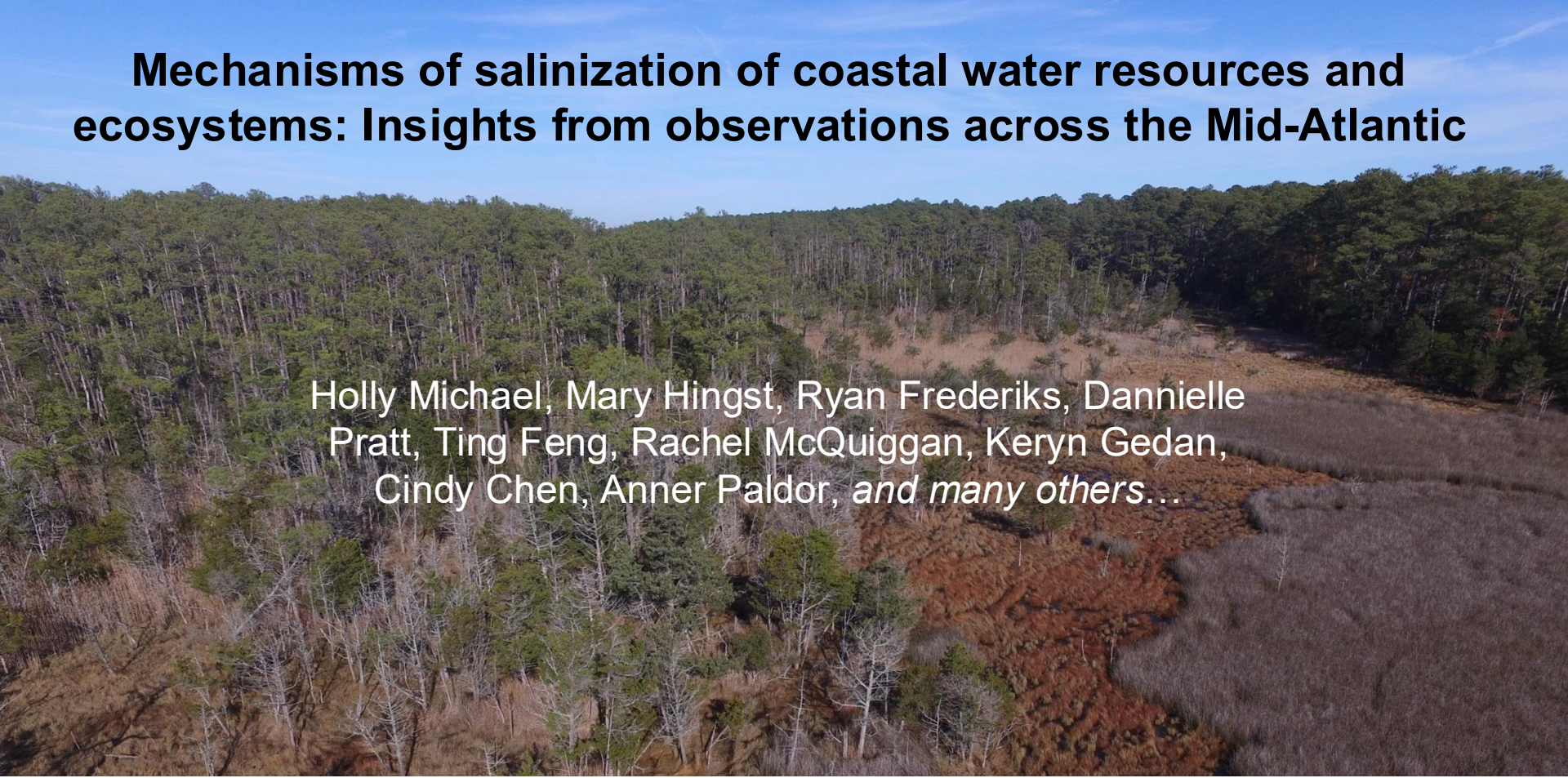
Mechanisms of salinization of coastal water resources and ecosystems: Insights from observations across the Mid-Atlantic



Holly Michael, Mary Hingst, Ryan Frederiks, Dannielle Pratt, Ting Feng, Rachel McQuiggan, Keryn Gedan, Cindy Chen, Anner Paldor, *and many others*…

PROJECT WiCCED WATER in the CHANGING COASTAL ENVIRONMENT of DELAWARE

NSF

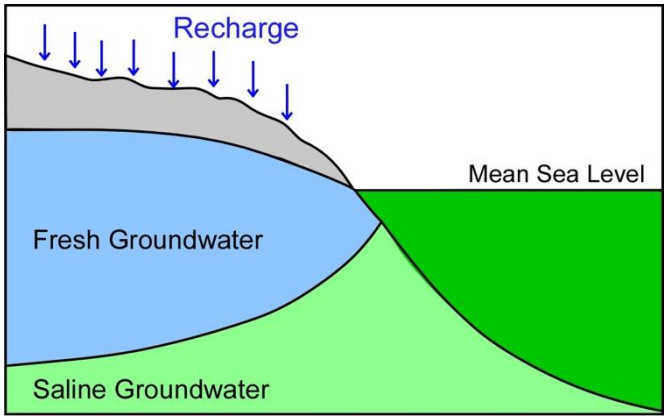
Delaware EPSCoR

UNIVERSITY OF DELAWARE DELAWARE ENVIRONMENTAL INSTITUTE

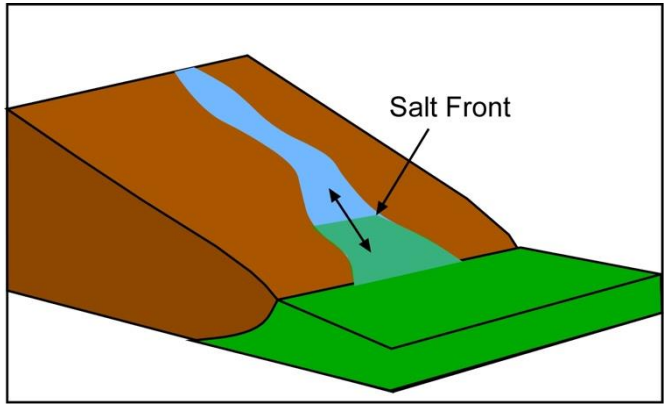
Coastal Critical Zone Network

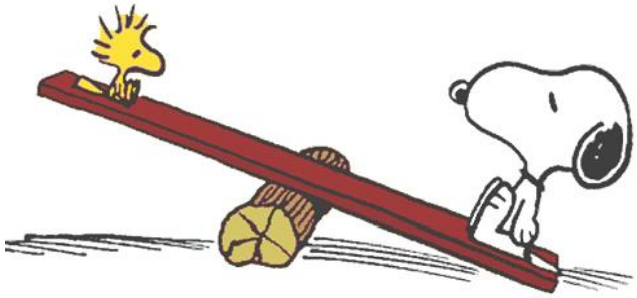
Coastal Hydrology is a land-sea balance

Groundwater

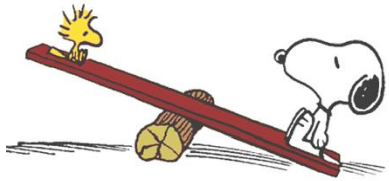


Surface Water

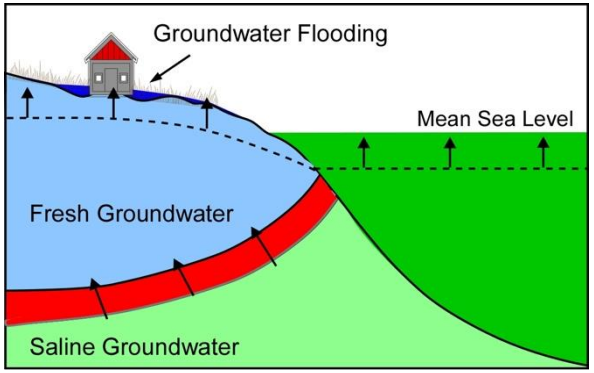




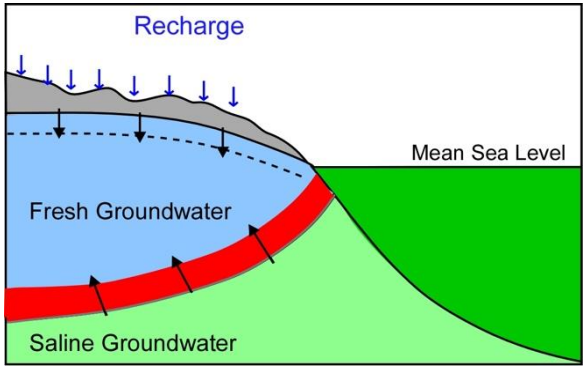
Mechanisms of Saltwater Intrusion into groundwater and surface water



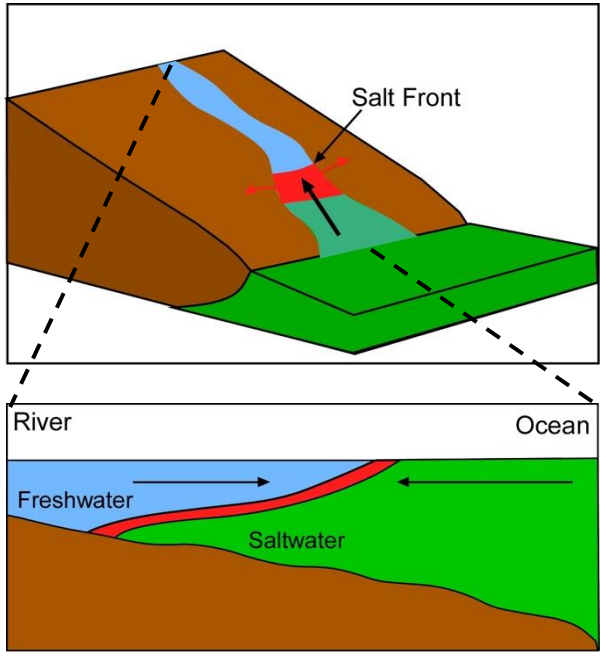
Sea Level-Rise



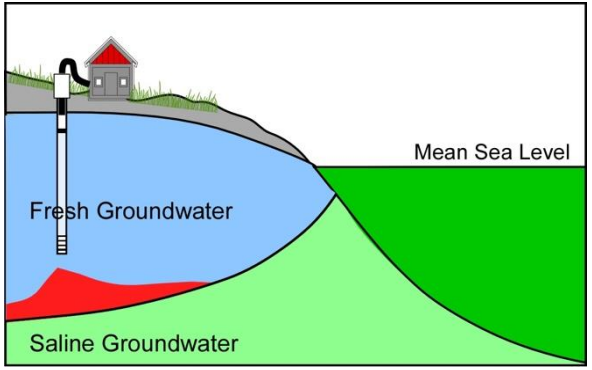
Reduced Rainfall



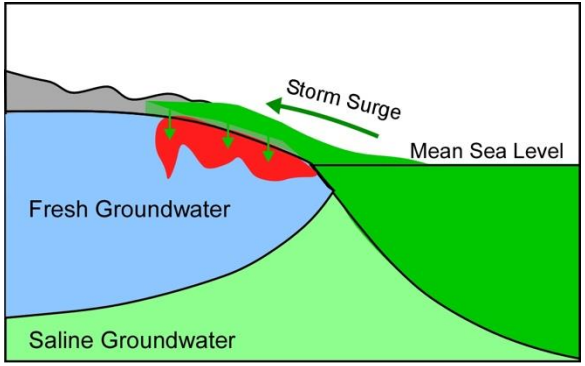
Stream Salinization



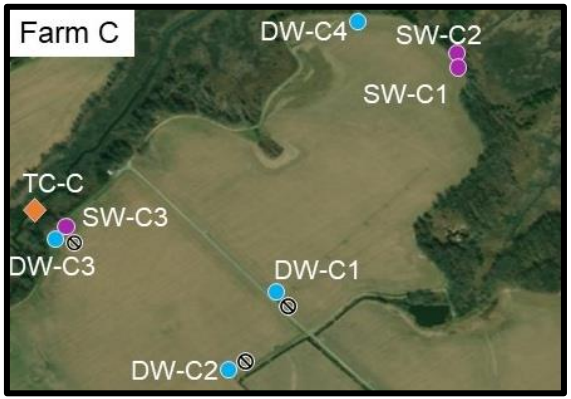
Pumping



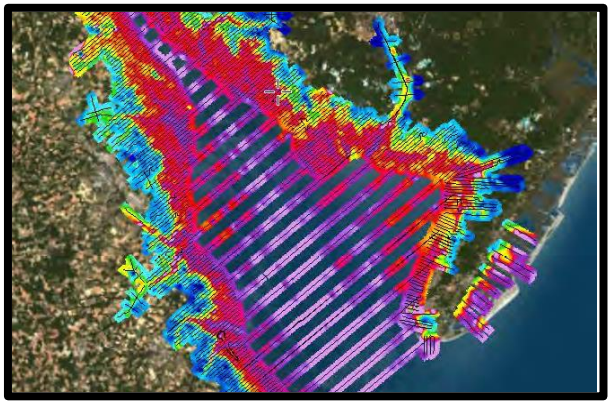
Storm Surges



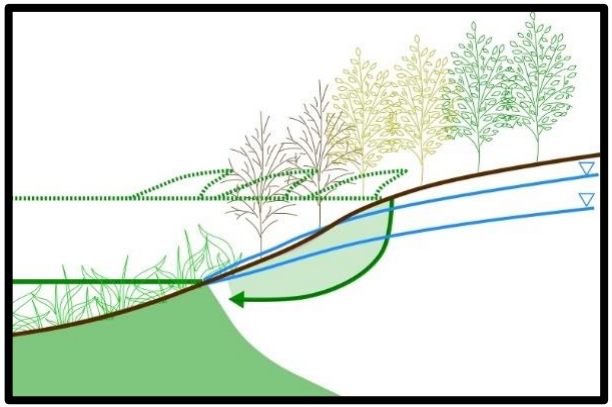
Some examples from around the Delmarva:



Drivers of salinization on farmland and competing water use



Large-scale salinity distributions and vulnerability analysis



Marsh migration into uplands

≡ BAY JOURNAL

Saltwater intrusion laying waste to Delmarva farms as sea level rises

The Southern Maryland Chronicle

abc NEWS

Ocean salt water entering Delaware River due to drought and sea level rise, water managers say

Drinking water is not yet impacted, but officials are taking urgent measures.

