How does the climate change impact to the estuarine, coastal ocean and lakes?

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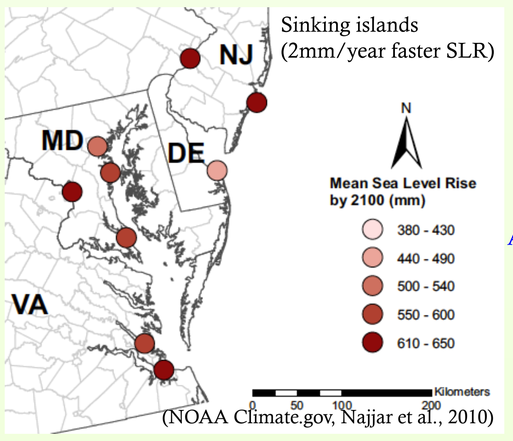
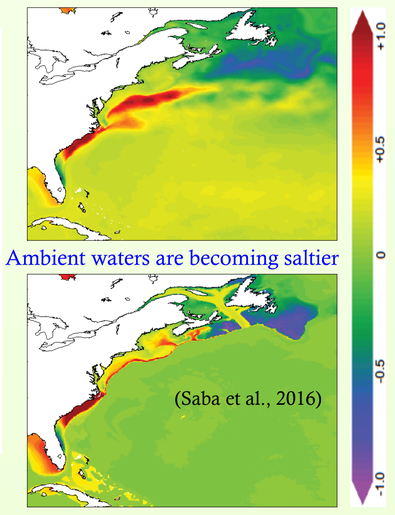
Chesapeake Bay (Eastern seaboard of the USA)



Sinking islands (2mm/year faster SLR)

(NOAA Climate.gov, Najjar et al., 2010)

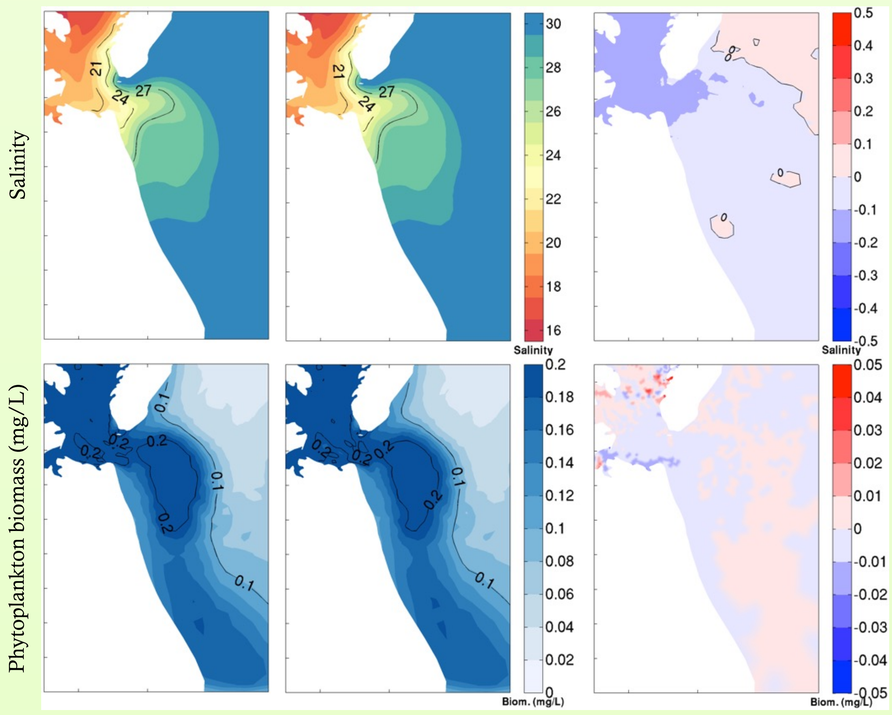


Ambient waters are becoming saltier

(Saba et al., 2016)

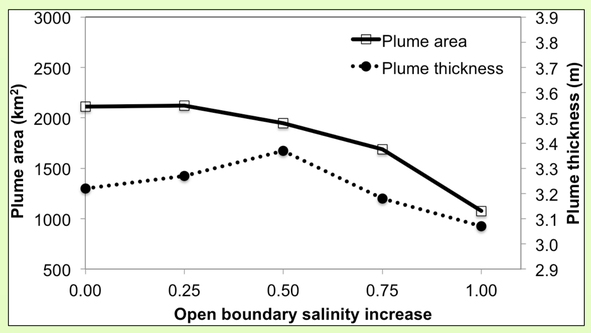
Projections of nutrients and phytoplankton

- Taking the difference between years 1995 and 2025 as an example, < 5% increase in terrestrial inputs induced **minor** in the CBOP structure and primary production.
- Projections of succeeding decades and other emission scenarios will be conducted when data are available in the future.



