Chester River Shallow Water Project – SCHISM model results

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Chesapeake Bay Program sub-committee meeting presentation

4/23.2015

VIMS | William & Mary
Virginia Institute of Marine Science

Acknowledgement:
(1) Grant supported by EPA Chesapeake Bay Program.
(2) SCHISM model development support by MD Environment service and MD Port authority

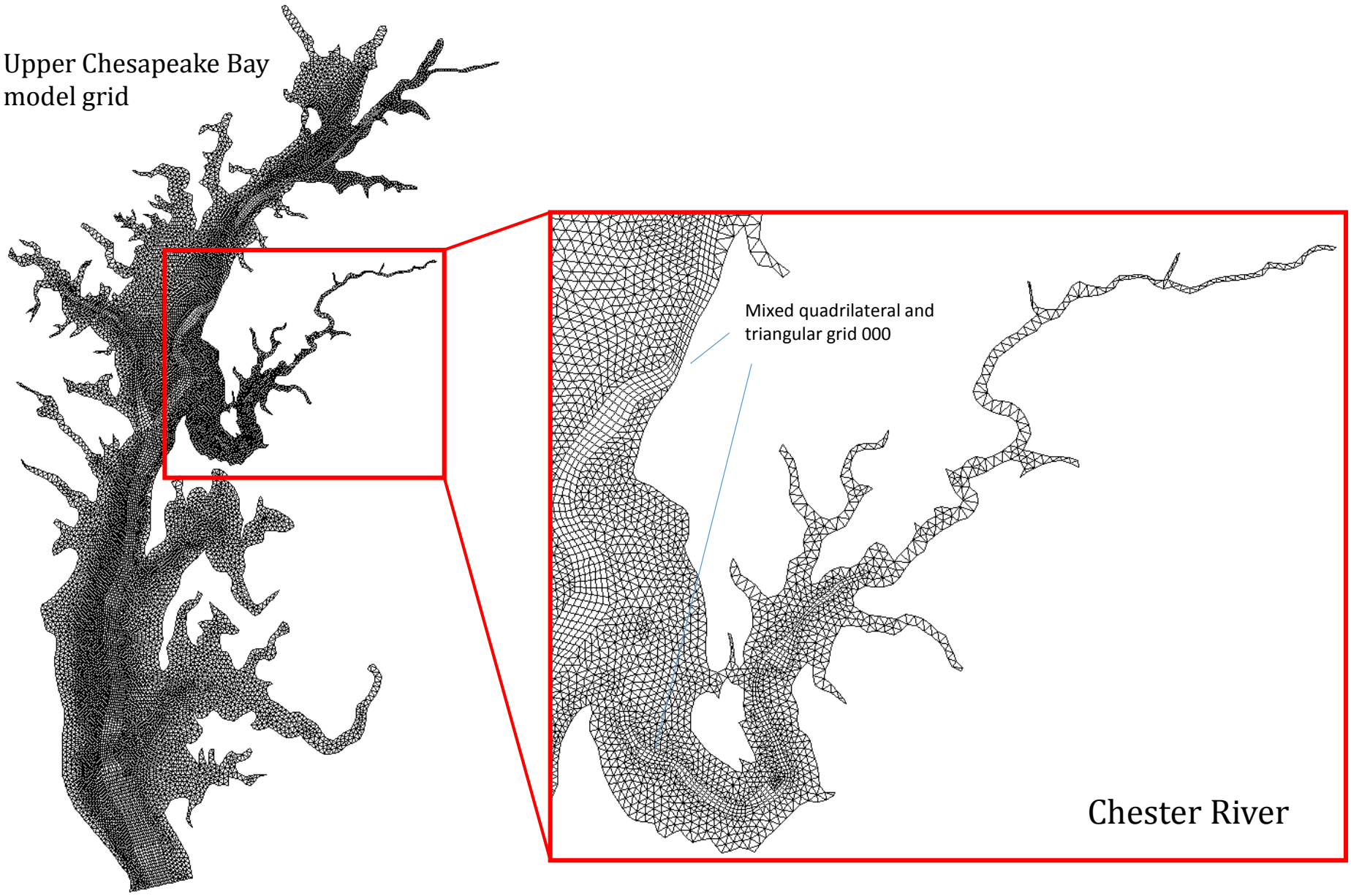
SCHISM: (Semi-implicit Cross-scale Hydroscience Integrated System Model)

- A derivative product of SELFE, distributed with Apache v2 license
- Galerkin finite-element and finite-volume approach: ***generic*** unstructured grids (mixed triangles and quadrangles)
- **Semi-implicit** time stepping: no mode splitting → large time step and no splitting errors
- **Eulerian-Lagrangian** method (ELM) for advection → more efficiency & robustness
- Hybrid *SZ* coordinates or LSC^2 in the vertical
- Configurable
  - Cartesian or spherical coordinates
  - 2D or 3D
  - Hydrostatic or non-hydrostatic
- Mass conservative transport (***implicit*** TVD^2)
- Fully parallelized with domain decomposition (MPI) with good scalability
- Well-benchmarked inundation scheme for wetting and drying (NTHMP)
- Operationally tested and proven (NOAA, DWR, CWB…)
- Has evolved into a comprehensive modeling system
- Open source and driven by user community needs; our goal is to develop a ***verifiable*** and ***comprehensive*** modeling system

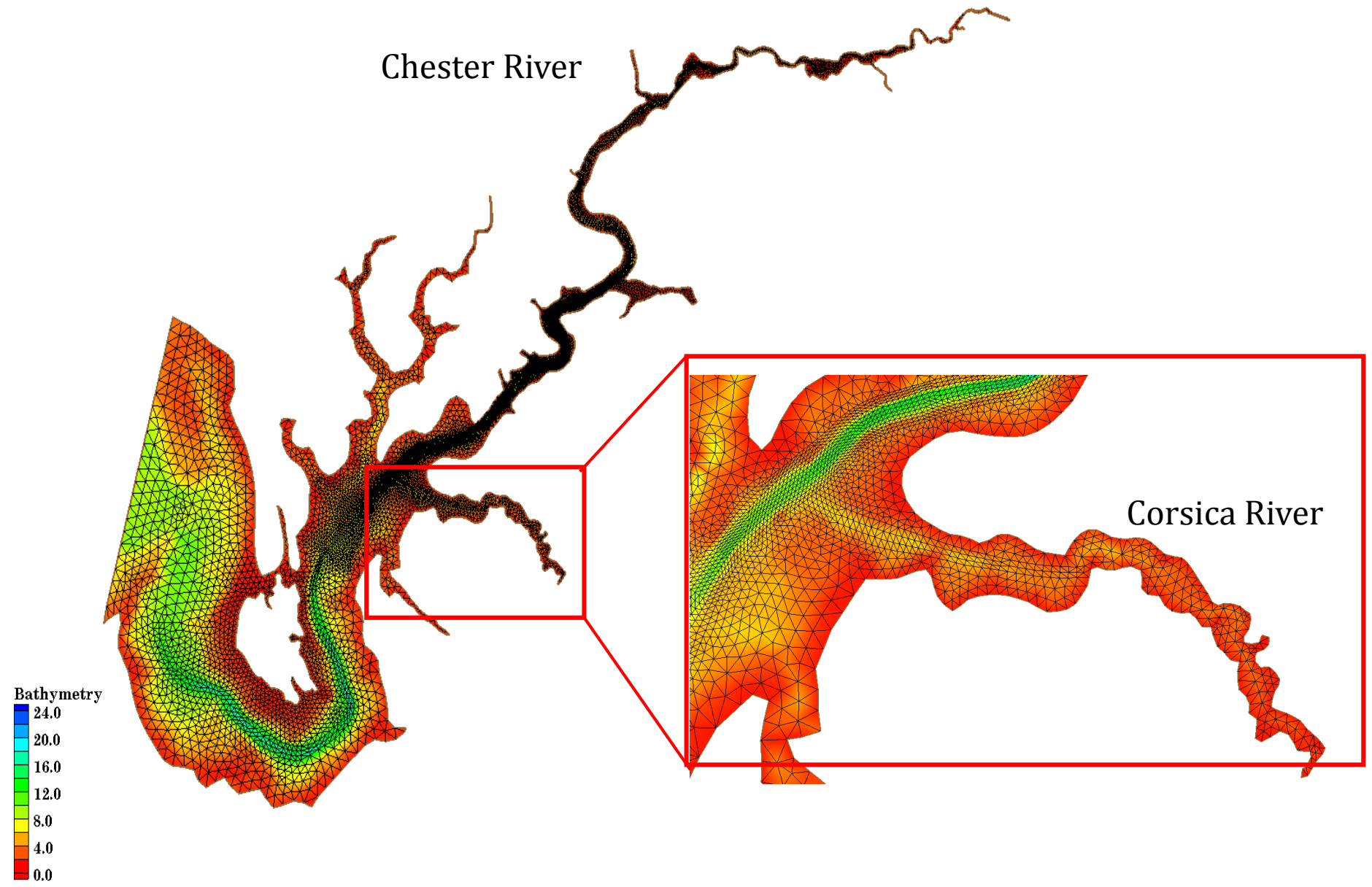
Community model: www.schism.wiki

SCHISM

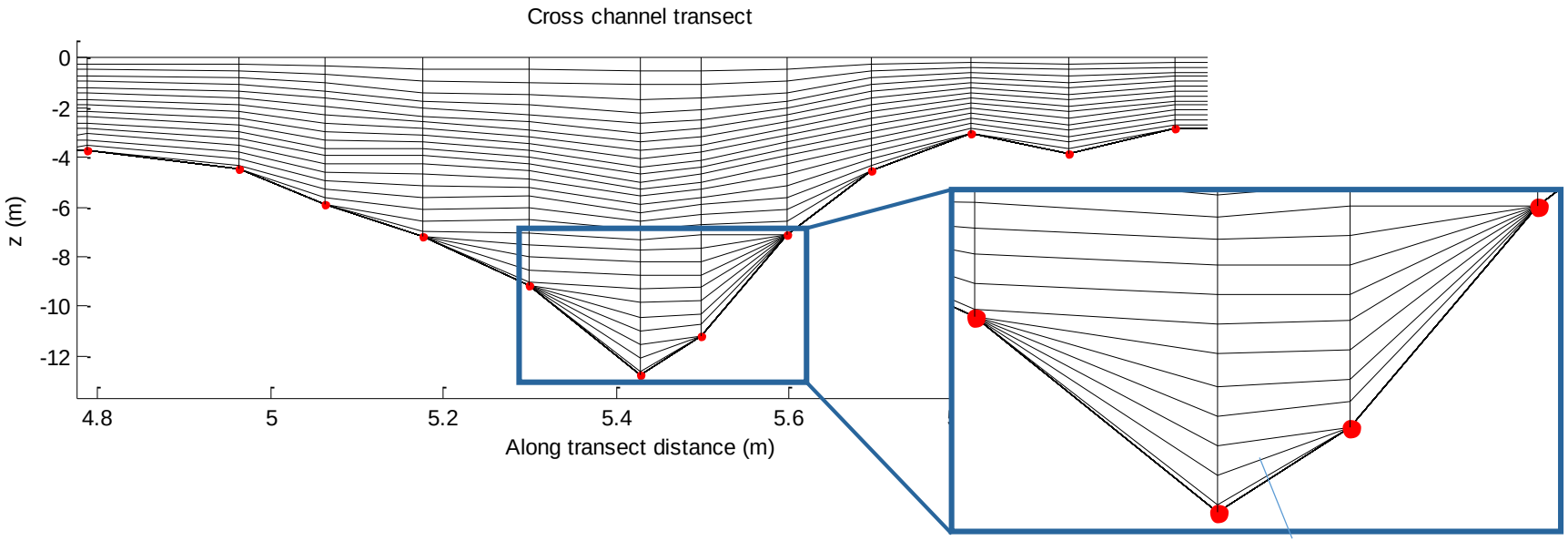
Upper Chesapeake Bay and Chester model grid



