MODELING THE RESPONSE OF A TIDALLY-DRIVEN SALT MARSH WITH A COMPLEX CHANNEL NETWORK

Ryan Mieras

University of Delaware

Center for Applied Coastal Research

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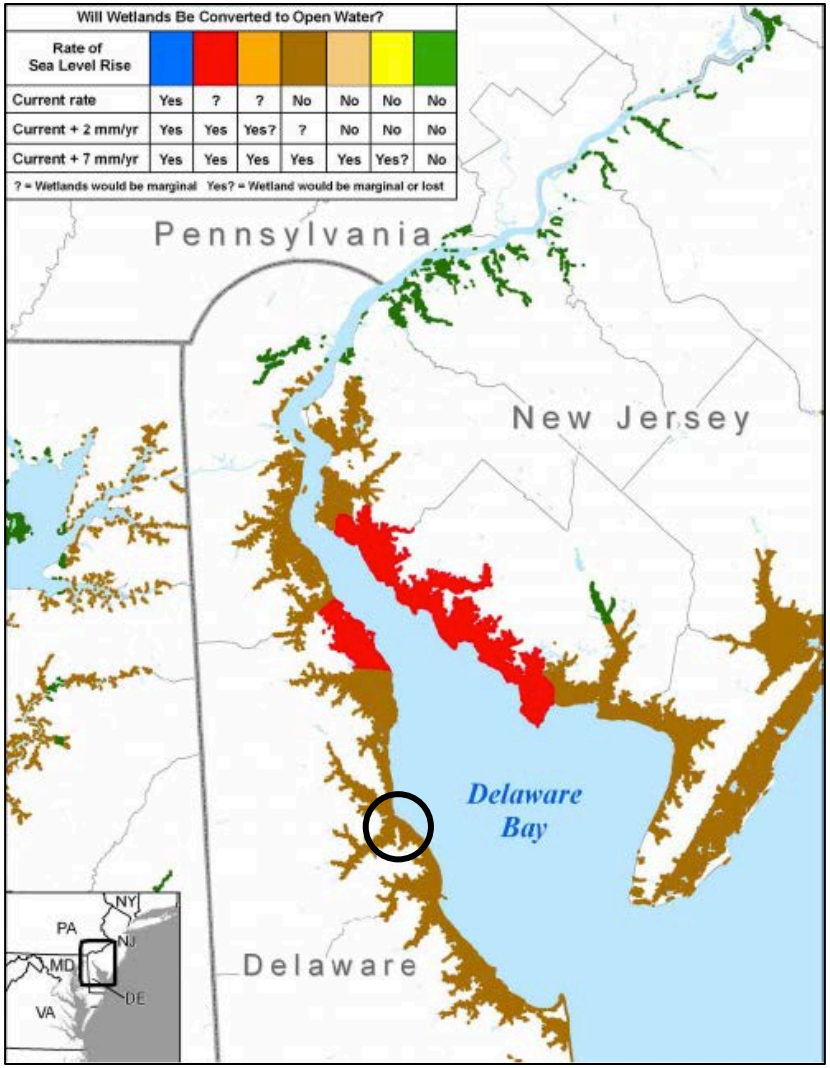
Why is it important to develop better models for marshes?

- They serve as a natural protective barrier for storm surge and Sea Level Rise (SLR). Can they keep up with SLR?
  - Places like Bombay Hook are already seeing substantial loss of wetlands
- Up to 2/3 of all Polychlorinated Biphenyls (PCBs) released in DE reside in the marshes. How does SLR affect the distribution of these contaminants?
- Marshes/wetlands make up almost 50% of the Delaware Bay coastline of Delaware, with more wetland area landward of many sandy beaches in the bay
- Delaware wetlands are home to a large variety of aquatic species and waterfowl

Implications of Sea Level Rise



Will Wetlands Be Converted to Open Water?

Rate of Sea Level Rise							
Current rate	Yes	?	?	No	No	No	No
Current + 2 mm/yr	Yes	Yes	Yes?	?	No	No	No
Current + 7 mm/yr	Yes	Yes	Yes	Yes	Yes	Yes?	No

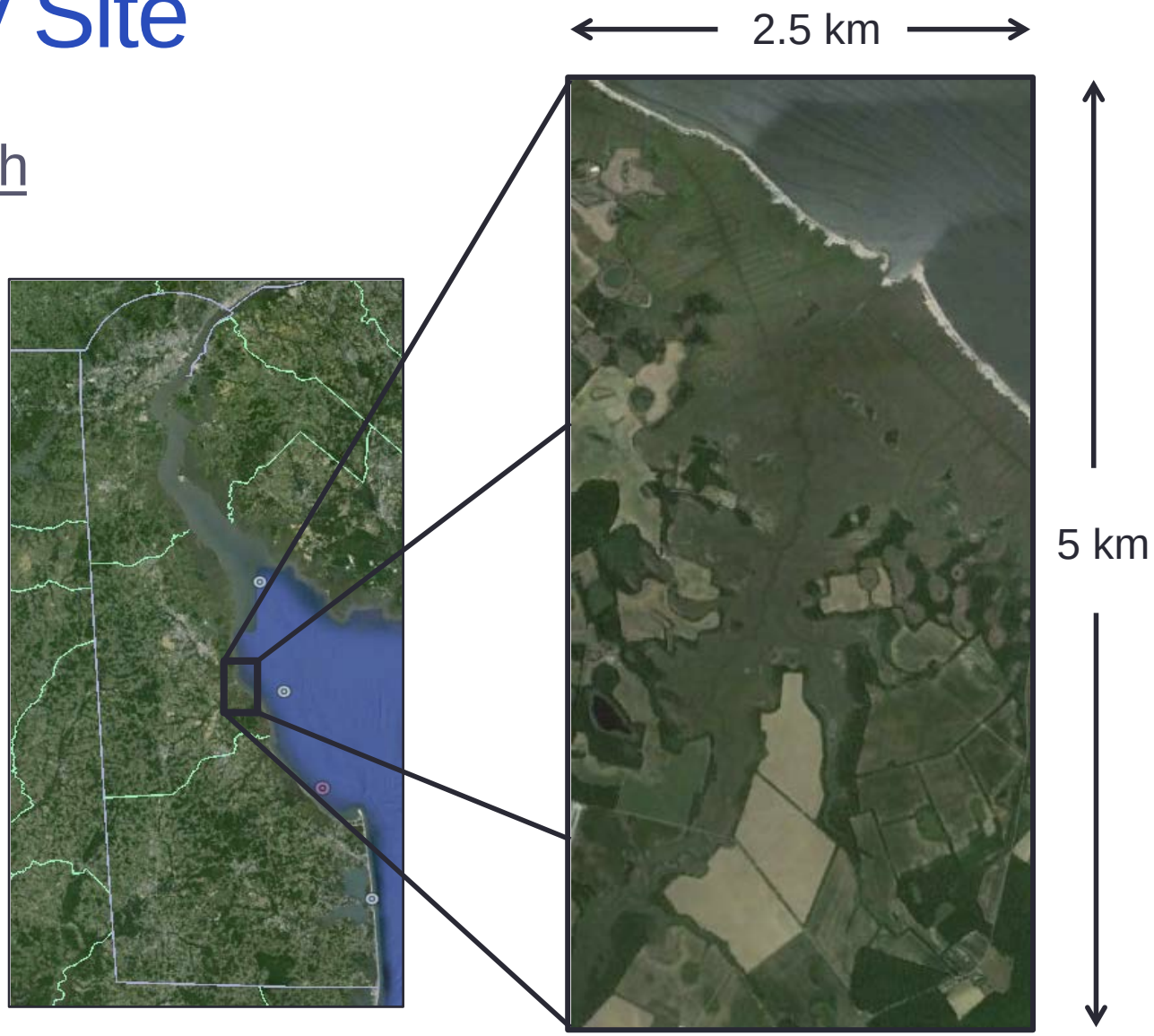
? = Wetlands would be marginal Yes? = Wetland would be marginal or lost

Adopted from an EPA study by Titus et. al., 2008

Field Study Site

Brockonbridge Marsh

- About 2 km SE of Bowers Beach, DE
- One main dead-end channel with several secondary channels branching off; empties into Delaware Bay
- Roughly 20 m wide and 2.5 m deep at mouth, narrowing further inland
- Connection to Murderkill River via small channel, only during spring tides
- Protected by higher elevation sand dunes at bay
- Site selected due to its fairly good accessibility



