

# Baroclinic 3D Modeling of Circulation Patterns in the Pamlico-Albemarle Sound System

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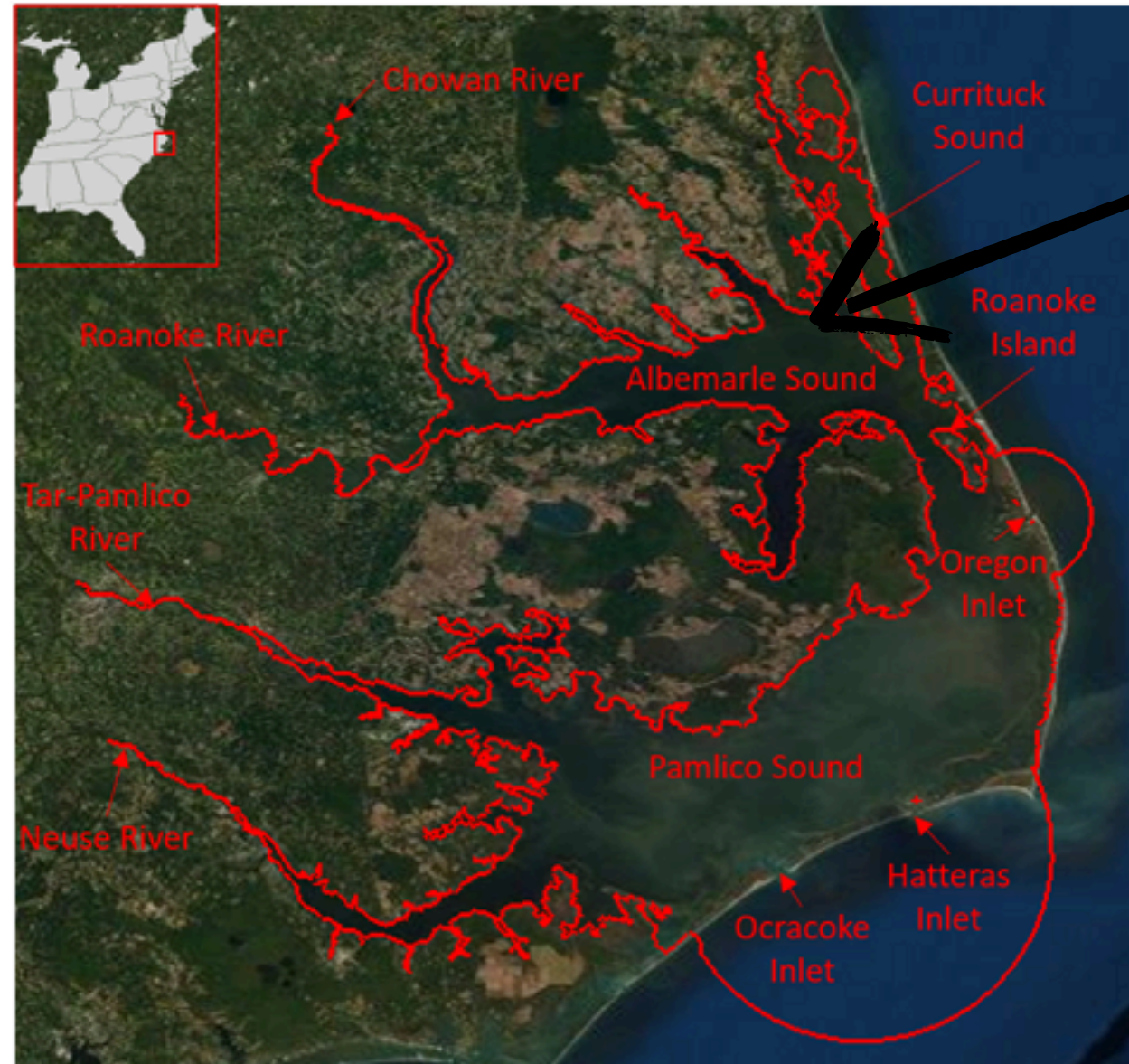


**NC STATE**  
**UNIVERSITY**



# Motivation/Problem

Why do circulation and stratification matter in PASS?



Riverine inputs / nutrient loading



Favorable conditions for HABs



Photo: Astrid Schnetzer



Photo: DEQ

Ecological and health impacts

## Health Impacts of Cyanotoxins

*Note: Not all cyanotoxins lead to all of these health impacts. These listed impacts are caused by microcystins or cylindrospermopsin, the two cyanotoxins that EPA has issued Health Advisories for.*

IN HUMANS		IN PETS
<p><b>Brain</b>                      Source: Ingestion                      Symptoms:                      • Headache                      • Incoherent speech                      • Drowsiness                      • Loss of coordination</p>	<p><b>Body</b>                      Source: Contact, e.g. swimming                      Symptoms:                      • Irritation in eyes, nose, and throat                      • Blistering around the mouth                      • Skin rash, including tingling, burning and numbness                      • Fever                      • Muscle aches (from ingestion)                      • Weakness (from ingestion)</p>	<p><b>Symptoms:</b>                      Vomiting                      Fatigue                      Shortness of breath                      Difficulty breathing                      Coughing                      Convulsions                      Liver failure                      Respiratory paralysis leading to death</p>
<p><b>Respiratory System</b>                      Source: Inhalation                      Symptoms:                      • Dry cough                      • Pneumonia                      • Sore throat                      • Shortness of breath                      • Loss of coordination</p>	<p><b>Organs</b>                      Source: Ingestion                      Symptoms:                      • Kidney damage                      • Abnormal kidney function                      • Liver inflammation</p>	
<p><b>Digestive System</b>                      Source: Ingestion, drinking contaminated water, or eating contaminated fish                      Symptoms:                      • Abdominal pain                      • Nausea                      • Vomiting                      • Diarrhea                      • Stomach cramps</p>	<p><b>Nervous System</b>                      Source: Ingestion                      Symptoms:                      • Tingling                      • Burning                      • Numbness</p>	

Estuarine circulation helps determine where nutrients, blooms, and toxins are transported, retained, or accumulated.

