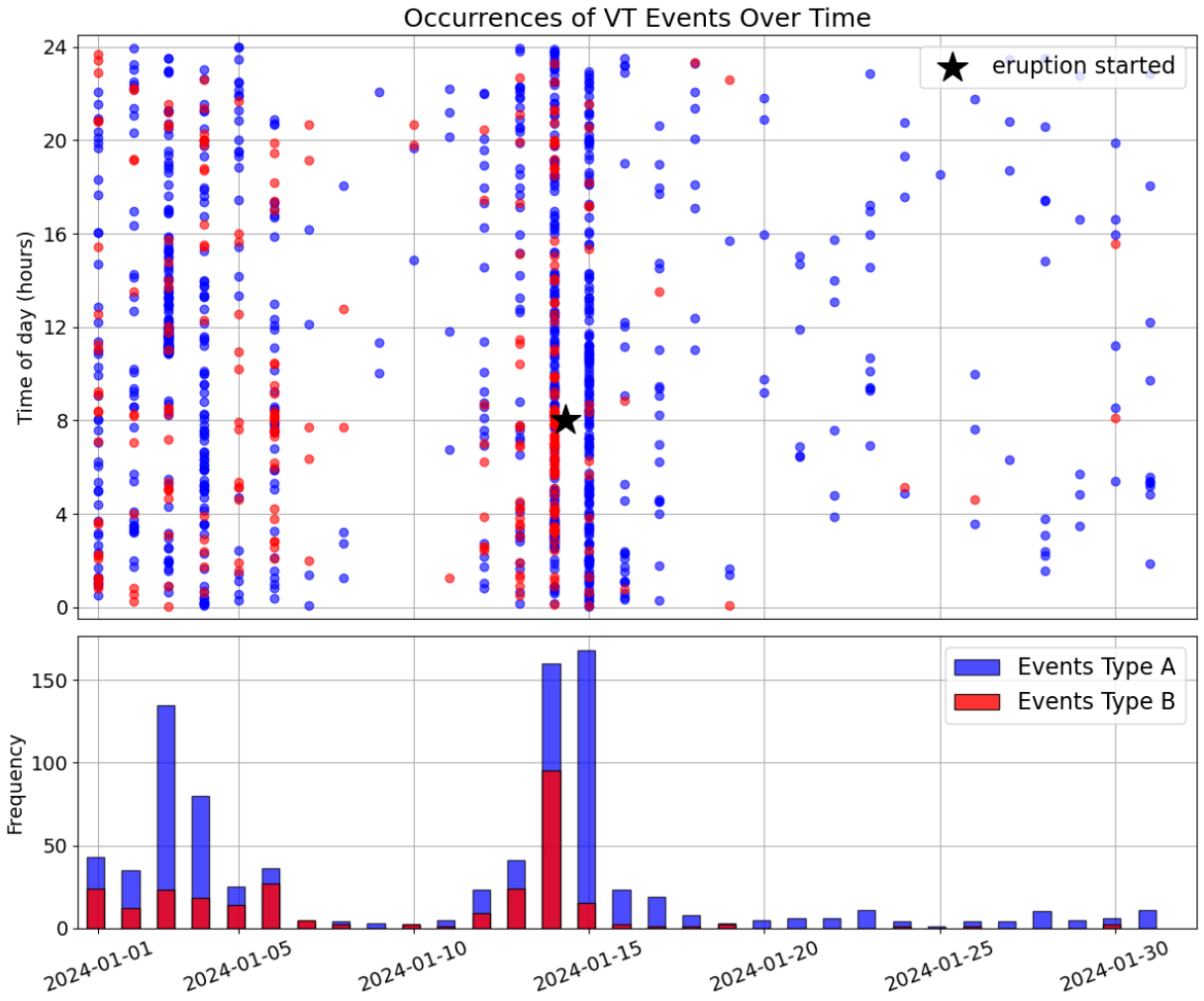


Type B





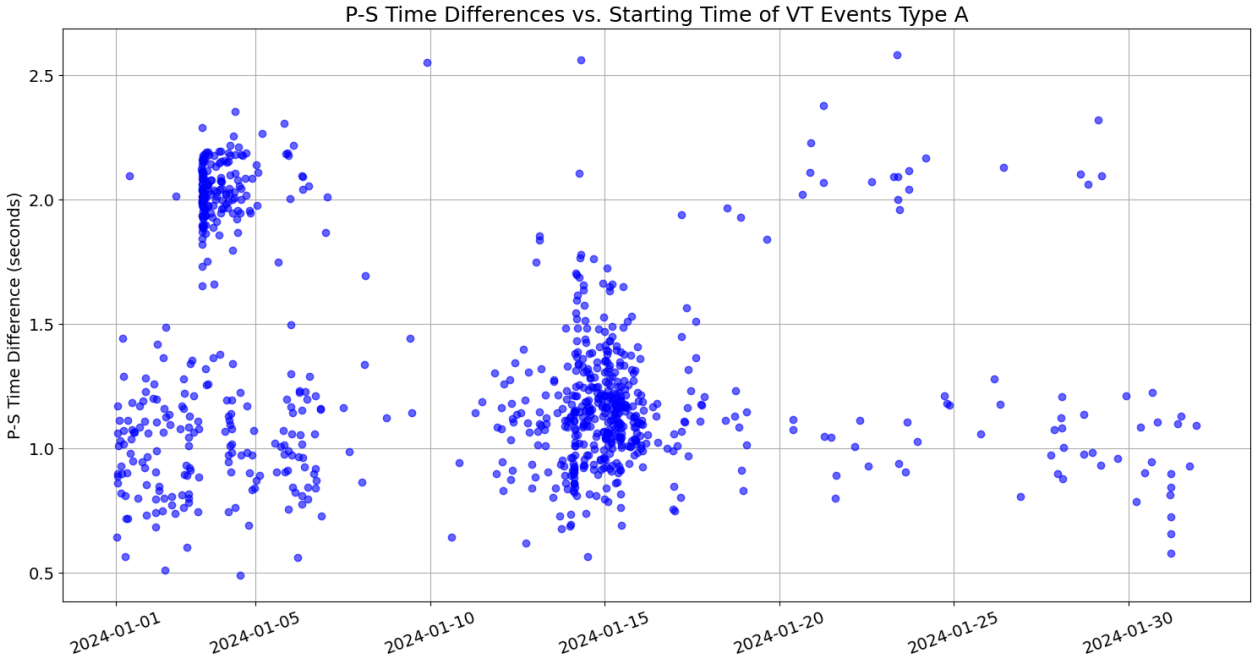
- The eruption on January 14 coincides with the peak frequency of VT events (both type A and type B).



The occurrences of VT events over January 2024, categorized by the time of day (hours).

- The clustering of VT Events around January 3 marks the start of a swarm and the concentration of points around January 14 suggests a notable clustering of events before the eruption.

- The concentration of events with shorter P-S times suggests shallower depths, while longer P-S times indicate deeper events.

