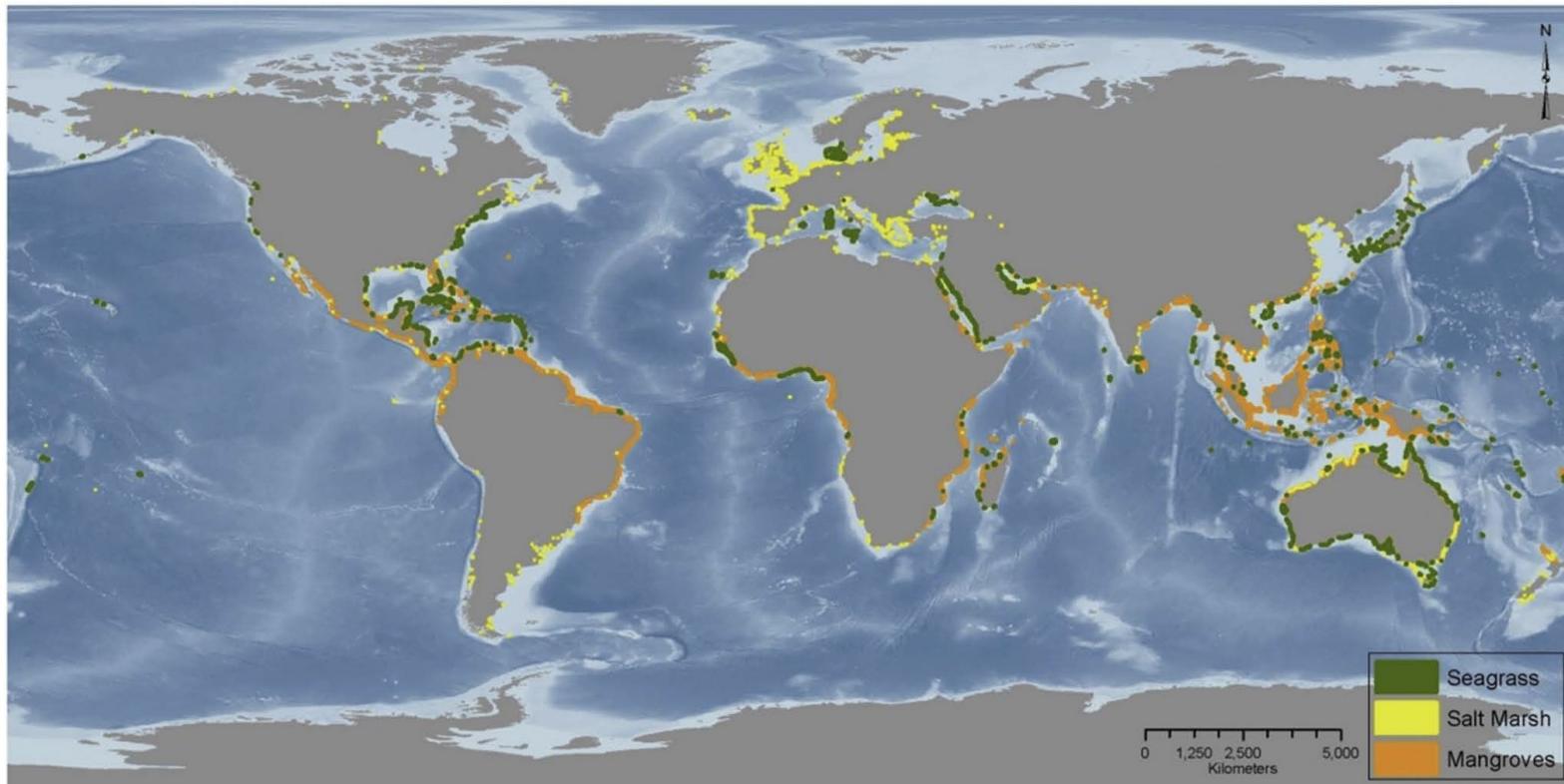


Quantifying the physical connection between wetlands and coastal waters

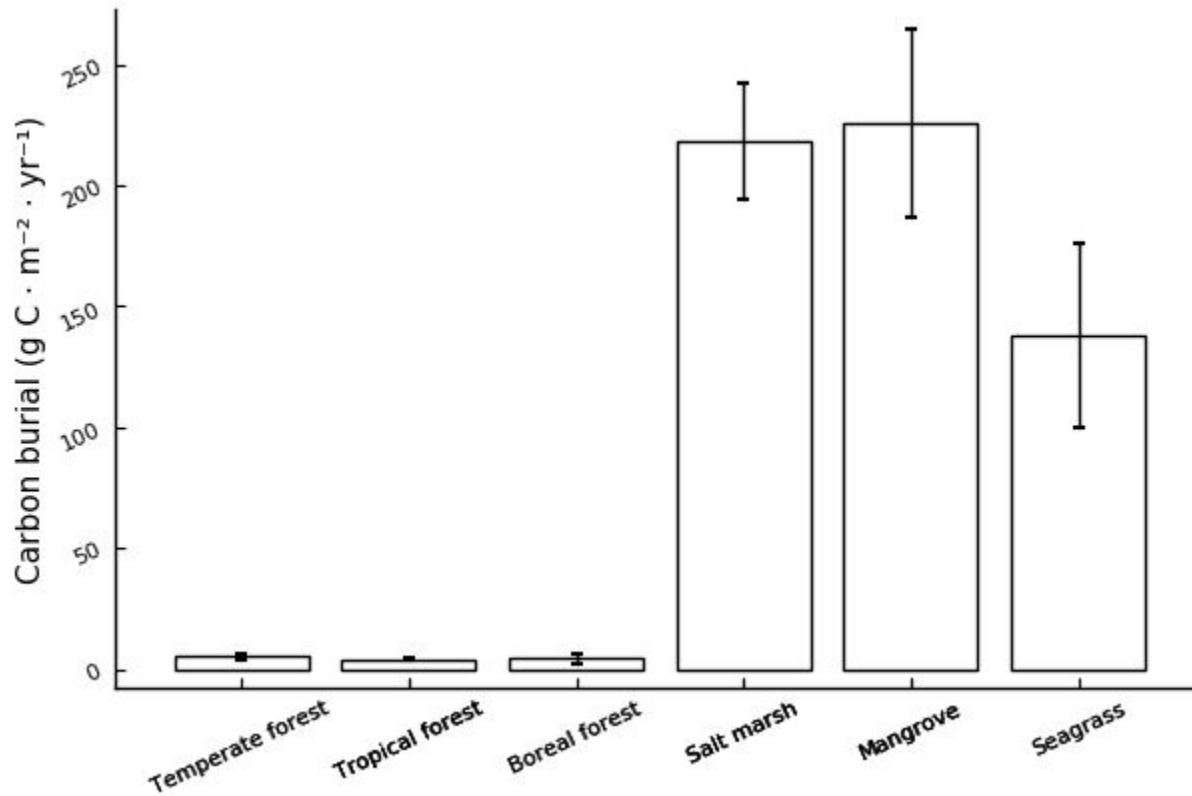
William S. Kearney



Coastal wetlands are globally distributed



Coastal wetlands are effective carbon sinks



After Mcleod et al. (2012). *Frontiers in Ecol. and Env.*



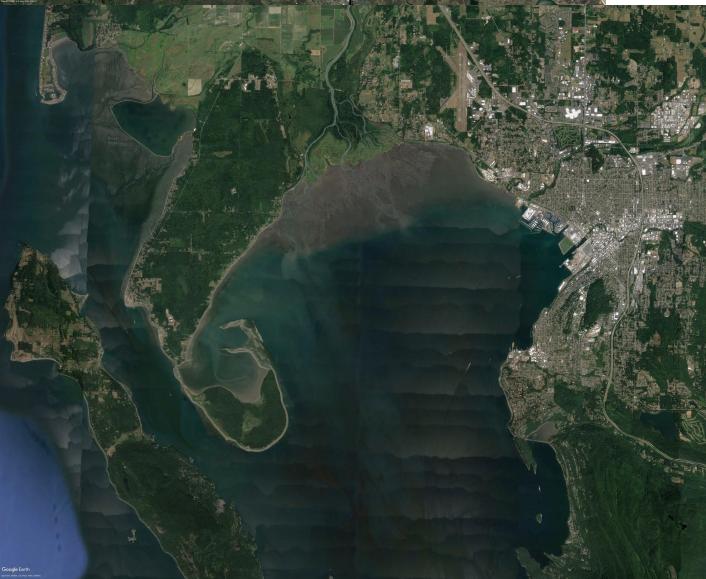




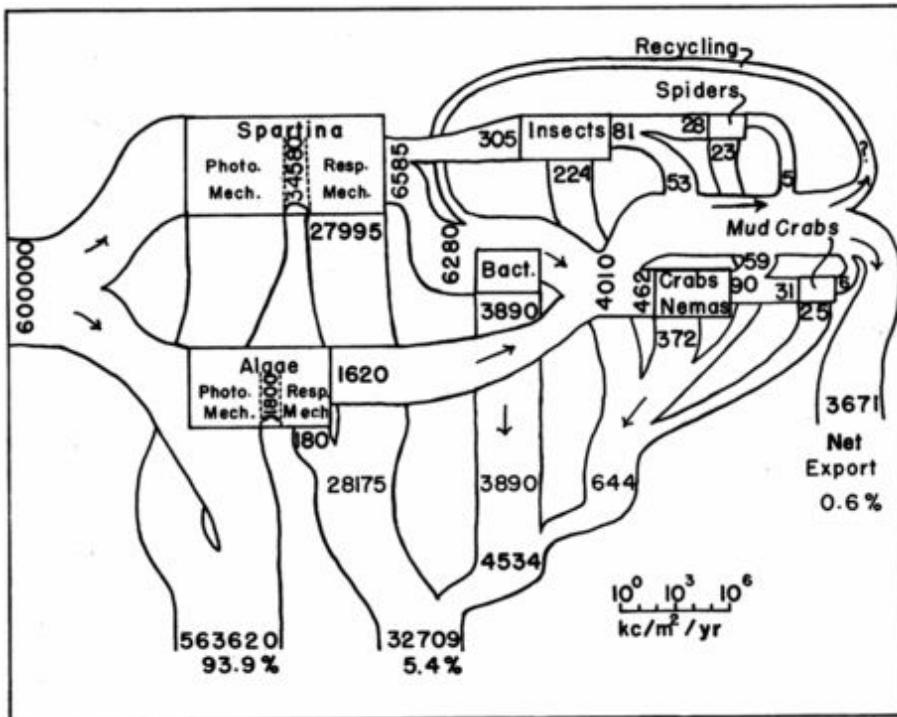




Clockwise from top left: WSK, VCR
LTER, [Tho Nau](#), [Nature Conservancy](#),
[City of Bellingham](#)



The outwelling hypothesis



John Teal (1962). Energy flow in the salt marsh ecosystem of Georgia:

“ . . . the tides remove 45% of the production before the marsh consumers have a chance to use it and in so doing permit the estuaries to support an abundance of animals.”

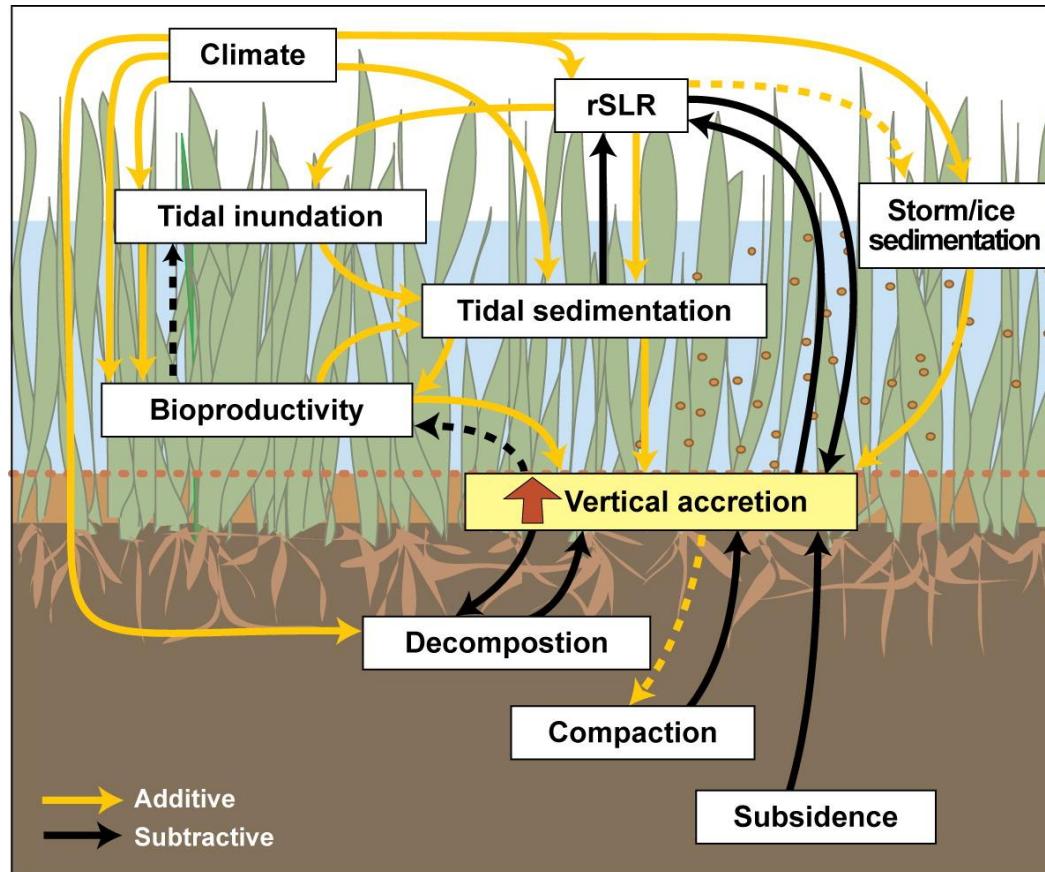
Nixon (1980). Between marshes and coastal waters

“The prevailing view among those working in the field now is that chaos reigns and that we dare not make any statement at all about what marshes are importing or exporting. . .

It is even becoming popular to dismiss the question of marsh-estuarine interactions as a ‘non-problem’ in which the flux is simply a site-specific function of marsh morphology and hydrography.”

Quantifying water and sediment exchanges

Marsches need sediment to accrete



Fitzgerald et al.
(2008). *Ann. Rev. Earth Planet. Sci.*

Living shorelines



[Resilient Boston Harbor](http://ResilientBostonHarbor.org)

Thin-layer placement

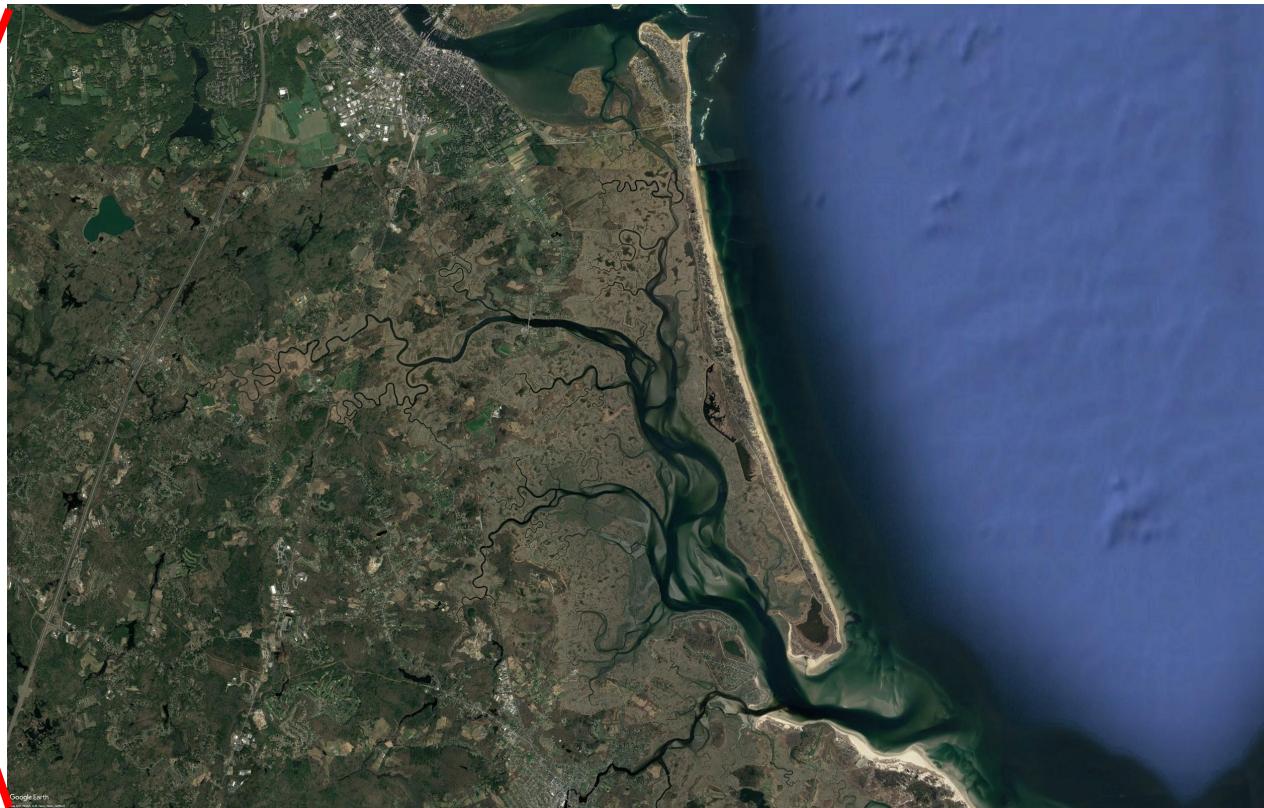


Thin-layer placement

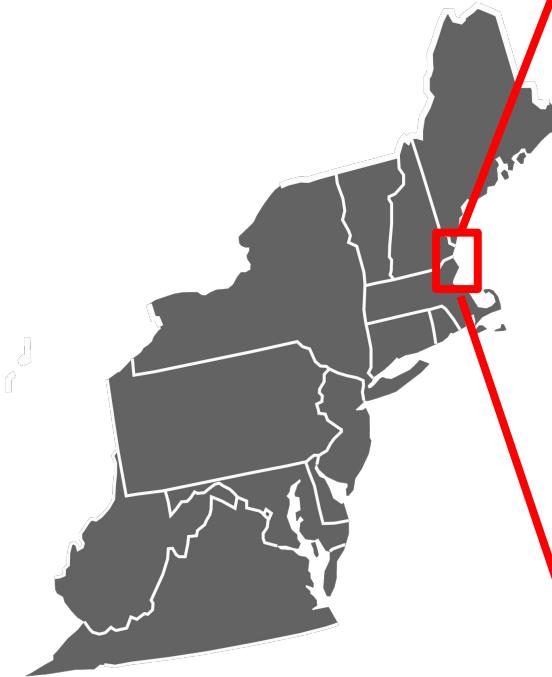


Successful if that sediment stays where it is placed

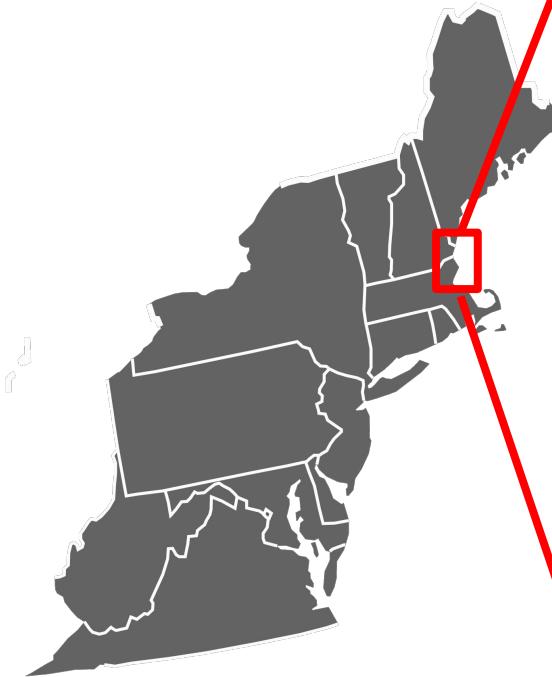
Plum Island Ecosystems LTER



Plum Island Ecosystems LTER



Plum Island Ecosystems LTER



Plum Island Ecosystems LTER



Plum Island Ecosystems LTER



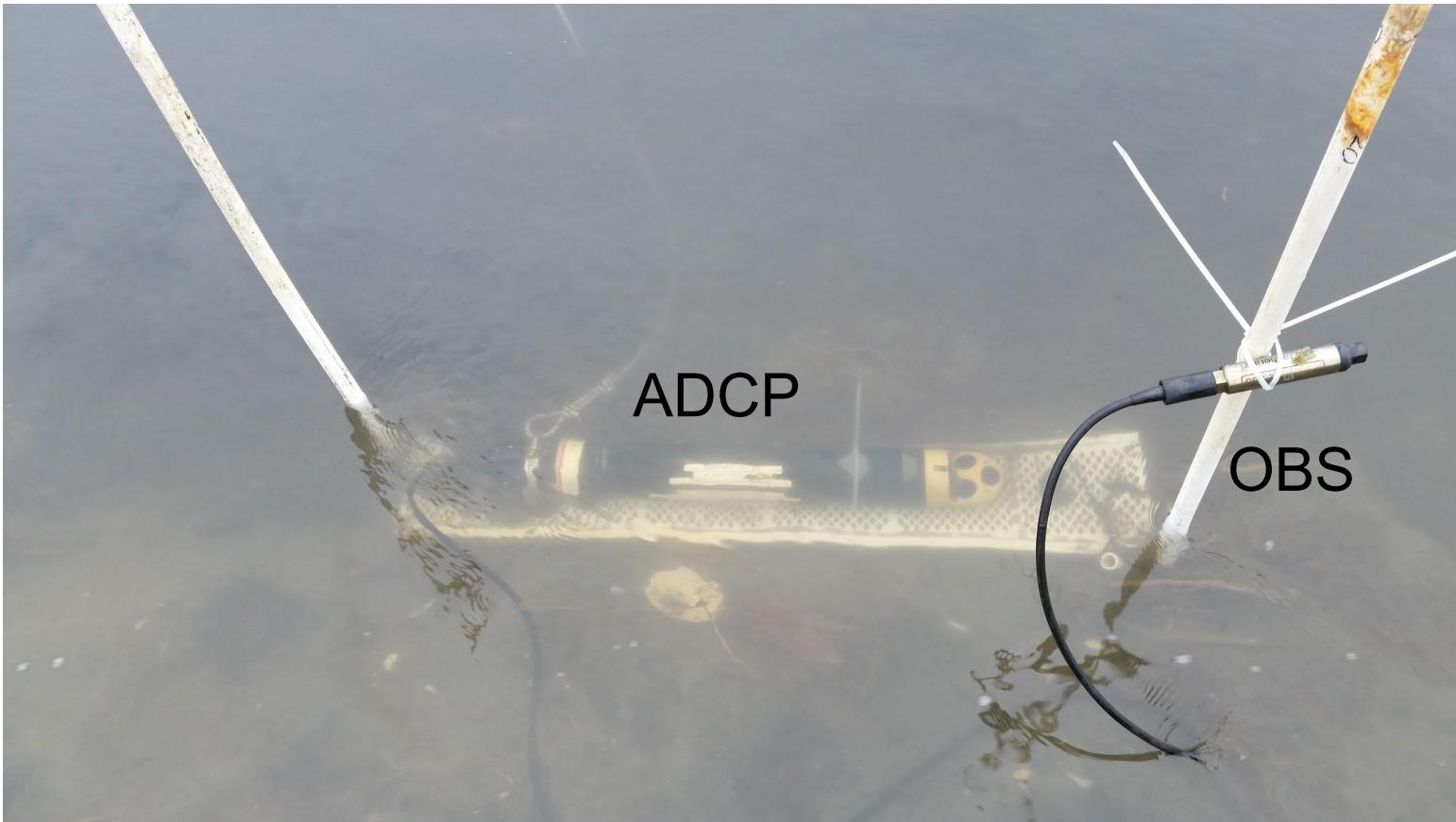
Plum Island Ecosystems LTER



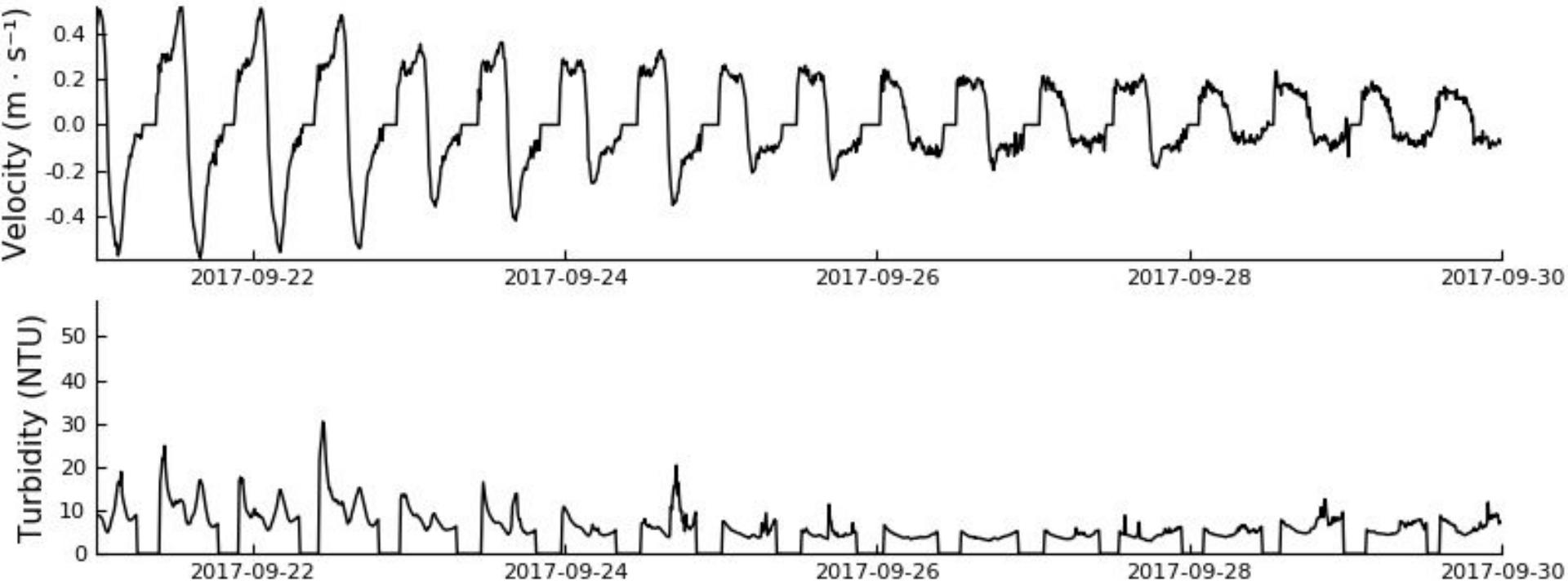
The marshes of Plum Island Sound



The acoustic Doppler current profiler



Time series from ADCP + OBS





Tidal stage-discharge models

LIMNOLOGY
and
OCEANOGRAPHY: METHODS

ASLO

Limnol. Oceanogr.: Methods 00, 2017, 00–00
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doi: 10.1002/lom3.10168

