Comparison of Shallow-water Models for Use in Supporting Chesapeake Bay Management Decision-making

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- **STAC workshop Part 1**
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- **STAC workshop Part 2**
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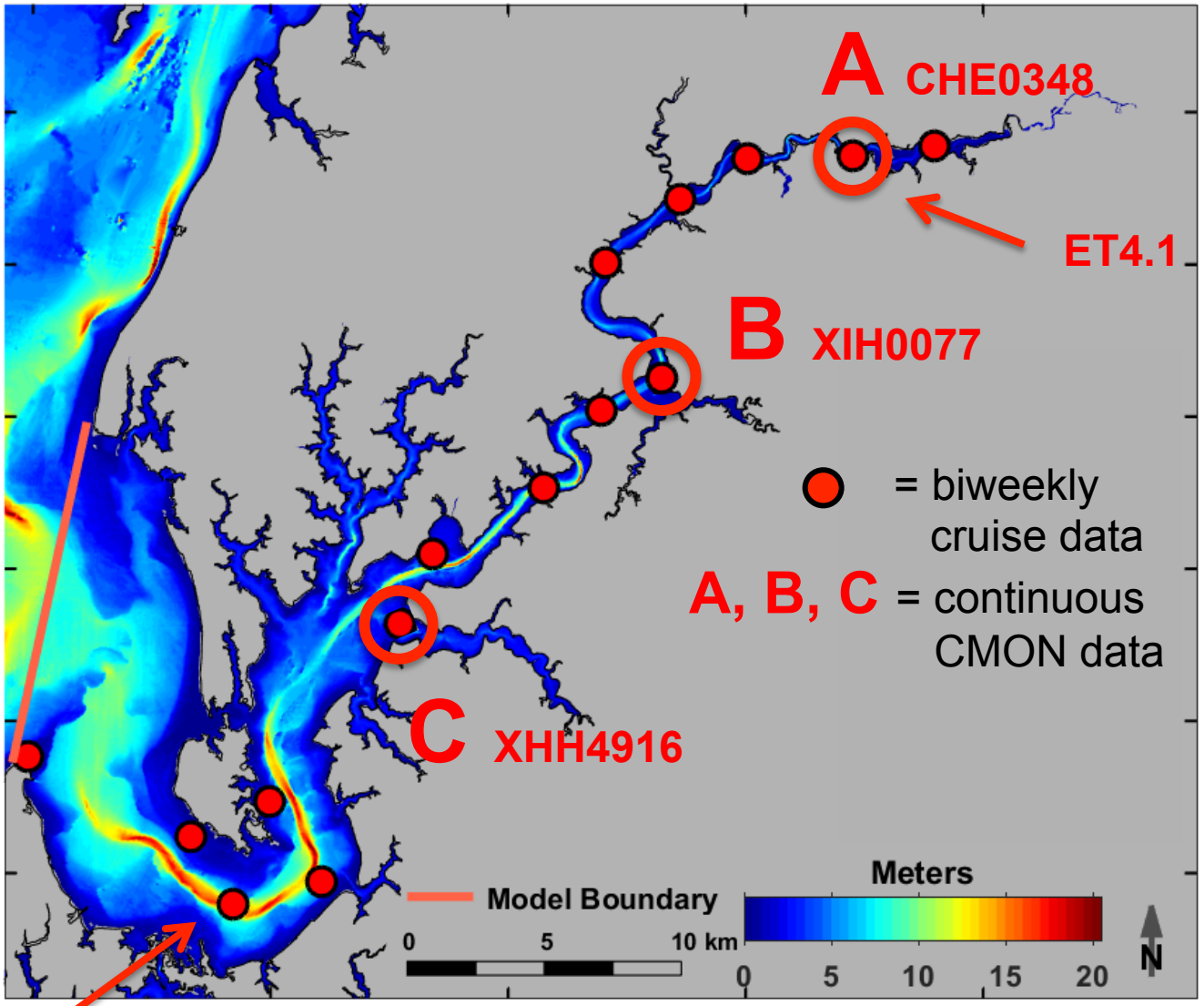
Chesapeake Bay Program
A Watershed Partnership

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Observations: 2003-2006



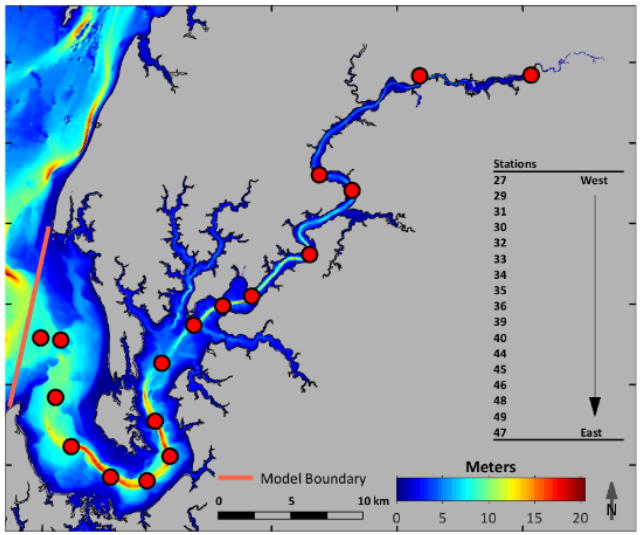
salinity, temperature, oxygen, chlorophyll, TSM

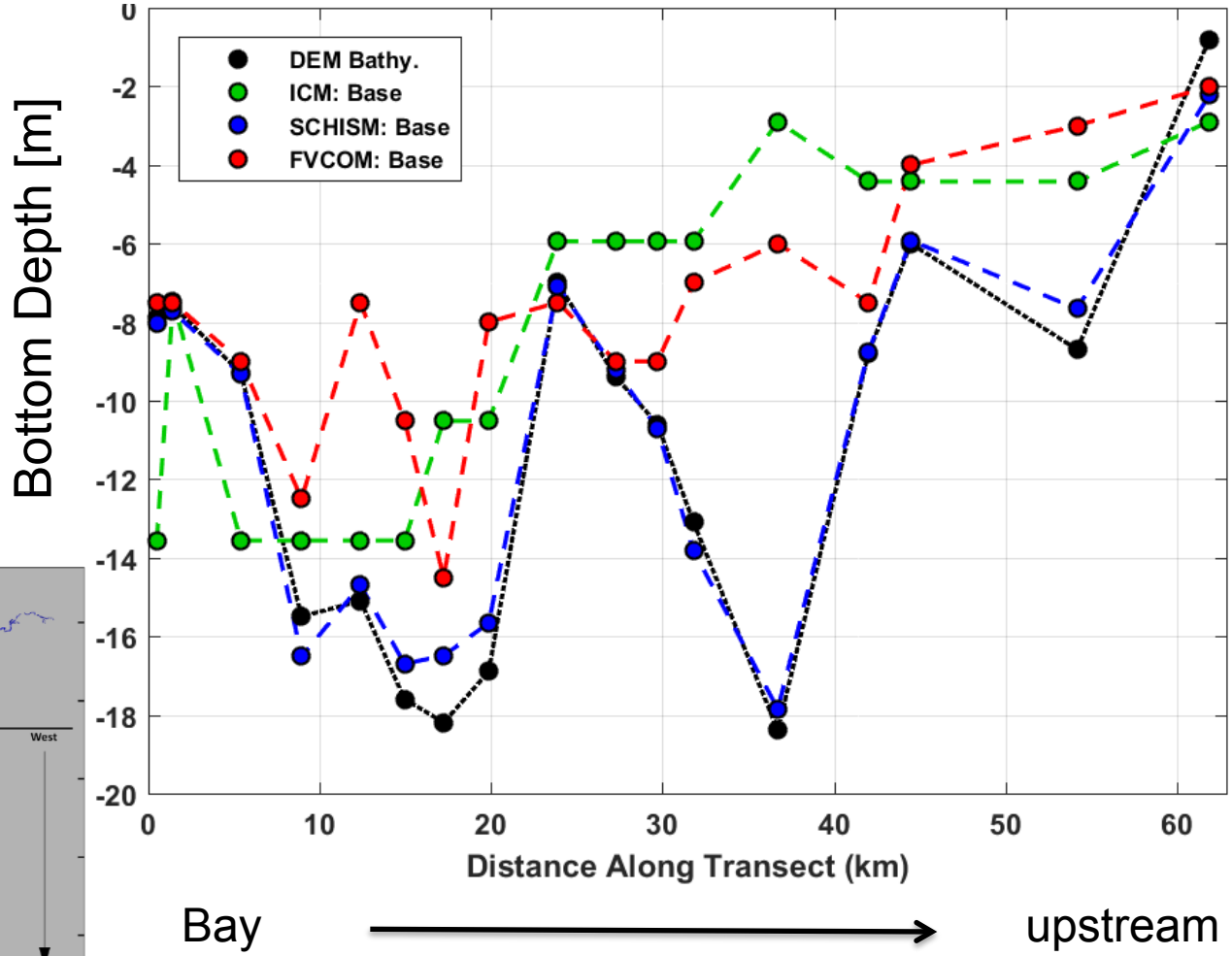
Participating Models

- All models use consistent winds, boundary conditions, freshwater & nutrient discharge
- Model grids differ considerably

Participating model	Horizontal resolution	Horizontal grid	Vertical grid
CH3D-ICM	**low**	structured	z-grid
FVCOM-ICM	medium	**triangular**	sigma
ROMS-RCA	**high**	structured	sigma
SCHISM-ICM	medium	**hybrid**	**hybrid**

Channel depths also differ among models





SCHISM channel depths closely follow DEM; FVCOM & CH3D-ICM are shallower.

