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

Marjorie Friedrichs, Aaron Bever and Raleigh Hood
Model Comparison Team

SCHISM team
Joseph Zhang
Harry Wang

ROMS-GL team
Dick Zimmerman
John Klinck
Chuck Gallegos
Victoria Hill
Mike Dinniman

ROMS-RCA team
Jeremy Testa
Damian Brady
Ming Li

FVCOM & CH3D team
Richard Tian
Ping Wang

Advisory Team:
Lewis Linker
Carl Cerco
Larry Sanford
Kevin Sellner

Chesapeake Bay Program
A Watershed Partnership

Chesapeake Bay
Shallow Water Multiple Model Effort

Why focus on the shallow waters of the Chesapeake Bay?

- This is where we have seen degradation of water quality
- This is where we are likely to see early responses to management actions

Why do we need improved shallow water models?

- We depend on models to assess the impacts of alternative management strategies

Why do we need multiple models of these waters?

- To increase scientific, management, and stakeholder confidence in the tools used to support and inform partnership collaborative decision making.

Challenges of Modeling Shallow Waters

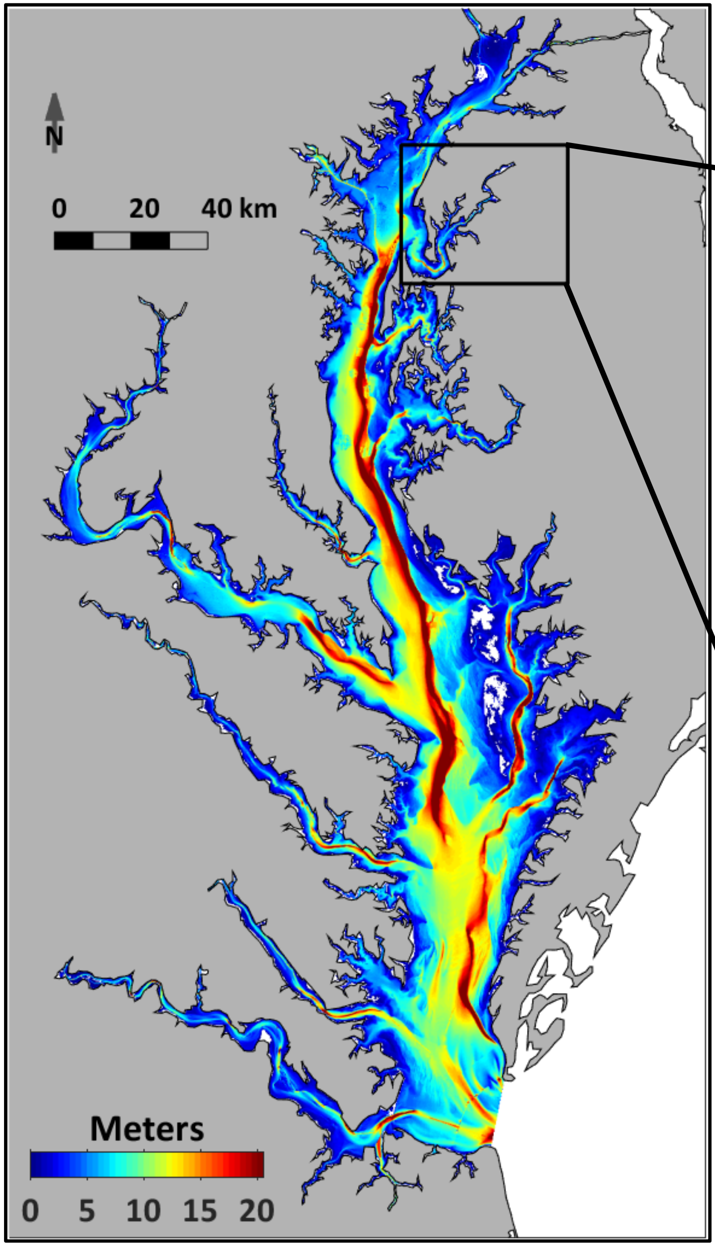
- Complex linkages between shallows & land, sediment and open Bay waters
- Processes vary on small time & space scales, requiring high resolution models
- Systems respond strongly to distant forcing: multiple spatial/temporal scales

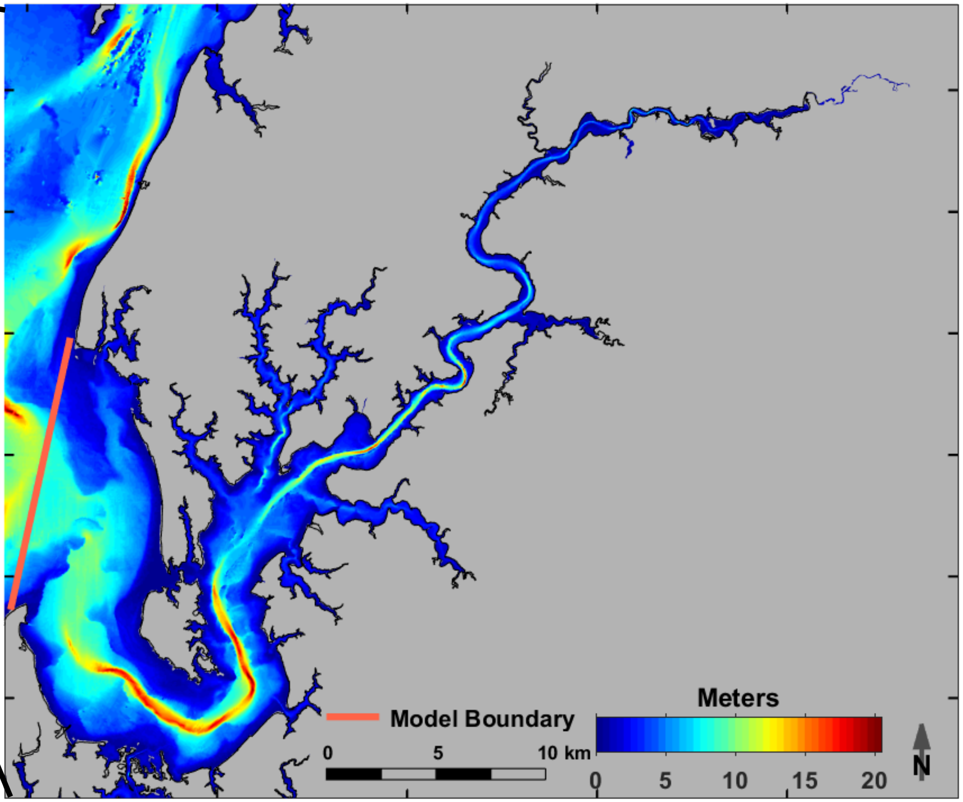
Outline

- **Study site: Chester River tributary**
- **Four participating models**
- **Cruise + mooring data**
- **Consistent forcing fields used by all models:**
  - Atmospheric conditions
  - Freshwater discharge
  - Open boundary conditions (OBC)
- **Model performance for hydrodynamics (T, S)**
  - Normal conditions
  - Two extreme events
- **Summary & implications**

