Modeling of Tsunami Generation, Propagation, and Inundation with a Non-hydrostatic Model

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NEOWAVE

Non-hydrostatic Evolution of Ocean Waves
• Adaptation of the nonlinear shallow-water model from Zygmunt Kowalik

Vertical flow and non-hydrostatic pressure (2D+)
• Flow over steep slopes including inertia
• Wave dispersion
• Tsunami generation from seafloor motion

Shock-capturing scheme for discontinuous flows
• Tsunami bores

First-order Governing equations
• Multi-level two-way nested grid

Extensive validation through NTHMP benchmarks and major earthquake and tsunami events after 2009

A community model maintained at UH with two primary active user groups
• Inundation mapping in Pacific Islands, Gulf of Mexico, Caribbean Islands and South America
• Seismologists
2009 Benchmark Challenge at OSU

Benchmark 1

Benchmark 2

Courtesy of P. Lynett
The 2011 Tohoku Earthquake and Tsunami from Finite Fault Solution

Rupture Duration: 148 sec
Computed and Measured Near-field Tsunami

Gauges at 20 to 50 m depth
Bathymetry at 20 arcsec res
Red line: model results
Back line: records
Runup and Inundation Modeling

Modeling Effort
- LiDAR topography and Japan coast guard bathymetry
- Four levels of two-way nested grids from 2 arcmin to 2 arcsec for the Tohoku and Hokkaido coasts
- Five levels with resolution as fine as 5 m at locations with large runup
Runup and Inundation Modeling
Onagawa, Miyagi
Runup and Inundation Modeling

Inundation measurement compiled by Dr. Haraguchi in Osaka City University.
http://www.jsgi-map.org/tsunami/google_tile_en.html

- : computed runup
○ : recorded runup
● : recoded inundation height
South China Sea

Manila Trench Earthquake Scenario
- Thorne Lay of UC Santa Cruz based on The GEM Faulted Earth Subduction Characterization Project (Berryman et al., 2013)
- Mw 8.25 with a 183 km by 50 km rupture area and 9.4 m uniform slip
- 10° strike, 15° dip, and 90° rake
- Rupture duration 30 sec

NEOWAVE Setup
- Bathymetry from GEBCO and digitized nautical charts
- Level-1 at 1 arcmin (~2 km) and Level-2 at 15 arcsec (~500 m)
Model Results
Maximum Surface Elevation
A non-hydrostatic model can account for details of rupture properties for studies of near-field tsunamis or vice versa.

The vertical velocity term in a non-hydrostatic model accounts for dispersion associated with tsunami generation, propagation, and transformation on continental slopes.

The first-order governing equations facilitates implementation of two-way grid nesting in modeling of dispersive tsunami waves.

A potential tool for studies of tsunami hazards in the South China Sea region.