Seismotectonics of Large Earthquakes and Tsunamigenesis

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Abstract

Large earthquakes generate most of the dangerous tsunamis, thus the global pattern of large earthquake occurrence is important to tsunami hazard mitigation. While tsunamis can be generated by a variety of mechanisms, the most common source for rapid displacement of a large volume of ocean water is the sea bottom deformation directly caused by the faulting of large underthrust earthquakes in subduction zones. This overview focuses on one key aspect of tsunamigenesis by large underthrust earthquakes: the global distribution of large earthquakes. In addition, I also discuss how some details of earthquake faulting and the rupture process affect tsunami generation.

First, what is the threshold size of an earthquake that generates a dangerous tsunami? It is difficult to set a strict lower bound to this threshold, especially given our realization that shaking-induced submarine landslides can produce large and dangerous local tsunamis. However, if we focus on tsunami generation by the direct effect of fault slip, it seems that most of the dangerous tsunamis will be generated by dip-slip earthquakes with Mw of 8 or larger (with exceptions of course). Furthermore, if we focus on trans-oceanic tsunami hazards, then we can mostly consider thrust earthquakes with Mw of 8.5 or larger. Where do the greatest earthquakes occur?

Following Uyeda's "comparative subductology" approach, Ruff and Kanamori noticed that just a subset of the world's subduction zones generate the largest earthquakes with Mw≥8.5; they suggested that "tectonic variables" such as convergence rate and subducted lithosphere age are correlated with large earthquake occurrence. Other tectonic variables may be as – or more – important than rate and age. For example, "trench sediments" and various other characterizations of the geological nature of subducted materials seem to play a role in great earthquake occurrence (e.g., see other contributions in this symposium from Scholl and Von Huene). While the observation that great earthquakes occur in select subduction zones remains true today, the interpretation and projection into future earthquake occurrence are open to vigorous debate (e.g., see contribution from Stein). I shall review the earthquake observations, tectonic variables, and some of the unresolved issues. Further investigation is required to answer the "Cascadia question" for the entire world: are there more subduction zones -- with no historical record of great earthquakes – that will generate great earthquakes in the future?

Another aspect of tsunami generation is how some details of earthquake faulting can enhance the displaced water volume. The up-dip edge of the seismogenic zone and imbricate faulting are expected to play important roles in this aspect. A key unresolved question is: are the greatest earthquakes *special* in the sense that co-seismic displacements occur in the otherwise aseismic portion of accretionary prisms?

One conclusion of this overview is that the large uncertainties in both the tectonic and seismological aspects of tsunami generation justify the construction of a uniform global tsunami early warning system.