By Julia Jacobo, Daniel Manzo, and Daniel Peck
November 27, 2024, 5:14 PM

Drinking Water Is at Risk in Parts of Long Island, Study Finds

Decades of pumping have allowed saltwater to threaten the aquifers that supply many communities, including Long Beach and Great Neck.

Listen to this article · 5:11 min Learn more Share full article 71

Homes in Long Beach, N.Y., one of several areas facing increasing risk of saltwater contamination of the groundwater. Tony Cenicola/The New York Times

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U.S. NEWS

Surfside collapse exposes an overlooked threat: Saltwater rising from underground

Researchers are trying to sound the alarm about the danger rising seas could pose to coastal buildings.

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ENVIRONMENT

Ghost forests are sprouting up along the Atlantic Coast

And they're as scary as they sound.

By Ula Chrobak | June 5, 2019

NBC News

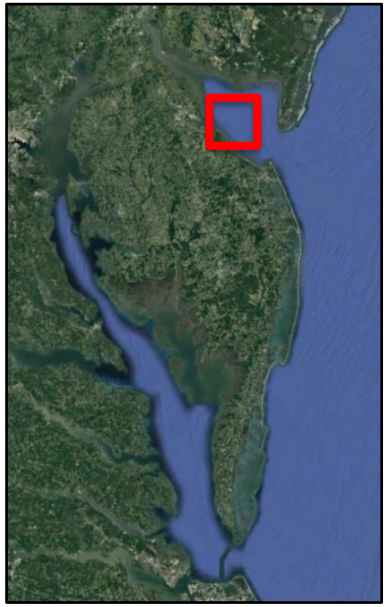
Salinization of water for drinking and irrigation

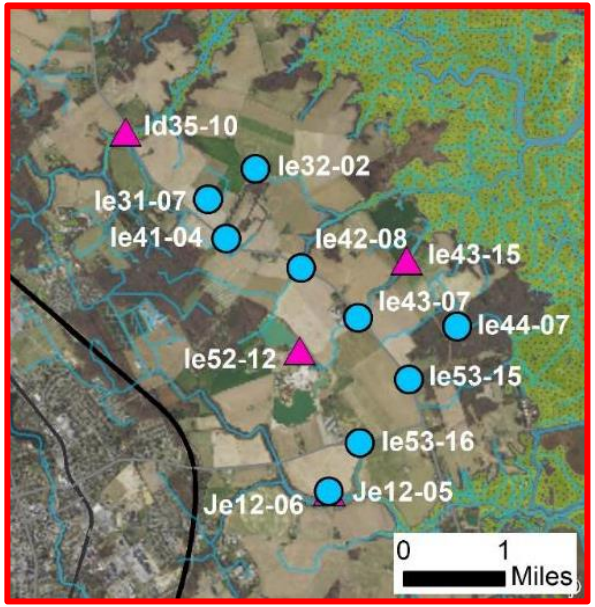
→ Measurements of saltwater intrusion in greater Dover

PROJECT WiCCED
WATER in the CHANGING COASTAL ENVIRONMENT of DELAWARE

40 Monitoring Locations

- Deep and shallow wells
- Streams
- Marshes
- Irrigation ponds





N

Legend

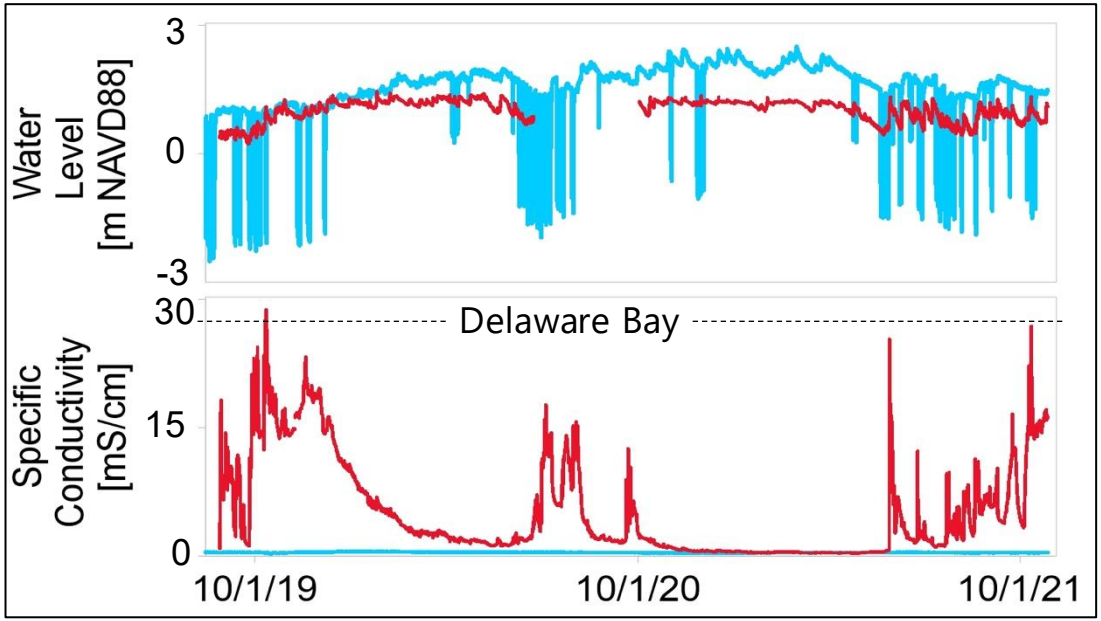
- test/monitoring well
- surface water gage
- temporary tide gage
- streams and rivers
- surface water
- swamp/marsh

Collaborators:

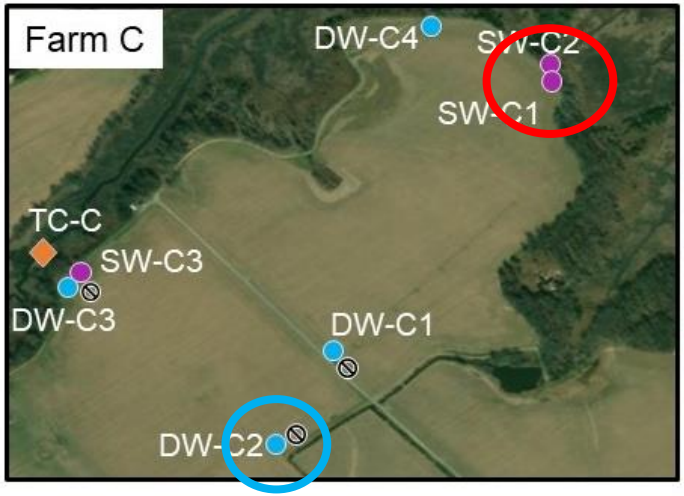
Mary Hingst, UD

Rachel McQuiggan, Scott Andres, Delaware Geological Survey

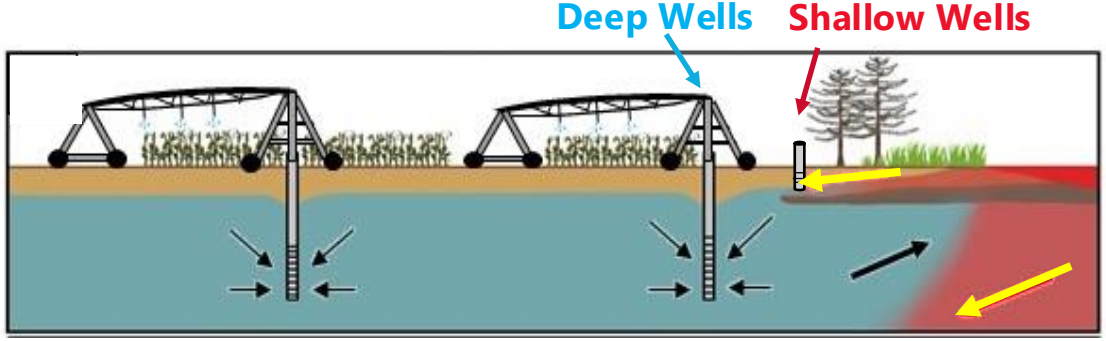
Farm C shallow and deep wells



Shallow Wells



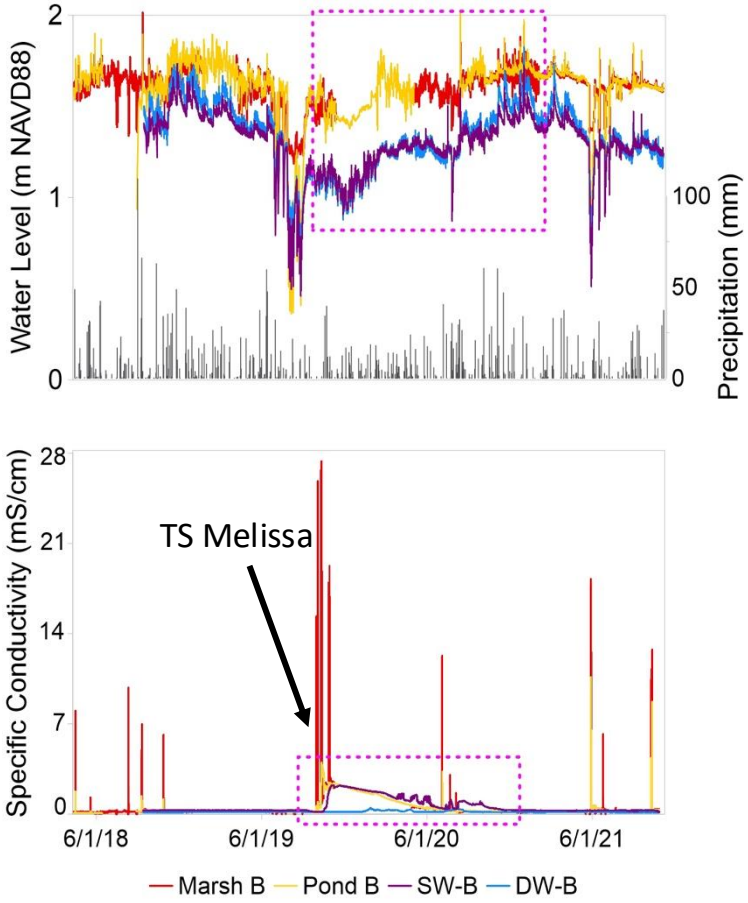
Deep Wells

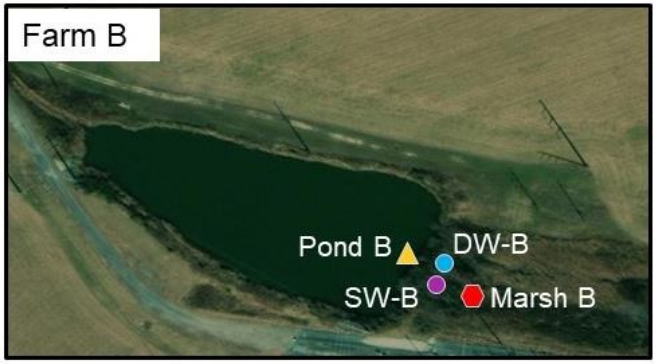


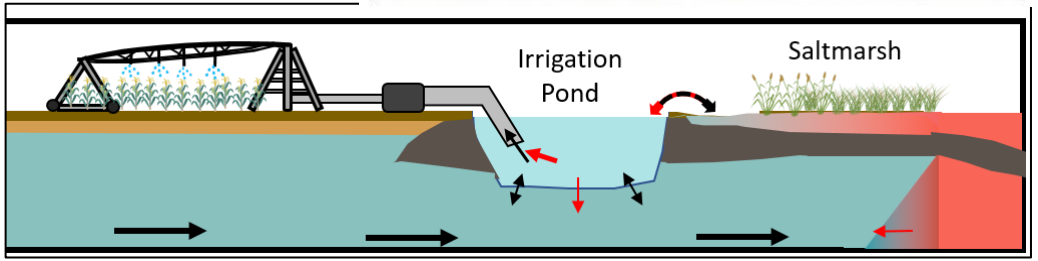
→ ***Shallow salinization due to pumping, storms, drought***