Stage-discharge relationship in tidal channels

William S. Kearney ,^{1*} Giulio Mariotti,² Linda A. Deegan,^{3a} Sergio Fagherazzi¹

¹Department of Earth and Environment and Marine Program, Boston University, Boston, Massachusetts

²Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, Louisiana

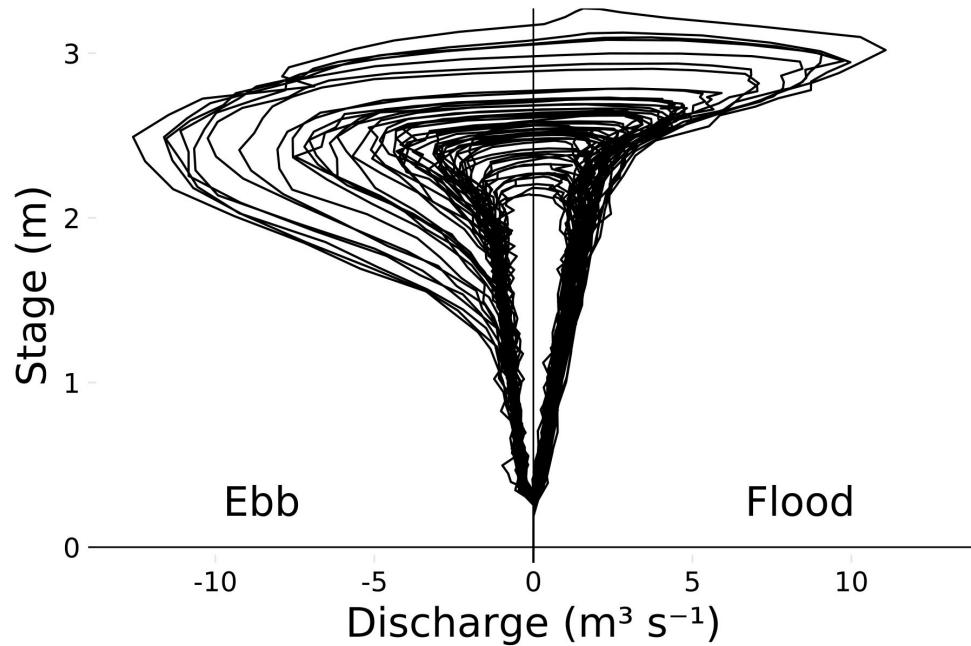
³The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts

The TIDE Fertilization Experiment



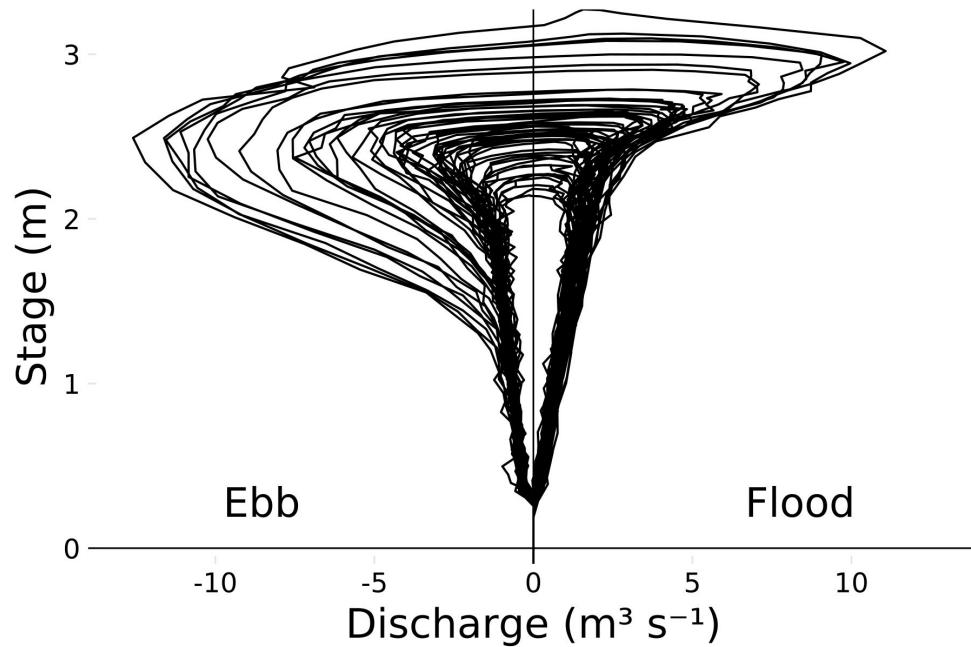
Tidal stage-discharge relationships

- Bidirectional



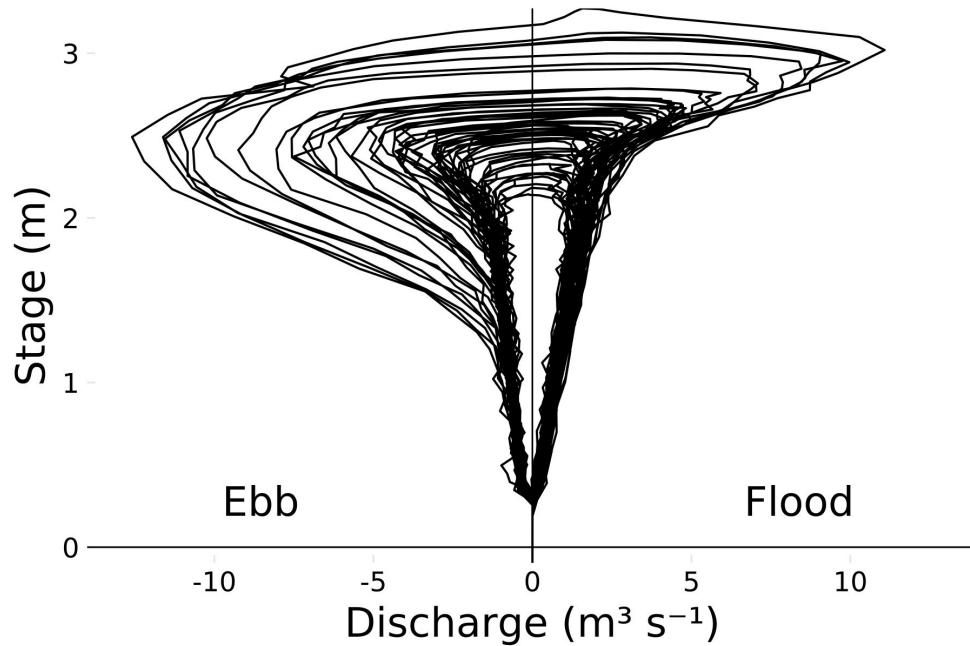
Tidal stage-discharge relationships

- Bidirectional
- Asymmetric

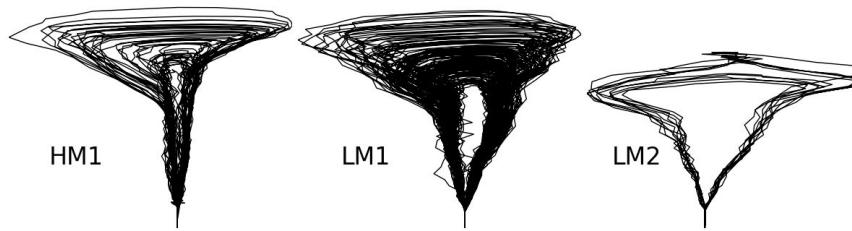
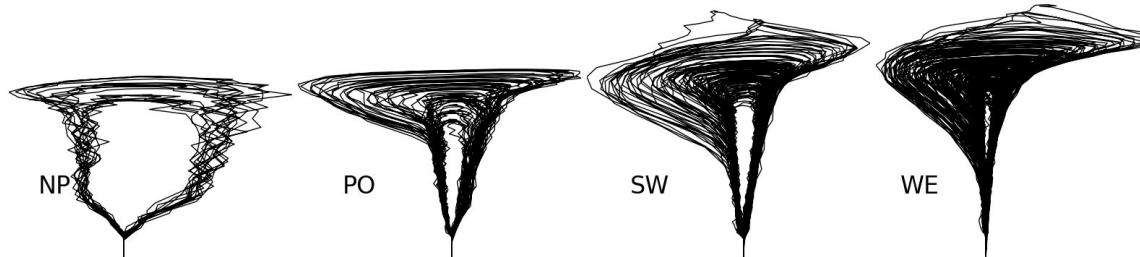
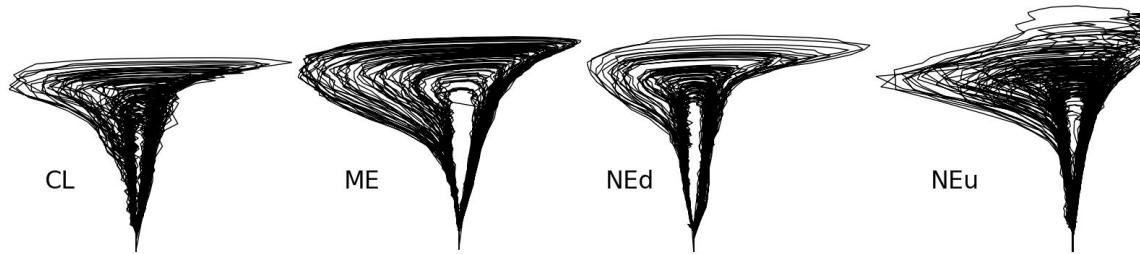


Tidal stage-discharge relationships

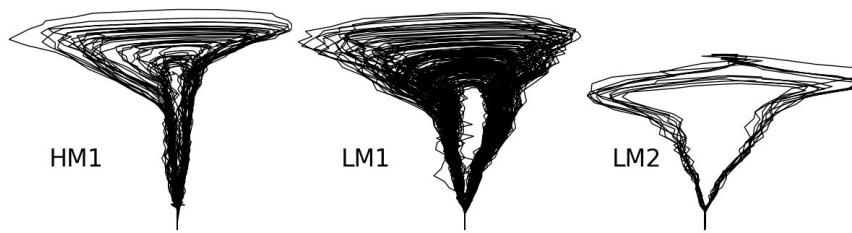
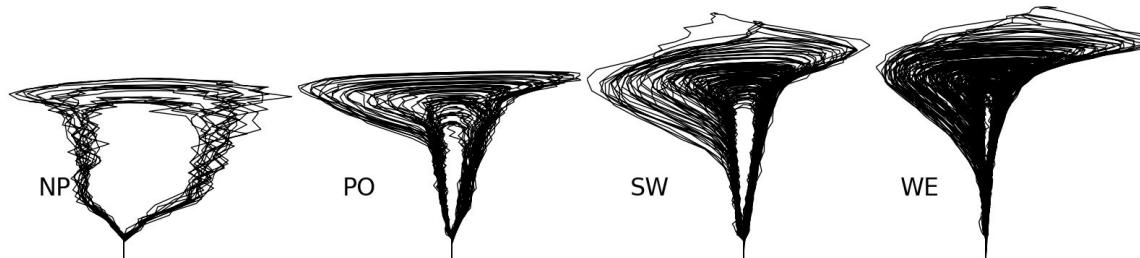
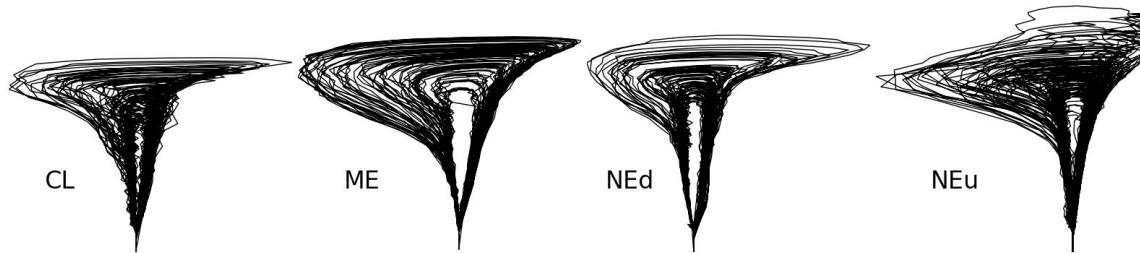
- Bidirectional
- Asymmetric
- Nonstationary



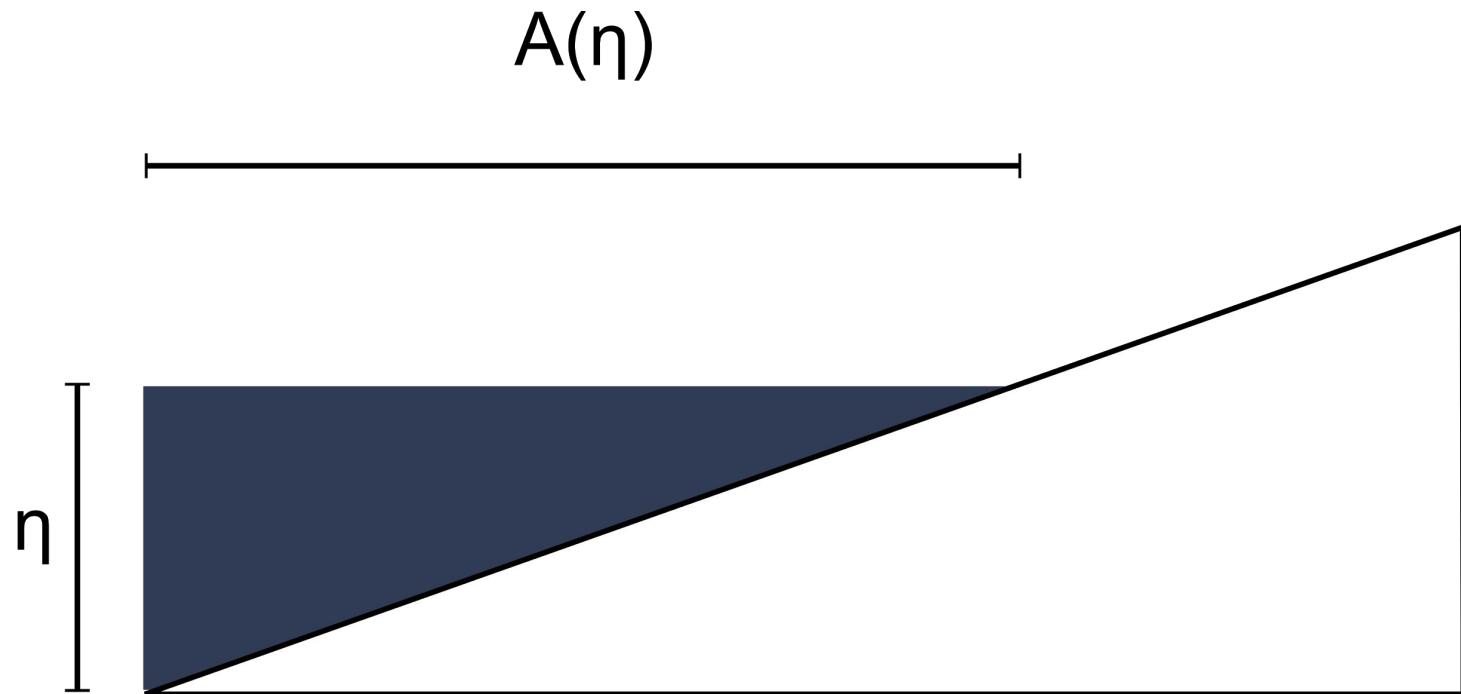
Stage-discharge plots



Stage-discharge plots: the fingerprint of a marsh

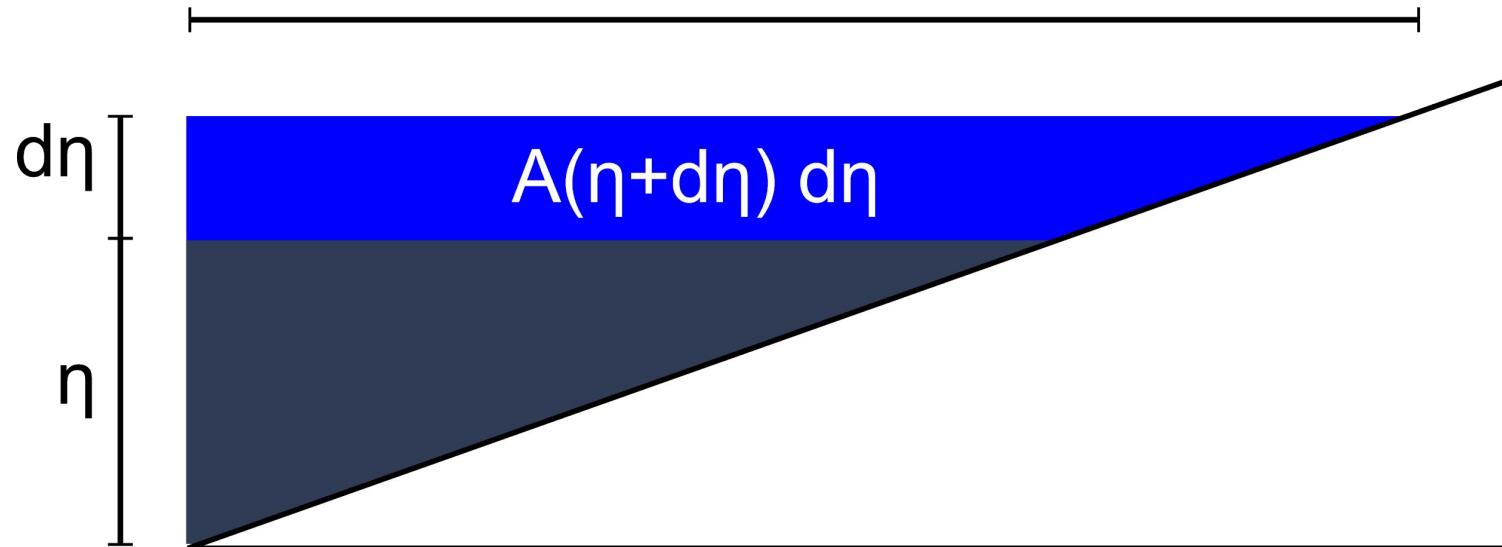


The rigid lid stage-discharge model

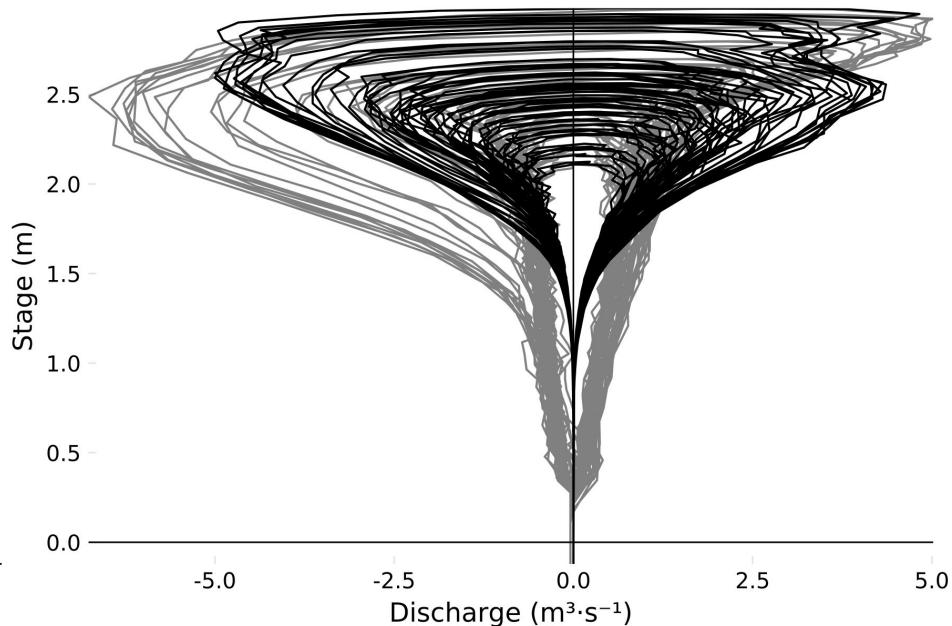
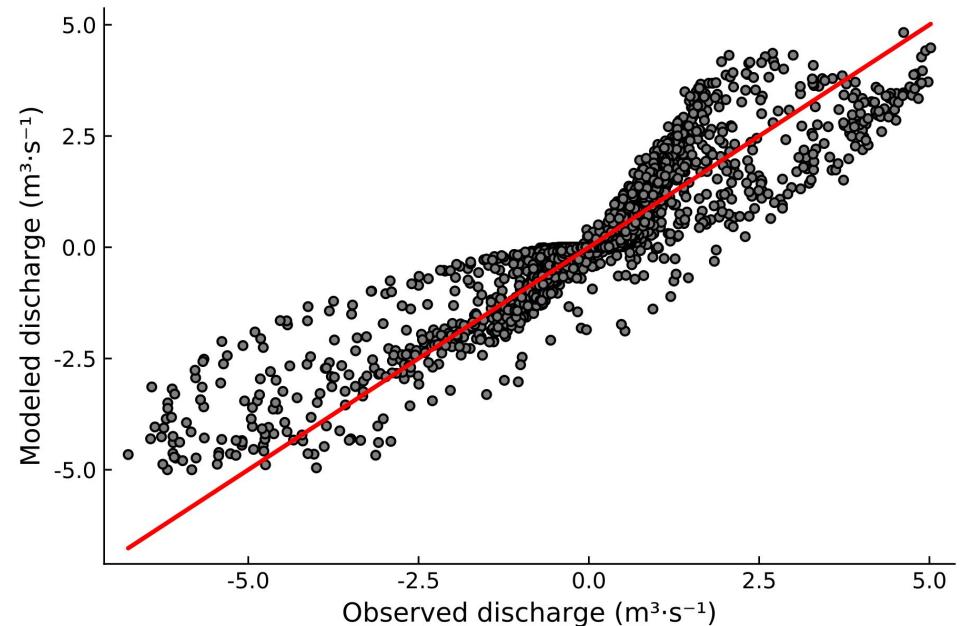


