7.5.19

Global Perspectives on Volcano Monitoring: Automation, Standardization, and Capacity Building

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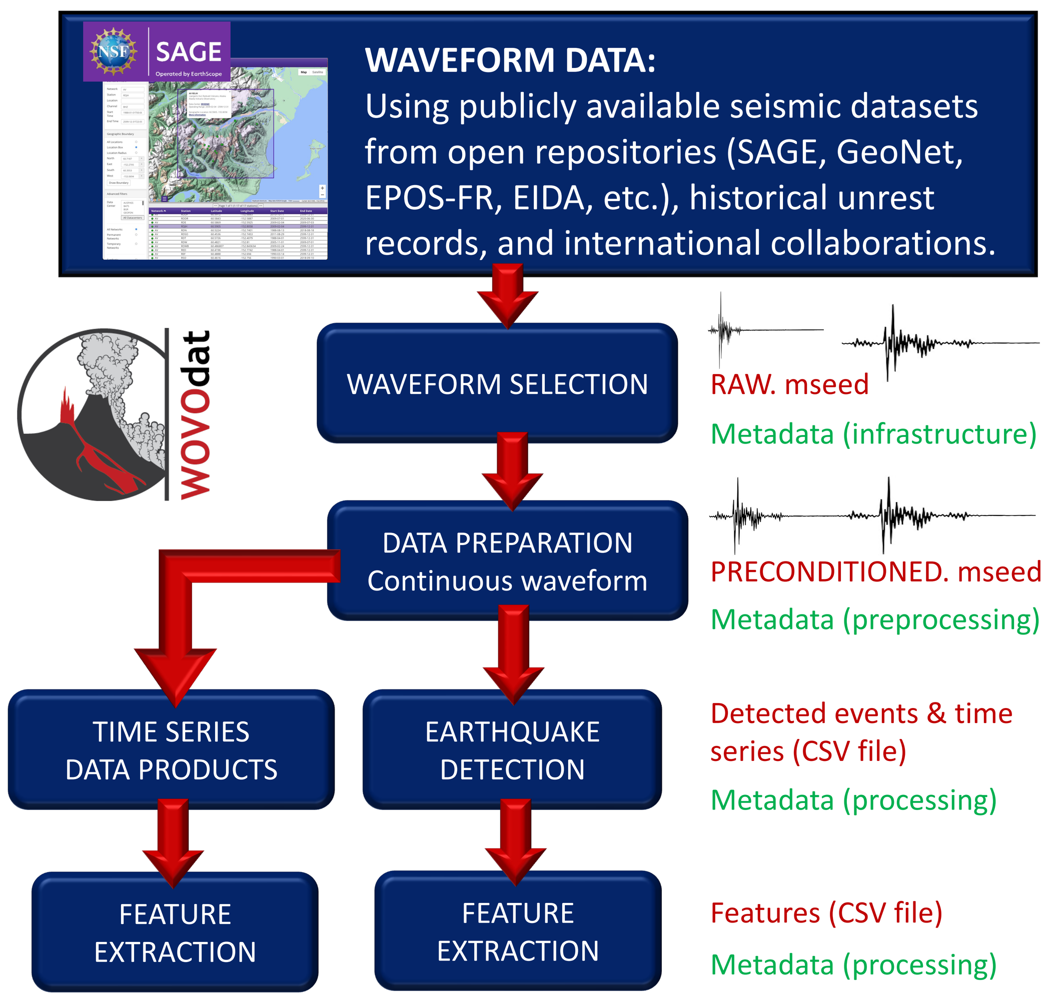
KEY POINTS SUMMARY

- Develop automated, standardized volcano monitoring workflows for reliable, efficient data processing, especially during crises to support early warning and timely decisions.
- Produce time-series outputs, including event classifications, amplitude analyses (RSAM, SSAM), and machine learning-based features.
- Identify and classify seismic characteristics across all volcanic activity stages to improve pattern recognition and eruption forecasting.
- Standardized data to enable consistent, cross-volcano and temporal comparisons with past unrest, strengthening probabilistic forecasting.
- Leverage public datasets, international part-nerships, and open-source tools to foster global collaboration and community capacity building.
- Contribute outcomes to WOVOdat, advancing shared knowledge and open science.