Brockconbridge Marsh Environment

Spartina Alterniflora

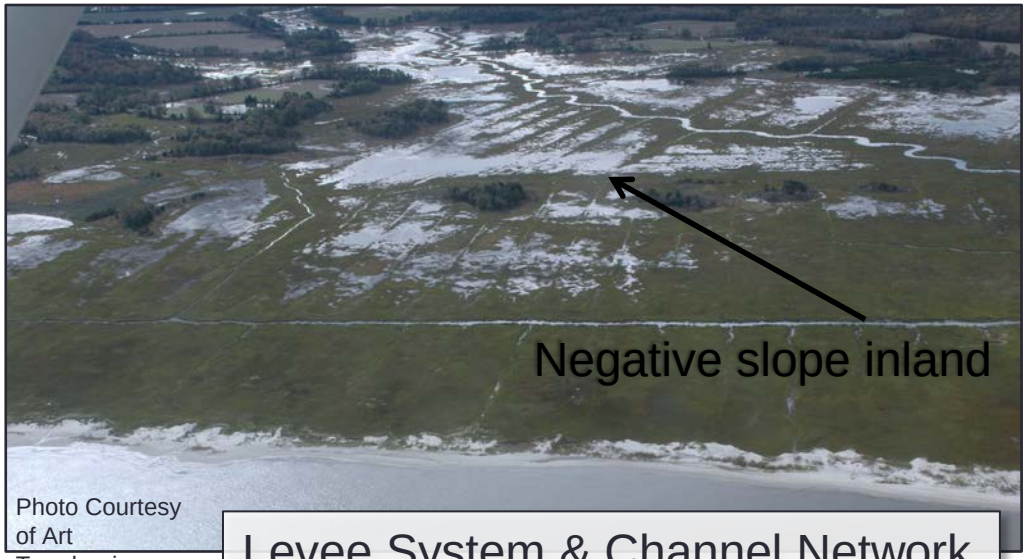


Photo Courtesy of Art Trembanis

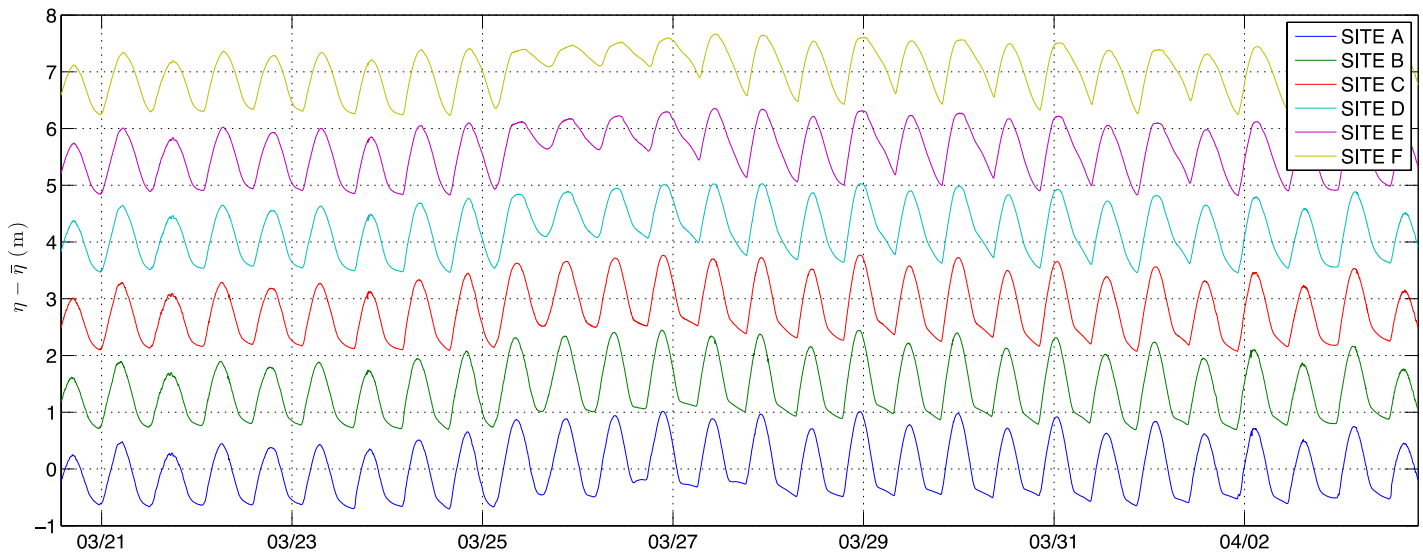
Levee System & Channel Network

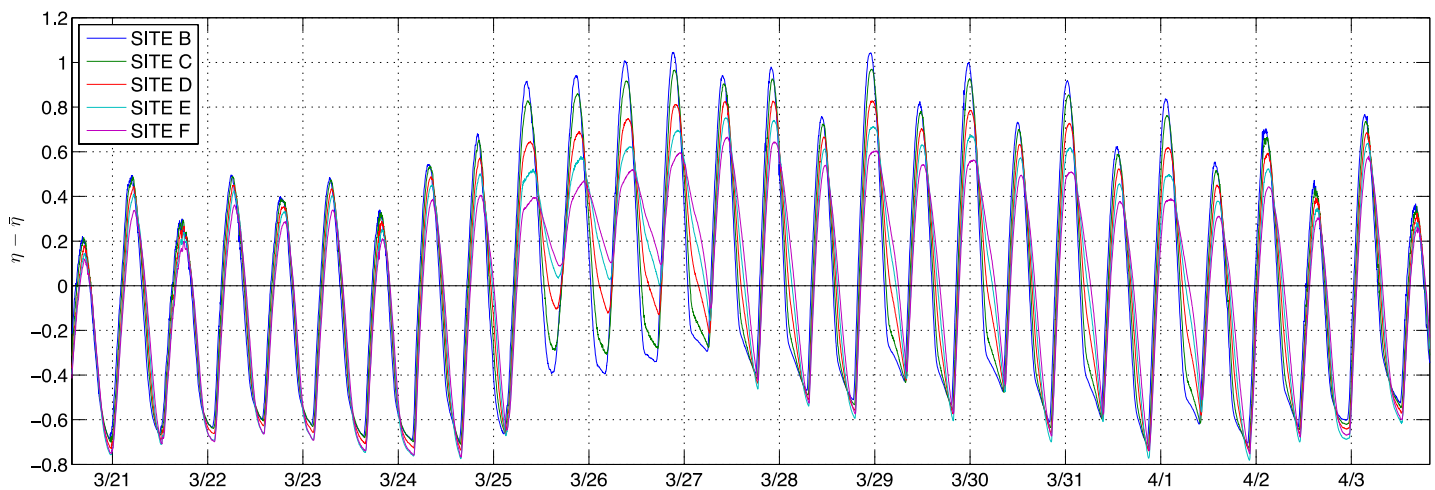
Spartina Patens

Mudflats

Deployment Configuration

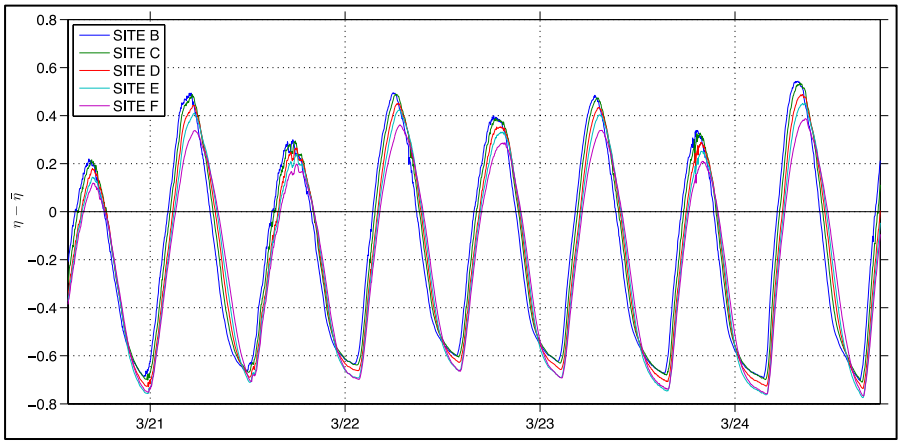
Surface Elevation Measurements



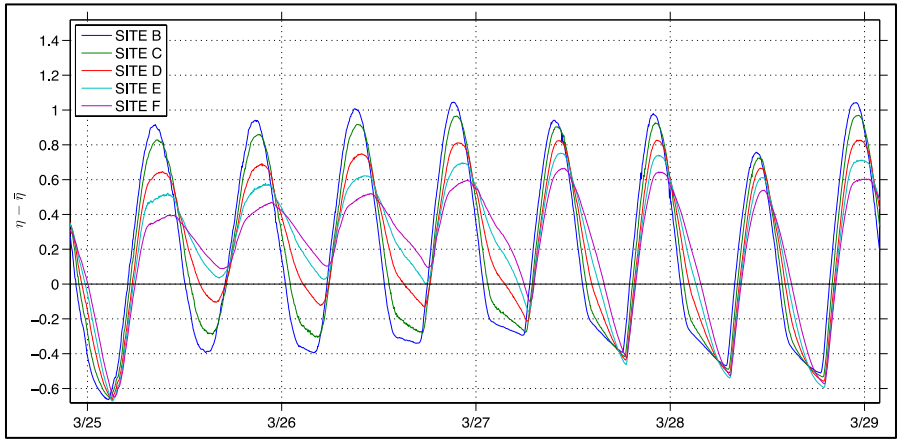


Surface Elevation Measurements

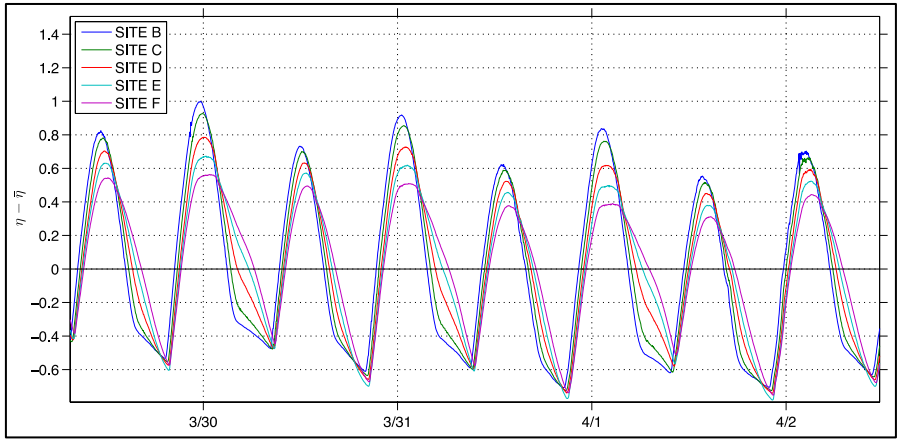
Before Storm



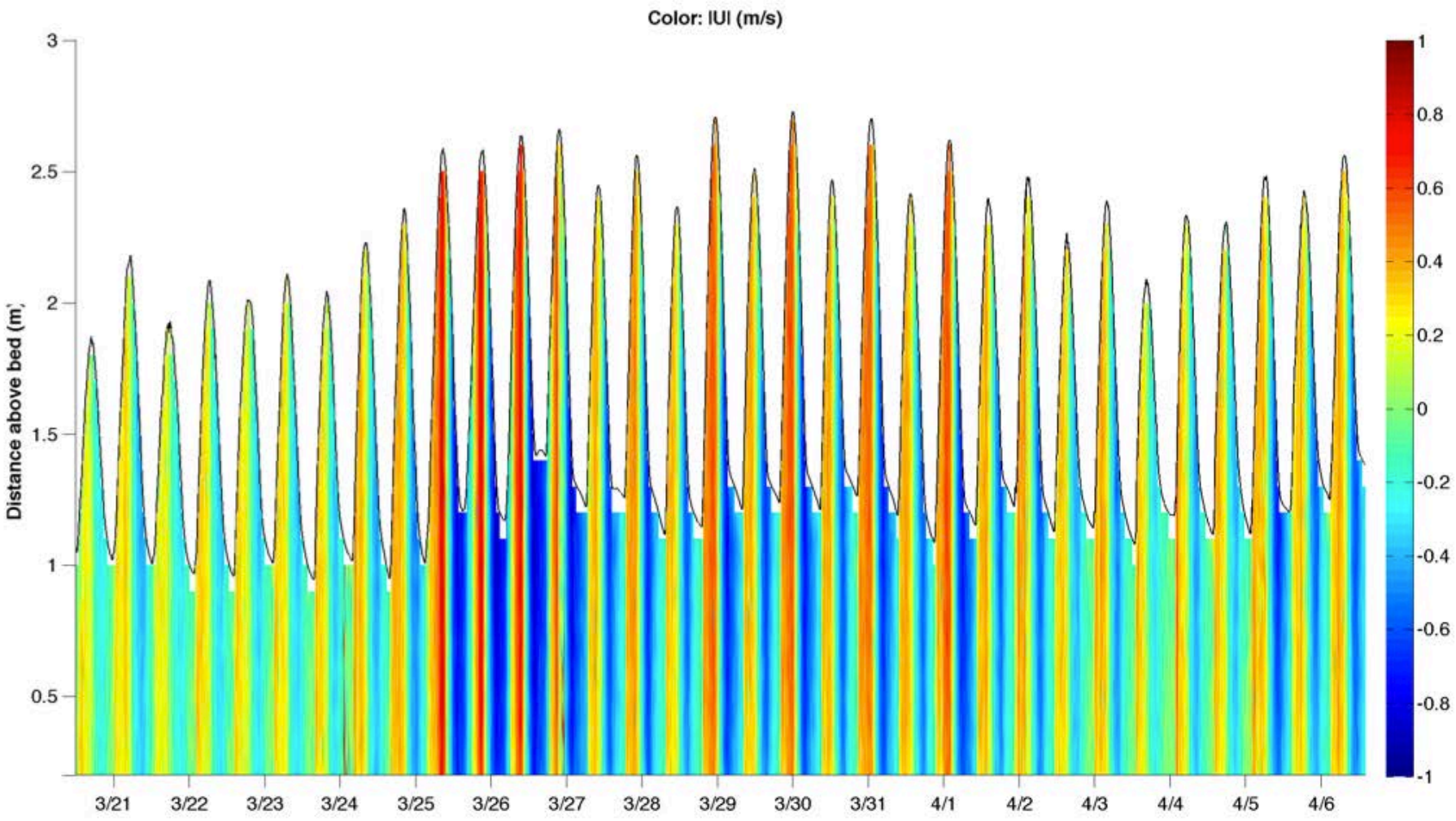
