Tsunami source estimation from tsunami deposit and numerical simulation

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Attempts to estimate a tsunami source from comparison of tsunami deposit distribution and simulated inundation area have been done for the 17th century giant earthquake along Kuril trench (Satake et al., 2008, EPS) or the 869 Jogan earthquake (Sawai et al., 2012, GRL). The 2011 Tohoku earthquake revealed that the tsunami inundation area extended farther inland than the distribution of sandy tsunami deposits. Numerical simulation of the 2011 tsunami indicated that flow depths and velocities were approximately 1m and 0.6m/s, respectively, at the most inland sand deposit sites on the Ishinomaki and Sendai plains. These values were used to re-estimate the size of the 869 Jogan earthquake, and the revised estimates show a larger size of the 869 earthquake (Namegaya and Satake, 2014, GRL). For a uniform-slip model, the fault length is at least 200 km, slip amount is at least 12 m, and Mw is at least 8.6. For the 2011-type variable-slip fault models, the fault length is at least 300 km and Mw is 8.8 or larger.

Recently, attempts have been made to estimate flow depths and velocities from the distribution of tsunami deposits as an inverse problem (e.g., Naruse and Abe, 2017, JGR). The tsunami source also controls the number of waves, duration and dominant period, as well as amplitude and velocity. For example, far-field tsunamis have long-lasting characteristics (Satake et al, Earth-Science Reviews, in press). Here we review studies using a sediment transport model developed by Takahashi (2012, J. Sed. Soc. Japan).

In this model, conservation of sediment mass in the bed load layer and the suspended load layer, as well as the exchange rate between these layers, are calculated, based on the bottom shear stress computed from ordinary tsunami numerical simulations. The total erosion and deposition of sediment thus computed are compared with the observation. While the original model was developed for single grain size, Gusman et al. (2018, Marine Geology) extended the model to multiple sand grain sizes from 0.063 to 5.657mm based on the hydraulic experiments, and compared the results with grain size distribution of the 2011 tsunami deposit in Numanohama coast on Sanriku coast. Further, they demonstrated that the observed thickness and grain size distribution are controlled by the amplitude and period of incoming wave, and indicated the possibility to study the tsunami source model from deposit.

Kusumoto (2018, Ph.D. thesis) applied one-dimensional sediment transport modeling to the 2011 Tohoku tsunami deposits at Idagawa lowland (Fukushima prefecture), Sendai plain, and Numanohama marsh, and compared the results with the observations. The slip amount and distribution of the 2011 Tohoku earthquake model (Satake et al., 2013, BSSA) were modified in ten different source models. These models produce different distribution and thickness of deposit. He also showed that the coastal forest has significant effects for tsunami deposit distribution. Comparison with the 869 Jogan deposit indicates that the 869 Jogan earthquake had the magnitude and fault length slightly smaller than the 2011 Tohoku earthquake.

Keywords: tsunami, tsunami source, tsunami deposit