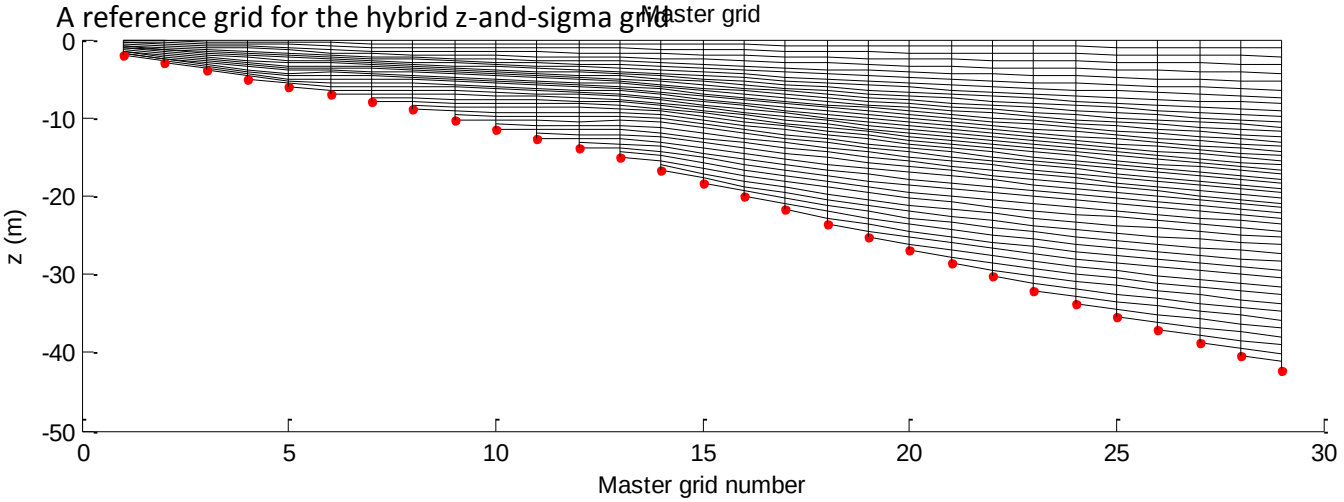
Chester model grid and Corsica River



The upper Chesapeake Bay model – **Vertical grid**

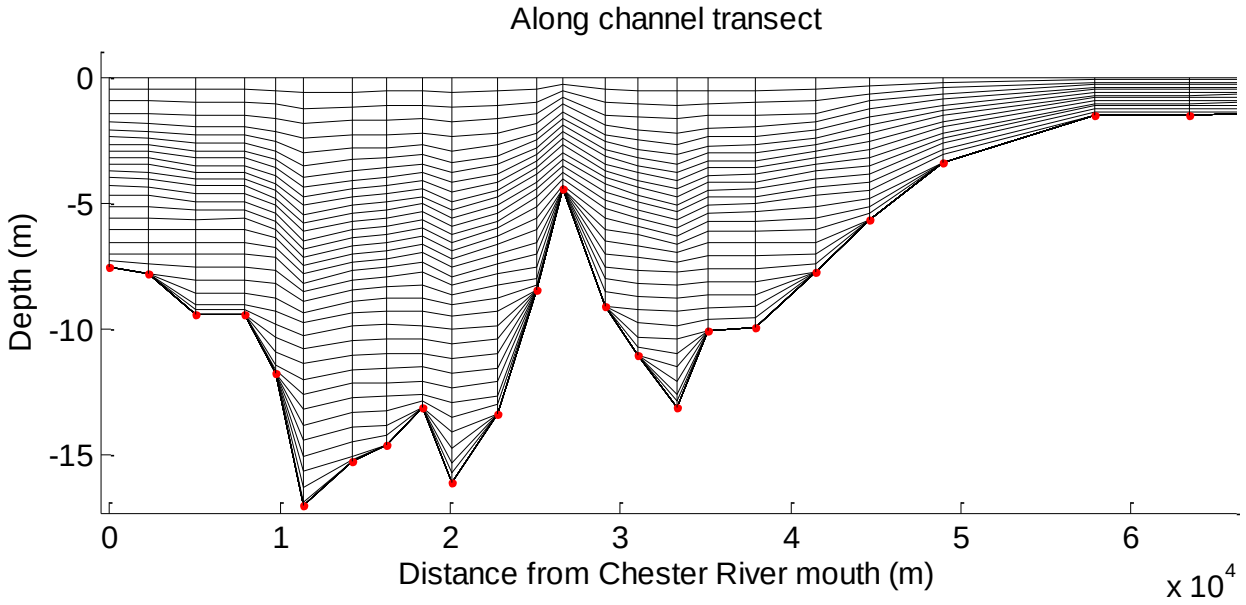


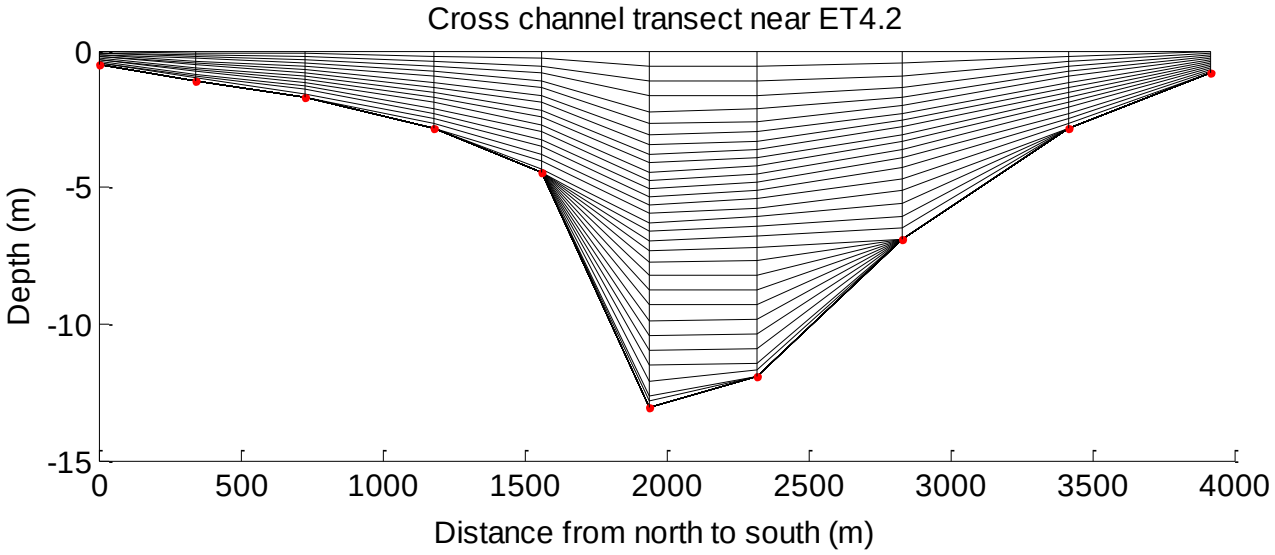
*Triangular grid for the bottom layer



*Reference: Zhang et al (2015): A new vertical coordinate system for a 3D unstructured-grid model. Ocean Modeling, Vol. 85, p16-31

