

A NUMERICAL STUDY ON THE IMPACT OF DIFFERENT TURBULENCE CLOSURE MODELS ON SALINITY AND SEDIMENT DISTRIBUTION IN THE DELAWARE BAY

by

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Top 10 technical needs (Kreeger et al, 2006)

- contaminants (e.g., forms, sources, fates & effects of different classes)
- tidal wetlands (e.g., status and trends of different types);
- ecologically significant species and critical habitats (e.g., benthos, reefs, horseshoe crabs);
- ecological flows (e.g., effects of freshwater inflow on salt balance and biota);
- physical-chemical-biological linkages (e.g., effects of sediment budget on toxics and biota);
- food web dynamics (e.g. identification and quantification of dominant trophic interactions);
- nutrients (e.g., forms, concentrations and relative balance);
- ecosystem functions (e.g. economic valuation of ecosystem services);
- habitat restoration and enhancement;
- invasive species (e.g., monitoring and control).

Need numerical model to address:

- Investigate effects of residual currents (e.g., buoyancy-driven and wind-driven factors)
- Complete understanding of hydrodynamics which is needed for modeling material transport (sediment, contaminant, nutrient etc.).
- The effect of upstream discharge and its relation to salinity intrusion
- Sediment and its effects on stream ecology, concentrations of metals and organic contaminants
- high turbidity, greater average depths, the knowledge of turbid zones, maximum, and its location

What is not available?

- High resolution models to capture finer scale (local) dynamics
- Insufficient representation of all forcings
- Representation of turbulence in 3D modeling to resolve mixing characteristics.
- Models that identify exact location of turbidity maximum.
- Inadequate sediment transport models to mimic the sediment dynamics.

Objective

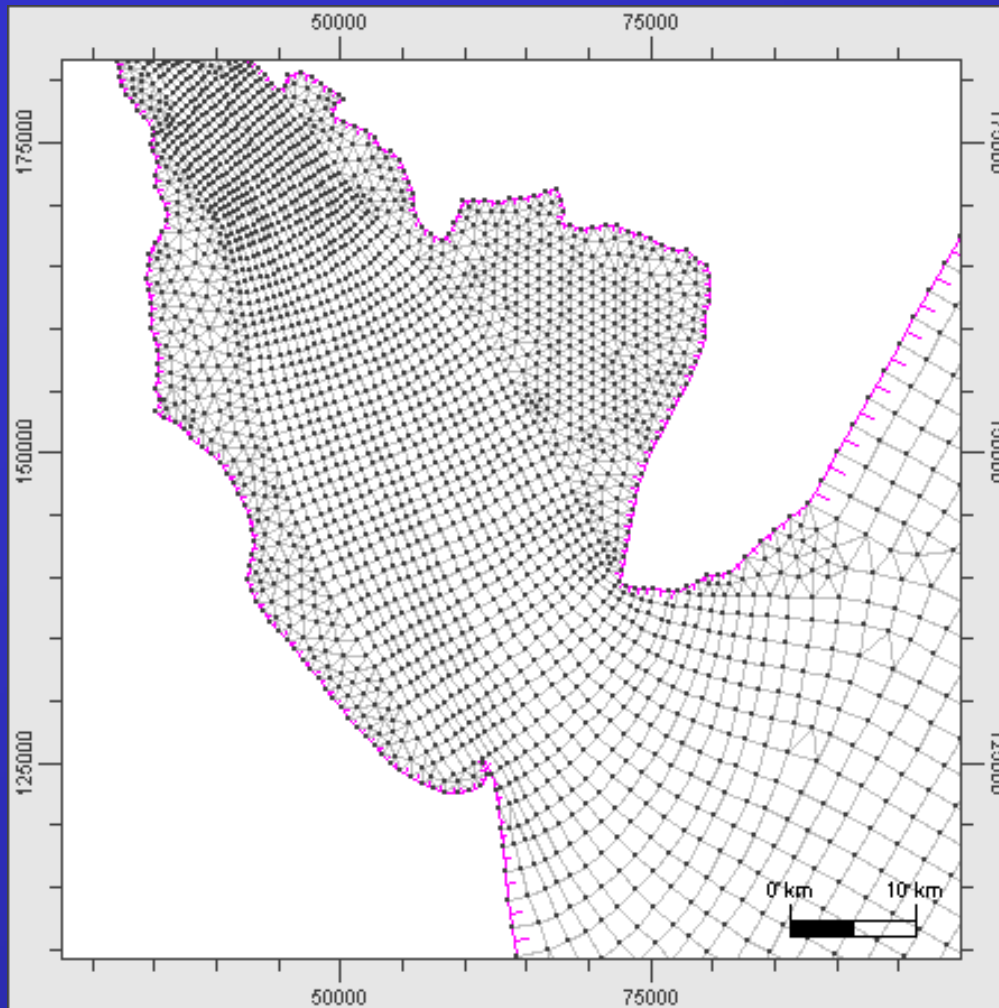
- High resolution 3D model (using the UnTRIM Kernel)
- Adequate representation of Turbulence and associated mixing, effects on Salinity field
- Sediment transport approach to model sediment dynamics

Turbulence Closure Model

- constant
- Algebraic model (1-equation)
- Yamada-Mellor 2.5 (2-equation original formulation)
- K-kl model (2-equation from GLS approach)
- k-epsilon (2-equation from GLS approach)
- k-omega (2-equation from GLS approach)
- *gen* (2-equation from GLS approach)

Does it matter?