The rigid lid stage-discharge model

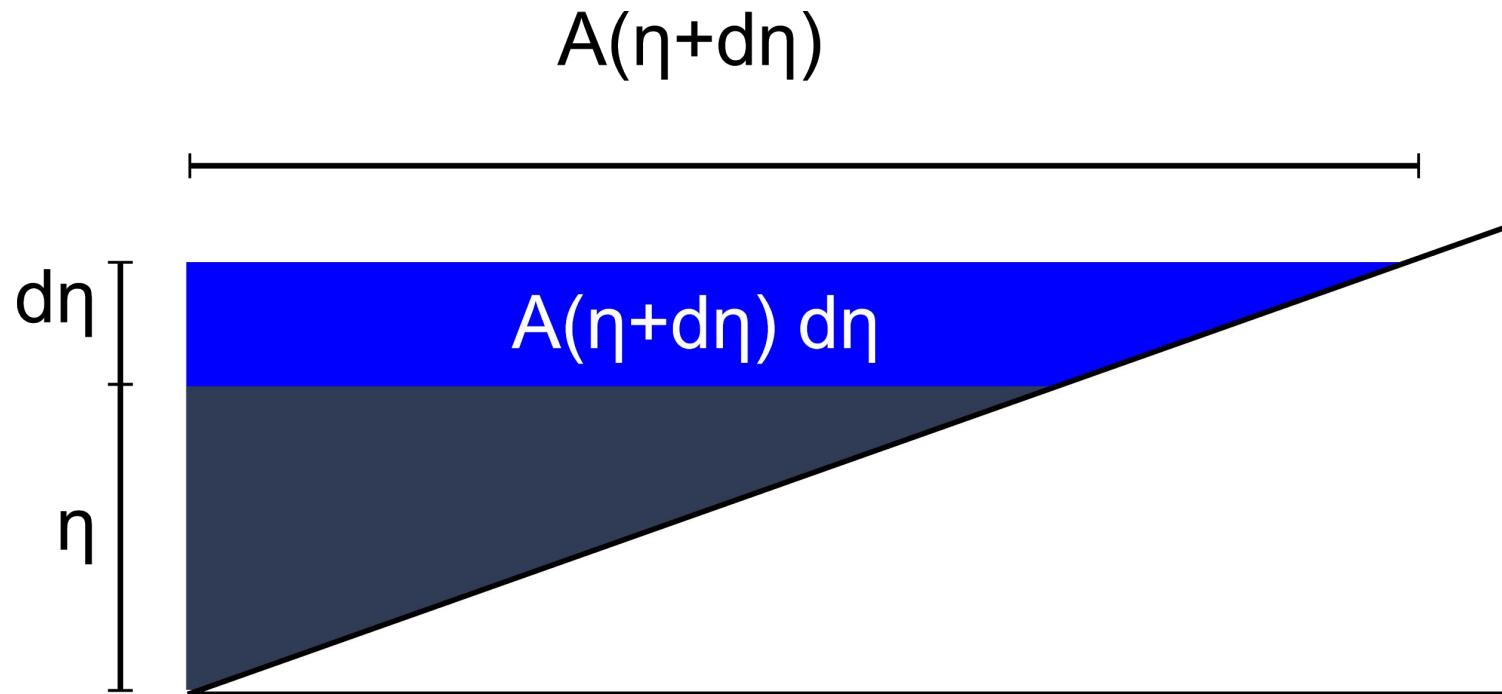
$$A(\eta + d\eta)$$



The rigid lid model does not work very well

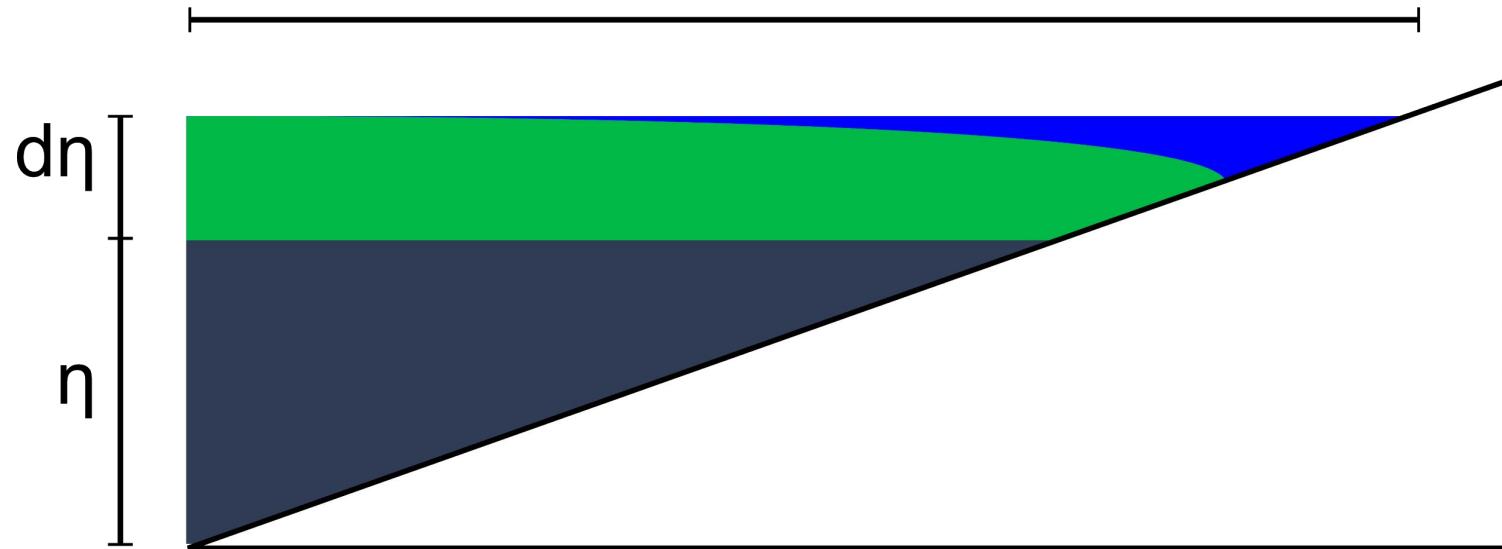


What is going wrong?



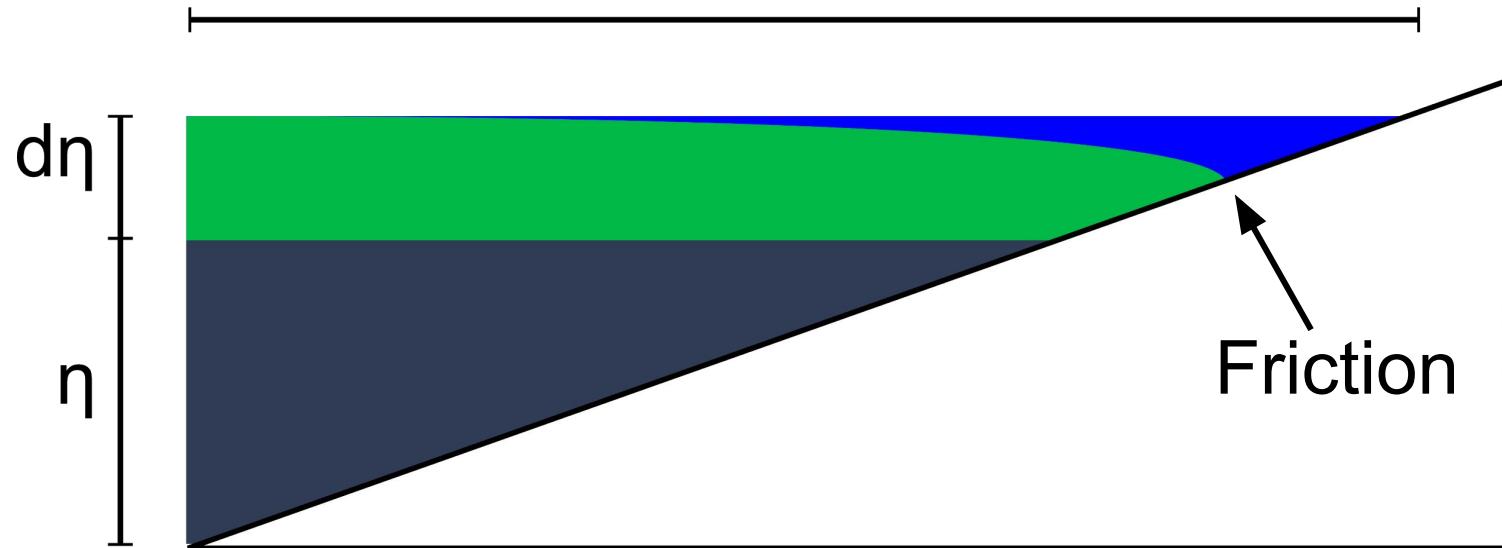
What is going wrong?

$$A(\eta + d\eta)$$

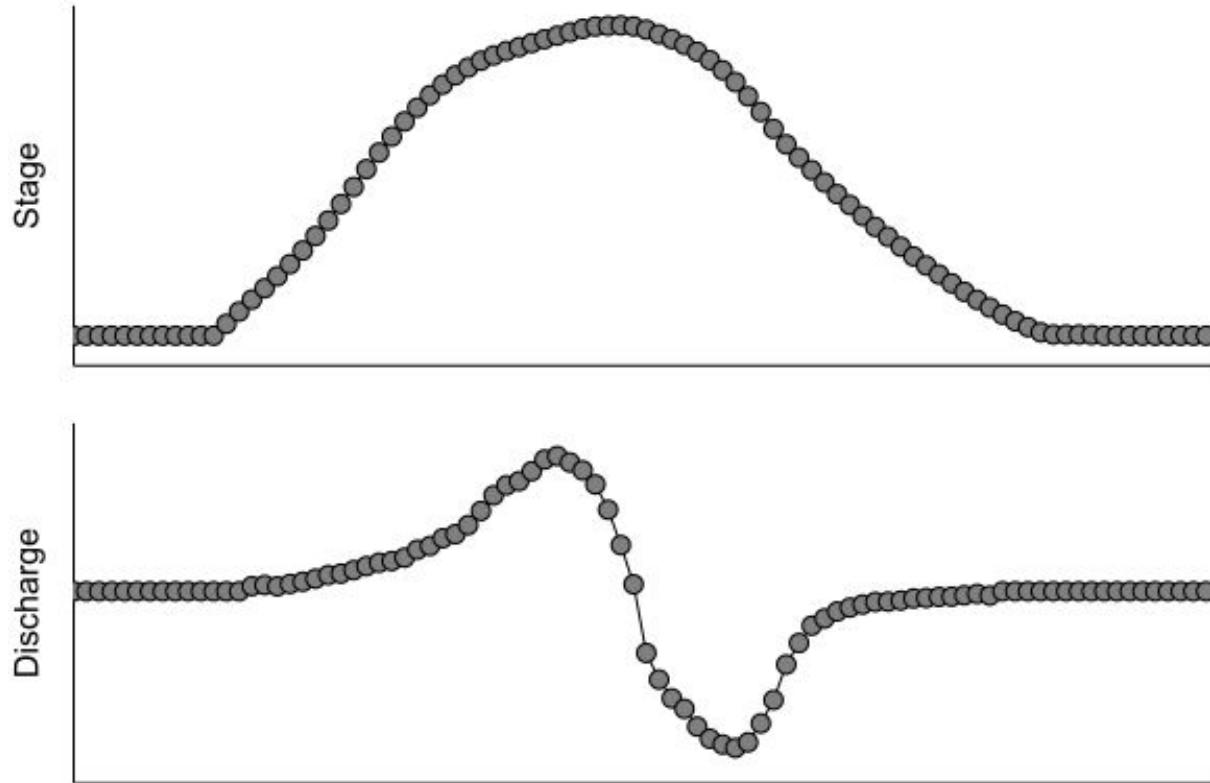


What is going wrong?

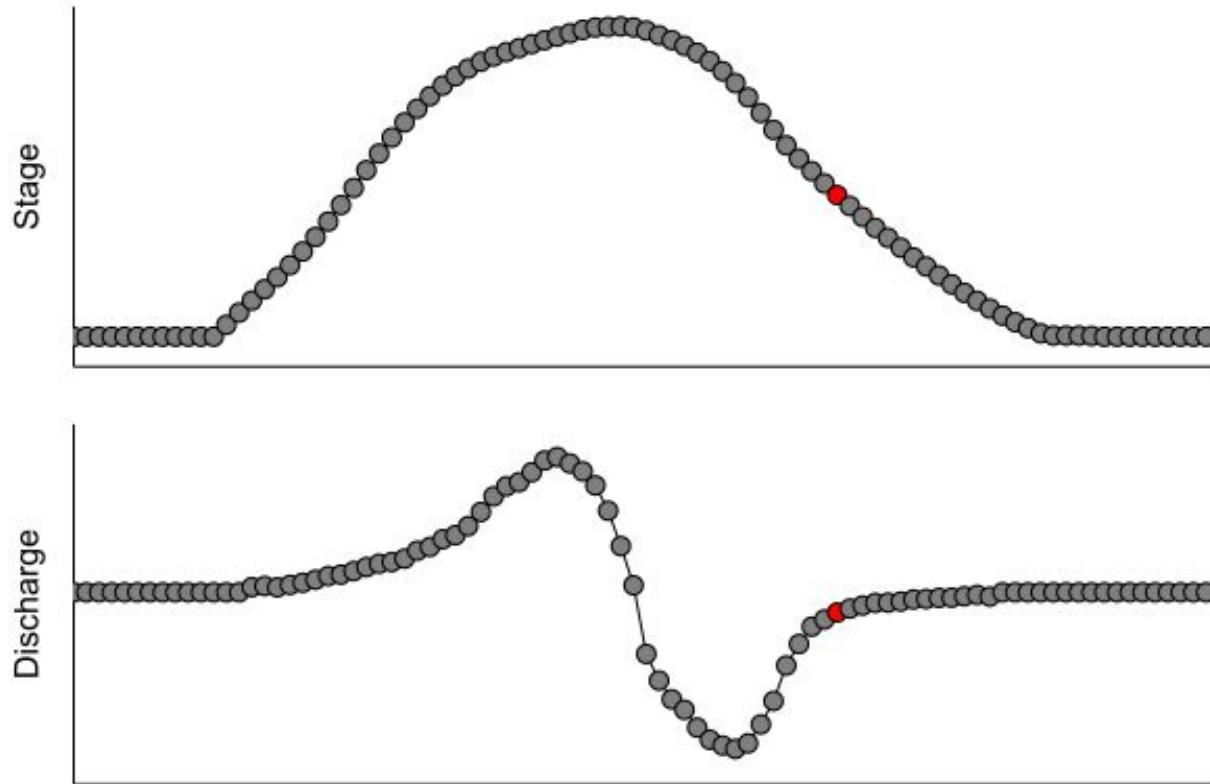
$$A(\eta + d\eta)$$



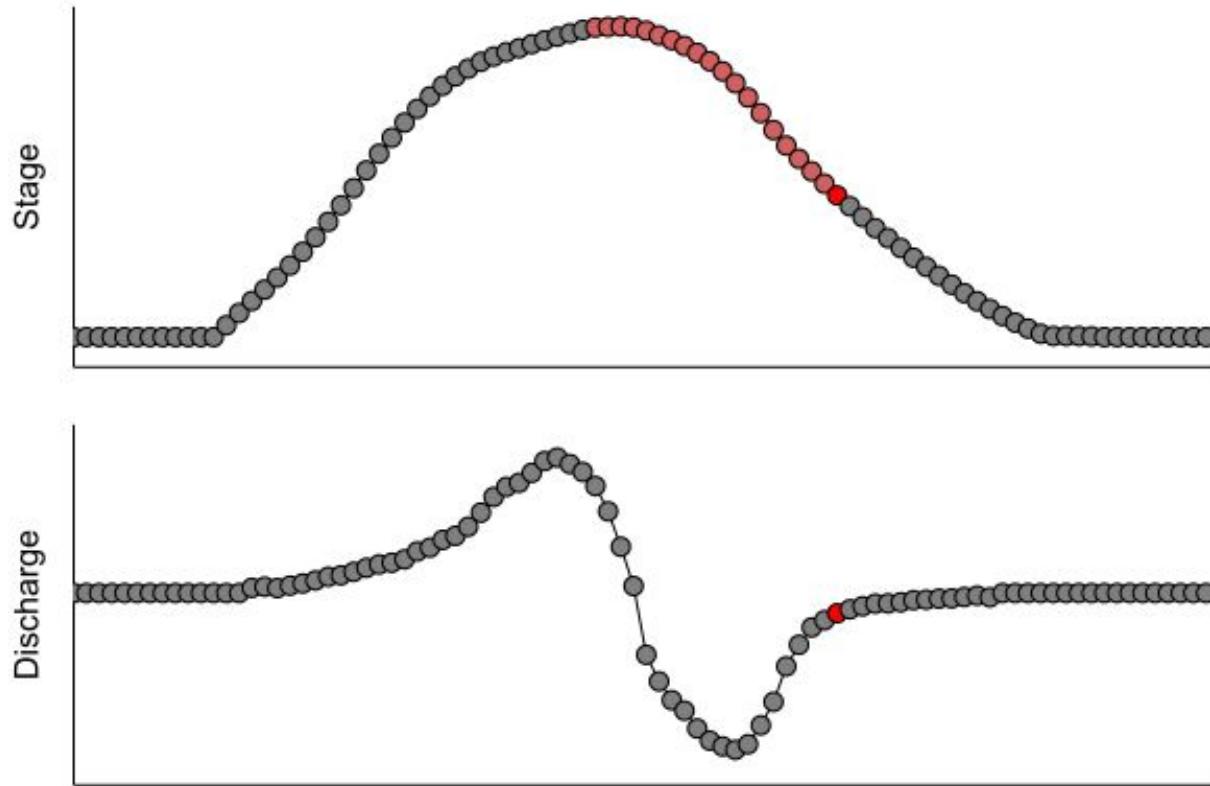
“Embedding” the time series



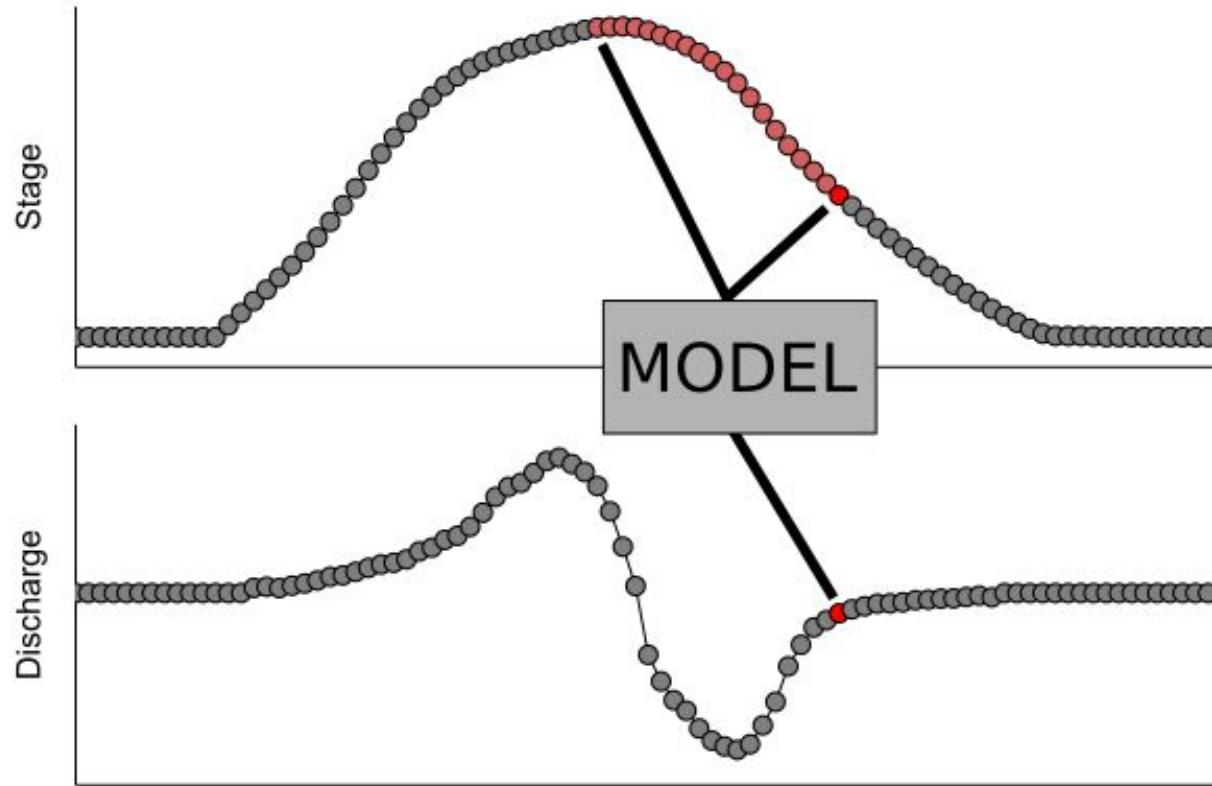
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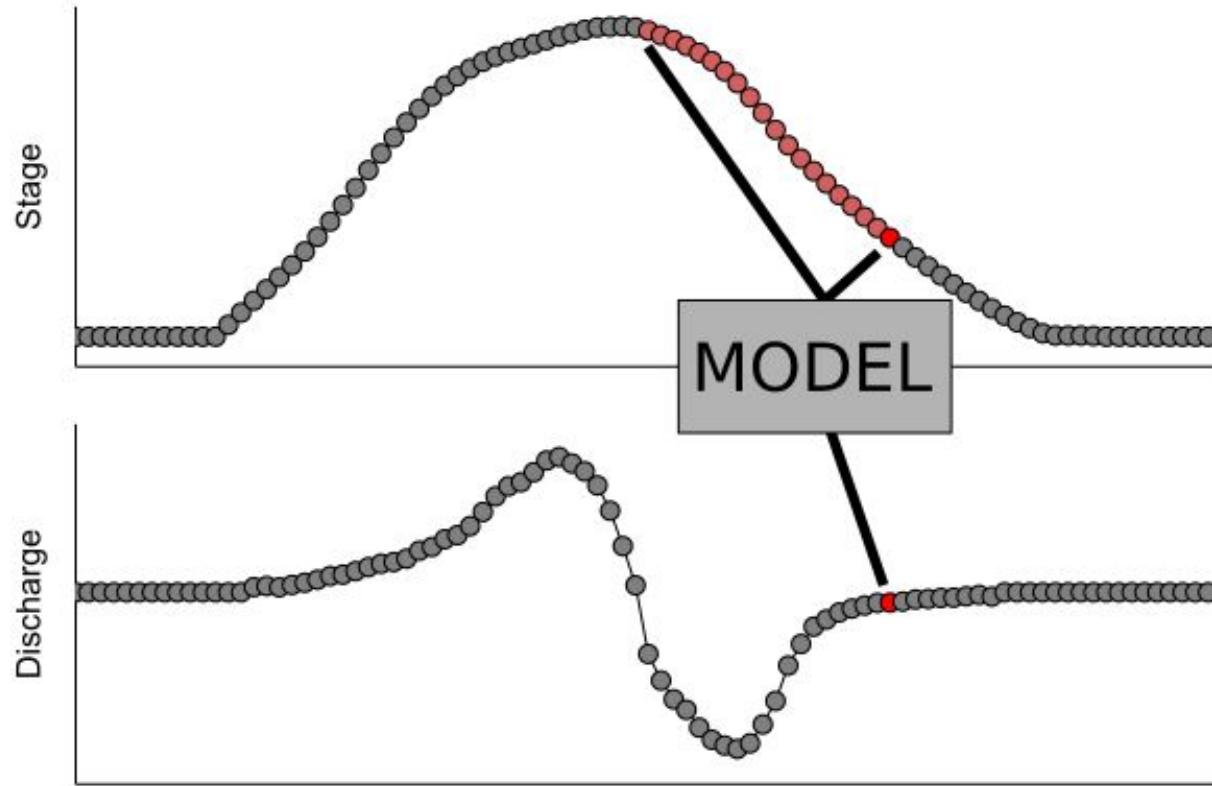
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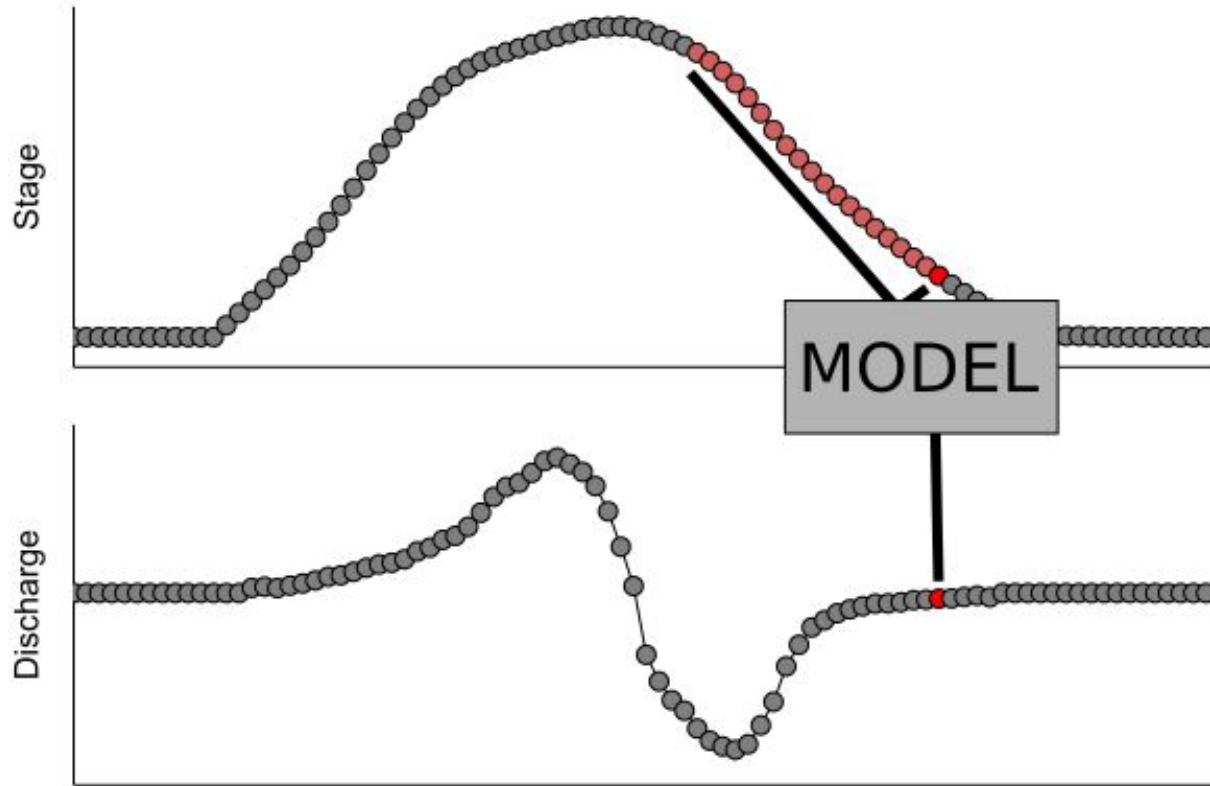
“Embedding” the time series



