Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

MIS003-01 Room: 303 Time: May 28 15:30-15:45

Near-field tsunami forecasting from ocean bottom pressure and onshore GPS data

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We have developed methods for near-field tsunami forecasting from cabled ocean bottom pressure gauge (OBPG) data and onshore GPS data based on the method developed by Tsushima et al. [20 09], tsunami Forecasting based on Inversion for initial sea-Surface Height (tFISH). tFISH is a versatile algorithm allowing rapid estimation of coastal tsunami waveform. The tsunami waveform calculation is based on the initial sea-surface height distribution inverted from OBPG data. By expressing a tsunami source as initial sea-surface displacement distribution, no specific assumptions are required for the source parameters, such as fault geometry, in performing the inversion. tFISH is equipped with very fast tsunami waveform calculation made by superposition of Green's functions calculated in advance and stored in a database. By virtue of the fast calculation, tFISH is applicable to real-time forecasting. Another merit of tFISH is that it performs the inversion and waveform synthesis repeatedly by progressively updating the OBPG data to improve accuracy of tsunami forecasting. In spite of these merits, tFISH has a major deficiency required to be remedied: the prediction accuracy of coastal tsunami by tFISH may not be high enough immediately after the earthquake occurrence. This shortage comes from slow propagation of tsunami. It may take at least ~ 10 min to obtain tsunami data sufficient to estimate parameters of a tsunami at OBPGs. If a great tsunami occurs near the coasts, the tsunami forecasting based only on tsunami data may not provide accurate predictions before actual tsunamis reach the coastal communities.
To overcome the shortage, we use onshore GPS data for the tsunami forecasting. Surface displacement due to coseismic slip at a seismic fault can be measured at GPS stations immediately after the earthquake. Furthermore, the extent of an earthquake fault can be estimated from the spatial pattern of coseismic surface displacement at GPS stations. We performed the inversion of the onshore GPS data of the 2003 Tokachi-oki earthquake to estimate the slip distribution at the predefined subfaults aligned on the plate boundary, and then we calculated coastal tsunami waveforms. Comparison between the observed tsunami waveforms and the calculated tsunami waveforms shows good agreement, demonstrating that onshore GPS data can provide rapid and fairly reliable tsunami forecasting. It is difficult for onshore GPS data to estimate accurate slip amount for far offshore area while the seafloor deformation can be measured by the OBPG. Therefore, joint use of GPS and OBPG data can improve the reliability of tsunami forecasting. As an example of the joint analysis, we developed an inversion method in which the OBPG data is inverted to improve tsunami source parameters by using the GPS inversion result as a reference model. We applied this new method (differential inversion) to the onshore GPS and the OBPG data of the 2003 Tokachi-oki earthquake. As a result, the accuracy of the forecasting progressively increases as the amount of OBPG data increases in the early period of the tsunami forecasting (10-15 min after the earthquake). These results demonstrate that the methods developed in the present study contribute to improvement of the forecasting accuracy of coastal tsunamis before sufficient quantity of OBPG data is available for reliable forecasting.

Keywords: Tsunami forecasting, Ocean bottom pressure gauge, GPS