DATA PROCESSING WORKFLOW & TOOLS DEVELOPMENT



Google Form

We invite the global volcano community to support the standardised analysis of seismic data by sharing your thoughts, tools, and datasets through this Google Form.

Your contribution will help develop unified, standardised, automated tools to improve eruption forecasting and support timely, consistent decision-making.

Join this international effort to advance volcano-seismic research and build open science for all.

Towards standardizing and integration of the global volcano monitoring data for research and crisis response.

EARTHQUAKE DETECTION

MOTIVATION:

- ❑ Some volcanic earthquakes were not identified by volcano observers, and the coda waves of detected earthquakes were often not fully captured.
- ❑ As a result, the recorded earthquake durations are shorter than their true lengths.

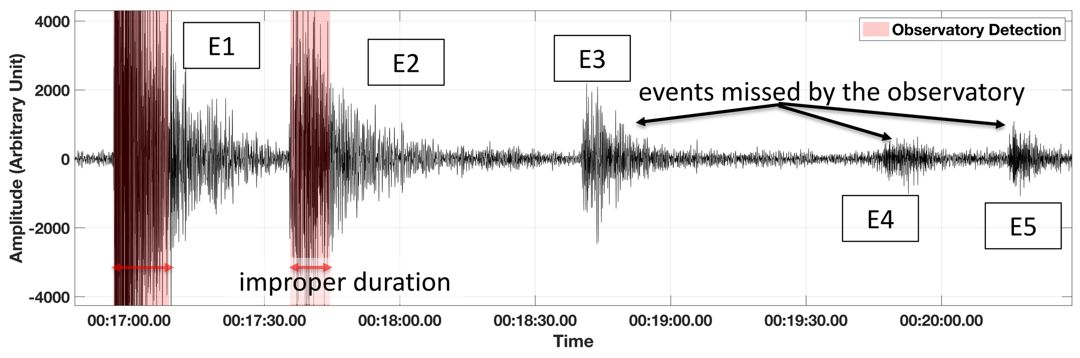


Figure 1. *Several visible earthquakes (E3, E4, and E5) were not identified by the observatory. Additionally, the coda waves of E1 and E2 were not fully captured.*

OBJECTIVE:

- ❑ Identifying more earthquakes
- ❑ Obtaining more proper durations for the detected earthquakes:
  - a) Not too short so that we get almost all the earthquake's phases (P, S, and Coda waves)
  - b) Not too long so that the noise does not overshadow the signals of interest

PROPOSED METHOD:

1. Derive noise statistics by applying STA/LTA to the noise segments from the 24-hour period of interest. The average and standard deviation of Log_{10}(STA/LTA) values across the noise are calculated. The mean is shown as the green line in Fig. 2, whereas the mean ± 3 standard deviations are indicated by the red lines.
2. The **trigger-on point** is identified when Log_{10}(STA/LTA) values exceed the upper red threshold.
3. The **transition point** is defined as the moment when the smoothed Log_{10}(STA/LTA) returns to the noise mean after one sinusoidal cycle (one peak – one trough). From this point, the algorithm searches for the **trigger-off point,** where the signal's envelope drops below a defined threshold (a constant multiplied by the envelope of the pre-event noise). The trigger-off point may occur either before (Fig. 2) or after (Fig. 3) the transition point, depending on the signal's characteristics.

