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Hypocenter Determination of Deep Crustal Earthquakes in Hokkaido by a Master Event Method with Cross-Correlation of waveforms

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1. Introduction

As the number, density and quality of seismic stations are recently enhanced, seismic events with small amplitude and large duration without any clear onsets of P and S waves have been discovered.

In this study, we combined Source-Scanning Algorithm (SSA) (Kao and Shan, 2004) and the conventional Master Event Method to improve the accuracy of relative hypocenter determination.

2. Method

At first, we select an event with large amplitude and clear signal as a reference or master event with the seismogram m_i (t) recorded at the i-th stations i (i = 1,,, N). e_i (t) is the seismogram at the same station for an event near the master event. We take the cross-correlation between m_i (t) and e_i (t) at each station. Next, applying the idea of SSA we read the time of the maximum cross-correlation at each station. Using the relation between the travel time and location-origin time based on the ray parameter and velocity structure around the master event, we average cross-correlations of all the stations at each grid point in space and time relative to the master event, which is called 'brightness'. Finally, we select the point and time with the maximum brightness as its hypocenter and origin time. We here need the assumption that the source functions of the two events are not far from each other, but we expect to determine the hypoceter and origin time of the target event relative to the master event precisely because any complicated propagation and site effects should be cancelled out by these procedures.

3. Result

We applied this method to the events around Mt. Taisetsu Caldera in the central Hokkaido at depth of 15-35 km. The events are called deep crustal low-frequency earthquakes and found under some active volcanos in Hokkaido (Takahashi et al., 2000: Matsubara et al., 2004). The hypocenters cannot be determined well using travel times of P and S wave because their onsets are not clear due to either the ductile lower crust or the possibility of the contribution of fluid. In this study, we selected an event on 24th November 2002 at the depth of 22 km as the master event, which is the largest in 2002-2004. We referred its location and origin time determined by Hi-net. We applied the present method to waveforms at 8 stations for other four events around the master event and relocated their hypocenters and origin times. P and S wave packets are identified in record for the master event, we used both P and S waves with time window of 20 sec as m_i (t). For the other events, P and S waves are barely identified even if they are band-pass filtered, because of their small sizes. Nevertheless, we pick up the same 20- sec P and S records as e_i (t) even without any clear onsets.

We used the one-demensional velocity model of Katsumata et al. (2003). As a result, we succeeded to relocate their hypocenters relative to the master event with accuracy of about 1 km in horizontal and 2-4 km in vertical. Another advantage of SSA is that the accuracy of hypocenter determination is defined clearly by calculating brightness at all the neighboring points and times. We compared our result with that with the seismograms after 5 Hz band- pass filtered in order to cut ambient noise. Their hypocenters are almost identical, and the original result using raw data with high frequency contents show its precision and stability with less estimated errors, encouraging us that we may process raw waveform data with our method. Compared with the results reported by Hi-net, our horizontal locations are almost similar, but the focal depths becomes systematically shallower. Although the detail of reasons for this discrepancy is not clear, this can be due to the readings of delayed onsets of P and S waves by Hi-net with much noise in seismograms. In summary, the present method is effective for hypocenter determination for events without any clear onsets of P and S waves.