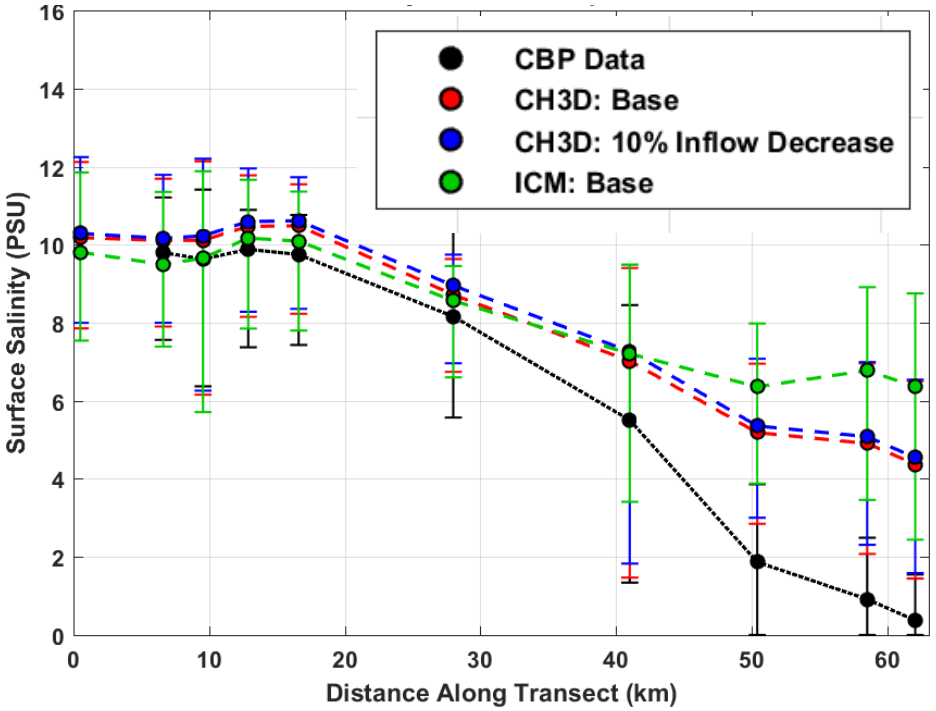
Simulation Experiments

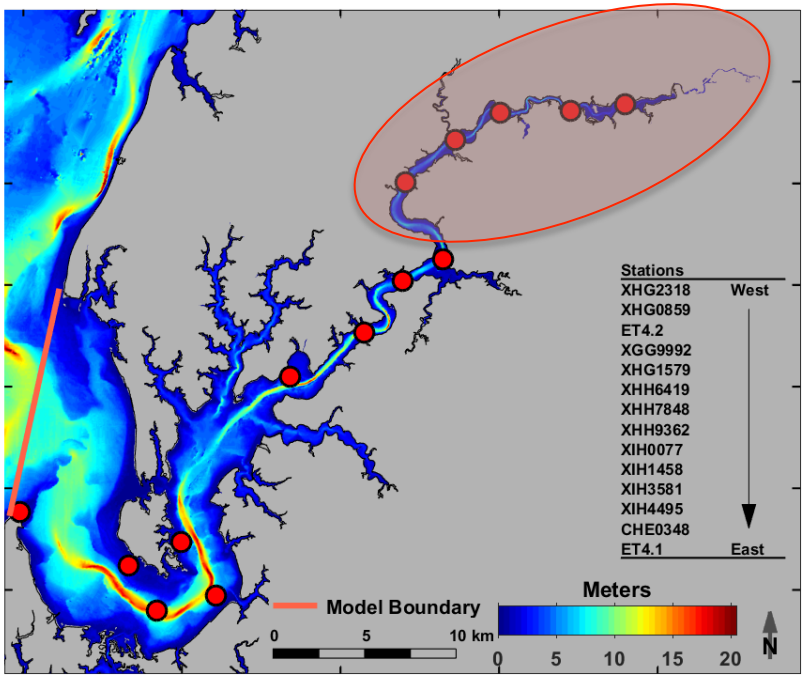
Three simulations for hydrodynamics (S, T) and water quality (chl, DO,TSS):

1) Base Case
2) 10% reduction in watershed inflow (freshwater and nutrients)
3) SCHISM Outer Boundary Condition (OBC) in place of CH3D OBC (for hydrodynamics only)

ICM salinity vs. CH3D salinity

Surface Salinity (Summer 2006)

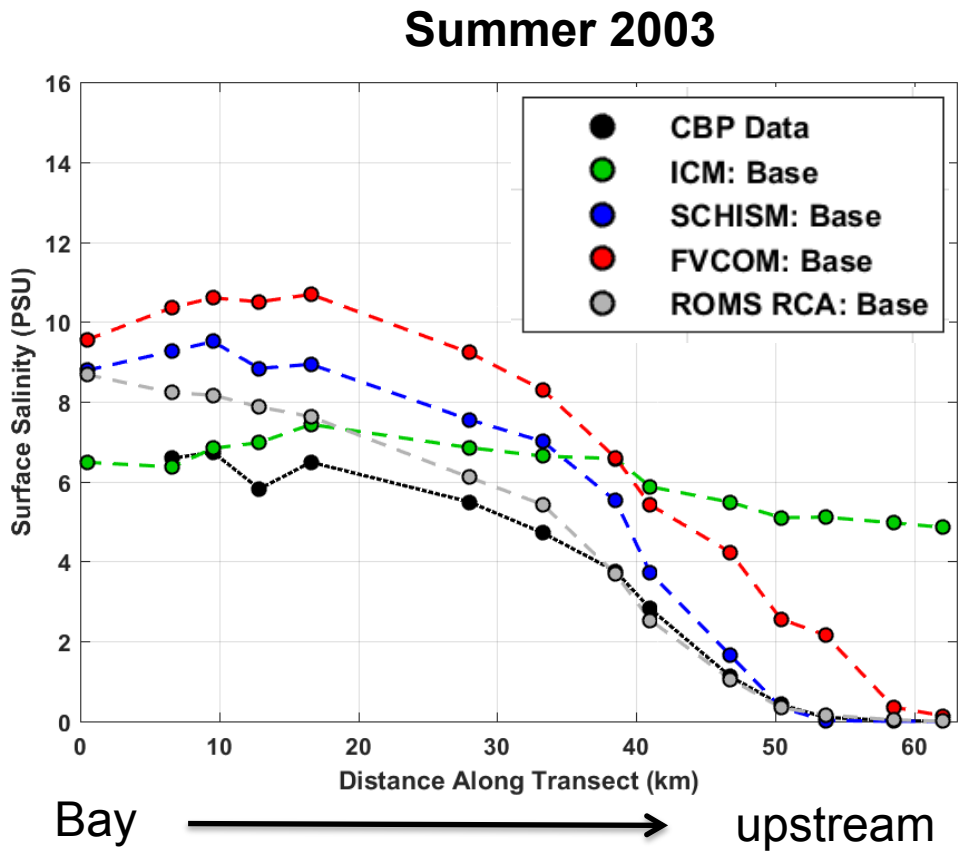


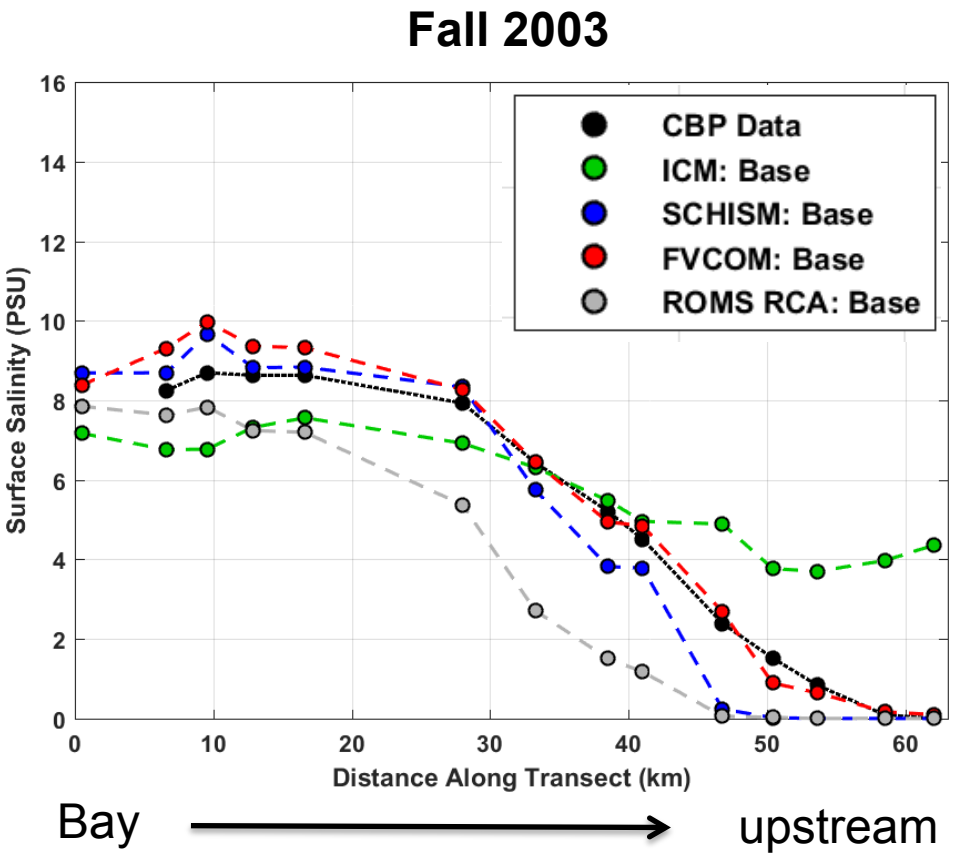


Bay ⟶ upstream

- In first 40 km → small difference between ICM & CH3D (ICM slightly better)
- In upper Chester → large difference between ICM & CH3D (CH3D better)

