Modeling Hurricane Waves and Storm Surge on Petascale Computers

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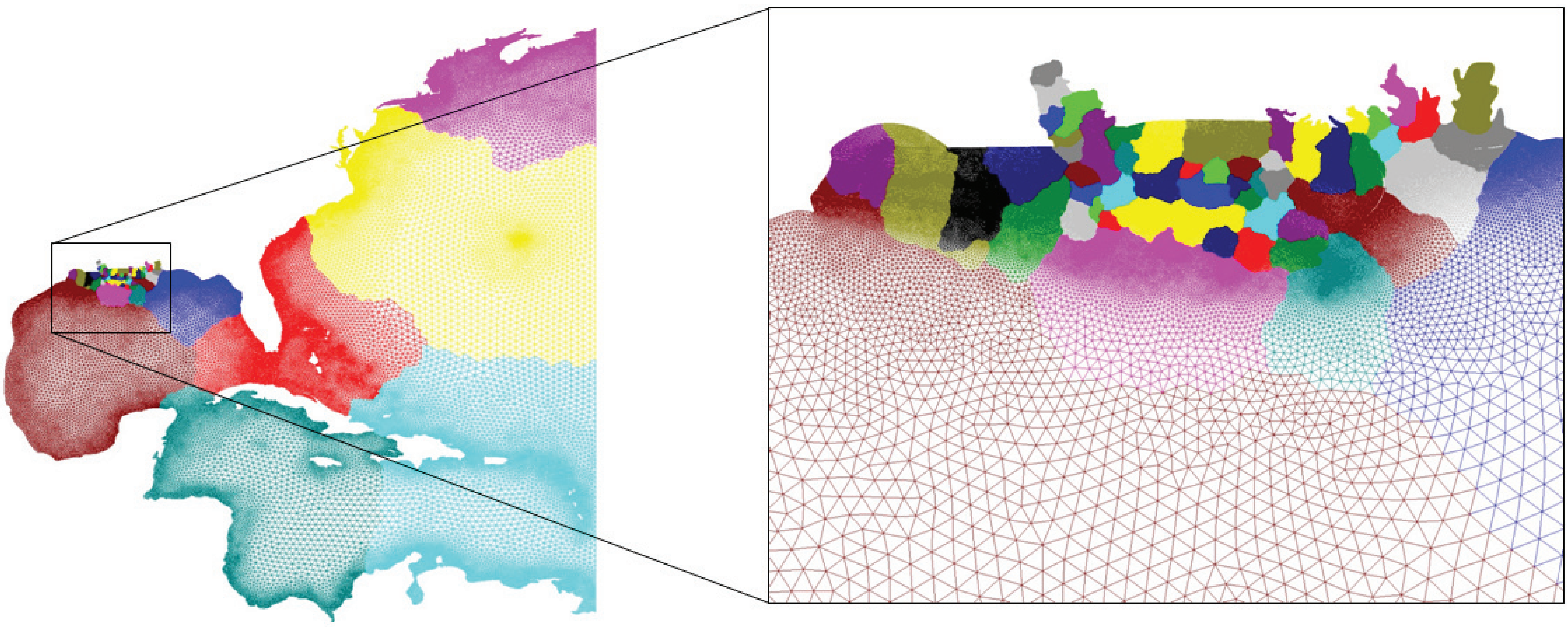
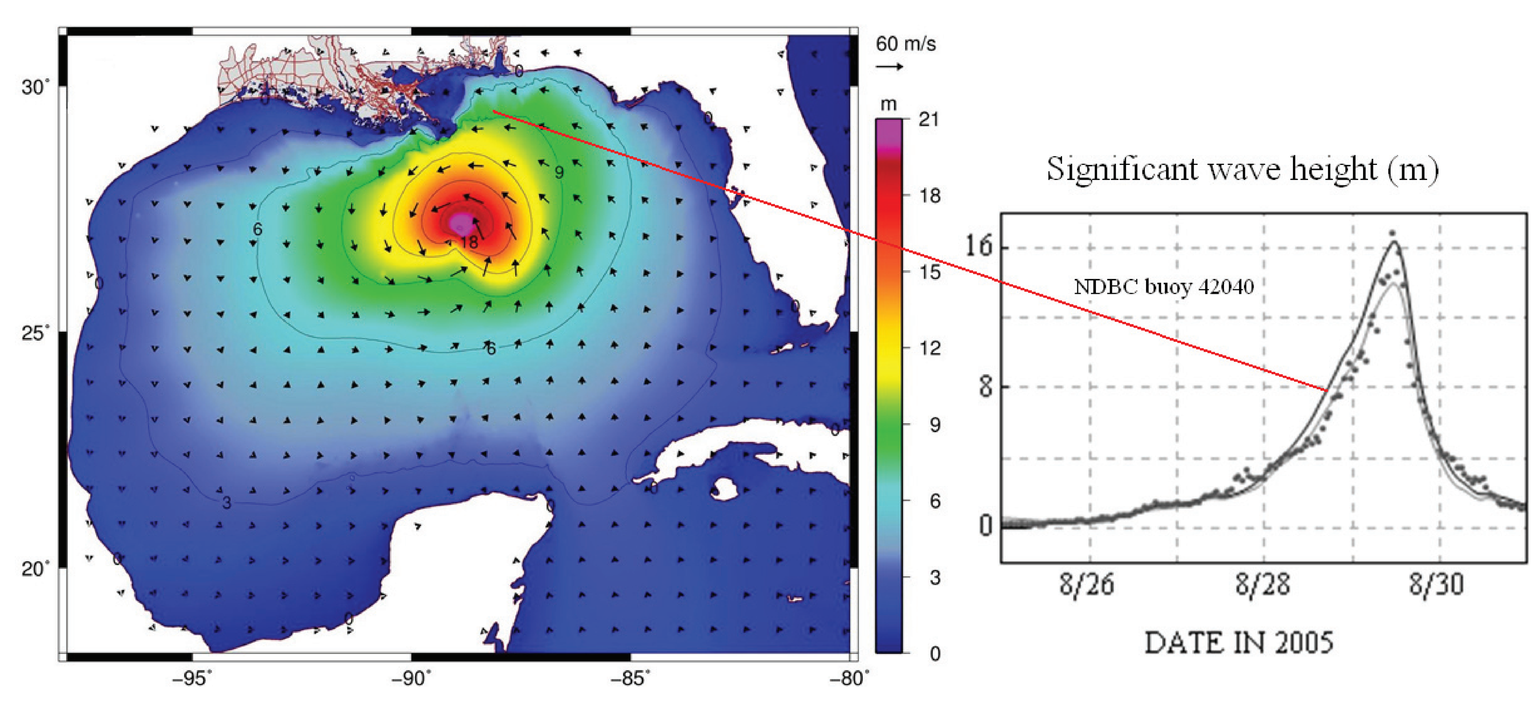
An efficient implementation of a tight coupling of the SWAN wave model and the ADCIRC circulation model has been explored within the framework of high performance computing environment. This scalable system enables to compute highly detailed and accurate hurricane waves and storm surges in the Gulf of Mexico and along the Louisiana and Mississippi coasts.