Study Site: Chester River

Chesapeake Bay



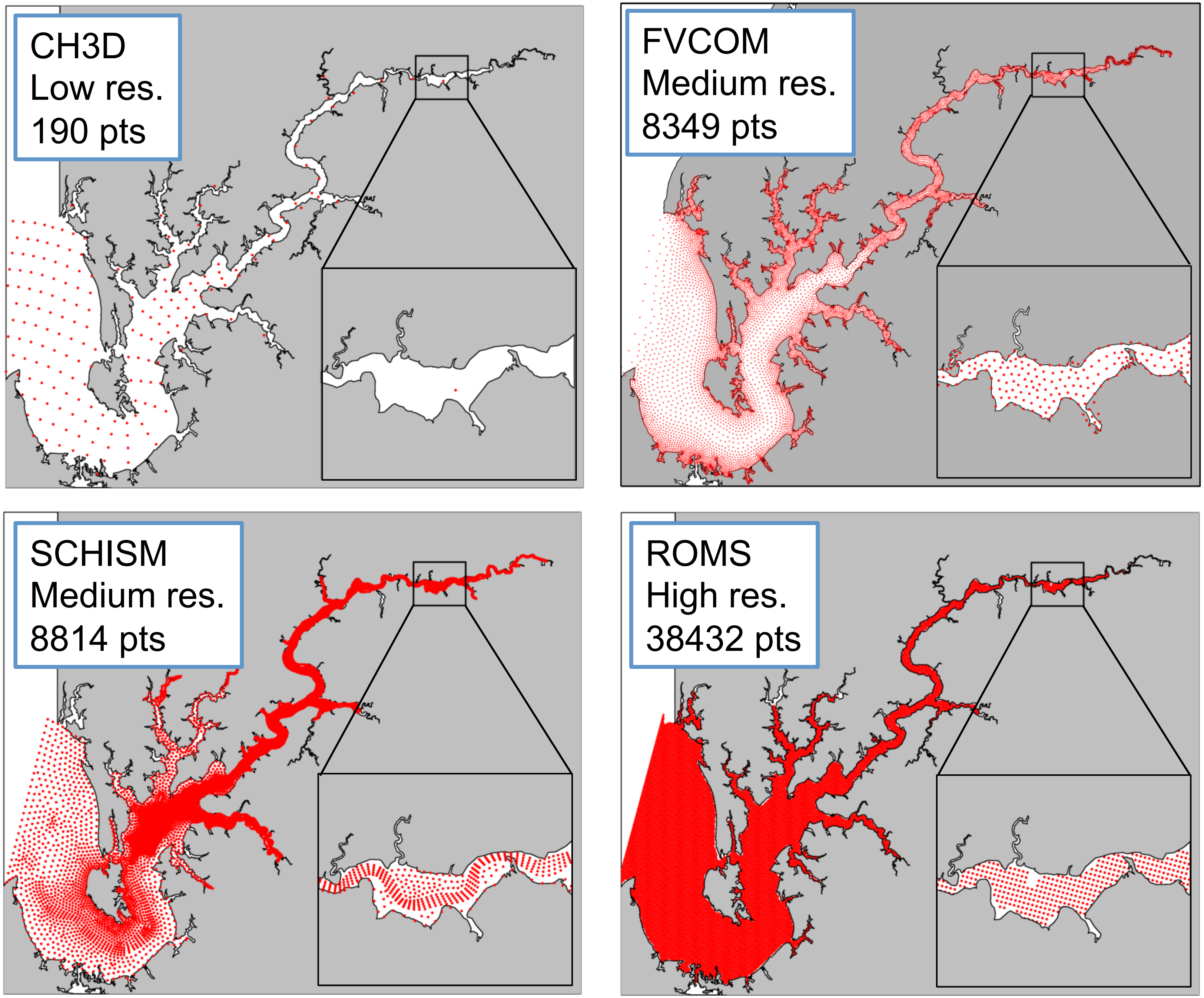


Chester River

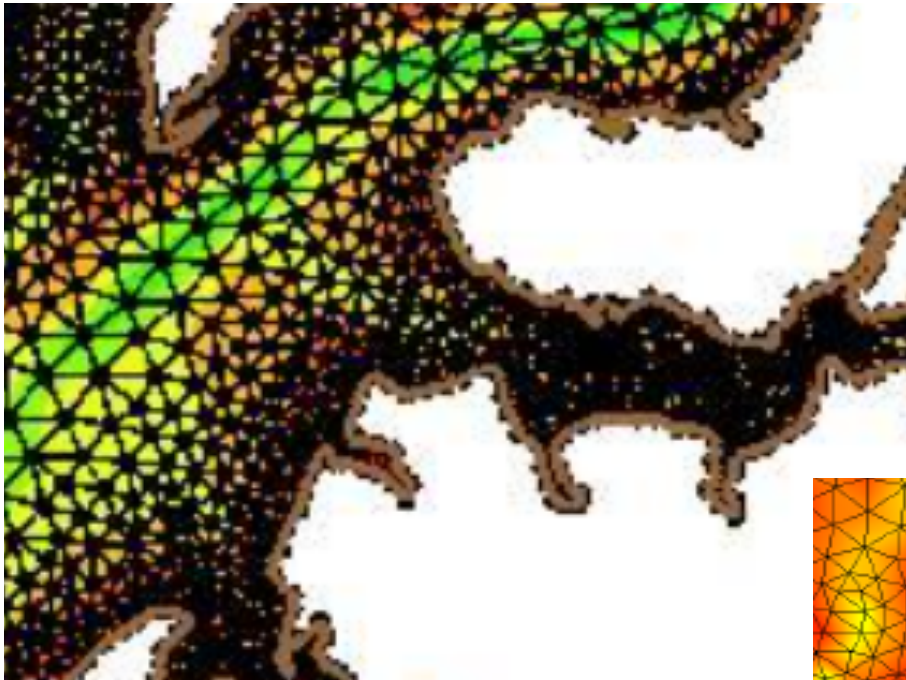
Four Models

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

*CH3D is the regulatory model currently used for management decisions in the Chesapeake Bay