During and Shortly After Storm



After Storm

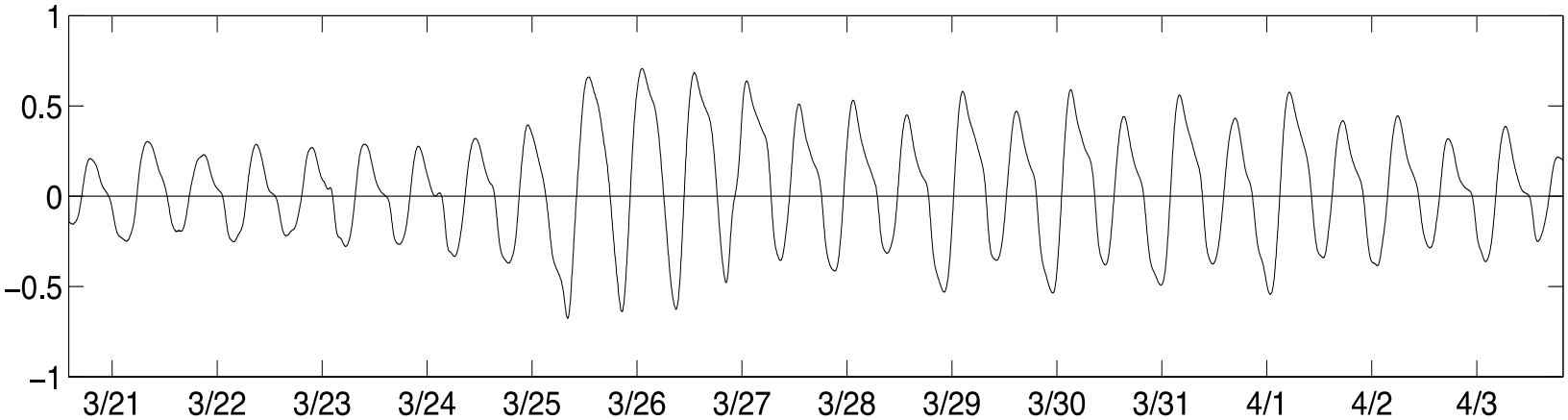


Velocity Profiles at Channel Mouth

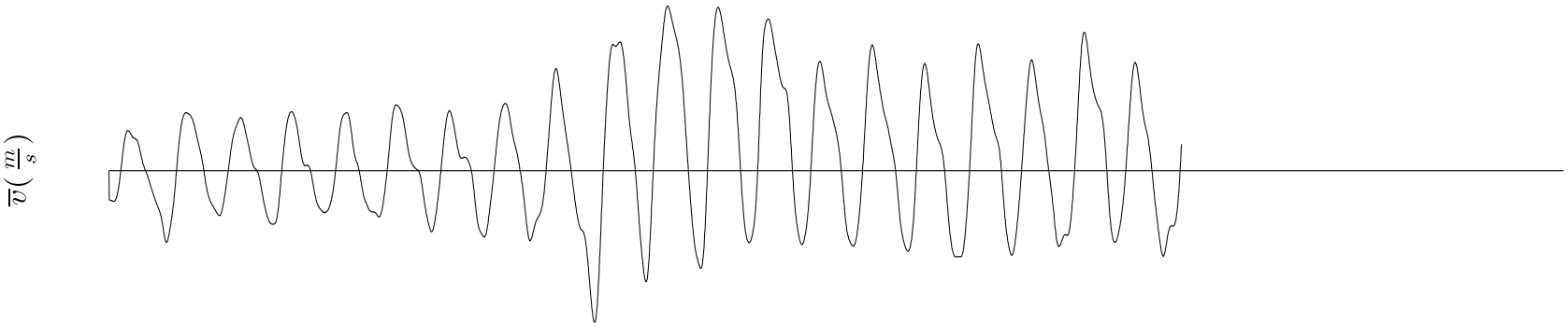


Depth Avg & Smoothed Velocity Signals

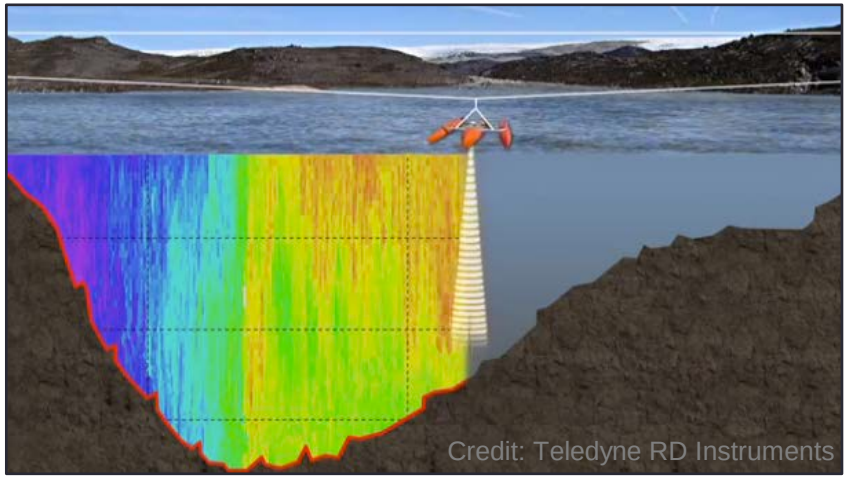
East/West



North/South

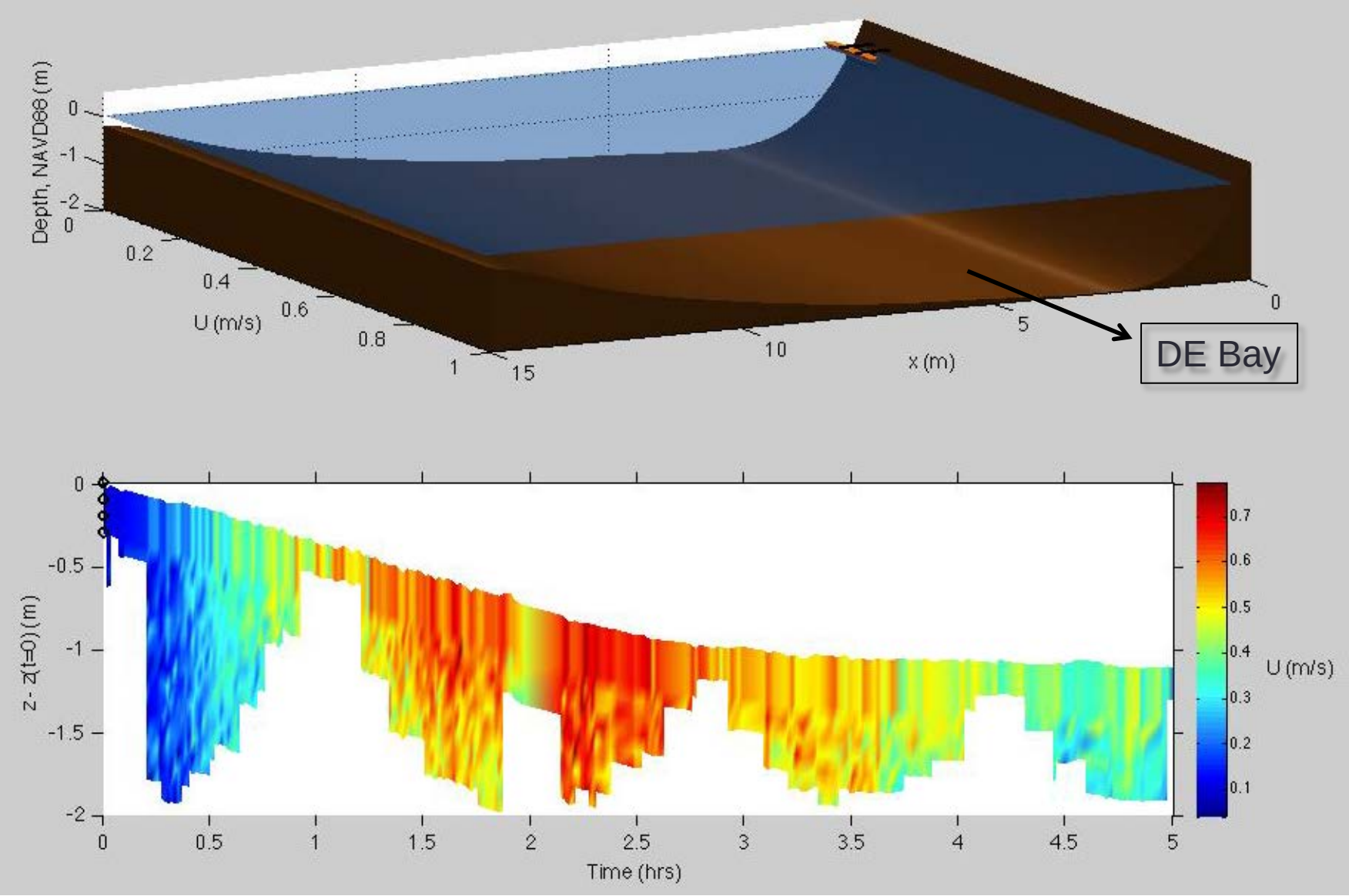


Discharge – Moving Boat Method



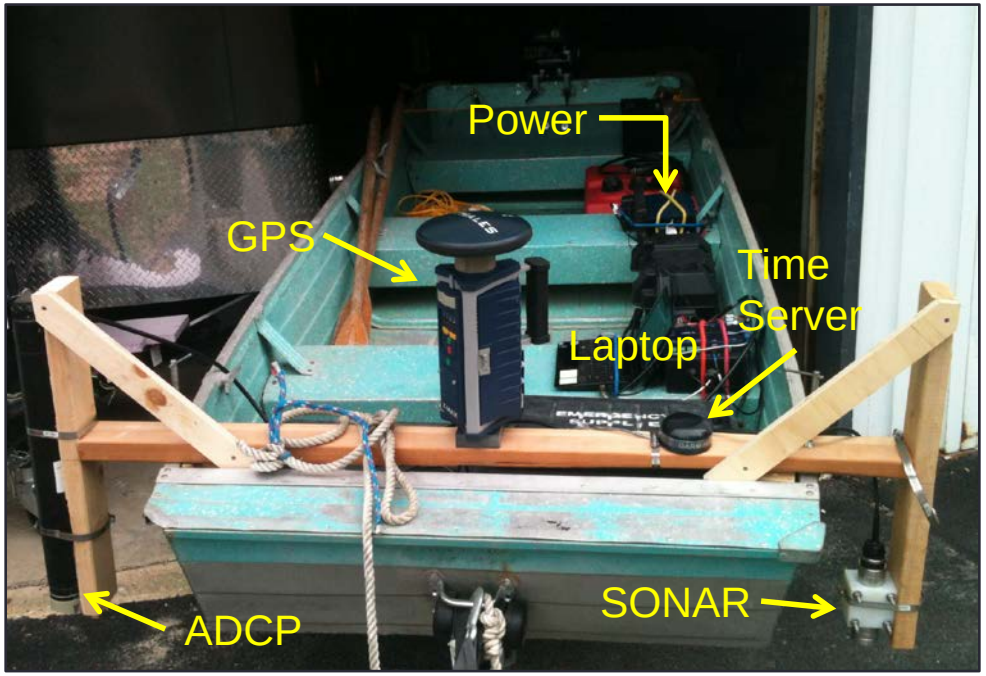
- Traversed the channel 3 times (5 hours total) essentially from high tide to low tide
