GNSS IN TSUNAMI EARLY WARNING SYSTEMS: CAN THE M~7 EARTHQUAKES BE PROCESSED?

Pupatenko, V.V.
Institute of Tectonics and Geophysics FEB RAS, Khabarovsk, Russia

Large tsunamis are infrequent but very dangerous natural hazards. Its main source is large underwater earthquakes, which cannot be predicted. However, one can use early registered earthquake data to forecast possible tsunami hazard and provide warning information to the people.

There are several tsunami forecast methods (Titov et al., 2005), but for the regions close to the epicenter, only one seismic method based on the magnitude threshold is applicable (Gusiakov, 2016). In this method the tsunami alarm is announced when the magnitude exceeds some threshold (M=7 for most of the regions). The theoretical efficiency of this approach shows extremely low probability (0.15%) of missing the tsunami, but also very high probability (77%) of false alarm (Gusiakov, 2016). The statistic of the Tsunami Early Warning Services proves these estimations (The 4(5) October 1994 Shikotan …, 2015).

One of the perspective concept in tsunami forecast is using the data of Global Navigational Satellite Systems (GNSS). Primarily, GNSS data can help with rapid reliable magnitude estimation of the strongest (M>8.5) earthquakes (Melgar et al., 2016). Moreover, GNSS data can also solve the false alarm problem. Using the rapidly measured coseismic slips in several GNSS stations, one can calculate parameters of the earthquake source model, which determine the tsunami occurrence probability and are the initial data for the tsunami modelling.

There are many papers dedicated to the application of GNSS data to the monitoring of tsunamis caused by the strongest earthquakes (Sobolev et al., 2007, Wright et al., 2012, Melgar et al., 2016 and others). Nevertheless, the possibilities of using GNSS data for the rapid estimation of source parameters for earthquakes with M<8 are still not investigated. Some of these earthquakes can occur outside the subduction zones. In this case, one cannot precisely preset the dip angle as well as strike and slip angles. Sobolev et al. (2007) showed that for the strongest subduction earthquakes only two stations could provide enough information for reliable estimation of magnitude and source size. However, even the little uncertainty in the predetermined dip angle can strongly distort the inversion results.

Therefore, there are several questions to answer: (1) which source model parameters can be calculate and which ones are better to be preset; (2) how many GNSS stations we need and how far they can be and (3) what is the minimum magnitude of an earthquake? It have be noticed that GNSS stations will be located on some distance from the epicenter and more likely from only one side.

The accuracy of rapid coseismic slip estimation is the key information to solve these problems. The author had validated the optimal method for slips estimation and calculated the typical statistical distributions of the slip estimation errors based on the collected large worldwide GNSS stations data set (Pupatenko, Shestakov, 2017), which was initially used to modelling the noise in highrate GNSS coordinate timeseries.

The statistical distributions of the slip errors can be directly used in the numerical modeling for the imitation of the earthquake source parameters estimation. In this paper the algorithm for that purpose was developed. It takes the positions of the earthquake and GNSS stations, generates synthetic “observed” slips, fits the optimal source parameters and compare them to the reference. As a result, this algorithm allows us to make the following conclusions:

1. The M=7-7.5 earthquakes generate coseismic slips strong enough to estimate some or even all of the earthquake source parameters with the network of ~10 stations located on the 100-300 km distance at one side of the earthquake.

2. The easiest parameters to estimate are magnitude, strike and slip angles, while dip angle and especially the hypocenter depth influent weakly to the far-field coseismic slips. The typical magnitude error is 0.1-0.2, the root-mean-errors of strike and slip angles are 10 and 15 deg., respectively.

3. The number of GNSS stations is not the key factor. Nevertheless, increasing the stations number compensates negative influence of the coseismic slip estimation errors and prevent huge mistakes in parameters estimation.

4. Narrow azimuthal distribution of the GNSS stations is not a problem if the epicenter coordinates are evaluated well. Adding several stations located in 300-400 km from the epicenter can still improve the result, though the coseismic slips at these stations may reach only several millimeters and are not detectable directly.

5. Earthquake source size and the real slip distribution is the main error source for estimated parameters and it much stronger affects the area within and near the rupture zone. It completely prevent using the GNSS stations within ~50 km from the epicenter of M~7.2 earthquake and. Stations within the 50-100 km will also

give inadequate errors if the simplified slip distribution used in modelling will not represent the real one well. If there are GNSS stations near the epicenter, their data is applicable only to magnitude estimation.

The reported study was funded by RFBR according to the research project № 18-35-00178.

References

Gusiakov, V.K. Tsunamis on the Russian Pacific coast: history and current situation // Russian Geology and Geophysics, 2016. № 57. Pp. 1259-1268.

Melgar, D. et al. Local tsunami warnings: Perspectives from recent large events // Geophysical Research Letters, 2016. Vol. 43. №. 3. Pp. 1109-1117.

Pupatenko, V.V., Shestakov, N.V. Noise modeling in high-rate realtime GNSS timeseries // Advances in Current Natural Sciences, 2017. №2. Pp 140-144.

Sobolev, S. V. et al. Tsunami early warning using GPS-Shield arrays // Journal of Geophysical Research: Solid Earth (1978–2012), 2007. Vol. 112. B08415.

Titov, V. V. et al. Real-time tsunami forecasting: Challenges and solutions // Natural Hazards, 2005. Vol. 35. №. 1. Pp. 35-41.

The 4(5) October 1994 Shikotan Earthquake and Tsunami. Chronicle of Events, Analysis of Impact and Current State of the Art. Special Issue / Compilers: I.N. Tikhonov and G.V. Shevchenko - 2nd Edition Revised. Yuzhno-Sakhalinsk: Institute of Marine Geology and Geophysics, Far Eastern Branch of Russian Academy of Sciences, 2015. 128 p.

Wright, T. J. et al. Real-time, reliable magnitudes for large earthquakes from 1 Hz GPS precise point positioning: The 2011 Tohoku-Oki (Japan) earthquake // Geophysical Research Letters, 2012. Vol. 39. L12302.