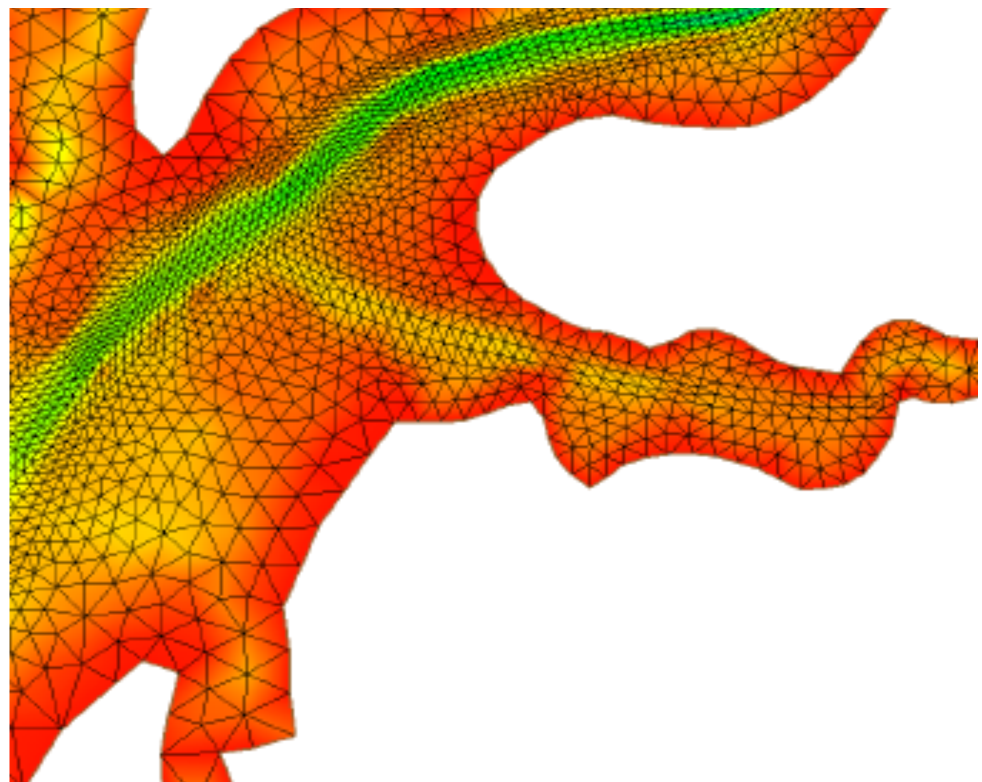

CH3D
Low res.
190 pts
FVCOM
Medium res.
8349 pts
SCHISM
Medium res.
8814 pts
ROMS
High res.
38432 pts

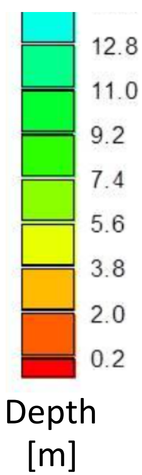
FVCOM



← FVCOM has a **low resolution grid in the trench**, with higher resolution on the flanks

