CONTROL ID: 1808137

TITLE: Earthquake and submarine landslide tsunamis: how can we tell the difference?

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ABSTRACT BODY: Several major recent events have shown the tsunami hazard from submarine mass failures (SMF), i.e., 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 be then used in modeling 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 SMF tsunamis, but for these a SMF 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 Japan event and present new tsunami simulations based on a combination of an earthquake source and an SMF mapped from offshore data. We show that the multi-source tsunami agrees well with available tide gauge data and field observations and the wave data from offshore buoys, and that the SMF generated the large runups in the Sanriku region (northern Tohoku). Our new results for the 2011 Tohoku 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 SMF component such studies may overestimate earthquake magnitude. Our seabed mapping identifies other large SMFs off Sanriku that have the potential to generate significant tsunamis and which should be considered in future analyses of the tsunami hazard in Japan.

The identification of two major SMF-generated tsunamis (PNG and Tohoku), especially one associated with a M9 earthquake, is important in guiding future efforts at forecasting and mitigating the tsunami hazard from large megathrust plus SMF events both in Japan and globally.

INDEX TERMS: 4217 OCEANOGRAPHY: GENERAL Coastal processes, 4333 NATURAL HAZARDS Disaster risk analysis and assessment, 4564 OCEANOGRAPHY: PHYSICAL Tsunamis and storm surges, 0545 COMPUTATIONAL GEOPHYSICS Modeling.