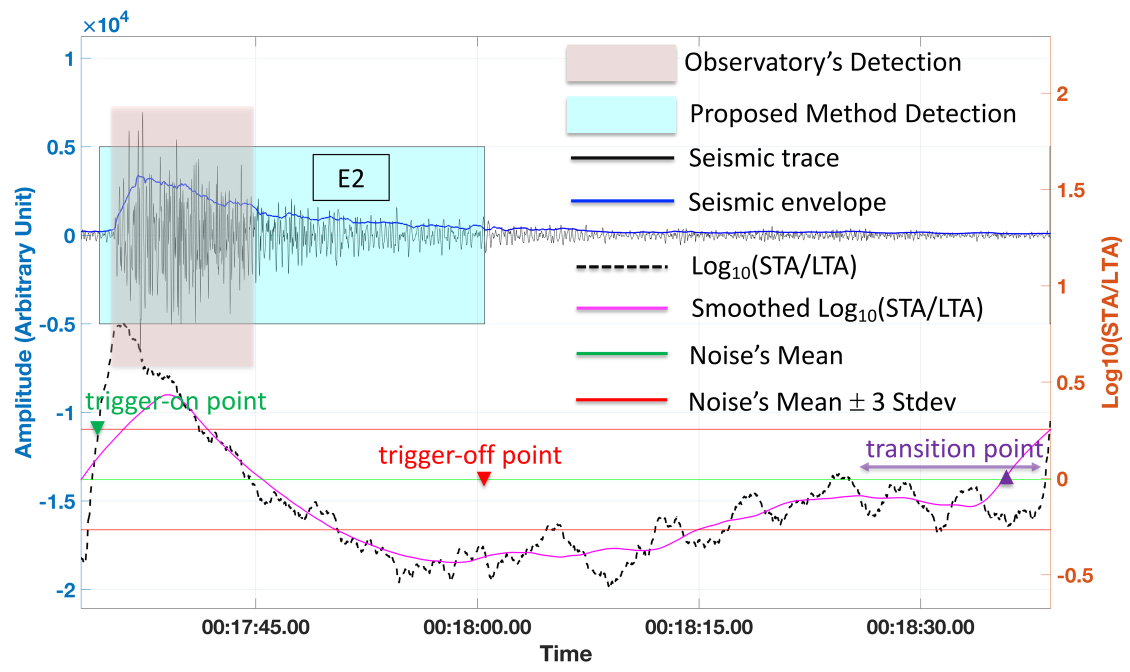


Figure 2. *Illustration of the proposed method applied to the detection of the E2 earthquake with an impulsive onset. In this case, the trigger-off point occurs before the transition point.*

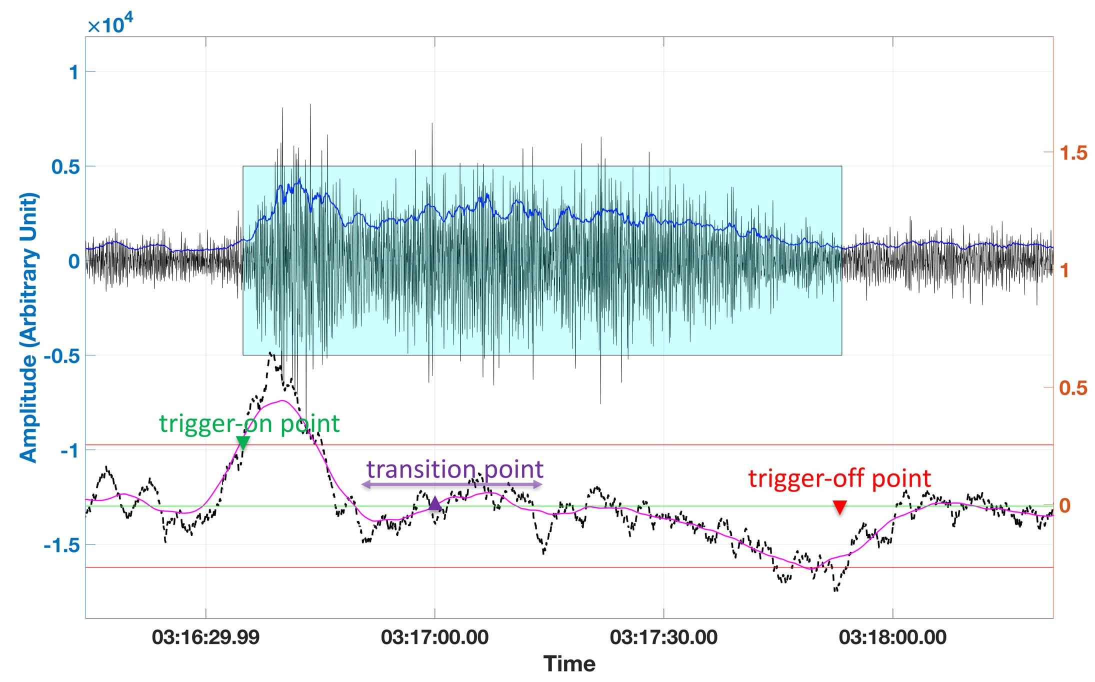
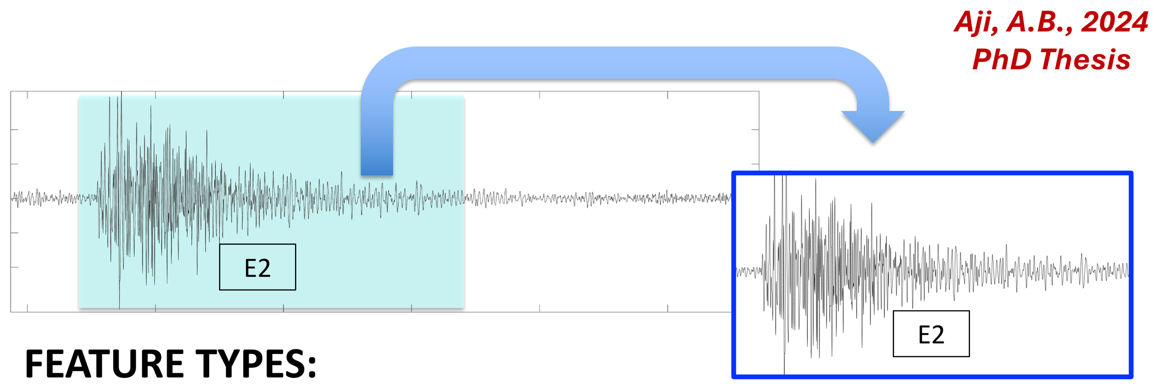


