Towards real-time monitoring with a seismic antenna at Merapi volcano, Indonesia

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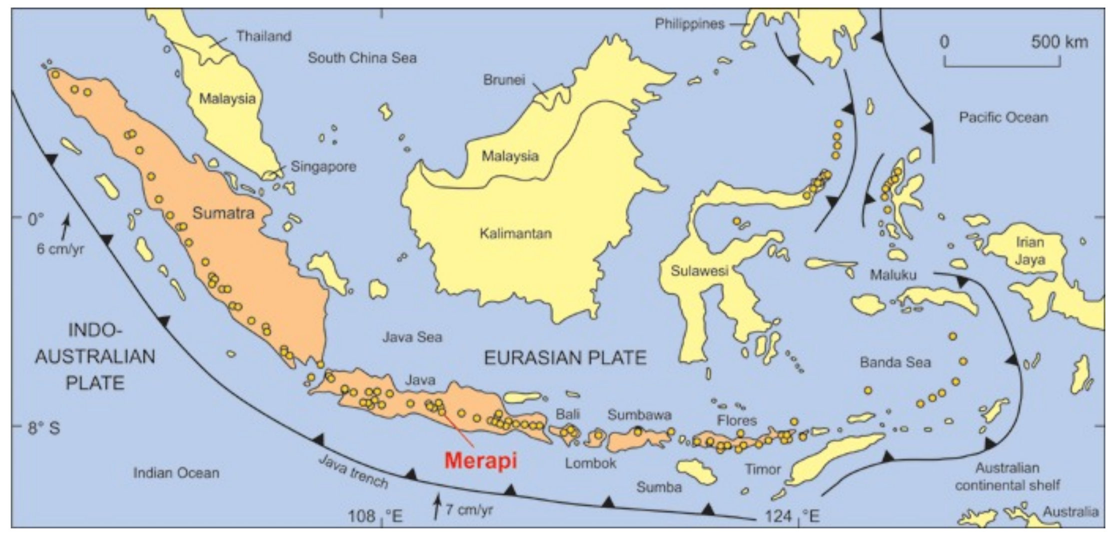
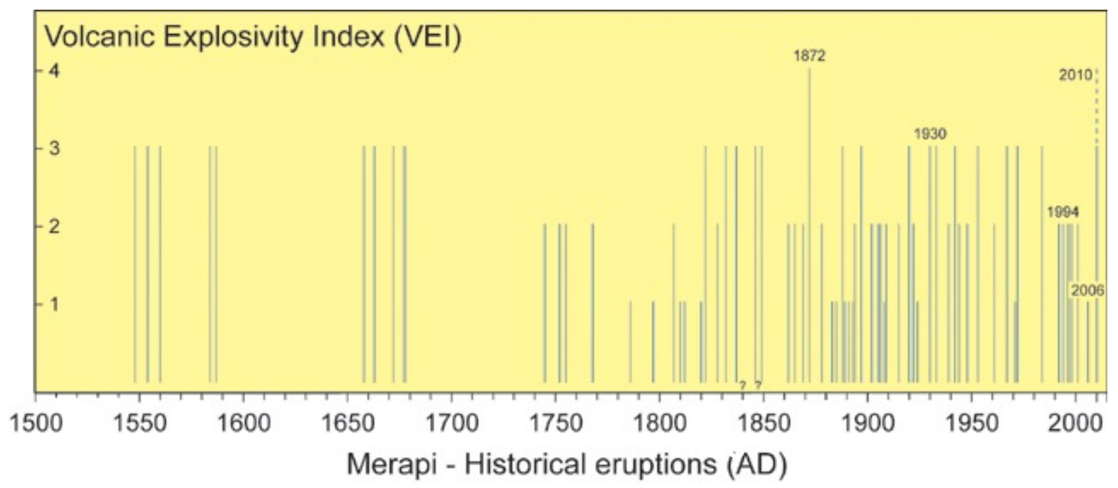
Tectonic settings and volcanic activity





Located about 30 km north of the city of Yogyakarta, Mount Merapi is considered as one of the most dangerous volcano of Indonesia with 3000 to 5000 fatalities since 1672 (Simkin & Siebert, 1994). About two million people live at less than 30 km from the active crater. The recent eruptive history of Merapi (Voight et al., 2000) is characterized by two eruptive styles:

1) recurrent effusive growth of viscous lava domes, with gravitational collapses producing pyroclastic flows known as « Merapi-type nuées ardentes » (VEI 2)

2) more exceptional explosive eruptions of relatively large size (VEI 3–4).

