

## A new method of hypocenter determination without clear phases: Application to low-frequency events beneath Tokachi-Dake

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Hypocenters are generally determined by a method that focuses on onsets of P and S waves. As the number, density and quality of seismic stations are recently enhanced, low-frequency events and tremor-like events with small amplitude and large duration without any clear onsets of P or S waves have been discovered. Epicenters of these events cannot be therefore determined precisely by the conventional methods. New approaches for epicenter determination are required without picking up onsets of P and S waves.

In this study, we introduce a new method, Relative Maximum Algorithm (called RMA hereafter). This is the hybrid method of the Source-Scanning Algorithm (SSA) (Kao, 2004) and the Network Correlation Coefficient (NCC) (Ohta, 2008). This utilizes the maximum of amplitude in each seismogram and determines its focal point and origin time relative to those of a reference event given. Using the relative difference in arrival time between the reference event and a target event at each station as our data set, we can remove complex site and path effects significantly, so that the measurement of the arrival time difference should become accurate. Compared with NCC that uses envelopes of observed data, we may avoid the non-uniqueness in our focal determination because we use the maximum of each record.

The events used in this study are located in a 20-30 km depth range in the Tokachi-dake region, in the middle of Hokkaido, Japan, which occurred in November 2002. We used seismograms recorded at up to twelve Hi-net stations around this volcanic region. We determine their focal points and compare their results each other. We confirm that the focal point of each event can be determined with precision of about 3 km in all the direction by three methods. Its horizontal location (i.e., hypocenter) is similar to each other, but RMA provides us with stable and accurate results even with the location in depth.

According to the results of focal points determined by RMA, low-frequency earthquakes (LFEs) under Tokachi-dake occurred not only in the depth range of 20-30 km, but some of them took place in a shallow region of 10-20 km as well. We consider there are some fluid migrations up to this shallow region, which was associated with the series of these seismic activities.

Keywords: hypocenter determination, waveform correlation, lower crust, low-frequency earthquake, volcanic region, Tokachi-Dake