→ ***Deeper groundwater remains fresh, but water levels exacerbate shallow salinization, and deeper SWI is likely on its way***

Farm B marsh, pond, shallow well, deep well



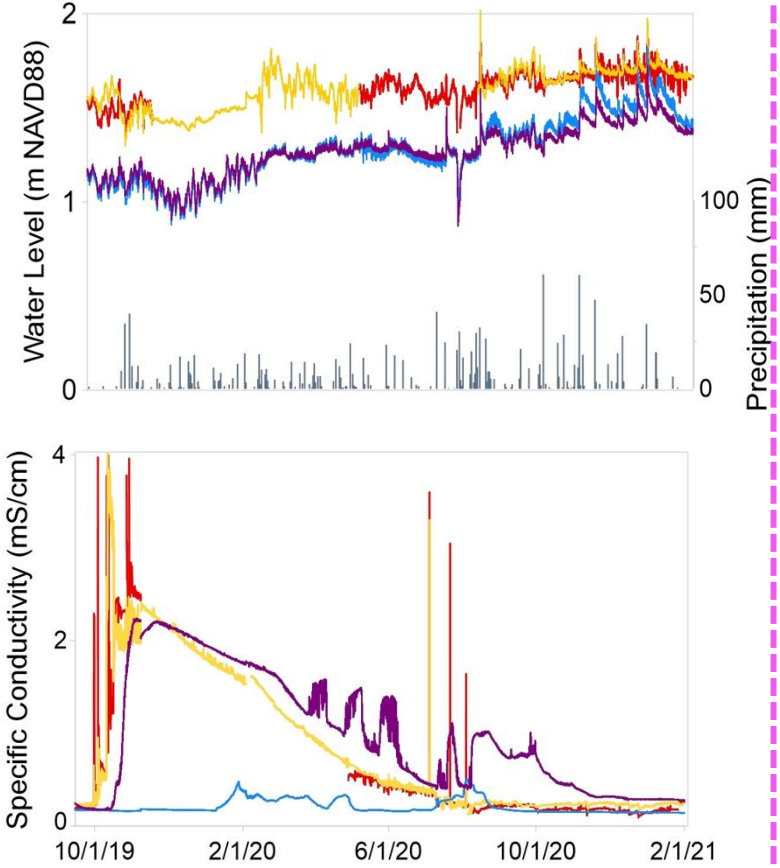


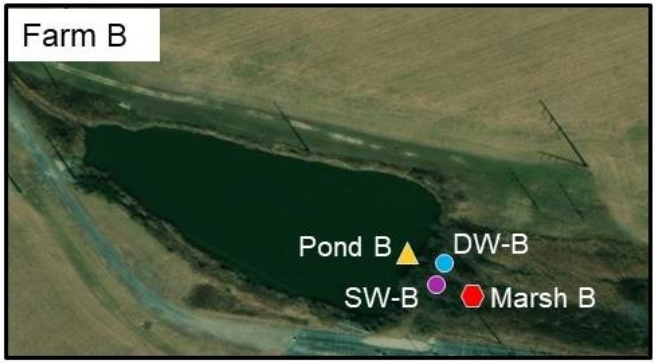


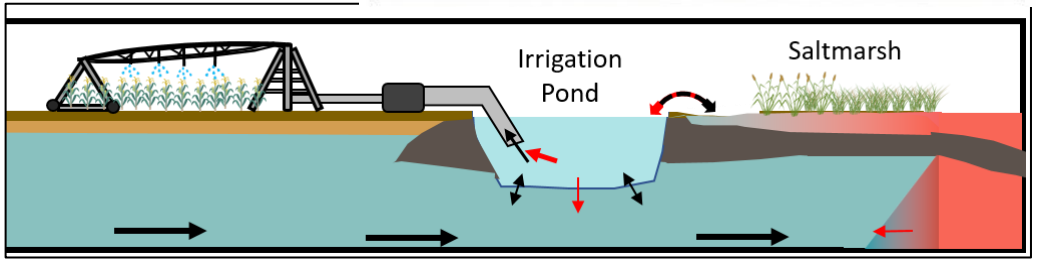
→ ***Tropical Storm Melissa caused a spike in salinity in the marsh and pond***

Hingst et al., *Groundwater*, 2022

Farm B marsh, pond, shallow well, deep well







→ ***Tropical Storm Melissa caused a spike in salinity in the marsh and pond***

→ ***Salinity in the shallow well spiked after 2 weeks***

→ ***Salinity in the deep well rose after a few months and did not recover for almost a year***

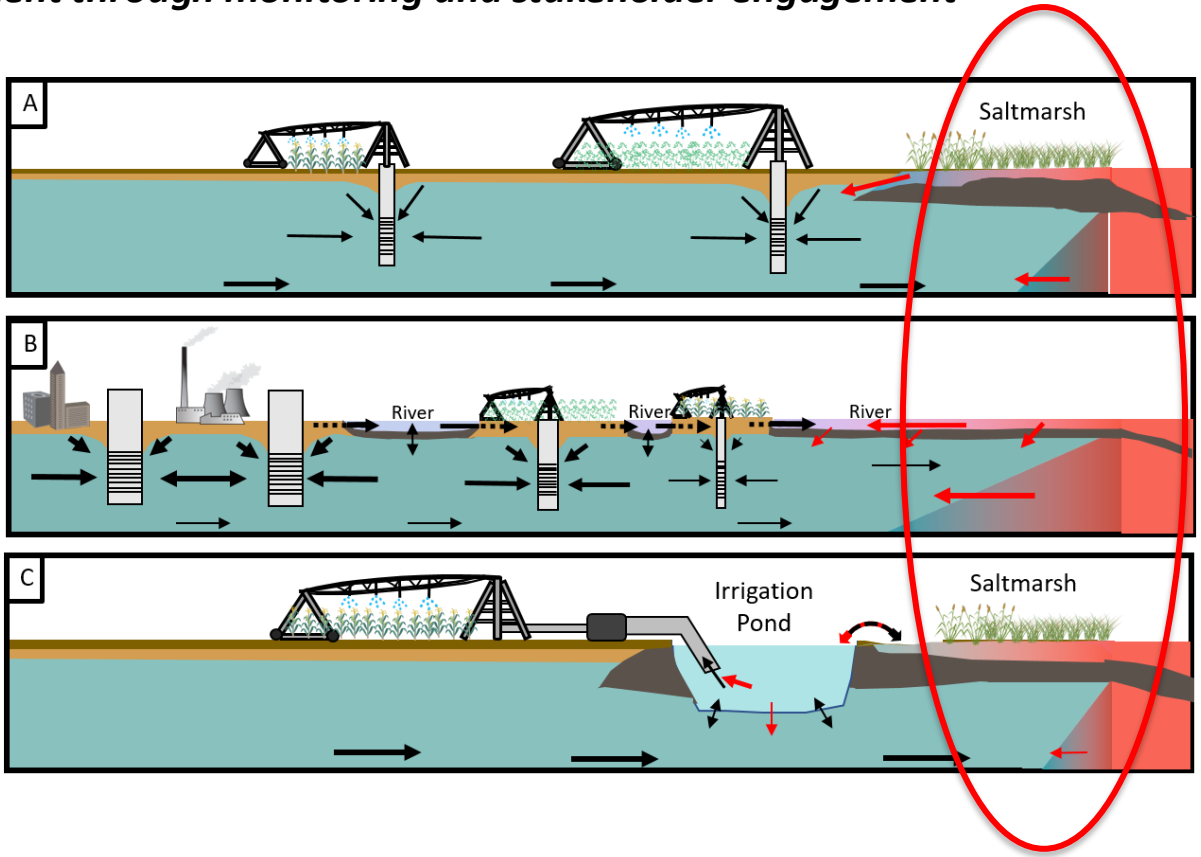
Hingst et al., *Groundwater*, 2022

Monitoring → New conceptual model of hydrogeology & salinization mechanisms
→ Important role of surface-to-subsurface salinization, gradient reversals
→ *Better water management through monitoring and stakeholder engagement*

Acknowledgement of saltwater intrusion by State Dept of Agriculture with notification of constituents

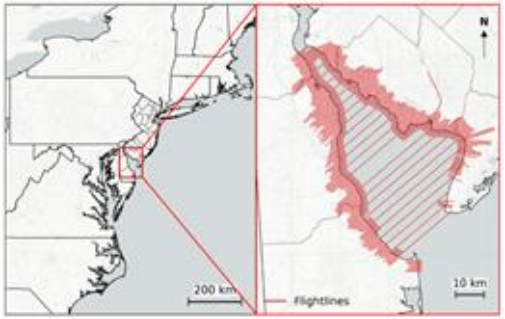
City of Dover altered the use of public supply wells, shifting to deeper wells during summer to avoid impacts to irrigators

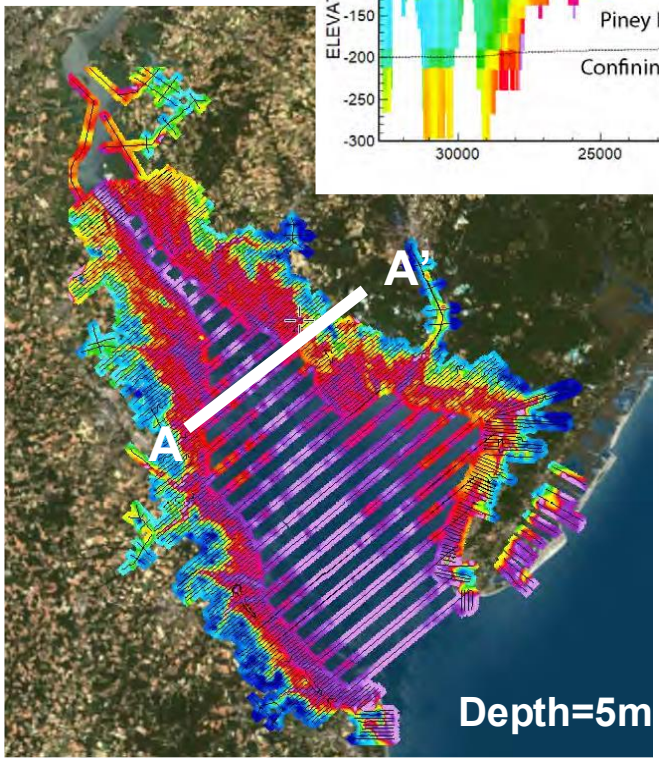
Landowner interventions to avoid pond salinization