Vertical discretization in the Chester River

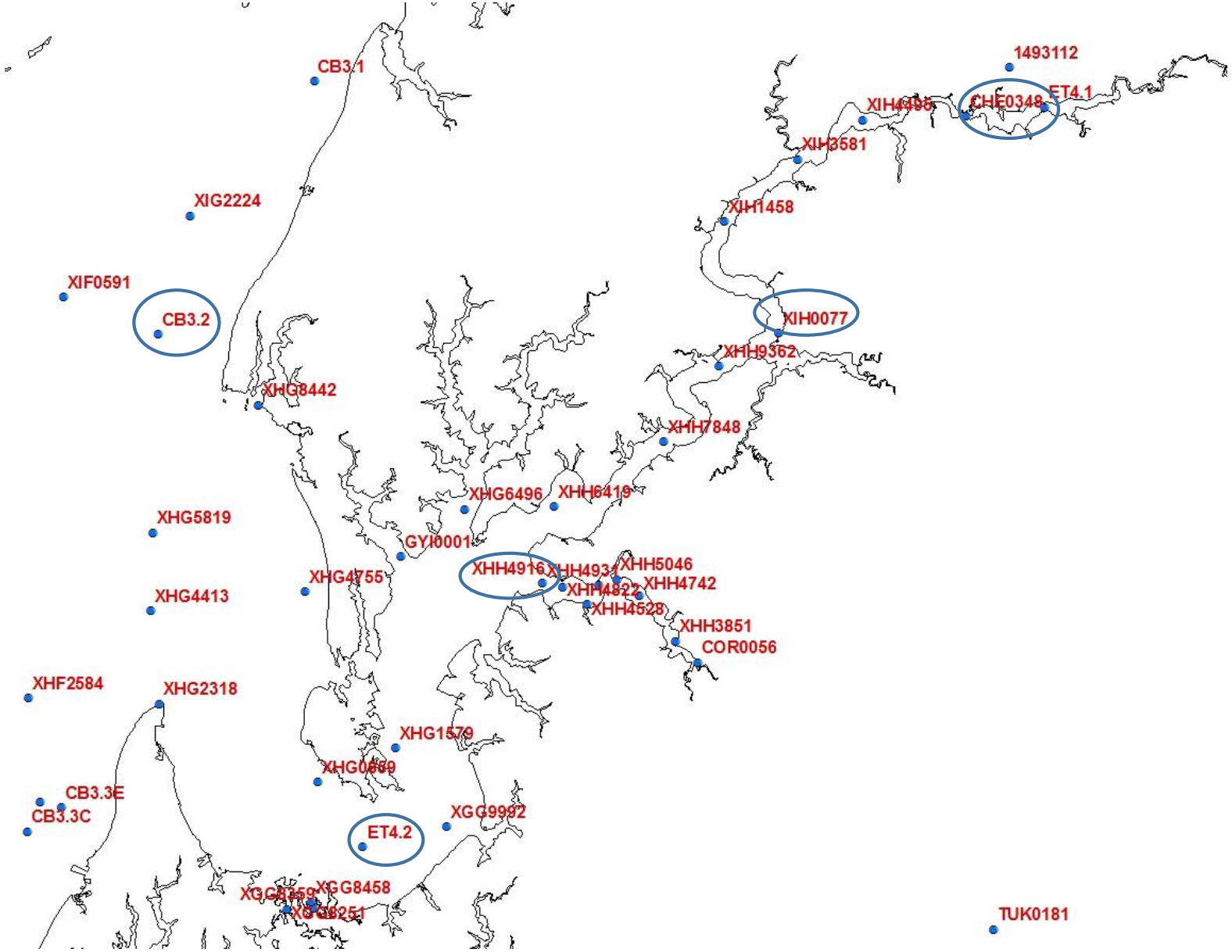




Chester River model setup

- Initial condition:
  - Interpolated from observation in 2003
- Boundary condition:
  - CH3D: elevation, salinity, temperature
  - Schism Upper Bay model: velocity
- Fresh water inputs:
  - Chester River fall-line load (provided by Bay Program)
  - Susquehanna River fall-line load for the upper bay model
  - Point and non-point sources provided by the HSPF watershed model results
- Wind:
  - Thomas Point station, spatially homogeneous throughout the domain
- Heat, radiation and precipitation:
  - North American Regional Reanalysis (NARR)
- Time step: 120 sec (hydrodynamic model); 360 sec (wind wave model)

Chester River monitoring station

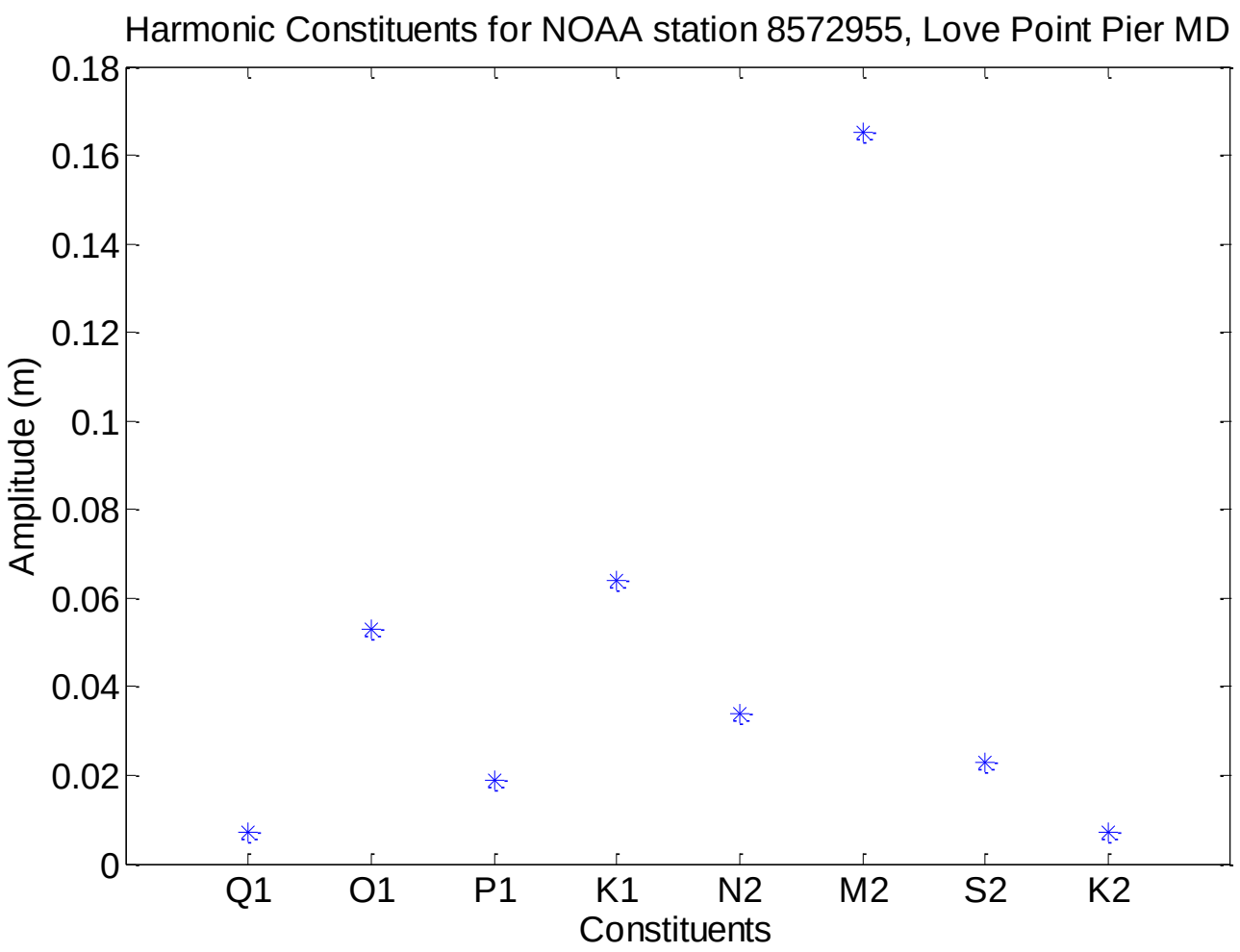


Model results

- Elevation
- Velocity
- Salinity
- Temperature
- TSS

(*Model results from 2003-2006 has been submitted to management team of the project, as of 03/2015)

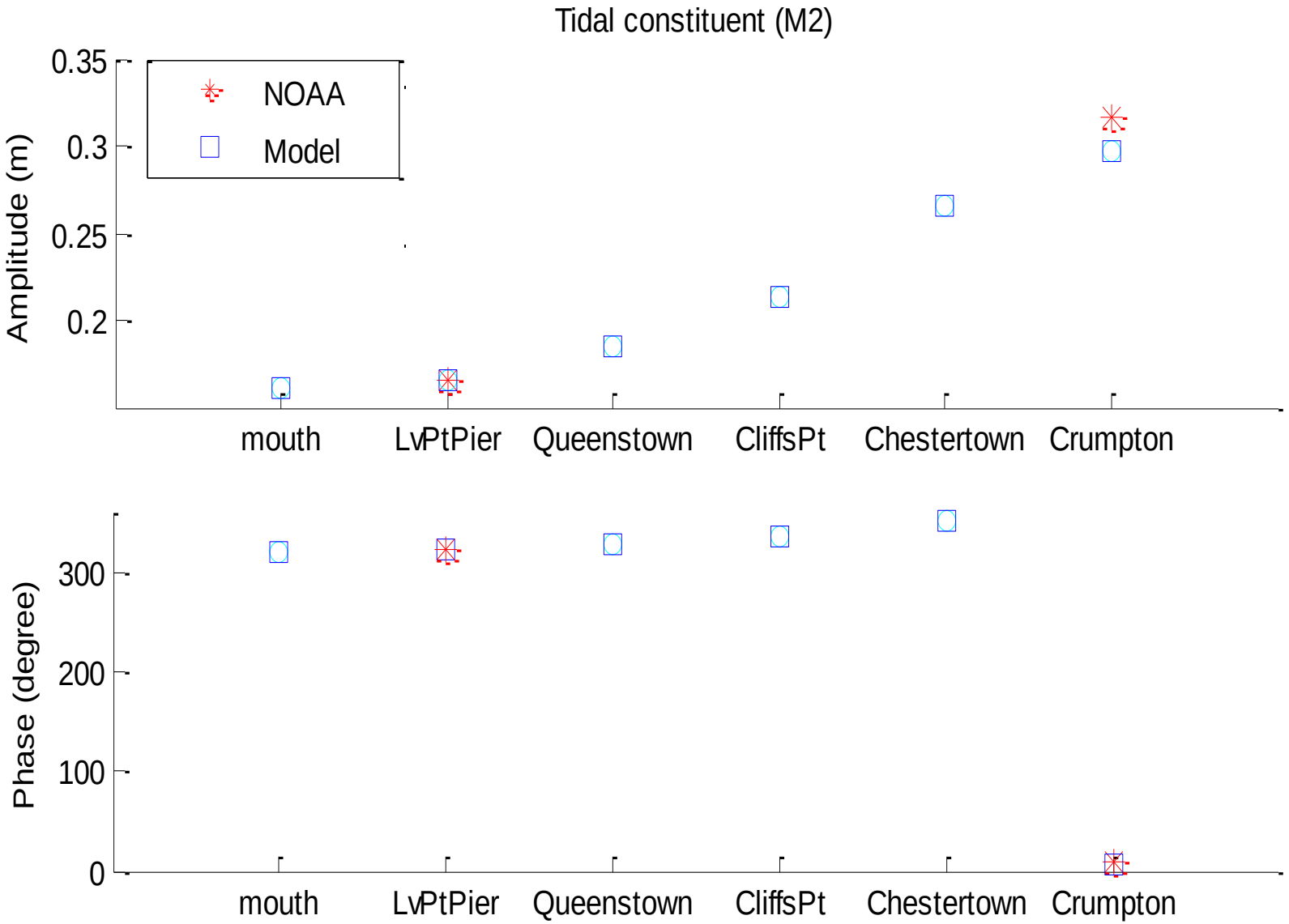
Model results – tidal elevation



Harmonic Components	Amplitude (m)
M2	0.170
K1	0.065
O2	0.060
N2	0.038
S2	0.020
P1	0.020
Q1	0.010
K2	0.010