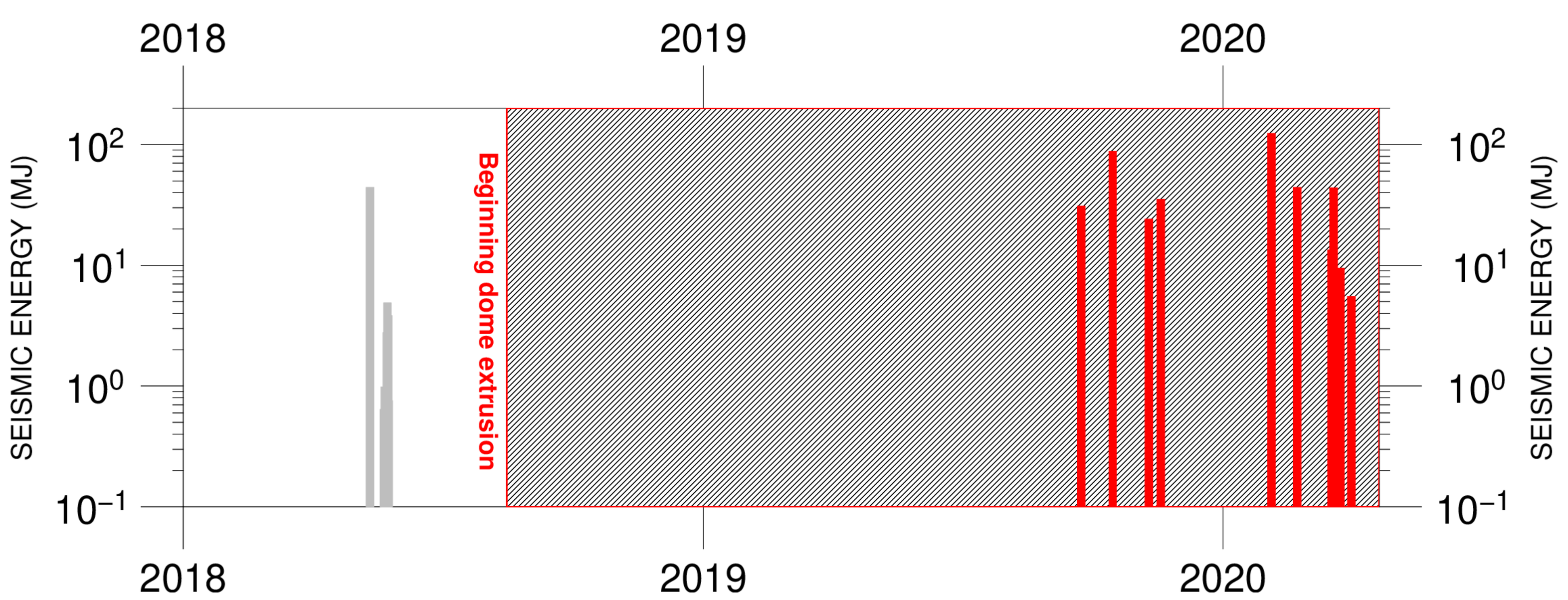
Recent phreatic and magmatic eruptive activity