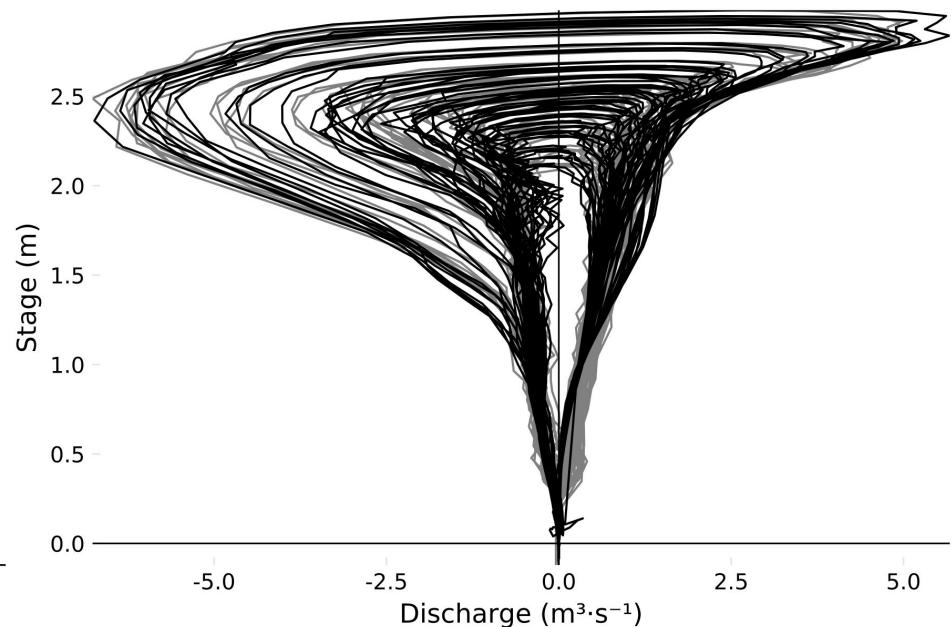
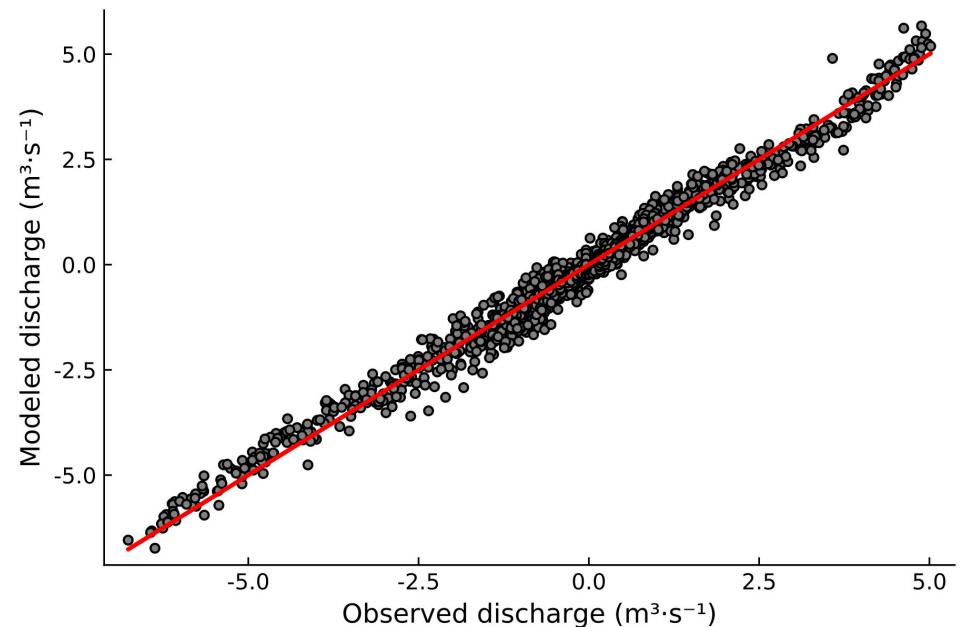
“Embedding” the time series



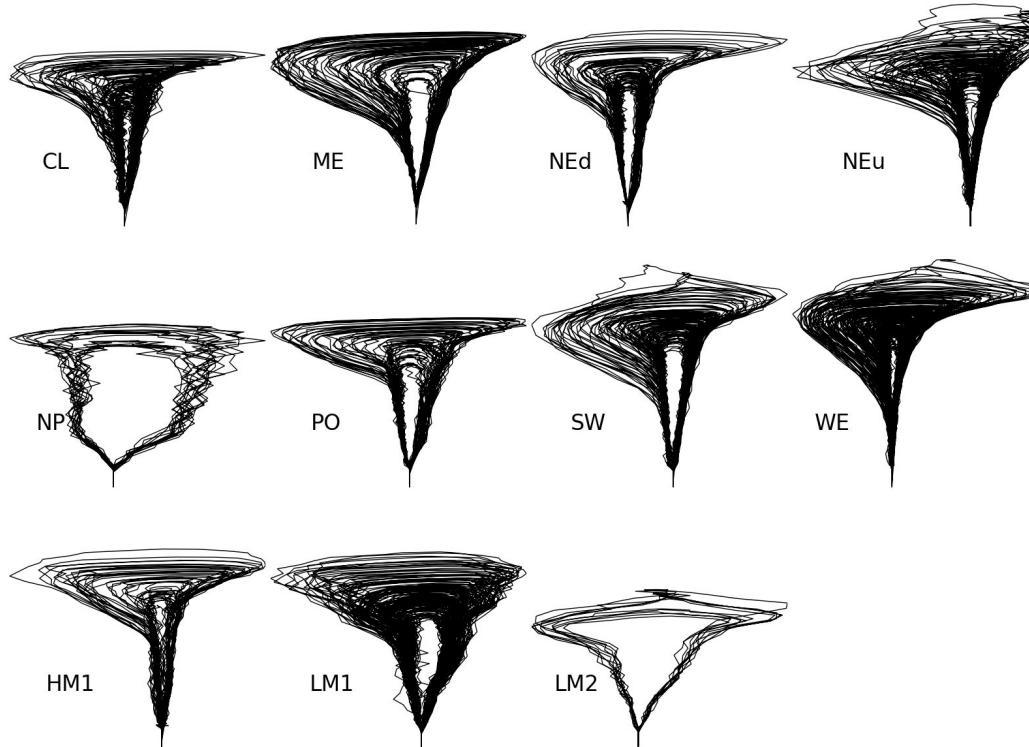
“Embedding” the time series



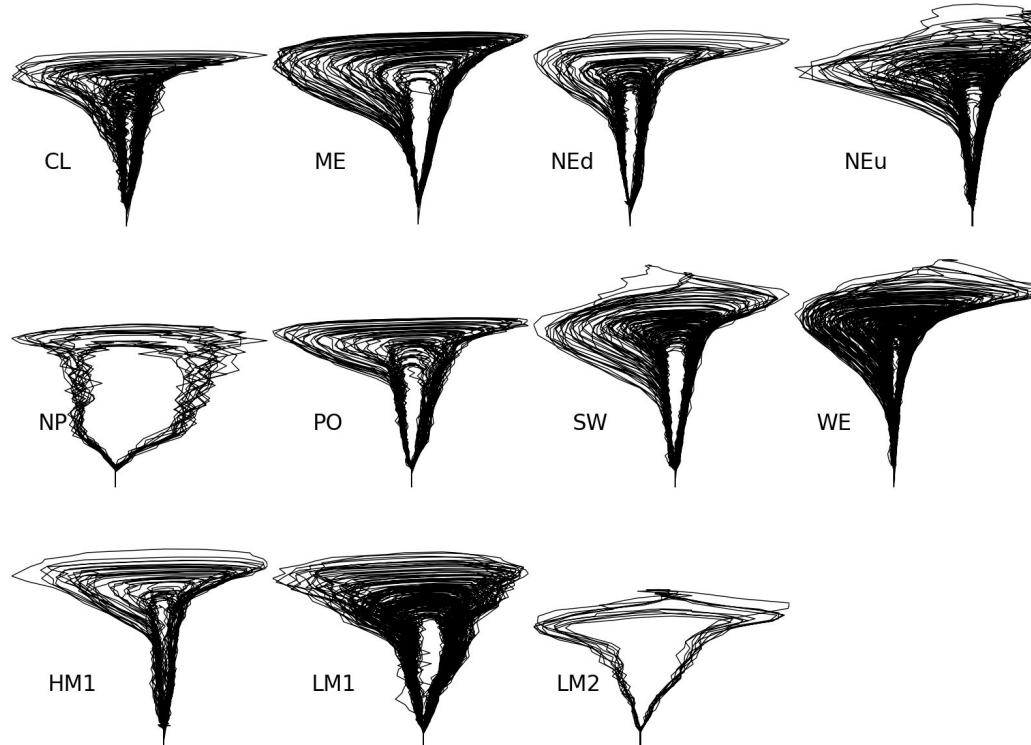
The new nonlinear time series model works well!



Problem: generalizing to ungauged marshes



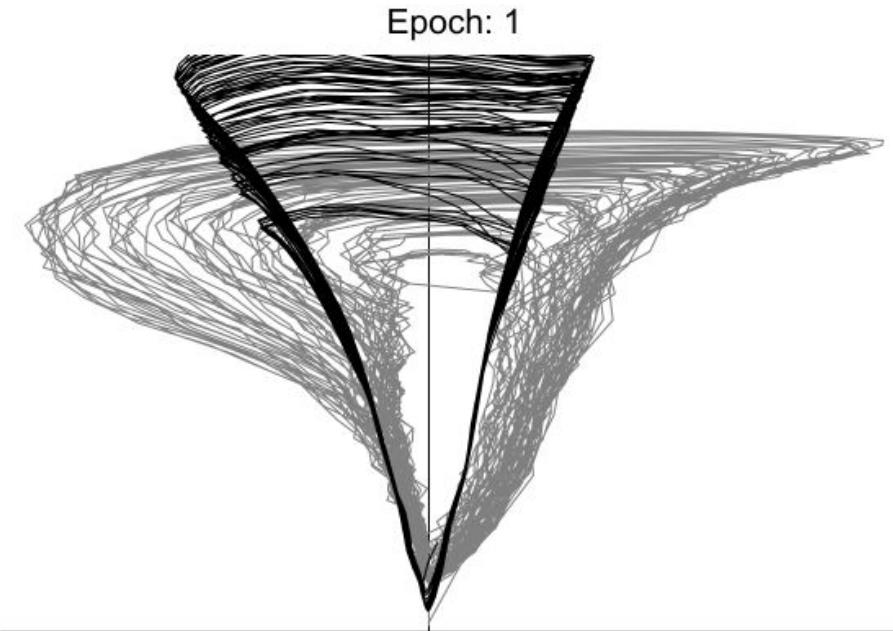
Problem: generalizing to ungauged marshes



Nixon: “simply a site-specific function of marsh morphology and hydrography.”

Deep learning as a possible solution?

- Feed all but one of the marshes into a neural network
- Predict on the held out marsh
- Works well, if you are careful

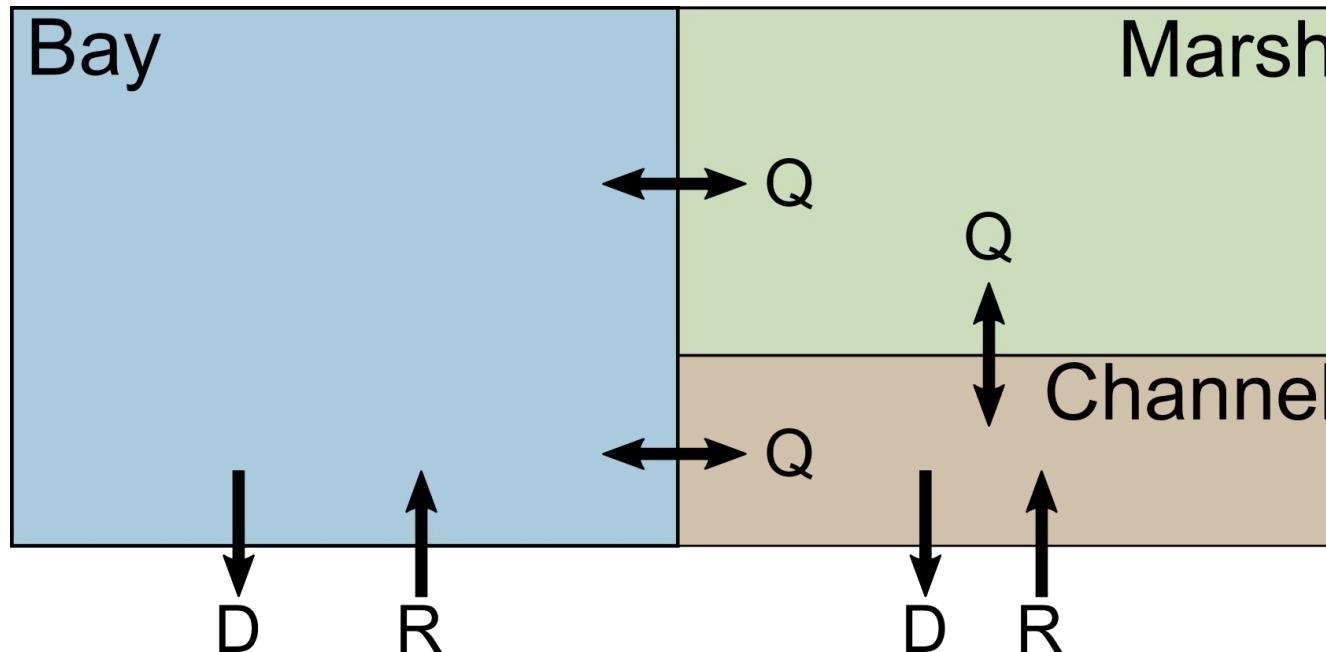


Sediment fluxes

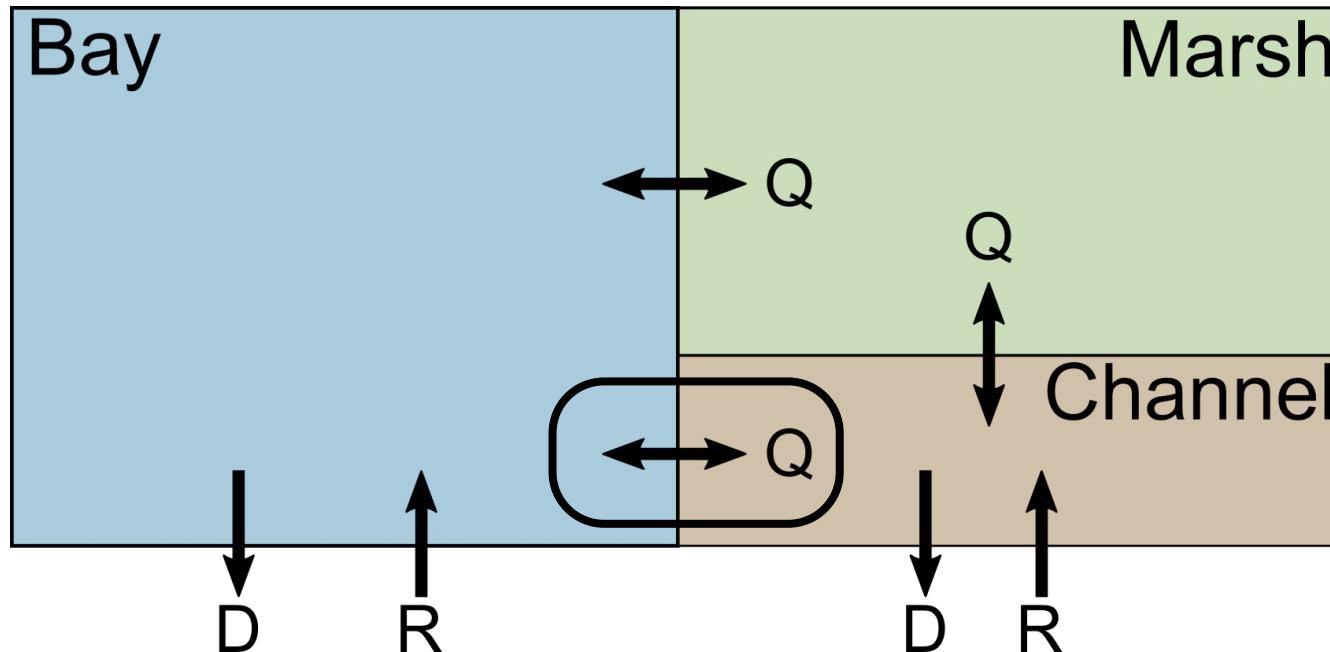
With:

- Neil Ganju and Zafer Defne, USGS
- Nat Weston, Villanova
- Linda Deegan, Woods Hole Research Center
- Nancy Pau, USFWS
- Sergio Fagherazzi, BU

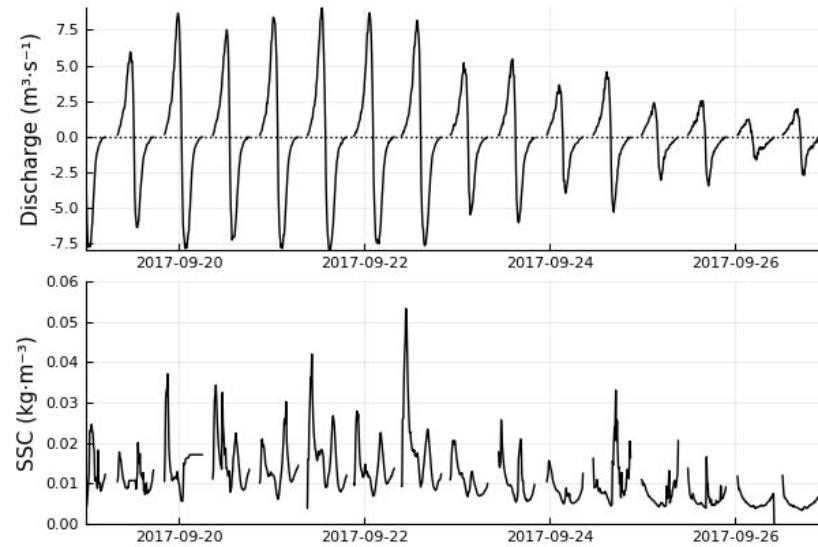
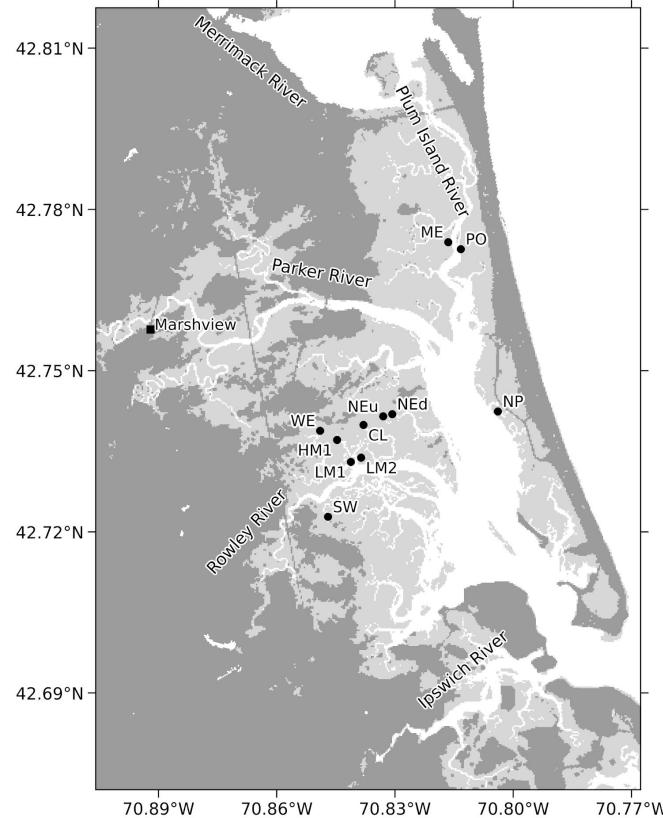
A conceptual model for sediment exchanges