Multiple model comparison: Surface Salinity

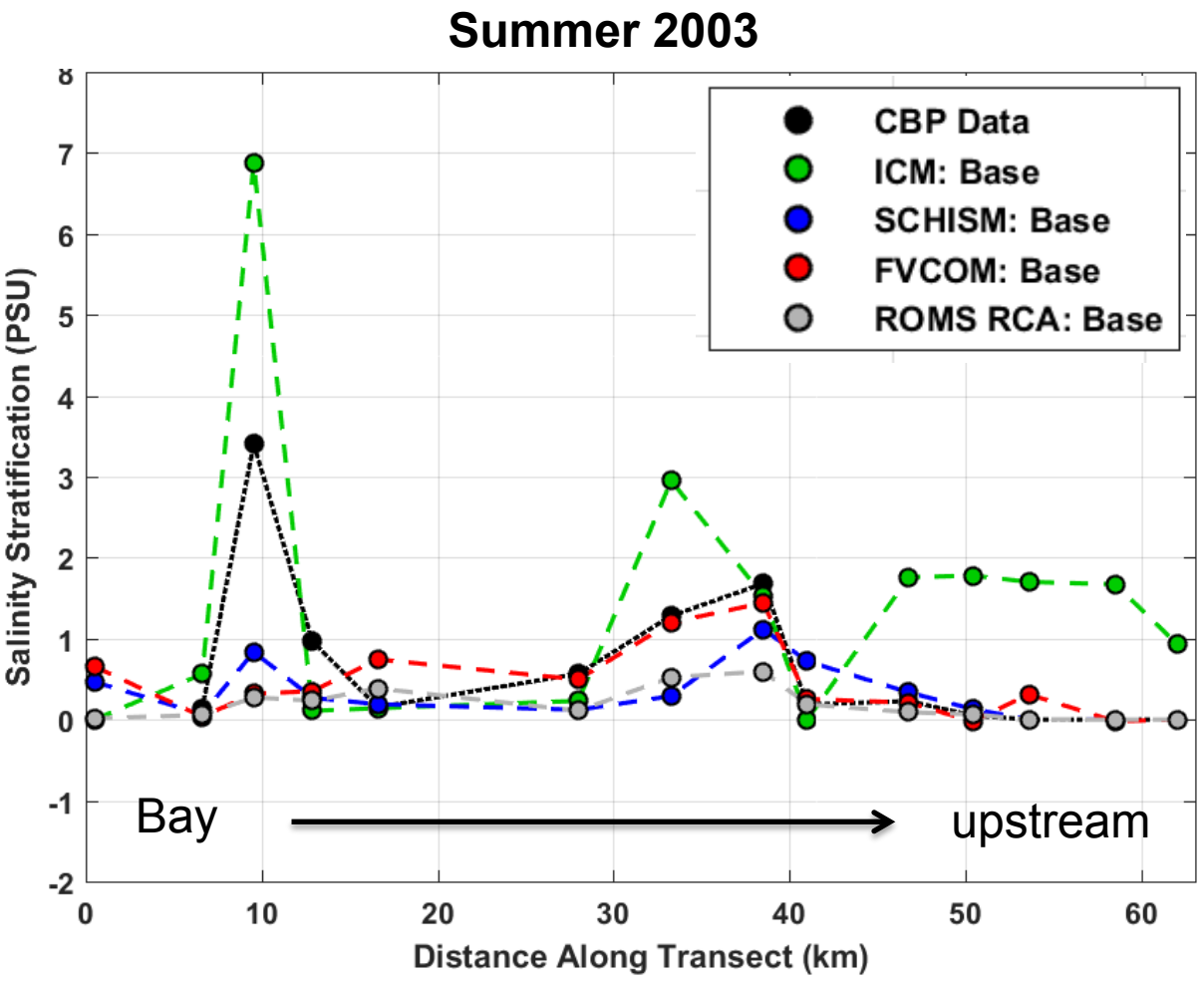




- ICM overestimates surface salinity in upper half of Chester
- FVCOM is always saltier than SCHISM
- Summer 2003: ROMS performs best
- Fall 2003: FVCOM and SCHISM perform best

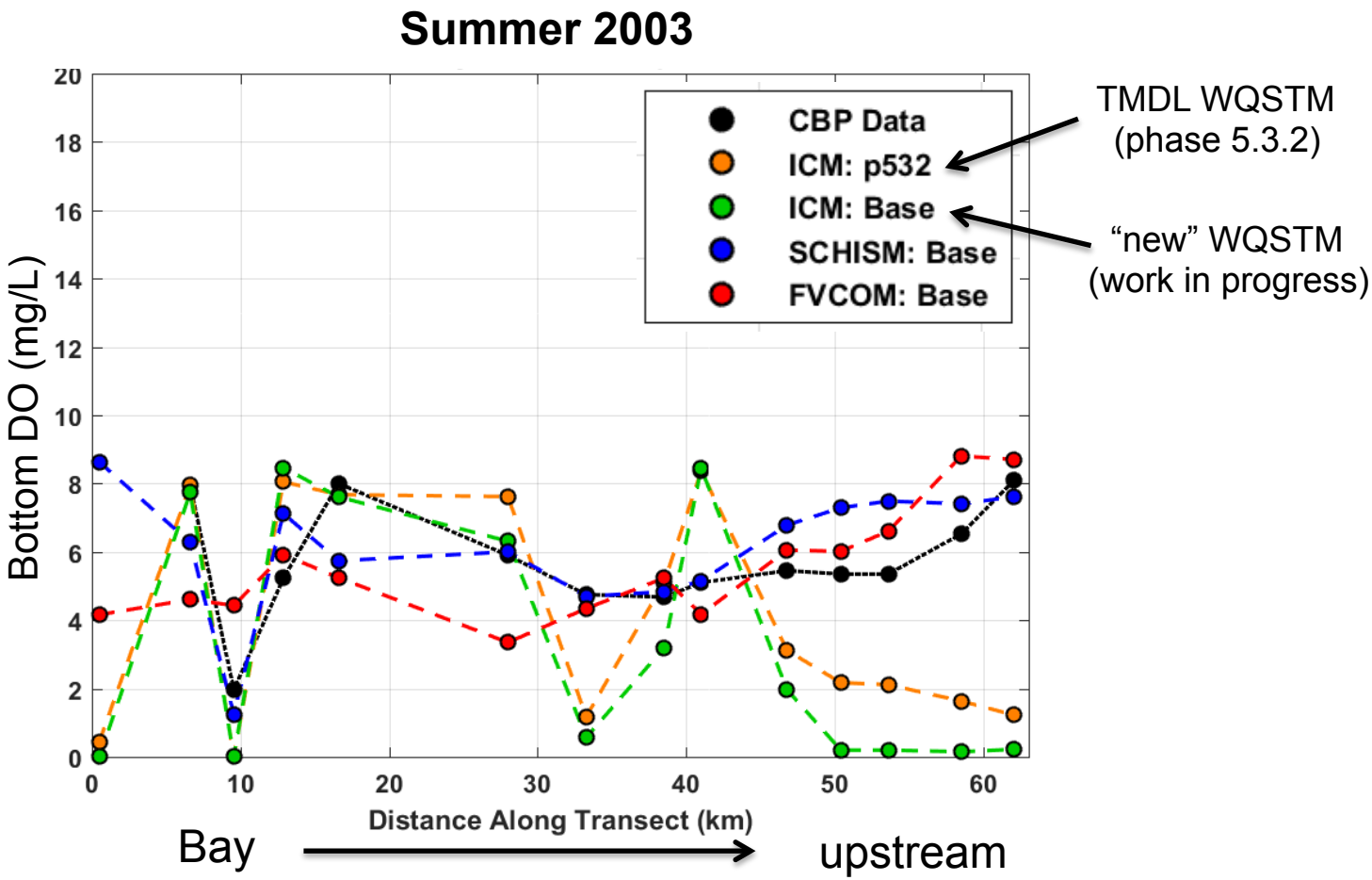
Multiple model comparison: Salinity Stratification

