

APPLYING A COMPOUND FLOOD MODEL ON OCEAN BASIN SCALES

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INTRODUCTION

Overland flood models with various degrees of complexity are often used to predict flooding in the coastal zone. One example of a compound flood model that is widely used is SFINCS (Leijnse et al., 2021). It can take into account the combined effects of tides, surge, waves, rainfall, wind and river discharge. Providing offshore boundary conditions of tide and surge for overland flood models typically falls in the realm of ocean circulation models, such as ADCIRC or Delft3D. Here we show that with some minor adjustments, the SFINCS model is also capable of simulating storm surge and tsunami propagation at ocean basin scales, at a fraction of the computational cost of traditional circulation models.

MODEL DESCRIPTION

The SFINCS model solves the shallow-water equations on a regular, staggered Arakawa-C grid. Local grid refinements are possible by using a quadtree approach. The governing equations are based on the Linear Inertial Equations, or LIEs (Bates et al., 2010), to which an optional advection term was added. SFINCS uses a sub-grid approach in which high-resolution topography details can be incorporated in the coarser grid scale. Computations can be offloaded to a GPU which speeds up simulations by 1 to 2 orders of magnitude. The LIEs generally work well for flows over flood plains but lack some terms that are important at large (ocean basin) scales. To simulate the generation of storm surge over the continental shelf, we added the Coriolis term, and a viscosity term. Furthermore, to simulate tsunami propagation in the Pacific Ocean, we added the option to run SFINCS on a global scale by stitching the east and west boundaries together at the International Date Line.

GULF OF MEXICO HURRICANES

We compare the simulated storm surge of SFINCS against traditional models (Delft3D) and observations for two hurricanes: Michael (2018) and Ian (2022). The model mesh of our Gulf of Mexico model has varying resolution ranging from 2 to 8 km. It covers the continental shelf and is cut off around the 500 m depth contour. When using the same wind forcing, SFINCS and Delft3D yield nearly identical results. Sensitivity tests are presented showing the effect of various forcing terms in the equations. Model run times are also compared, with the SFINCS models typically finishing in a matter of seconds, and Delft3D in minutes using similar grid spacing.



Figure 1 - Quadtree SFINCS mesh Gulf of Mexico

TOHOKU TSUNAMI

The Tohoku earthquake (M_w 9.1) struck northeastern Japan on March 11, 2011, and triggered a tsunami with waves up to 40 meters high at the coast. As far away as Chile, over 17,000 km away from the source, the tsunami reached run-up heights of almost 5 m. Here we attempt to simulate the propagation of the tsunami across the Pacific Ocean using SFINCS. The initial tsunami wave was generated with the Okada (1980) model, based on USGS data. The reduced-complexity compound flood model does a surprisingly good job at simulating wave heights and arrival times over large distances. Figure 2 shows the observed and simulated water surface elevation at DART buoy 32412 off the coast of Peru. At a distance of more than 15,000 km from the source and 18 hours after the earthquake occurred, SFINCS predicts the arrival time within 2 minutes of the observations. Simulation results and run times (ranging between seconds and minutes) on a CPU and GPU are compared for different grid resolutions.

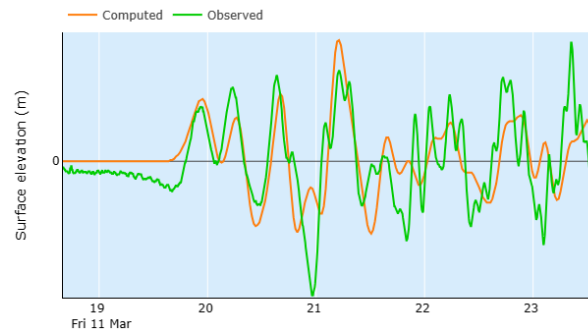


Figure 2 - Simulated and observed surface elevation at DART buoy 32412 during Tohoku tsunami

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