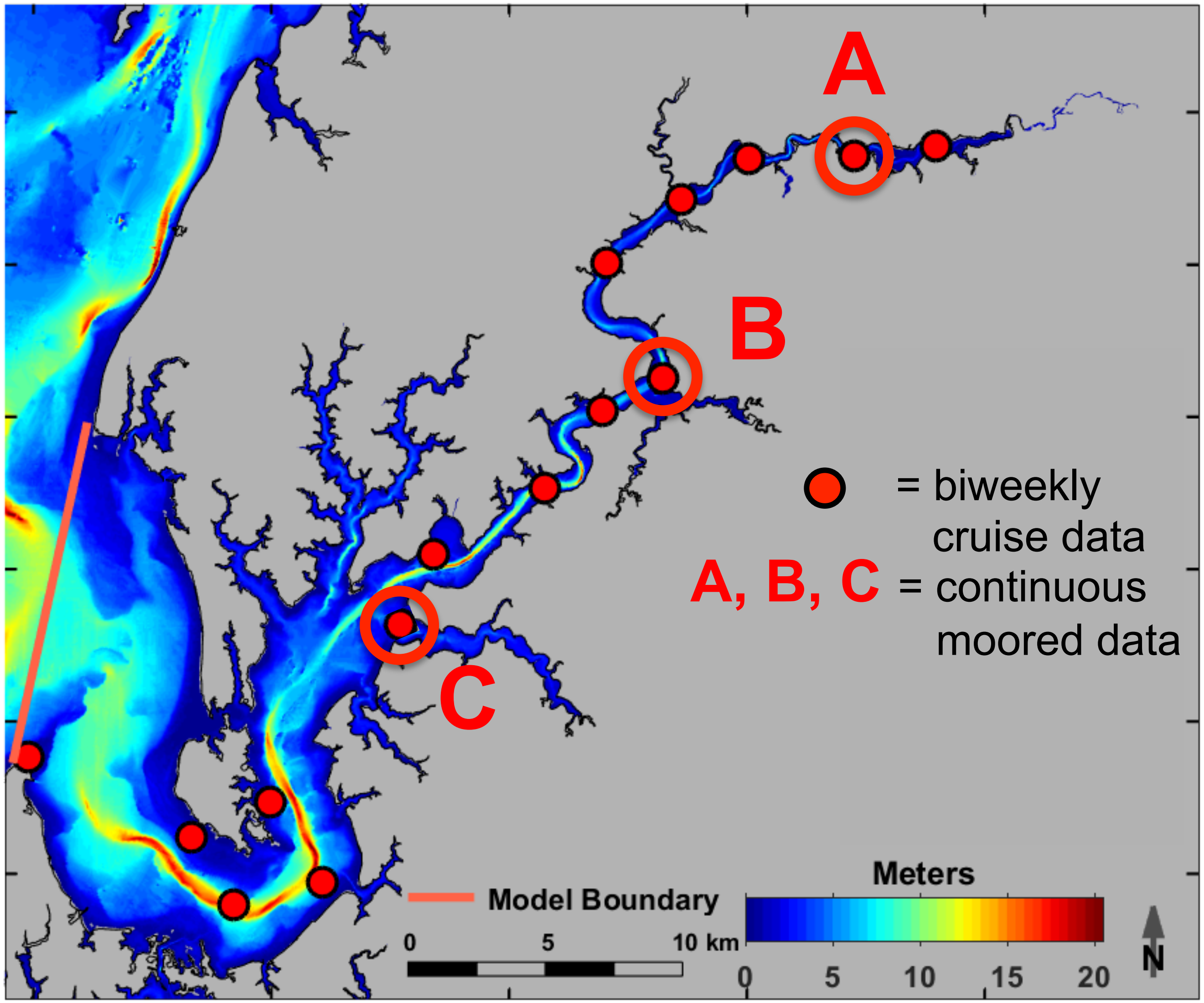
SCHISM





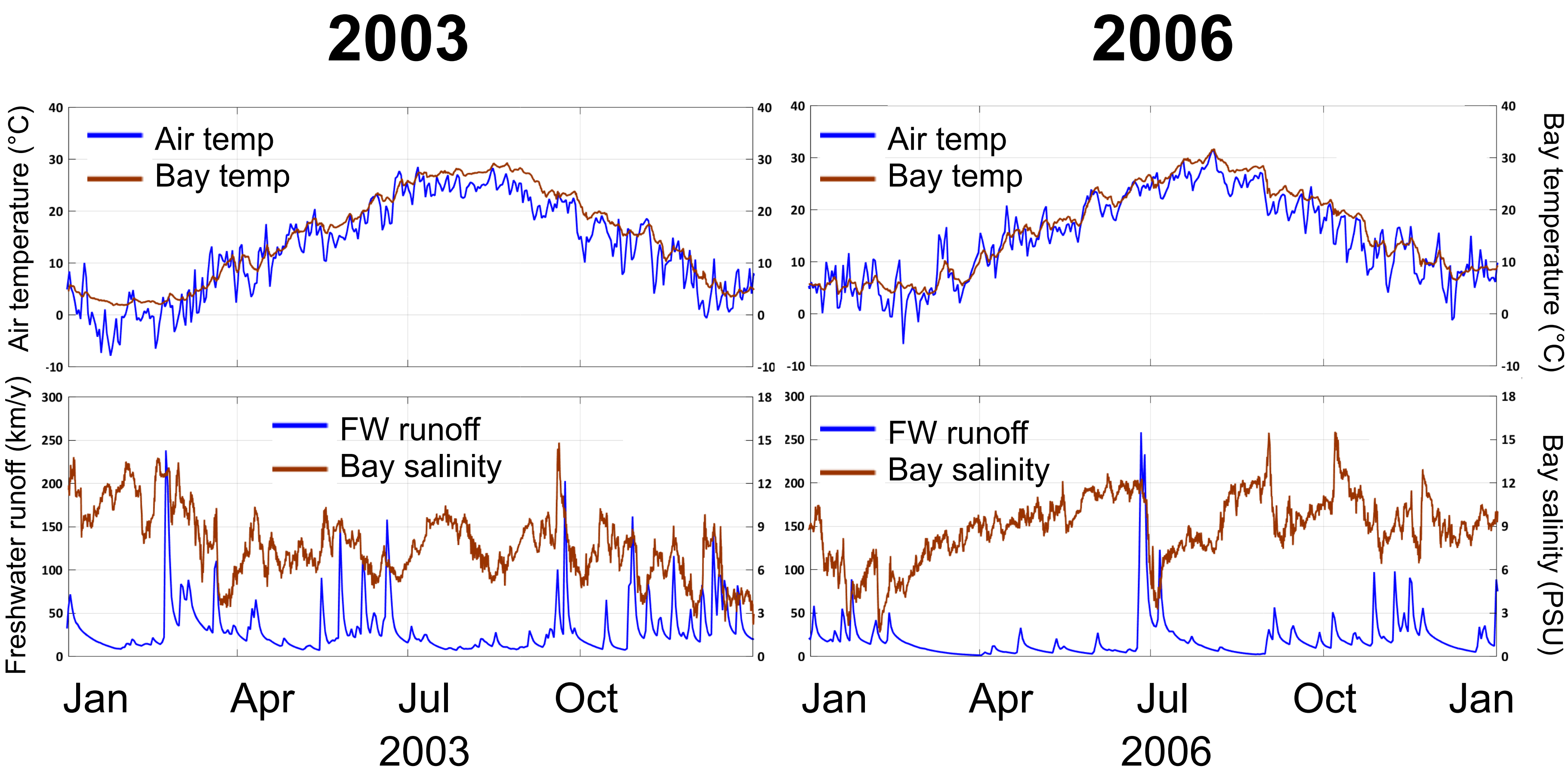
SCHISM has **a high resolution rectangular grid in the trench**, and lower resolution on the flanks →

Observations: 2003 & 2006



Chester River Model Forcing

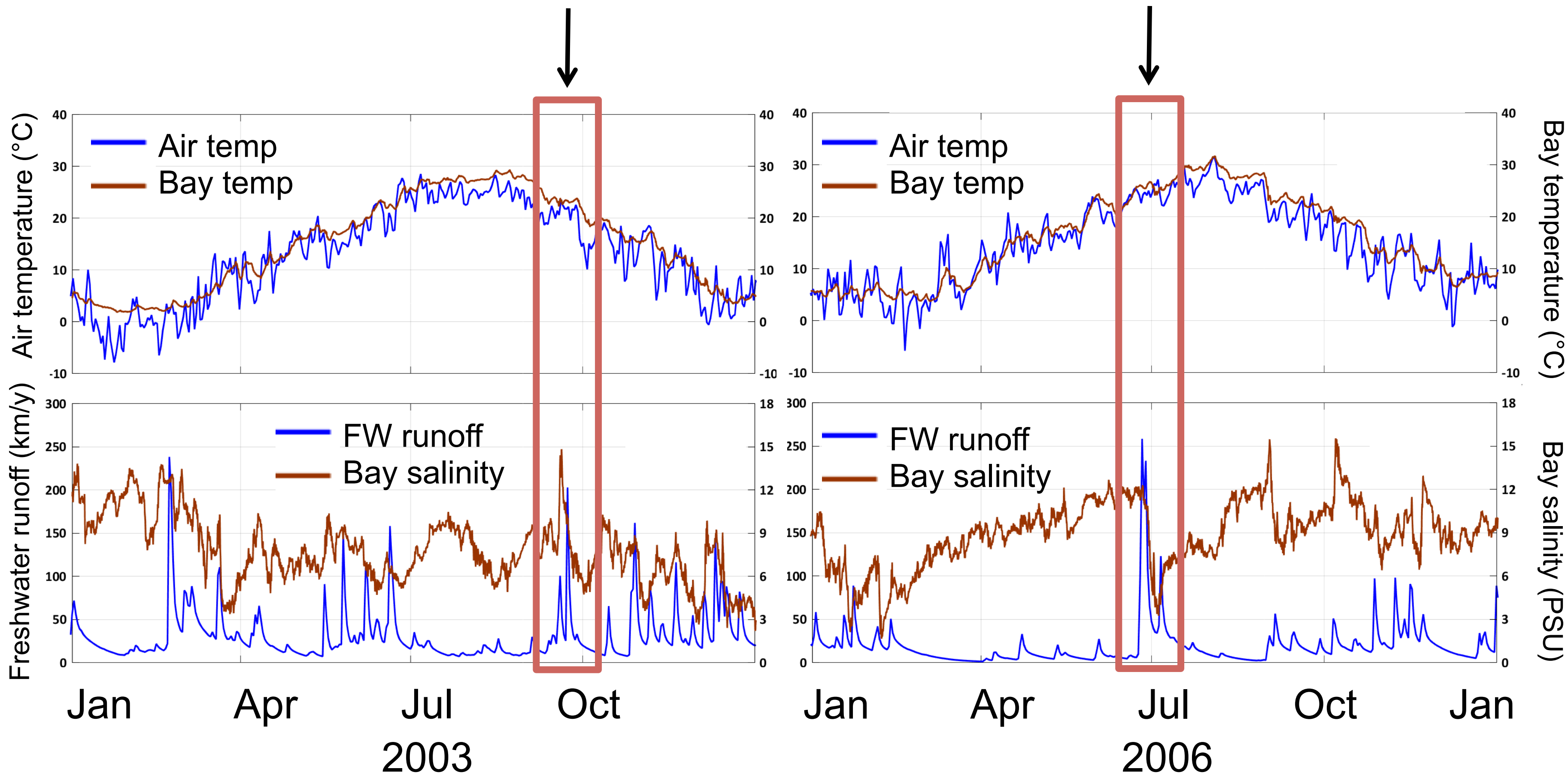
consistent for all models



Bay temperature and Bay salinity are obtained from the CH3D model, and the FW runoff is obtained from the CBP watershed model.