# Research Question and Objectives

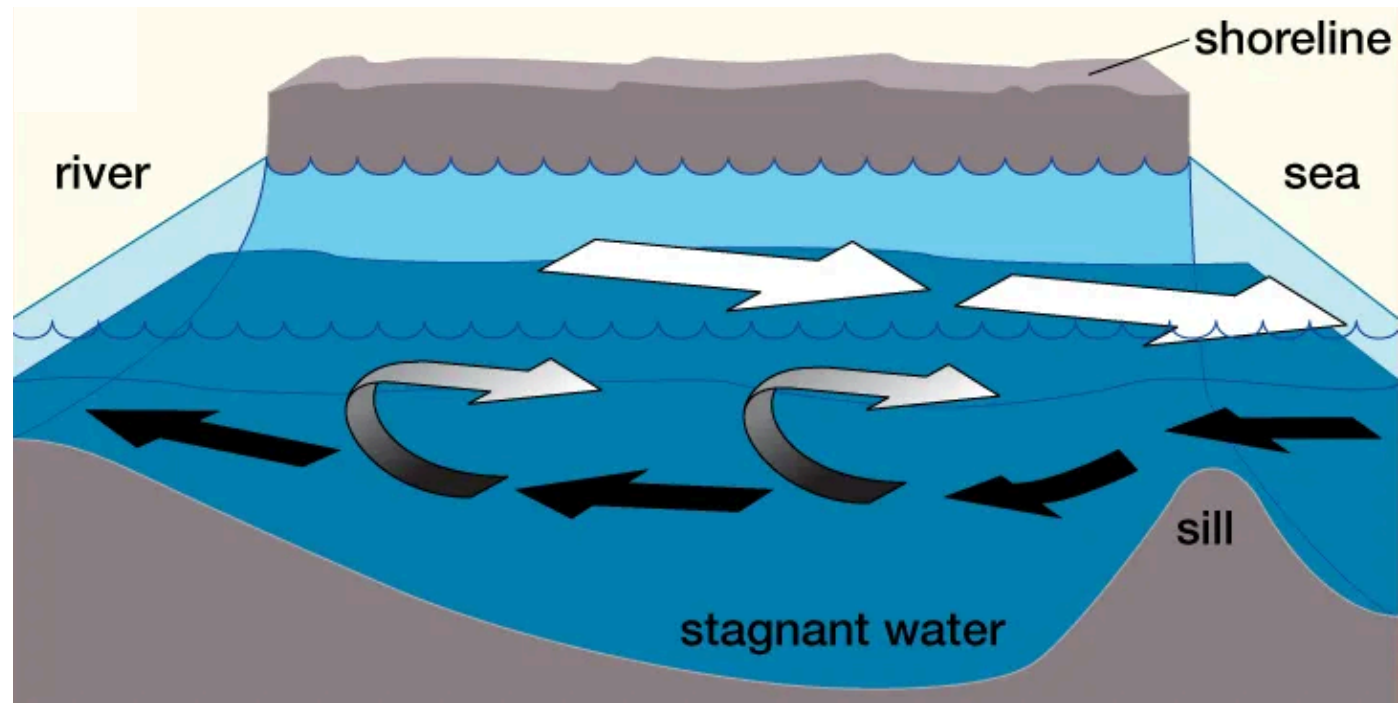
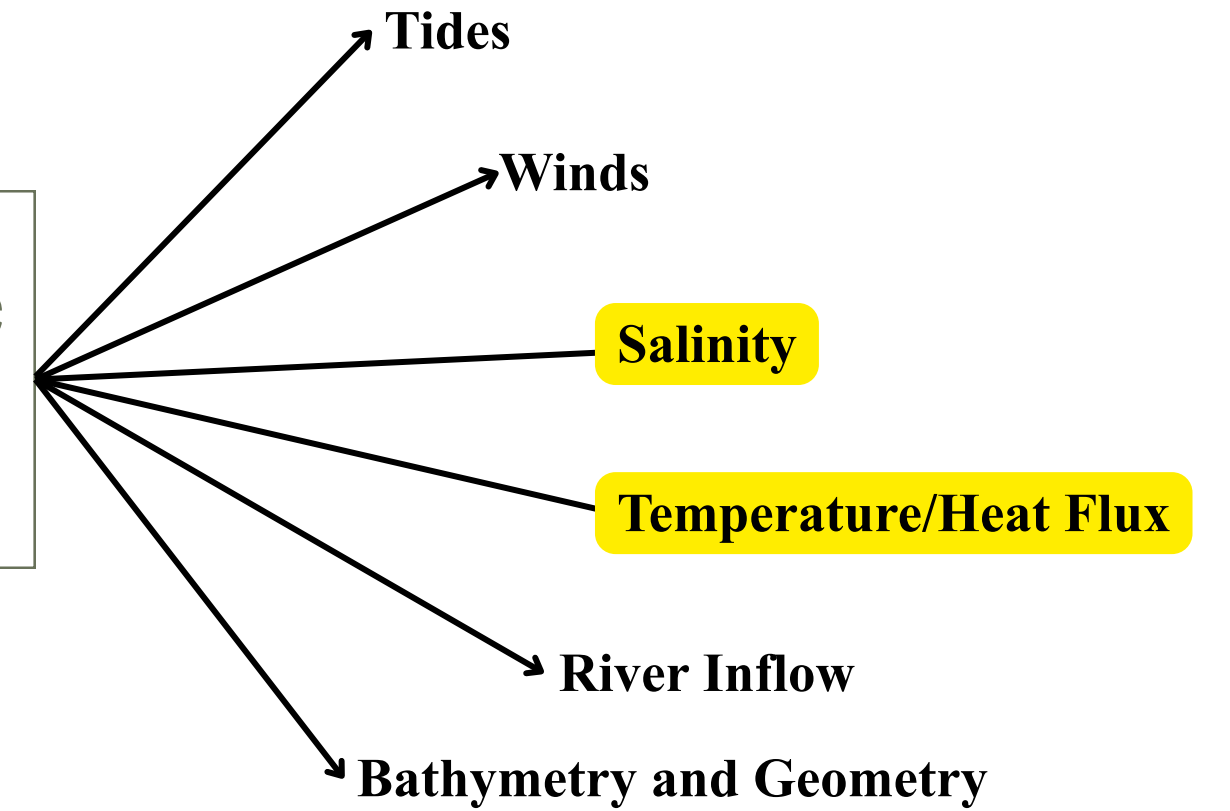


Photo: Encyclopædia Britannica

## Drivers of Estuarine Dynamics



Salinity and temperature are emphasized because they shape density structure and influence bloom-favorable conditions.

How does surface salinity in PASS vary in space and time under tides, winds, river inflow, and heat flux?

## Objectives:

- Develop and configure a coastal circulation model for 3D baroclinic simulations over the full PASS and apply it to a summer-long hindcast with all required forcing and boundary inputs.
- Examine spatial gradients, temporal variability, and exchange patterns in surface salinity.

# ADCIRC 3D Model Setup and Forcing

## Initial Salinity & Temperature

- Derived from **SalWise** climatology.
- Provides a climatological baseline density structure.

## River Fluxes

- Time-varying **USGS** discharge.
- Roanoke, Chowan, Tar–Pamlico, and Neuse Rivers.

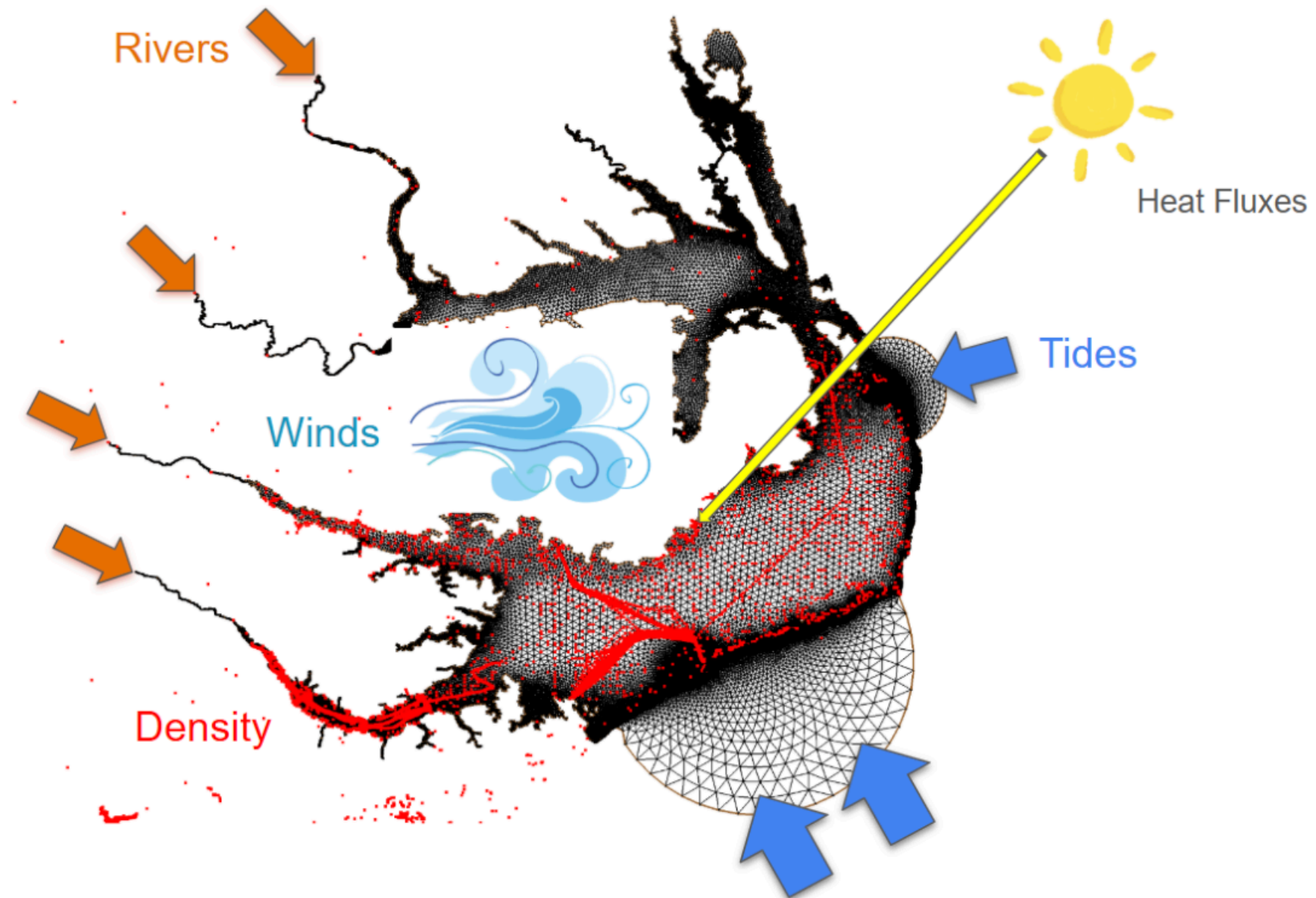
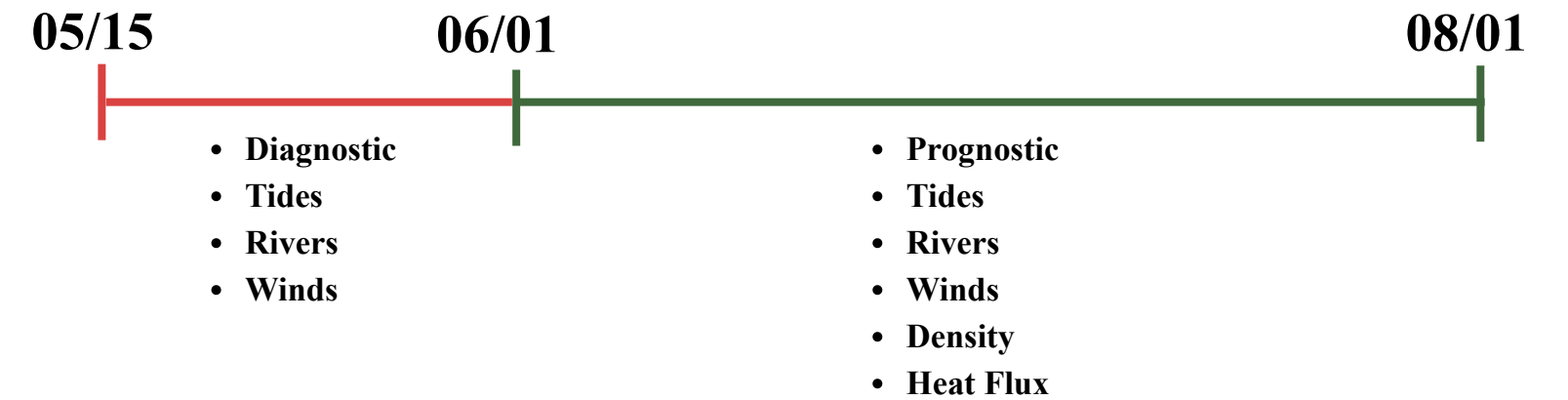
## Tides and Winds

