The role of submarine landslides in the Great Eastern Japan tsunami of 2011

D. R. Tappin (British Geological Survey)

Several major recent tsunamis have shown the hazard from submarine landslides. In 1992 a small earthquake-triggered landslide generated a tsunami over 25 meters high on Flores Island. In 1998 another small, earthquake-triggered, sediment slump-generated tsunami up to 15 meters high devastated the local coast of Papua New Guinea killing 2,200 people. It was this event that led to the recognition of the importance of marine geophysical data in mapping the architecture of seabed sediment failures that could then be used in modelling and validating the tsunami generating mechanism. Seabed mapping of the 2004 Indian Ocean earthquake rupture zone demonstrated, however, that large, if not great, earthquakes do not necessarily cause major seabed failures, but that along some convergent margins frequent earthquakes result in smaller sediment failures that are not tsunamigenic. Older events, such as Messina, 1908, Makran, 1945, Alaska, 1946, and Java, 2006, all have the characteristics of submarine landslide tsunamis, but for these a landslide source has not been proven.

When the 2011 tsunami struck Japan, it was generally assumed that it was directly generated by the earthquake. The earthquake has some unusual characteristics, such as a shallow rupture that is somewhat slow, but is not a “tsunami earthquake.” A number of simulations of the tsunami based on an earthquake source have been published, but in general the best results are obtained by adjusting fault rupture models with tsunami wave gauge or other data so, to the extent that they can model the recorded tsunami data, this demonstrates self-consistency rather than validation.

Here we consider some of the existing source models of the 2011 Great Eastern Japan event and present new tsunami simulations based on a combination of an earthquake source and a submarine landslide mapped from offshore data. We show that simulation of the multi-source tsunami agrees well with available tide gauge data and field observations and the wave data from offshore buoys, and that the additional landslide can explain the recorded elevated runups in the Sanriku region of northern Honshu. Our results for the 2011 Great Eastern Japan event suggest that care is required in using tsunami wave and tide gauge data to both model and validate earthquake tsunami sources. They also suggest a potential pitfall in the use of tsunami waveform inversion from tide gauges and buoys to estimate the size and spatial characteristics of earthquake rupture. If the tsunami source has a significant landslide component such studies may overestimate earthquake magnitude.

Our seabed mapping identifies other large slides off Sanriku that may have generated significant tsunamis in the past and which should be considered in future analyses of the tsunami hazard in Japan. The identification of two major submarine landslide-generated tsunamis (PNG and the Great Eastern Japan event), especially one associated with a M9 earthquake, is important in guiding future efforts at forecasting and mitigating the tsunami hazard from large megathrust plus landslide both in Japan and globally.