Geophysical Research Abstracts, Vol. 8, 09021, 2006
SRef-ID: 1607-7962/gra/EGU06-A-09021

Effects of frequency dispersion on tsunami propagation and coastal impact

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Most modern long wave models used to simulate tsunami propagation are based on depth-averaged nonlinear shallow water (NSW) wave approximations, and hence neglect frequency dispersion and vertical structure of horizontal velocities. The 12/26/04 tsunami Indian Ocean tsunami revived the discussion within the tsunami community on when NSW models are sufficiently descriptive of the physics to characterize the coastal impact of tsunamis. For instance, Kulikov (2005) performed a wavelet analysis of satellite altimetry data recorded in deep water, and showed the importance of dispersive effects on tsunami wave evolution; in particular, the leading edge of the wave components, with 10 km wavelength, were significantly delayed relative to much longer waves in the main wavefront. He concluded that a long wave model including dispersion, such as a Boussinesq model (BM), should be used for this event. Here, we frame the discussion in a broader context. The reason why NSW models have been so commonly used is that they are normally able to offer much higher spatial resolution than BM, given practical constraints. Ultimately, the quality of the predictions of tsunami inundation are a result of an ensemble of choices, in particular: underlying physics, numerical algorithms, and grid resolution. To address this puzzling and often contradictory ensemble of choices, we systematically inter-compare modeling strategies based on the combination of these three inter-related choices, rather than a single choice (e.g., model physics). We use two NSW models [ELCIRC (Zhang, Baptista et al. 2004) and SELFE (Zhang and Baptista Submitted), which we apply both in their 2D and 3D forms; and a 2D fully nonlinear BM model (FUNWAVE; Wei

et al (1995) and recent improvements)]. All these models represent recent advances in state-of-the-art, and have only recently started being applied to tsunami modeling. ELCIRC and SELFE are based on horizontally-unstructured grids, and their efficient algorithms conveniently allow for exceptionally resolved representation of specific coastal features. FUNWAVE is based on structured (orthogonal or curvilinear) grids, and improves upon the classic weakly nonlinear and dispersive models. These alternative modeling strategies will be applied to selected case studies, and evaluated with metrics that range from conservation of basic properties to numerical efficiency, qualitative wave/run-up characteristics, and quantitative model-data comparisons. We will seek guidelines on when and where particular physics, numerics and grid resolutions should be used. Case studies will include the 12/26/04 Indian Ocean tsunami and hypothetical tsunami scenarios for the Cascadia Subduction Zone on the Eastern North Pacific.

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