Figure 3. *Application of the proposed method to an earthquake with an emergent onset. In this case, the trigger-off point occurs after the transition point.*

FEATURE EXTRACTION

Aji, A.B., 2024 PhD Thesis



FEATURE TYPES:

- ❑ Statistical Feature (mean, standard deviation, kurtosis, skewness, etc.)
- ❑ Entropy Feature (Shannon entropy, Rényi Entropy, etc.)
- ❑ Shape Descriptor Feature (rate of attack, rate of decay)
- ❑ Energy Descriptor Feature (max energy, min energy, etc.)
- ❑ Polarity Feature (rectilinearity, azimuth, planarity, etc.)

The project emphasizes capacity building through open-source tools and training, actively involving students and observatory staff. Participants gain practical experience in analysing seismic activity across eruption stages, with observatory feedback guiding tool improvement and validation.

FEEDBACKS FROM THE OBSERVATORY

- ❑ Merapi Volcano Observatory (MVO) currently uses manual detection and classification.
- ❑ Eight volcano observers are stationed across two local observatory posts.
- ❑ There is no standardised procedure to define the onset (trigger – on) and the tail (trigger – off) of an earthquake
- ❑ Observers rely on two main methods for classifying the detected earthquakes:
  - a) Visual inspections of waveform shapes and amplitudes.
  - b) Audio cues from an audio system connected to seismic drum plots.

Merapi Volcano Observatory
BPPTKG – CVGHM – Geological Agency

MVO - VOLCANIC EARTHQUAKE PICKING SYSTEM (VEPS):