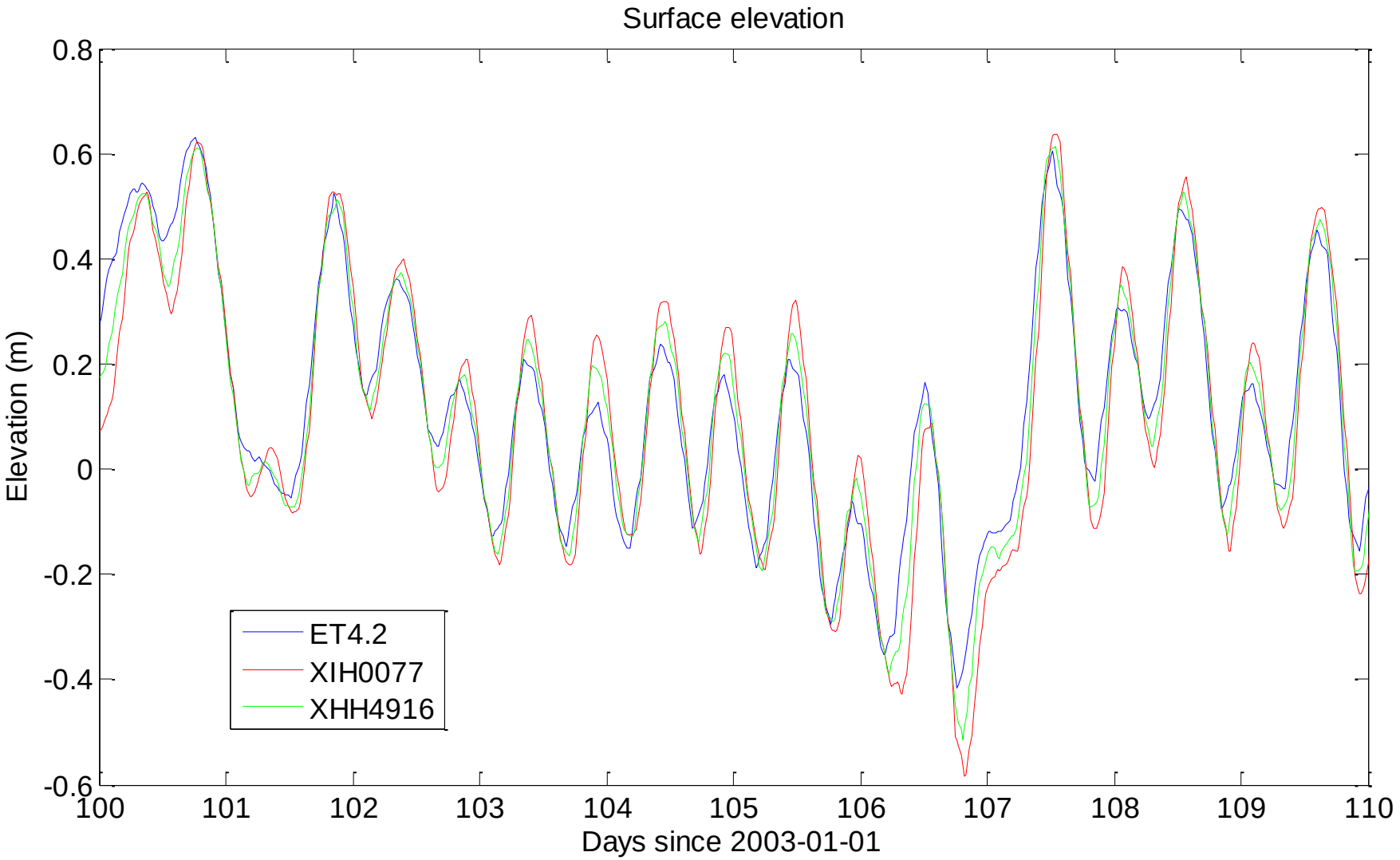
Model results – M2 tidal range and phase spatial distribution

- Chester River

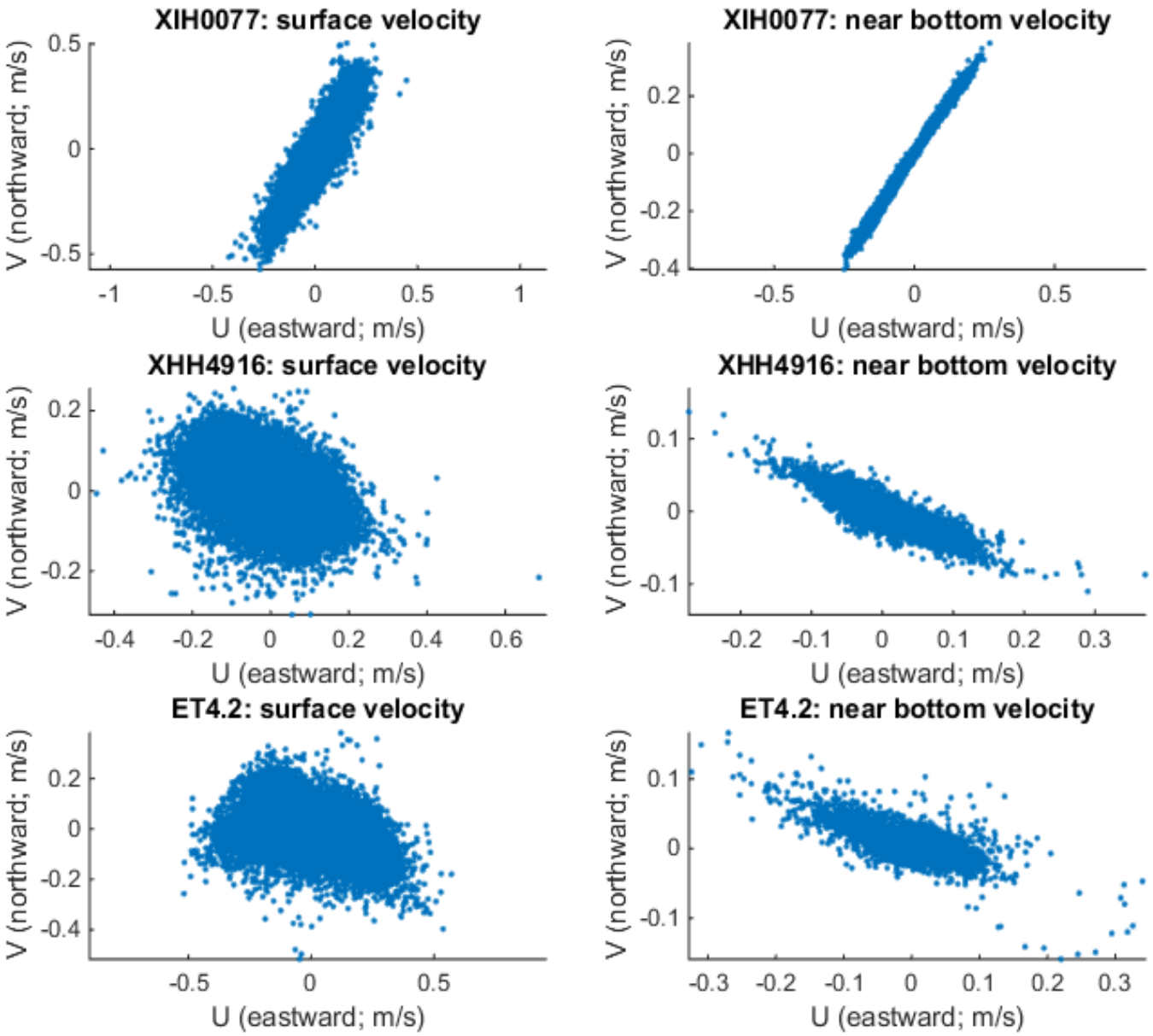


Model results – surface water level (evidence of influence of the wind)

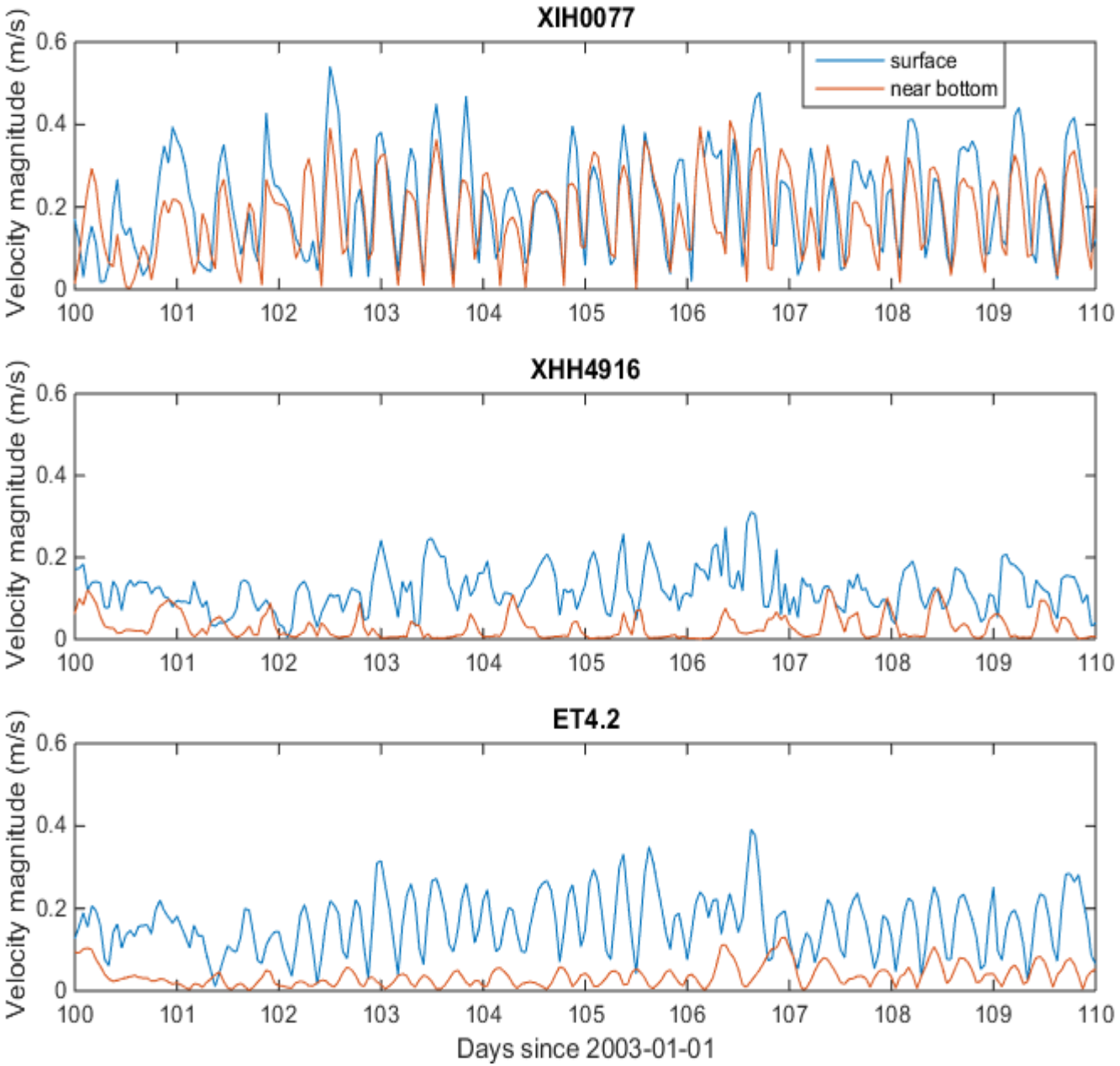
- Chester River (ET4.2, XIH0077) and Corsica River (XHH4916)