Stratification = bottom S minus surface S



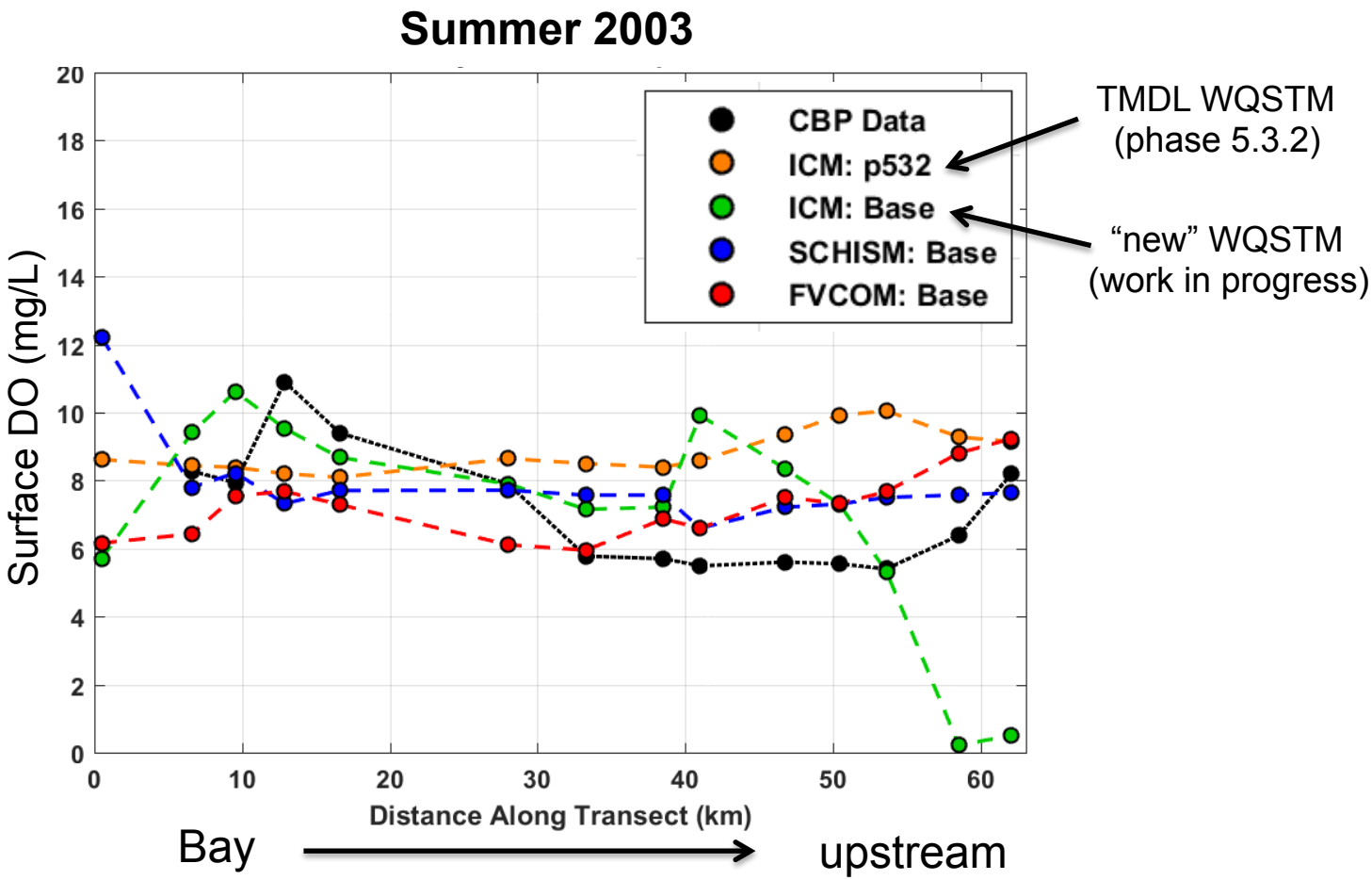
- ICM overestimates stratification in the channel and upstream
- ROMS & SCHISM often underestimate stratification

Multiple model comparison: Bottom DO



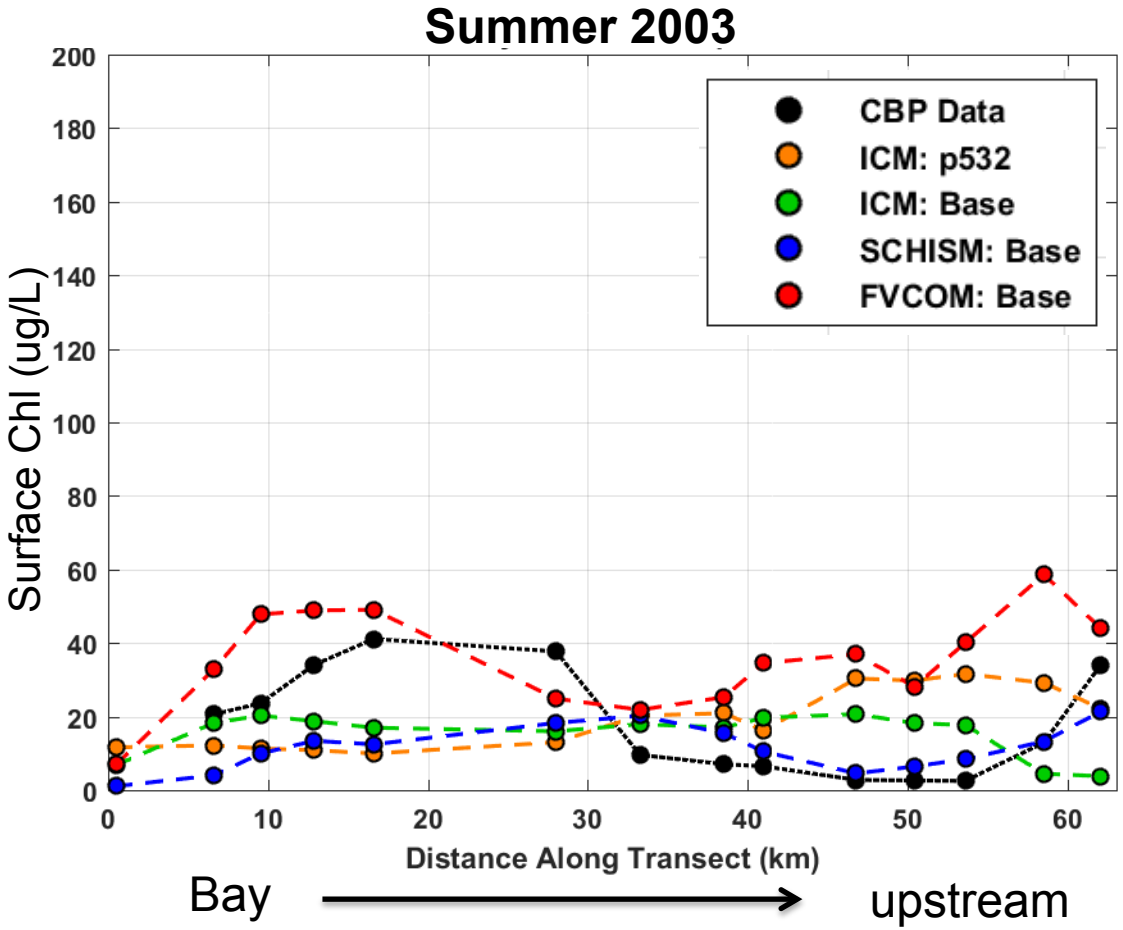
- High resolution models show much improved bottom DO in upper Chester and at Chester mouth

Multiple model comparison: Surface DO



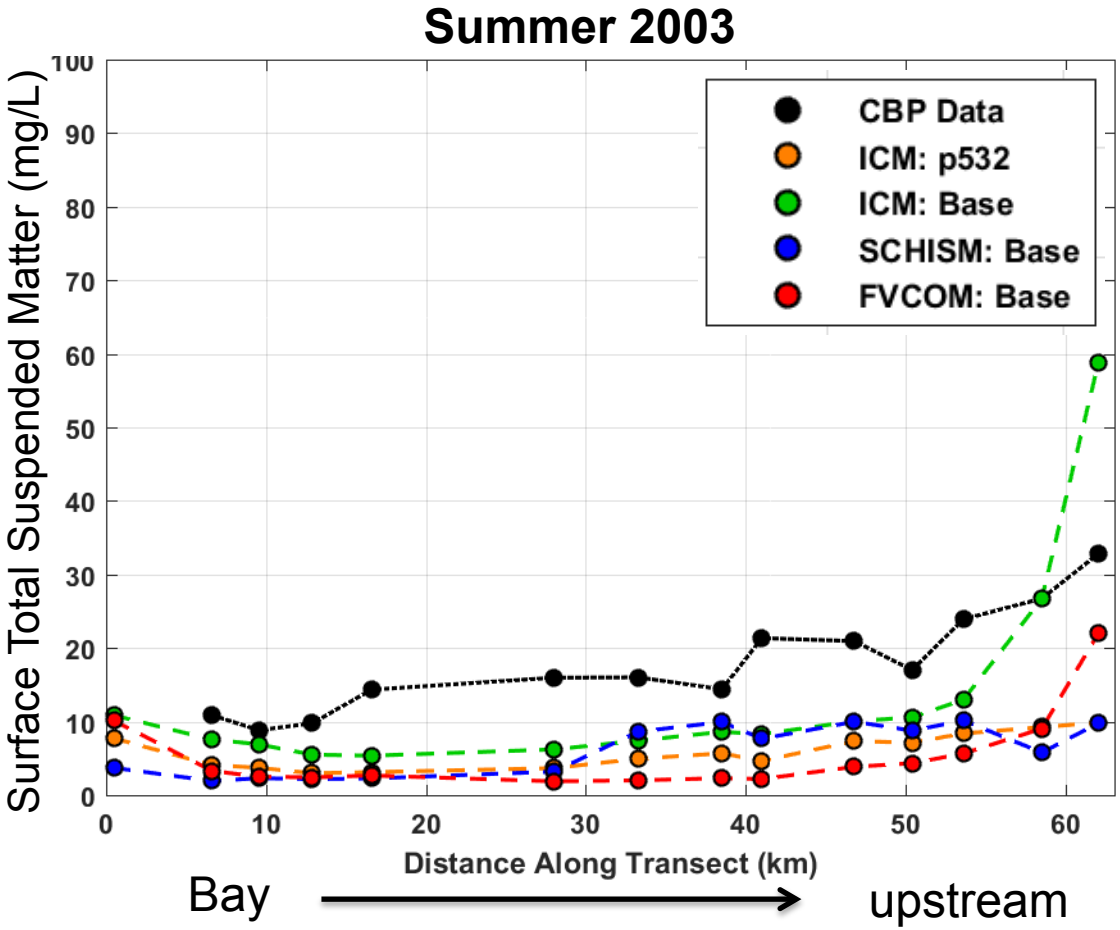
- Models perform more similarly for surface DO
- Surface DO in upper Chester for "new" WQSTM needs investigation

