Optimized Local Time-Stepping for the Ocean and Atmosphere

Objective

- Create a new local time-stepping (LTS) method that is optimized to take time-steps as large as possible for the shallow water equations (SWEs), which are foundational for models of the ocean and atmosphere.

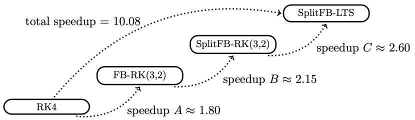
Approach

- Adapt an existing global time-stepping scheme optimized for the SWEs (FB-RK(3,2)) to a LTS framework.
- Prove that the resulting scheme exactly conserves mass and vorticity.
- Implement the scheme, along with a certain operator splitting, in the DOE ocean model MPAS-Ocean.
- Test the resulting scheme, SplitFB-LTS, in a real-world test case by modeling the storm surge cause by hurricane Sandy in Delaware Bay using meshes of highly-variable spatial resolution..

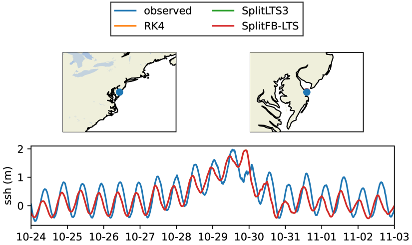
Impact

- SplitFB-LTS outperforms the classical four stage, fourth order Runge-Kutta scheme (RK4) in terms of computational speed by a factor of 10.08.
- SplitFB-LTS outperforms a comparable LTS scheme (SplitLTS3) by a factor of 2.28.
- The solution produced by SplitFB-LTS is qualitatively equivalent to those produced by SplitLTS3 and RK4.

(a)



(b)



A breakdown of the speedup achieved by SplitFB-LTS verus RK4 (a), and the sea surface height solution produced by each tested scheme at a given tidal gauge (b).

Jeremy R. Lilly, Giacomo Capodaglio, Darren Engwirda, Robert L. Higdon, and Mark R. Petersen. "Local Time-Stepping for the Shallow Water Equations Using CFL Optimized Forward-Backward Runge-Kutta Schemes". In: Journal of Computational Physics 520 (Jan. 2025), p. 113511. issn: 0021-9991. doi: 10.1016/j.jcp.2024.113511.