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[1] In contrast to far-field tsunami amplitudes that are fairly well predicted by the seismic moment of subduction zone earthquakes, there exists significant variation in the scaling of local tsunami amplitude with respect to seismic moment. From a global catalog of tsunami runup observations this variability is greatest for the most frequently occurring tsunamigenic subduction zone earthquakes in the magnitude range of $7 < M_w < 8.5$. Variability in local tsunami runup scaling can be ascribed to tsunami source parameters that are independent of seismic moment: variations in the water depth in the source region, the combination of higher slip and lower shear modulus at shallow depth, and rupture complexity in the form of heterogeneous slip distribution patterns. The focus of this study is on the effect that rupture complexity has on the local tsunami wave field. A wide range of slip distribution patterns are generated using a stochastic, self-affine source model that is consistent with the falloff of far-field seismic displacement spectra at high frequencies. The synthetic slip distributions generated by the stochastic source model are discretized and the vertical displacement fields from point source elastic dislocation expressions are superimposed to compute the coseismic vertical displacement field. For shallow subduction zone earthquakes it is demonstrated that self-affine irregularities of the slip distribution result in significant variations in local tsunami amplitude. The effects of rupture complexity are less pronounced for earthquakes at greater depth or along faults with steep dip angles. For a test region along the Pacific coast of central Mexico, peak nearshore tsunami amplitude is calculated for a large number ($N = 100$) of synthetic slip distribution patterns, all with identical seismic moment ($M_w = 8.1$). Analysis of the results indicates that for earthquakes of a fixed location, geometry, and seismic moment, peak nearshore tsunami amplitude can vary by a factor of 3 or more. These results indicate that there is substantially more variation in the local tsunami wave field derived from the inherent complexity subduction zone earthquakes than predicted by a simple elastic dislocation model. Probabilistic methods that take into account variability in earthquake rupture processes are likely to yield more accurate assessments of tsunami hazards. *INDEX TERMS:* 4564 Oceanography: Physical: Tsunamis and storm surges; 7215 Seismology: Earthquake parameters; 3250 Mathematical Geophysics: Fractals and multifractals; 3210 Mathematical Geophysics: Modeling; *KEYWORDS:* tsunami, slip, subduction zone, stochastic, fractal

1. Introduction

[2] Shallow subduction zone earthquakes are one of the most common sources of destructive tsunamis in the world. Events such as the 1960 Chile and 1964 Alaska earthquakes resulted in large displacements of the seafloor that were transferred as gravitational instabilities in the ocean: the tsunami. Although subduction zone events most frequently generate high local tsunami runups, it is important to note that back arc events and, to a lesser degree, outer rise events have also generated tsunamis with high runups [*Satake and Tanioka*, 1999]. To accurately assess the hazard posed by tsunamis generated by subduction zone earthquakes, it is critical that we understand how local tsunamis are affected by details of earthquake rupture.

[3] Despite differences in the underlying physics of wave propagation in the ocean and in the solid earth, the tsunami wave field emanating from an earthquake source can be thought of as an extension to the seismic wave field. *Ward* [1980] and *Okal* [1982] demonstrate that far-field tsunami waveforms can be reconstructed through the superposition of normal modes in the same way Rayleigh waves are reconstructed. Likewise, analysis of source effects on the local tsunami wave field parallels similar analyses in strong motion seismology. As detailed in this study, rupture complexity, as represented by heterogeneous slip distribution patterns, has an important effect on near-field tsunami records. The computation of the local tsunami wave field is considerably simpler than computing elastic wave propagation in the solid earth owing to the fact that the propagation velocity of long waves in the ocean is directly available from bathymetry. However, site response for tsunami waves in the form of local resonance, trapped modes of