Model results – Velocity scatter diagram



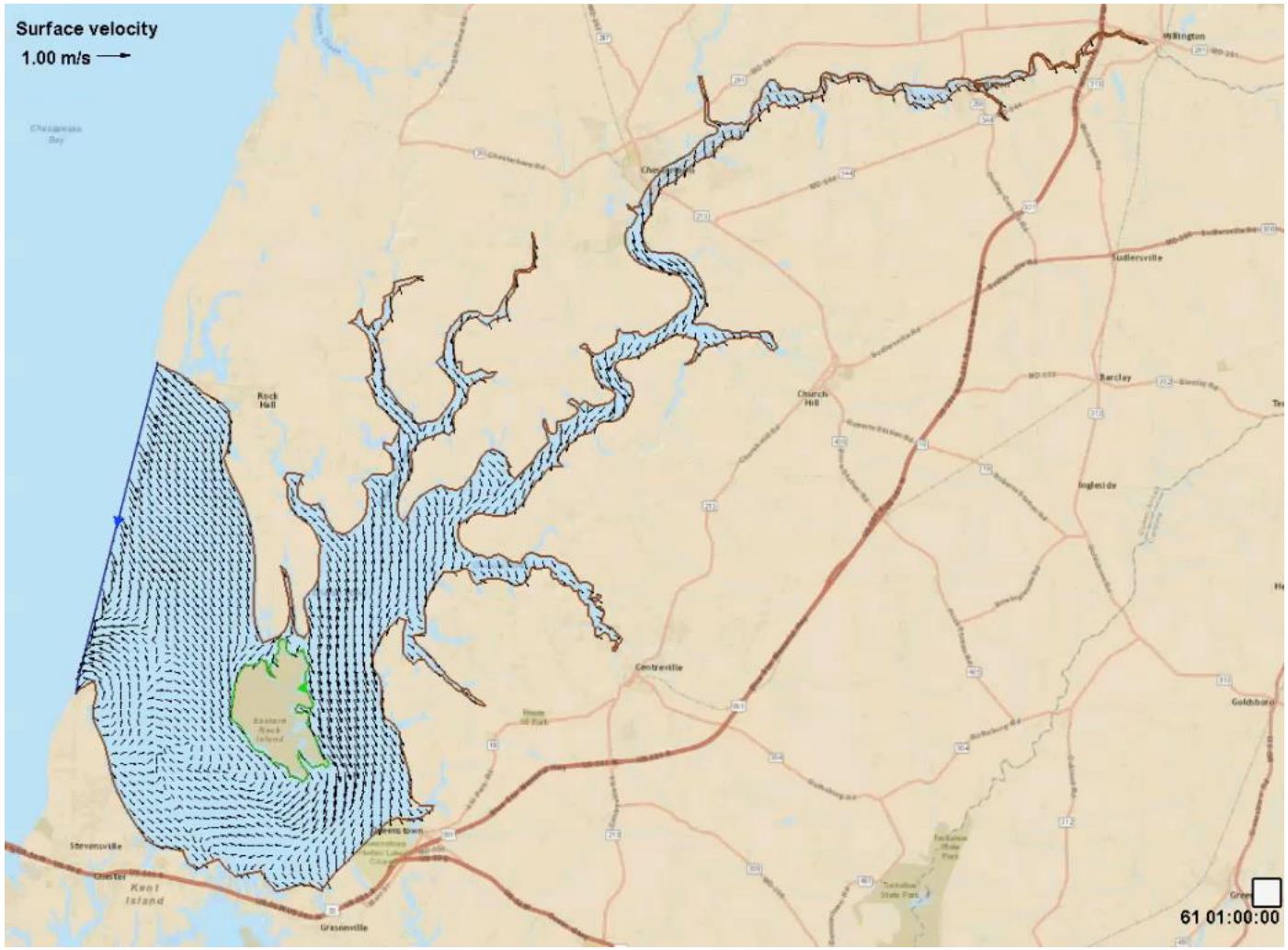
Model results – Velocity magnitude



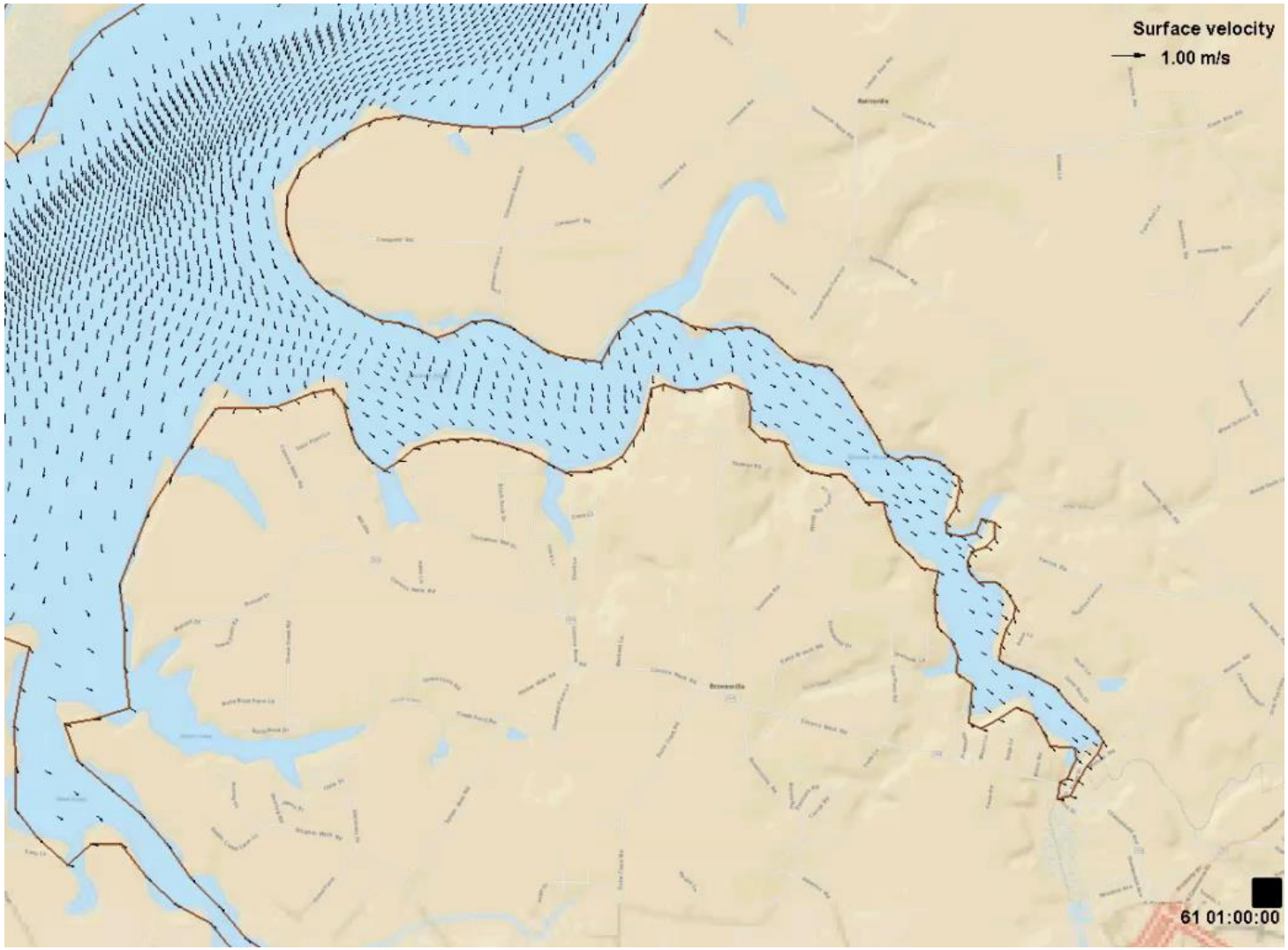
No velocity data for comparison;

Attempt made to contact
Douglas R. Levin of Washington College

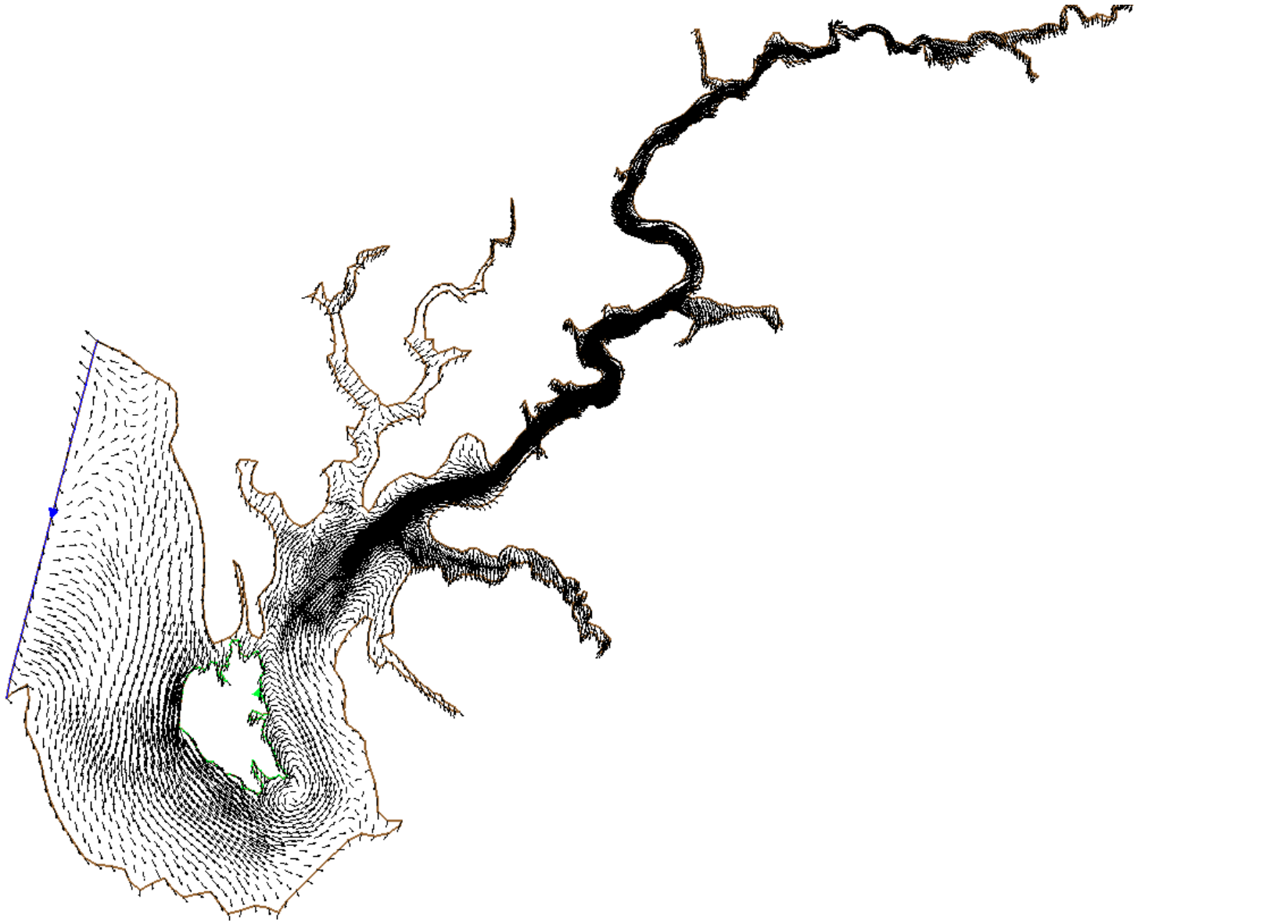
Model results – Velocity animation – Chester River