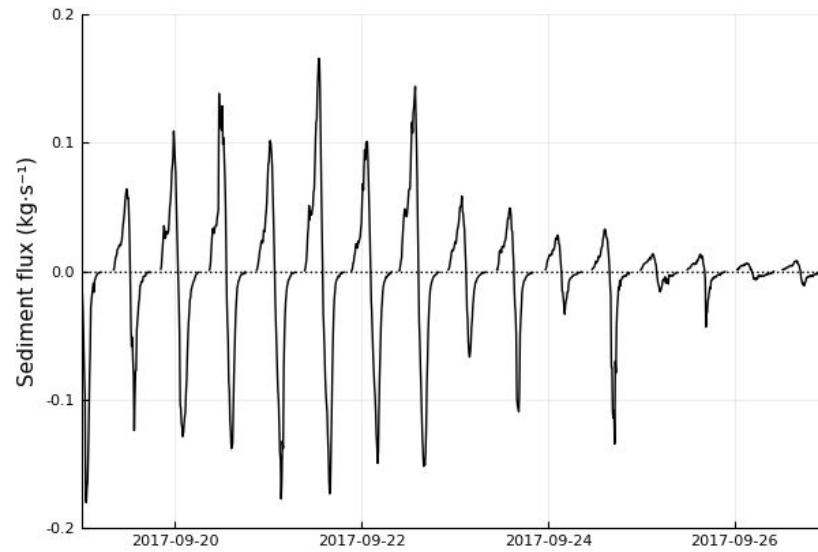
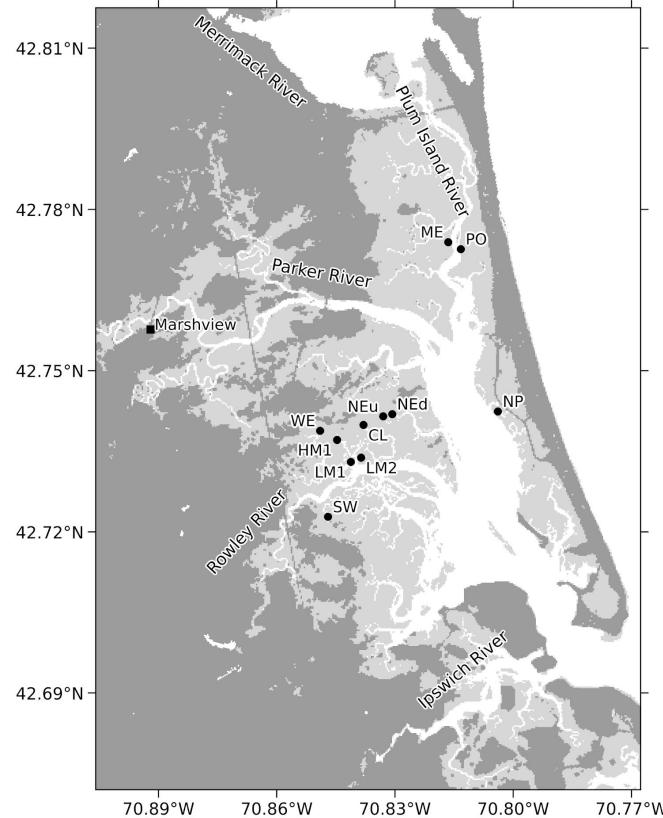
A conceptual model for sediment exchanges



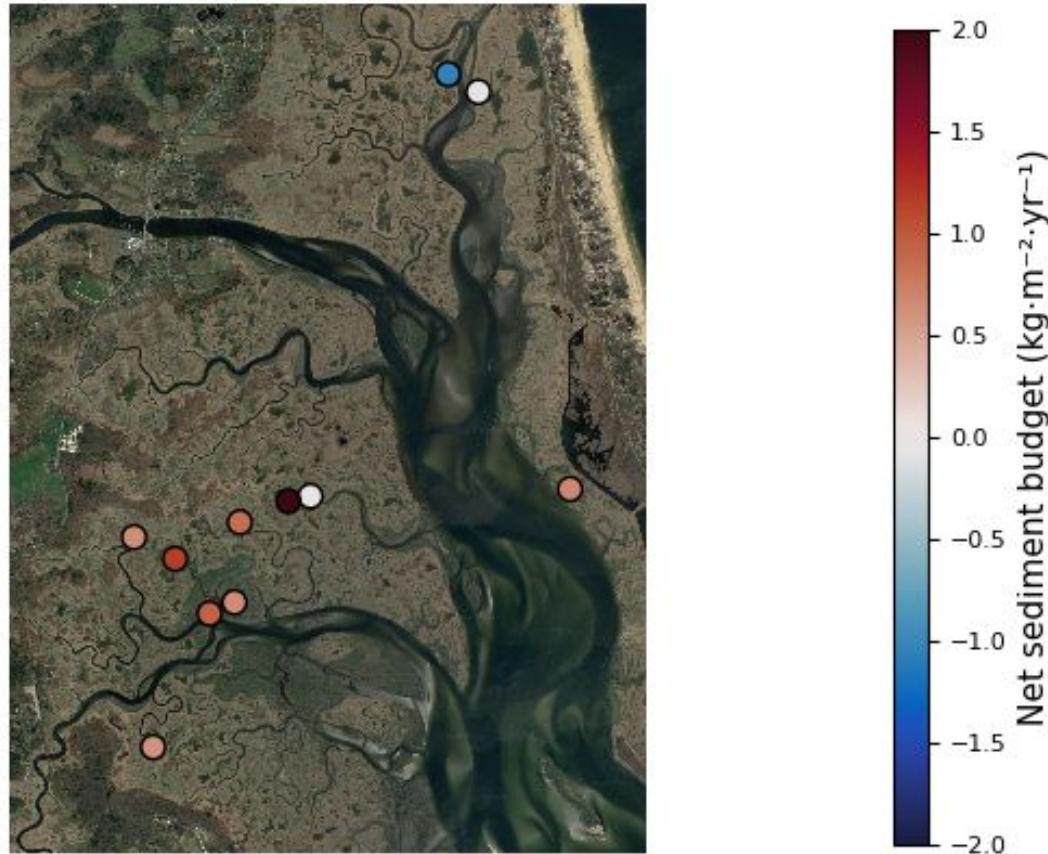
Computing a marsh sediment budget



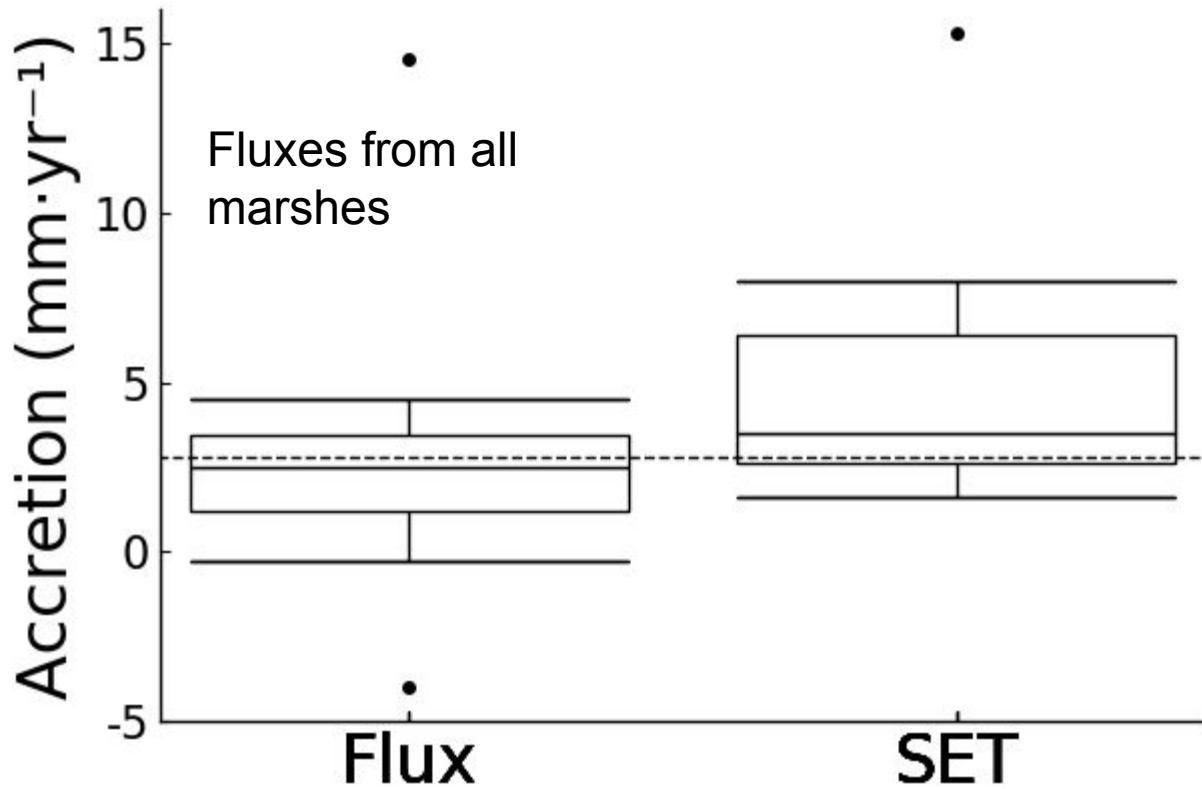
Computing a marsh sediment budget



Plum Island marsh sediment budgets

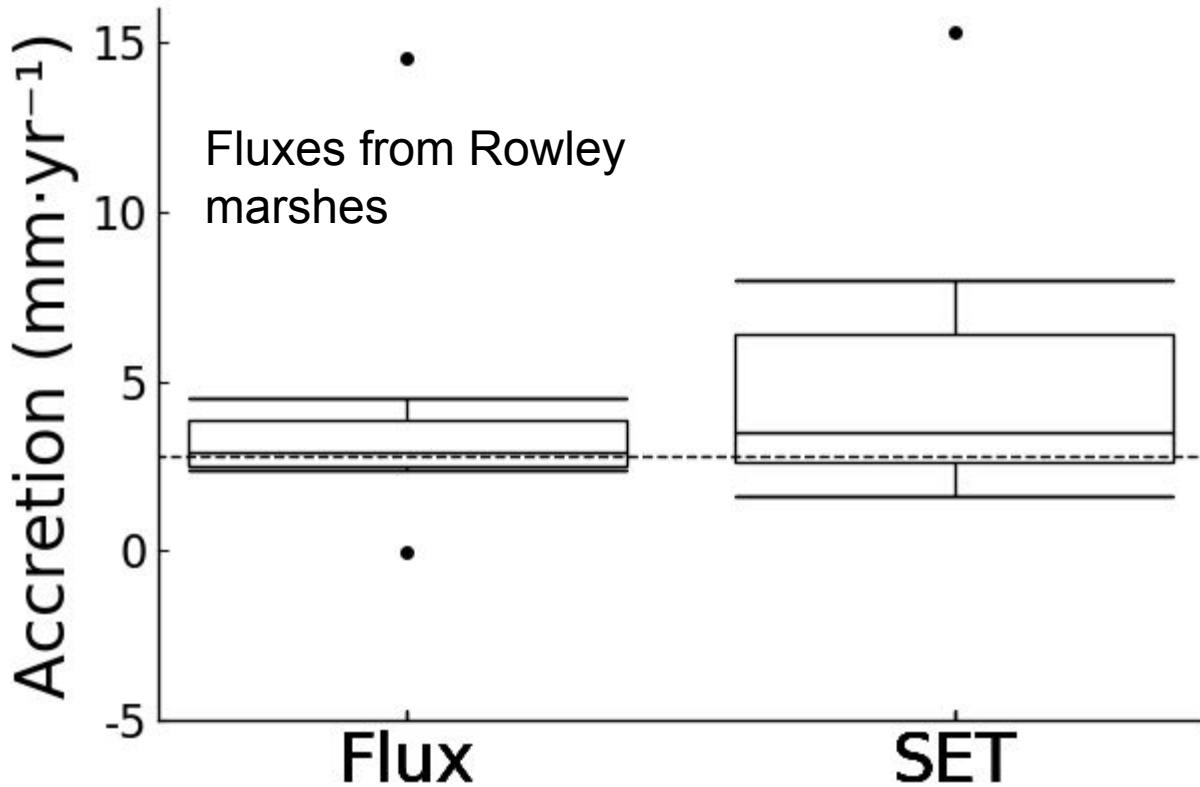


Flux-based estimates comparable to surface accretion measurements



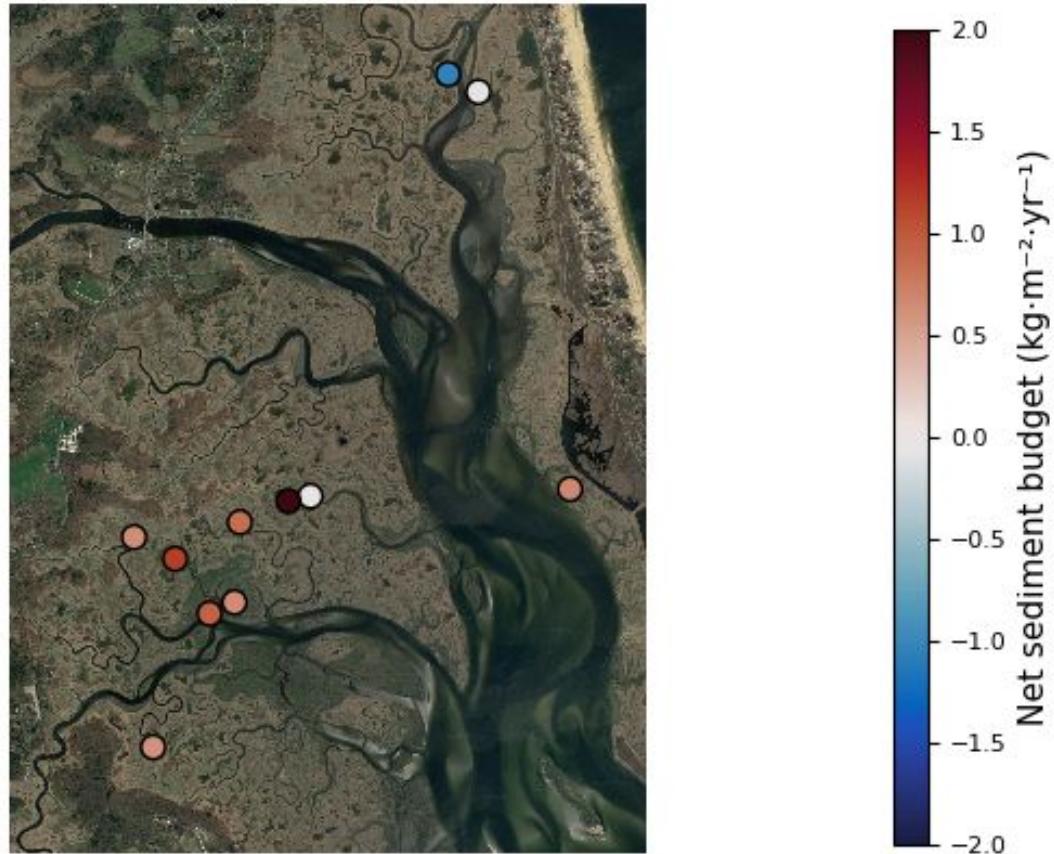
Sam Bond, PIE LTER

Flux-based estimates comparable to surface accretion measurements

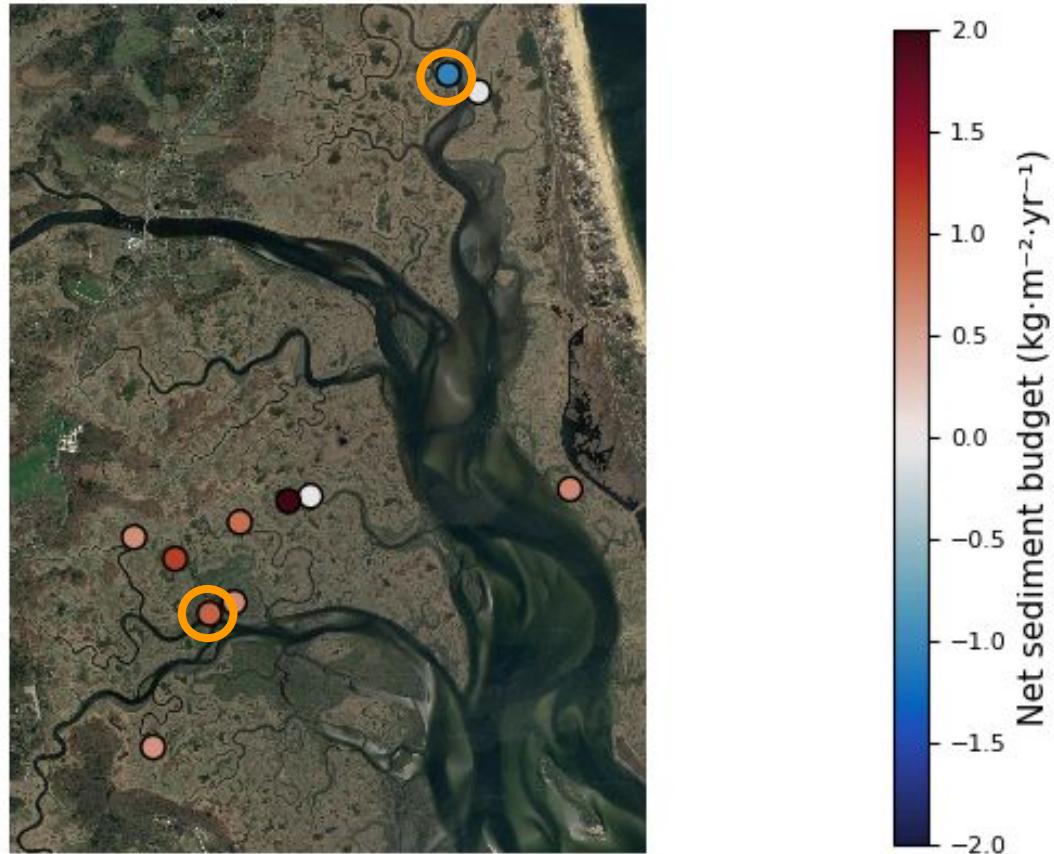


Sam Bond, PIE LTER

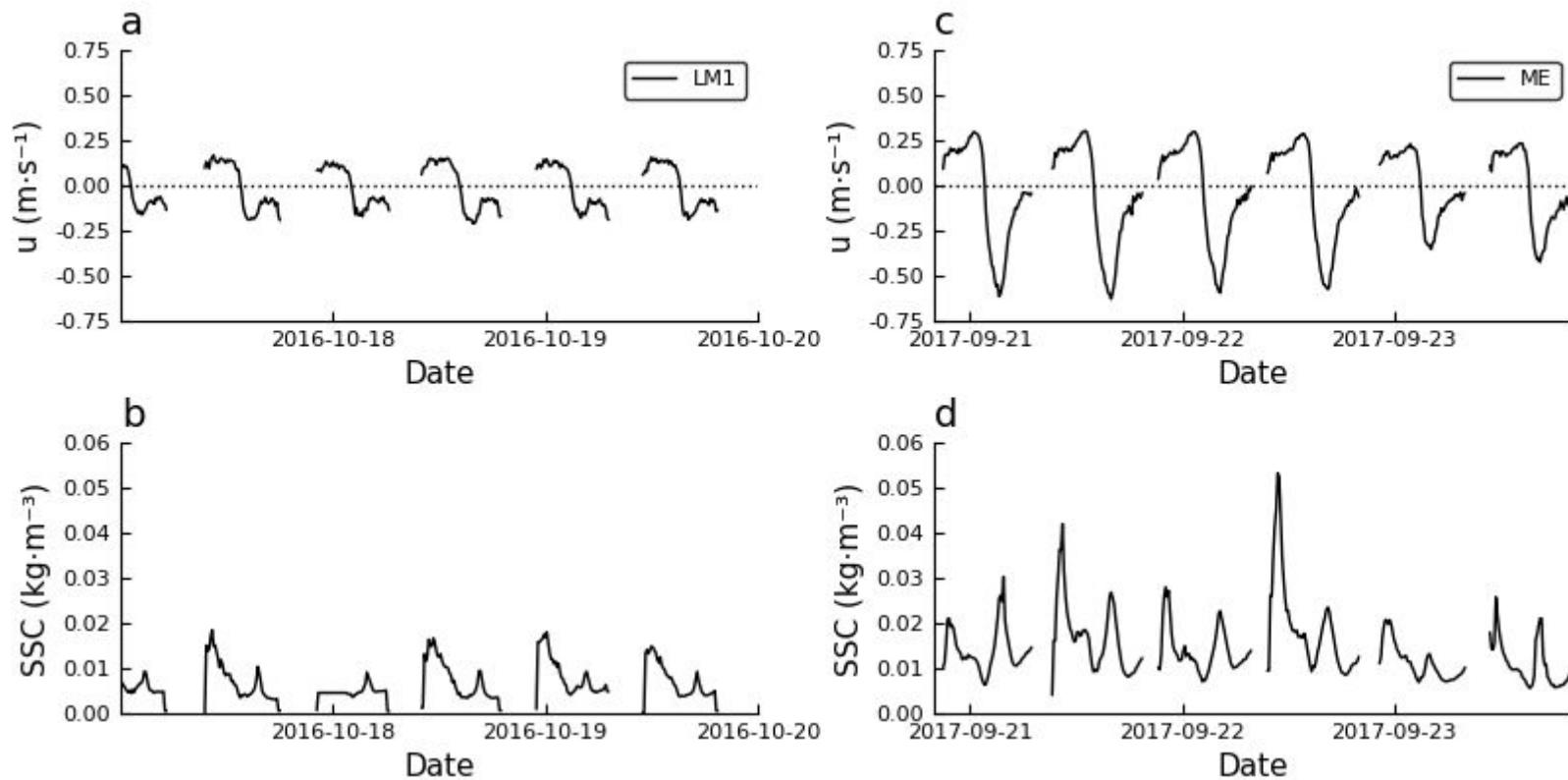
Investigating spatial variability



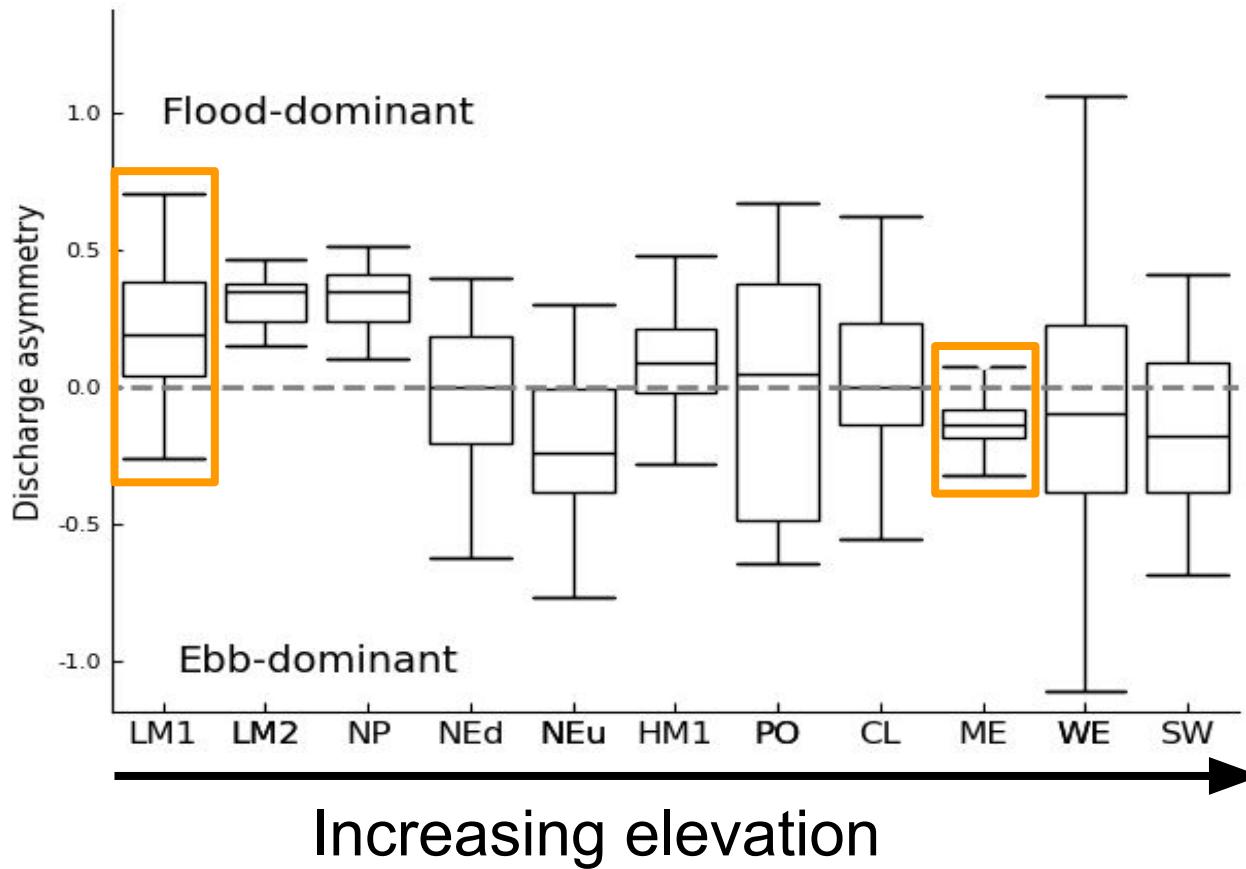
Investigating spatial variability



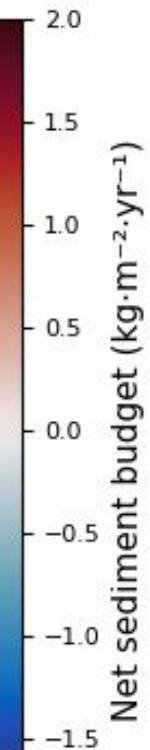
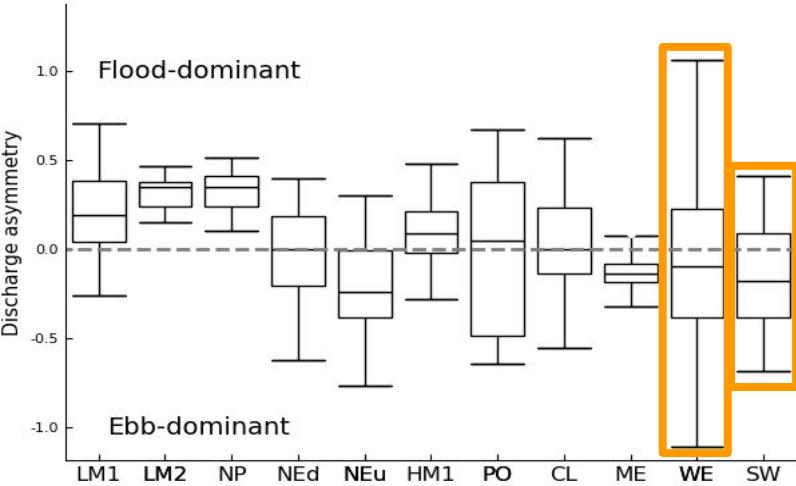
Hydrodynamic variability → Sediment flux variability