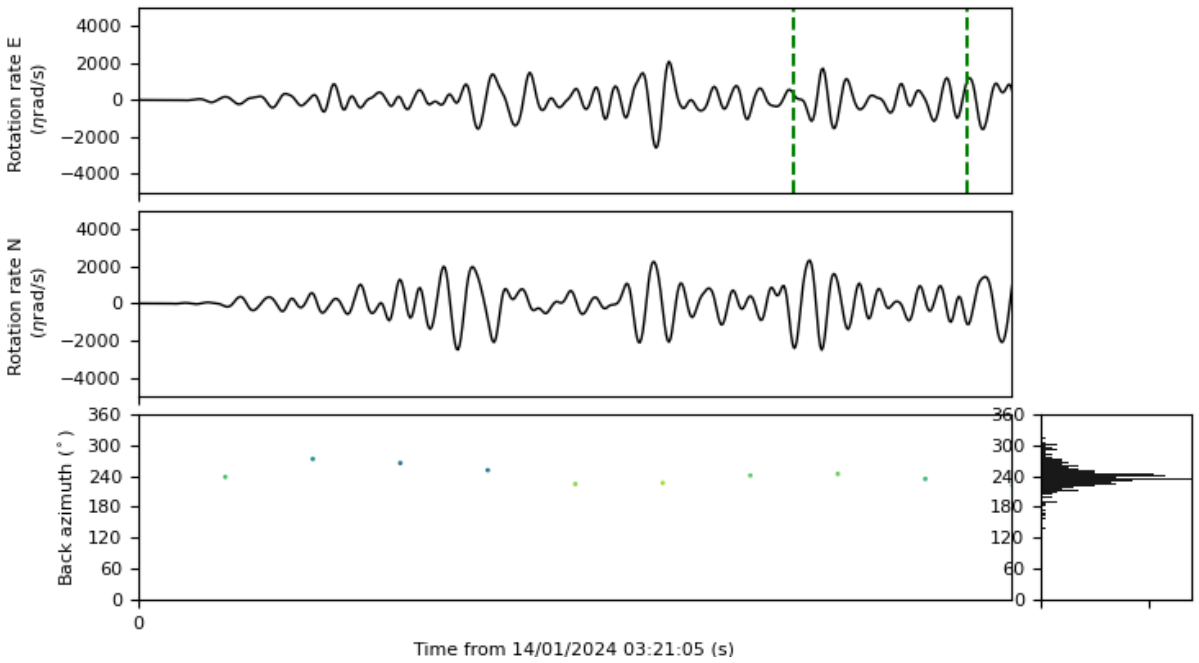


The P-S time difference against P time over January 2024.

Back Azimuth computation

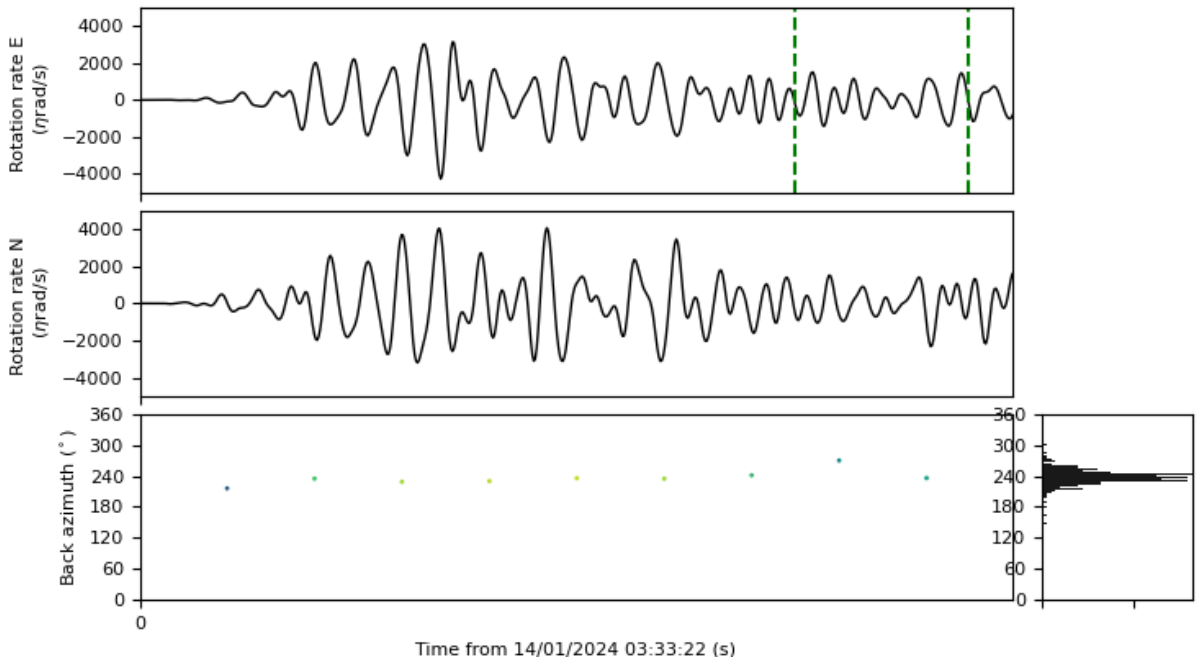
- The back azimuth angle is represented in the lower plot, showing the directional information of the seismic events.
- The histogram on the right side of both plots shows a predominant direction around 240° (southwest).