- Tidal forcing includes eight harmonic constituents:  $K_1$ ,  $O_1$ ,  $P_1$ ,  $Q_1$ ,  $M_2$ ,  $S_2$ ,  $N_2$  and  $K_2$ .
- Applied winds and surface pressures are from the **North American Mesoscale (NAM) model**.

## Heat Fluxes

- Time series from **ERA5**.
- Includes sensible, latent, shortwave, and longwave heat-flux components.

## Timeline of simulation (2024)



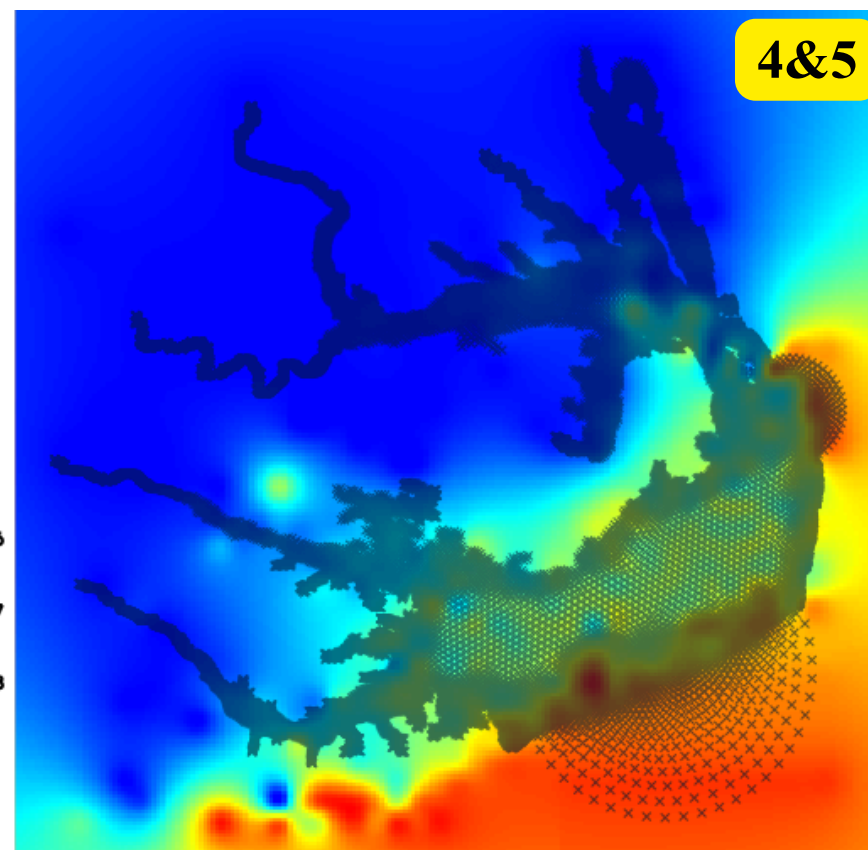
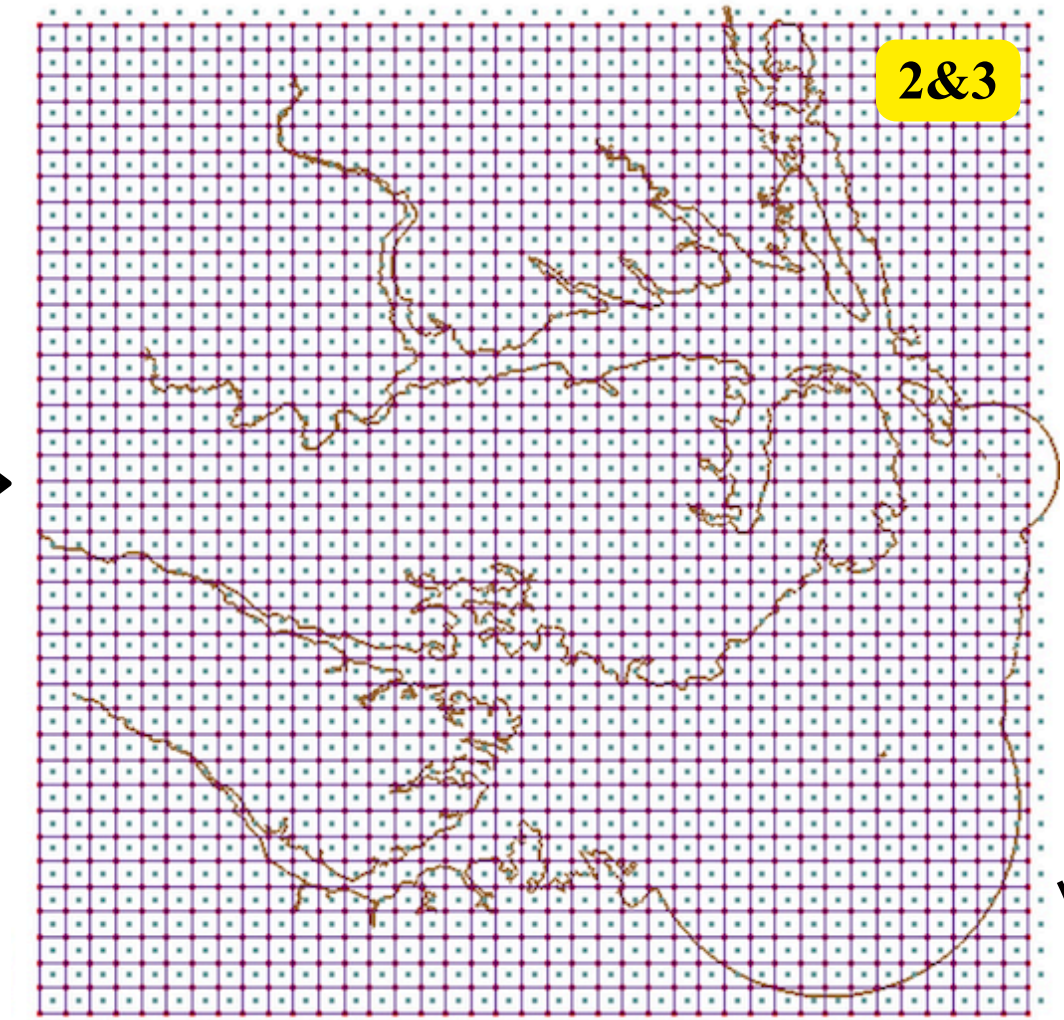
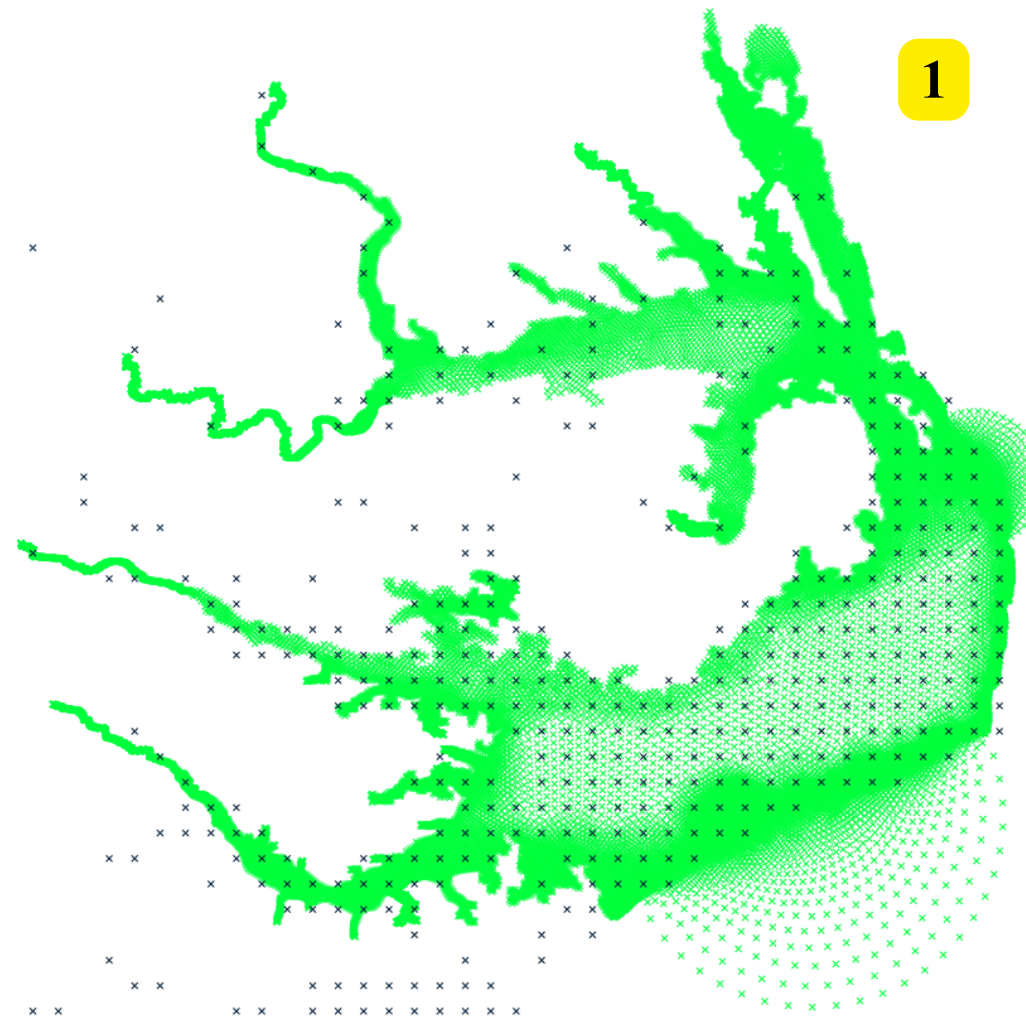
# Salinity and Temperature Initialization (SalWise)