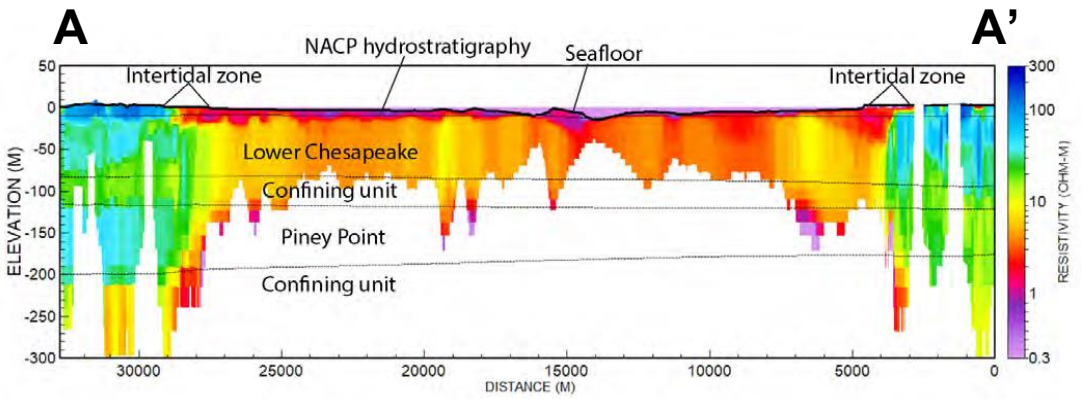


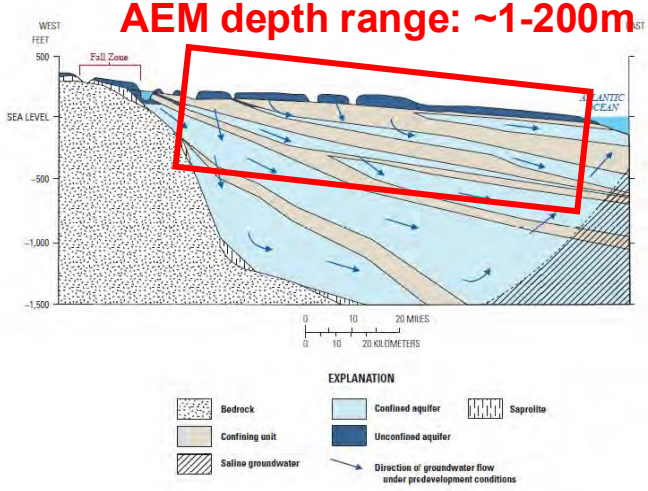
Airborne Electromagnetics

2022 SkyTEM survey





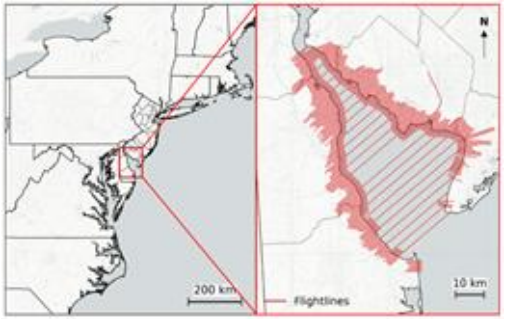


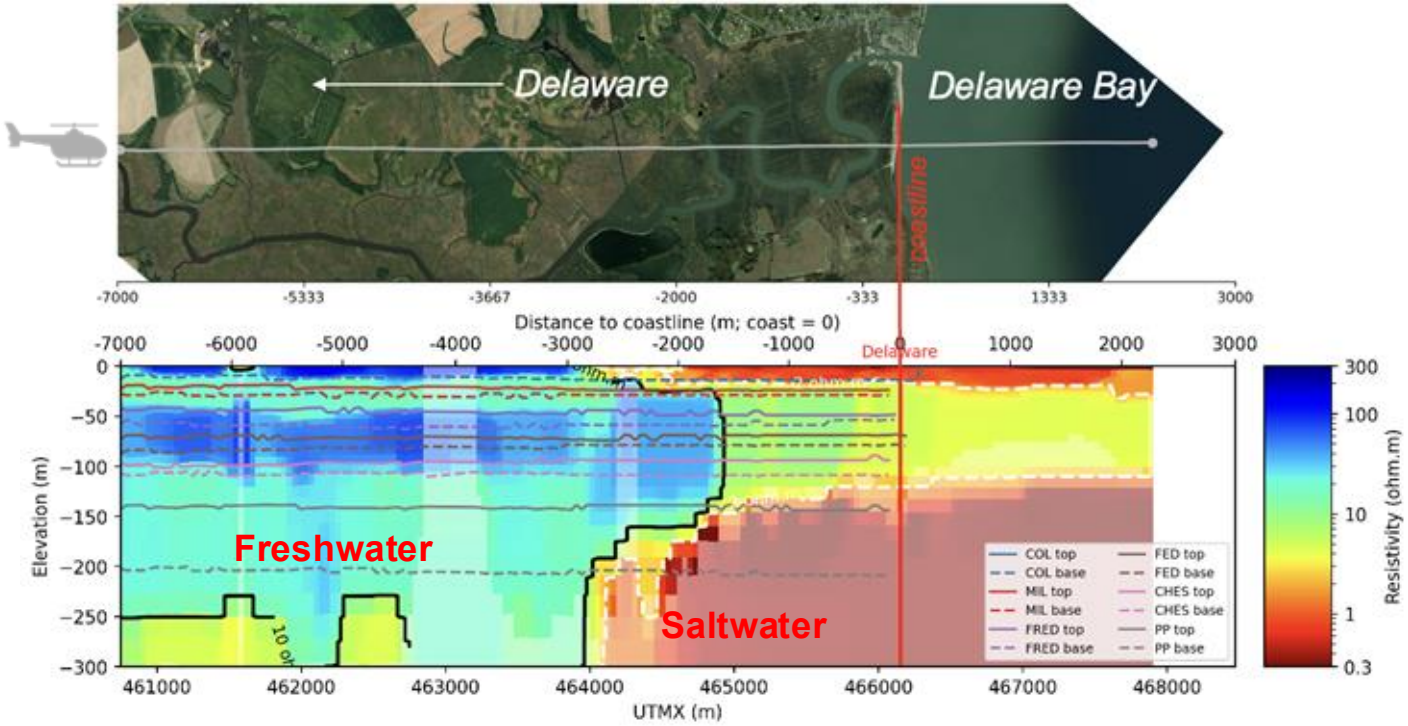


Lyndsay Ball, Burke Minsley, USGS

Airborne Electromagnetics

2022 SkyTEM survey

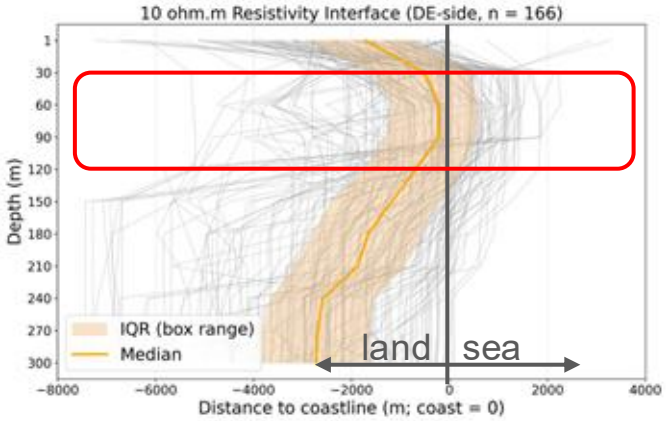


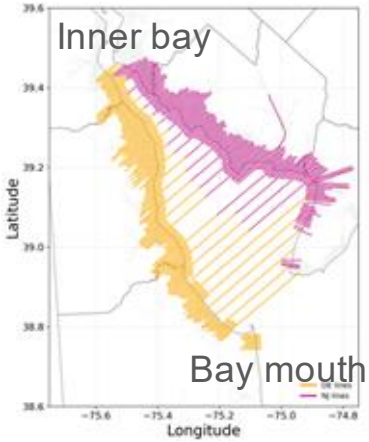


Ting Feng, UD

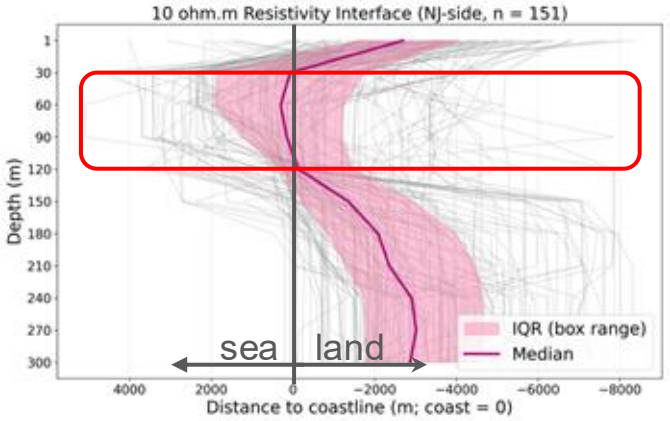
Interface Patterns – freshwater under marshes…and the bay