Grids



Coarse Grid

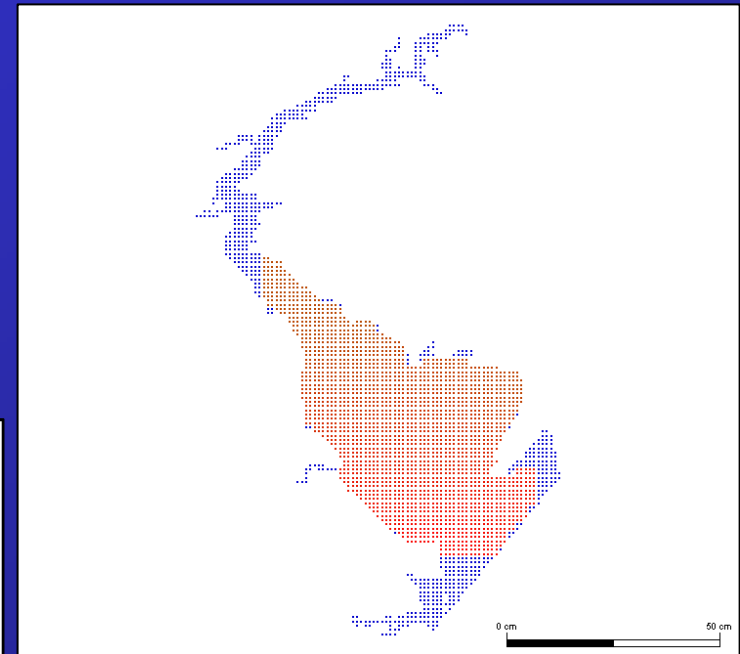
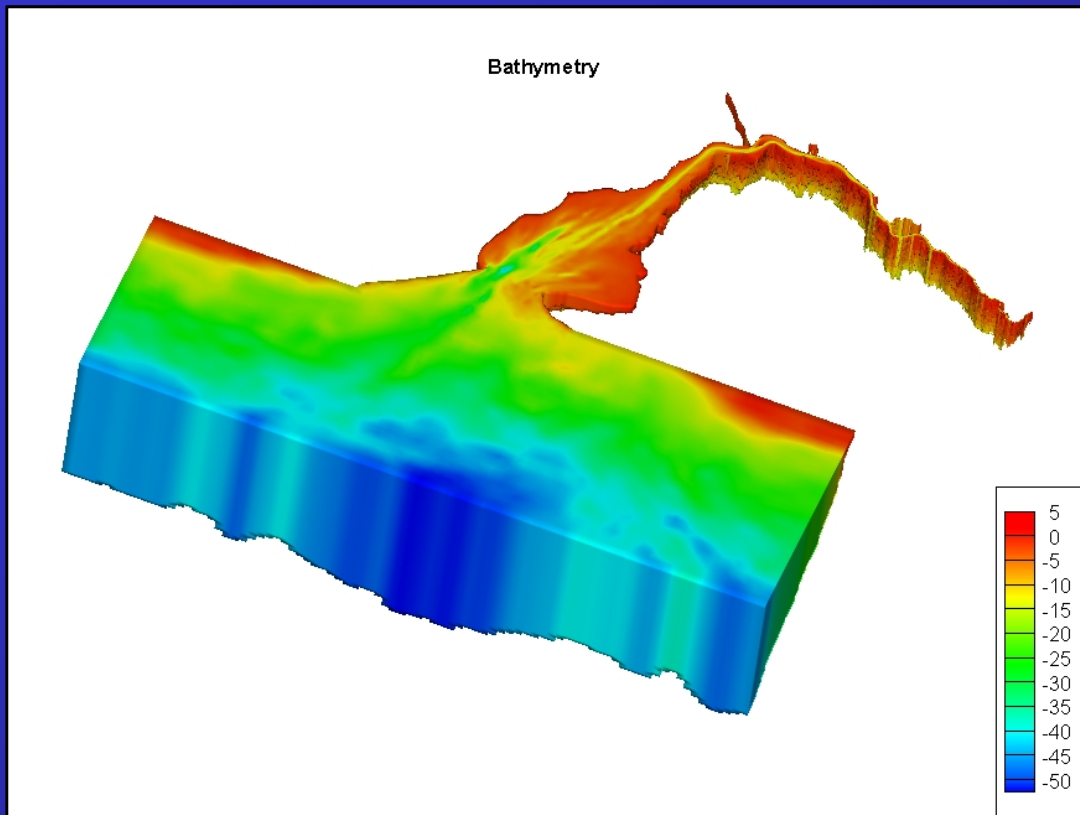
- # of elements in a layer: 9763
 - 7145 Quadrilaterals
 - 2618 Triangles
- 34 vertical layers (z-grid) 1 m spacing
- Edge length varies: 39 m to 2500 m

Fine Grid

- # of elements in a layer: 49218
 - no Quadrilaterals
 - 49218 Triangles
- 45 vertical layers (z-grid) var. spacing
- Edge length varies: 10 m to 1500 m

Bathymetry and Vertical Datum

Bathymetric depths from GEODAS (NGDC- National Geophysical data system)



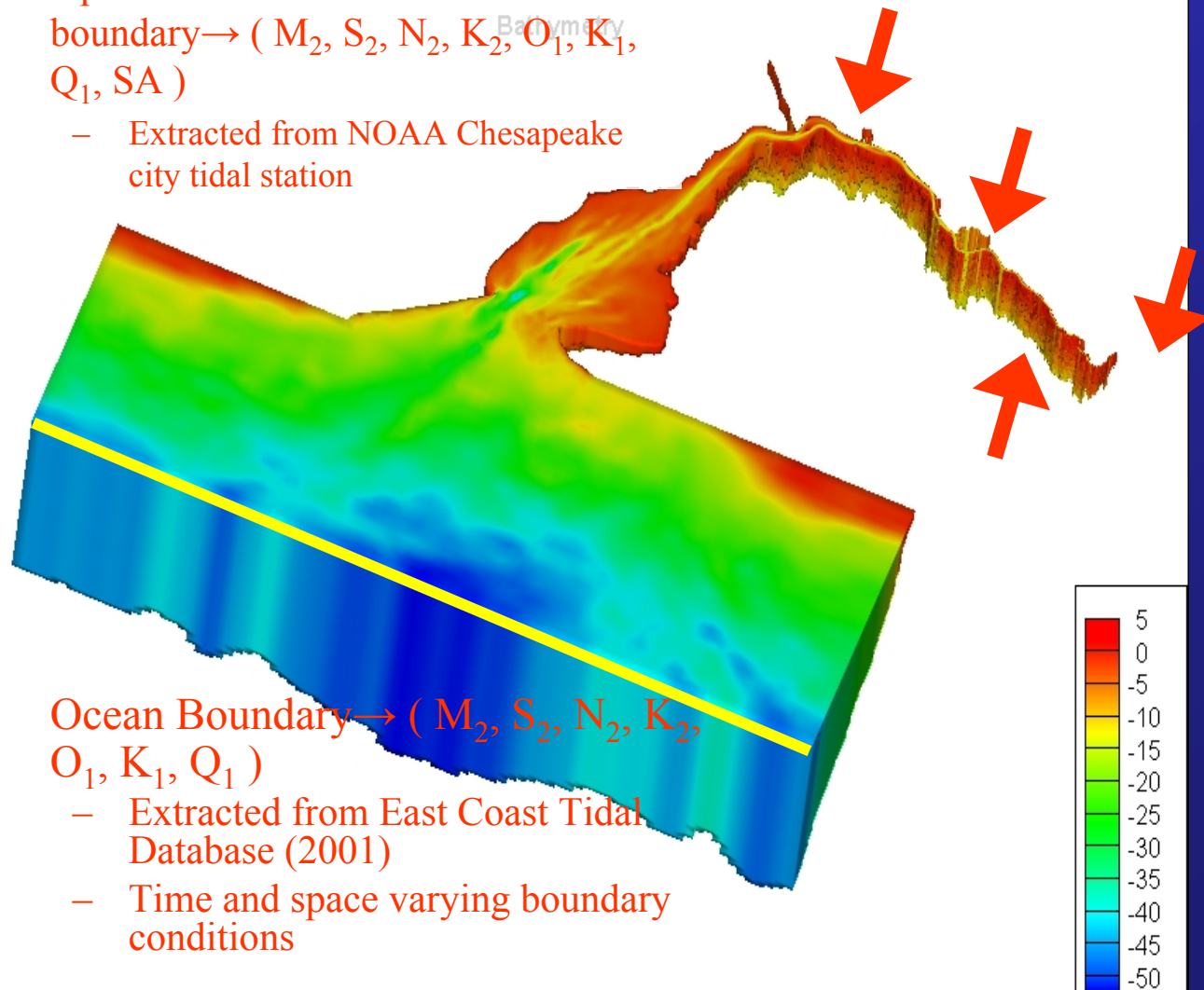
- VDatum Transformation Tool (NOAA) MLLW to MSL
 - Conversion from one vertical datum to another.
 - Available on red marked areas only!
 - Extrapolation using stations and boundary conditions.