## SalWise

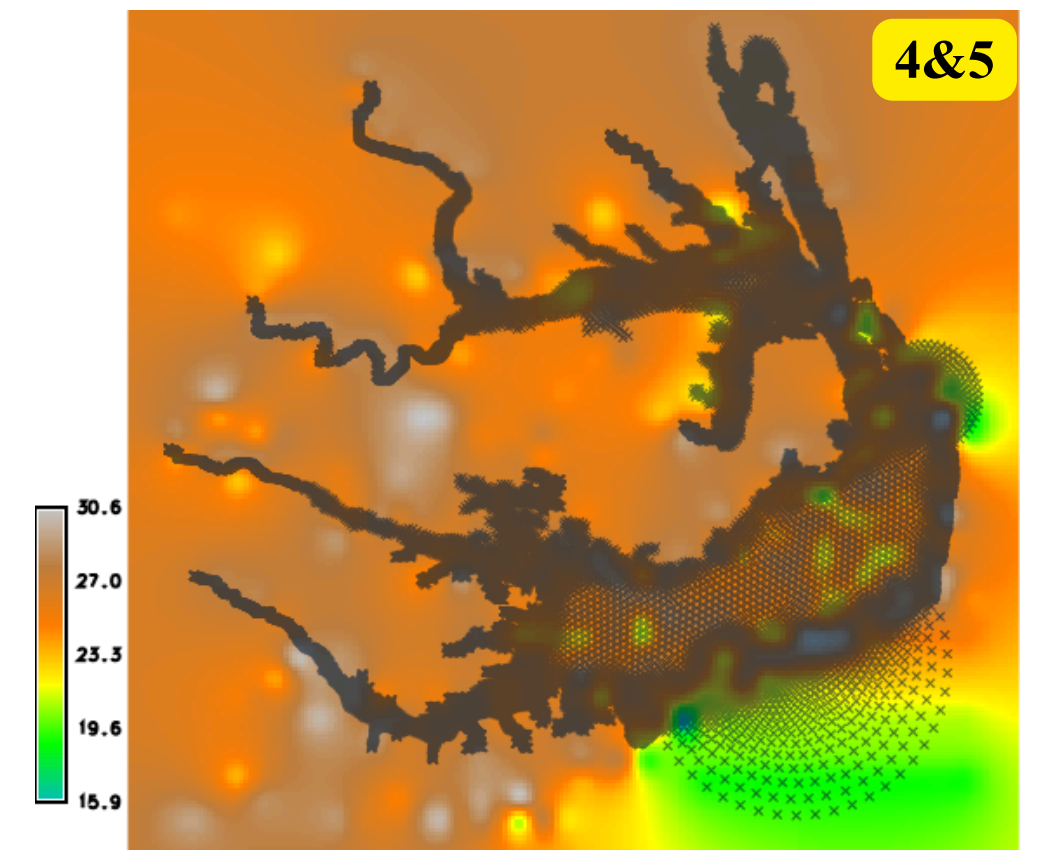
- Developed at the University of North Carolina by Dr. Niels Lindquist and Dr. Stephen Fegley
- Over 1,980,000 records
- From 1945 - 2014

## SalWise-to-ADCIRC Workflow

1. Select **June** SalWise records (1945–2014).
2. Create equal-area bins across PASS.
3. Group observations by bin and average.
4. Build continuous surfaces in GRASS GIS.
5. Interpolate fields to ADCIRC mesh nodes.