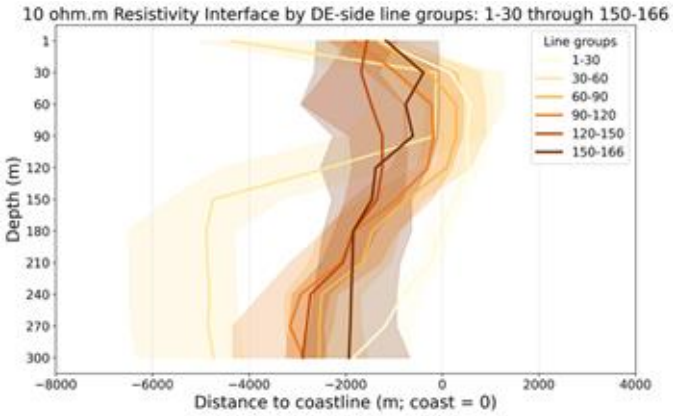
DE side

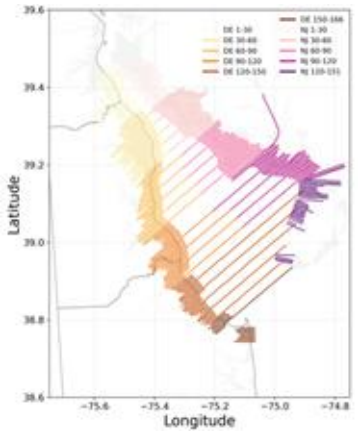


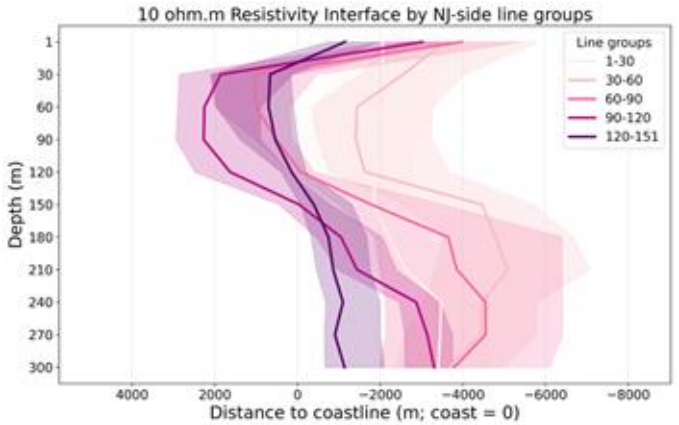


NJ side



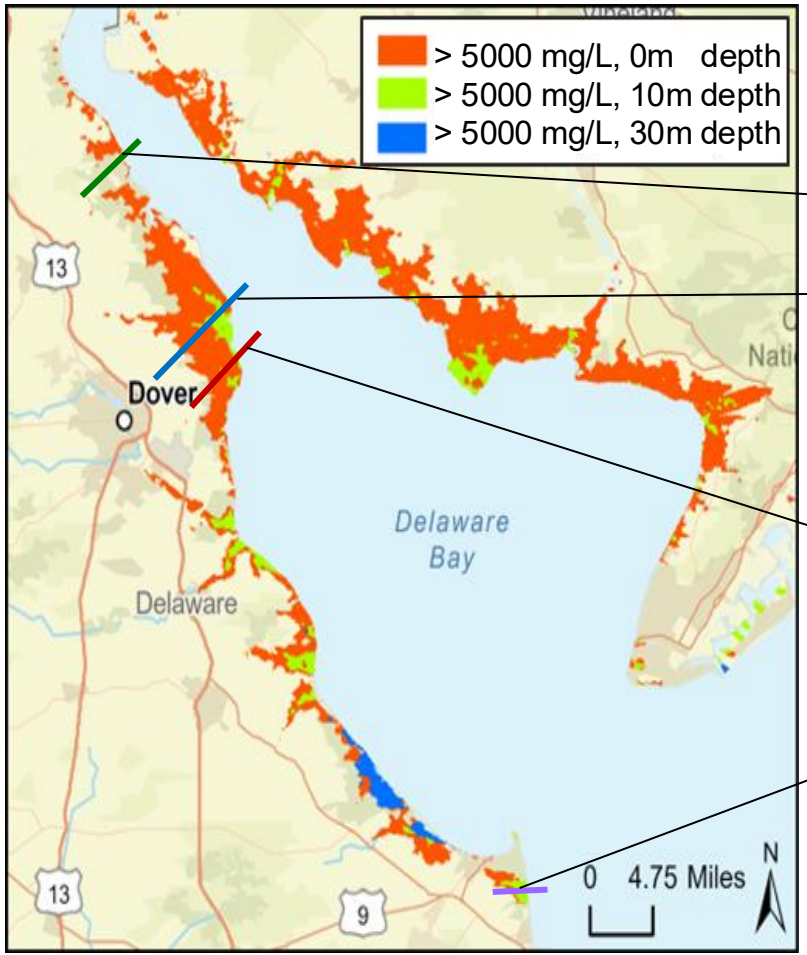


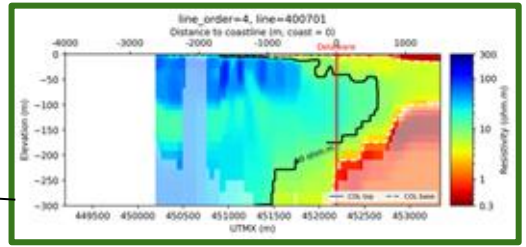


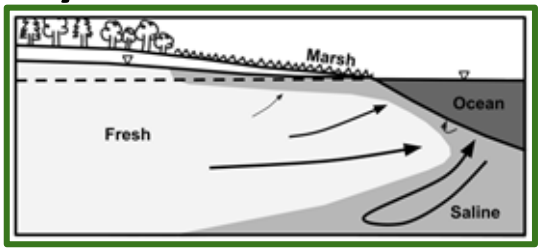


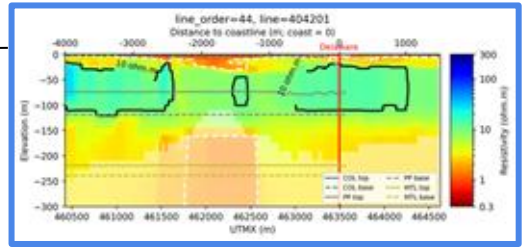
Ting Feng, UD

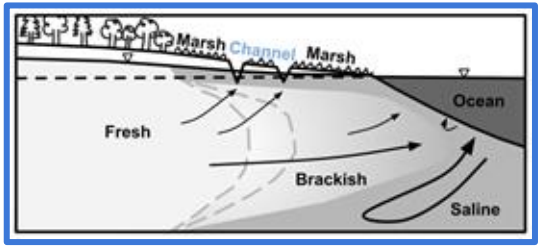
Interface Patterns – freshwater under marshes…and the bay

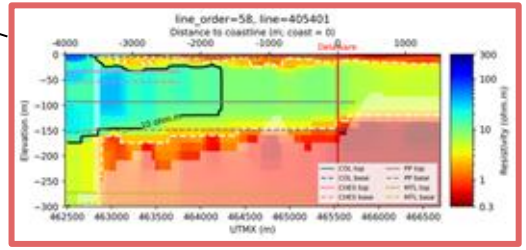


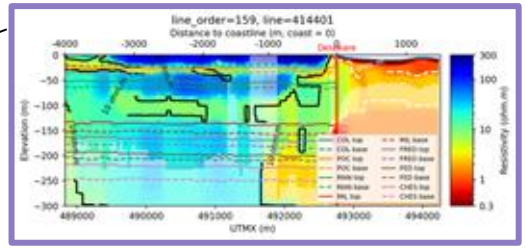


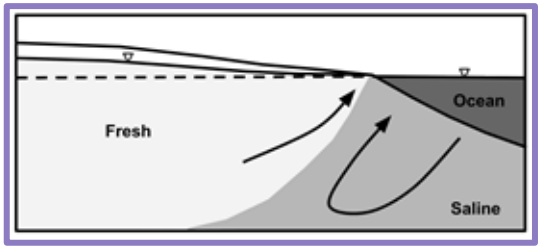








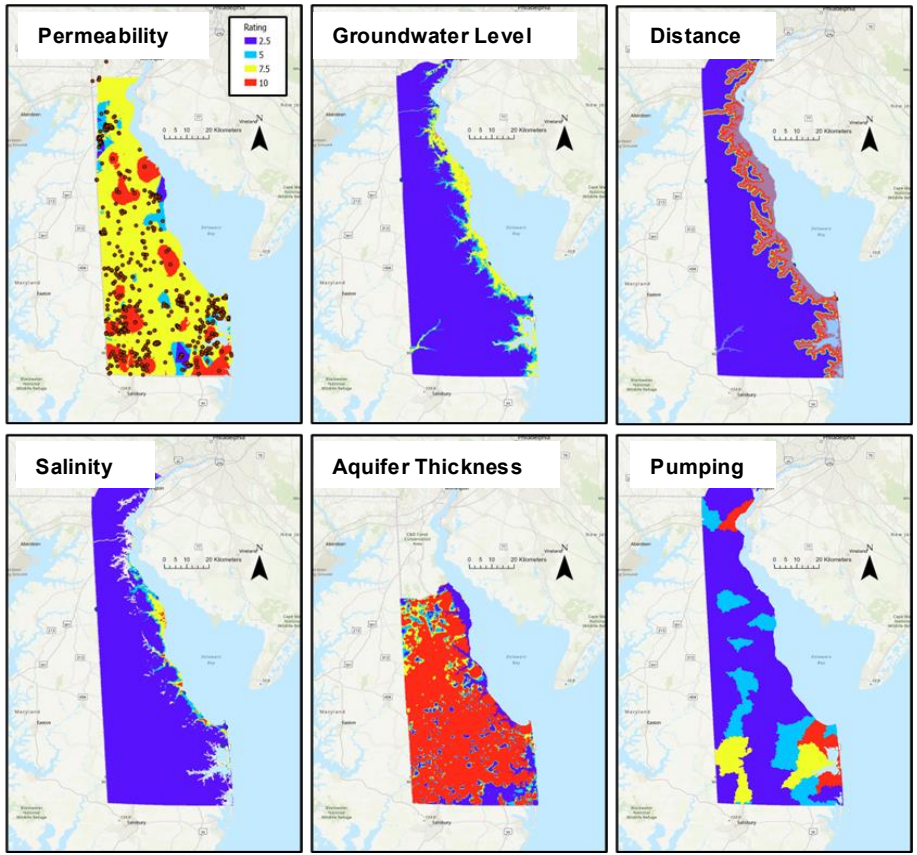


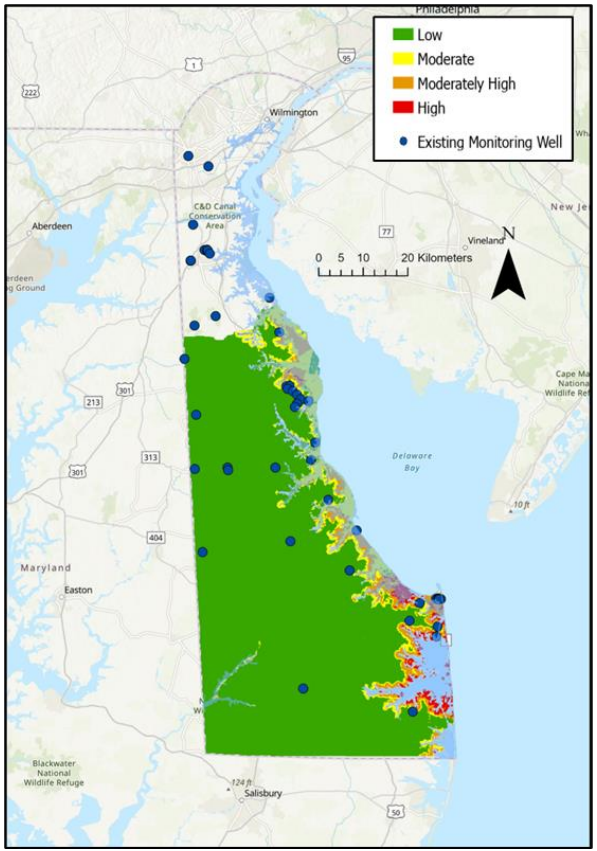


Ting Feng, Rachel McQuiggan, Dannielle Pratt, UD

→ Vulnerability Analysis

With DNREC and DGS: Large-scale data collection and modeling
→ State-wide saltwater Intrusion monitoring network

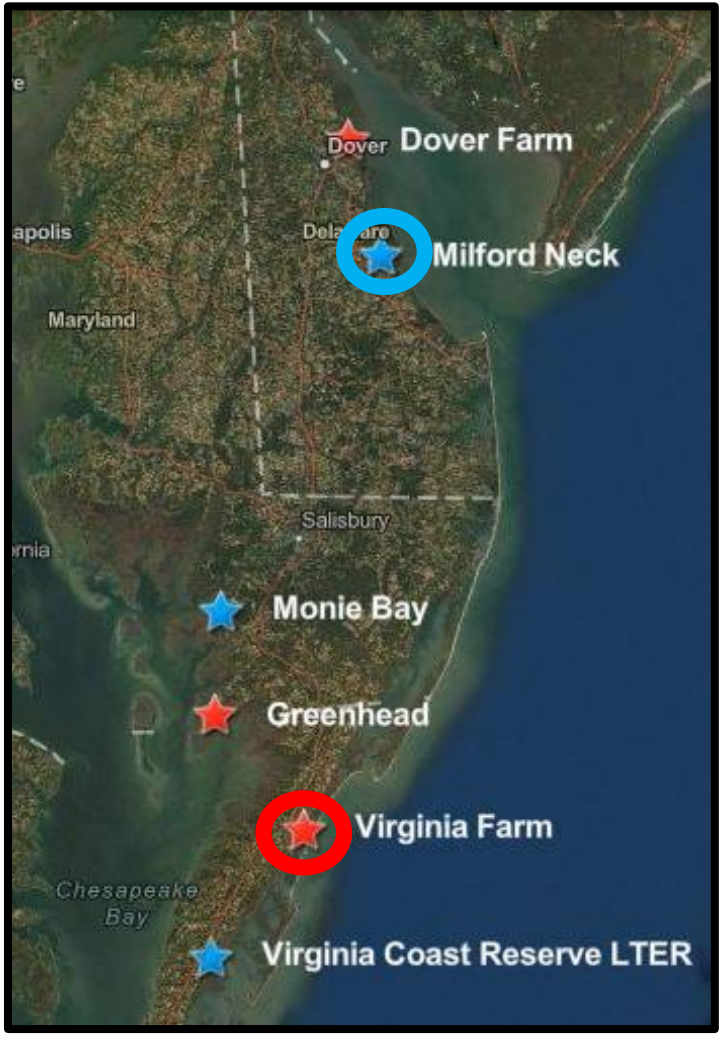




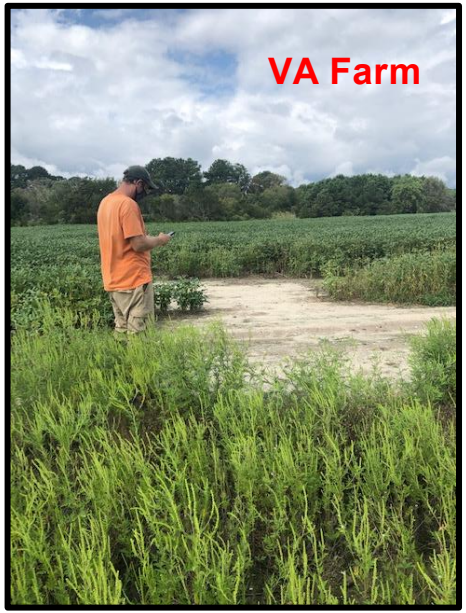
Romana Ibrahim and others, UD, DGS, DNREC


NSF
Coastal Critical Zone Network
Coastal Critical Zone Team:
Holly Michael, UD, PI
Keryn Gedan, GWU, Co-PI
Kate Tully, UMD, Co-PI,
Sam Clem, Yo Chin, Angelia Seyfferth, UD, Co-Pis
Sergio Fagherazzi, BU, Co-PI
Matt Kirwan, VIMS, Co-PI
Stephanie Stotts, UMES, Co-PI
Lee Slater, Rutgers Newark
VIMS | William & Mary
Virginia Institute of Marine Science
BOSTON UNIVERSITY
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC
NEWARK R
UNIVERSITY OF MARYLAND
UNIVERSITY of MARYLAND EASTERN SHORE

Field data collection across the marsh-upland transition:
6 sites across DELMARVA Peninsula



- **Marsh-forest** transition
- **Marsh -agriculture** transition



Interdisciplinary Approach

Hydrological data

Groundwater data
- Groundwater Level
- Groundwater Conductivity
- Groundwater Temperature

