Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MIS25-09 Room:106 Time:May 24 11:15-11:30

Estimation and sensitivity of fault parameters from distribution of tsunami deposit

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Comparisons of distribution of tsunami deposit with computed tsunami inundation is a useful method to estimate fault parameters. Sawai et al. (2012, GRL) assumed 14 different fault models of the AD 869 Jogan earthquake, and compared the computed tsunami inundation areas with distribution of tsunami deposit in Ishinomaki and Sendai plains, and Odaka lowland. The 14 fault models include outer-rise normal-fault earthquake associated with the 1933 Showa Sanriku earthquake, tsunami earthquake on shallow plate interface near the Japan trench such as the 1896 Meiji Sanriku earthquake, active-fault earthquake in Sendai bay, and interplate earthquakes with various fault depths, widths, lengths, and slip amounts. They showed that an interplate earthquake of 200 km long and 100 km wide with 7 m slip can produce tsunami inundation to cover the distribution of the tsunami deposit.

Nanayama et al. (2003, Nature) surveyed tsunami deposit along the Pacific coast of Hokkaido, and concluded that unusual tsunamis occurred along the Kuril trench with an average interval of about 500 years. The most recent tsunami is dated in the 17th century. Satake et al. (2008, EPS) assumed the fault models including "Giant fault model" with depth range of 0 km to 85 km, tsunami earthquake, and interplate earthquakes. They showed that an interplate earthquake of 300 km long and 100 km wide, and slip of 5 m and 10 m in the north and the south, respectively (Mw8.5), can produce tsunami inundation to cover the distribution of the tsunami deposit.

Sensitivity analyses of computed tsunami inundation to fault lengths and slip amounts are also helpful to estimate these fault parameters. We examined the sensitivity to fault lengths and slip amounts of the AD 869 Jogan earthquake. We assumed various interplate fault models with four different lengths (100, 200, 300, 400 km), three uniform slip amounts (6, 9, 12 m), and two top depths (15, 31 km). Fault width is fixed at 100 km (Uniform Slip Models). We also assumed variable slip models using slip distribution of the 2011 Tohoku earthquake (Satake et al., 2013, BSSA) (Variable Slip Models). Tsunami inundation distances were computed on the 869 topography in Ishinomaki and Sendai plains in Miyagi prefecture (Sawai et al., 2012, GRL) and Odaka (Sawai et al., 2012, GRL) and Ukedo (Imaizumi et al., 2010, internal report) in Fukushima prefecture, and compared with maximum transportation distances of sandy tsunami deposit on 10 transects.

As a result of Uniform Slip Models, the fault model of the 869 earthquake requires the fault length of at least 200 km and the slip amount of at least 9 m to completely inundate up to the tsunami deposit on the 10 transects. For Variable Slip Models, we found that fault length of more than 200 km is also needed. However, when fault length exceeds 200 km with slip amounts of more than 9 m in Uniform Slip Models, or when fault length exceeds 200 km in Variable Slip Models, the computed inundation distance increases very little. This indicates the following two points. One is that we cannot judge whether the fault length is 200 km or more, and field studies of tsunami deposit are necessary on the northern part or the southern part. The other is that inundation distance does not simply increase with fault parameter but saturates due to topography. The computed tsunami inundation areas show that the margin between the calculated inundation limit and upland, which is defined as altitude more than 10 m (T.P.), is small and it is difficult for tsunami to inundate for a longer distance except for two transects in Sendai plain.

Geological studies after the 2011 Tohoku earthquake (e.g. Goto et al., 2011, Marine Geology; Abe et al., 2012; Sedimentary Geology; Sawai et al., 2012, GRL) reported that the tsunami inundated more extensive than the tsunami deposit. However, it is difficult to apply a simple relationship to estimate the accurate magnitude of the 869 earthquake, because of the saturation problem.

Keywords: tsunami deposit, fault model, the AD 869 Jogan earthquake, tsunami computation, inundation distance