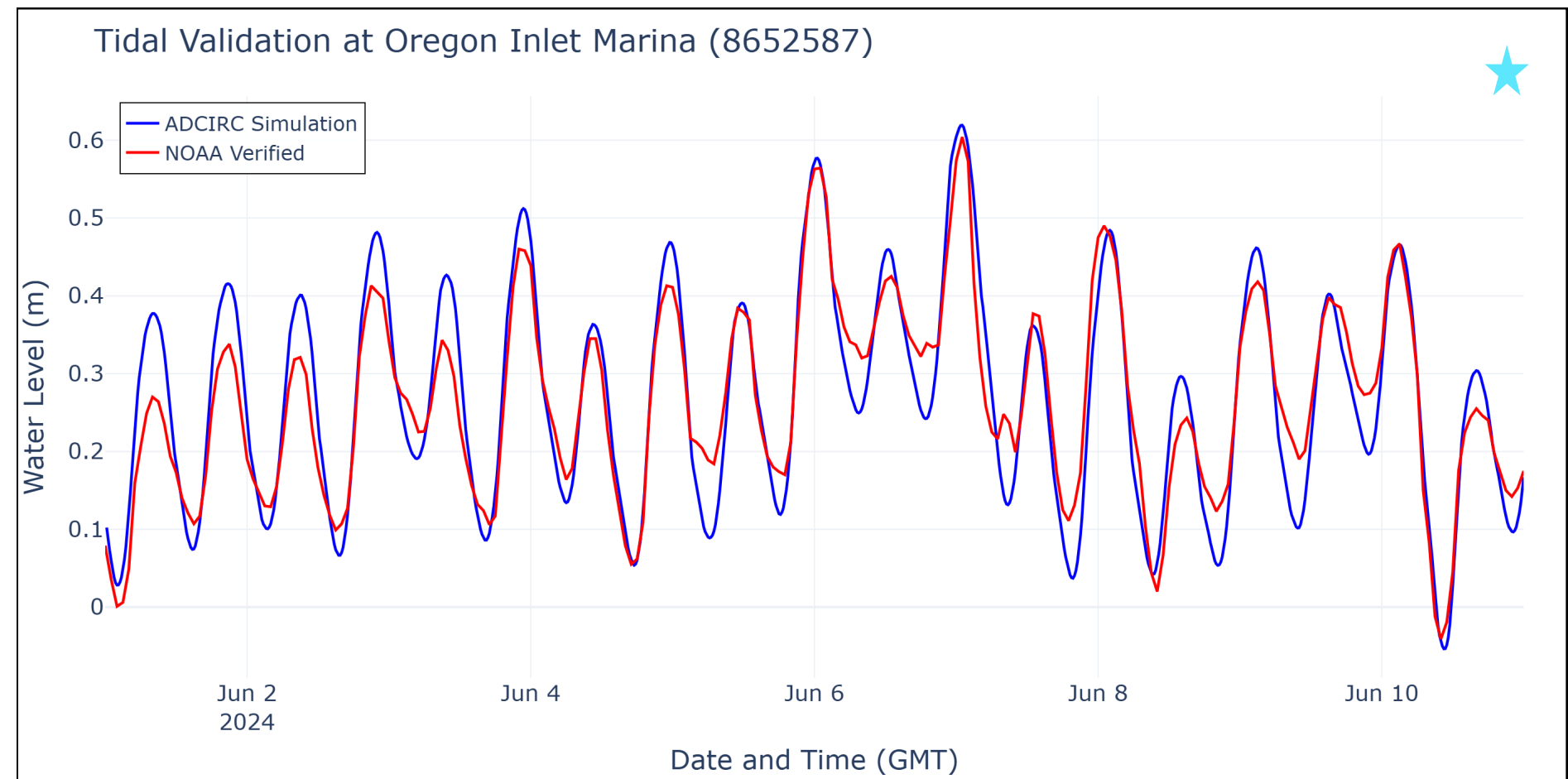
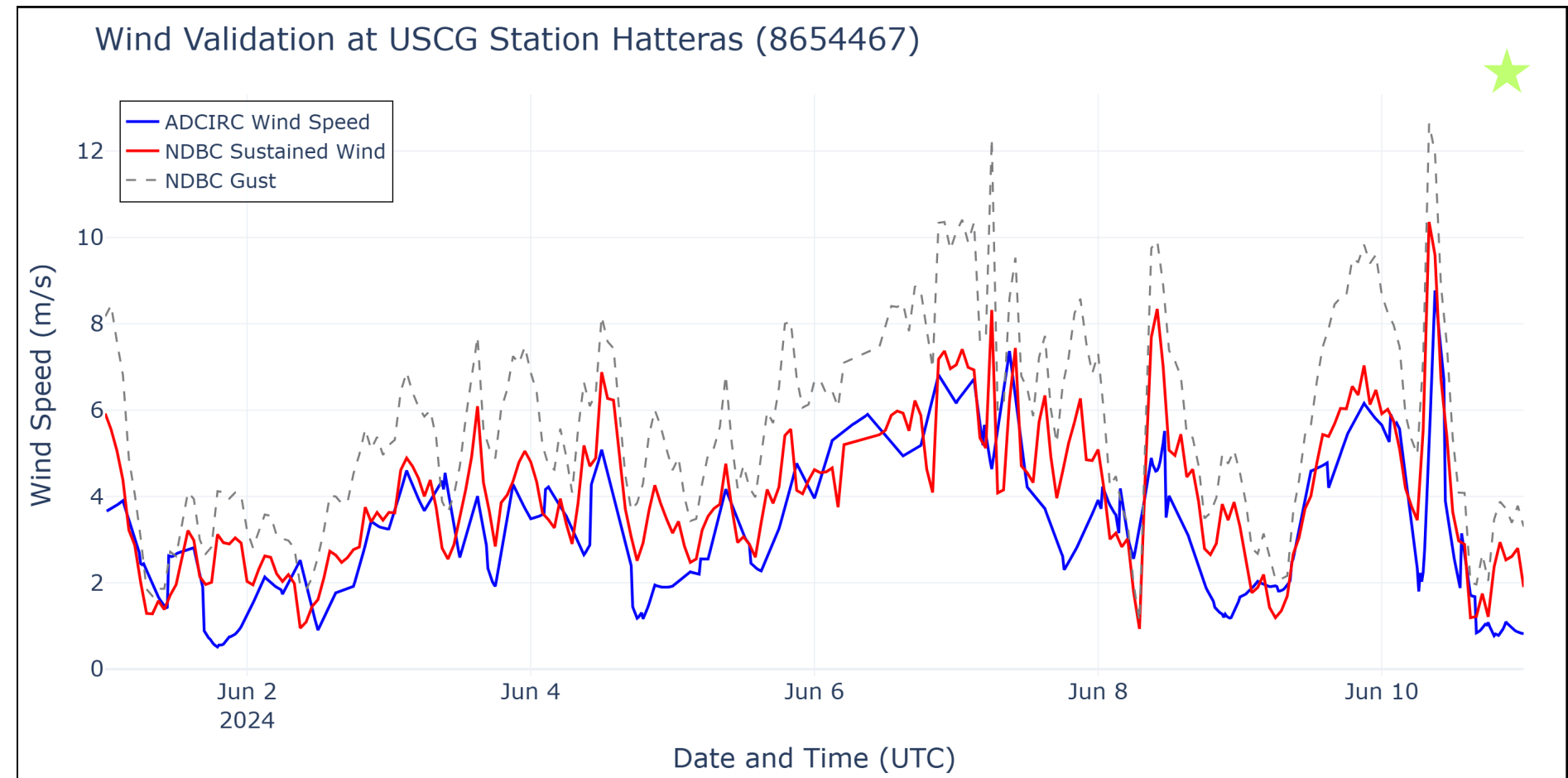
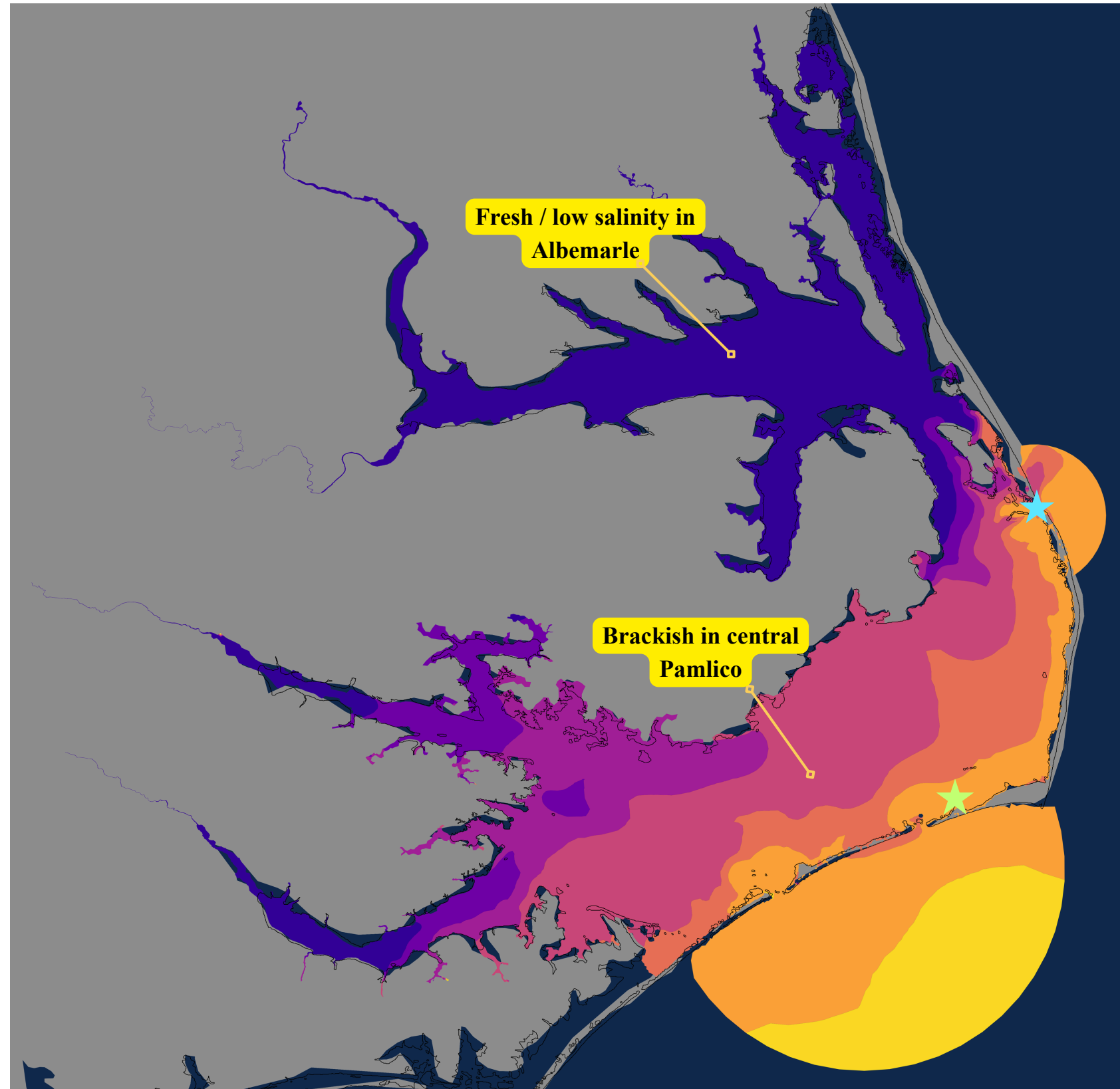
Initial surface salinity field