- Goal was to use these data, combined with bottom-mounted ADCP data at mouth, to get a better picture of the cross-channel variation to compute discharge
- Limited by the nature of marshes and the difficulty of site access; public use of the inlet; and the fact that the mouth is only crossable by foot during low tide

Discharge – Moving Boat Method

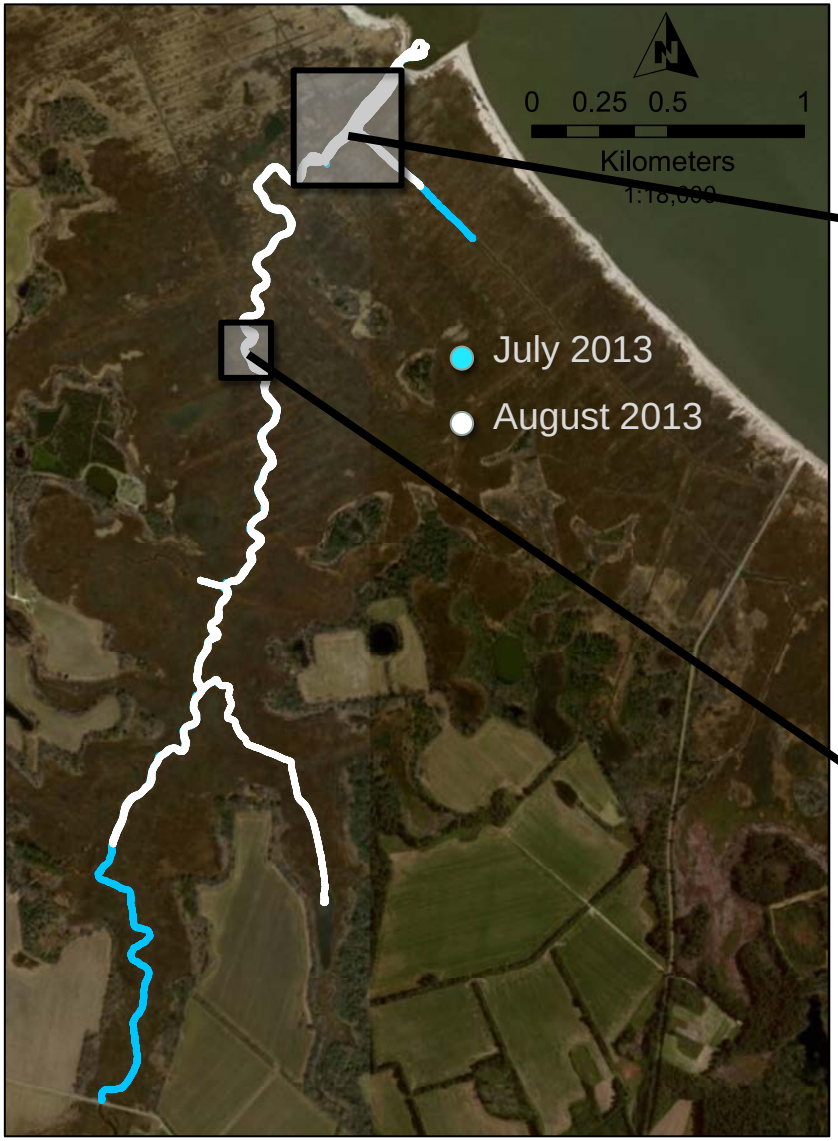


Surveying Brockonbridge Gut Bathymetry

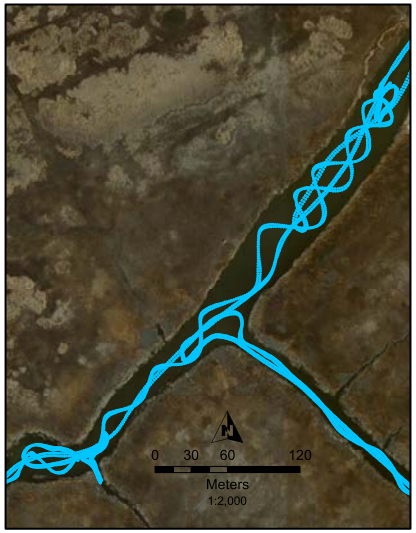
- 2 surveys, July and August 2013
- Aquadopp (10 cm blanking)
- Sonar (30 cm blanking)



