ICoM

Integrated Coastal Modeling

Sub-grid scale methods for the nearshore and across the floodplain to overcome resolution limitations in MPAS-O

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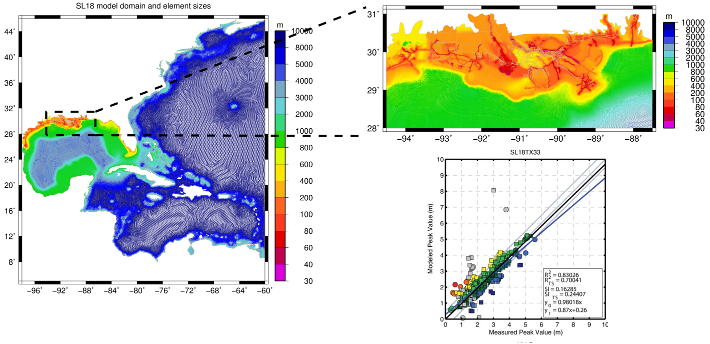
ADCIRC-based tide & storm surge model



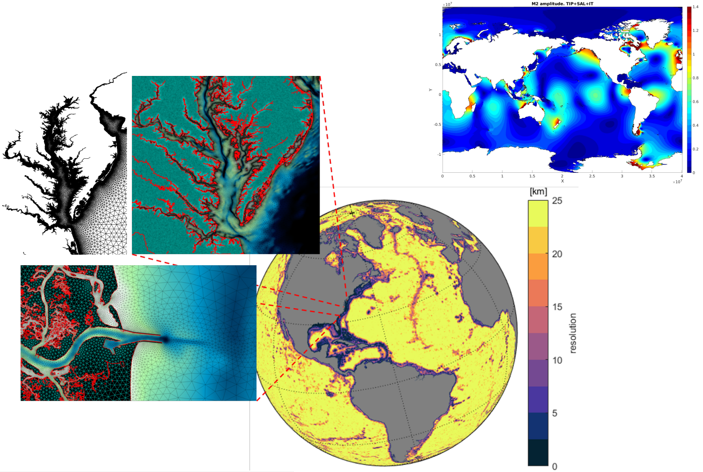
Ike high water marks[a]: observed vs. ADCIRC

- Finite element based hydrostatic flow model. Typically, run in 2D mode (one-layer) for high-resolution detailed studies of storm tide events.
- Variable mesh resolution with resolution down to ∼ 30-40m in coastal regions.

[a] Kerr et al., *JGR*, 2013

ADCIRC-based tide & storm surge model

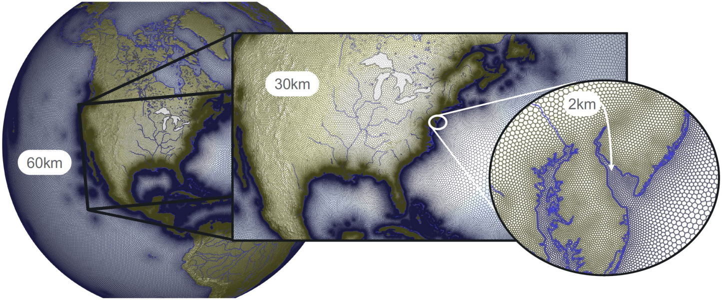
- Recently extended to a global domain[1].
- Selected by NOAA for a next installment of Global-ESTOFS[2].



[1] see Pringle et al., *GMD*, in revision, 2020; GlObal Coastal Ocean Flood Forecasting system, https://wpringle.github.io/GLOCOFFS/

[2] Extra tropical Surge and Tide Operational Forecast System, https://ocean.weather.gov/estofs/estofs_surge_twlev.php

MPAS hexagonal mesh



- Currently, MPAS-O resolves the ocean and its coast no finer than 6 km[3].
- Resolution in the coastal zones will not be finer 2 km in the foreseeable future.
- Potentially insufficient to capture the hydrodynamics of the terrestrial-aquatic interface connecting the upland hydrology and the ocean through the dendritic hydraulic conveyances penetrating the coastal floodplain.