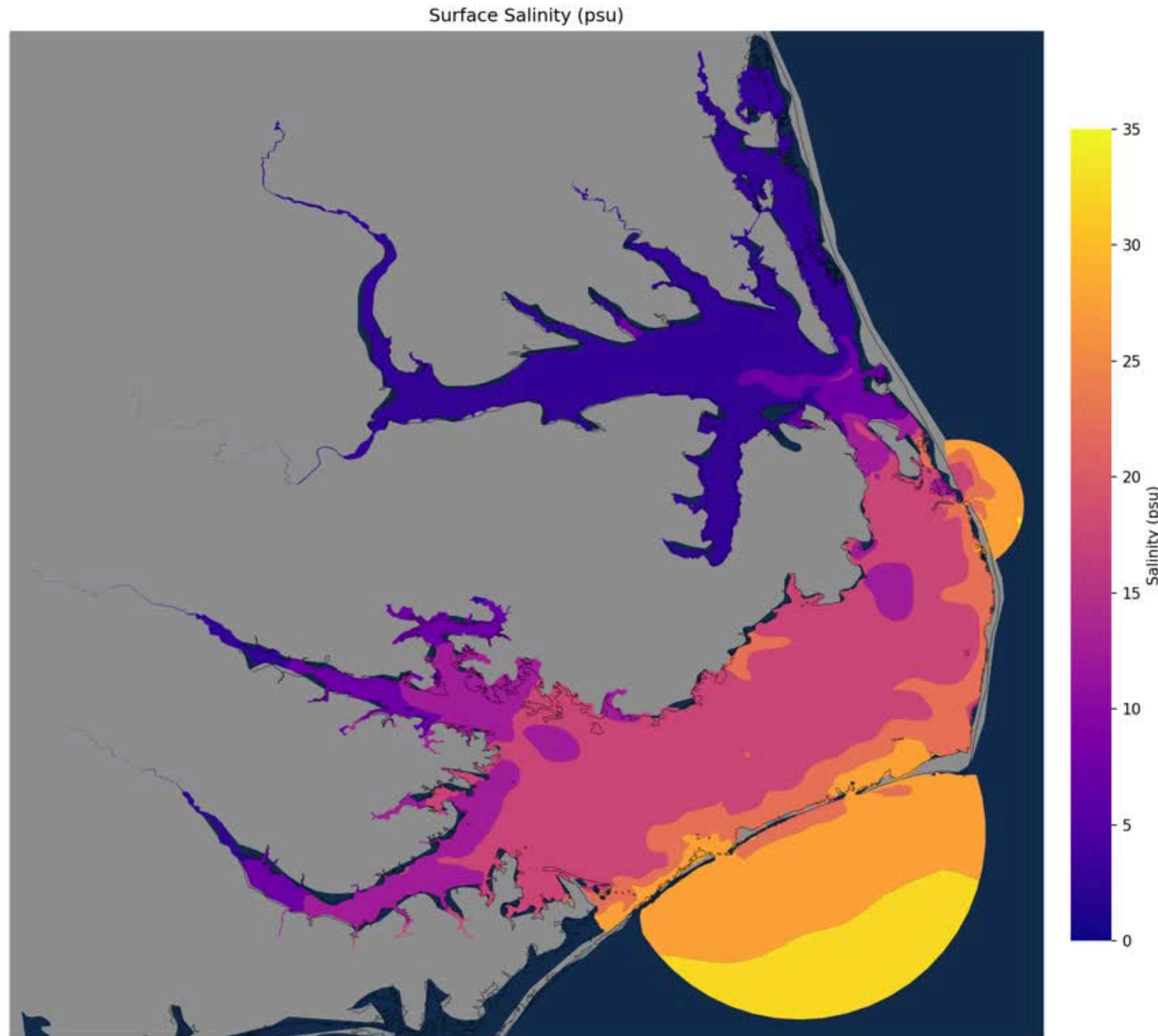
Initial surface temperature field

June climatology used to initialize summer 2024 salinity and temperature fields

# Results: Surface Salinity Structure with Tidal and Wind Validation

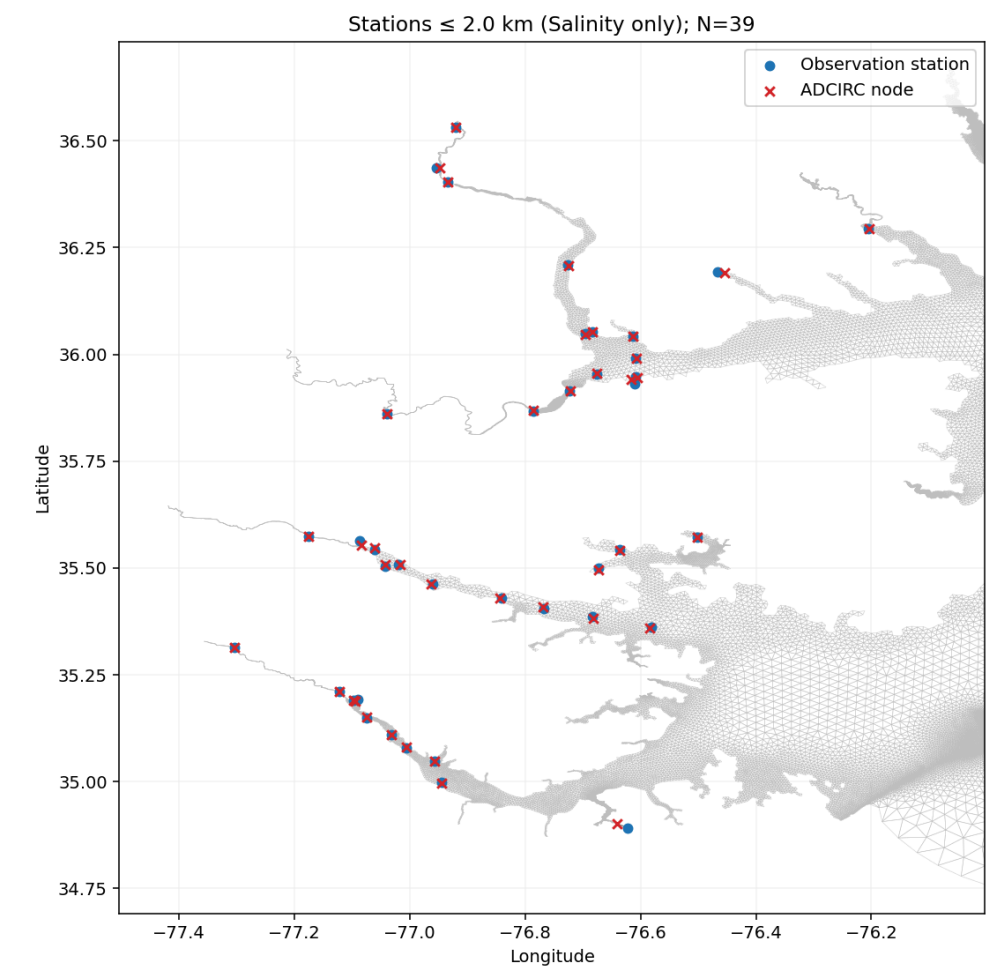


