Detection of dynamically-triggered earthquakes using CNN for seismic phase discrimination

Kengo Shimojo
Meteorological Research Institute, Japan
shimjo@mri-jma.go.jp

Temporary stress disturbances caused by the passage of seismic waves from a large earthquake can trigger local seismic activities in distant areas (several times the fault length of the main shock) (e.g. Hill et al., 1993). In Japan, it has become known that dynamically triggered earthquakes occur in geothermal and volcanic areas (e.g. Yukutake et al., 2011), along active faults where large inland earthquakes have occurred in the past (e.g. Enescu et al., 2016), and in the tectonic tremor region of the Nankai Trough (e.g. Miyazawa and Mori, 2005). Since seismic activity caused by dynamic stress changes would reflect the fluids and fault plane conditions in the area, capturing dynamically triggered earthquakes in detail may be useful for disaster prevention.

However, dynamically triggered seismic activities are difficult to detect automatically because the magnitudes are generally small and occur during times when the noise level is high due to subsequent waves after the large earthquake. Some studies have attempted automatic detection using techniques such as template matching (Peng and Zhao, 2009), but this method is not suitable in areas where the number of earthquakes is small, or where the distribution of template earthquakes is unbalanced, and in such area capturing dynamically triggered earthquakes relies on visual inspection.

Therefore, we utilize the PhaseNet model which learns seismic waves observed in Japan (Naoi et al., 2024) for seismic wave discrimination and picking phase to the observed velocity waveforms at the stations operated by JMA, MOWLAS, and universities all over Japan, and perform the automatic detection of dynamic triggered earthquakes using parameters (probability threshold for detection and filter-band for observed waveforms) that were tuned to resemble the distribution of the stations where triggered earthquakes were detected by visual inspection immediately after the 2016 Kumamoto earthquake (Enescu et al., 2016).

As shown in Figure, calculating β-value (Matthews and Reasenberg, 1998) for each station, we can obtain the distribution of stations similar in detail to the result of visual inspection. In addition, we will also present the results of applying this technique to earthquakes of M7 or larger occurring around the world, and the relationship between triggered areas and dynamic stresses.

References

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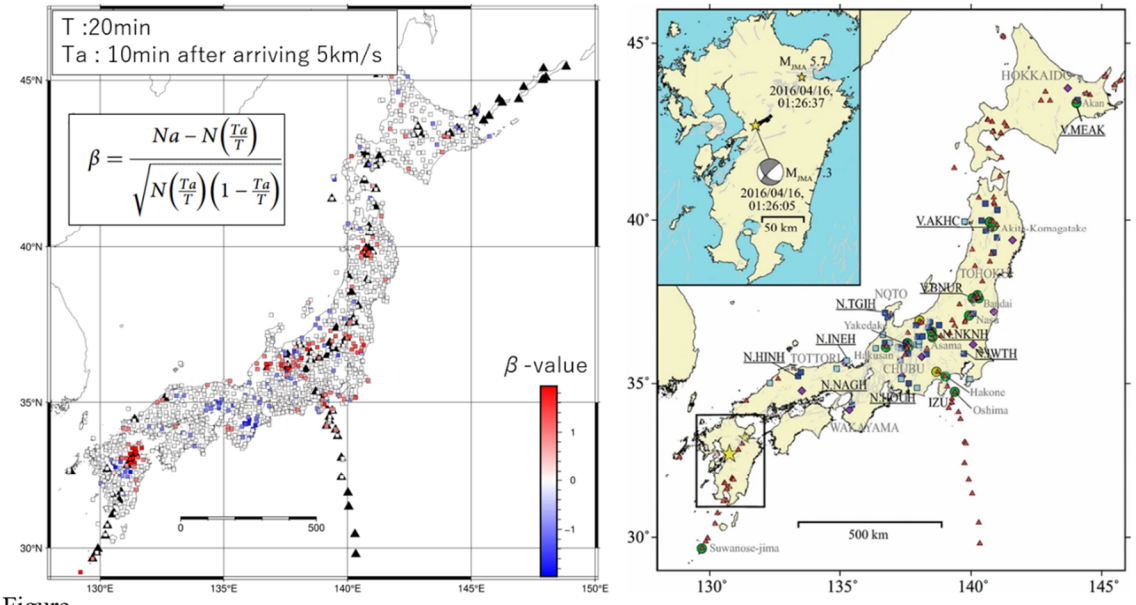

Figure

Left: Distribution of β values for each station when Ta is set as 10 minutes from the arrival time of the 5 km/s wave from the Kumamoto earthquake.

Right: Distribution of stations where triggered earthquakes were visually detected (Enescu et al., 2016).