Soil data
- Soil moisture
- Soil water conductivity
- Soil Temperature

The Ecohydrology of Coastal Ghost Forests

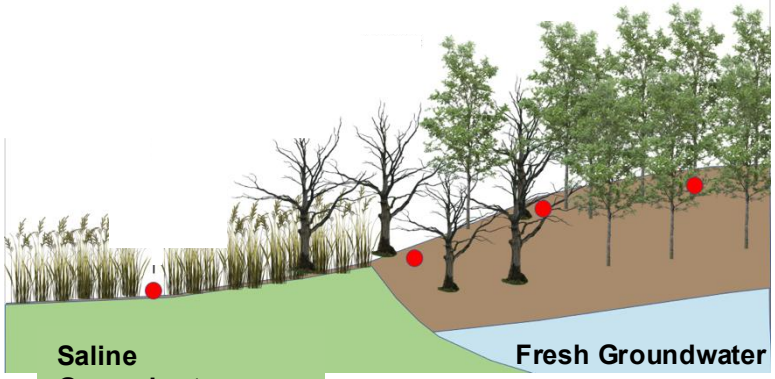
Sergio Fagherazzi[1] | Giovanna Nordio[1] | Jacopo Boaga[2] | Giorgio Cassiani[2] | Holly A. Michael[3,4] | Dannielle Pratt[4] | Tyler C. Messerschmidt[5] | Matthew L. Kirwan[5] | Stephanie Stotts[6]

Ecological & Geomorphological data

- Sap Flux
- Biomass
- Competition
- Zonation
- Land-Surface Elevation

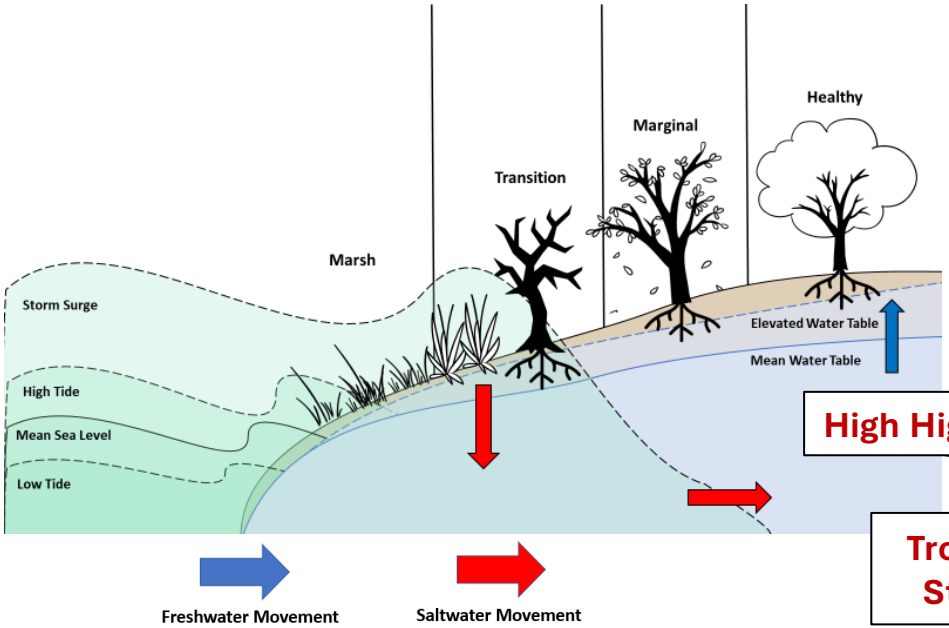
Biogeochemical data

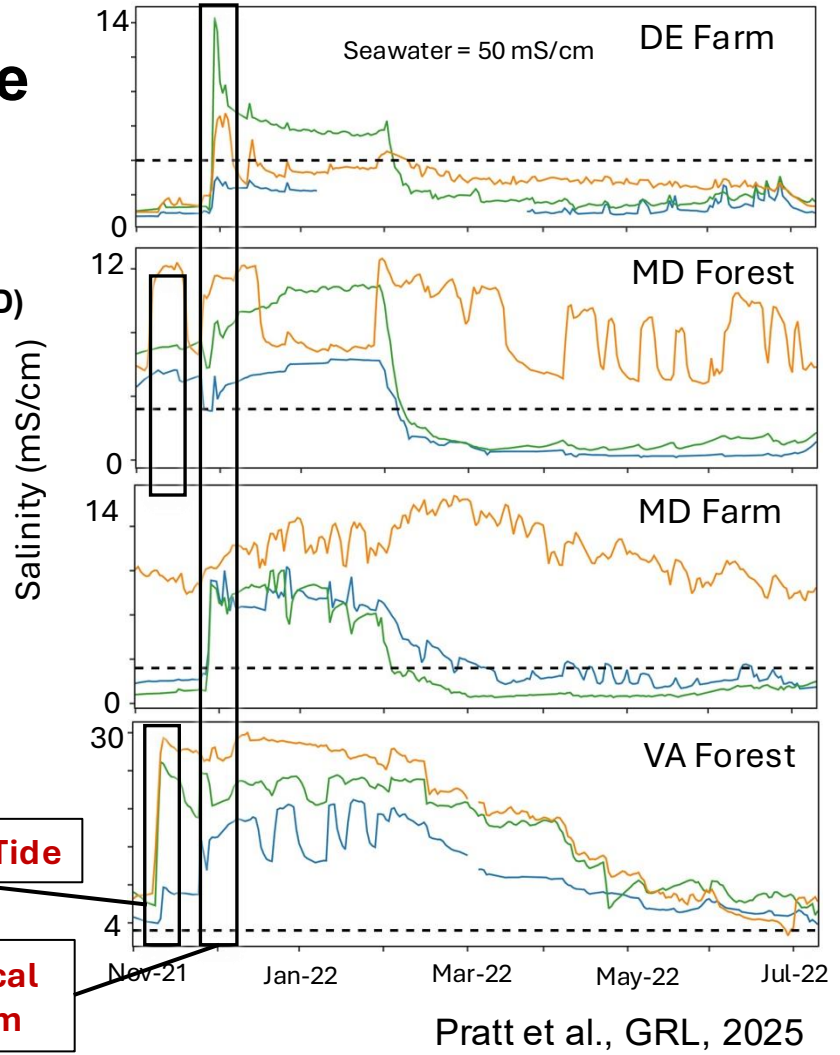
- Carbon
- Redox
- Salinity



Local characteristics control surge salinization extent and duration

Low Elevation= Greater extent of surge up transect (VA/MD)
High Channel Salinity= Higher salinity infiltrating subsurface (VA/MD)
Low Permeability= Longer recovery time (VA/MD, within-site)



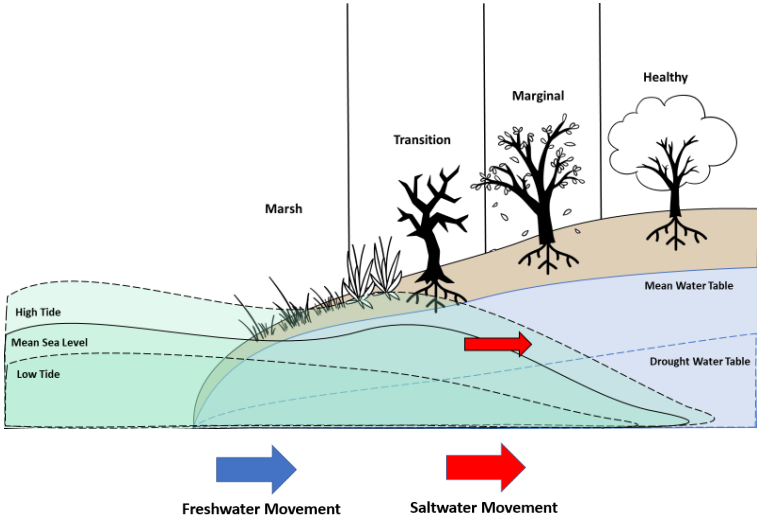


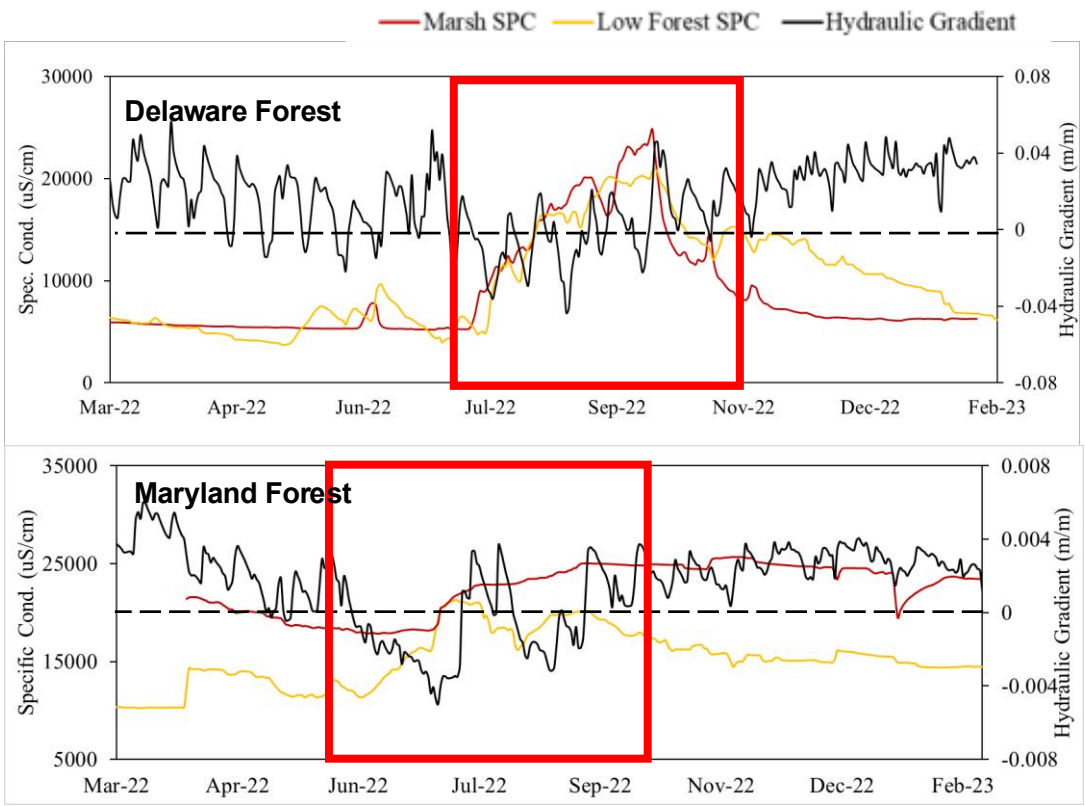
Pratt et al., GRL, 2025

Increased intensity of droughts drives aquifer salinization

Drop in water table= reversal of groundwater flow from marsh to high forest

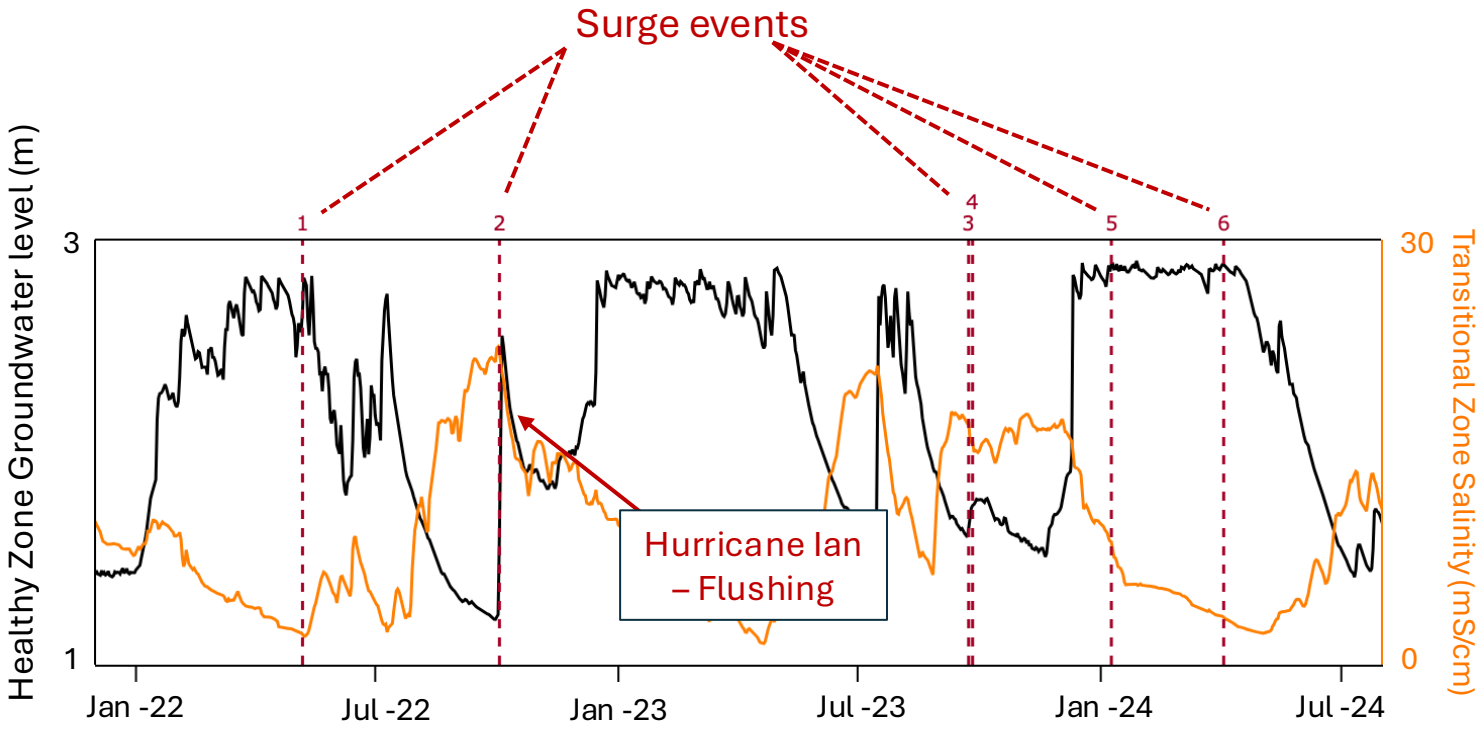
Saltwater intrudes into upland laterally when hydraulic gradient reverses





Pratt et al., GRL, 2025

Hurricanes can cause flushing



Pratt, D., Guimond, J. A., Bacmeister, E. S., Fagherazzi, S., & Michael, H. A. (2025). Terrestrial groundwater drives coastal ecosystem shifts. *Geophysical Research Letters*, *52*(14), e2025GL116251.