Multiple model comparison: Surface Chlorophyll



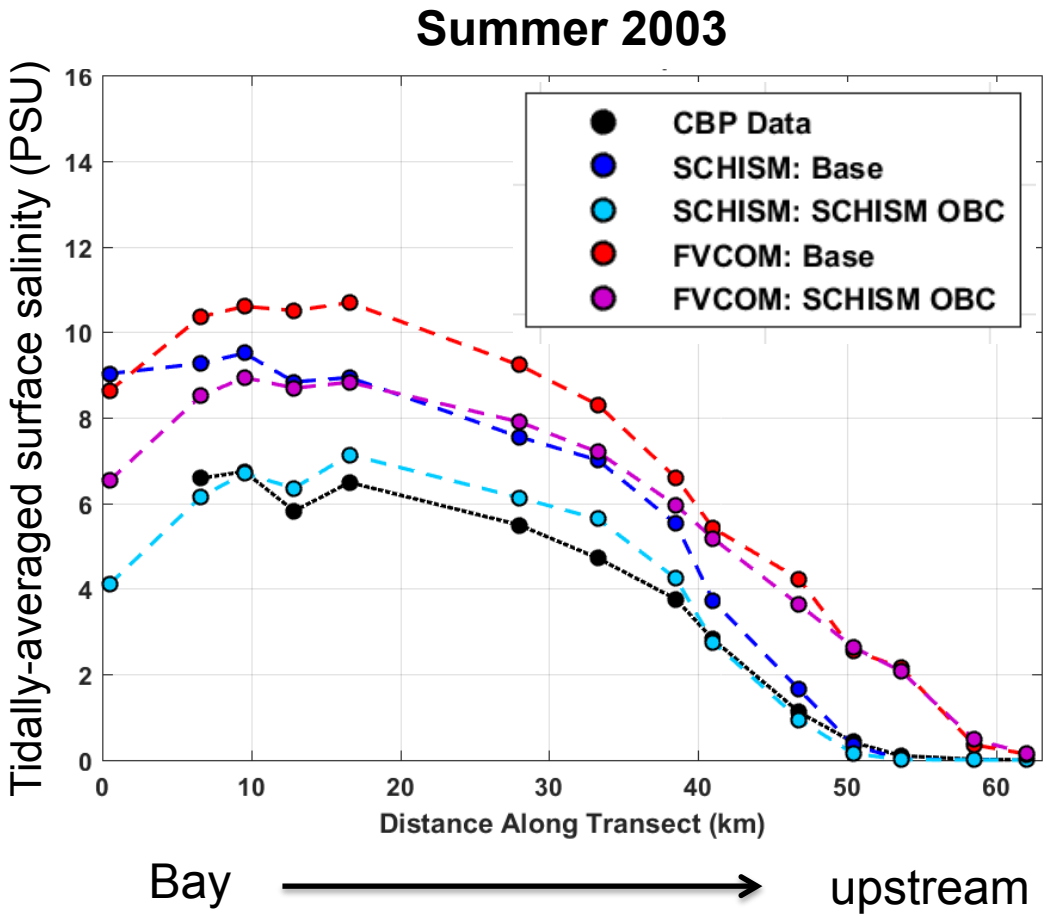
- Lots of variability between models; SCHISM produces low Chl near ~50km (improved coastline and bathymetry)

Multiple model comparison: Surface Total Suspended Matter



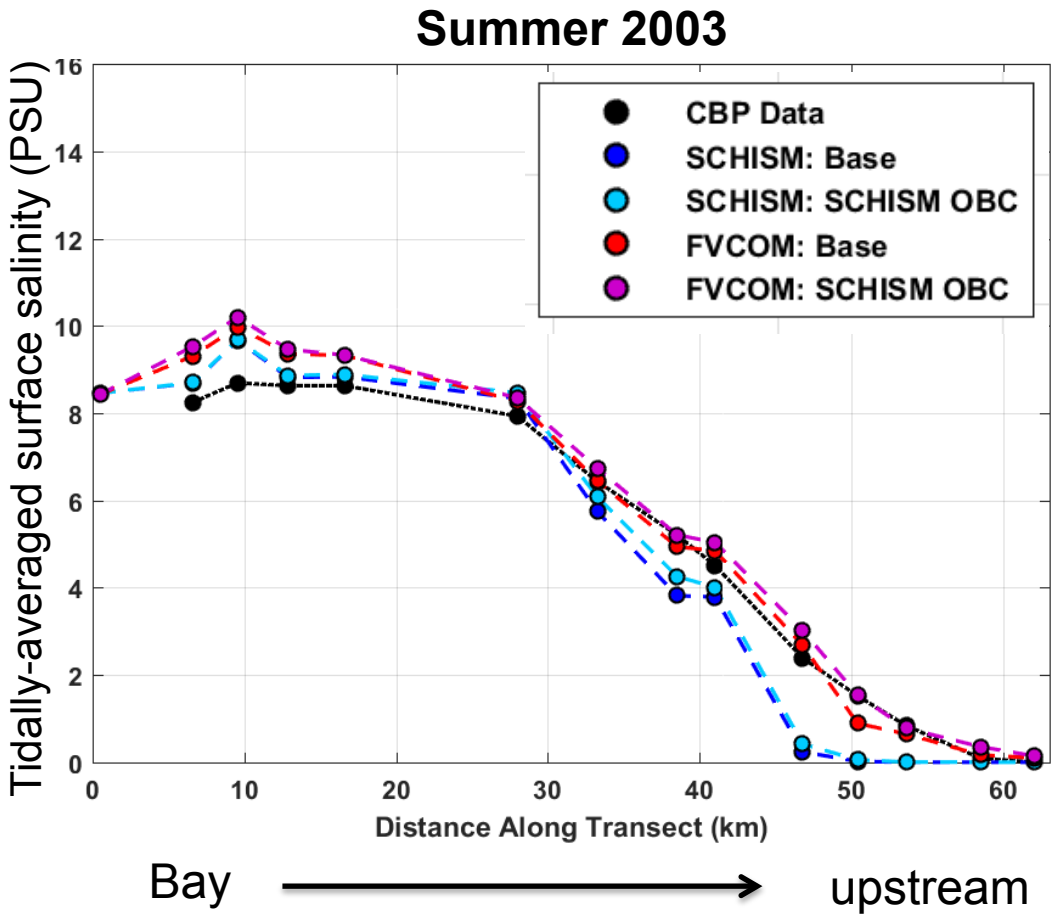
- Models generally underestimate suspended matter
- "New" WQSTM represents improvement throughout most of Chester

Multiple model comparison: Effect of changing OBC on surface salinity



- Effect of change in OBC is felt 45 km up the tributary

Multiple model comparison: Effect of 10% change in freshwater input



- Effect of 10% change in freshwater input on salinity is negligible
  (10% change in nutrient inputs has negligible effect on water quality too)

Summary

1. **Models simulate hydrodynamics relatively well**
   - → All models reproduce temperature well
   - → Higher resolution models produce better upstream salinity (near zero) and stratification (much lower) than WQSTM
   - → Models are very sensitive to bathymetry
2. **Water quality is more challenging to simulate**
   - → *Very* preliminary results indicate that:
     - High resolution models produce much better DO in upstream Chester (and at mouth)
     - High resolution bathymetry and coastline affects residence time which may improve chlorophyll simulation
     - "New" WQSTM simulation seems to produce higher (more realistic) total suspended matter
3. **Sensitivity experiments:**
   - → 10% reduction of freshwater/nutrient inflow has negligible effect on water quality & hydrodynamics (compared to changing models)
   - → Change in salinity OBC affects salinity ~45km up Chester River

Future Work

1. **Sensitivity experiments:**
   - → Investigate changes in bathymetry
   - → Nutrient reduction scenarios (rivers and mouth)
     - Historical high loads (1985)
     - Lowest loads (all forest)
     - 2025 TMDL loads
   - → Use 2025 TMDL loads from the Watershed Model only
   - → Use 2025 TMDL water quality conditions at mouth of Chester only

2. **Additional variables**
   - → Nitrate
   - → Light attenuation
   - → SAV

Workshop Discussions

We need more time to digest our results, but:

1. **Carefully resolving the channel bathymetry and coastline is critical in the Shallow Waters of the Bay**
   - Unstructured grids hold promise
   - Implicit time step may be important to allow for higher grid resolution (given fixed computational resources)

