Modeling the Asian Tsunami Evolution and Propagation with a New Generation Mechanism and a Non-Linear Dispersive Wave Model

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Abstract

A common approach in modeling the generation and propagation of tsunami is based on the assumption of a kinematic vertical displacement of ocean water that is analogous to the ocean bottom displacement during a submarine earthquake and the use of a non-dispersive long-wave model to simulate its physical transformation as it radiates outward from the source region. In this study, a new generation mechanism and the use of a highly-dispersive wave model to simulate tsunami inception, propagation and transformation are proposed. The new generation model assumes that transient ground motion can accelerate horizontal currents with opposing directions above the fault line whose successive convergence and divergence can generate a series of potentially destructive waves. The new dynamic model incorporates the effects of earthquake moment magnitude and duration, ocean compressibility through the buoyancy frequency, the effects of focal and water depths, and the orientation of ruptured fault line in the tsunami magnitude and directivity.

For tsunami wave simulation, the nonlinear momentum-based wave model includes important wave propagation and transformation mechanisms such as refraction, diffraction, shoaling, partial reflection and transmission, back-scattering, frequency dispersion, and resonant wave-wave interactions. Using this model and a coarse-resolution bathymetry, the new mechanism is tested for the Indian Ocean tsunami of December 26, 2004. With a fine-resolution bathymetry and a new flooding algorithm, the tsunami transformation and inundation of low-lying coastal areas is also simulated using the wave output of the ocean-scale model.

It is shown in the present study that with the proposed generation model, the observed features of the Asian tsunami such as the initial drying of areas east of the source region and the initial flooding of western coasts are correctly simulated. The generation of a series of tsunami waves with periods and lengths comparable to observations are also well simulated. Furthermore, the shoaling behavior of the tsunami waves during flooding of dry land was also simulated by the new run-up algorithm. Finally, the new generation and propagation models can explain the combined and independent effects of various factors in tsunami generation and transformation taking into consideration the properties of the ocean and geologic disturbance.