Dome growing since August 2018

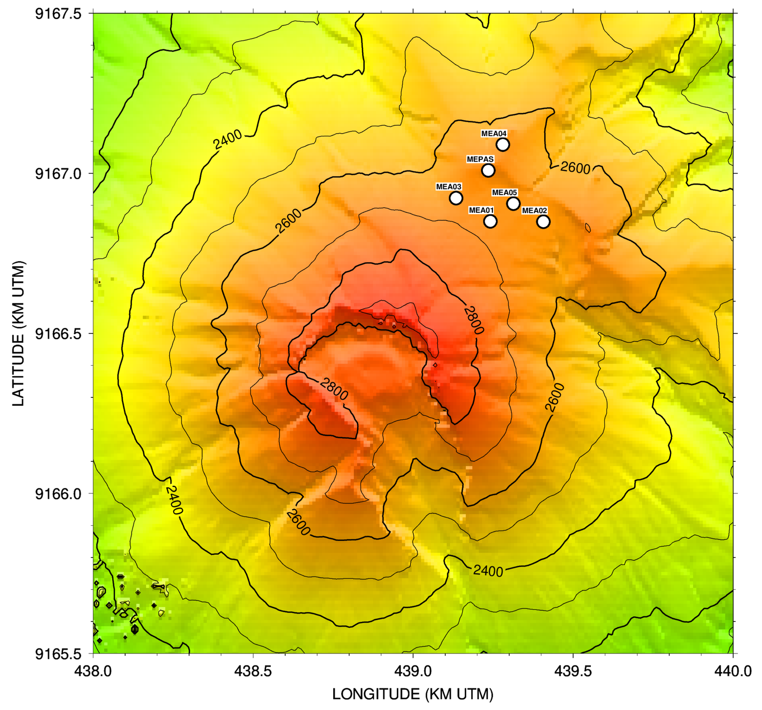
Explosion associated with dome collapse

A series of phreatic eruptions occurred in May–June 2018 followed by a magmatic eruption characterized by dome extrusion that started in August 2018. Magmatic explosions associated with dome collapse occurred in 2019 and 2020.

- 12 phreatic explosions between May 11, 2018 and June 1st, 2018
- 13 magmatic explosions between September 22, 2019 and April 10, 2020



Seismic antenna geometry



Pasar Bubar seismic antenna

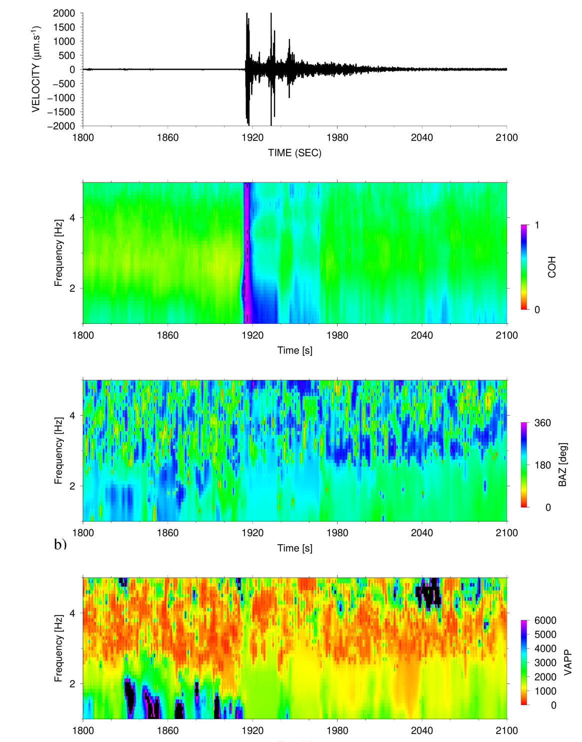
Position of the seismic recorders composing the seismic antenna MEA (white circles).

Sensors have a flat response characteristic from 30 s to the Nyquist frequency (50 Hz). This network has an aperture of 280 m. The shortest distance between sensors is 100 m.

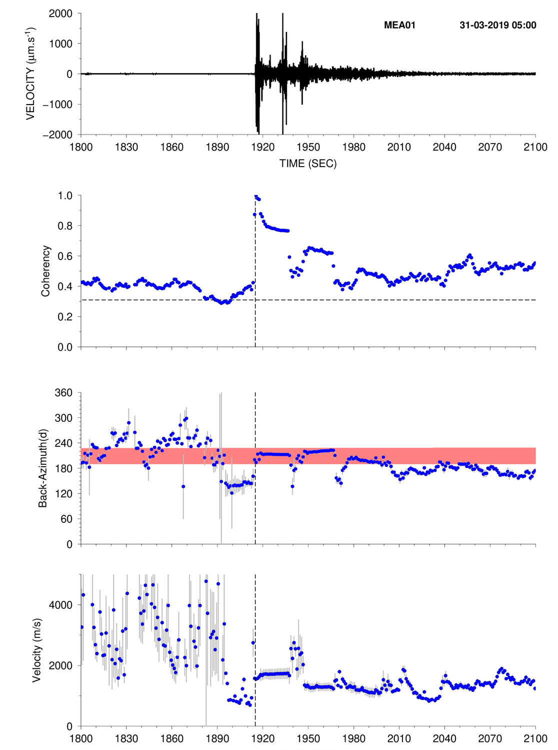
Array processing

In the perspective of a real-time application, the main analysis, which consists of estimating the slowness vector, requires a shorter computation time than the data acquisition time. We thus focused on a signal processing technique based on the calculation of time delays on the vertical component only and in a single frequency band. Given a set of time delays and associated errors calculated between each couple of sensors in the frequency domain, the corresponding slowness vectors can be recovered by inversion (Métaxian et al., 2002).

