Determination of Appropriate Source Models for Tsunami Forecasting: Application to Large Earthquakes in Central Sumatra, Indonesia

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The subduction of the Indo-Australian plate beneath the Eurasian plate off the west coast of Sumatra has often resulted in large tsunamigenic earthquakes. Great earthquakes have occurred along this plate boundary such as the 2004 Sumatra–Andaman earthquake (Mw 9.1) and the 2005 Nias earthquake (Mw 8.6). On September 12, 2007, a great earthquake (Mw 8.4) occurred offshore of the Bengkulu province of Sumatra. According to the US Geological Survey, the mainshock at 18:10 local time (11:10 UTC) was followed by two large aftershocks (Mw 7.9 and Mw 7.1) at 23:49 UTC and 03:35 UTC, respectively. The mainshock generated a large tsunami along the Bengkulu coastline and caused damage at several locations along the Bengkulu coastal area. A few years later, another large earthquake (Mw 7.8) occurred on October 25, 2010, off the west coast of Mentawai Islands at 21:42 local time (14:42 UTC). This earthquake also generated a large tsunami and caused more than 400 casualties around the Mentawai Islands. Although the moment magnitude of the 2010 earthquake is much smaller than that of the 2007 earthquake, the tsunami heights resulting from the former 2010 earthquake were higher than those resulting from the latter 2007 earthquake, indicating that tsunami heights are difficult to forecast.

An advanced method to determine appropriate source models that can explain the tsunami heights along coastal areas is needed for tsunami warning purposes. In this study, fault parameters were estimated from the W-phase inversion and fault length and width were calculated from suitable scaling relations between those and magnitude for the 2007 and 2010 earthquakes. Tsunami numerical simulations were conducted using various slip amounts or corresponding rigidities. The best slip amount or corresponding rigidity was selected by comparing the measured and computed tsunami heights.

The 2007 great Bengkulu earthquake (Mw 8.4) was a typical interplate earthquake that occurred at the subducted plate interface. The measured tsunami heights along the coast of Sumatra Island were well explained by the computed tsunami from the source model estimated by our method using the rigidity of 3.0×10^{10} Nm^{-2} (7.59-m slip amount). This rigidity is consistent with the depth dependent rigidity curve estimated by Tanioka et al. (2017) at an estimated depth of 30 km (Figure). The 2010 Mentawai tsunami earthquake (Mw 7.8) occurred at the plate interface near the trench. The measured tsunami heights along the coast of Mentawai Islands were also explained well by the computed tsunami from the source model estimated using the method with a rigidity of 1.5×10^{10} Nm^{-2} (8.17 m slip amount). This rigidity is slightly larger than the depth dependent rigidity curve estimated by Tanioka et al. (2017) at an estimated depth of 17 km (Figure). These results indicate that the rigidity differences along the plate interface as suggested by Bilek and Lay (1999) have a considerable impact on tsunami height estimation as also suggested by Tanioka et al. (2017). These results also suggested that a blue dashed line in Figure should be used for the rigidity estimate along the plate interface off Sumatra in Indonesia. Therefore, appropriate slip amounts of source models for tsunami forecast in this region can be estimated rapidly using the results of W-phase inversion and this depth dependent rigidity (a blue line in Figure).

References

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