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Tsunami Inundation Forecasting System Based on a Database: A Case Study in Owase, Japan

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In this paper, we conducted a study of a tsunami inundation forecasting system with a case study in Owase City, Japan. In this study, a database that consists of precomputed tsunami inundation and waveforms from multiple scenarios is developed. The system is divided into two stages. In the first stage, preliminary earthquake information is used to find the appropriate tsunami inundation scenario in the database. In the second stage, a real-time tsunami waveform simulation is conducted to find the best-case scenario by minimizing the error between computed tsunami waveforms and those in database. Furthermore, this method is able produce good tsunami inundation forecasts in a reliable time.

INTRODUCTION

The 2011 Tohoku earthquake left more than 15,000 people dead or missing (Kazama and Noda, 2012). It was the biggest earthquake followed by a tsunami ever recorded in Japanese history. Tsunami warnings and advisories were issued for areas along the coast of Hokkaido to Kyushu and the Ogasawara Islands (Ozaki, 2011). The Japan Meteorological Agency (JMA) estimated that the initial earthquake magnitude was Mjma 7.9, obtained within three minutes after the earthquake. Then, it was revised to be Mjma 8.4 in more than an hour after the earthquake (Ohta et al., 2012). Further study revealed that those magnitudes underestimated the actual earthquake magnitude of Mw 9.0 (e.g., Gusman et al., 2012; Satake et al., 2013).

A future Nankai Trough earthquake located in the southeast region of Japan is expected to occur in the near future and could be possibly more destructive than the 2011 Tohoku earthquake. On the basis of historical records, Ishibashi (2004) explained that a great earthquake has a recurrence interval of 100–200 years. Compared with the other earthquake zones in Japan, the Nankai Trough is located very close to the coast (less than 150 km) (Mulia et al., 2017); if an earthquake followed by a tsunami occurred, a resulting tsunami wave would need only a short time to reach the coast.

On the basis of experiences during the 2011 Tohoku tsunami and the possibility of a tsunami generated by a future great interplate earthquake of the Nankai Trough, a robust and accurate tsunami inundation forecast system is required. Tang et al. (2008) developed a tsunami forecast model for the Pacific and Atlantic coasts by using a tsunami source function database. DART (Deep-ocean Assessment and Reporting of Tsunami) data were used as the main input of the system. When an earthquake occurred, the data obtained from DART were used to compute a tsunami source for real-time tsunami simulation. Abe and Imamura (2012) applied a tsunami inundation database for a tsunami inundation forecasting system in the case of the 2011 Tohoku earthquake. Real-time tsunami height information obtained from GPS buoys was used as an additional constraint to produce an accurate inundation forecast. However, because of the limited number of GPS buoys, when a GPS buoy is located far from the forecasted area, it may produce the wrong inundation forecast. Gusman et al. (2014) proposed a new real-time tsunami inundation forecast system called NearTIF (Near-field Tsunami Inundation Forecasting), also with the study case of the 2011 Tohoku earthquake. This system uses a database that consists of a tsunami inundation map and tsunami waveform at the virtual comparison points. The database was developed by assuming a number of hypothetical thrust-type earthquake scenarios in a subduction zone. Van Veen et al. (2014) implemented an early warning system in Sumatra called RiskMap. This system was also constructed based on 1,250 hypothetical earthquake locations. This system was purposed not only to produce tsunami inundation forecast but also to warn residents by turning on sirens for the warning and evacuation process. Those previous studies have a similar assumption in developing their database; they assume simple fault model scenarios as tsunami sources and compute them by solving a nonlinear shallow water equation. The method proposed by Tang et al. (2008) may be suitable for far-field tsunamis in which DARTs are located far from the coast, while the methods proposed by Abe and Imamura (2012), Gusman et al. (2014), and Van Veen et al. (2014) are more appropriate for near-field tsunamis, as their methods utilize an observational system that is close to the coast. Earthquake information is not necessary for the method of Gusman et al. (2014) but is still required for the other methods. Oishi et al. (2015) conducted direct tsunami numerical simulation by using the K supercomputer. It was required only 1.5 minutes to obtain accurate tsunami inundation in Sendai City.

From those previous studies, it can be concluded that there are two main types of tsunami inundation forecasting systems: those that utilize a database and those that conduct direct numerical forward modeling (NFM). For direct NFM, a high-performance computer or supercomputer is usually used to shorten computational

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