Do dynamic feedbacks accelerate or resist marsh migration?

Received: 25 August 2023 | Revised: 10 November 2023 | Accepted: 14 November 2023

DOI: 10.1111/gcb.17081

Global Change Biology

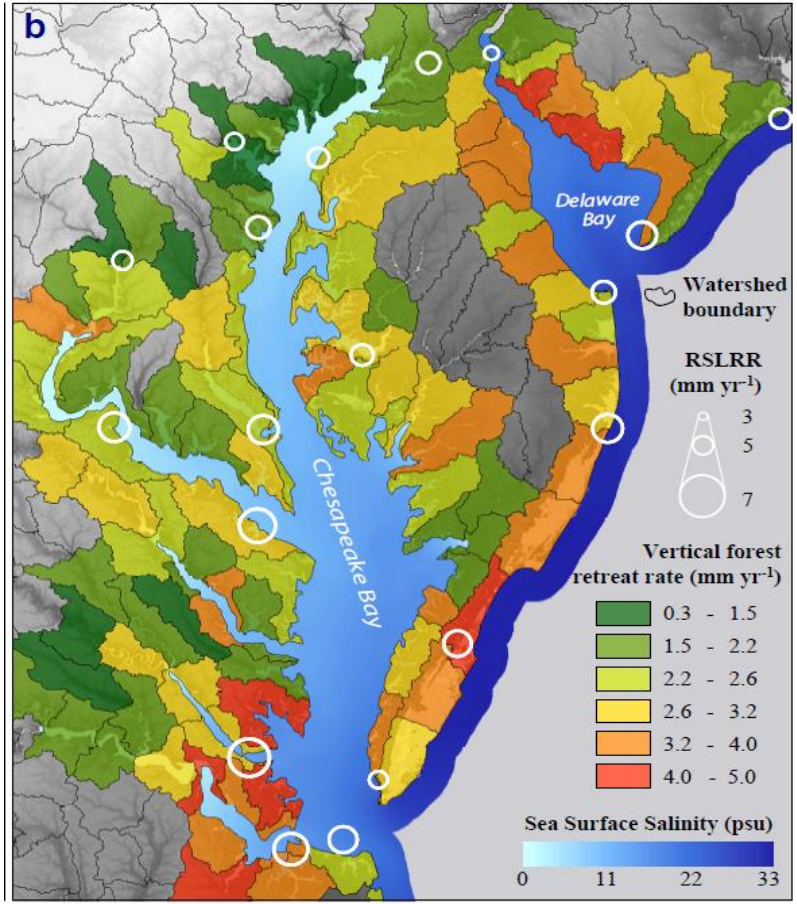
RESEARCH ARTICLE

Upland forest retreat lags behind sea-level rise in the mid-Atlantic coast

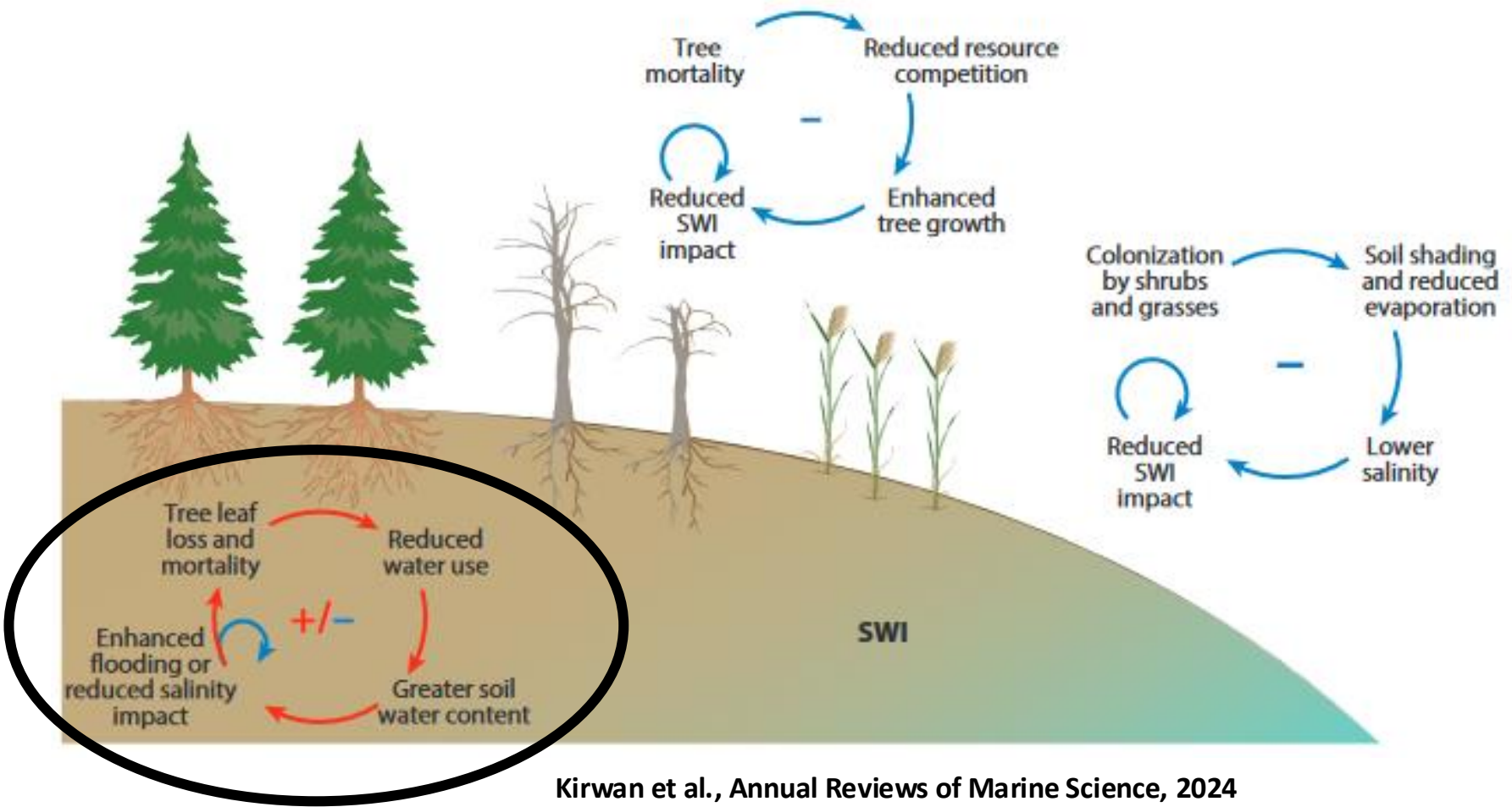
Yaping Chen | Matthew L. Kirwan

- Marsh-forest boundary migrated inland between 1984 and 2020
- Average vertical retreat rate (2.4 mm yr^{-1}) slower than SLR rate (5.6 mm yr^{-1}).

→ Multi-decadal lag suggests dynamic processes resist tree mortality

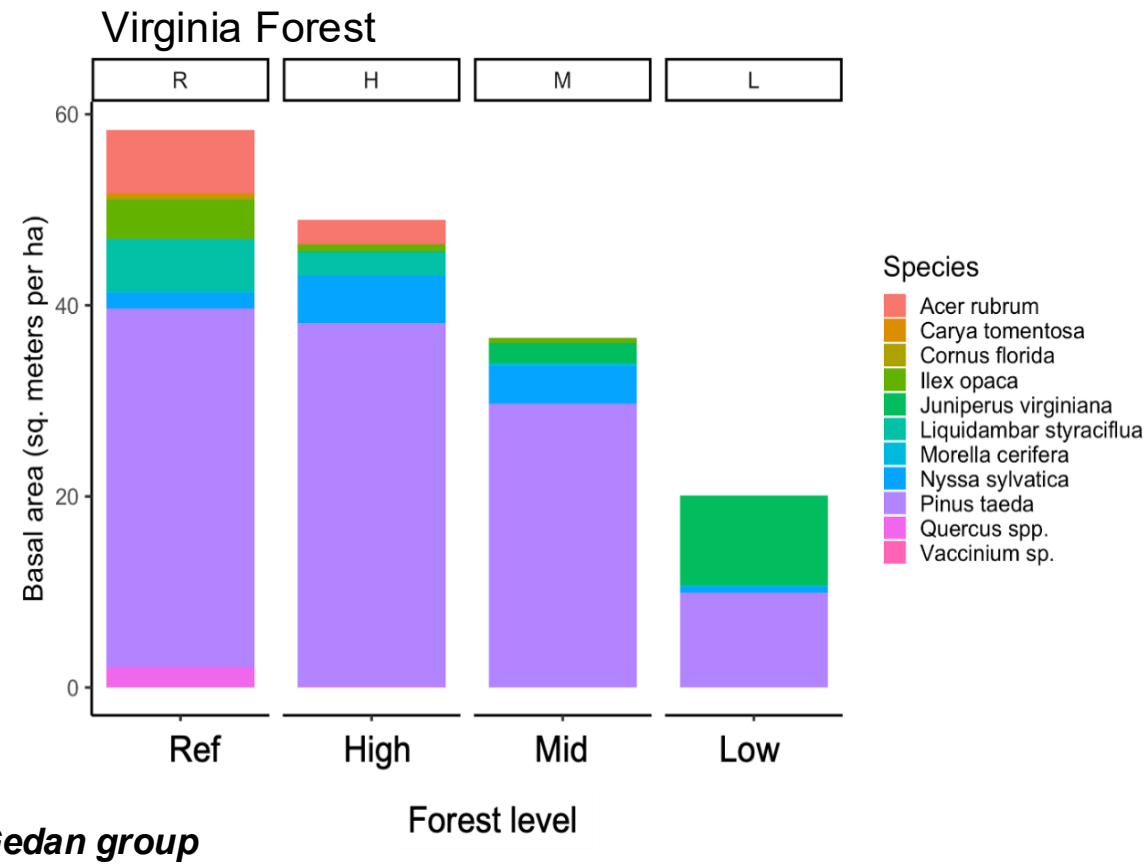


Example Hypothesized Feedback Loop: Hydrology-Ecology-Hydrology…



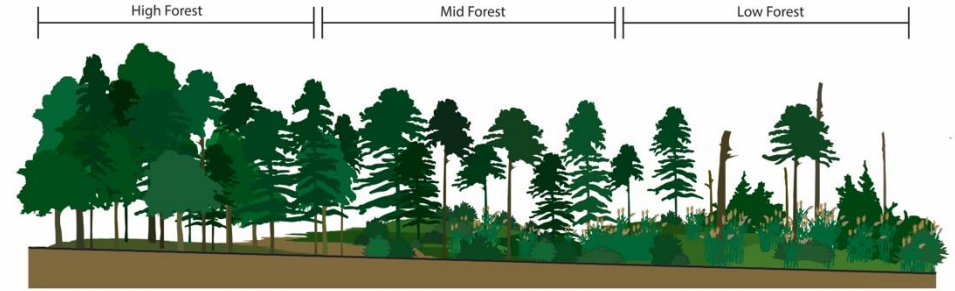
Kirwan et al., Annual Reviews of Marine Science, 2024