Boundary Conditions

Chesapeake & Delaware canal

boundary \rightarrow ($M_2, S_2, N_2, K_2, O_1, K_1, Q_1, SA$)

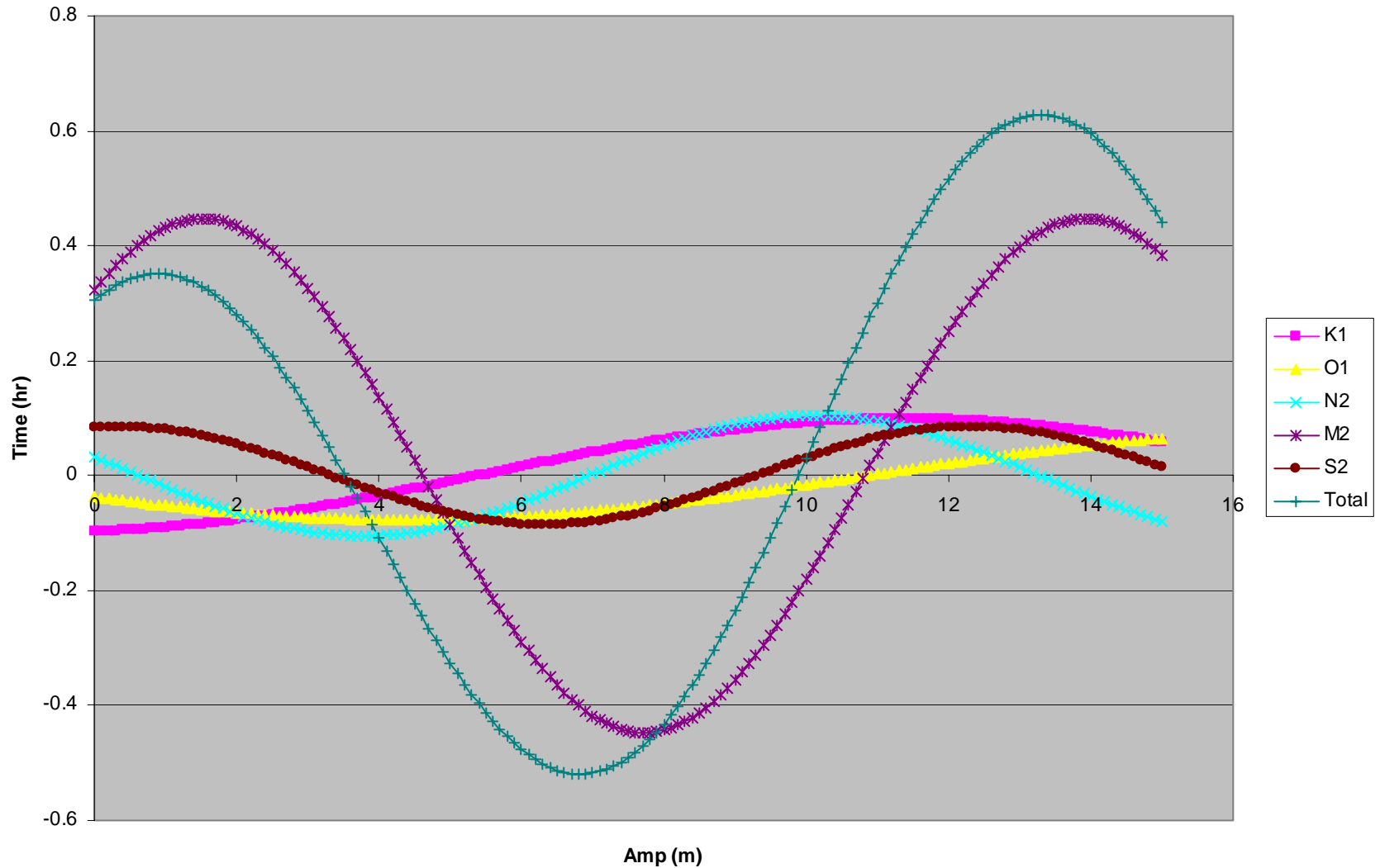
- Extracted from NOAA Chesapeake city tidal station

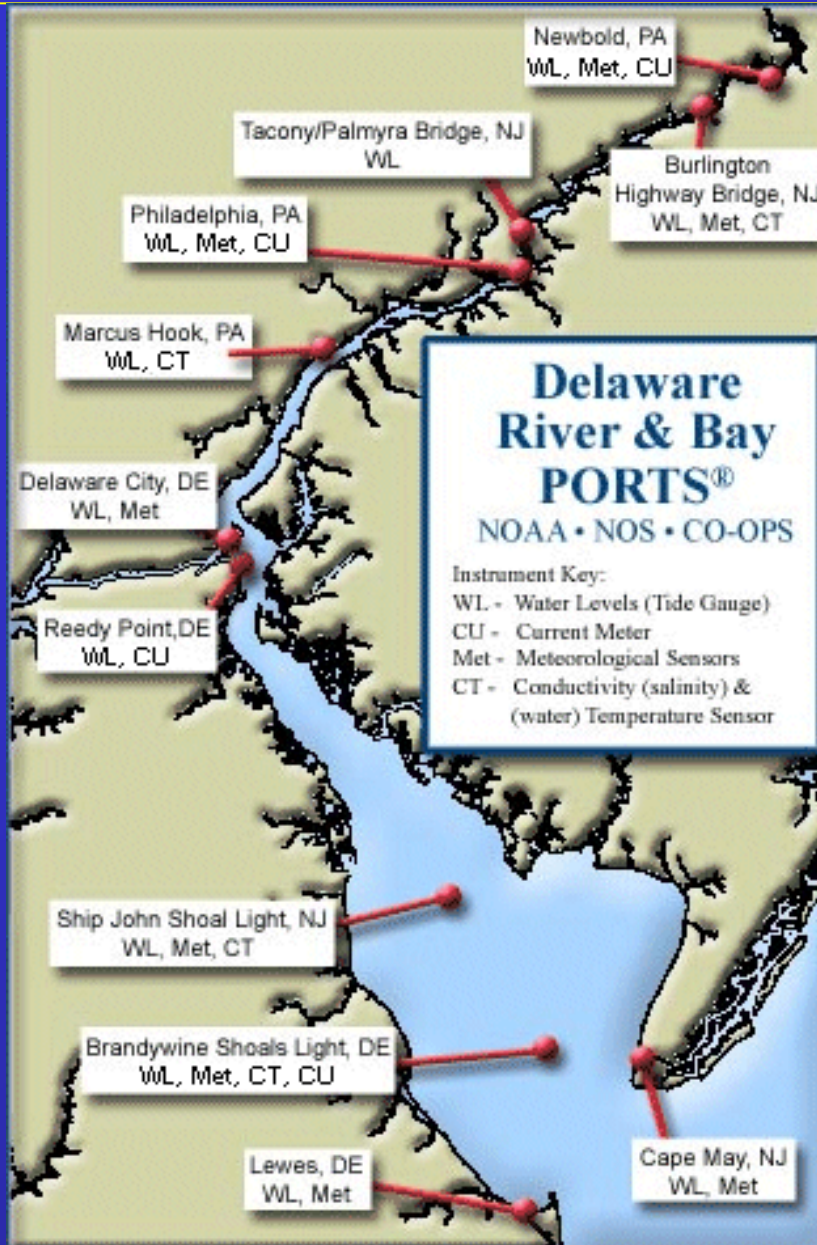


Ocean Boundary \rightarrow ($M_2, S_2, N_2, K_2, O_1, K_1, Q_1$)