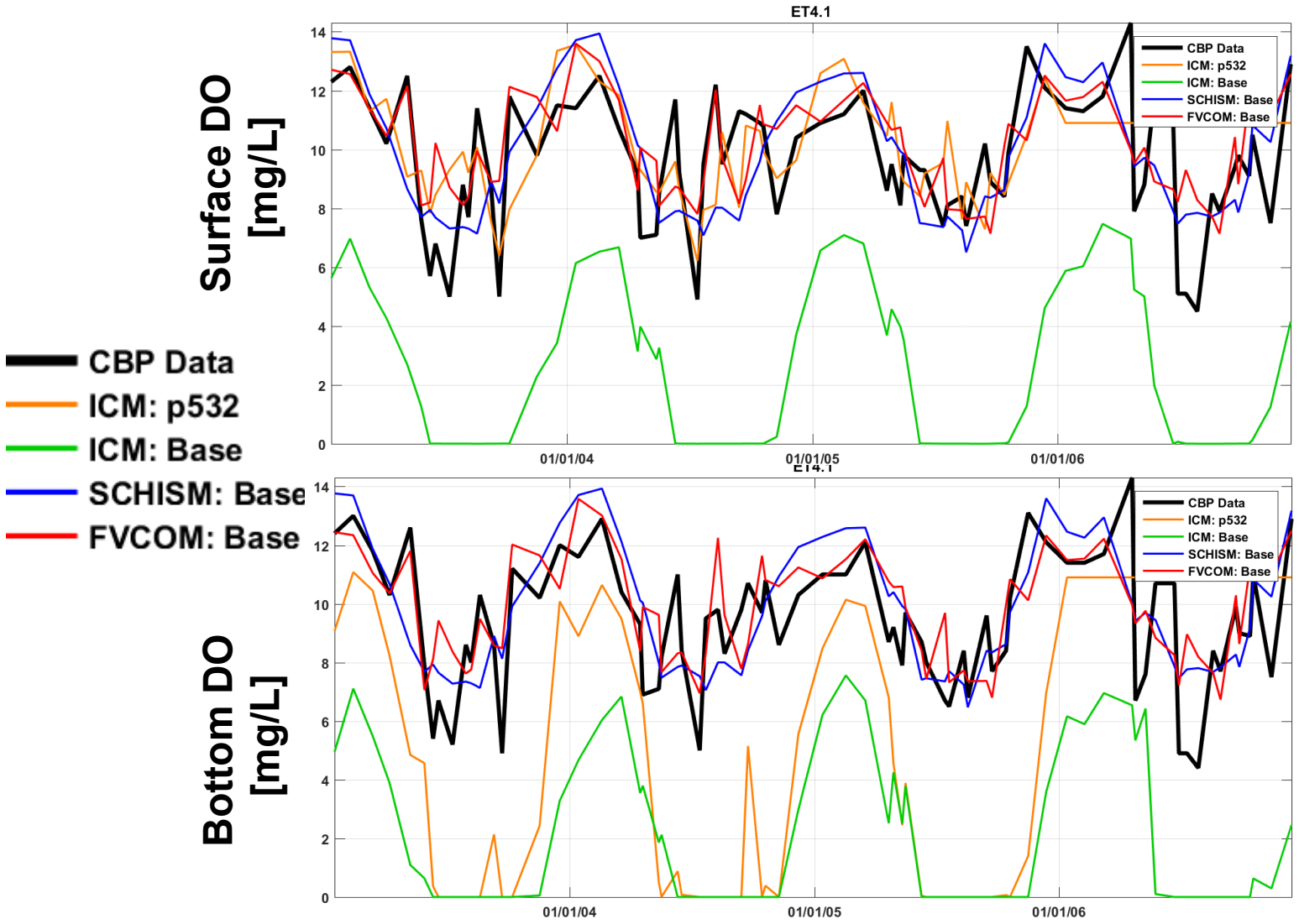
2. **Shallow water data would be more widely used if calibrations were provided**

3. **Multiple model intercomparisons need to continue, and not end with this project**

4. **Need open discussions <u>ASAP</u> regarding future of water quality modeling in the Chesapeake Bay**

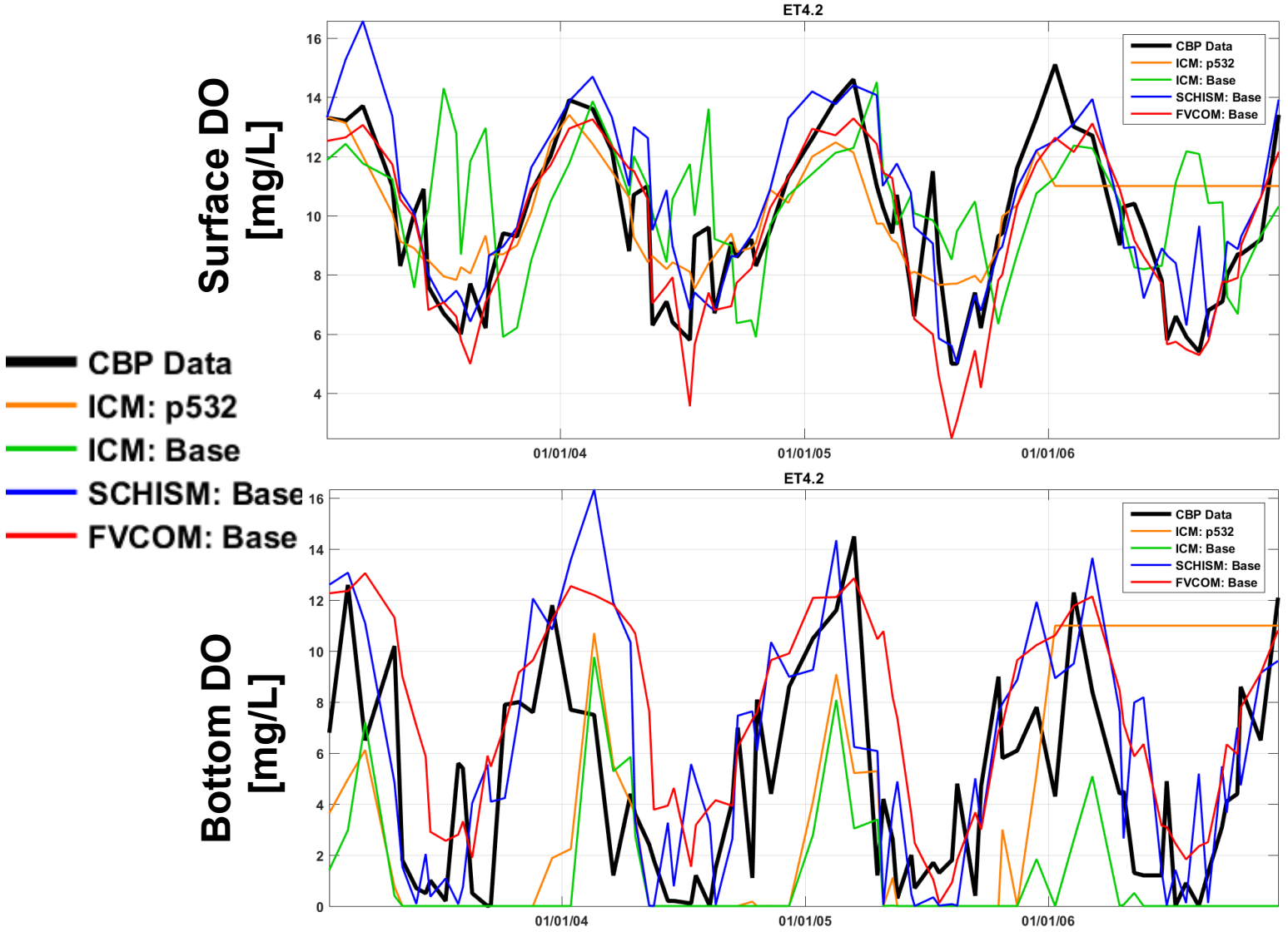
Extra Slides

Vertical DO time series: at ET4.1



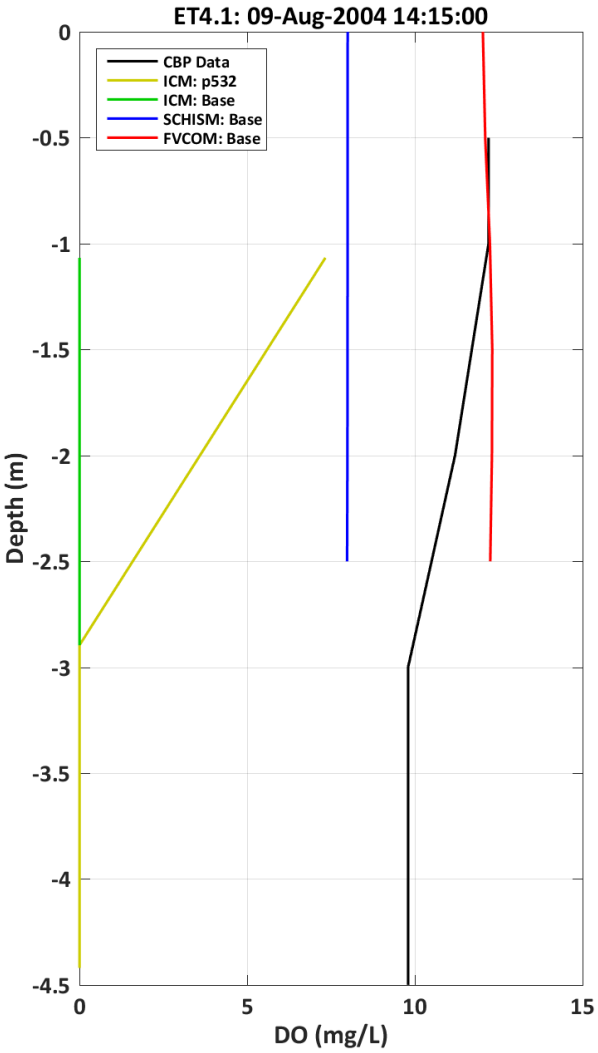
- All models (except for new ICM) simulate surface DO well at the surface
- Both ICMs underestimate bottom DO, showing significant anoxia/hypoxia