“Hurricane Isabel”

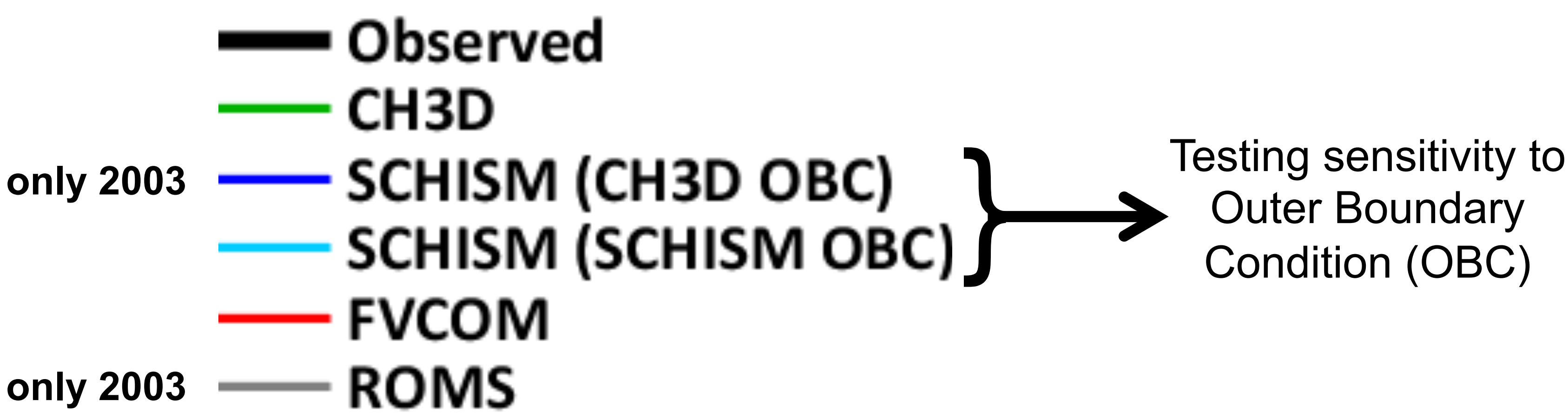
“Mid-Atlantic US Flood of 2006”



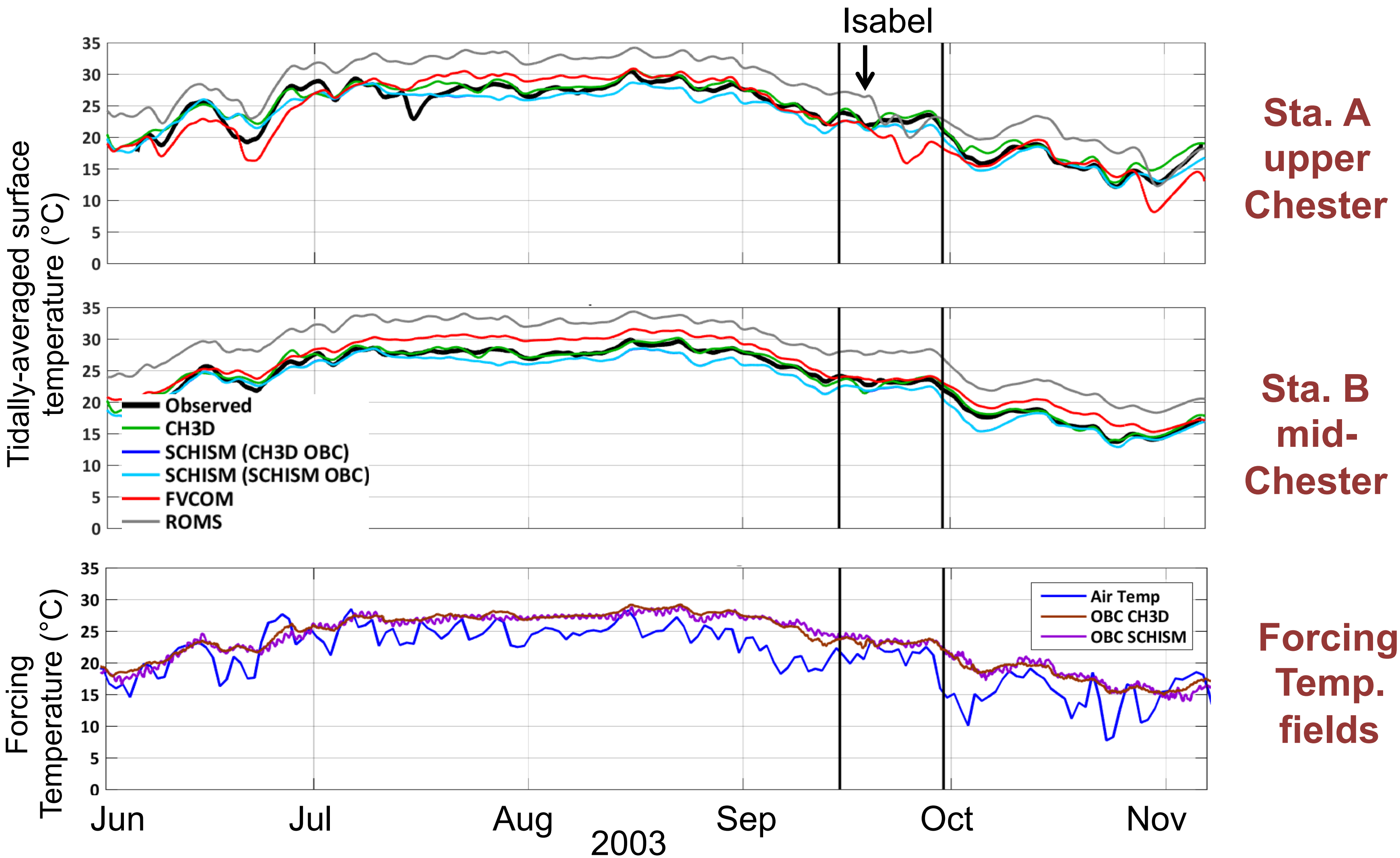
Response driven by salinity entering from Bay

Response driven by freshwater inflow

Can our shallow water models reproduce observed hydrodynamics (T, S) in the Chester River under normal conditions and during extreme events driven by tidal surge and freshwater inflow?