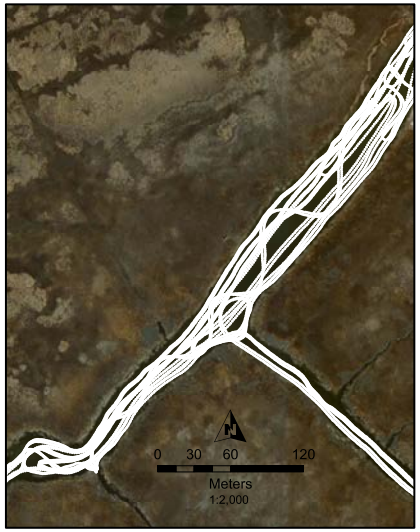
Survey Tracks

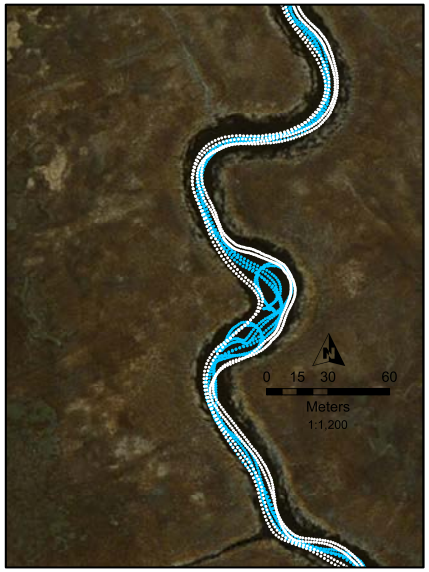


July



August

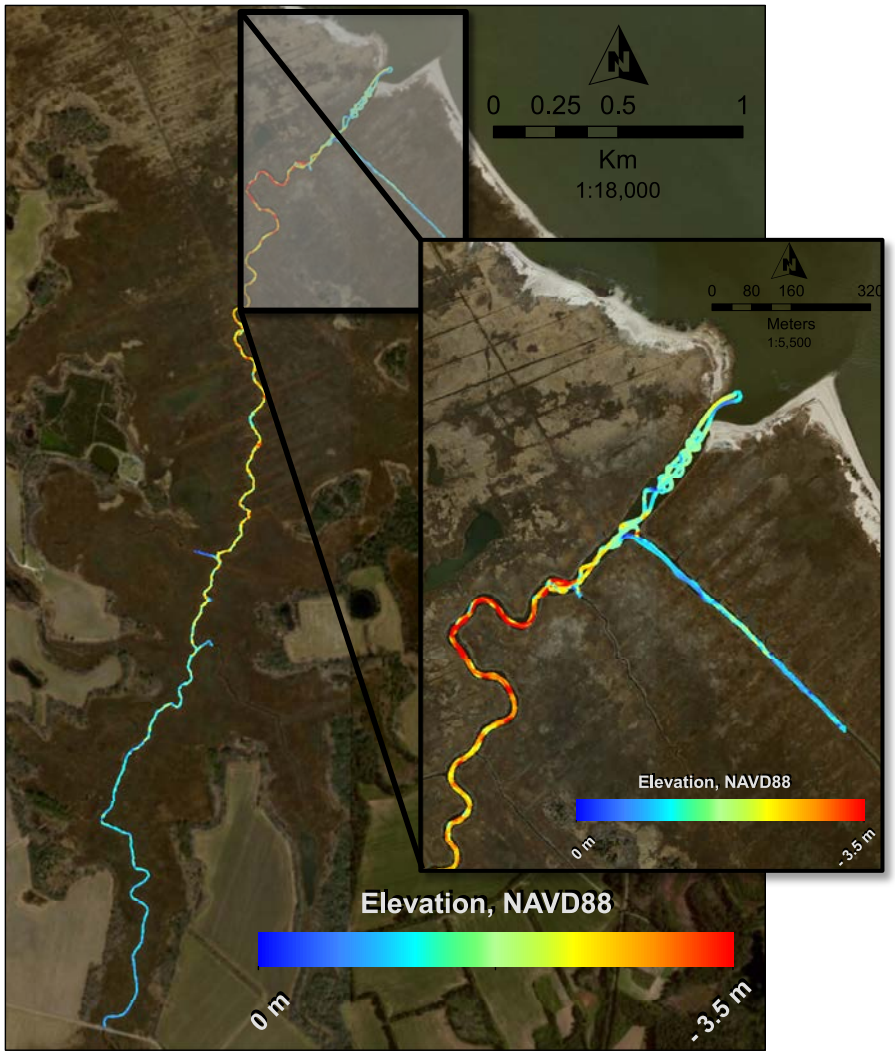




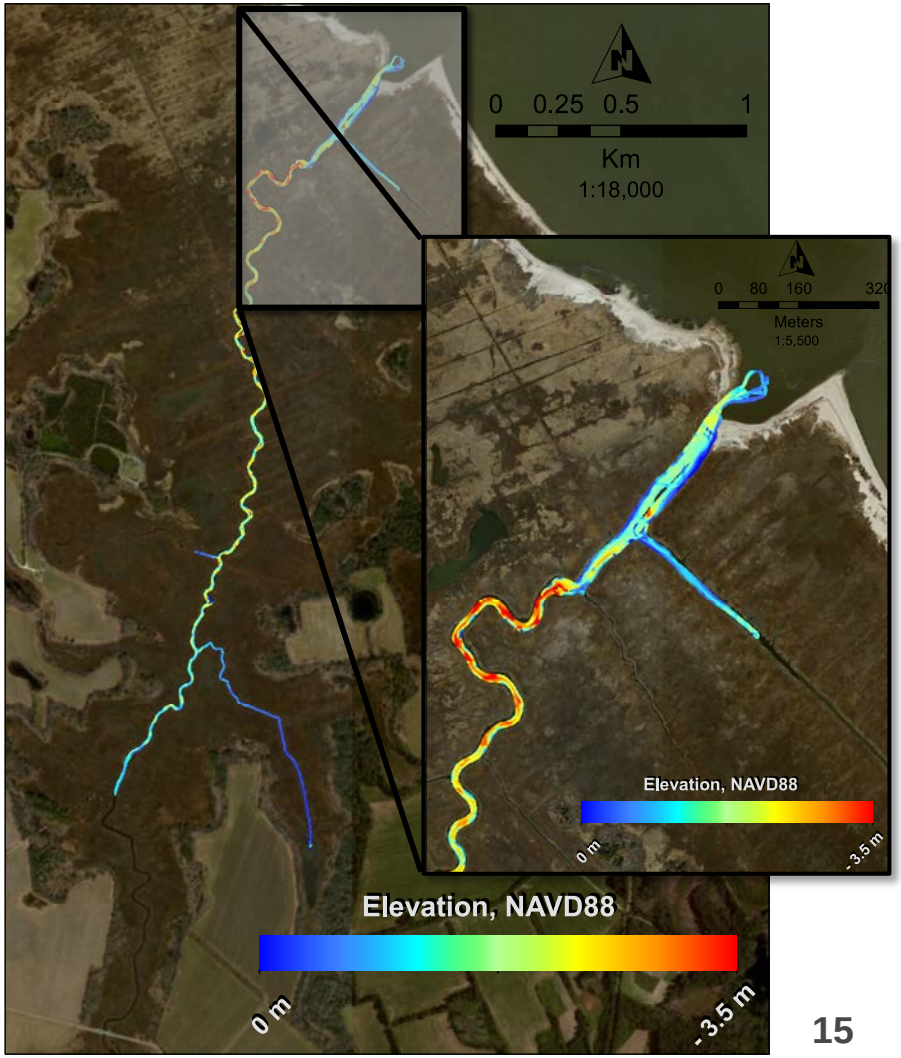
Left: example of July vs August tracks

Channel Bathymetry

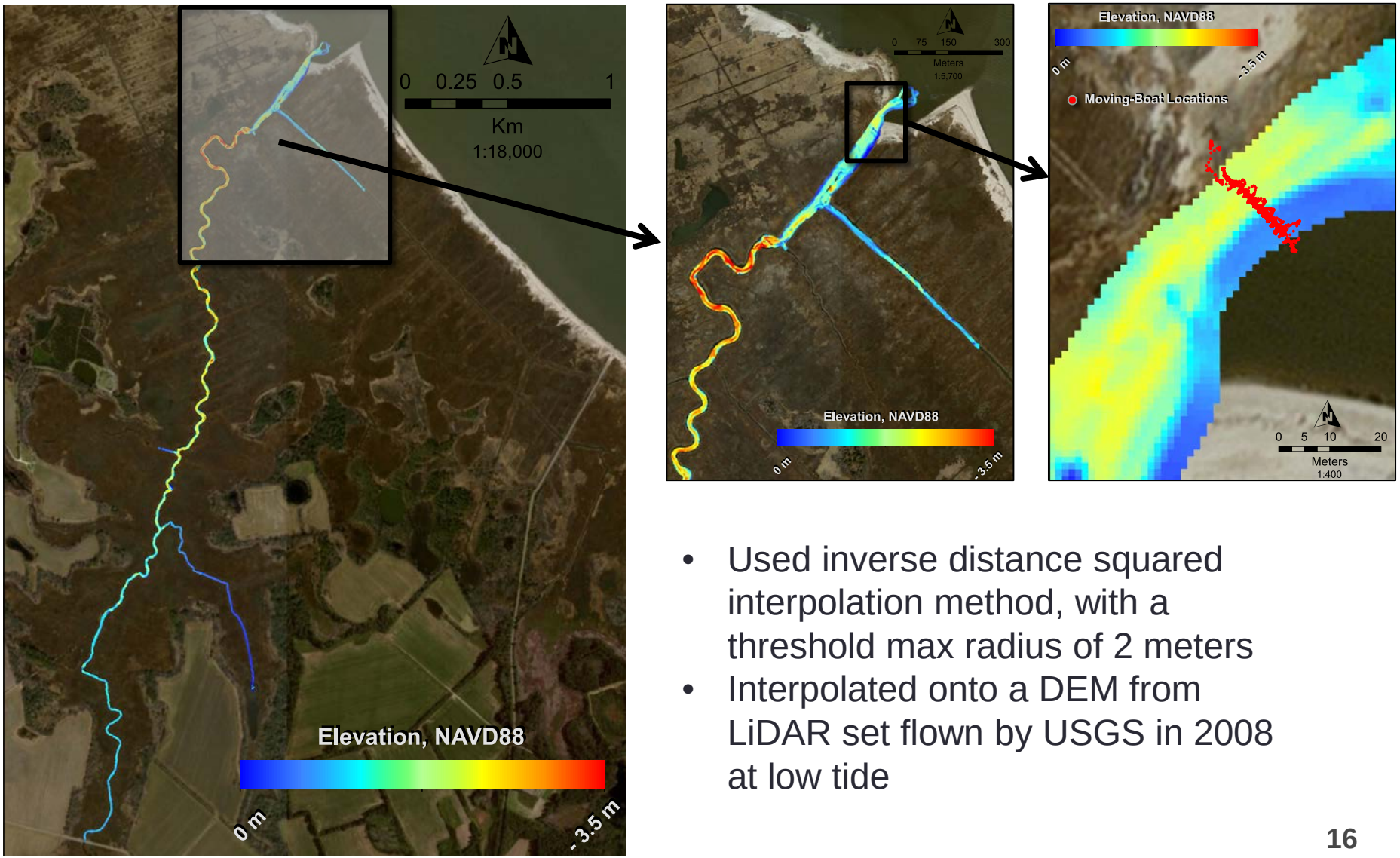
July Survey



August Survey



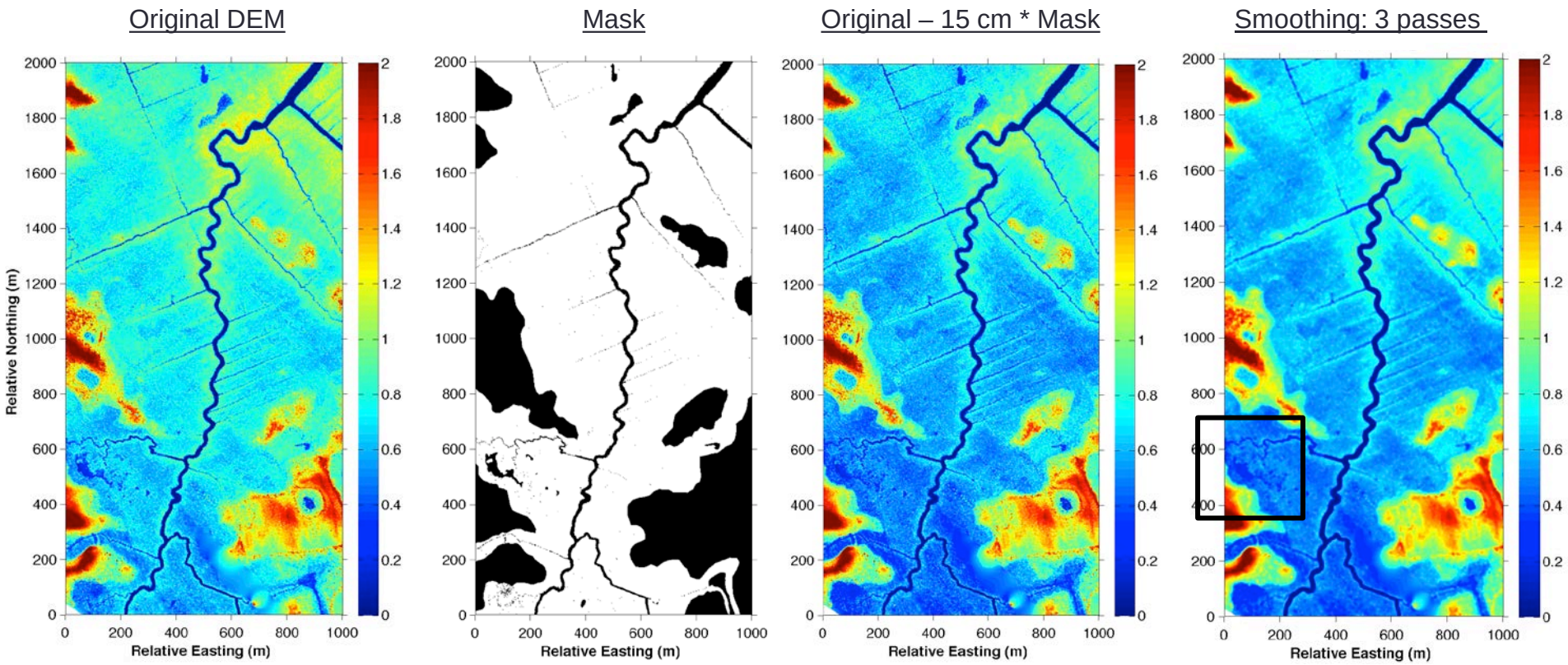
Interpolating Survey Points onto a DEM



- Used inverse distance squared interpolation method, with a threshold max radius of 2 meters
- Interpolated onto a DEM from LiDAR set flown by USGS in 2008 at low tide

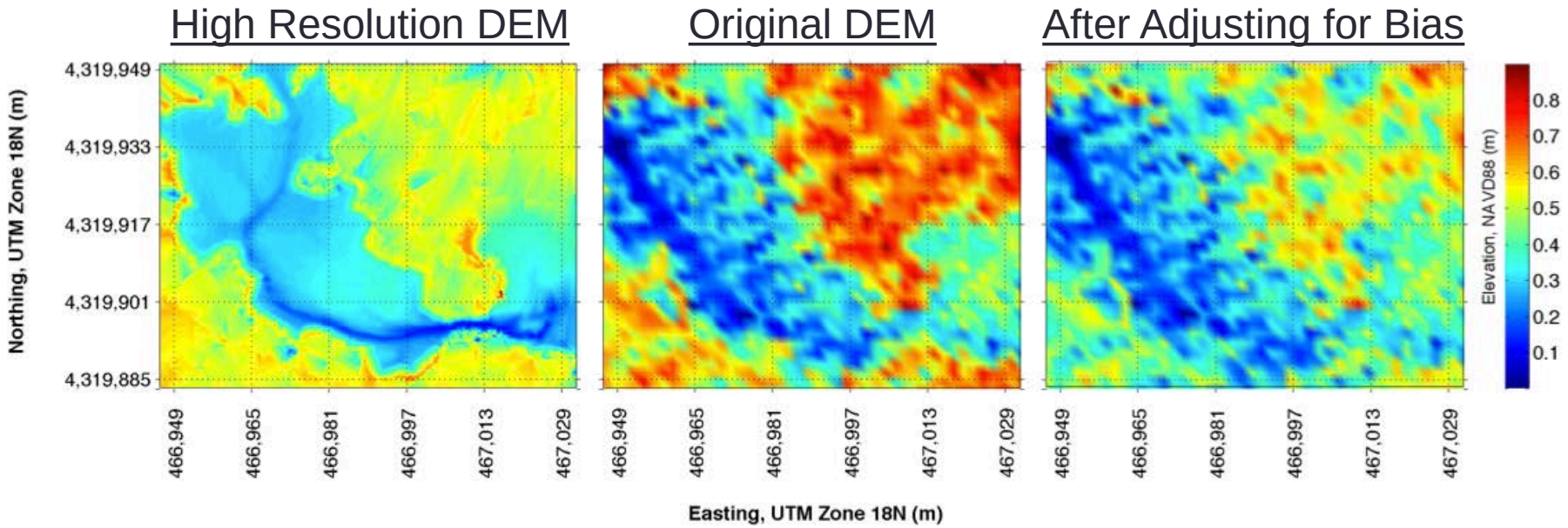
Adjusting Grid for Bias and Noise

- Vegetation inhibits LiDAR's ability to ping off the marsh surface, introduces local biases
- High-resolution DEM necessary for resolving as many secondary & tertiary channels as possible, important for flow routing
- Moving window averaging technique creates smoother surface, while maintaining resolution of smaller channels; increases model computation speed



Verifying Adjustment for Bias

- Bias determined by comparing LiDAR points to known control survey points around the marsh. Global bias of -0.05 m and vegetation bias of 0.15 m was determined (T. McKenna, DGS)
- We can also compare results to a high resolution DEM constructed from > 26,700 data points (Pieterse, Puleo and McKenna)