# Results: Surface Salinity Evolution and Validation

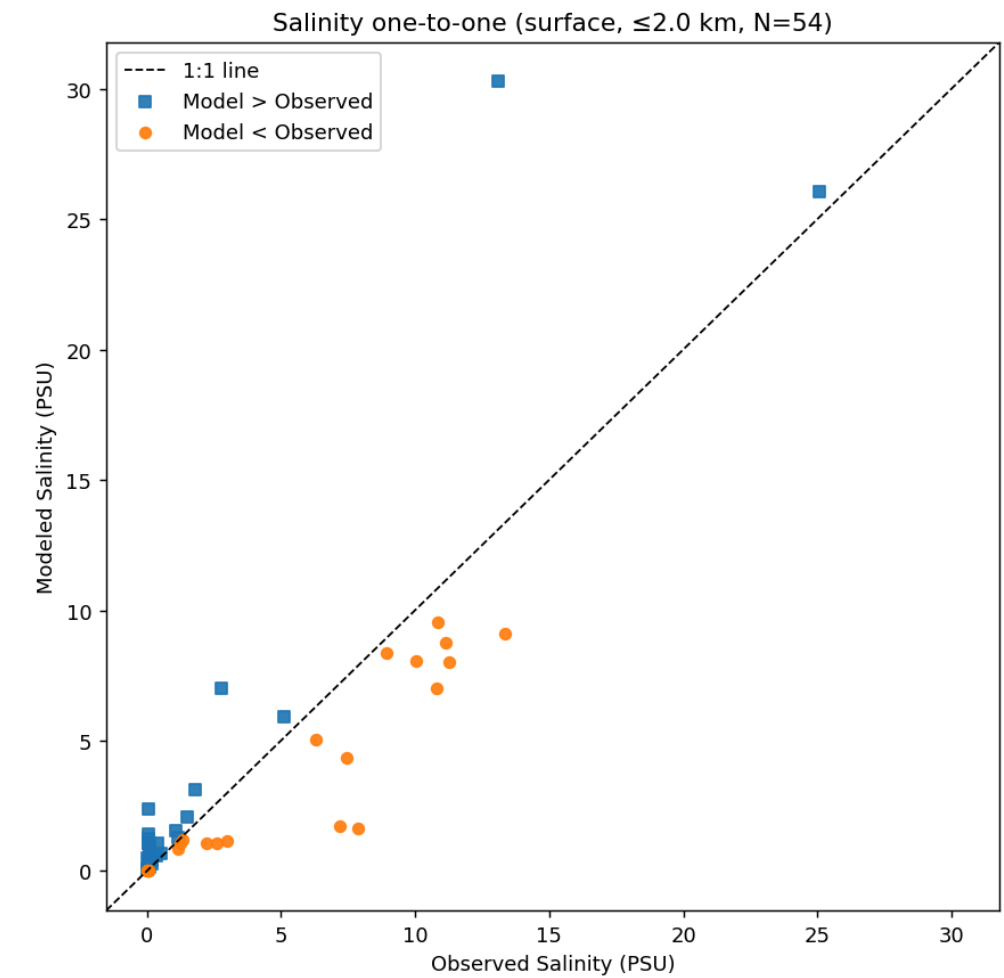


Broad salinity regimes are captured, but verification remains limited by sparse observations.

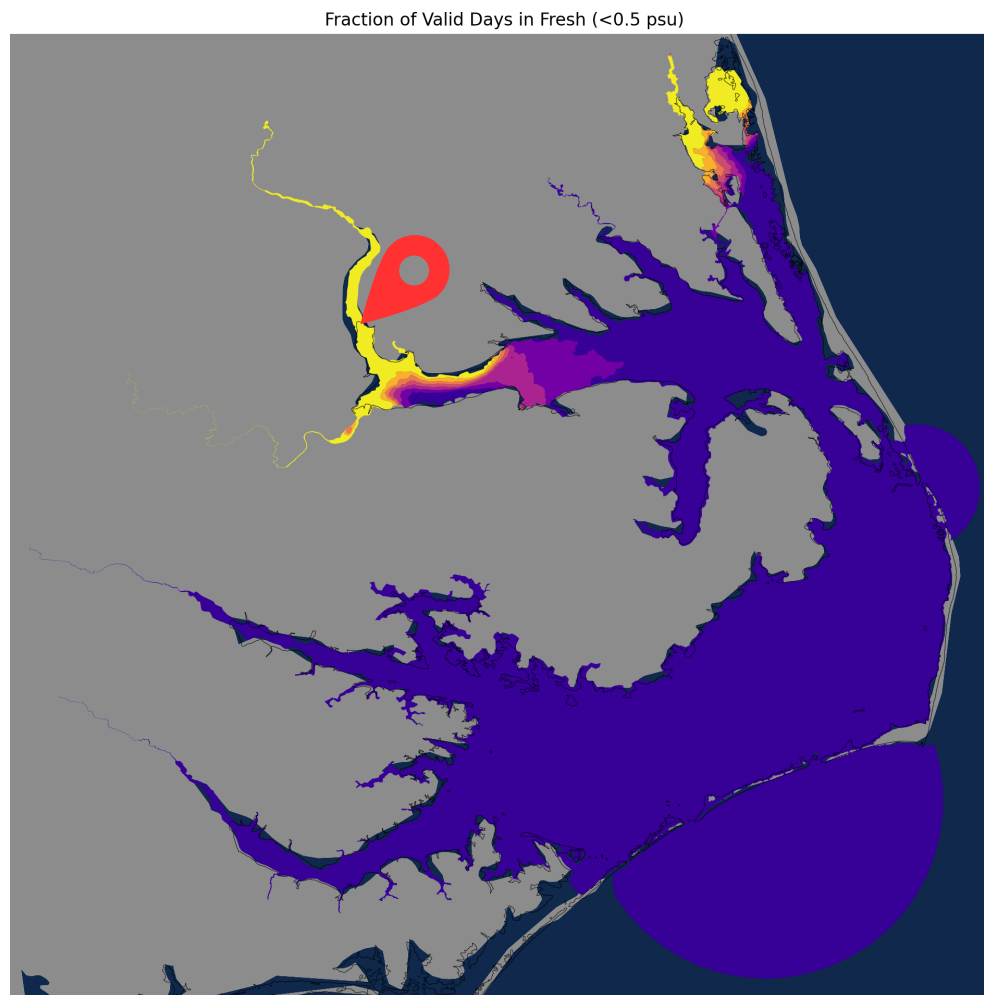
## WQP stations matched to nearby ADCIRC nodes