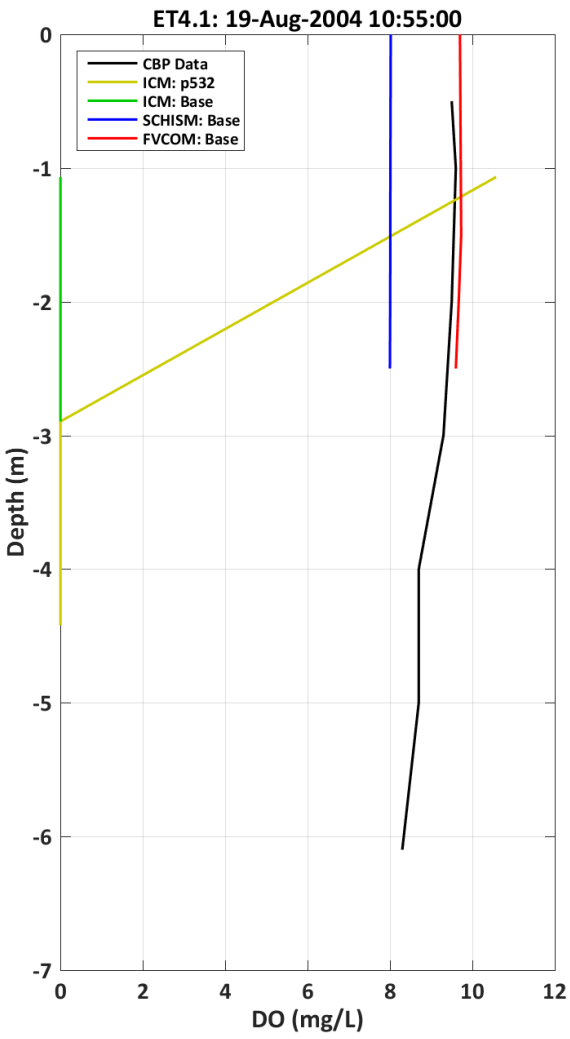
Vertical DO time series: at ET4.2

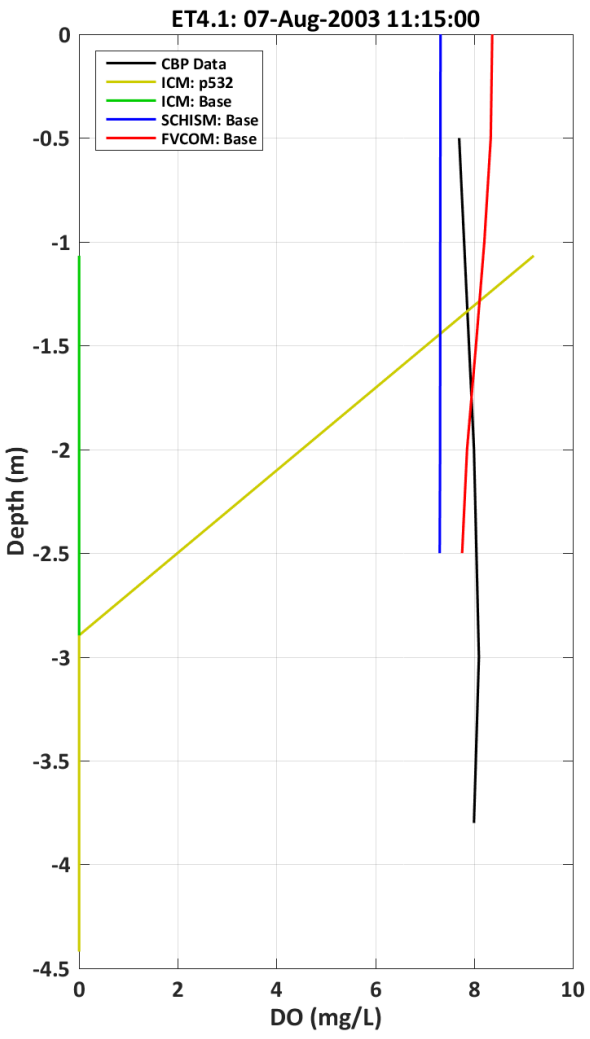


- All models (except for new ICM) simulate surface DO well at the surface
- Both ICMs underestimate bottom DO in Sept-March (anoxia in late fall)

Vertical DO profiles: in August at ET4.1

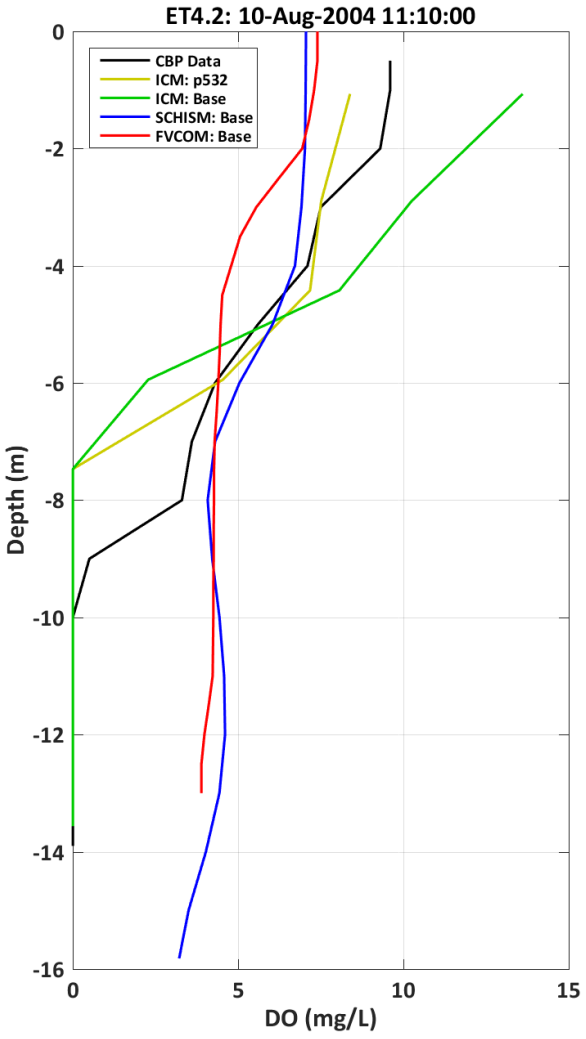


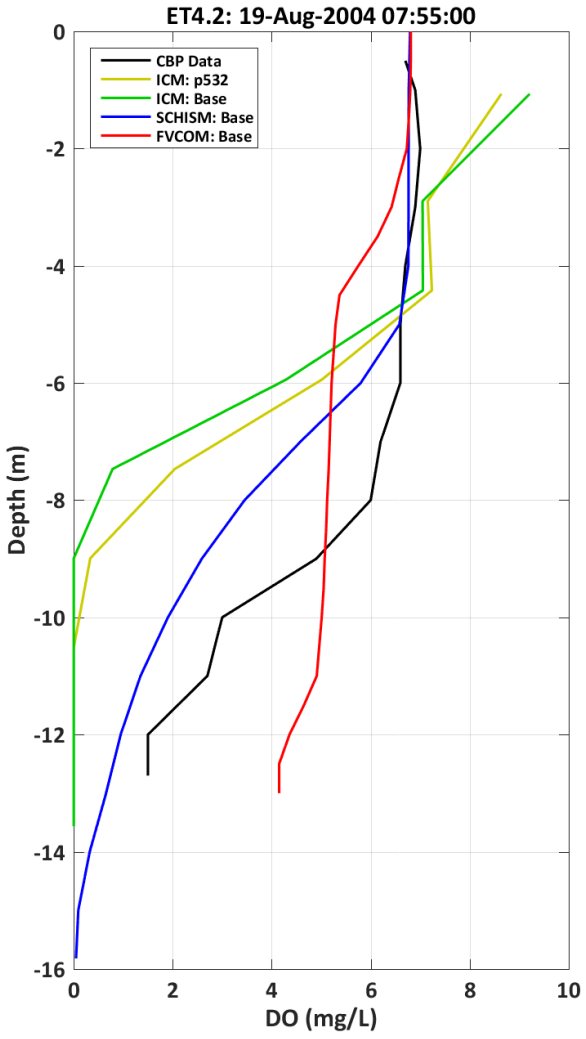


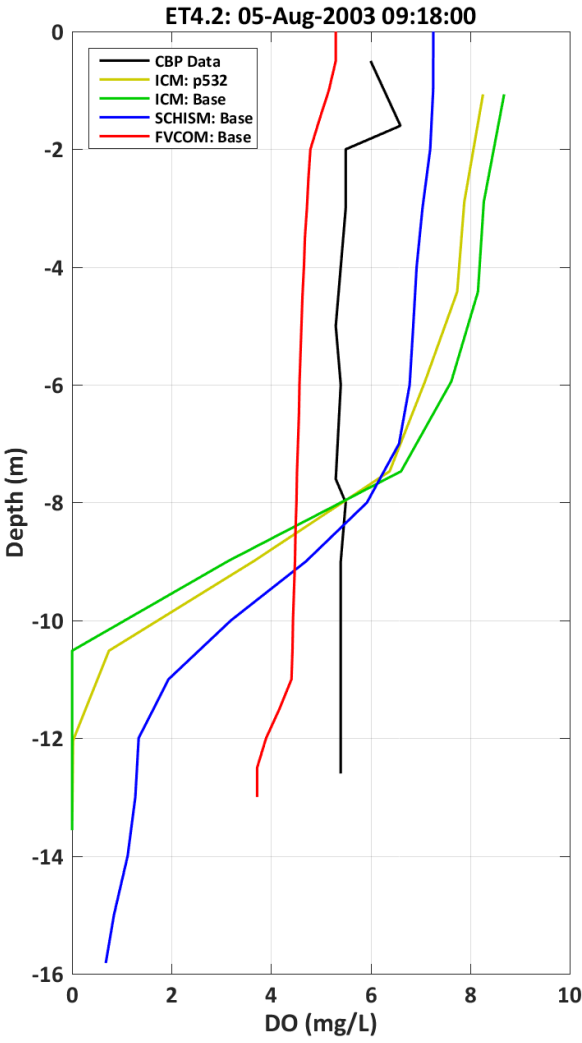


- Both ICMs are too anoxic at depth; ICMp5.3.2 is better at surface
- SCHISM and FVCOM do well (no DO stratification)