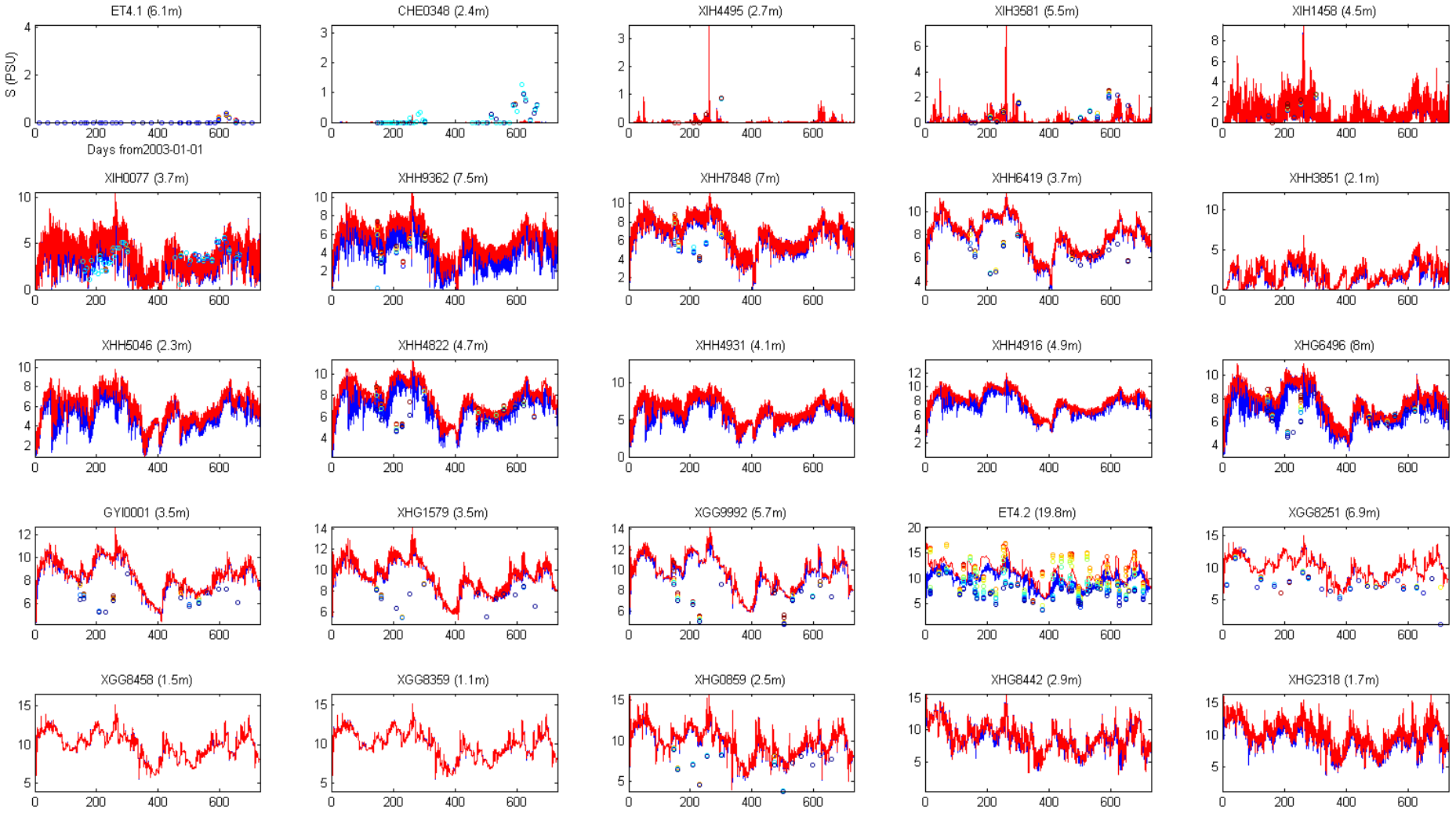
Model results – Velocity animation near Corsica River



Model results – Velocity distribution on an un-strucutured grid



Model results – salinity (with the CH3D b.c.)

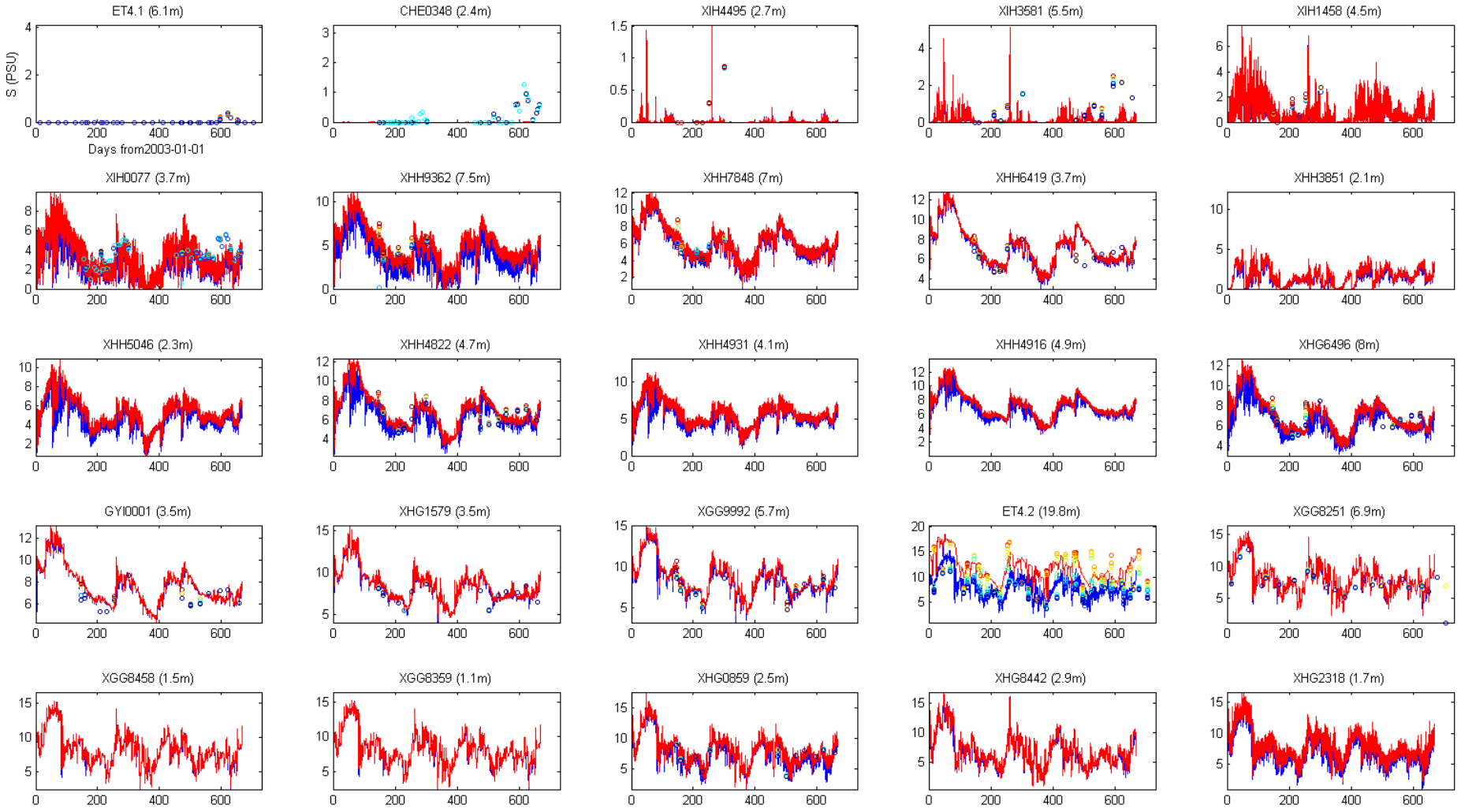


Observation: Bottom Surface

Model: Bottom Surface

* The depth of each station is the maximum sampling depth

Model results – salinity (with the upper bay b.c.)