We estimate the slowness vector and deduce the back-azimuth and the apparent slowness (or velocity) for successive 20 seconds time windows along the seismograms recorded by MEA array.



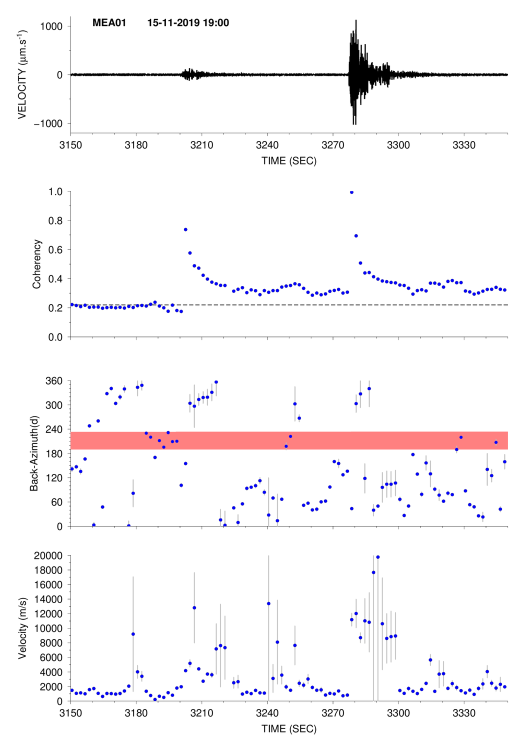
Multi-frequency analysis



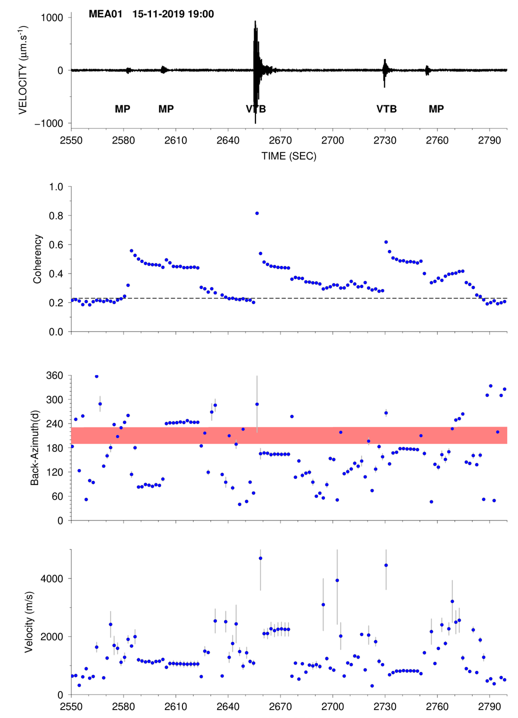
Frequency-band 0.5-3 Hz

Analysis of different volcano-seismic events

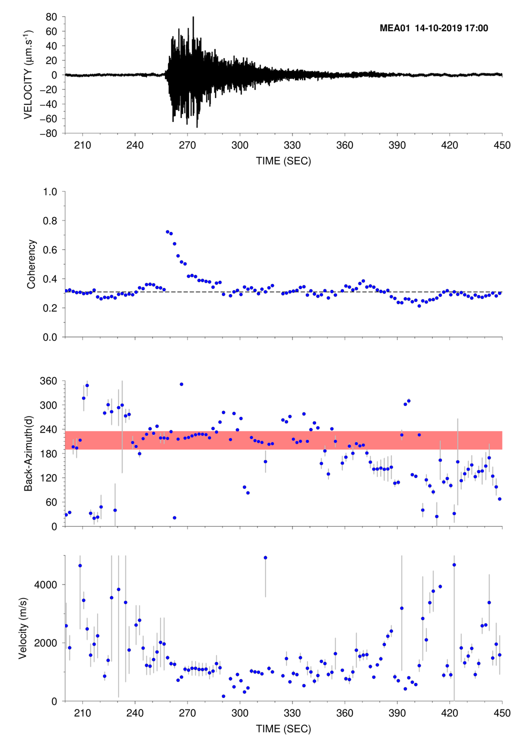
The position of the antenna in the crater area makes it possible to estimate the slowness vector only for superficial sources (<2 km deep)