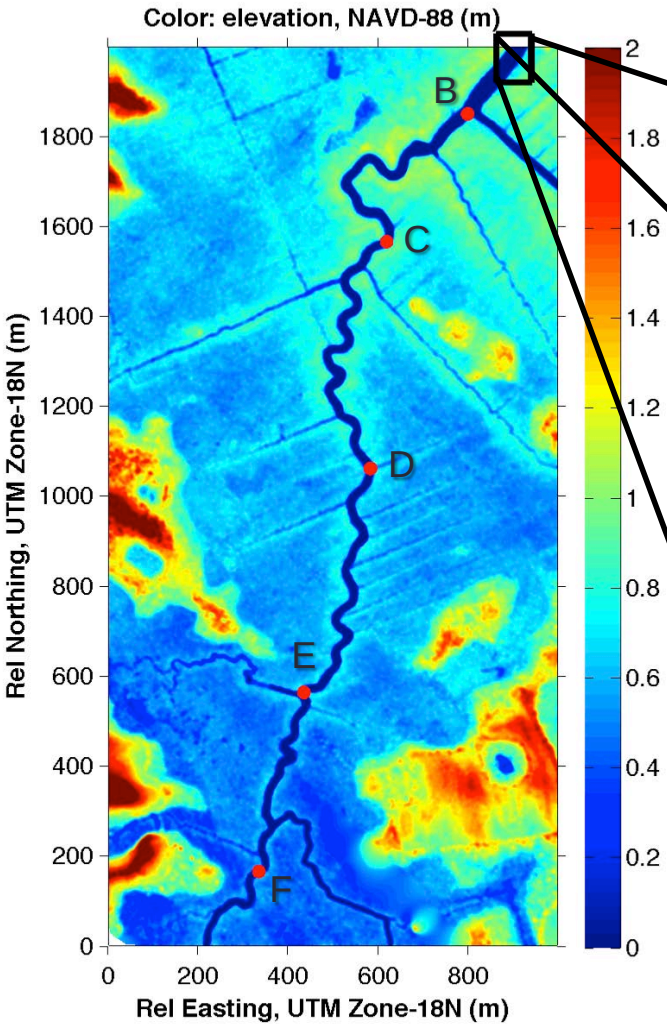
NearCoM – Nearshore Community Model

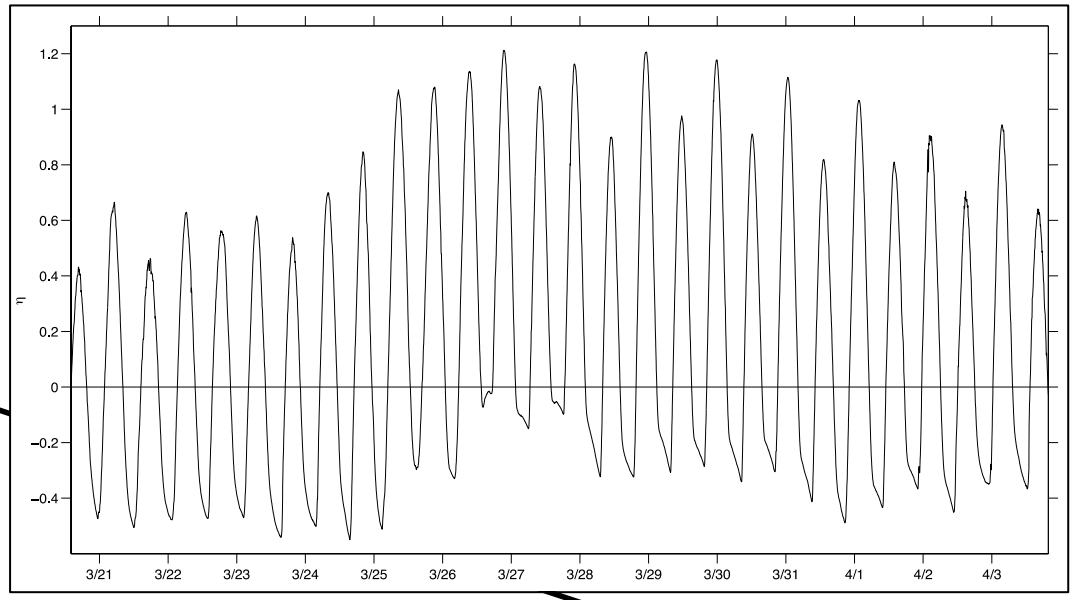
- SWAN (wave model)
- SHORECIRC (nearshore circulation model)
  - Quasi 3-D (2D horizontal w/ effect of vertical structure of horizontal flows)
  - Hybrid TVD finite-volume and finite-difference scheme
  - Solves conservative forms of the fully Nonlinear Shallow Water Equations
- Sediment Model

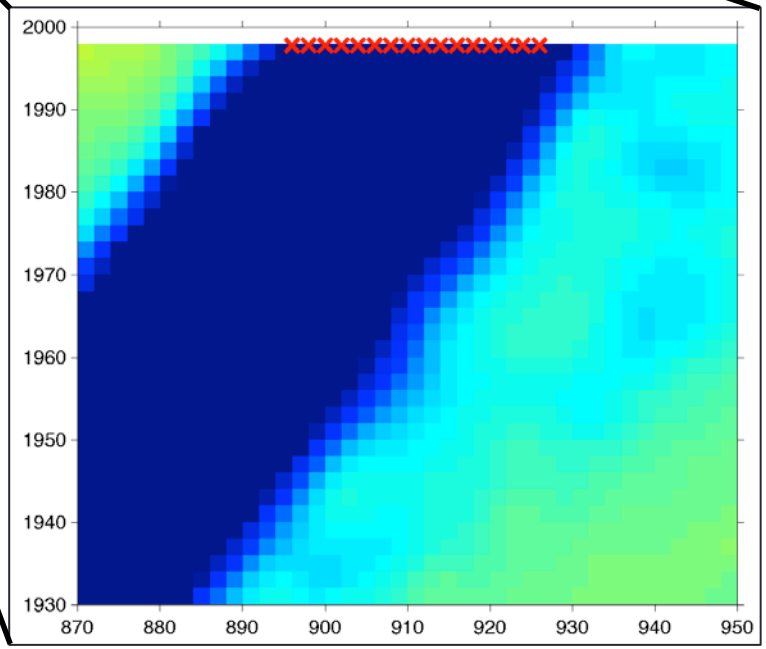
→ Fully parallelized with MPI

→ 14 day simulations can be completed in ~1.5 - 2 days w/ 800 processors

Boundary Condition







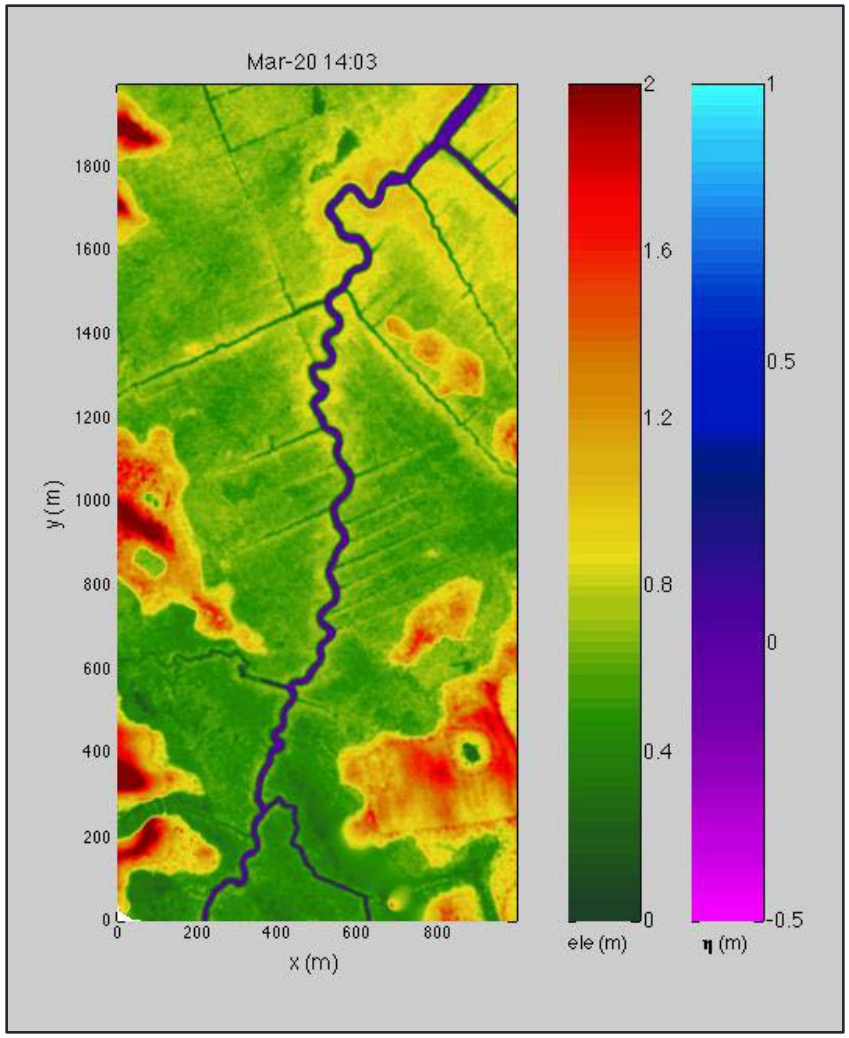
Physics & Wetting/Drying

- Currently, all model runs have been conducted with constant friction (Manning number) across the entire domain, and no wind stress applied
- A minimum depth value is supplied for wetting/drying, which treats all cells with water depth below this value as dry
  - Typically, min depth should be O(1) smaller than the average wave height