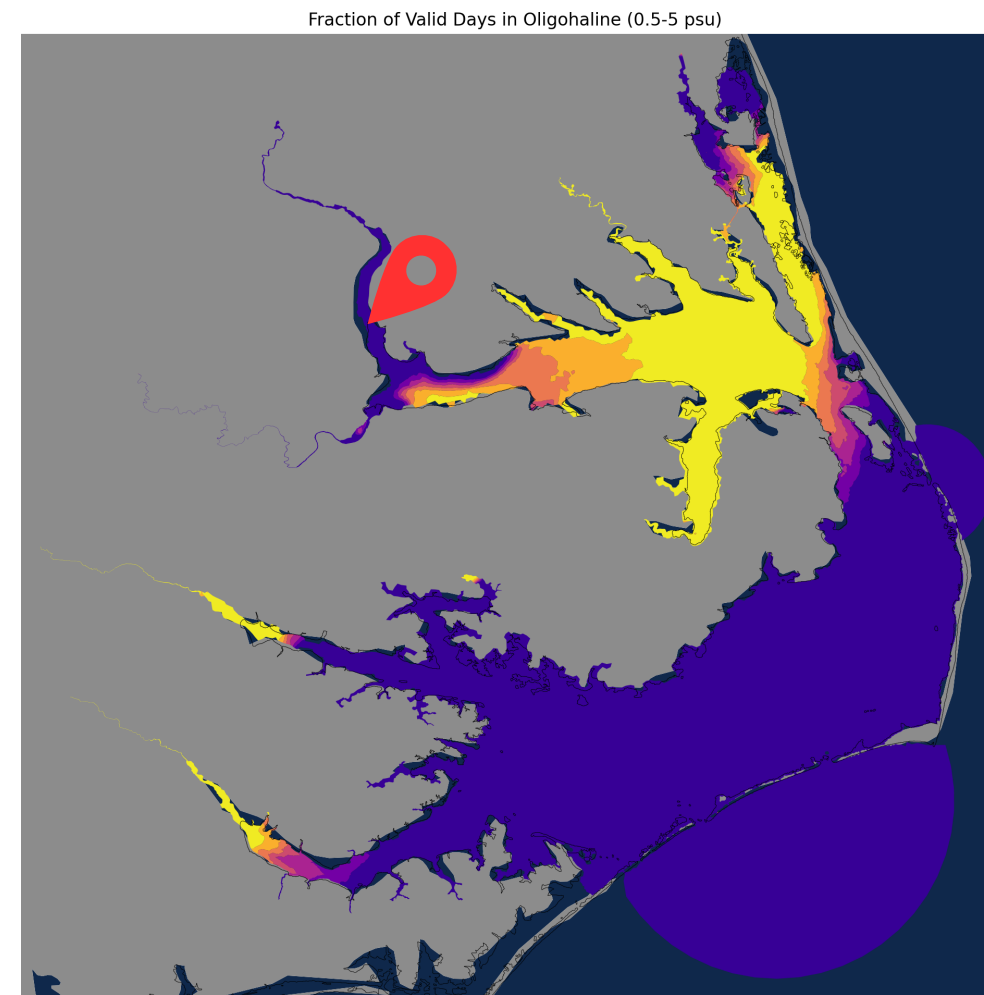
## Surface salinity: model vs observed



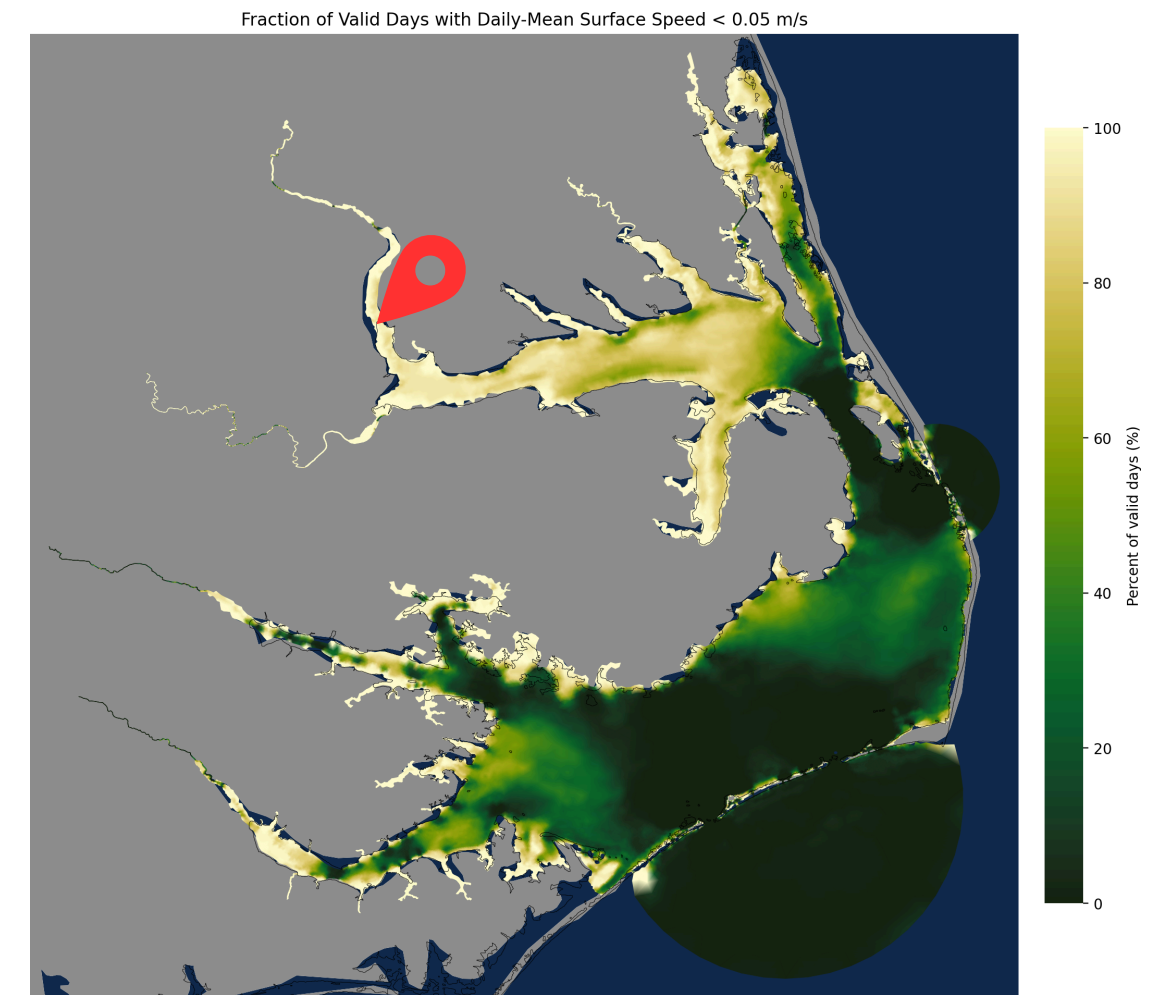
# Preliminary Analysis: Hydrodynamic Indicators of Potential HAB-Favorable Zones



Persistent river-dominated conditions



Persistent low-salinity estuarine habitat



Weak flushing / possible retention

## Interpretation

- Fresh and oligohaline persistence highlight low-salinity habitat relevant to cyanobacterial presence.
- High fraction of low daily-mean surface speed suggests weak flushing and possible retention.
- Their overlap in the Chowan/upper-estuarine region indicates hydrodynamic conditions that may favor bloom persistence or accumulation.

THURSDAY, AUGUST 22, 2024

## NCDEQ Division of Water Resources advises the public to avoid algal bloom in Chowan River

The North Carolina Department of Environmental Quality Division of Water Resources (DWR) advises the public to avoid contact with green or blue water in parts of the Chowan River in Chowan and Bertie counties due to an algal bloom that has lingered in the area since Aug. 16. The bloom has been observed from near the community of Rockyhock to below the U.S. 17 bridge over the Chowan River near Edenton.

NCDEQ advisory for a Microcystis bloom in the Chowan River, August 2024

# Conclusions and Future Work

## Key takeaways

- PASS surface salinity shows a clear fresh-to-brackish-to-marine gradient.
- The model captures the main wind variability and tidal phase behavior, but salinity validation remains preliminary because observations are sparse.
- Persistent fresh-to-oligohaline conditions together with weak flushing in the Chowan/upper-estuarine region indicate a hydrodynamically favorable setting for possible HAB persistence or accumulation.
- A reported NCDEQ Chowan River bloom event in August 2024 provides near-period real-world context that is consistent with, but does not prove, the model-based interpretation.

## Future Work

### Mesh Improvement

- Evaluate and refine mesh in channels and inlets.

### Forcing & Boundary Conditions

- Replace constant ocean T/S with time-varying NAOR boundary conditions at the open ocean boundary.

### Transport and Risk

- Add particle tracking from rivers, inlets, and interior basins to quantify residence times and transport pathways.
- Better connect modeled circulation to HAB transport and risk.