Deep VT event

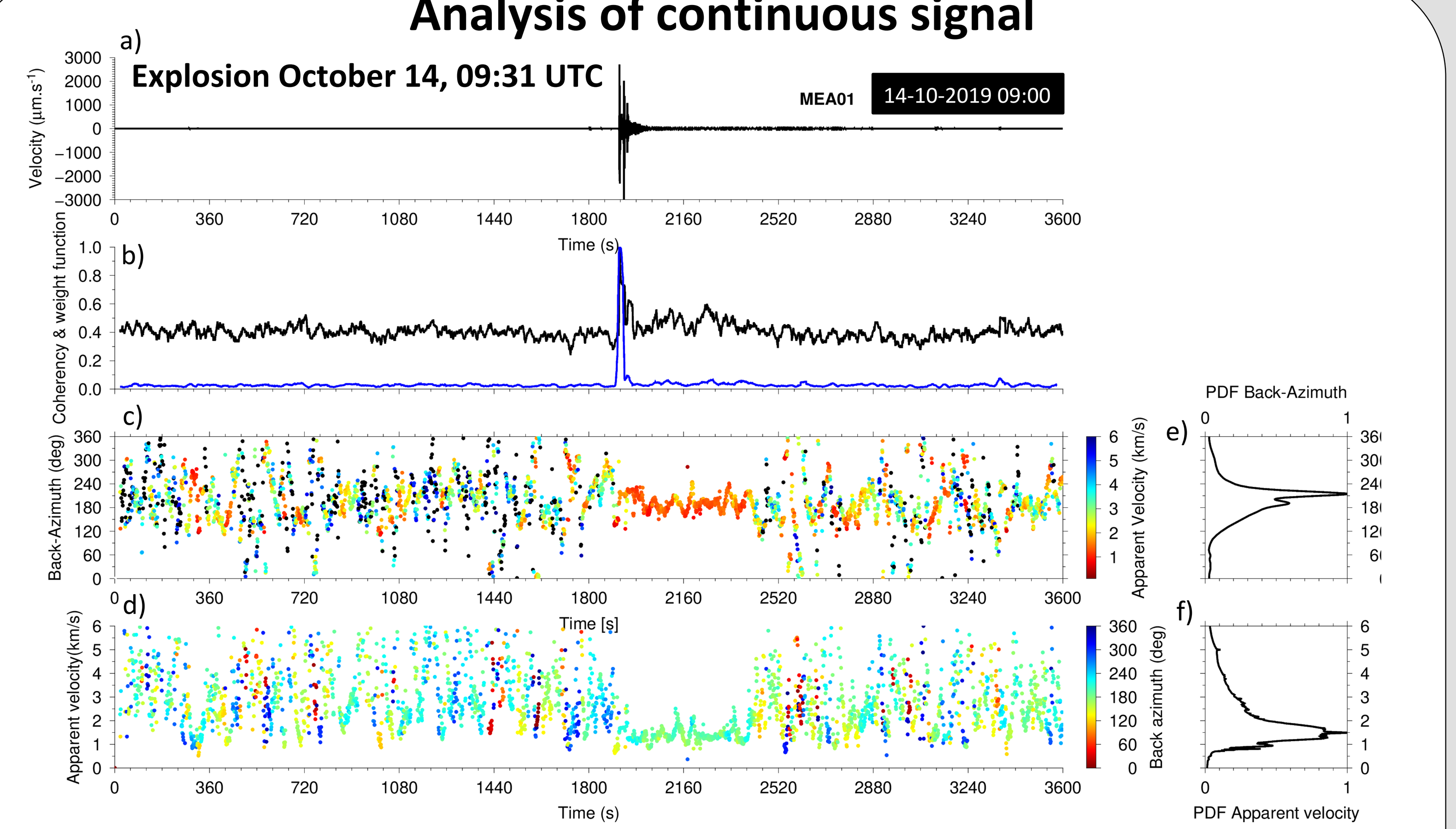


Multi-phase event (Hybrid) and superficial VT event



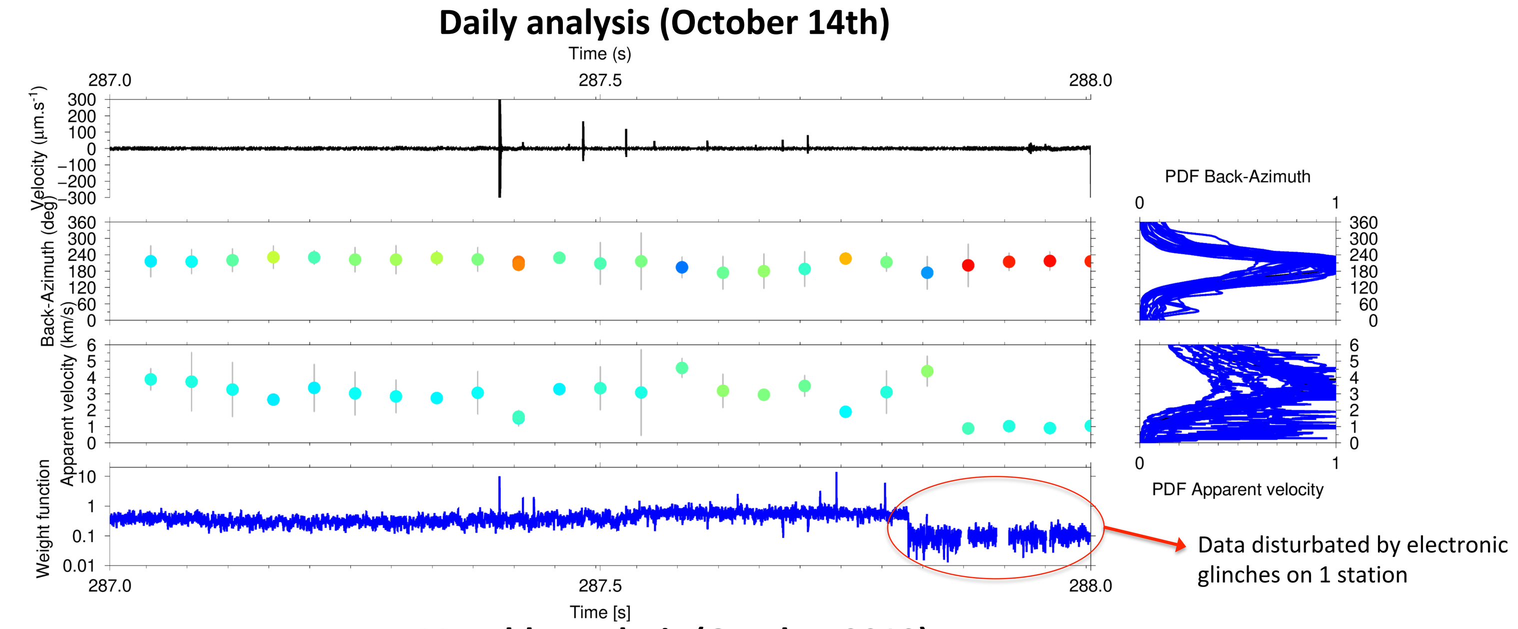
Pyroclastic flow event

Analysis of continuous signal

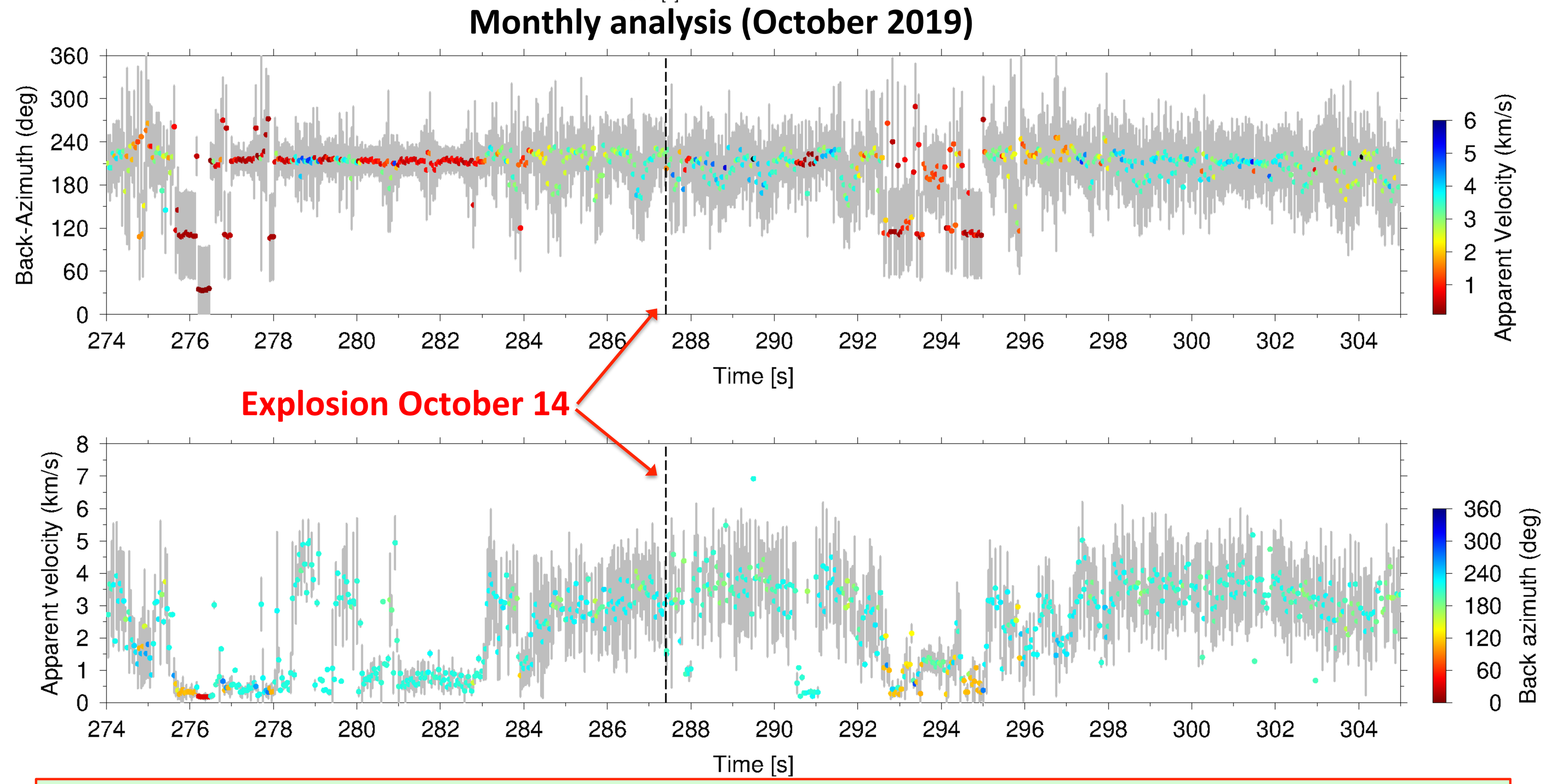


a) Unfiltered seismic record
b) Coherency averaged over all the pairs of stations (black) and a weight function expressed as a function of the derivative of the time delays (blue)
c) and d) Back-azimuth and apparent velocity expressed respectively as function of the apparent velocity and back-azimuth represented in color
e) and f) Hourly PDF of the back-azimuth and apparent velocity obtained by weighting time values of these 2 parameters by the weight function represented in b)

Daily analysis (October 14th)



Monthly analysis (October 2019)



Main results

- We estimate hourly values of a PDF of back-azimuth and apparent velocity in the frequency band 0.5-3 Hz, indicating the origin of the dominant seismic source as well as the type of waves and the source depth.
- Back-azimuth between 190° and 235° point the crater area
- Depending on the type of waves, apparent velocities between 1 and 2 km/s indicate superficial sources
- Time-variations of apparent velocity are not explained for now
- Computation takes a few seconds per day of data sampled at 100 Hz for an antenna of 4 to 6 sensors, making this processing adapted to monitoring.
- We plan to integrate this tool in WebObs system (Beauducel et al., 2020) for real-time monitoring of Merapi.