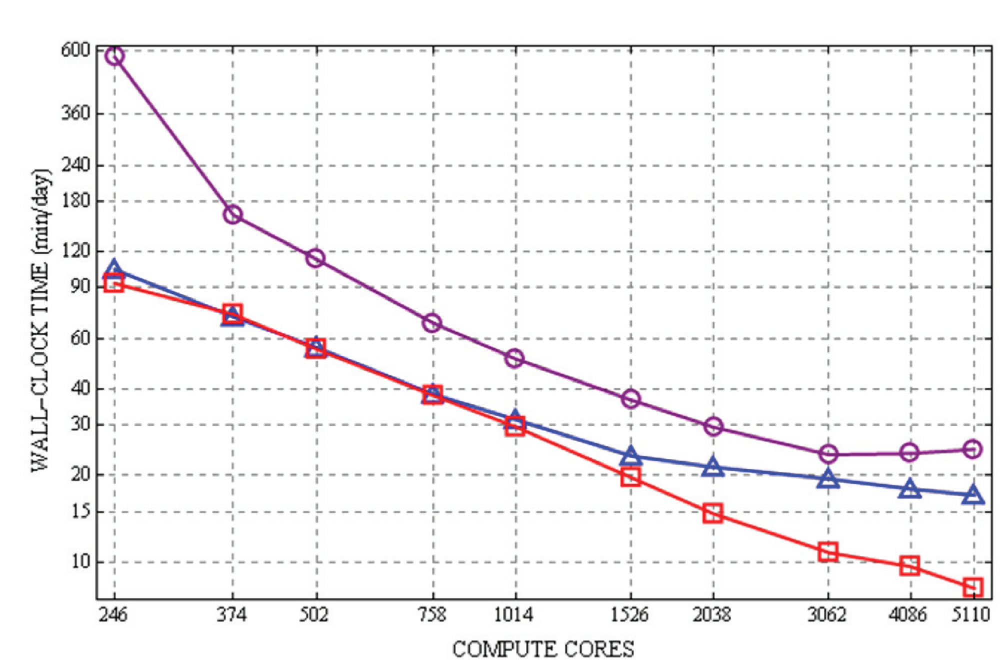
The models SWAN and ADCIRC are coupled tightly, so that they run as the same program on the same computational core, use the same unstructured SL15 mesh with 2.4 million grid points (see figure below) and pass wind speeds, water levels, currents and wave-driven forces, all residing at the same grid points, through memory or cache. This mesh utilizes basin-to-floodplain scale domains and increases locally the resolution in regions with large spatial gradients. The coupled model benefits from a highly efficient implementation, which makes use of an identical grid to eliminate the need for nesting, interpolation between models, iteration of model runs, and global communication. Furthermore, identical grids allow the physics of wave-current interactions to be resolved correctly in both the circulation and the wave model.





SWAN generates waves in deep water, dissipates waves due to wave steepness, bathymetry and bottom friction. ADCIRC applies wind, wave and tidal forces to create set-up and wave-driven currents, and then returns the water levels and currents to SWAN. The coupled model integrates seamlessly the physics from ocean to shelf to floodplain. An application of this coupled model is demonstrated in left figure for the validation of wind waves and storm surge for Hurricane Katrina (2005) in the Gulf of Mexico, southern Louisiana and Mississippi. SWAN+ ADCIRC simulates hurricanes with high levels of accuracy. The highest significant wave height of 16m measured is predicted rather good.

Parallellism is achieved through the use of domain decomposition (see figure above) and MPI. The presented coupled model was benchmarked on Ranger of TACC and on Huygens of SARA and appears to be highly scalable. The figure alongside (purple line) shows linear scaling up to 3,000 cores and wall-clock times of 24 minutes per day on the SL15 mesh. As the tight coupling adds no overhead, it will maintain linear scaling to larger numbers of computational cores when applied to meshes with larger number of grid points. Thus, SWAN+ADCIRC may be significantly more scalable to petascale architectures than commonly used wave-surge models employing heterogeneous meshes and the mechanics of managing the coupling (e.g., ESMF and OpenMI).



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