Model results – temperature

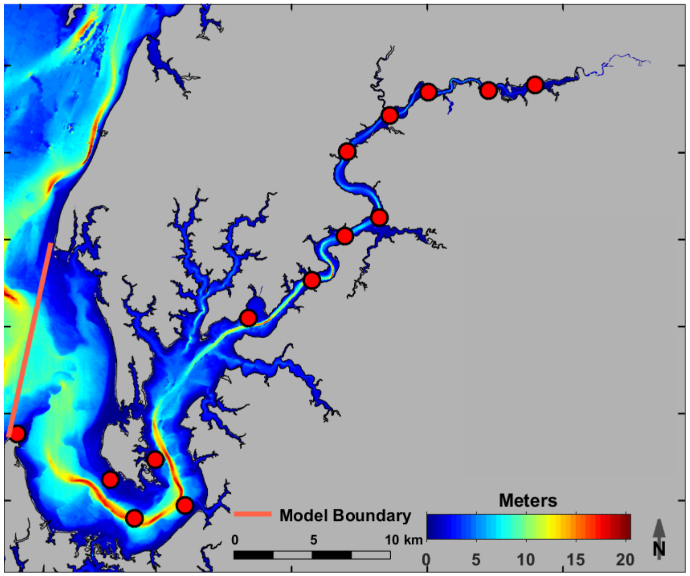


- Models simulate T well, as long as realistic forcing is used
- Results appear insensitive to grid resolution and OBCs
- Model skill is generally same before, during and after Isabelle

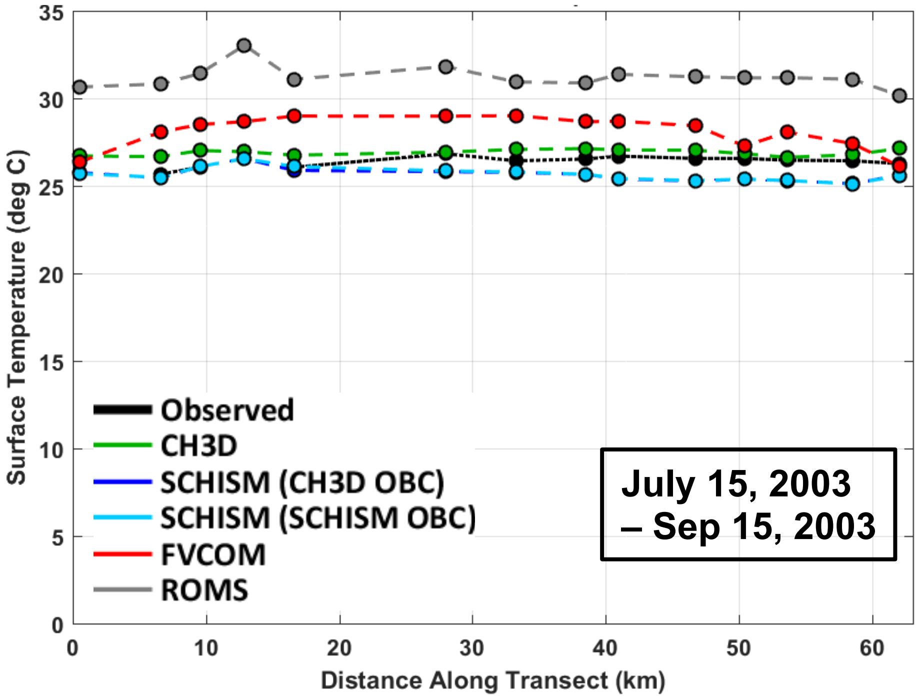
Model results – temperature

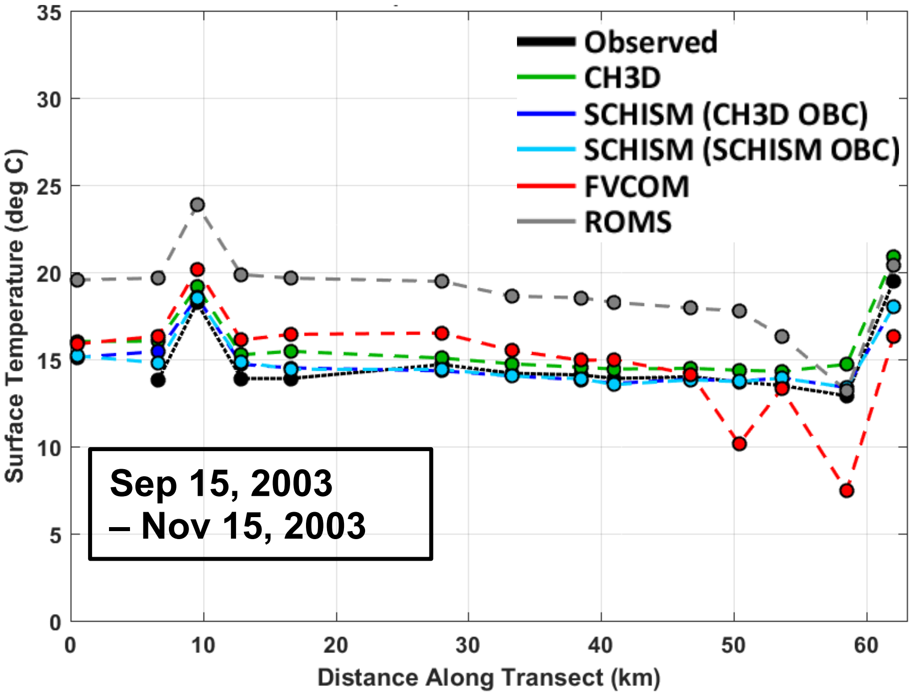
Similar results along entire transect:

- Models simulate T well
- Insensitive to grid resolution and OBCs
- Model skill is generally same before & after events