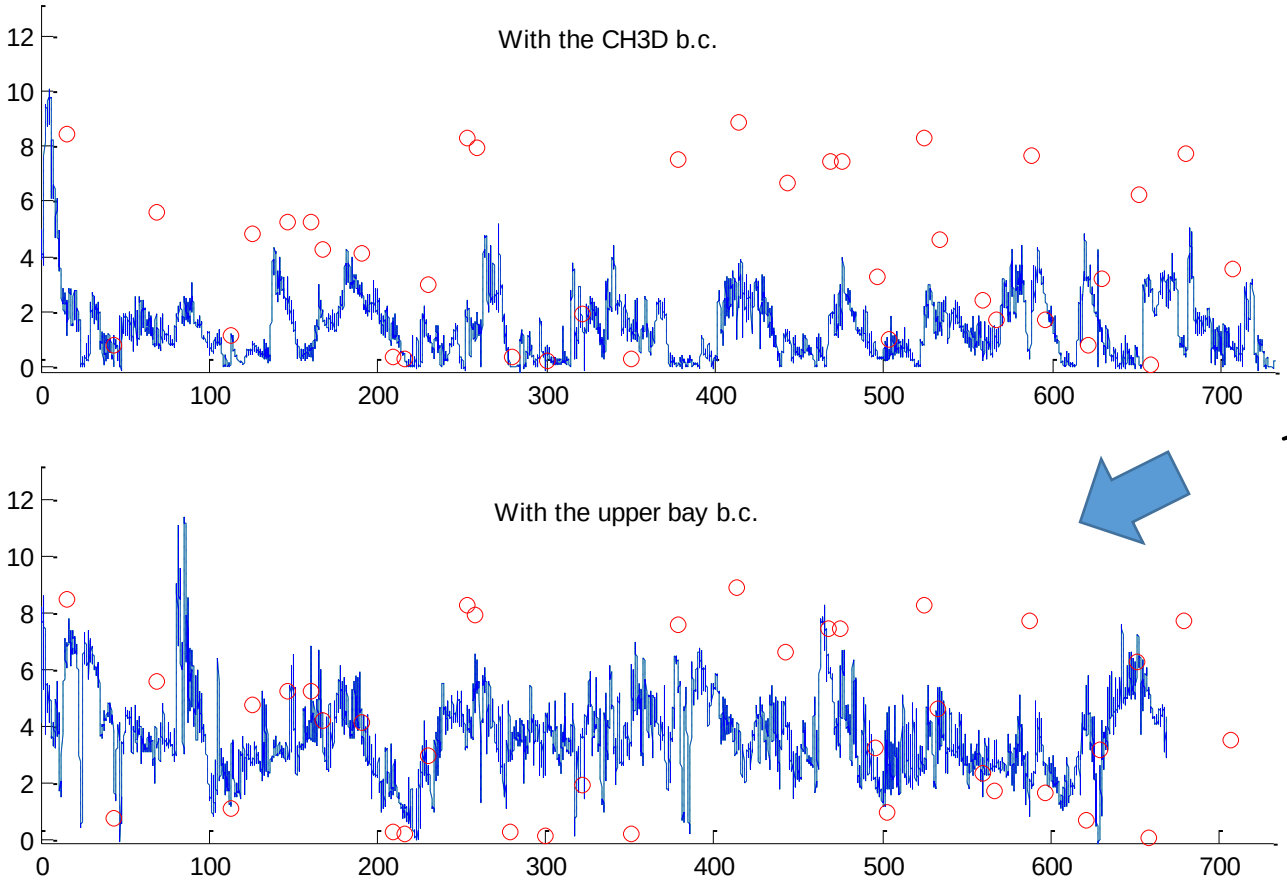
Observation: Bottom Surface

Model: Bottom Surface

*The depth of each station is the maximum sampling depth

Model results – salinity stratification

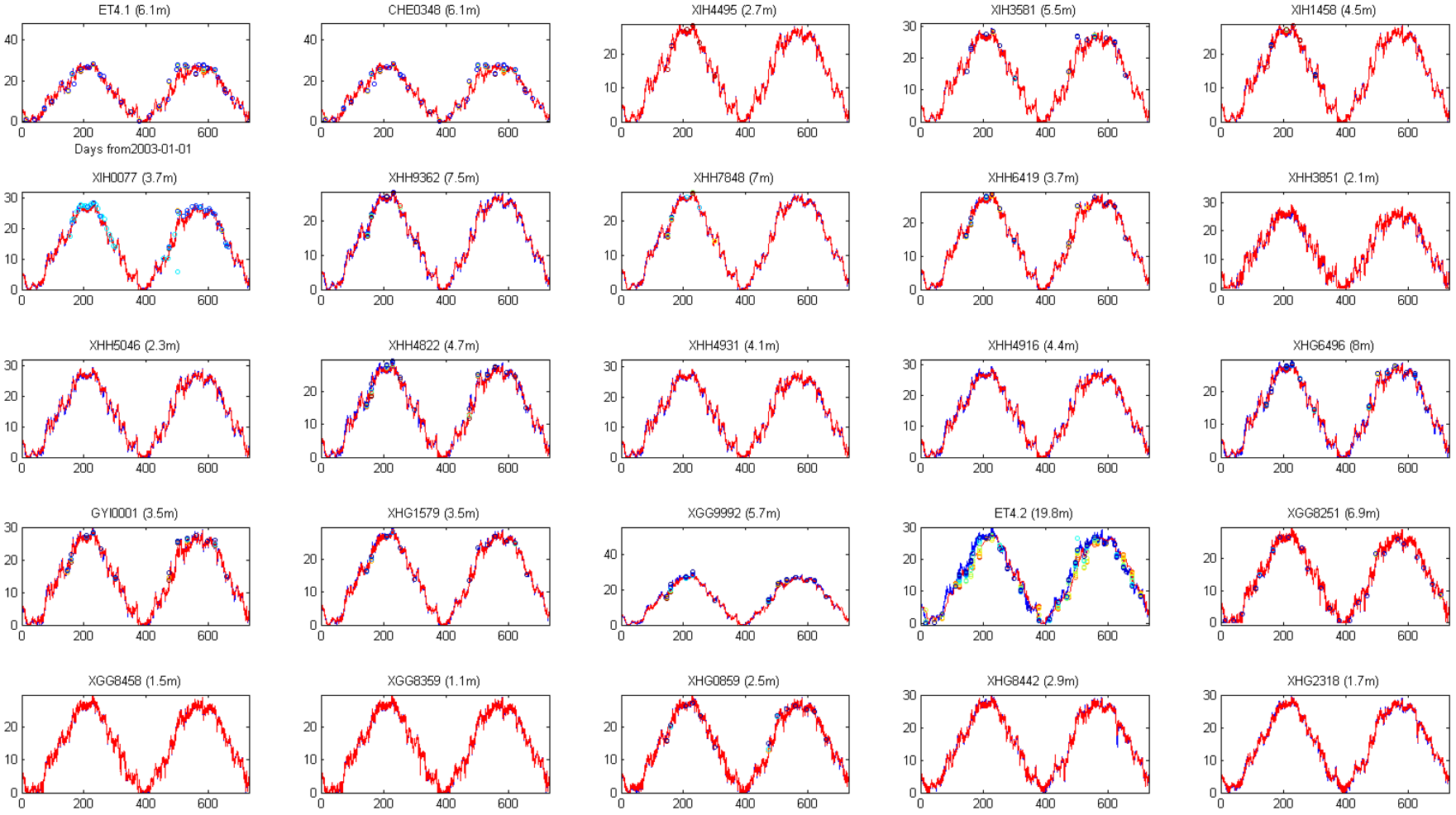
Stratification (of salinity) equals bottom minus surface salinity at ET4.2)



The result from Upper Bay Model (or with nudging at the open boundary of the Chester River grid

Observation: ○ Model: ——

Model results – temperature (with the CH3D b.c.)



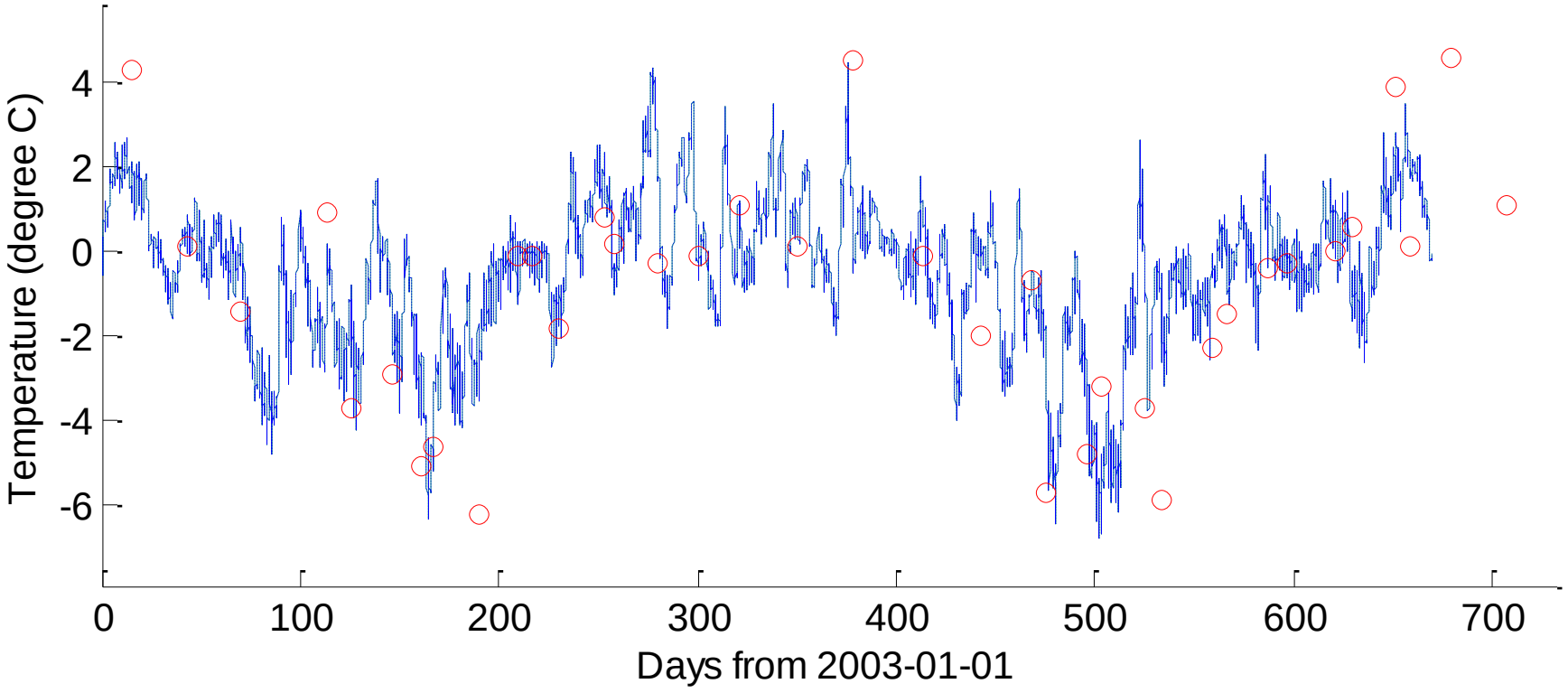
Observation: Bottom Surface

Model: Bottom Surface

*The depth of each station is the maximum sampling depth

Model results – temperature stratification

Stratification (of temp) equals bottom minus surface temperature at ET4.2)



Observation: Model:

Computational performance

	Chesapeake Bay model	Upper Bay model	Chester River model
Nodes (horizontal)	13426	13484	8325
Elements(horizontal)	21409	22268	15104
Average vertical layers	25	23	17
Run time (with 48 CPUs on Hurricane Cluster)	614 times faster than real time (2 years of simulation finished in 1.2 day)	675 times faster than real time	1288 times faster than real time
Run time (with 128 CPUs on Hurricane Cluster)	1064 times faster than real time (2 years of simulation finished in 0.7 day)	869 times faster than real time	1641 times faster than real time

*when the wind wave model was coupled, the run time reduced by factor of 5

Erosion and Deposition formulation

Erosion

: $E_q = E_{0,q}(1-p) f_q \left(\frac{\tau_{sf}}{\tau_{cr,q}} - 1\right)$, *if* $\tau_{sf} > \tau_{cr,q}$

$E_{0,q}$: bed erodibility constant
p : sediment porosity
f_q : volumetric fraction of sediment of class q
$\tau_{cr,q}$: critical shear stress (calculated internally)
τ_{sf} : bed shear stress