Vertical DO profiles: in August at ET4.2



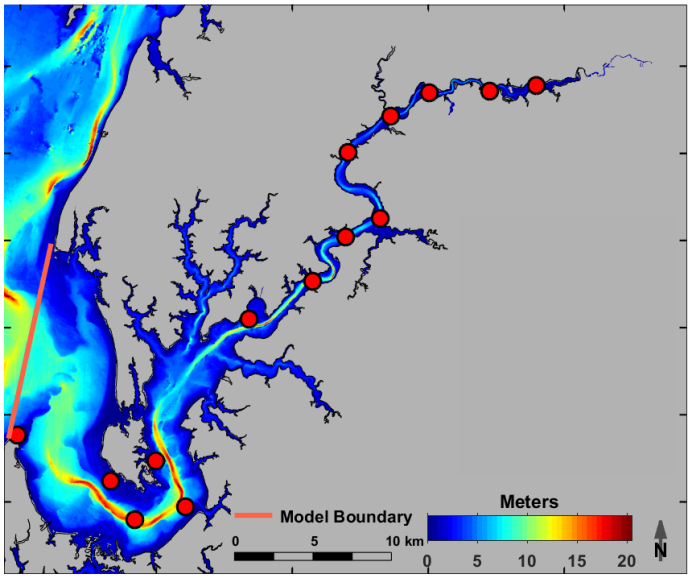




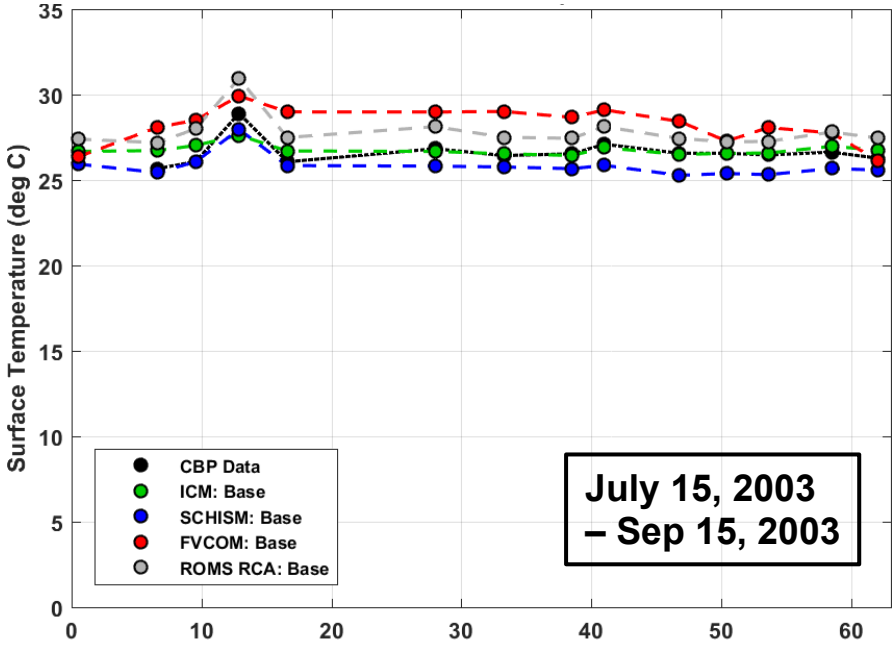
- Data show temporal variability in DO stratification; models do not
- Two ICMs are similar, and generally too hypoxic/anoxic

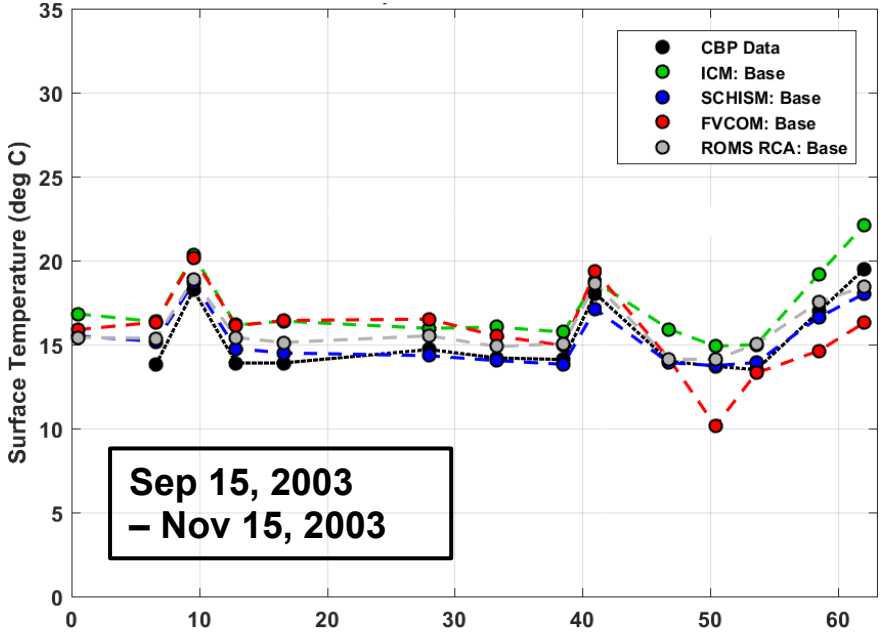
Model results – temperature

- Generally models simulate T well throughout transect
- Except in upper Chester where FVCOM is too cold and ICM is too warm by 3-4°C in Fall 2003



Surface Temperature



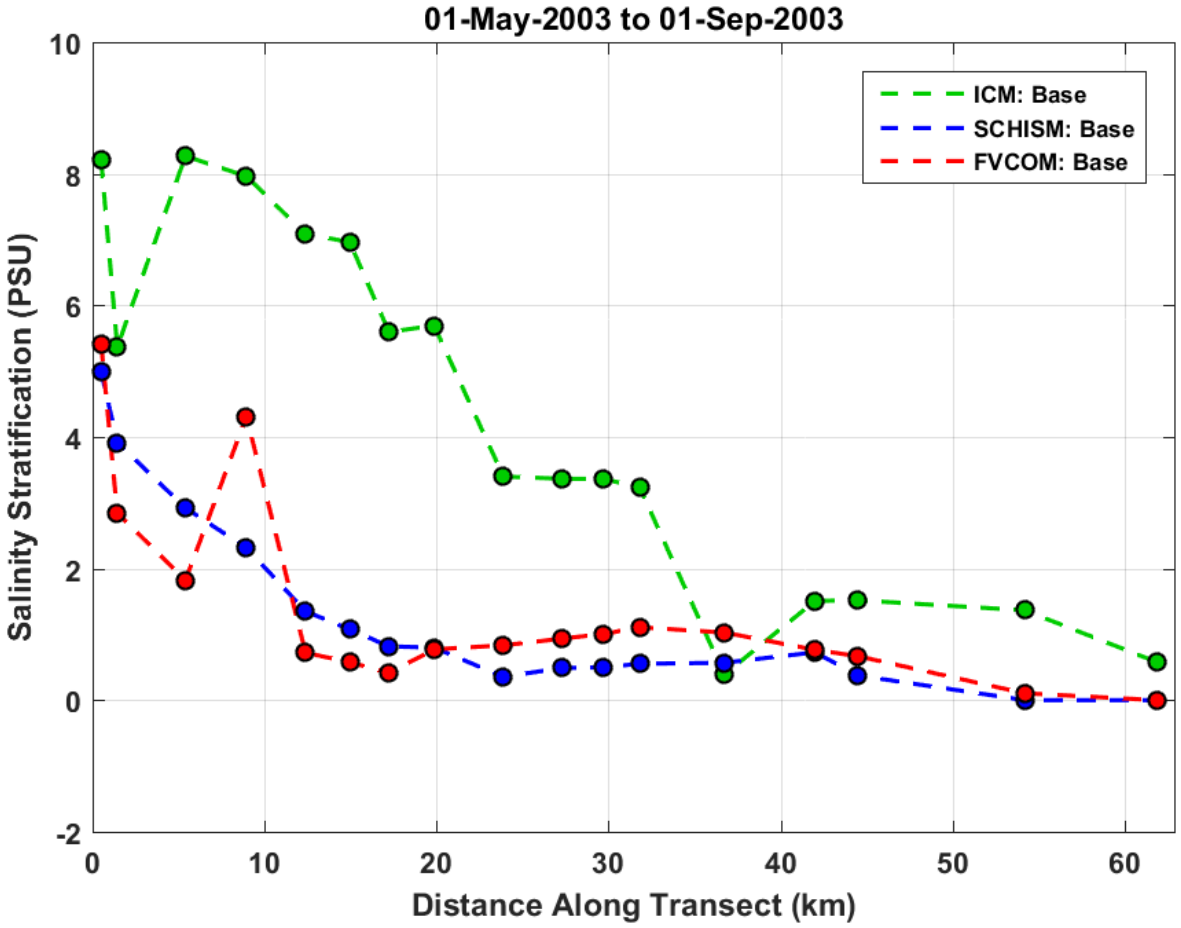


Bay → upstream

Bay → upstream

Stratification: 2003 transect along channel

Stratification = bottom S minus surface S



ICM generates much more stratification throughout Chester