Oct 26-29, 2020 ESMD PI Meeting

Implementation of turbulence and sediment transport models in MPAS-Ocean

Zhendong Cao
Qing Li
Carolyn Begeman
LeAnn Conlon
Elizabeth Hunke

- Motivation
- Workflow and timeline
- Preliminary result
- Testing in progress

LA-UR-20-28433

Motivation

Turbulence closure model

- Present vertical turbulent mixing model in MPAS-Ocean is not suitable for simulating turbulent mixing in the estuarine environment

  - Shallow & weak stratification – overlapping surface and bottom boundary layer

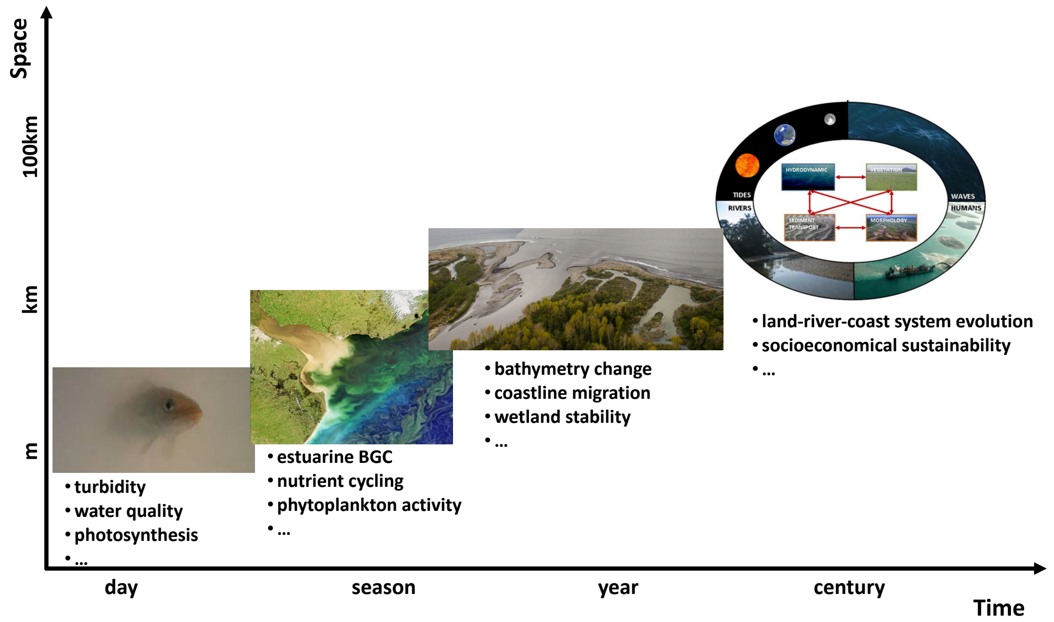
  - Transient turbulent flow, highly variable & not in equilibrium with surface forcing

  - Tidal impact

- The General Ocean Turbulence Model (GOTM) provides a set of state-of-the-art two equation turbulence model and is widely used in regional ocean models for the coastal regions

Sediment transport model

- Sediment transport is important to coastal environment in various spatiotemporal scales



- Present MPAS-Ocean lacks the function of simulating sediment transport

Workflow and timeline

Workflow

1 *Bedload transport*
- empirical formulae
  - Meyer-Peter-Muller (1948)
  - Nielsen (1992)
  - Soulsby-Damgaard (2005)

2 *Suspended-load Phase-I*
- empirical formulae for SSC
  - Zyserman-Fredsøe (1994)
  - Lee (2004)
  - Goldstein-Coco-Murray-Green (2014)

3 *Sediment settling velocity*
- Van Rijn (1989)
- Soulsby (1997)
- Cheng (1997)

4 *GOTM implementation*

MPAS-O → Velocity shear, stratification, surf/bot forcing → GOTM

Each column

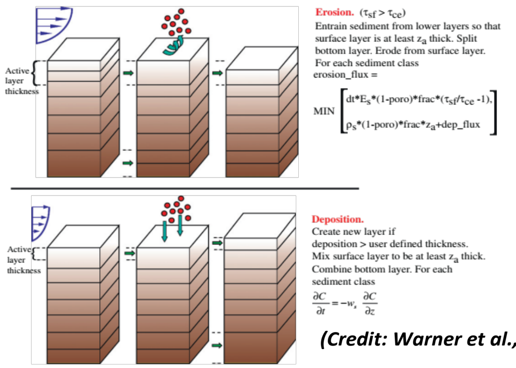
GOTM → Vertical turbulent viscosity & diffusivity → MPAS-O

5 *Model testing-I*
- steady uniform open channel

6 *Suspended-load Phase-II*
- 3D transport
- scaler equations plus extra source terms

$$\frac{\partial C}{\partial t} + \nabla \cdot (C\mathbf{u}) + \nabla \cdot (\epsilon \nabla C) = -\frac{\partial w_s C}{\partial z} + E_s$$

