Development of automatic tsunami-detection method based on continuous analysis of offshore tsunami waveforms

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Large tsunamis can be generated by not only earthquakes but also natural phenomena. For example, in the 1998 Papua New Guinea earthquake, it was pointed out that the tsunami was amplified by a submarine landslide. When the non-seismic tsunamis are generated offshore, the offshore tsunami observation is effective for early and direct tsunami detection. In Japan, dense offshore tsunami observation networks such as S-net and DONET are in operation, and it has been shown that an optimal interpolation method that is one of the data-assimilation techniques is effective to estimate the present tsunami-wavefield from the ocean-bottom pressure gauge (OBPG) data of these networks without earthquake information (e.g., Maeda et al., 2015). In these methods, the time history of the observed data is gradually incorporated into the tsunami propagation model during the successive analysis. On the other hand, if the time series data are directly used in a single analysis and the time history information is explicitly incorporated, the wavefield is more strongly constrained and the ability of tsunami monitoring may be improved. In this study, we are investigating a method for automatic detection of tsunamis by simple analysis of tsunami waveforms (time series data).

Our method is inspired by the GRiD MT (Tsuruoka et al., 2009), which automatically estimates the origin time, hypocenter location, moment tensor (MT) solution, and magnitude from seismic waveforms. First, in advance of tsunamigenic phenomena, a sea surface element wave source is distributed in the sea area to be monitored, and the Green's function of the tsunami waveform at the OBPGs is obtained by tsunami numerical calculation. Then, assuming that the tsunami is generated at one elemental source, the initial sea-surface displacement at any elemental source is estimated from the observed tsunami waveforms at multiple stations, and the variance reduction (VR) between the observed and theoretical waveforms is calculated. This is done for all the elemental wave sources. This successive analysis is carried out at temporal intervals to monitor the spatio-temporal distribution of VR, and the time and location of tsunami generation are detected based on the increase of VR.

The method was tested by synthetic tests in the sea area along the Japan Trench. A Gaussian distribution (size: ~10 km) is used as an elemental wave source from off the Etorofu Island to off the Boso Peninsula. The data length of the OBPG waveform used for the inversion is 15 minutes before the time of analysis execution. The analysis is conducted every minute from 15 minutes before to 15 minutes after the true origin time. Our method was applied to the synthetic observations of the S-net OBPGs that were computed by assuming a 50-km-long and 25-km-wide fault model near the trench. The results showed that the VR was maximum (about 0.3) at the elemental source nearest the true fault location at the timing consistent with the true source time, indicating the possibility of detection by our method. In the future, we will examine the effect of the difference of the target tsunami source and the real observation noise on the performance of our method.

Acknowledgments: This work was partially supported by JSPS KAKENHI Grant Number JP18K04674.

Keywords: Tsunami, non-seismic tsunami, Automatic detection