- Extracted from East Coast Tidal Database (2001)
- Time and space varying boundary conditions

Tidal Boundary Condition

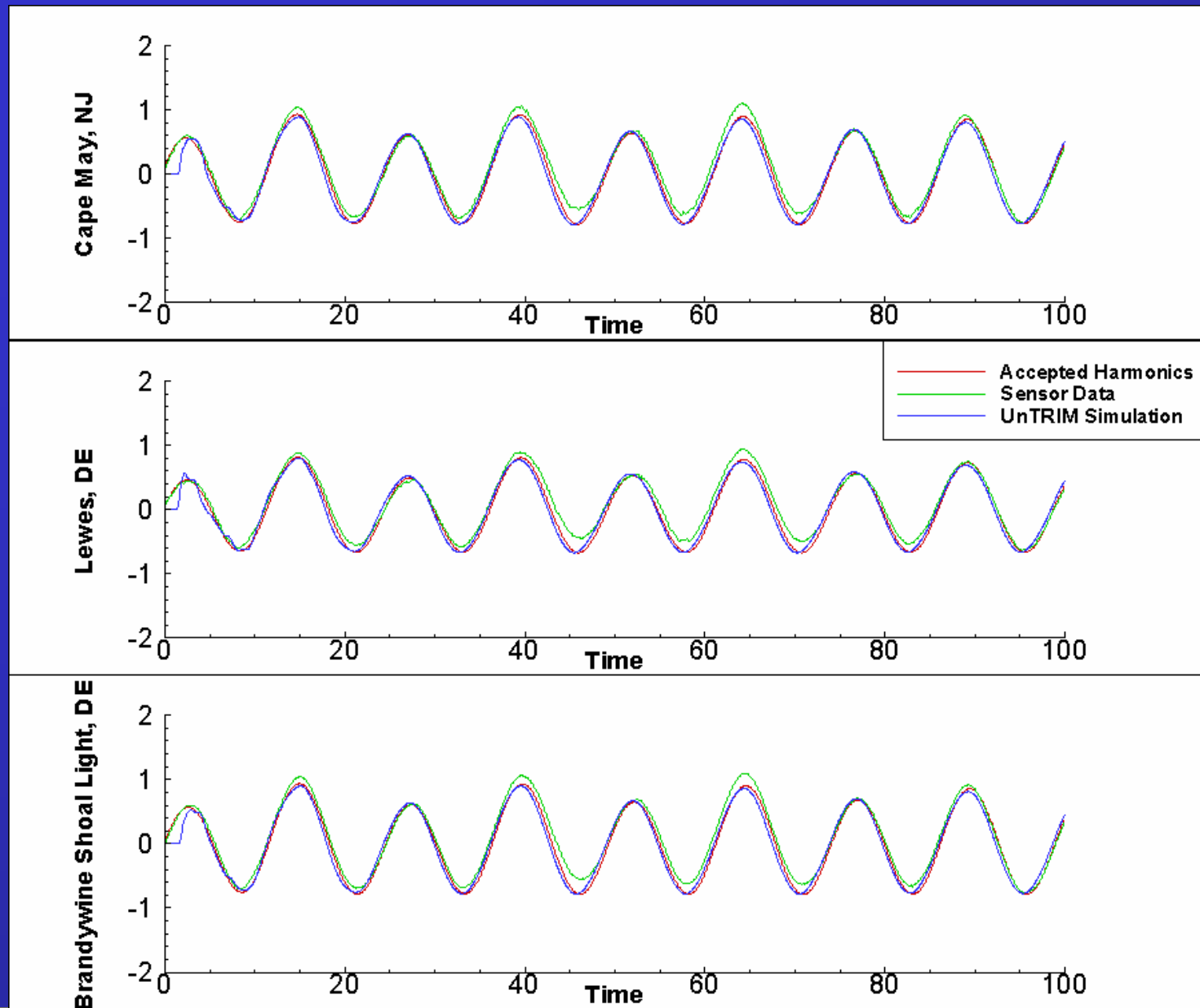