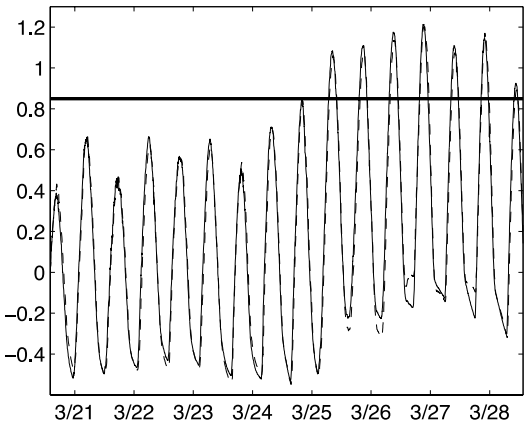
Parameter values used for results that follow:

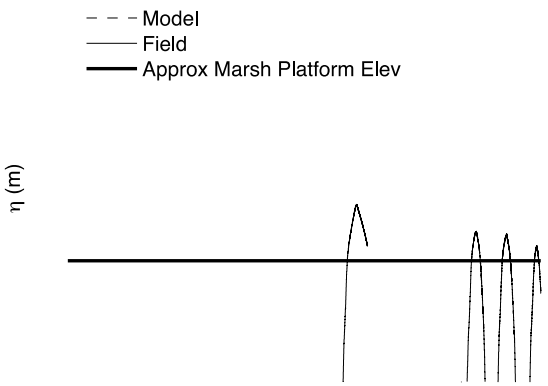
- Manning = 0.02
- Min Depth = 0.01 m

Marsh Flooding

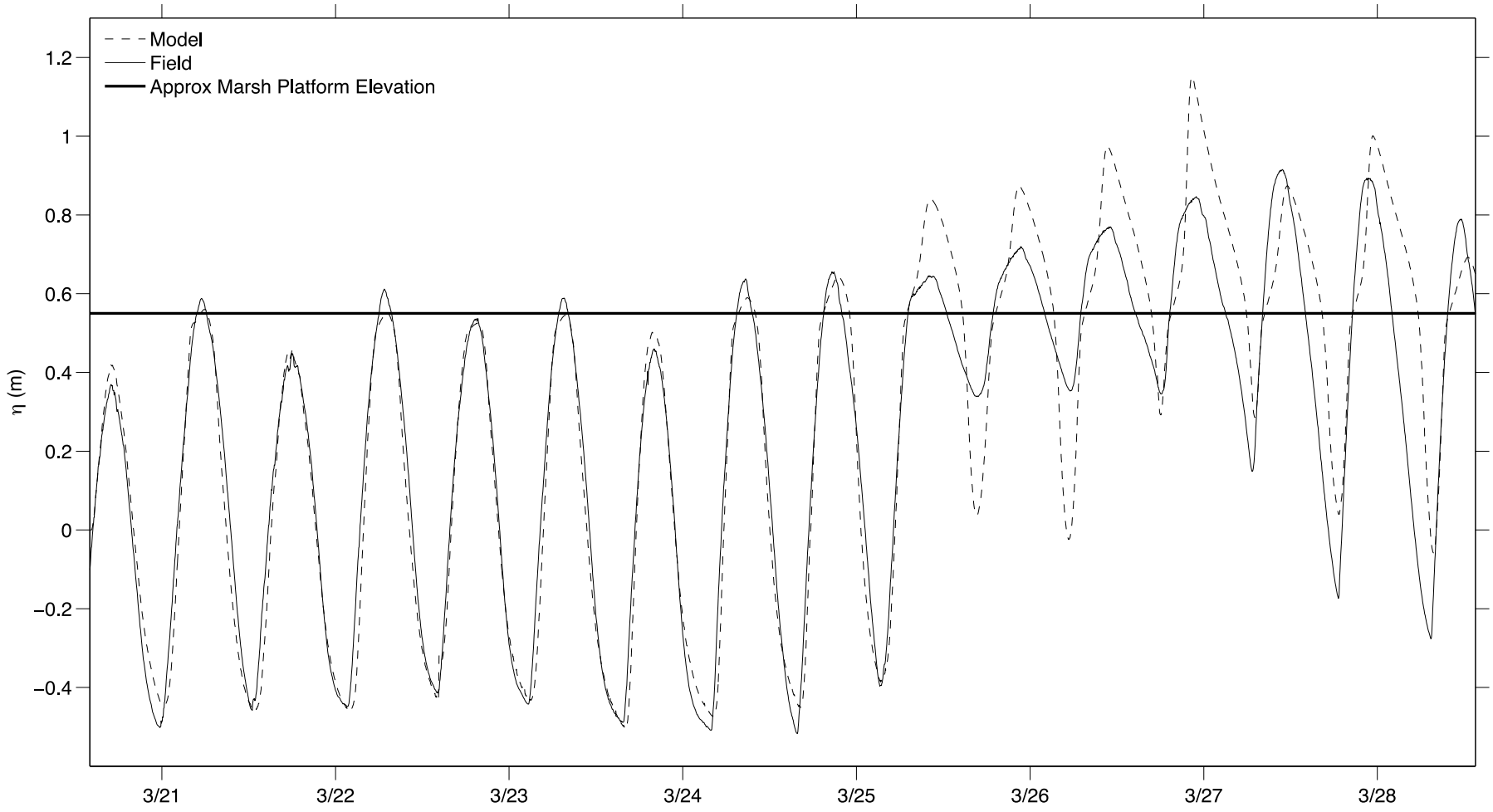


Model vs Field – η(t)



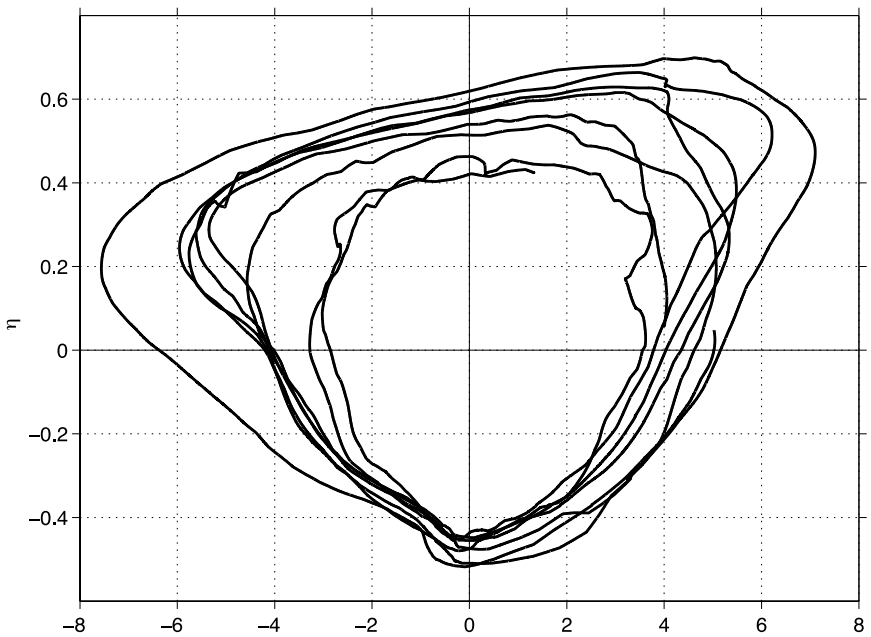


Closer look at Site F

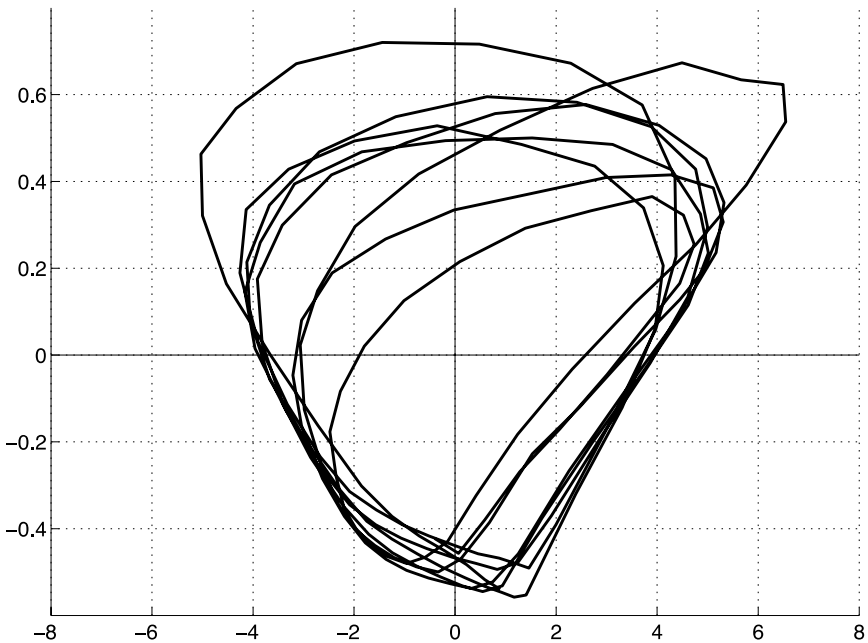


Discharge vs Eta – Model vs Field

Model



Field



*Only for first 4 days of data, before the storm

Conclusions

- The combination of large spatial and temporal scales, coupled with the necessity but limited availability of high resolution grids, makes modeling these systems very challenging
- These large scales play important roles in marshes, which raises questions about model efficiency and stability in long time simulations
- Processes at sub-grid scales are likely very important for routing the flow in marsh environments like Brockonbridge Marsh
- Additionally, the data during the storm, as well as the post-Sandy aerial photo, showed it can take the marsh several days to recover from high wind surge events
- Inclusion of variable friction, as well as wind forcing, will hopefully provide more insight into how much of a role these factors play in marshes, especially during wind-driven surge events

Questions?