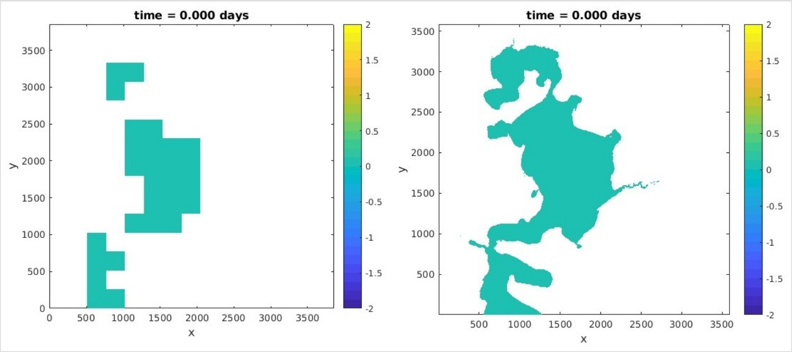
[3] Petersen et al., *J. Adv. Model. Earth Syst., 2019*

Subgrid Modeling with unresolved topography

- Example: Tidally-driven flow in the Buttermilk bay, MA.

Surface elevation. $\Delta x = \Delta y = 256$ m

Conventional | Subgrid

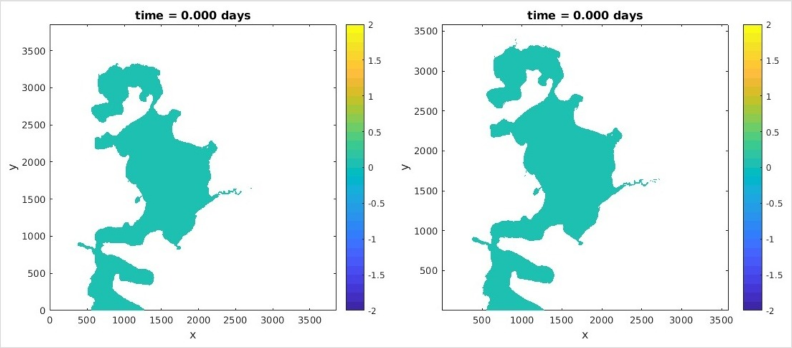


Subgrid Modeling with unresolved topography

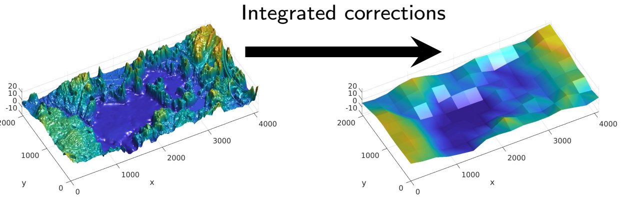
- Example: Tidally-driven flow in the Buttermilk bay, MA.

SURFACE ELEVATION. $\Delta x = \Delta y = 8$ M

CONVENTIONAL SUBGRID



Subgrid modeling with unresolved topography



8 m resolution | 256m resolution

- Subgrid modeling takes fine resolution features and aggregates/integrate to use on coarse grid.
- An approach is based on applying formal averaging over a 'grid' volume following Whitaker (1997) to 2D Shallow Water Equations leading to [4].

$$\frac{\partial \not{V}}{\partial t} + \frac{\partial}{\partial x}(\langle u\rangle_{V,W}\langle H\rangle_G) + \frac{\partial}{\partial y}(\langle v\rangle_{V,W}\langle H\rangle_G) = 0,\ \not{V} = \phi\langle H\rangle_W$$

$$\langle H\rangle_G \frac{\partial \langle u\rangle_{V,W}}{\partial t} - \langle u\rangle_W \nabla\cdot(\langle \boldsymbol{u}\rangle_{V,W}\langle H\rangle_G) + \frac{\partial}{\partial x}(c_{uu}\langle u\rangle^2_{V,W}\langle H\rangle_G) + \frac{\partial}{\partial y}(c_{uv}\langle u\rangle_{V,W}\langle v\rangle_W\langle H\rangle_G) = -gc_{\eta x}\langle H\rangle_G \frac{\partial\langle \eta\rangle_W}{\partial x} - c_{M,f}|\langle \boldsymbol{u}\rangle_{V,W}|\langle u\rangle_{V,W}.$$

[4]for more detail see, Kennedy et al., *Ocean Modelling*, 2019

Work plan

- Adapt and apply subgrid theory of Kennedy et al., 2019 to an external-mode solver of MPAS-O.
  - Relatively straightforward as the external mode equations are similar to 2D SWEs.
  - Offer potentially significant improvement to both water surface elevation and depth-averaged velocity in wetting/drying zones connecting oceans and land.
- Develop baroclinic subgrid theory for partially dry area and implement into MPAS-O.
  - Much greater challenges.
  - Will require additional theories and their suitable numerical implementation in different vertical coordinates that fit into the framework of MPAS-O.
- Couple subgrid ocean with land and rivers.
- Test all components on useful projects.