Solid Earth Physics Seminar
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A Probabilistic Description of Tsunami Phenomenology

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Abstract: Despite recent advancements in our understanding of tsunami physics, various surprises seem to accompany tsunamis that occur in nature. Deviations from the expected behavior (i.e., deterministic analysis derived from current theory) are associated with the overall severity of the tsunami (either much greater or much less severe than expected), extreme runups in isolated locations, high runups that occur much later than the first arrival, and earlier than expected first arrivals. I examine available data for each observable phase of tsunami evolution: from generation through propagation and coastal interaction. This data includes slip kinematics from the inversion of seismic waveforms, deep-ocean bottom pressure recordings of open-ocean propagation, tide gauge records of the coastal response, and spatial, post-tsunami runup distributions. Obvious data gaps include direct measurements of sea floor movement (elastic deformation), dense spatial measurements of wave histories, and temporal evolution of the runup process. The phenomenology of tsunami waves is best described in three regimes, building upon the classic work of Professor Carrier: (1) the near-field regime, at coastal locations broadside (i.e., directly across) from the rupture zone; (2) the near-field regime, at coastal locations oblique to the rupture zone; (3) the far-field regime. For (1), maximum tsunami amplitudes and runup occur primarily (though not exclusively) with non-trapped tsunami phases (first arrivals) and are primarily affected by spatial heterogeneity of coseismic slip within the rupture zone. This characterization tends to be manifest at regional distances as well, along azimuths close to the beaming axis of tsunami energy. Two-point statistics used to describe slip heterogeneity may be transferred to describing spatial runup distributions, but only for the simplest offshore physiography. For (2) and (3), maximum tsunami amplitudes and runup are caused by the complex interaction of excited edge waves (trapped modes) and occur at times much later than the first arrival. For (3), the tsunami time series is also affected by scattering, reflection, focusing and defocusing caused by irregularities in the bathymetry during trans-oceanic propagation. Here, we can test whether tsunami amplitudes can be described by a Rayleigh distribution, as commonly used for other ocean waves in a random sea. Observations are compared to theoretical, deterministic predictions to find possible clues in explaining the physics underlying the stochastic part of tsunami observations.