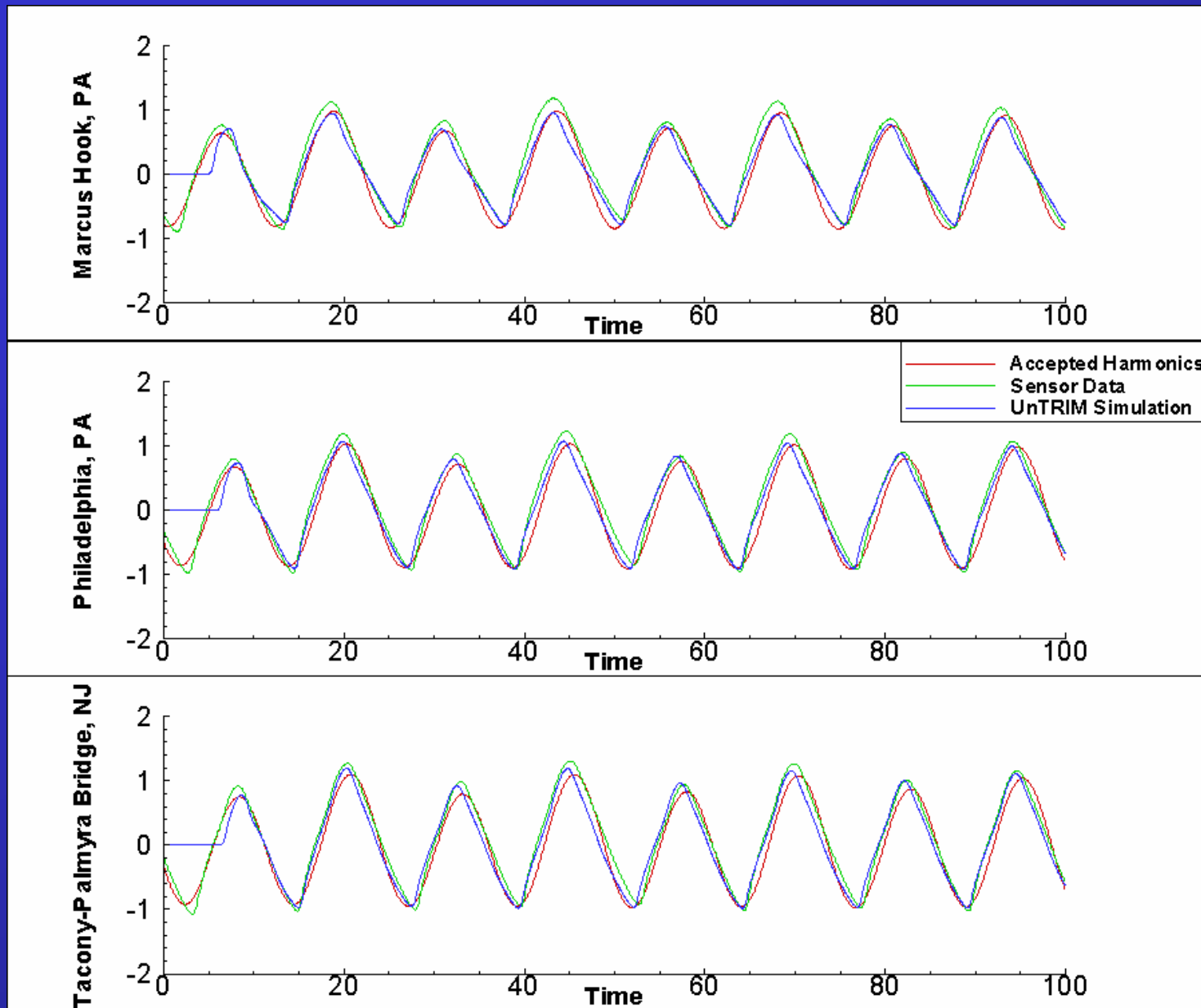


Results: Free Surface Elevation

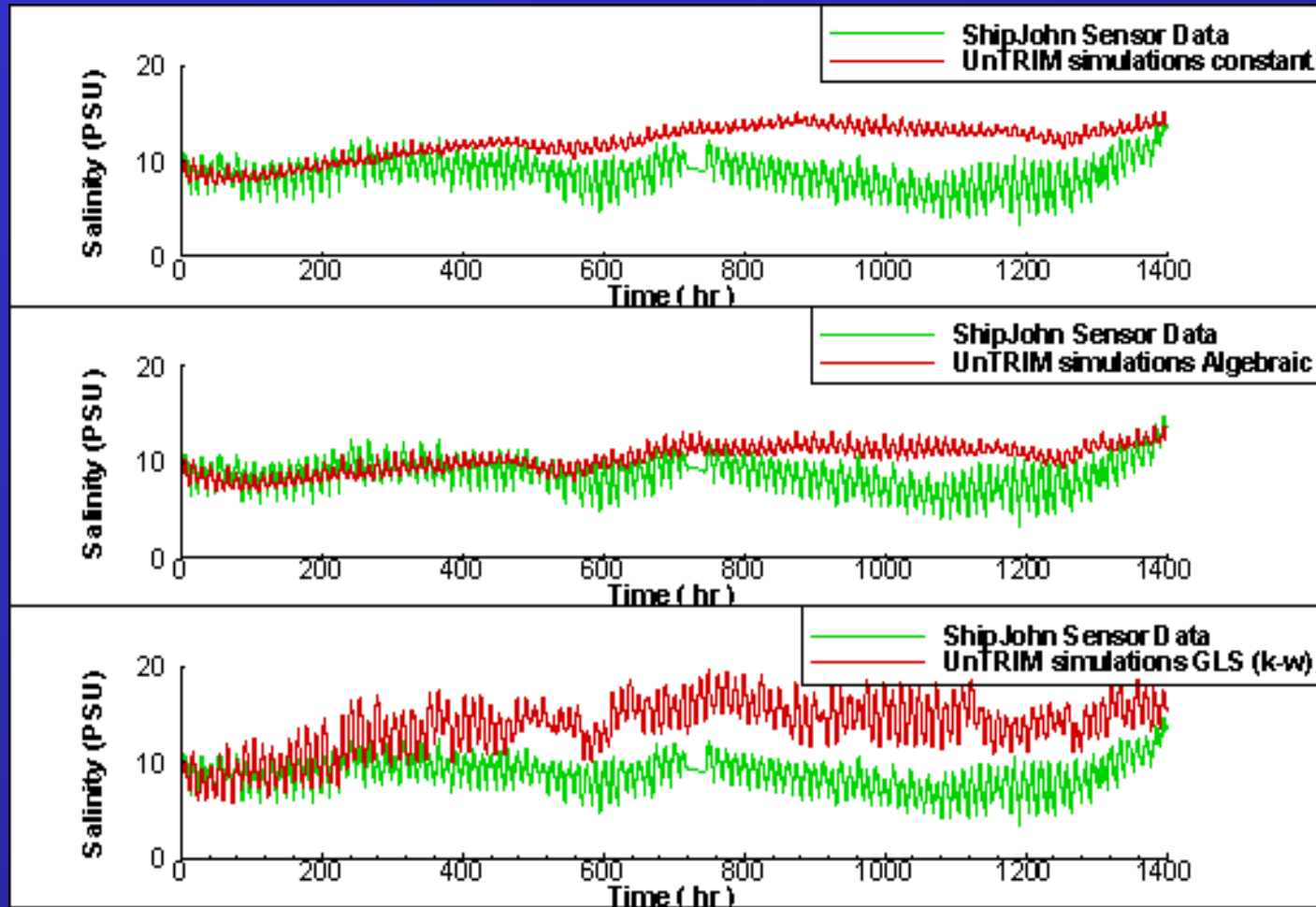
Comparison to NOAA observations:

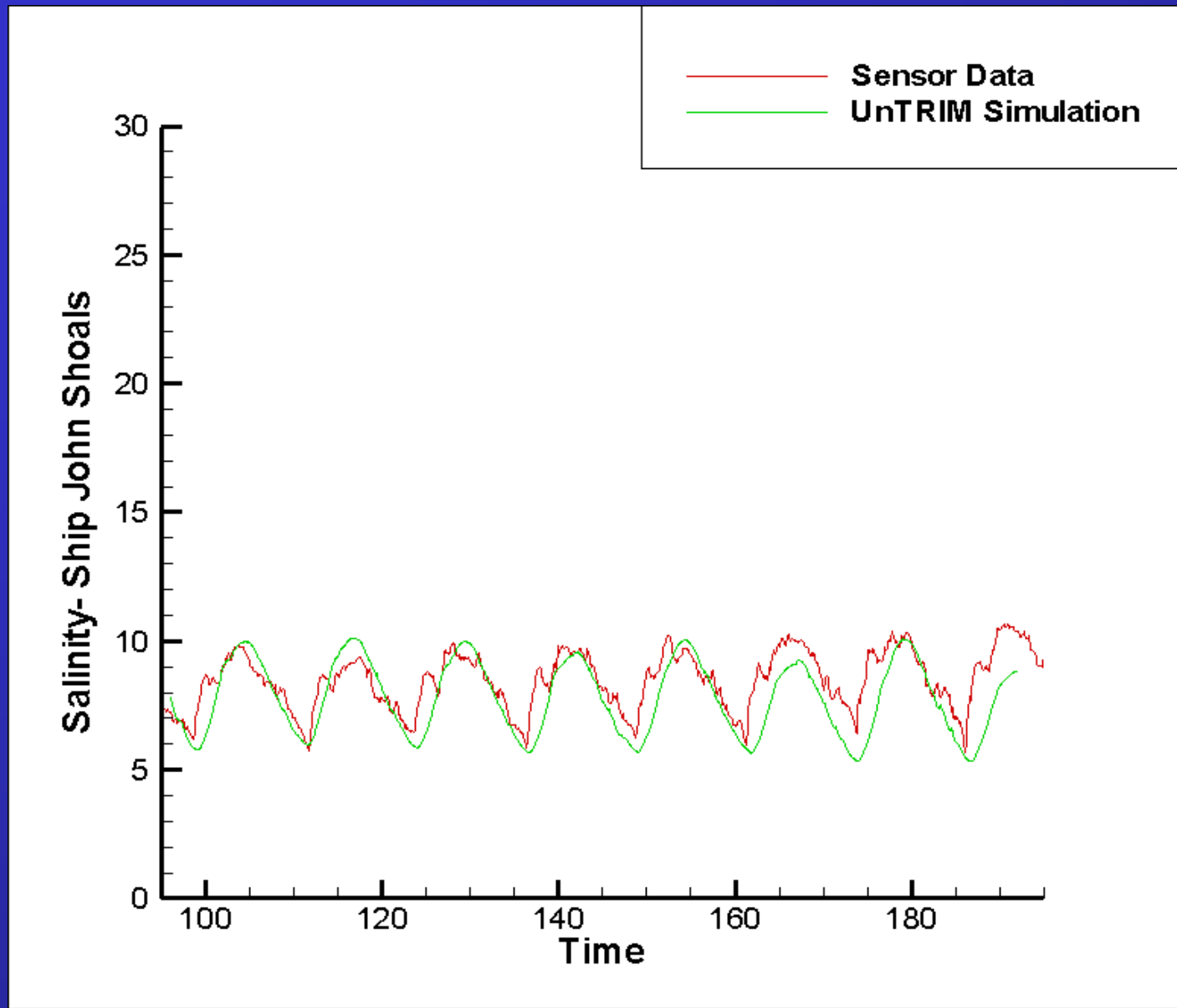
- Ports Programs



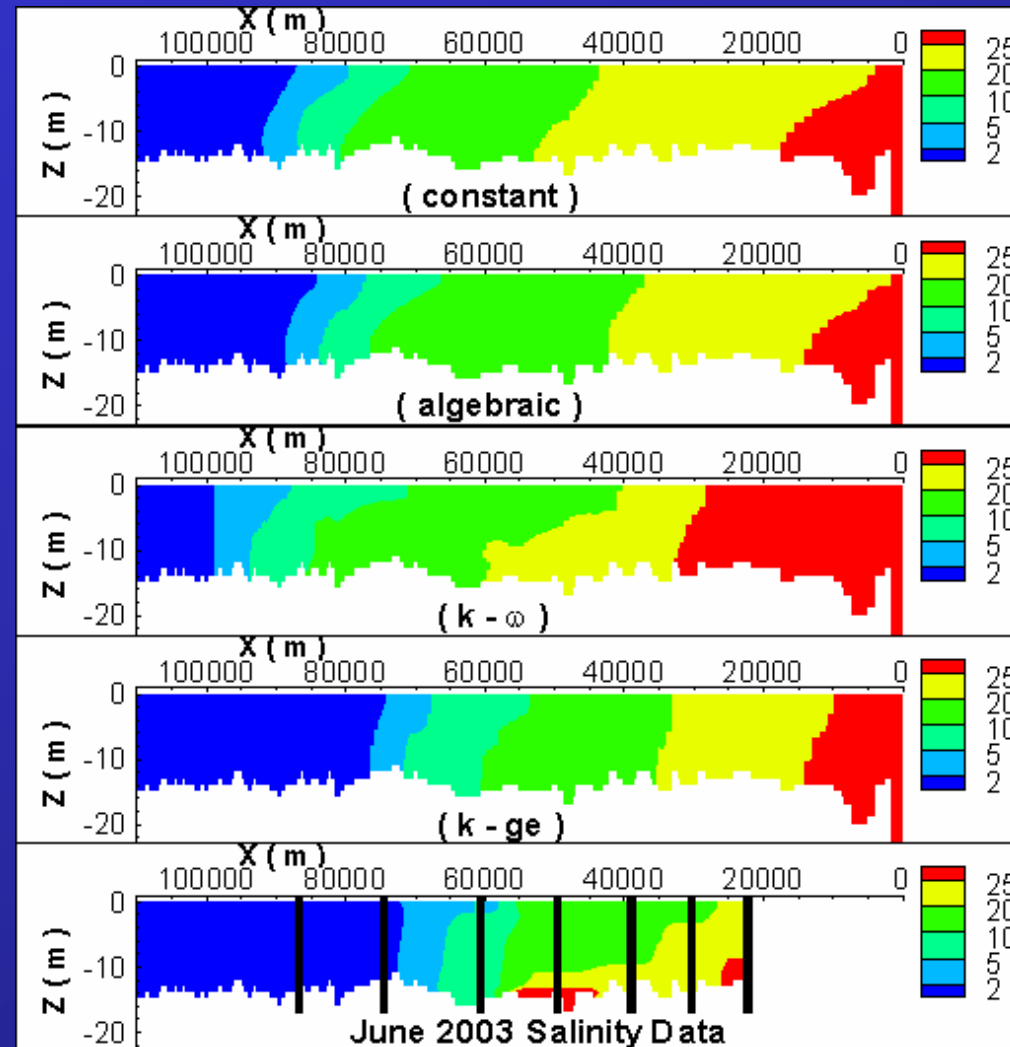


Results: Salinity Time Series





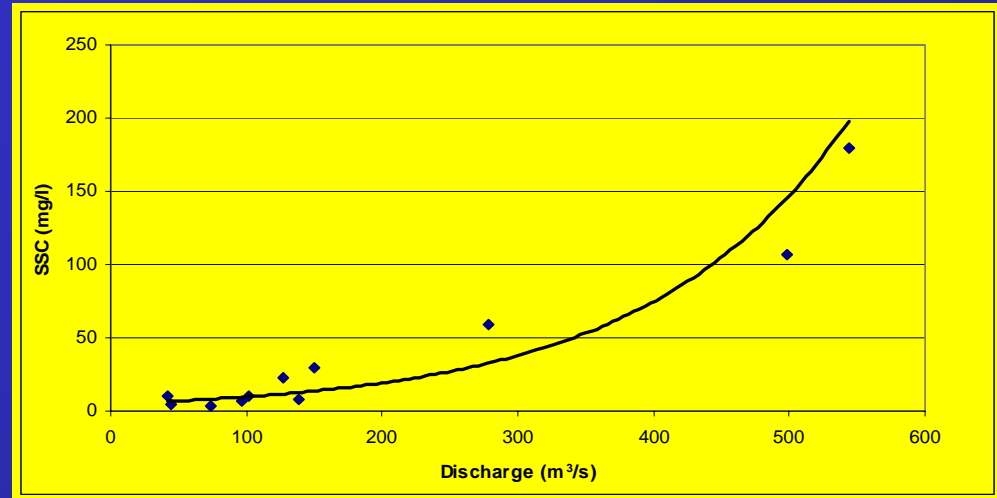
Results: Salinity Profile



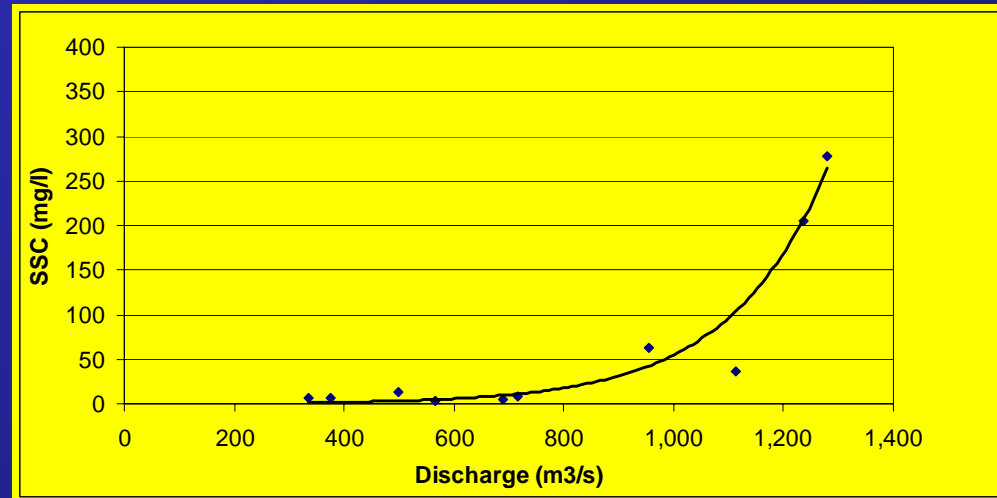
Sediment

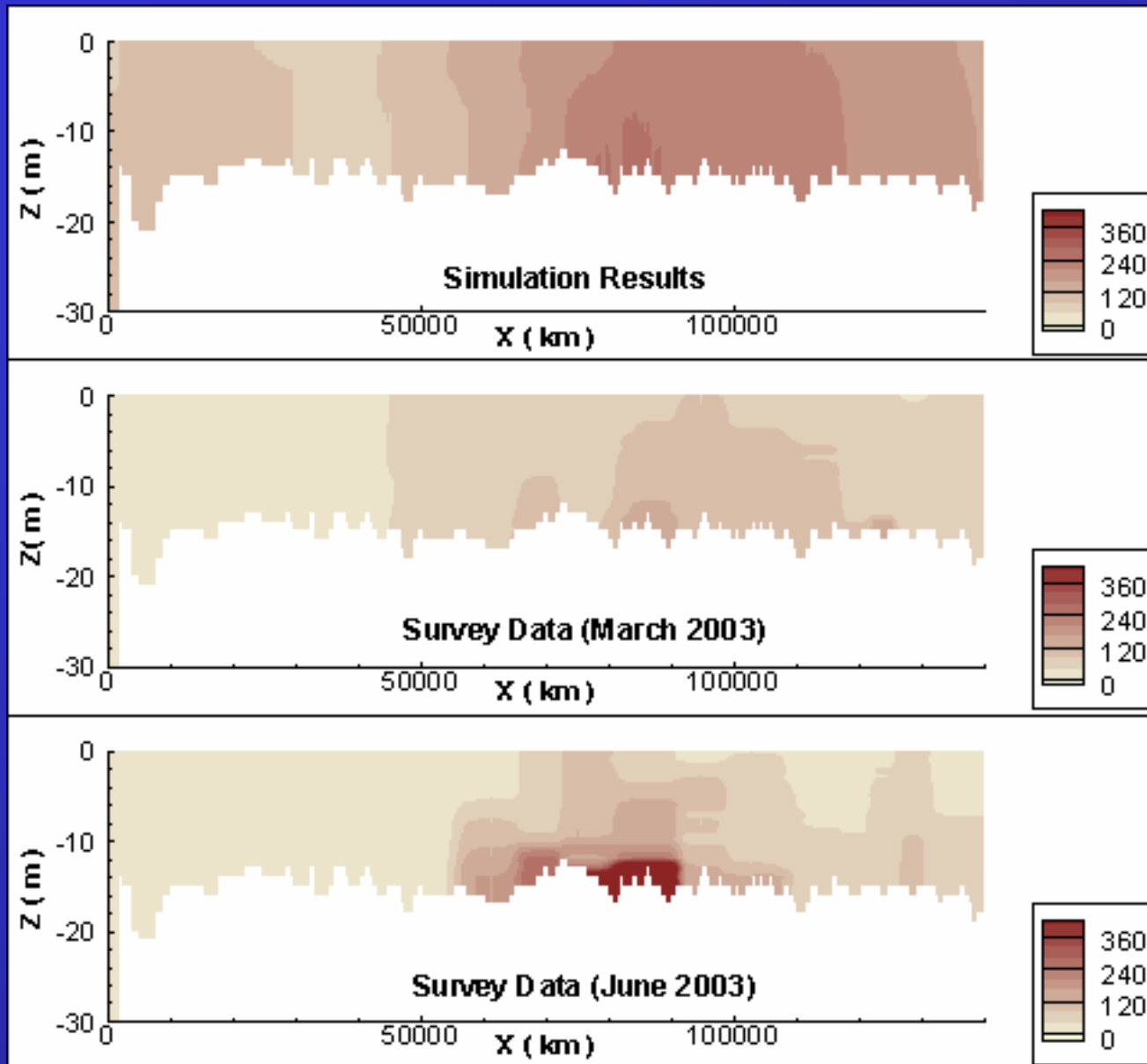
- Values for critical shear $\sim 0.2\text{Pa}$
- single class \Rightarrow settling velocity is a function of Sediment conc.
 $w_s = 0.001 (C_m) \text{ [m/s]}$
- Initial condition: 10mm of erodible material everywhere
- run for 47 days for initial distrib.
- track deposition and erosion for 15 days