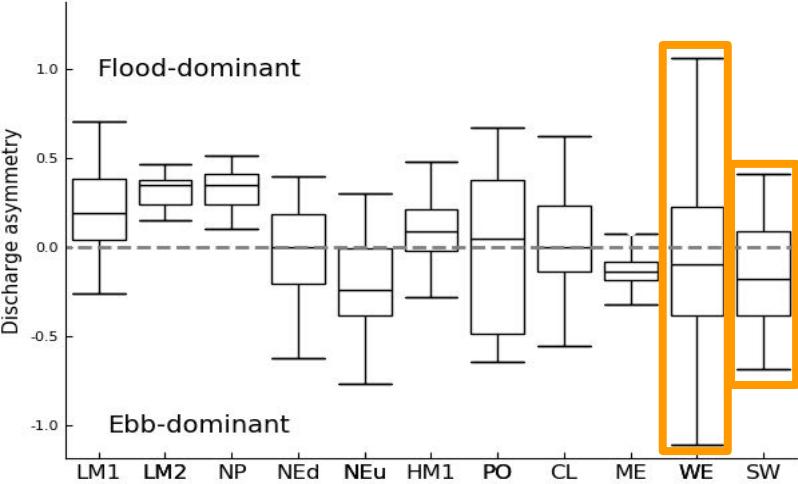
Discharge asymmetry a function of elevation



But ebb dominant marshes also import

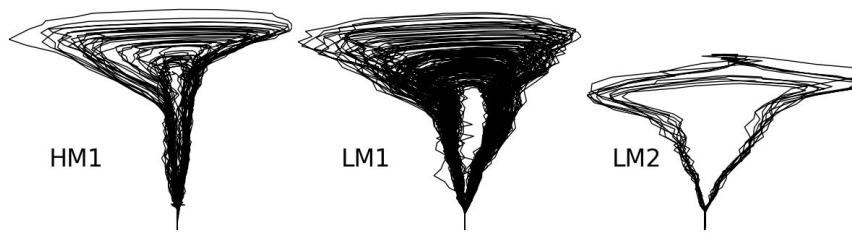
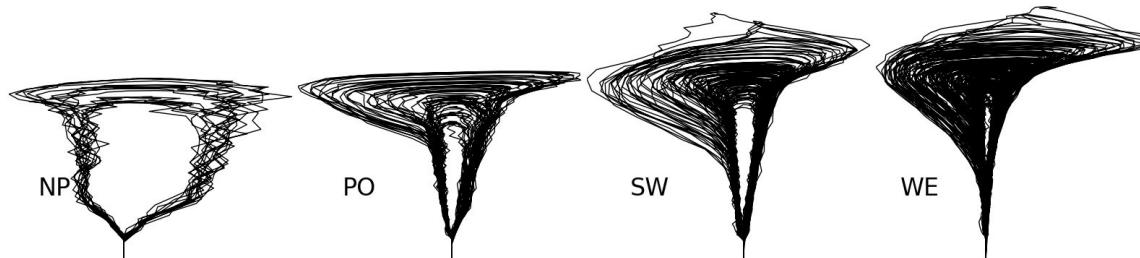
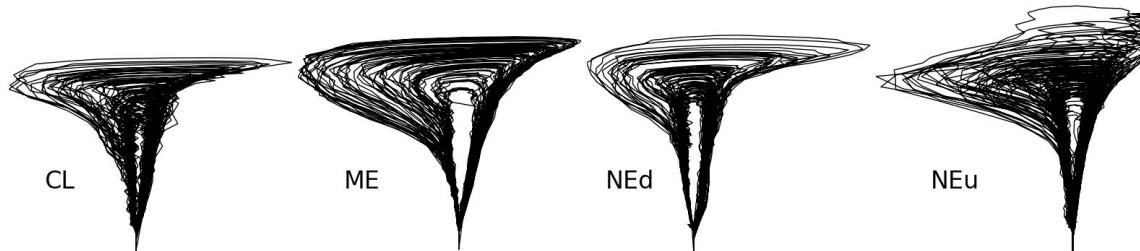


But ebb dominant marshes also import



“simply a site-specific function of marsh morphology and hydrography”?

Stage-discharge plots: the fingerprint of a marsh



Summary

- Net fluxes of sediment depend on the balance between sediment supply from the estuary and local resuspension.

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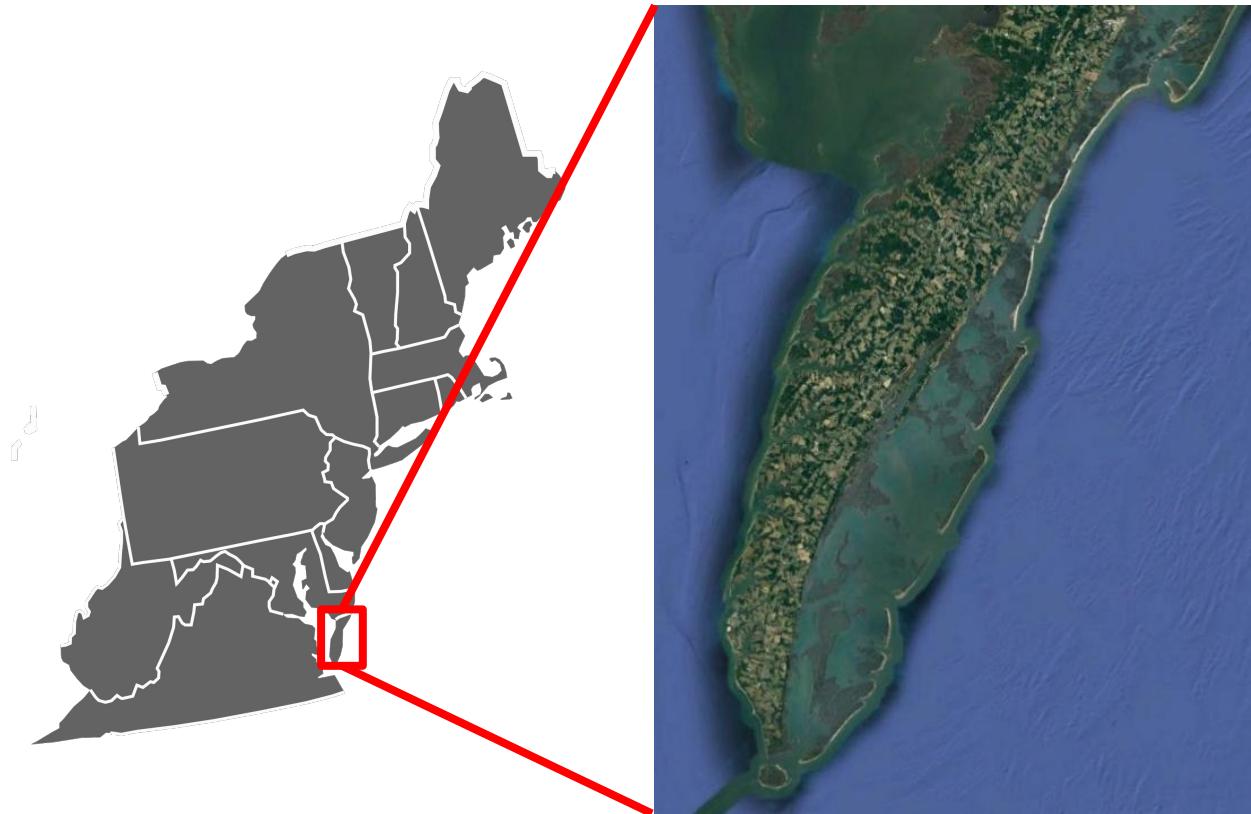
Summary

- Net fluxes of sediment depend on the balance between sediment supply from the estuary and local resuspension.
- Net effect of local resuspension depends on the ebb-flood current asymmetry.
- The variability in sediment supply is driven by estuary-scale gradients in sediment sources.

Inference of sediment exchanges in a coastal lagoon

With Matthew Reidenbach, UVA

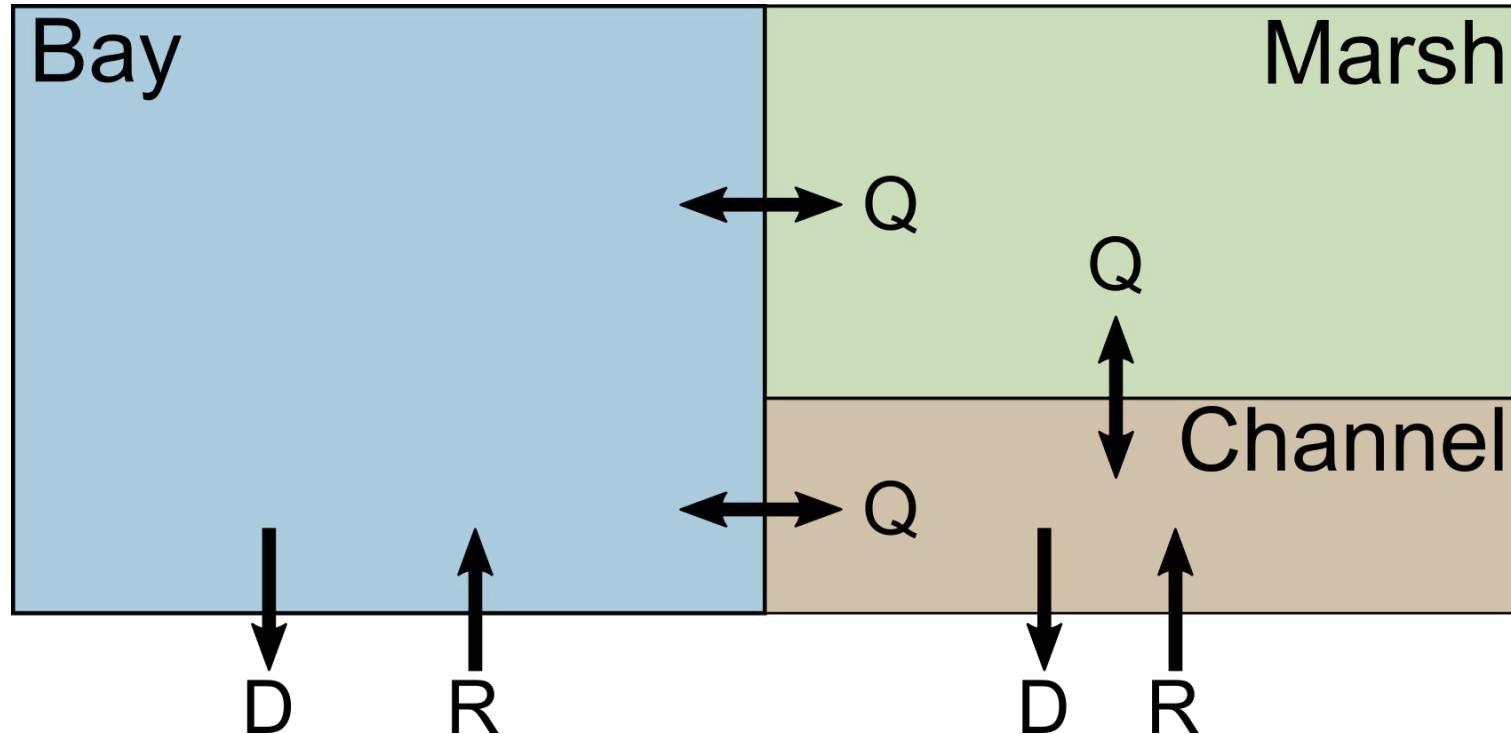
Virginia Coast Reserve LTER



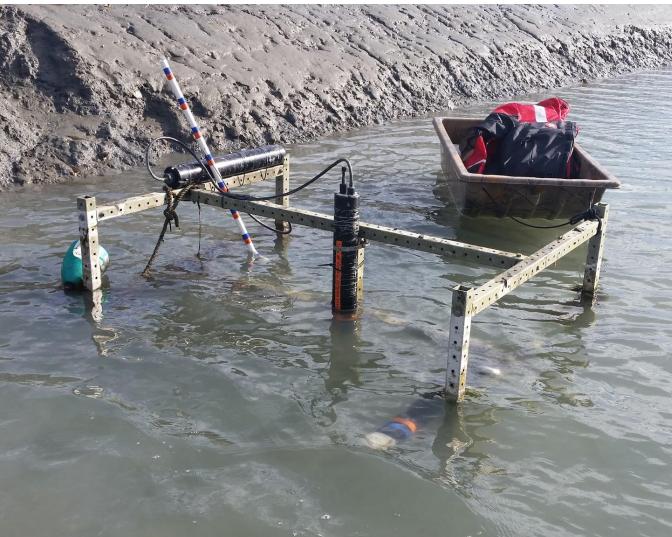
Virginia Coast Reserve LTER



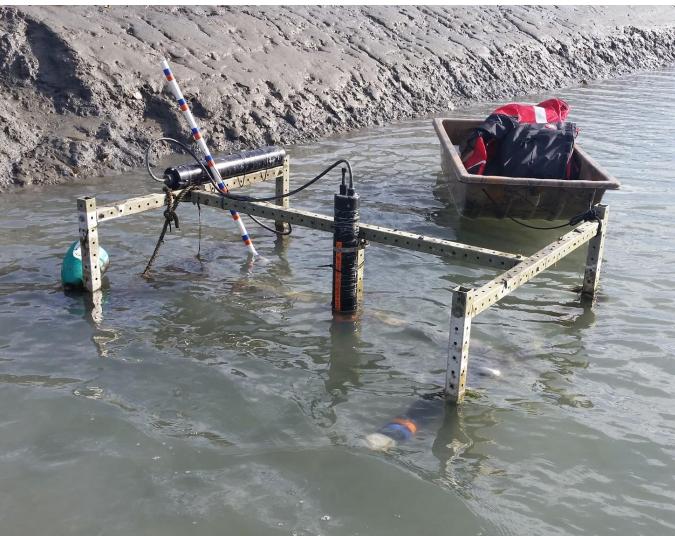
Revisiting the model of sediment exchange



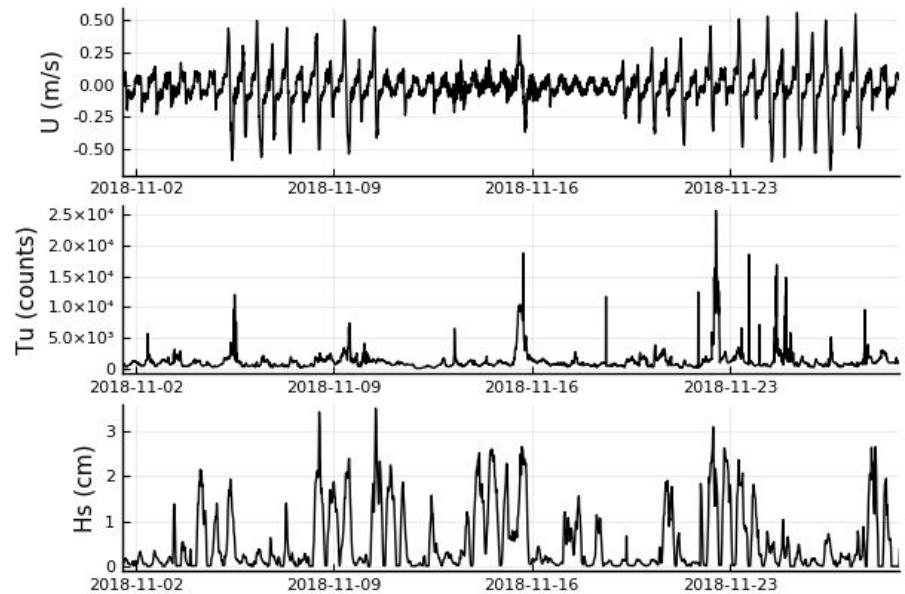
The Short Prong instrument suite



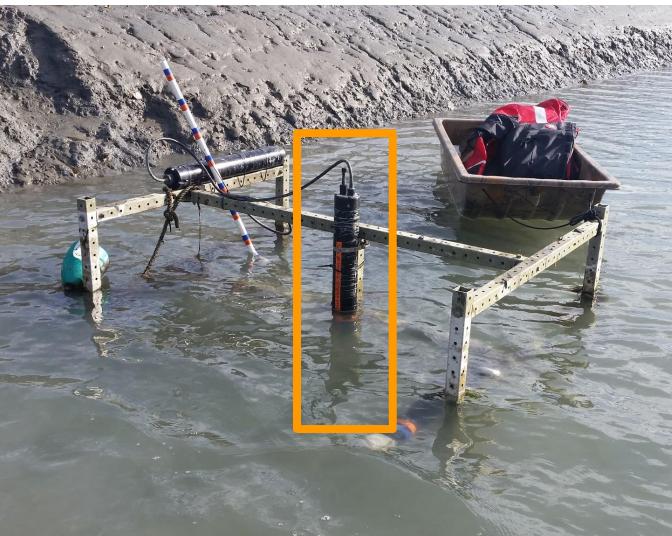
The Short Prong instrument suite



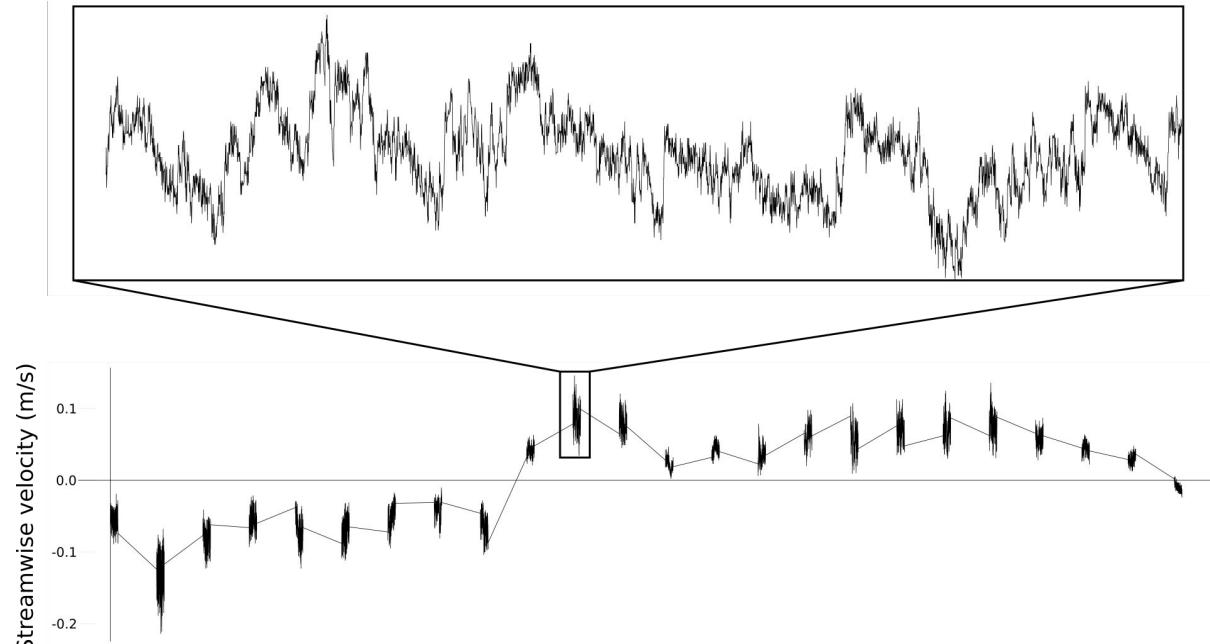
- ADCP + OBS
- Bay wave gauge



The Short Prong instrument suite



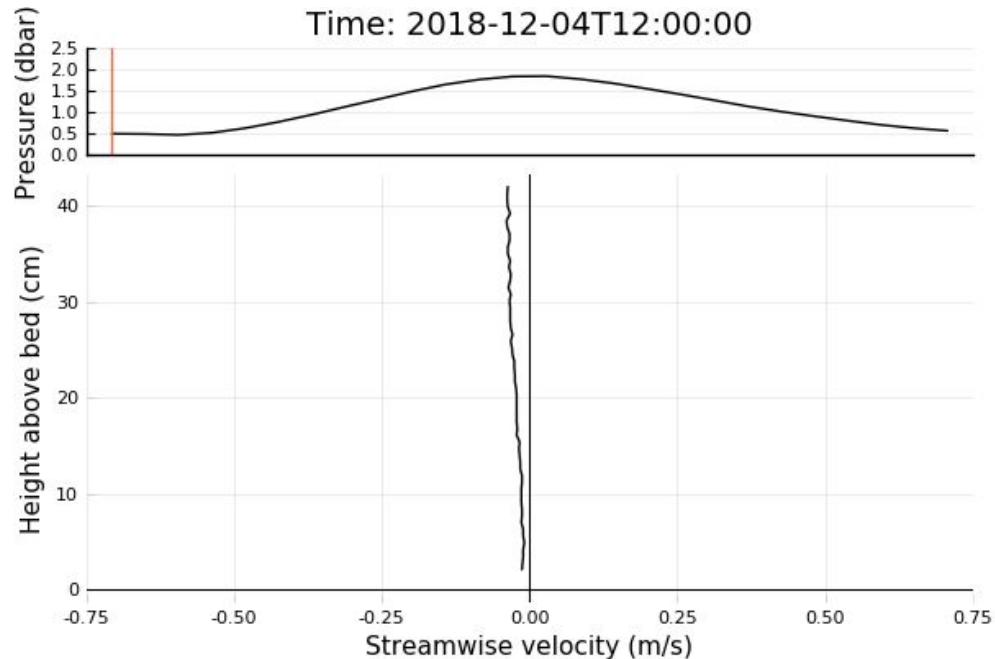
- ADCP + OBS
- Bay wave gauge
- Acoustic Doppler velocimeter @ 16 Hz