Surface Temperature

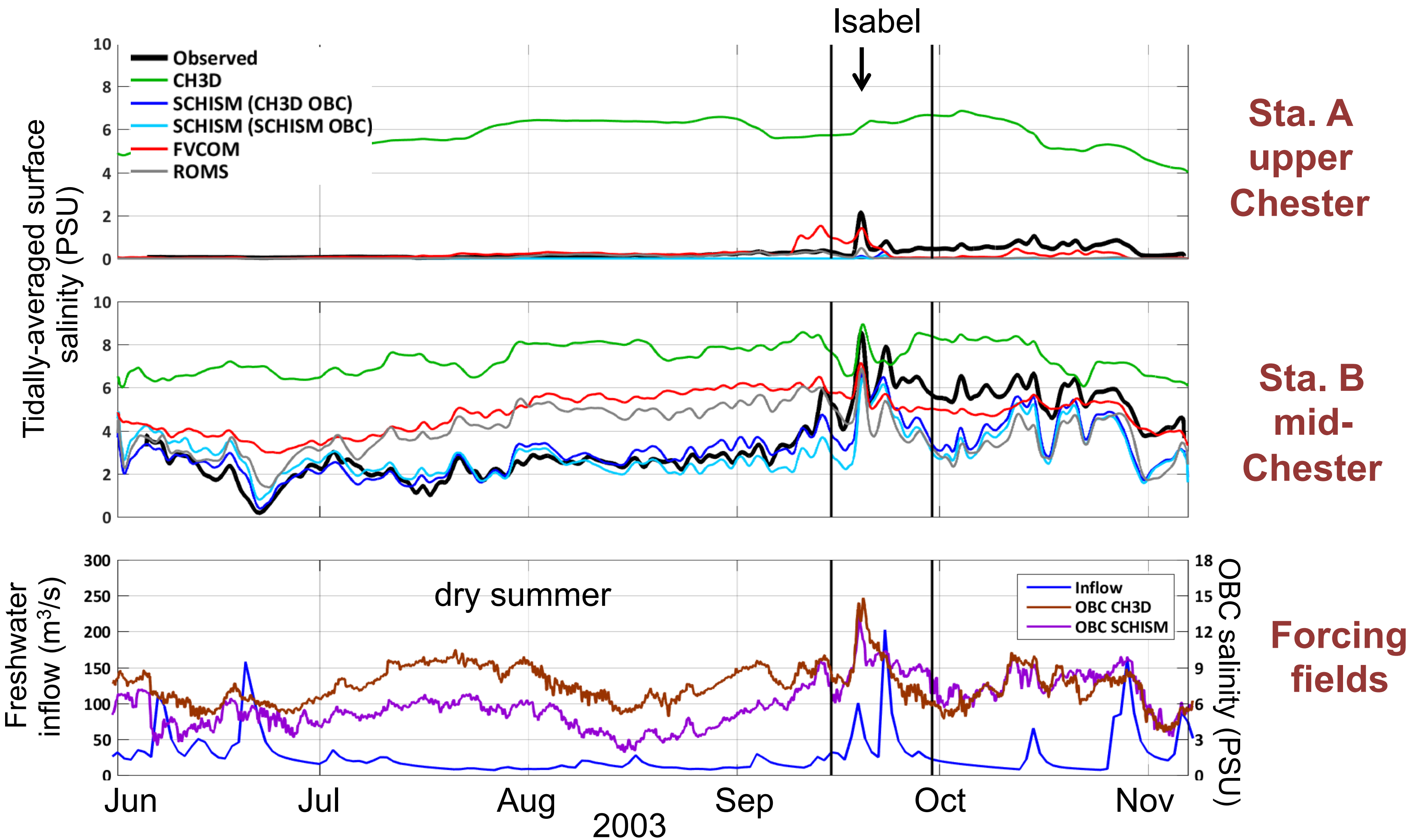




Bay → upstream

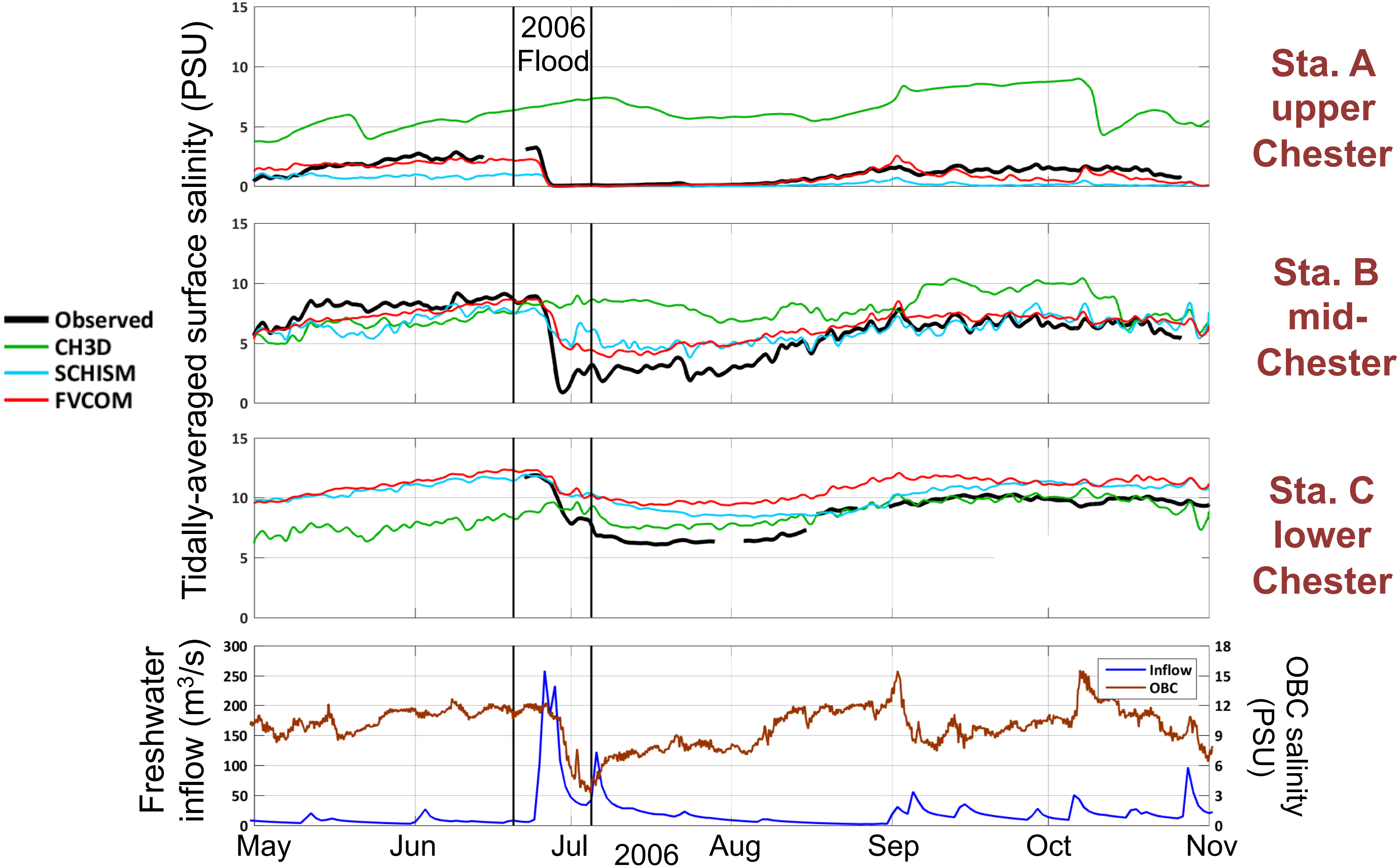
Bay → upstream

Model results – salinity – 2003



- Large differences between models (low res. model is too salty in upper Chester)
- Event response - Only SCHISM produces strong pulse in salinity in mid-Chester, but response is short-lived
  - No models produce strong salinity pulse in upper Chester