Deposition

: $D_q = w_{s,q} C_1$

$$W_{s,q} = \frac{v_a}{d_{50,q}} \left[\left(10.36^2 + 1.049 D_{*,q}^3\right)^{1/2} - 10.36 \right]$$

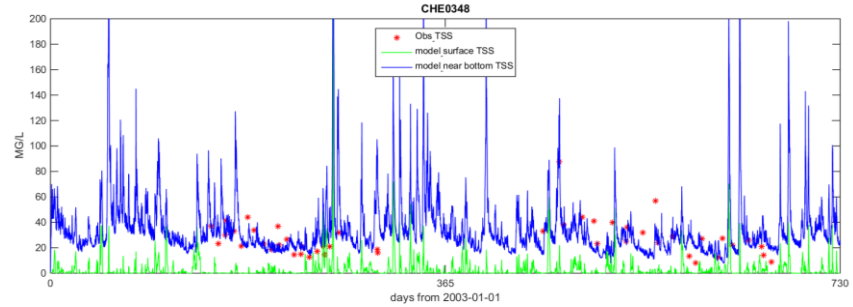
$W_{s,q}$: settling velocity
C_1 : sediment concentration
v_a : kinematic viscosity of water
$d_{50,q}$: median grain sediment diameter of class q
$D_{*,q}$: dimensionless sediment diameter of class q

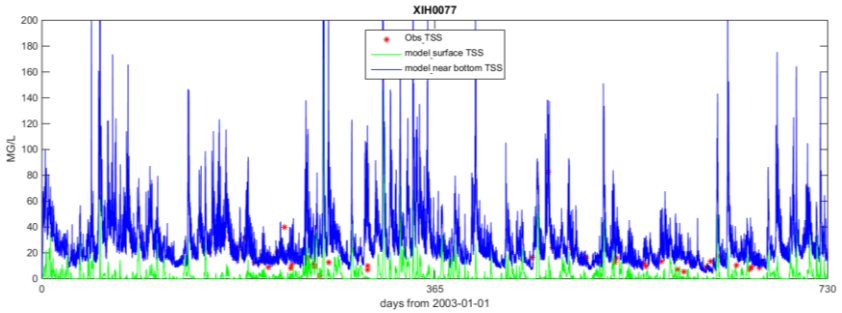
Some constants used in the model

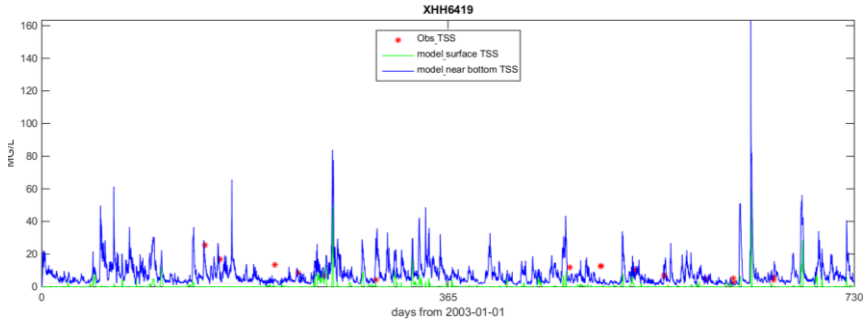
$E_{0,q}$: 1.6e-4, 1.6e-4, 1.6e-4 (kg/m2/s)
$d_{50,q}$: 0.01, 0.02, 0.055 (mm)
f_q : 1/3 , 1/3 , 1/3
p : 0.4

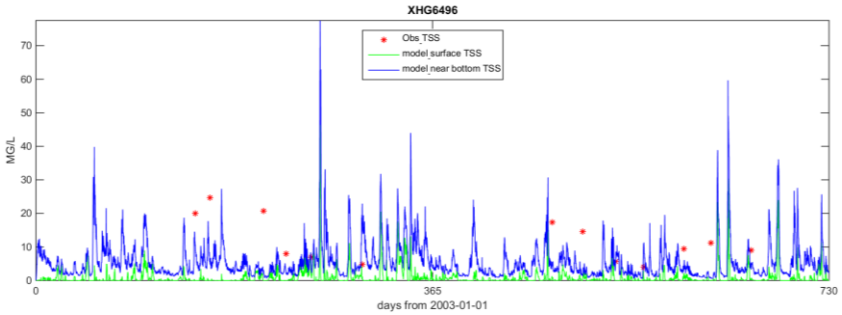
Reference: Pinto et al. (2012): Development and validation of a 3D morphodynamic modeling system for non-cohesive sediments Ocean Modeling, Vol. 57-58, p1-14.

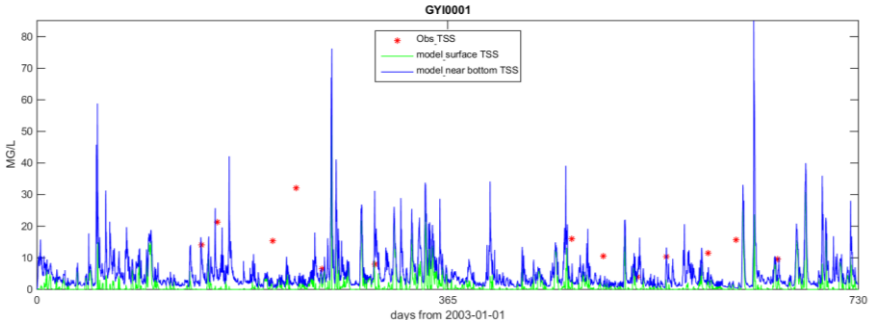
Model results – TSS

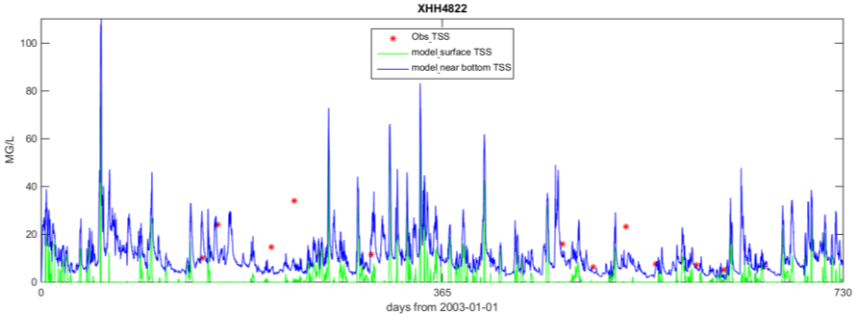


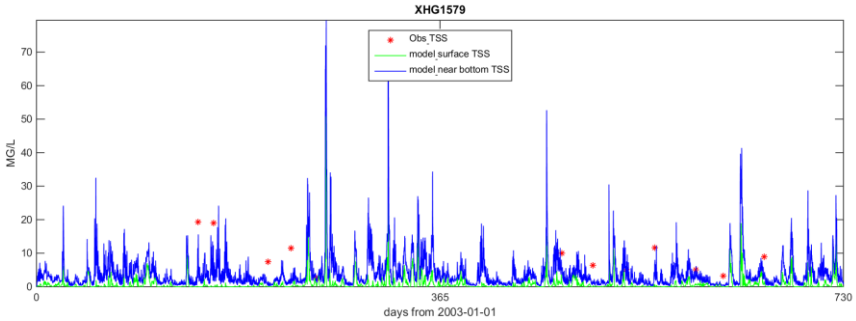


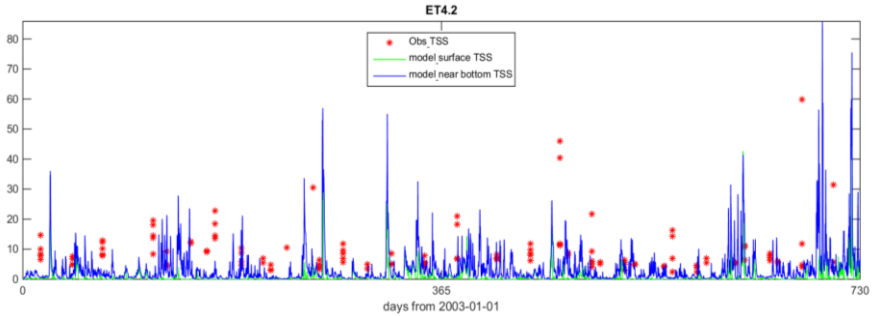




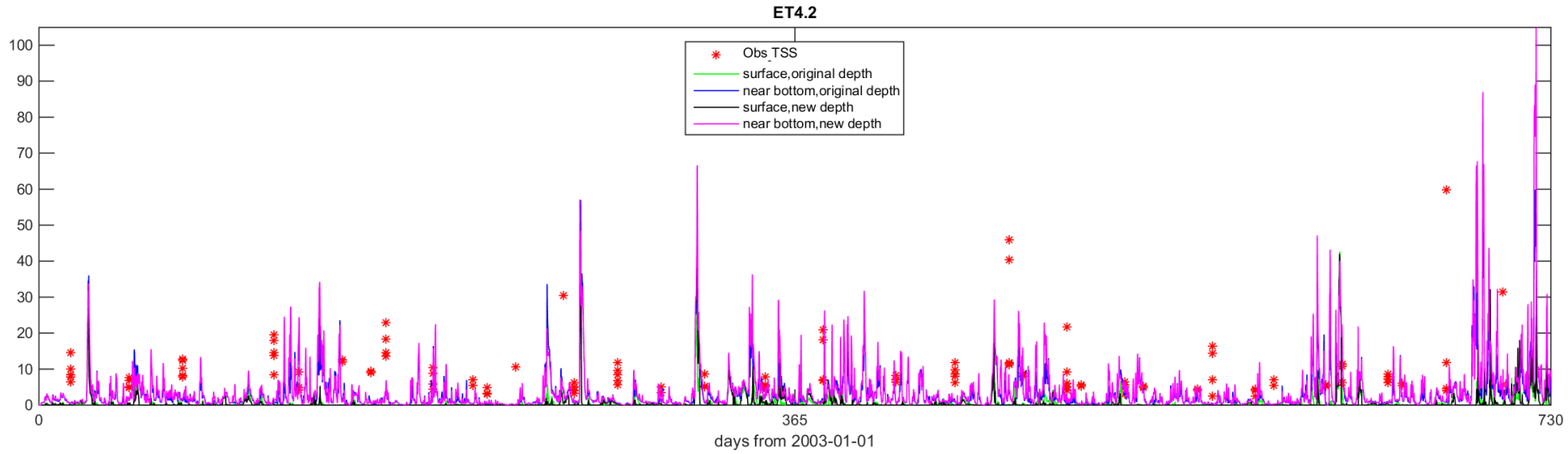








Model results – TSS in the lower Chester River



The TSS in ET4.2 is under-predicted similar to the salinity !!!