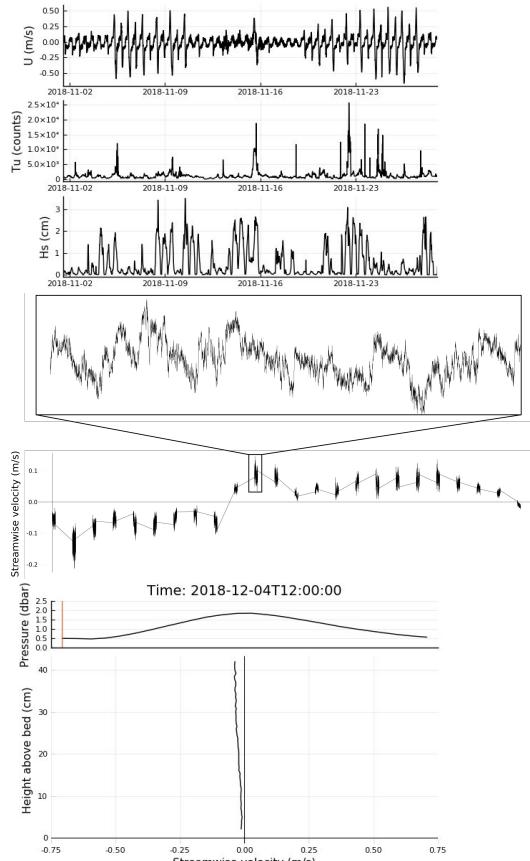
The Short Prong instrument suite



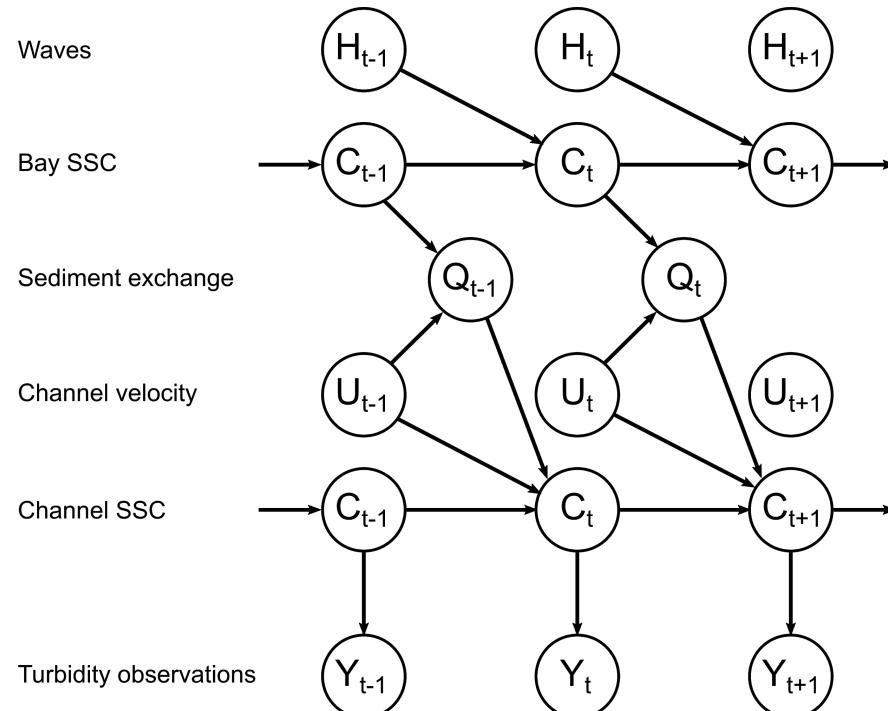
- ADCP + OBS
- Bay wave gauge
- Acoustic Doppler velocimeter @ 16 Hz
- Downward-looking high-resolution ADCP



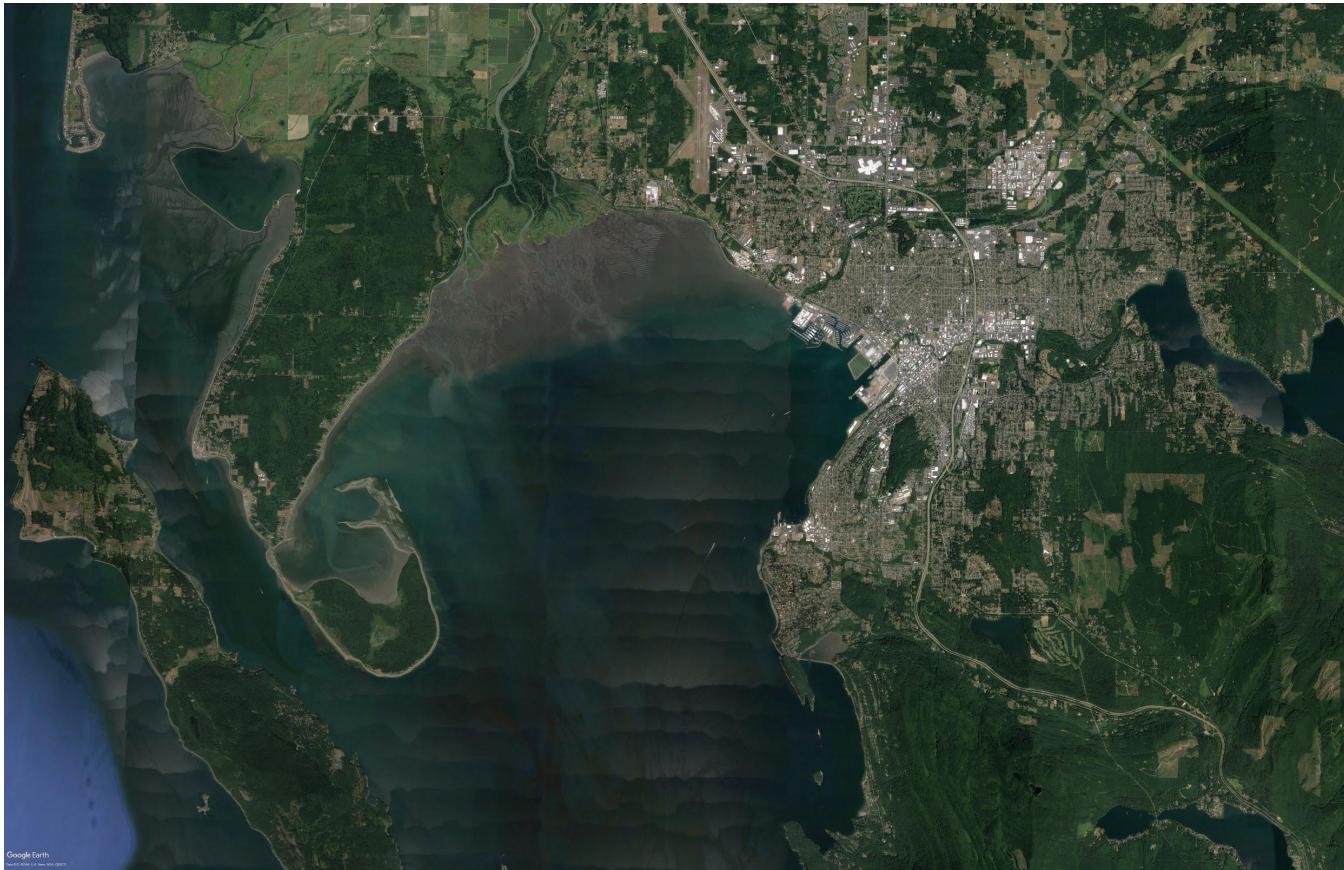
State-space modeling of the Short Prong data



Goal: Make statistical inferences on the sediment exchange by synthesizing these observations.



Bay-wetland exchange in Bellingham Bay



Acknowledgements

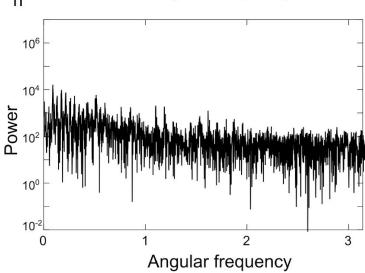
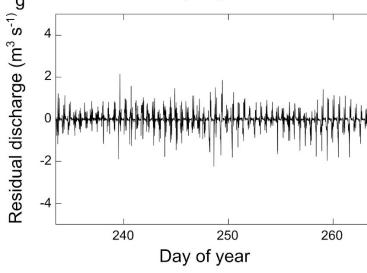
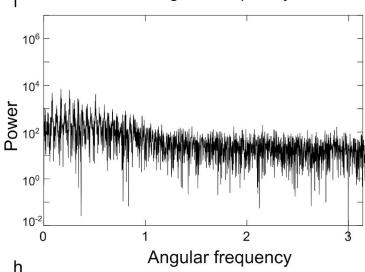
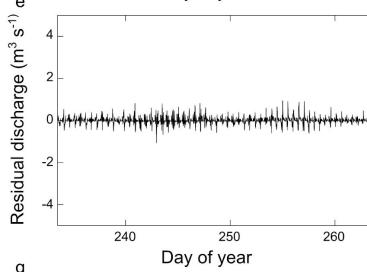
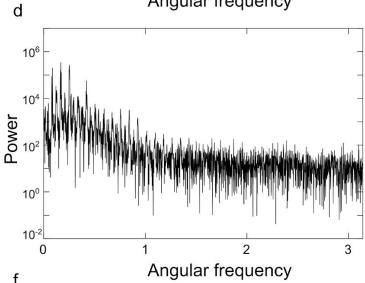
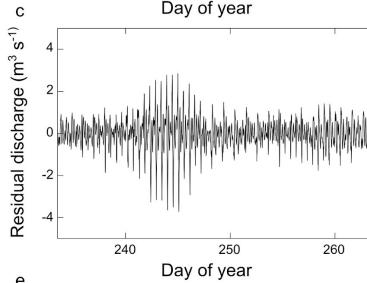
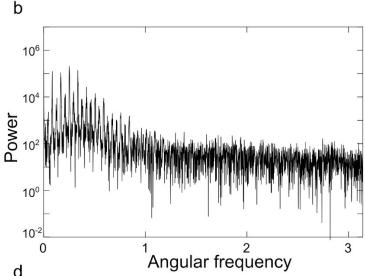
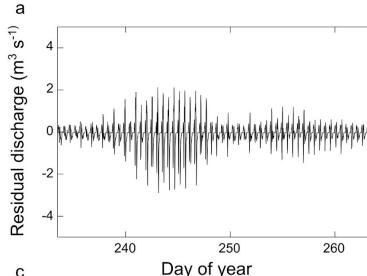
- Collaborators: Sergio Fagherazzi, Giulio Mariotti, Neil Ganju, Zafer Defne, Nat Weston, Linda Deegan, Inke Forbrich, Anne Giblin, Matthew Reidenbach
- Nancy Pau, USFWS
- Hillary Sullivan, David Behringer, Ian Craick, Amanda Davis, Brian Donnelly
- Students of the BU Marine Program
- PIE LTER + VCR LTER
- NSF DEB-1354251, DEB-1832221, OCE-1238212, OCE-1637630, OCE-1151314, Warren-McLeod Summer Research Fellowship

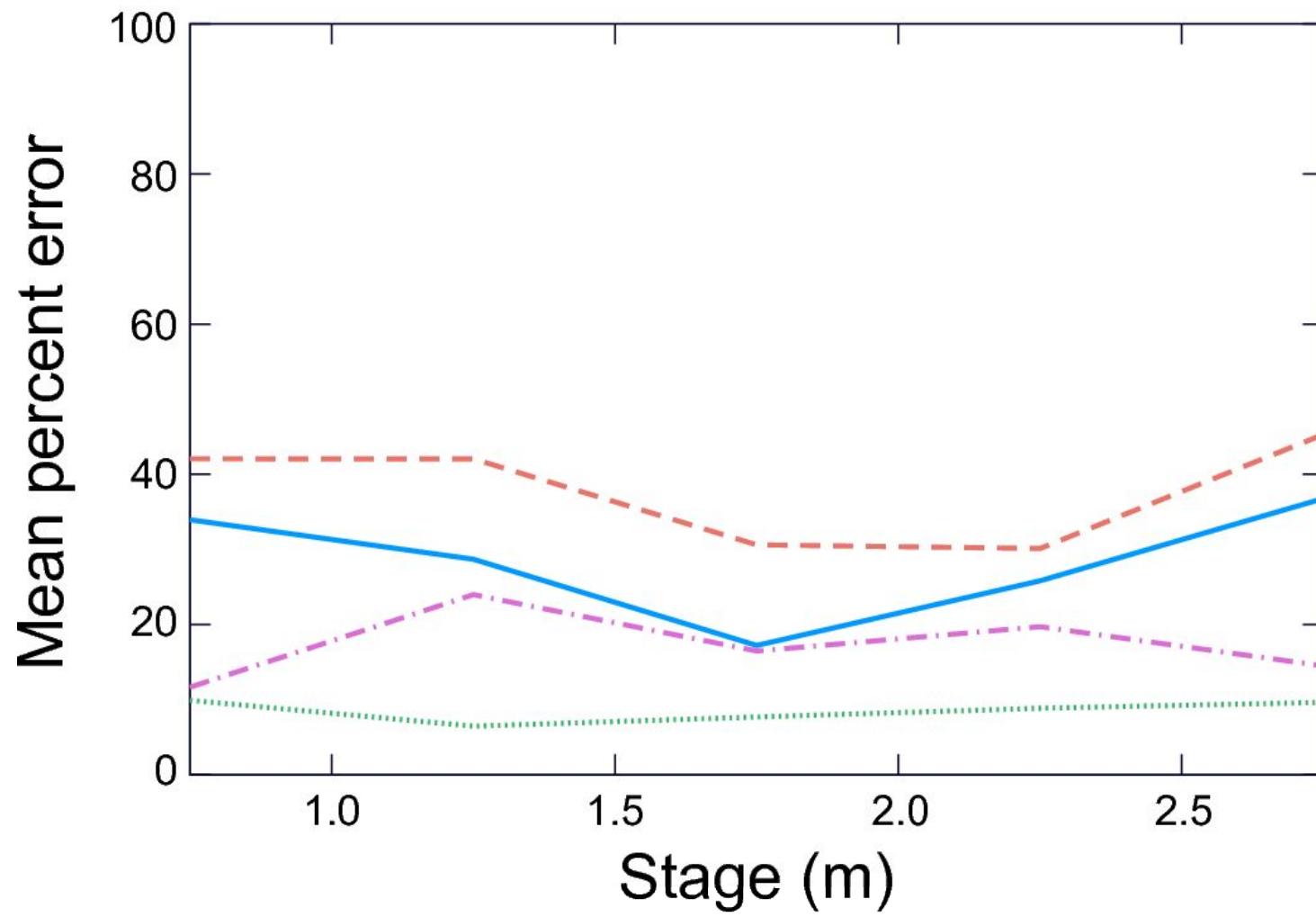


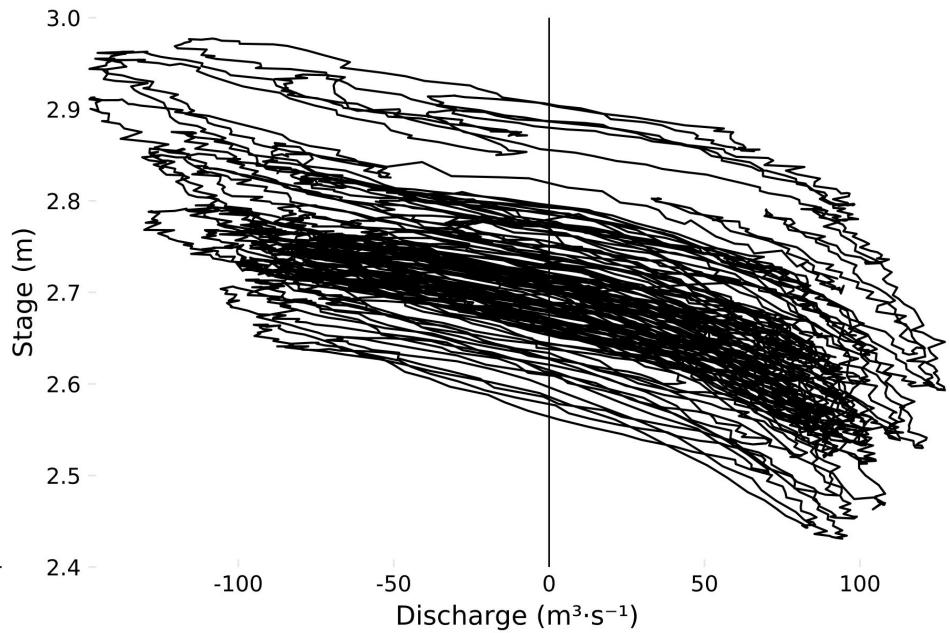
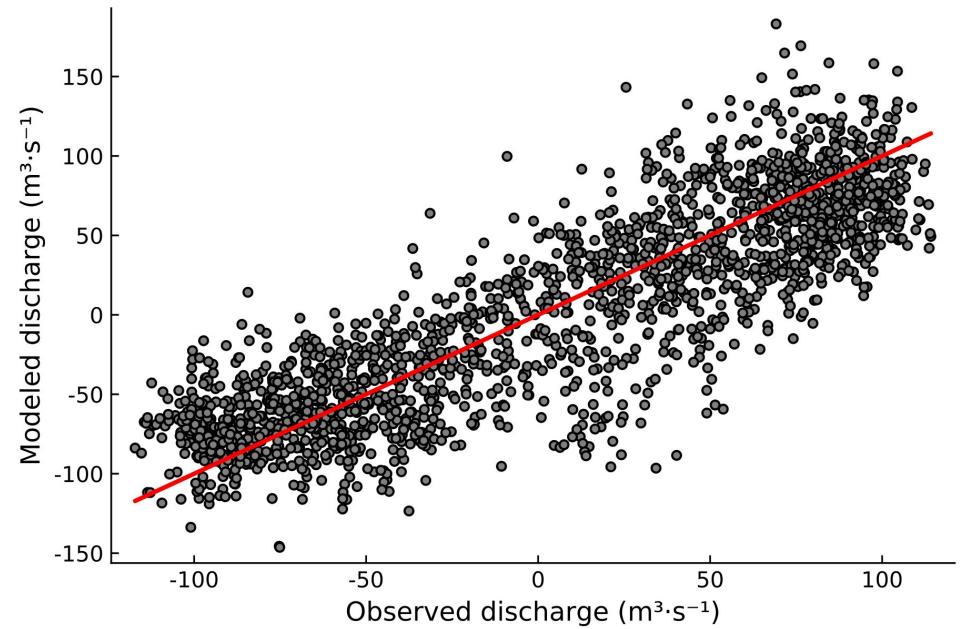
Conclusions

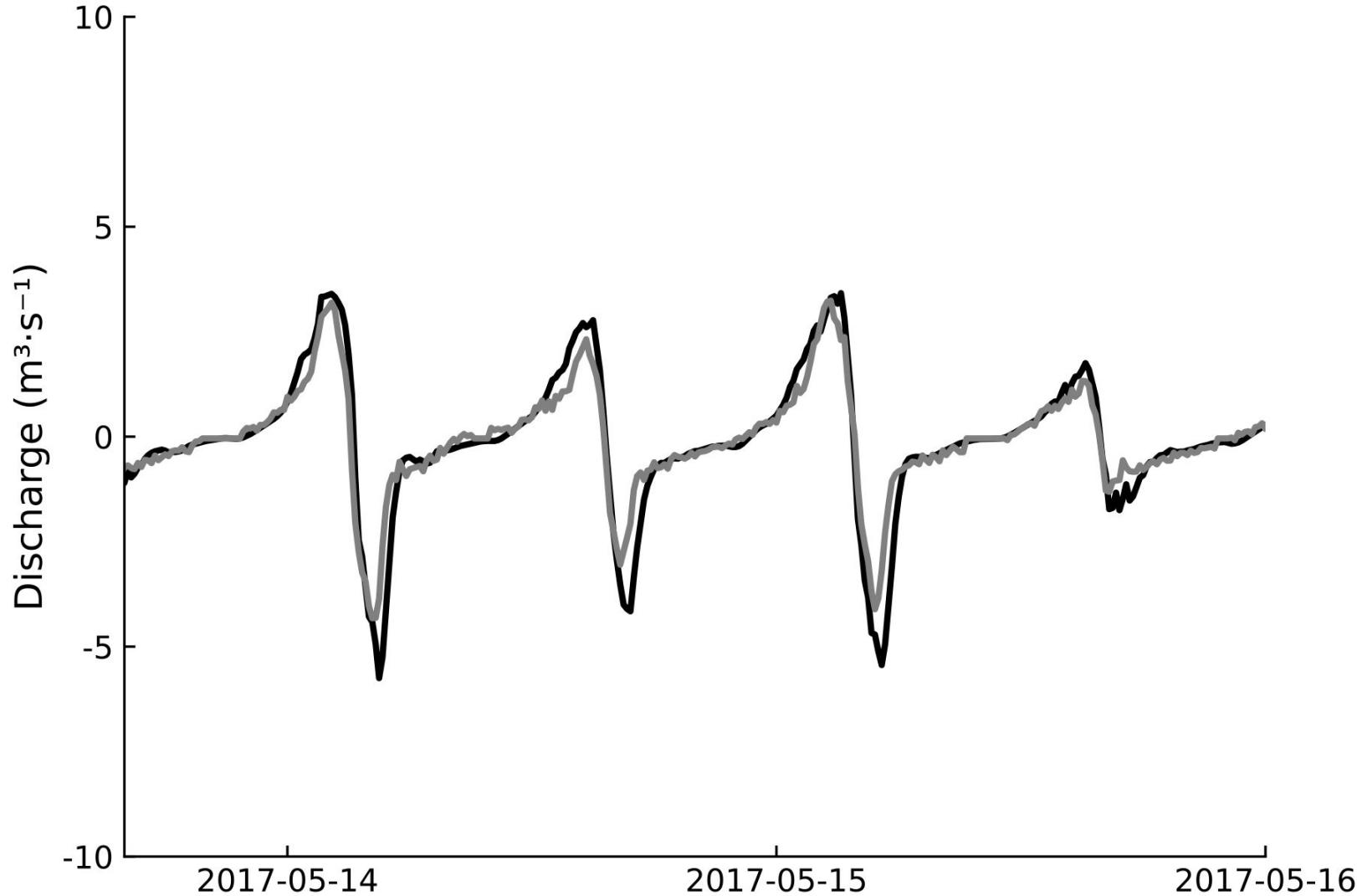
- Fluxes **are** a “site-specific function of marsh morphology and hydrology.”
- Tidal asymmetry is a fundamental physical parameter of a given marsh.
- Physically inspired machine learning models enable more efficient use of limited flux observations.
- Spatial variability in fluxes is controlled by spatial variability in hydrodynamics and sediment supply.