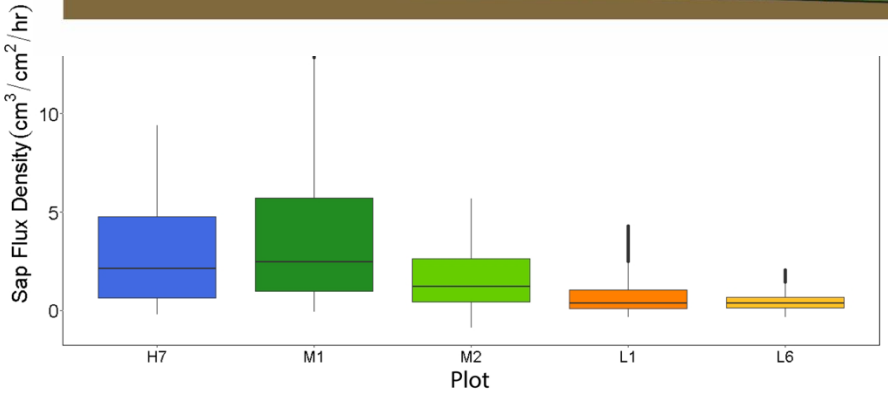
Hydrology (water levels, salinity) causes species abundance and composition change along the transition zone



Gedan group

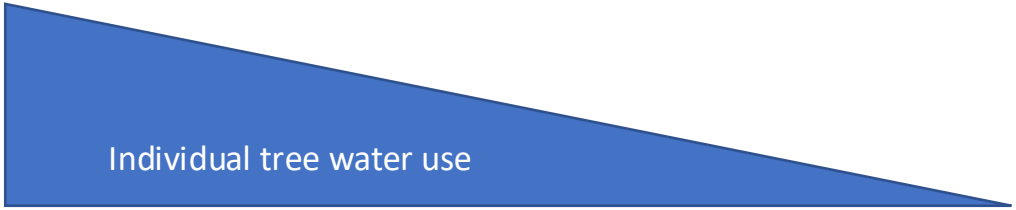
Feedback loops may amplify or mitigate rates of change





Salt causes trees to take up less water:
75% less water use in low forest trees relative to high forest.

→ ***Higher water tables and soil moisture***

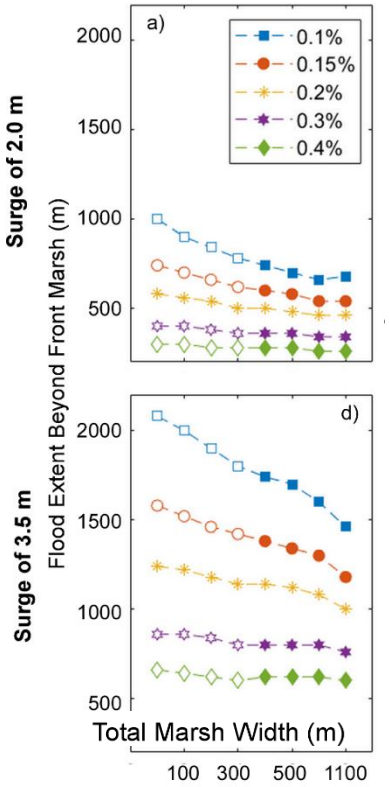


Negative feedback to salinity

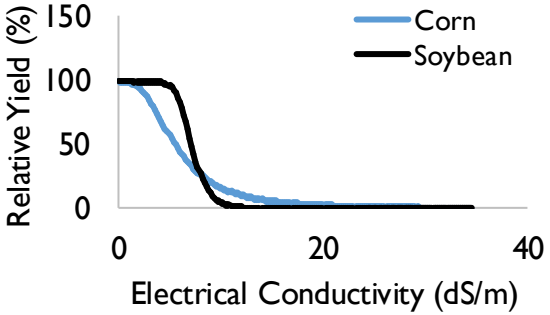
Positive feedback to waterlogging

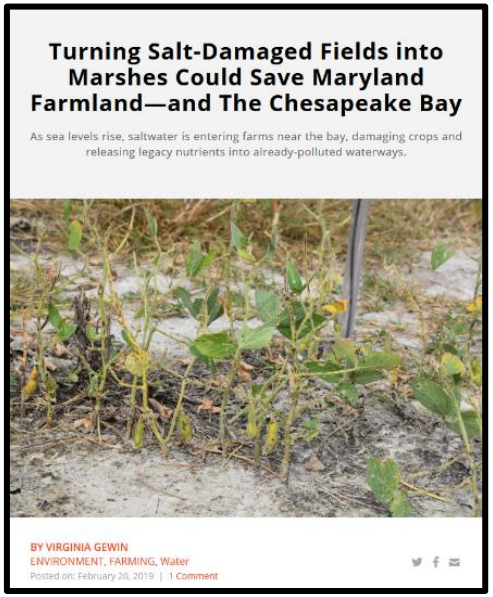
Gedan group

Management strategies may amplify or mitigate rates of change



Marsh migration protects farmland from surge flooding, saltwater infiltration, and aquifer salinization, maintains crop yields, and increases ecosystem services



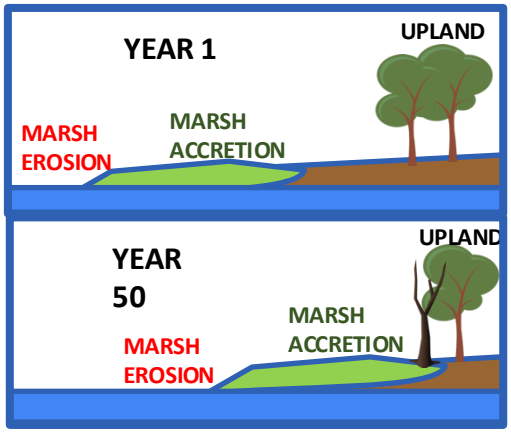


→ **Allowing change may slow change**
→ **Potential Policies to incentivize conversion**

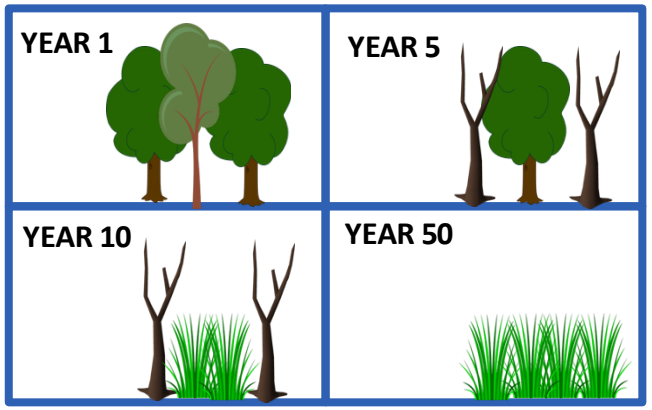
Guimond and Michael, WRR, 2021

Integrative Modeling Efforts

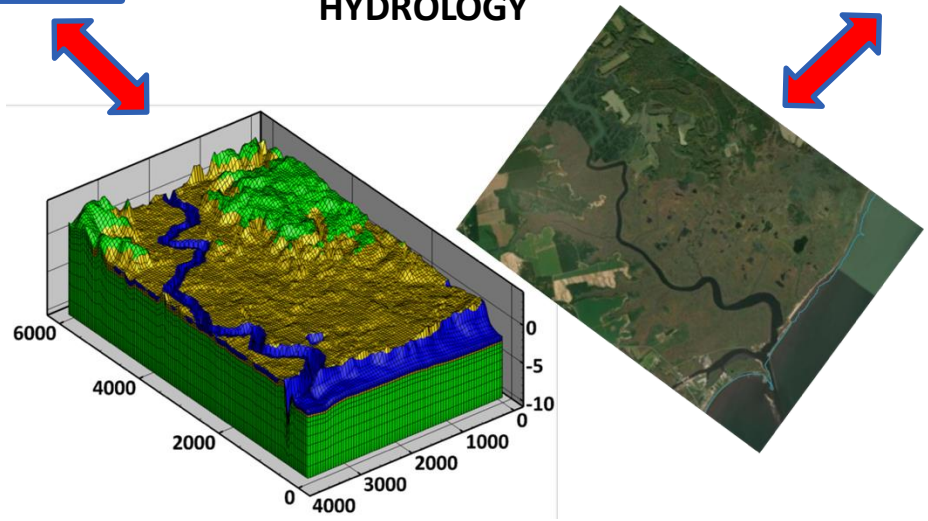
GEOMORPHOLOGY



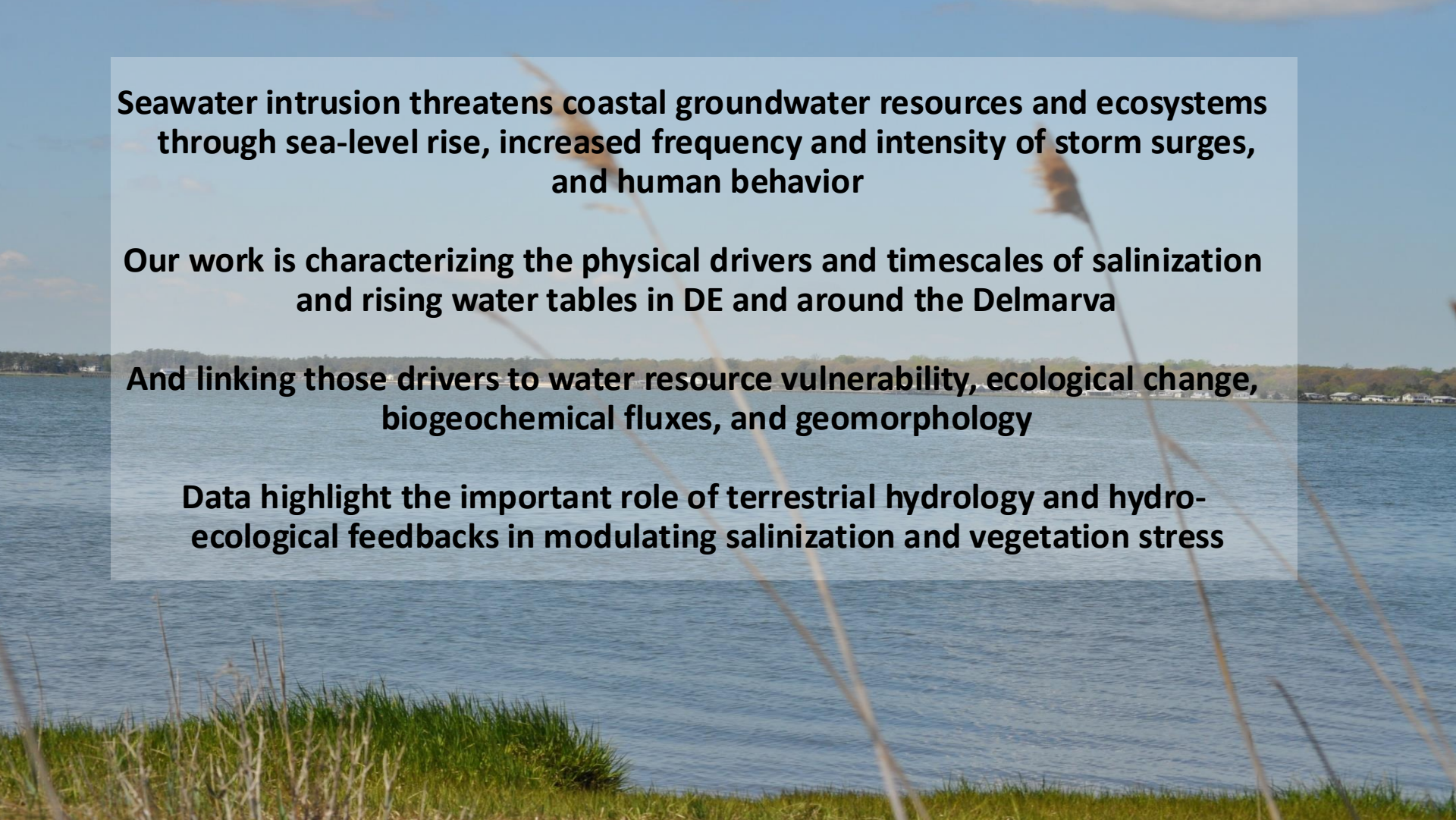
ECOLOGY



HYDROLOGY



Postdoc Cindy Chen



Seawater intrusion threatens coastal groundwater resources and ecosystems through sea-level rise, increased frequency and intensity of storm surges, and human behavior

Our work is characterizing the physical drivers and timescales of salinization and rising water tables in DE and around the Delmarva

And linking those drivers to water resource vulnerability, ecological change, biogeochemical fluxes, and geomorphology

Data highlight the important role of terrestrial hydrology and hydro-ecological feedbacks in modulating salinization and vegetation stress

Thank you!

Contact information: Holly Michael, hmichael@udel.edu

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US Geological Survey
University of Delaware