SSC Schuylkill River

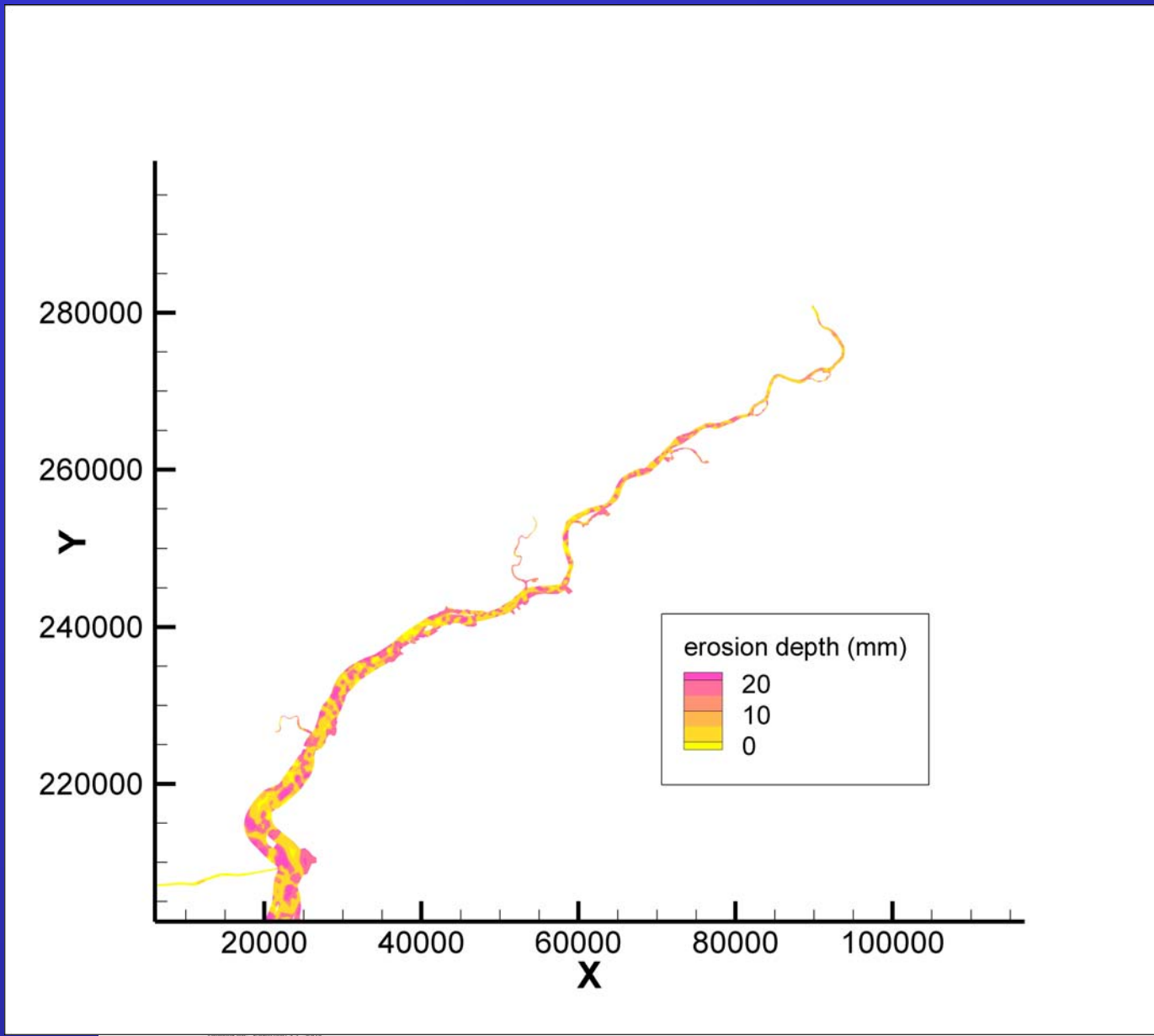


SSC Delaware River





(Cook, Sommerfield
Wong, 2006)



Zone 2

Side Scan Radar of bottom near Tacony-Palmyra Bridge indicative of Bedload Transport

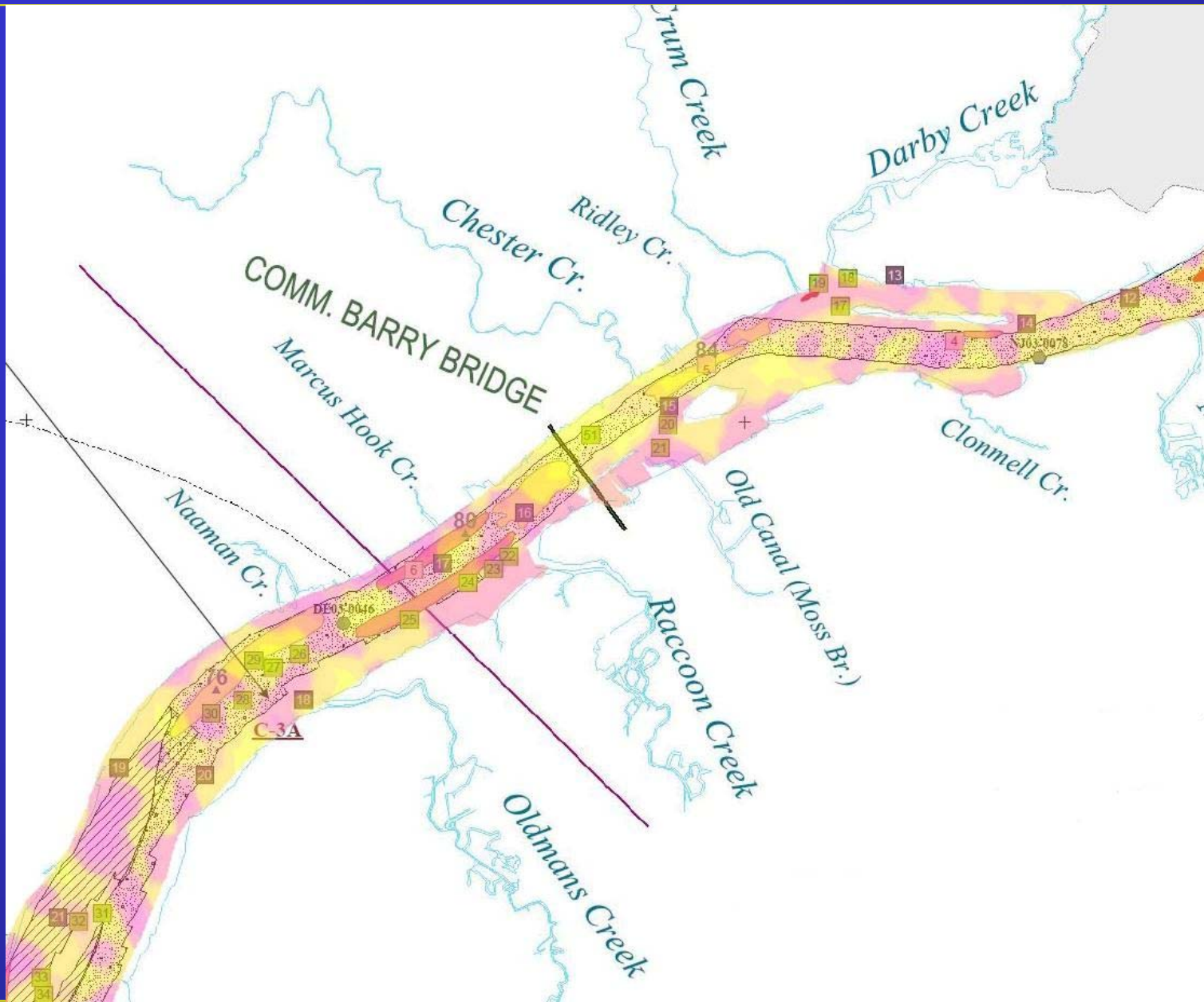
Bed Description

Intensity	Dominant Sediment Type	Bottom Morphology and Bedforms
weak	Mud and fine mud	Flat, no bedforms
strong	Moderately well-sorted sand and gravel	Wavy, well-developed banks of ripple and sand
weak	Mud	Flat to wavy, sediment furrows
strong	Mixed gravel, sand, and mud	Flat to wavy, sediment ripples and tracks
medium	Poorly sorted sand and gravel	Flat to wavy, sediment ripples
very weak	Cobble and bedrock	very

Coastal 2003 Sites

- A
- B
- C





Future Outlook

- Increasing the capabilities of the sediment model by adding the information for bottom sediments and mapping them to a database
- adding a bed load model which will run simultaneously with suspended sediment model, and capability of running the model with different class of sediments if data becomes available.
- Integration of a geo-morphological model allowing bathymetry changes during simulations => long term evolution of bed.
- Add elements to along periphery to include marshes. UnTRIM can handle wetting & drying.
- Expanding code to include pollutant fate and transport modules

Runtime Properties

SIMULATION	TIME STEP	CPU TIME	RT / CPU RATIO
3D (Fine Grid)	150 seconds	~ 42 seconds	~3.1
3D (Coarse Grid)	150 seconds	~ 8 seconds	~ 18.5
3D (Coarse Grid) New Computer	150 seconds	~ 6 seconds	~ 25

Simulation period: 62 Days

Data Storage Demands

Duration of Simulation	Velocity	Water Surface Elevation	Salinity (or any scalar transport variable)	TOTAL
3D/single day*† (Fine Grid)	1550 MB/ Day	55 MB/ Day	975 MB/scalar/Day	2580 MB / Day
3D/single day*† (Coarse Grid)	215 MB/ Day	15 MB/ Day	120 MB/scalar/Day	350 MB / Day

*3D simulations are performed with 34 vertical layers

† Simulation output every 10 minutes (at every two time steps)