Geophysical Research Abstracts
Vol. 14, EGU2012-9787, 2012
EGU General Assembly 2012

Tsunami Wave Propagation: Recent applications of a Finite Element Tsunami Model

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The devastating tsunami in December 2004 triggered numerous activities aiming at the installation of a tsunami early warning system in the Indian Ocean. Since the time available for early warning is very short especially along the Indonesian coast facing the Sunda trench, first estimates of the tsunami impact after an earthquake are based on precomputed tsunami simulations. These can rely only on a thoroughly tuned and verified model.
The wave propagation model TsunAWI is based on finite elements and employs a triangular discretization of the model domain which is very flexible with respect to resolution and allows for an excellent representation of complicated coastlines and bathymetry. In addition to convergence tests, benchmark cases and laboratory experiments data obtained from real events played an important role in its validation. The key issue in modelling the tsunami is wetting and drying. The original algorithm to solve this problem is discussed. Full and reduced formulation of the momentum advection for finite elements and parameterization of horizontal diffusion are presented. Using the well-known Okushiri test case, the influence of nonlinearity on the wave propagation is demonstrated. The TsunAWI simulation results of the Indian Ocean tsunami were compared to available data from satellite altimetry, tide gauge records and inundation measurements obtained in field surveys. It turns out that the model operating on the variable resolution mesh is able to capture different scales of the wave propagation without employing nesting techniques. Large scale wave propagation as well as inundation results in the Northern tip of Sumatra agree well with available data.
A typical tsunami wave is much shorter than tidal waves, which is why they are usually neglected in tsunami modelling. However, in coastal areas with strong tidal activity, nonlinear interactions of tidal and tsunami waves can amplify the magnitude of inundation. The effect can come from the nonlinearity of the momentum equation or the difference in the water level depth in the presence of tides. It is shown that inclusion of tides can have a significant effect on the amplitude and phase of tsunami waves.
Since the accuracy of the shallow water model decreases in coastal regions with steep bathymetry gradients, we augmented TsunAWI with a module dealing with the otherwise neglected nonhydrostatic part of pressure in the momentum equation. After each time step, the velocity results computed by the hydrostatic model are corrected. The nonhydrostatic correction can be activated on demand, when the coastline geometry and bottom toporgaphy require it to obtain realistic simulation results.
In the context of the Tsunami Warning System the development of an additional Simulation Module (SIM) was completed, allowing the comparison of sensor data in an actual earthquake event with precalculated data of the tsunami scenarios. By comparing seismic and GPS data the module selects the best matching scenarios, which support the Chief Officer on Duty in the warning center in deciding if a warning to the population is to be disseminated.