- Type A

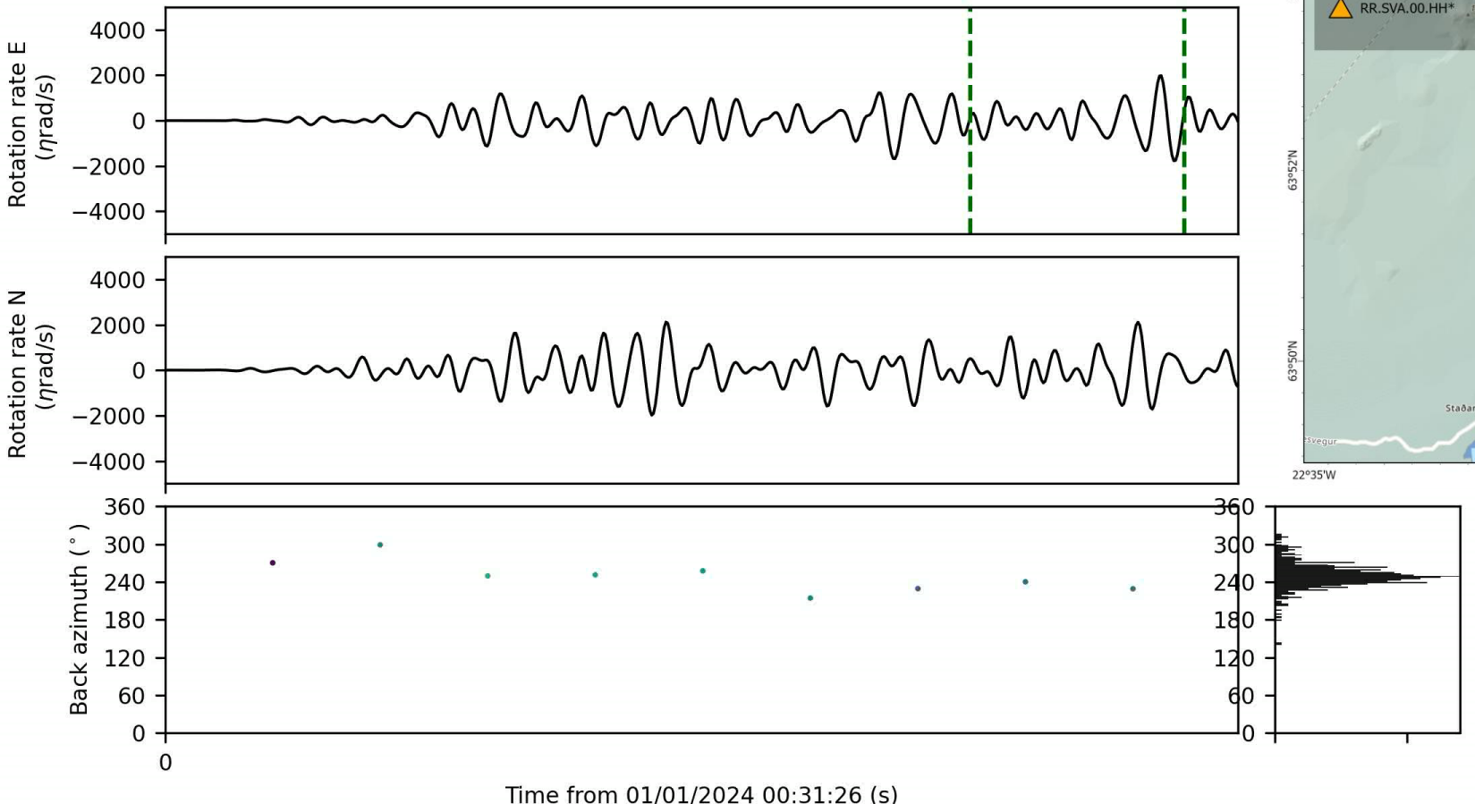


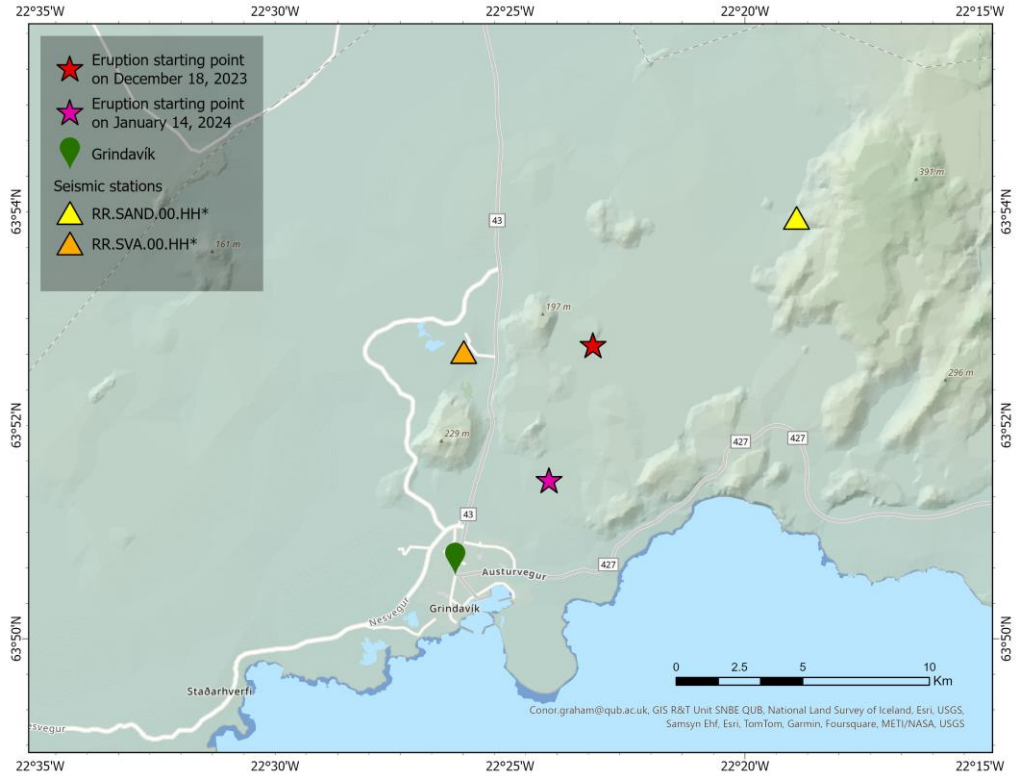
The rotation rates for the E (east) and N (north) components, as well as the back azimuth for VT Events Type A.

- Type B



The rotation rates for the E (east) and N (north) components, as well as the back azimuth for VT Events Type B.

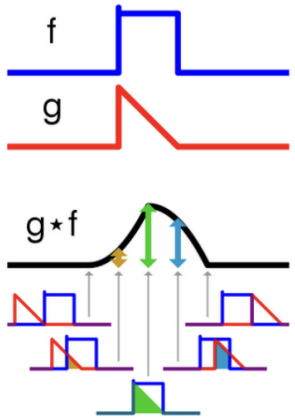




The rotation rates for the E (east) and N (north) components, as well as the back azimuth for all VT Events.

The direction of all events is between 180° - 260° (south - southwest).