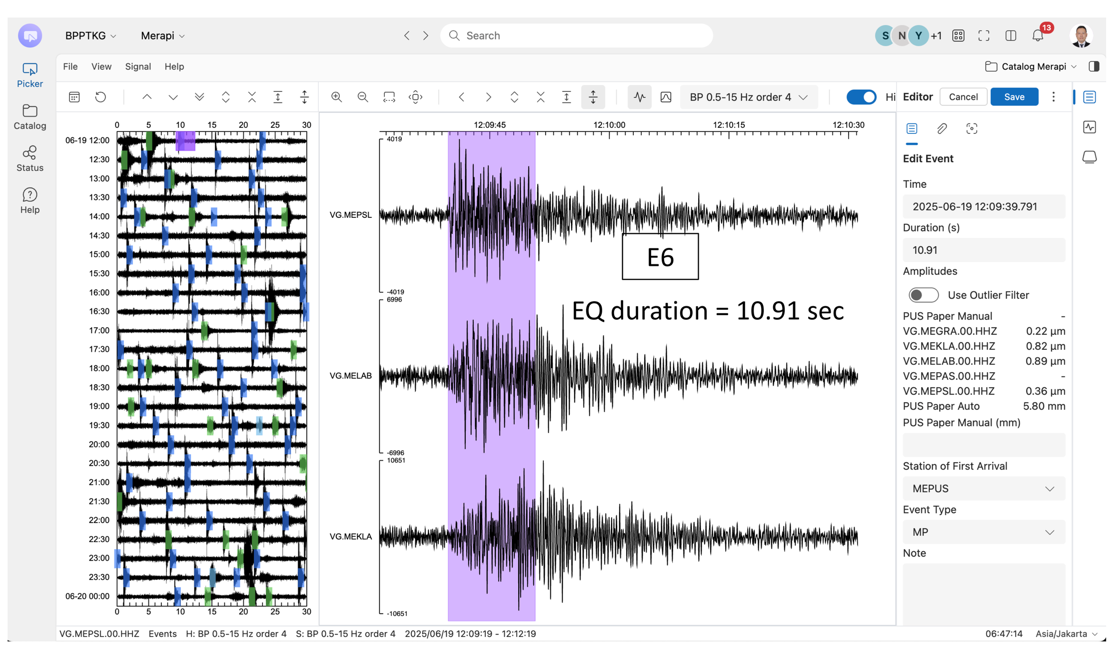


Figure 4. MVO has been developing an earthquake picking system, which has been in use since late 2024. Using this system, volcano observers continue to manually detect and classify earthquakes.

AUTOMATIC DURATION DETERMINATION FOR VEPS:

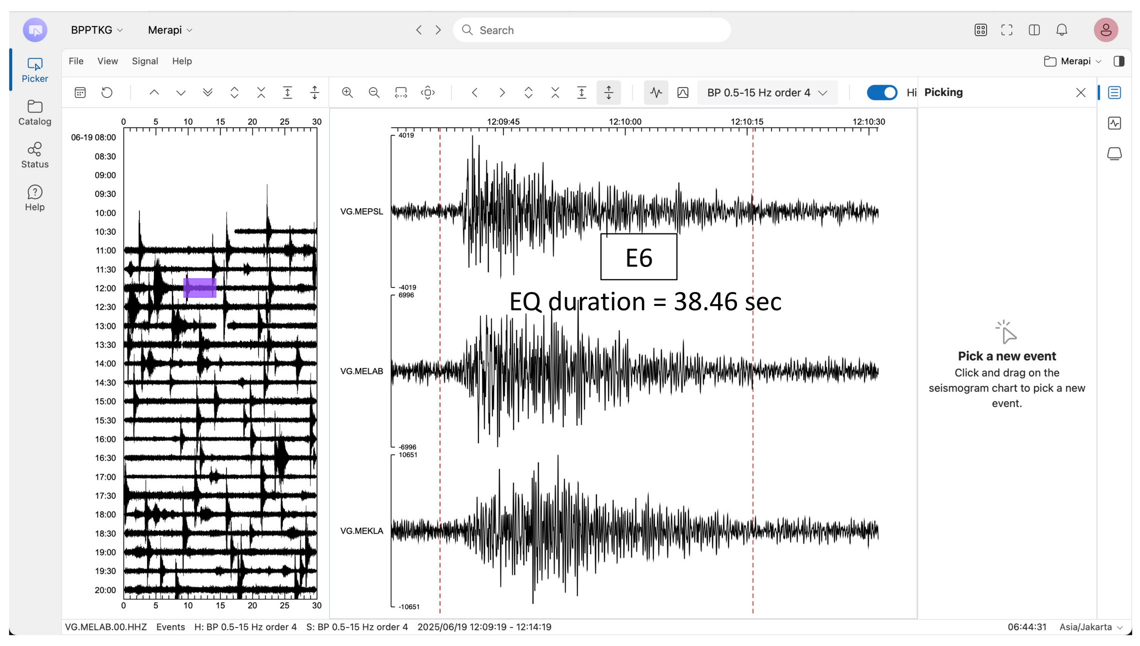


Figure 5. MVO is testing automatic duration determination. For the E6 event, manual picking measured 10.91 seconds (see Fig. 4), while the automated system estimated 38.49 seconds.

Selected references:

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3. *Latto, R.B., Turner, R.J., Reading, A., and Winberry, J.P., 2024. Towards the systematic reconnaissance of seismic signals from glaciers and ice sheets – Part 1: Event detection for cryoseismology. The Cryosphere, 18, 2061 – 2024.* https://doi.org/10.5194/tc-18-2061-2024

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