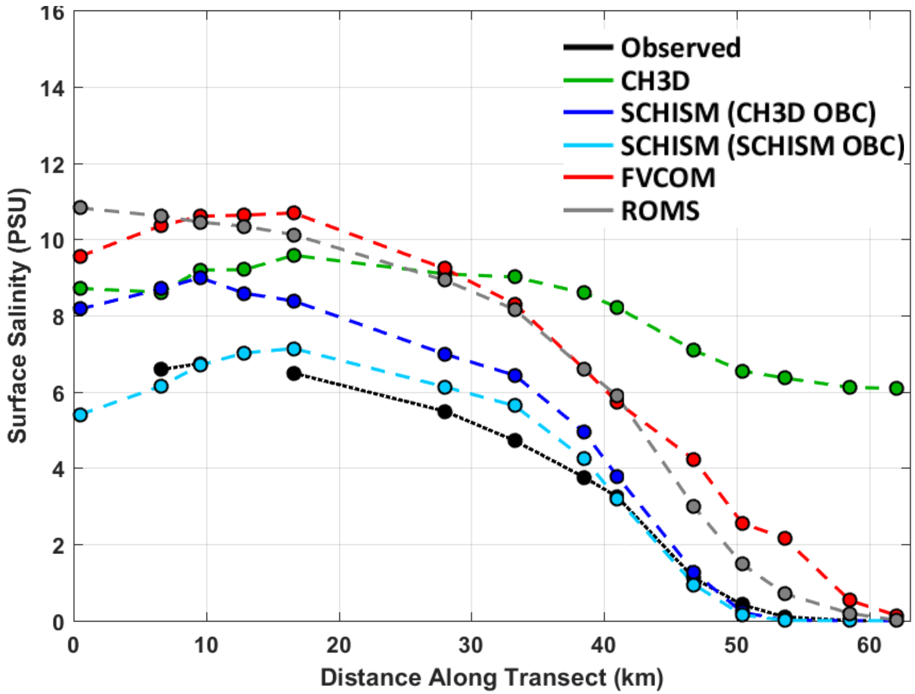
Model results – salinity – 2006



- Low res. model misses upstream salinity gradient and shows no event response
- FVCOM produces higher salinity at the uppermost station
- Both higher res. models show a clear response to the freshwater pulse, but is too weak at mid and lower Chester stations.

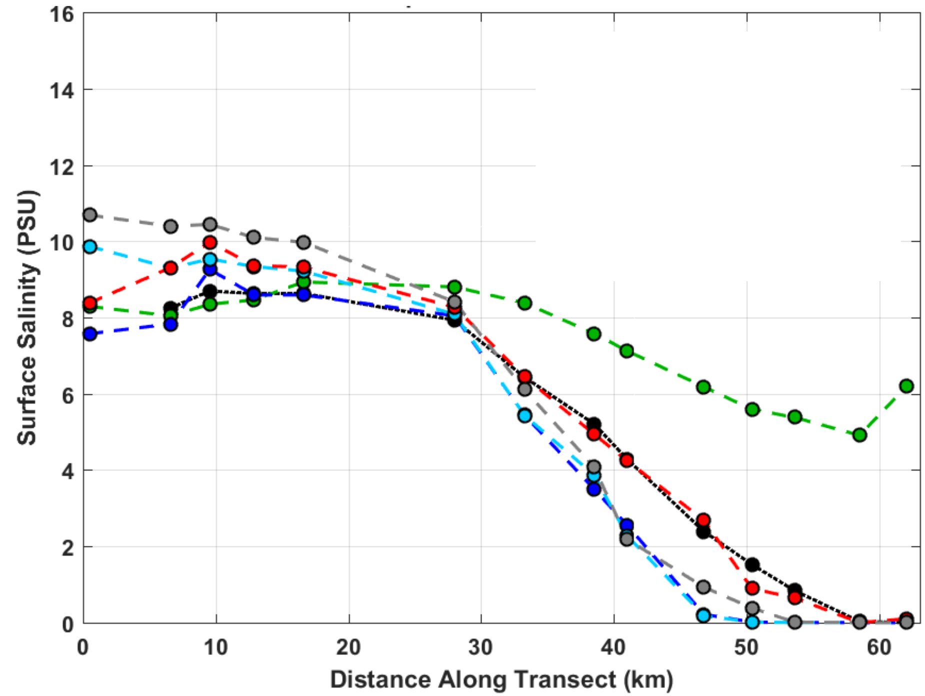
Model results – salinity – 2003

Summer 2003: Low runoff



Bay → upstream

Fall 2003: High runoff



Bay → upstream

- Low res. model overestimates surface salinity in upper half of Chester
- Low run off: SCHISM performs best
- High run off: FVCOM performs well in upper tributary
- Effect of OBC is felt 45 km up the tributary in summer 2003 (low run-off) and 25 km up the tributary in fall 2003 (high run-off).

Summary

1. **Models simulate temperature well**
   → Atmospheric temperature & wind forcing are required

2. **Simulating salinity is more challenging**
   → Low resolution model does not capture downstream salinity gradient
   → During low runoff SCHISM does best (strong OBC effects for ~45km)
   → FVCOM does best in uppermost reaches of tributary
   → ROMS performs similarly to FVCOM during low runoff, and to SCHISM during high runoff

3. **Data show immediate & prolonged response to extreme events, but…**
   → Low resolution model shows no response
   → Higher resolution models show responses that are weak & short-lived
   - Runoff driven events: models do equally well
   - Tidal surge events: SCHISM reproduces effects of tidal surge well up into tributary, due to hybrid triangular/rectangular grid geometry?

Implications for Water Quality Management

- **If we are not correctly simulating distributions of a conservative tracer such as salinity, our dynamic mixing processes are likely wrong**
  - → Significant ramifications for nutrients and water clarity!
  - → Must make sure our mixing processes are correct, to avoid tuning our water quality, biogeochemical and living resource models to make up for hydrodynamic model deficiencies

- **Information from open boundary travels ~45km up the tributary**
  - → Must have confidence in the simulation we use for our open boundary conditions!

- **Accurately simulating dynamic mixing processes during extreme events is critical!**
  - → Effects of extreme events are long-lived (~2 months)
  - → More extreme events with future climate change