Cross-correlation technique

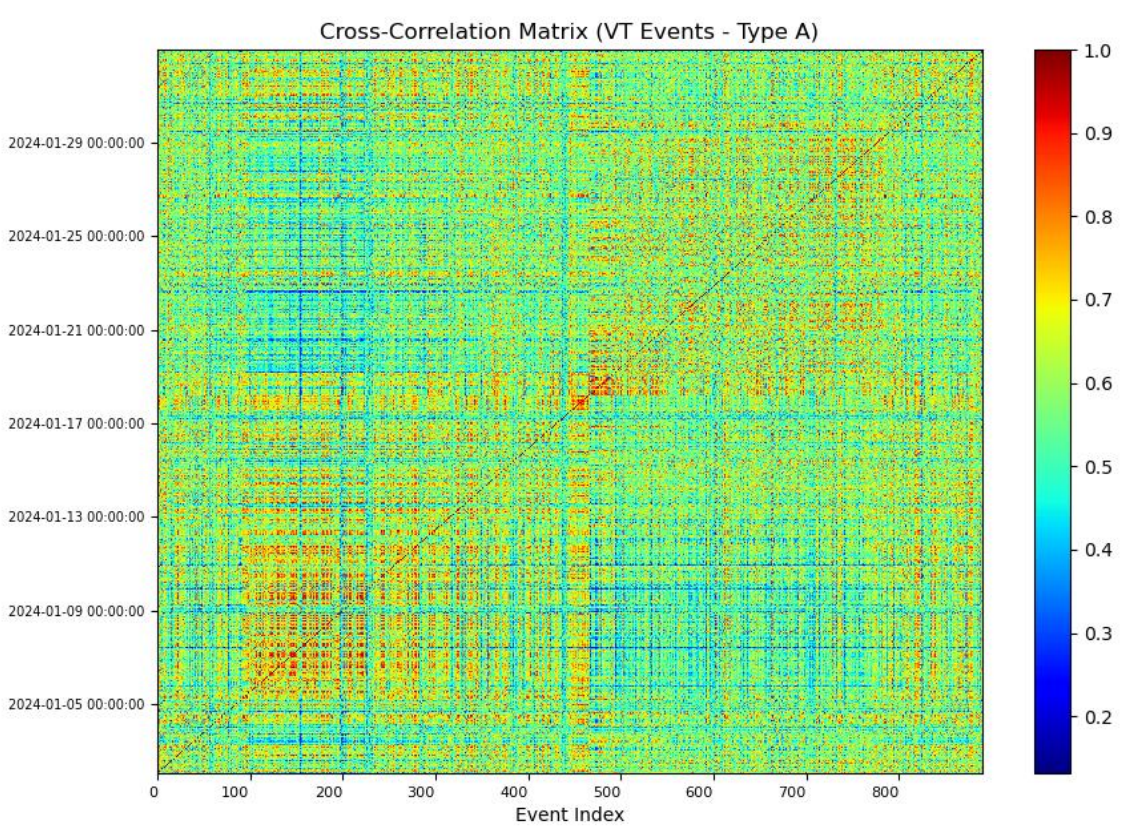


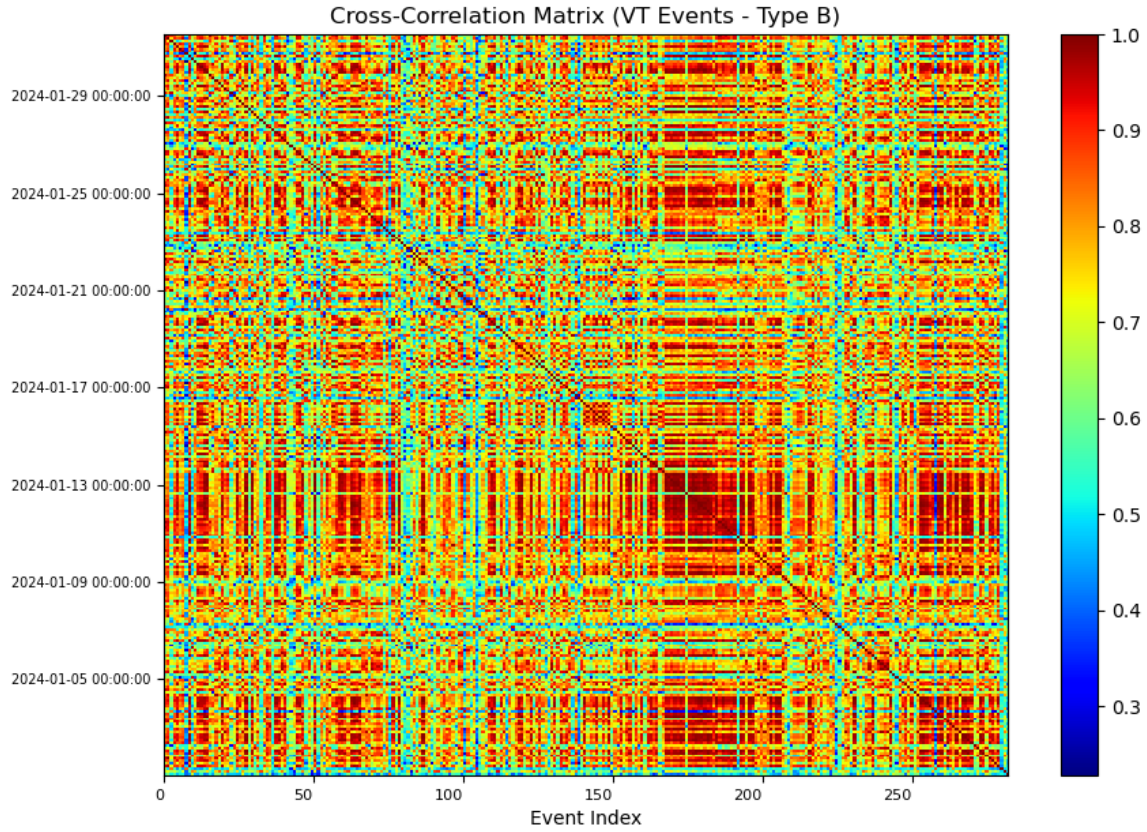
$$c(\tau) = (g \star f)(\tau)$$

$$c_k = \sum_i g_i f_{k+i-1}$$

$$c(\tau) = \int_{t_0}^{t_0+T} g(t) f(t+\tau) d\tau$$

From: https://en.wikipedia.org/wiki/Cross-correlation





The results obtained through successive iterations of the cross-correlation coefficient (CC).