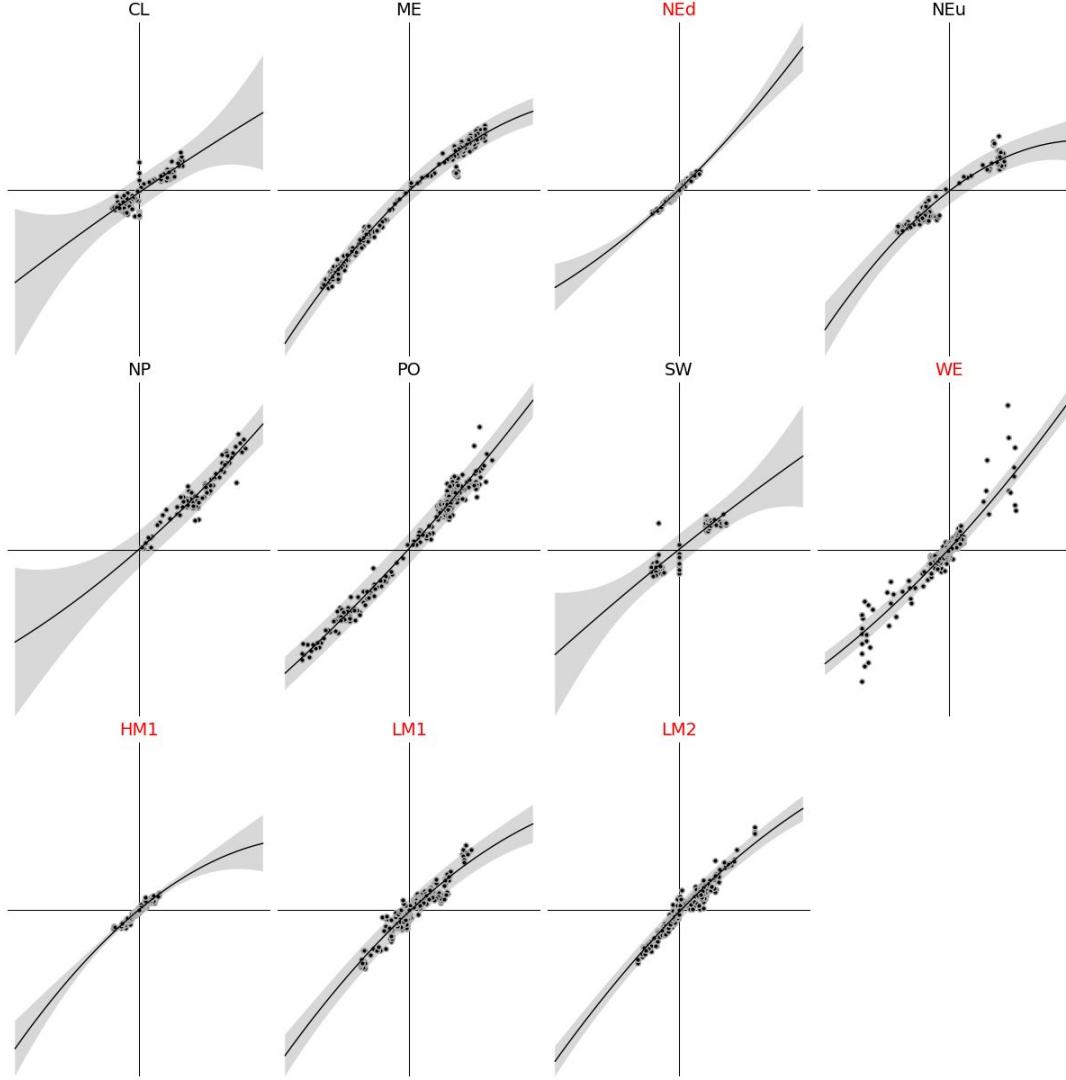


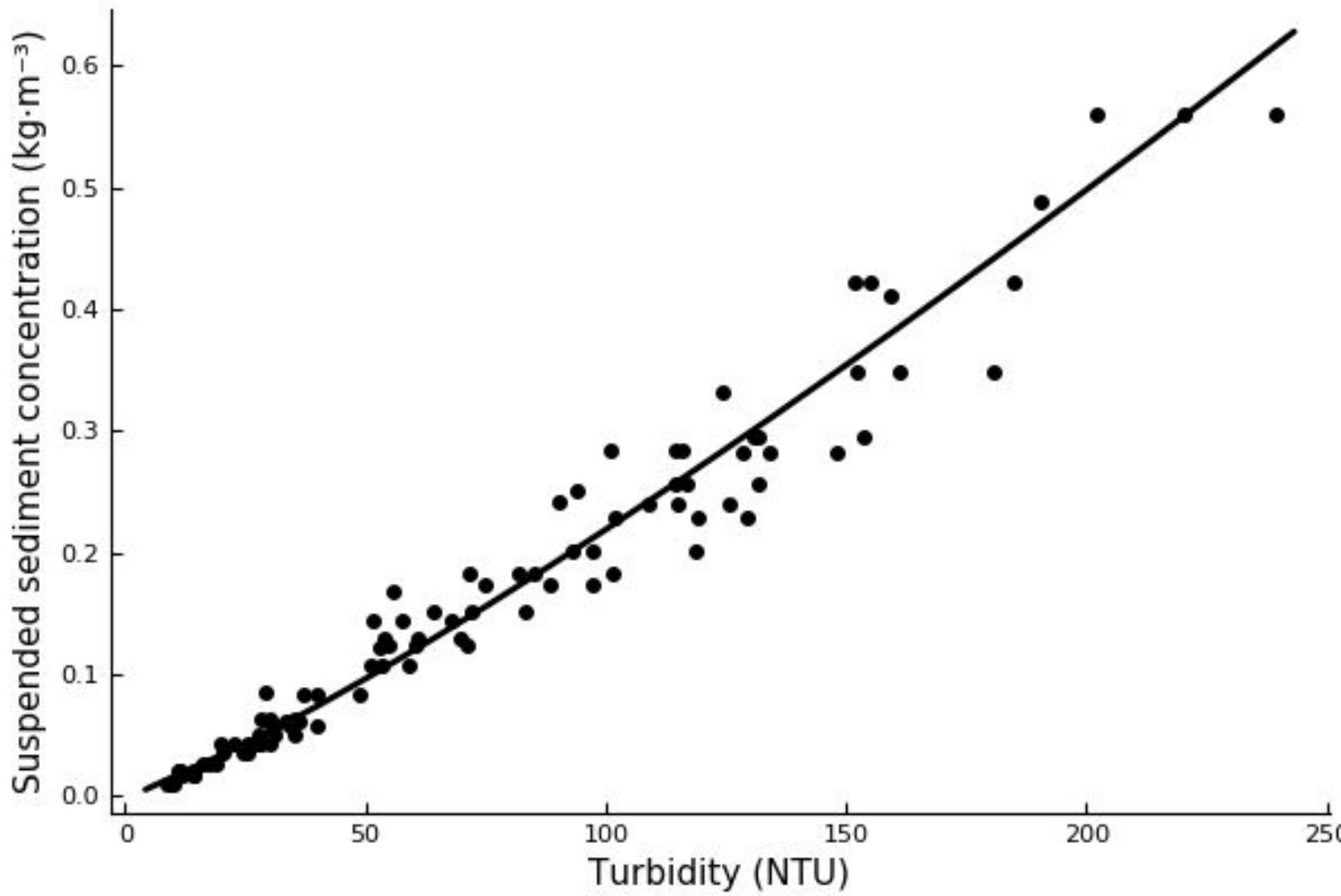


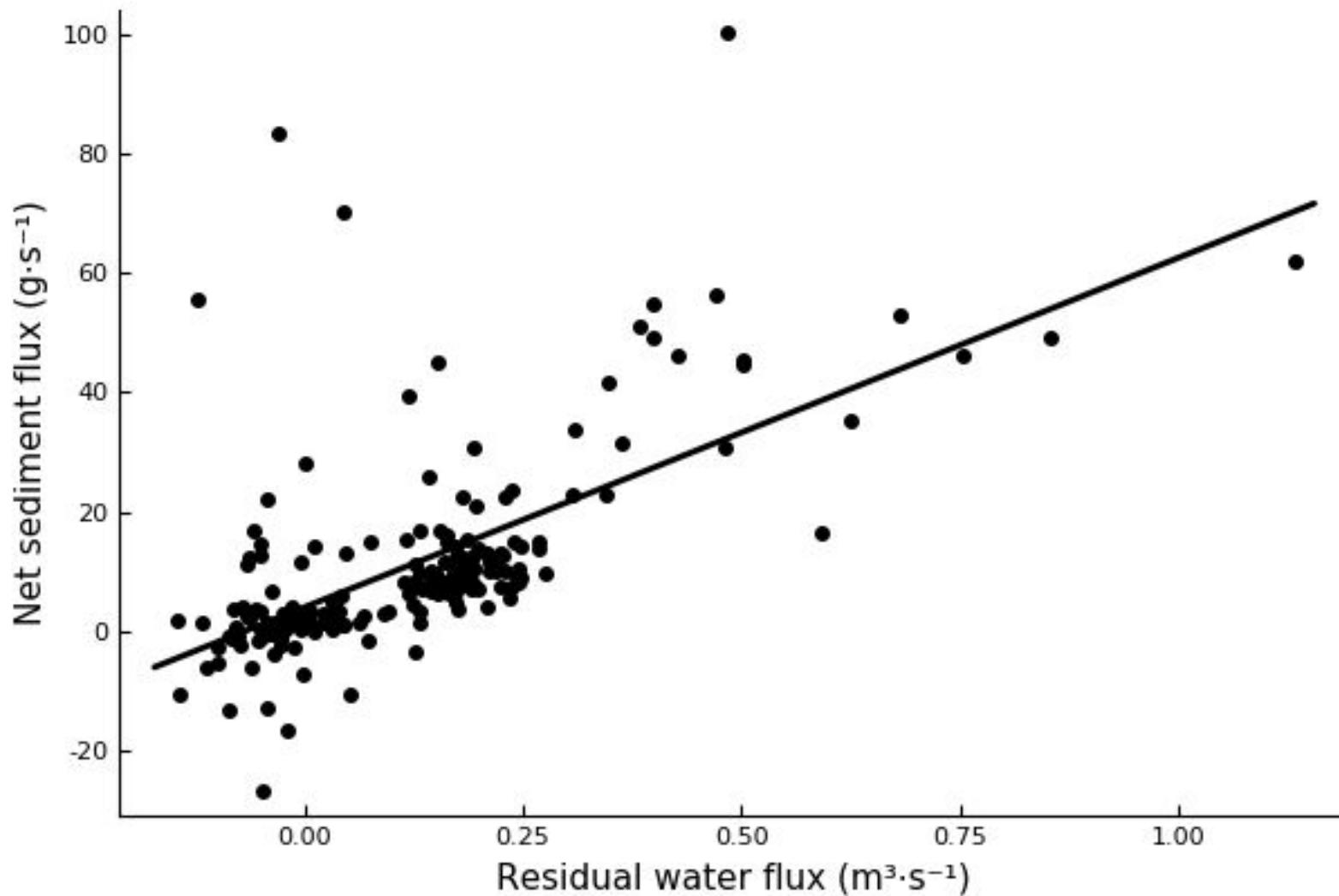










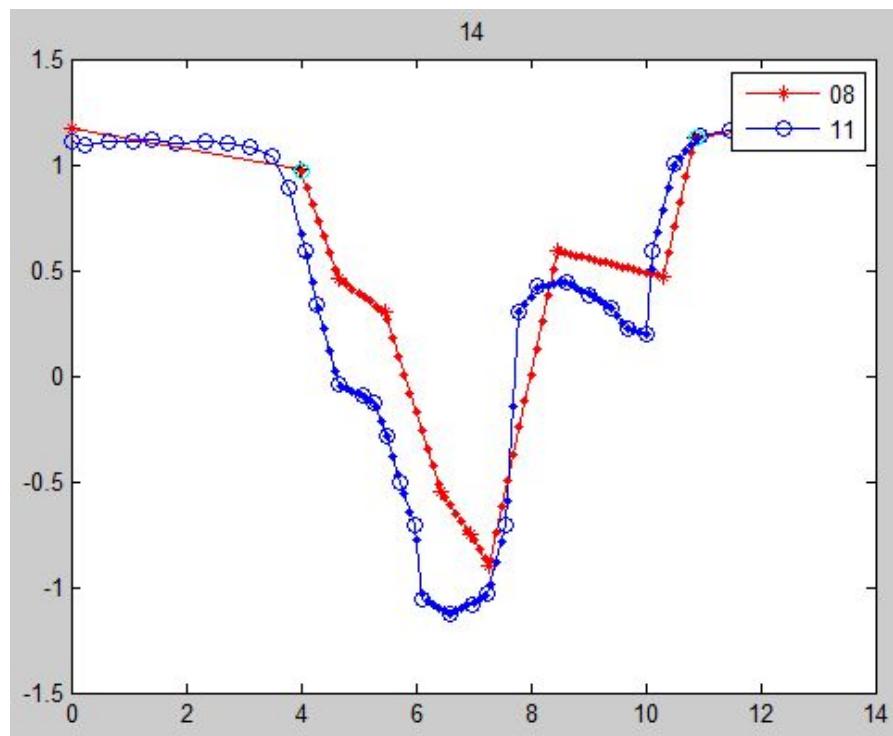
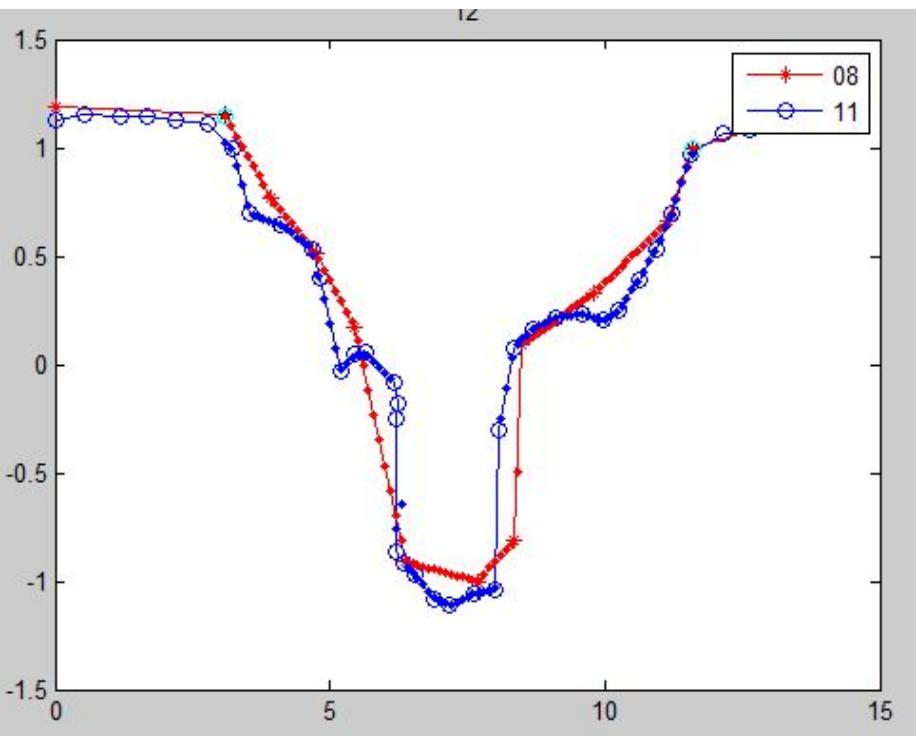


Reference

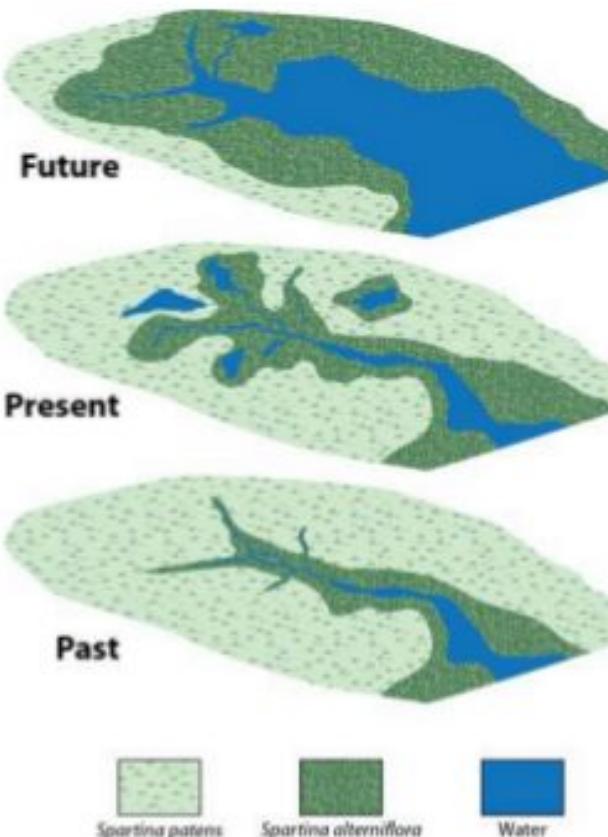
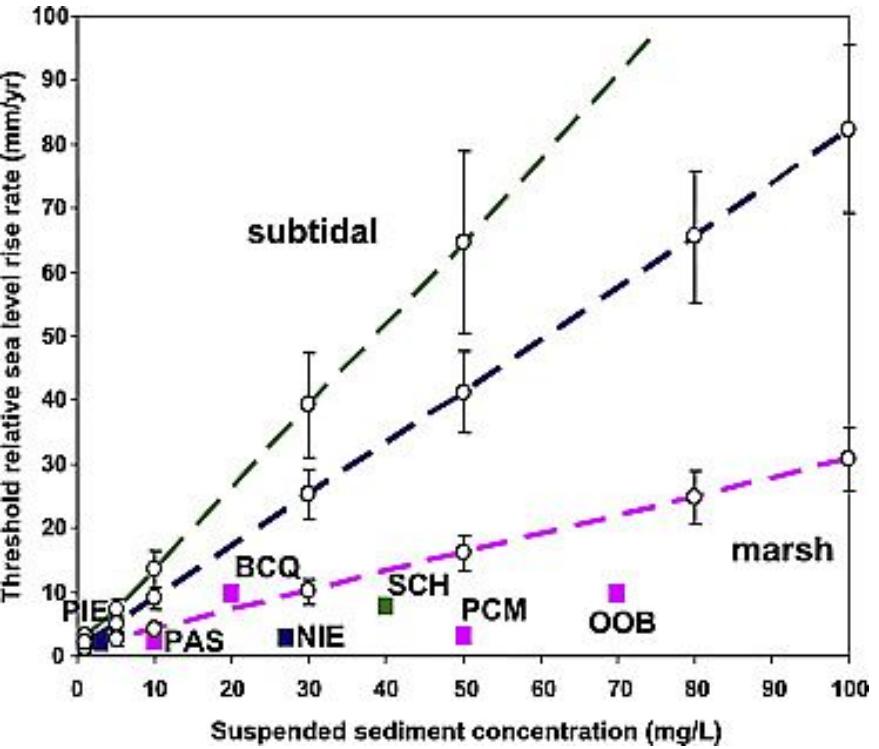


Nutrient-enriched



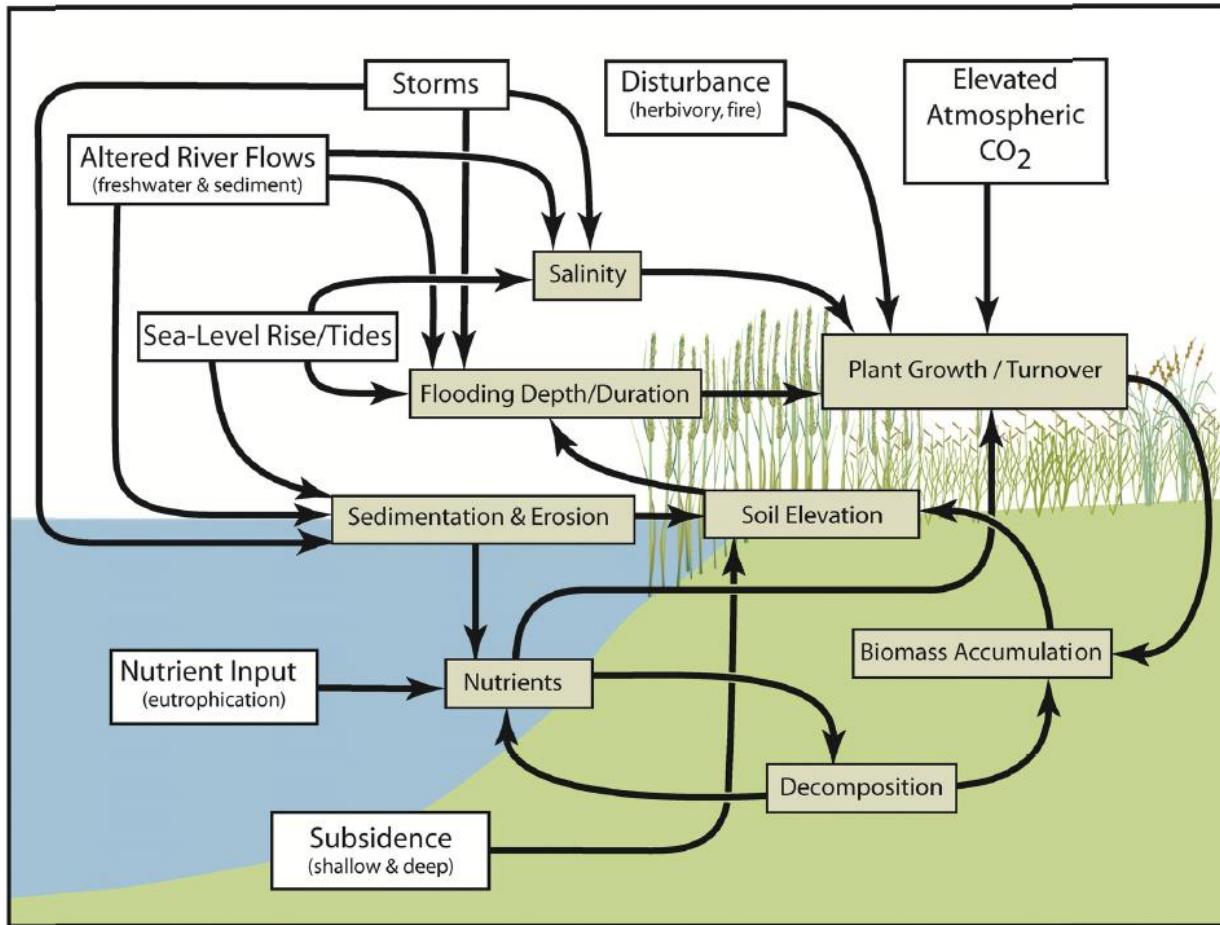


GPS cross-sections of fertilized salt marsh channels collected by
students in Estuaries and Nearshore Systems

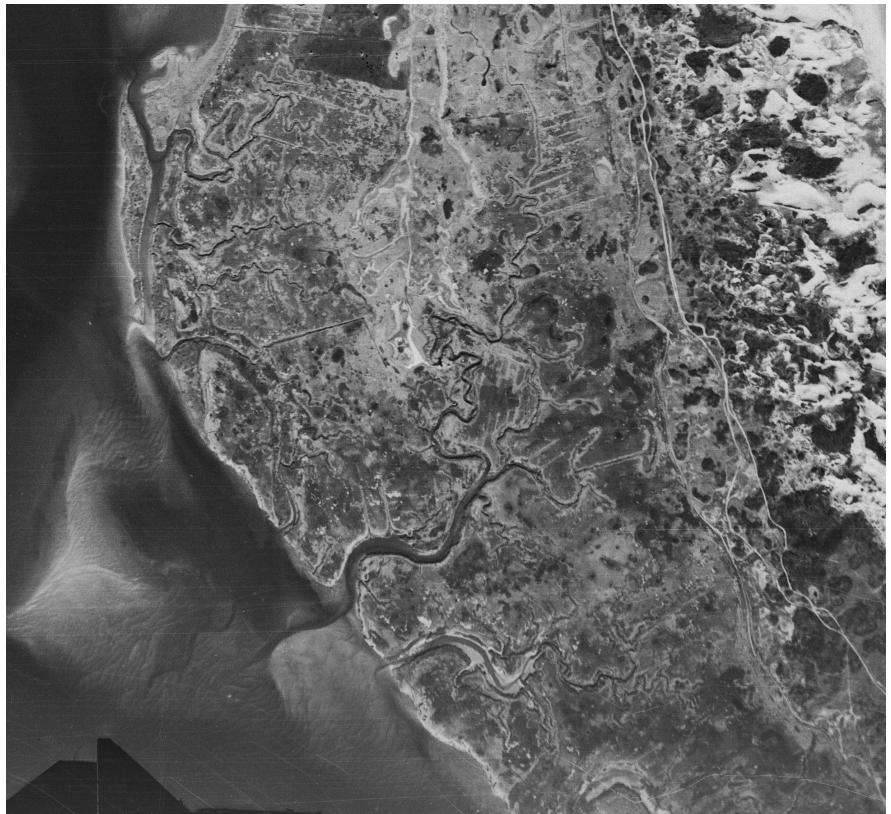


Craig Tobias and Scott Neubauer (2019). Salt marsh biogeochemistry — an overview :

“High variability in terms of hydrology, basin age, and geomorphological setting, among other features, makes it a futile task to draw broad conclusions with respect to the direction and magnitude of particulate and dissolved organic C (POC and DOC) fluxes that will apply to all marshes at all times.”



The North Pool



1938



2018