3D scalar equation + deposition + erosion



(Credit: Warner et al., 2008)

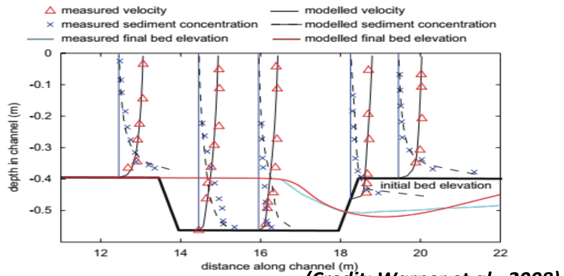
7 *Model testing-II*
- Salt intrusion and sediment transport in a 2D estuary

8 *Bathymetry change*
- result of bedload and suspended-load
- Exner equation

$$(1-\phi)\frac{\partial Z_b}{\partial t} + \left(\frac{\partial q_{bx}}{\partial x} + \frac{\partial q_{by}}{\partial y}\right) = \frac{C_{source,b}}{\rho_s}$$

change = bedload flux + erosion/deposition

9 *Model testing-III*
- 3D trench migration



(Credit: Warner et al., 2008)

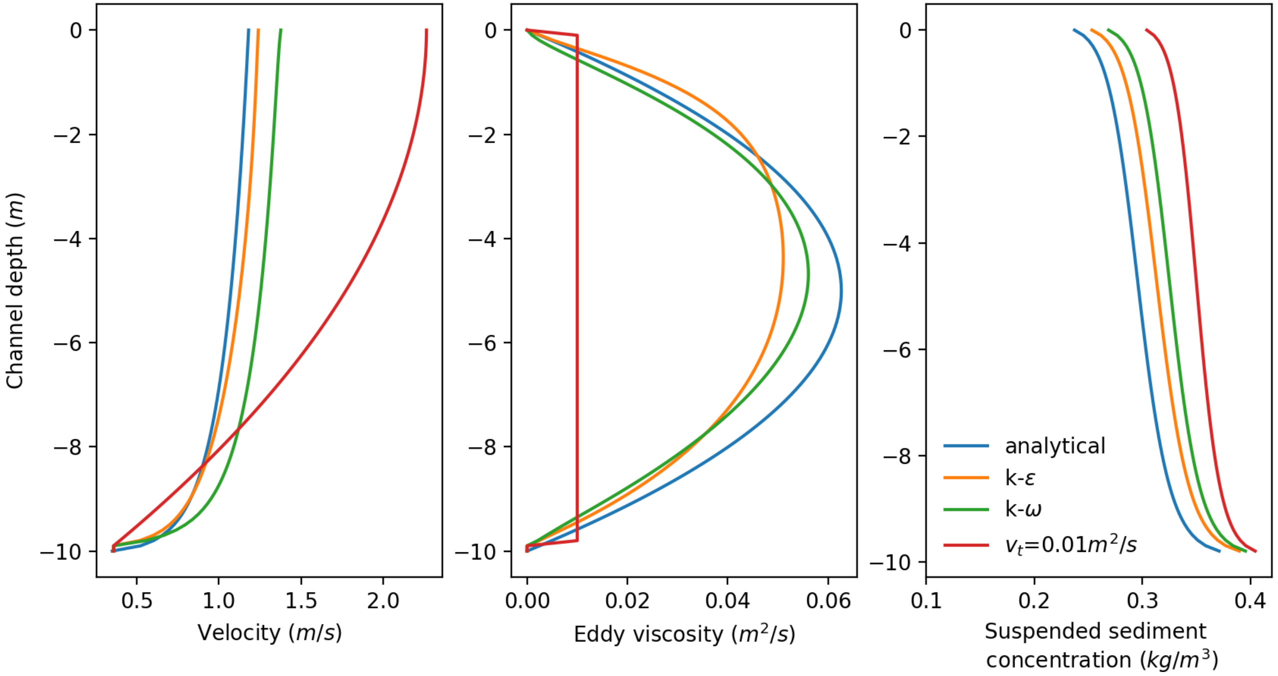
10 *Delaware Bay application*

FY1 | FY2 | FY3

Timeline

Preliminary Result: model testing I

- Single water column forced by a constant pressure gradient, which is balanced by a bottom drag
- Three test cases:
  - k-ϵ turbulence model
  - k-ω turbulence model
  - Constant turbulent viscosity ($\nu_t = 0.01$ m²/s)
- Analytical solution
  - Turbulent viscosity $\nu_t(z) = \kappa u^* z(1 - z/D)$
  - Velocity $u(z) = \frac{u^*}{\kappa} \ln z/z_0$
- Suspended sediment concentration
  - Goldstein-Coco-Murray-Green (2014)



κ: von Kármán constant; u^*: friction velocity; D: water depth

Testing in progress: model testing II

- Sloped 2D estuary with river inflow of freshwater on one side and tidal flow of seawater on the other side
- Evolution of salinity – advection versus mixing
- Sediment transport: bedload + 3D suspended load