Tsunami early warning system in Japan and plans towards practical uses of GNSS data to tsunami warning operation of the JMA

*NISHIMAE Yuji[1], ISHIKAWA Norihiko[2]

1. Japan Meteorological Agency, 2. Geospatial Information Authority of Japan

A tsunami warning must be issued immediately after occurrence of an earthquake because many earthquakes occur near coasts and a tsunami hits coasts in a short time in Japan. The Japan Meteorological Agency (JMA) issues a tsunami warning in about three minutes. Numerical tsunami simulation is a powerful tool to predict a tsunami. Numerical tsunami simulation takes a long time and the time are not adequate to terminate calculation up to issuance of a tsunami warning. For this reason, the JMA calculates a lot of tsunami simulations to various source models in advance and creates a database of tsunami scenarios. And when an earthquake actually occurs, the closest scenario are chosen from the database based on the hypocenter and magnitude of the earthquake, and a tsunami warning can be issued in about 3 minutes. The magnitude called JMA magnitude (Mjma) is used the first warning to ensure issuance of a tsunami warning in about 3 minutes. The amplitude of seismic waves with short periods is used for quick estimation of Mjma. Mjma based on the short-period waves is saturated in case of a huge earthquake. As a result, the size of the earthquake is likely underestimated. Actually, in case of the Great East Japan Earthquake, the JMA could quickly obtain Mjma and could issue a tsunami warning in about 3 minutes. The estimated Mjma was 7.9 and it was by far smaller than moment magnitude (Mw) of 9.0 and that led underestimation of the tsunami heights. The JMA have developed several methods how to evaluate underestimation of Mjma. And if underestimation of Mjma is evaluated using those methods, the JMA will issue a tsunami warning based on the largest assumed tsunami heights or the largest size of the earthquake in the region. And then, after the accurate Mw will be obtained by CMT analysis or W-phase analysis, the tsunami warning will be updated. The JMA have also updated or lifted the tsunami warning using sea level changes observed by offshore and coastal tide gauges besides the earthquake data. The Meteorological Research Institute of the JMA developed the new method called tsunami Forecasting based on Inversion for initial sea-Surface Height (tFISH) to predict more accurate tsunami heights. tFISH is a method for predicting tsunami heights along coasts from distributions of initial tsunami heights at the tsunami source estimated by inverse analysis of tsunami waveforms observed at offshore tsunami meters. tFISH has been used to update a tsunami warning since March 2019.

The Geospatial Information Authority of Japan (GSI) has operated GNSS Earth Observation Network System (GEONET) which consists of more than 1000 GNSS sites. The GSI recently developed the REal-time GEONET Analysis system for Rapid Deformation monitoring (REGARD) (Kawamoto et al., 2017). REGARD can rapidly and automatically estimate a rectangular fault model or slip distributions on plate boundaries based on permanent displacements which are generated at the GNSS sites by an earthquake. In post-evaluation of the Great East Japan Earthquake, REGARD could estimate Mw 8.8 in about three minutes (Kawamoto et al., 2017). If Mw by REGARD could be obtained in time up to issuance of a tsunami warning, the Mw might be used for evaluation of underestimation of Mjma.

The JMA has considered criteria and procedures for utilization of Mw by the REGARD in cooperation with the GSI and has used to update tsunami warning as a trial in tsunami warning operation since March 2019 if solutions of all of CMT analysis are estimated in low quality. The JMA has plan to use a rectangular fault model or slip distributions estimated by REGARD as the initial source of real-time numerical tsunami simulation. The JMA is now exploring potential for abovementioned utilizations of REGARD.

Reference
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