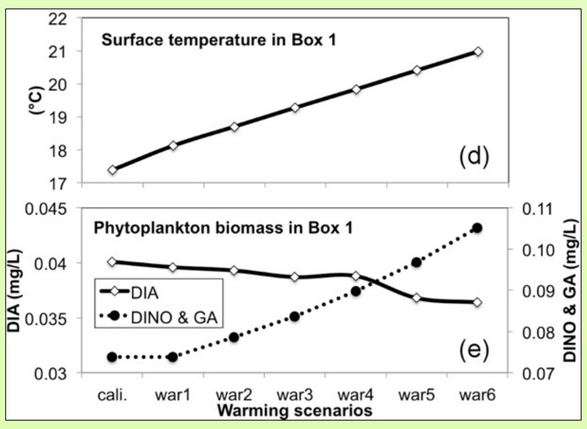
Sensitivity to the ambient salinity

Increasing salinity in the ambient ocean could potentially **reduce the plume size and thickness.**



Sensitivity to the ocean temperature rise

- Diatoms: optimal growth temperature 16 °C; dinoflagellates and green algae: 24-26 °C.
- Direct impacts: seawater warming up **accelerates the species succession** in spring and **increases the overall primary production** in spring.



Keynotes

- Under the CMIP5 projections, the CBOP would increase in plume area and thickness.
- Increasing ambient salinity restrained the alongshore CBOP extension and reduced the phytoplankton biomass all over the plume.
- Sea level rise favored the alongshore, offshore, and vertical CBOP penetration, and promoted primary production in all these regions.
- Increment in heat flux strengthened thermal stratification and increased buoyant outflow as well as the plume area, which exerted direct and indirect effects on the algal growth.

Challenges yet to overcome

- Parameterization of numerical model with mechanisms incorporating the integrated wetting and drying, wave-current interactions, biochemical and sediment.
- Precision in global vs. local climate change variables.
- Coupling with watershed data for the future biogeochemical projections.

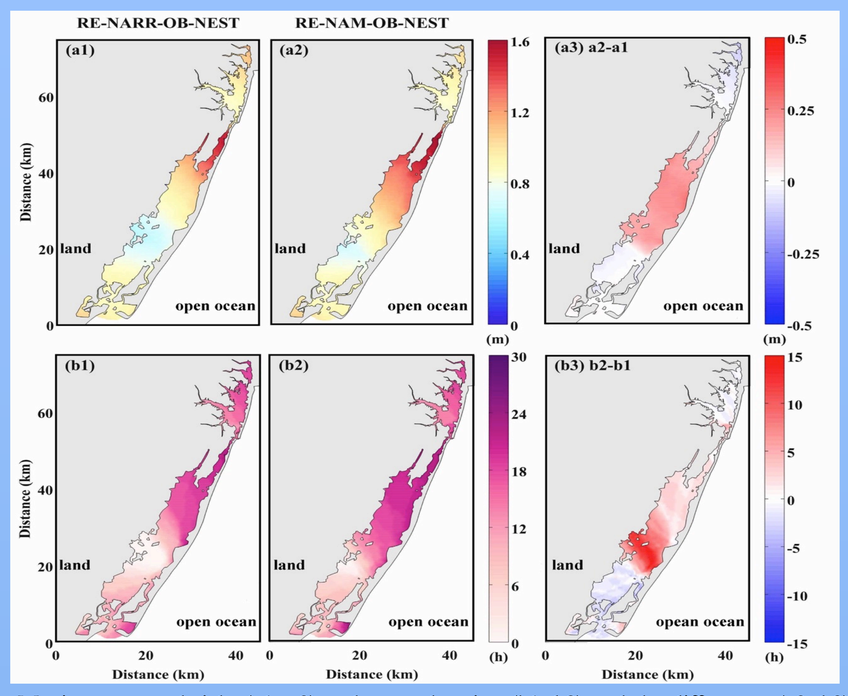
Motivation and Objectives

Response of potential climate change

Coastal Oceans
Estuaries
Lakes
→ Air-sea interactions changes
Hydrodynamic changes
Biochemical changes
→ Susceptibility
Identification
Projection

Maryland Coastal Bays

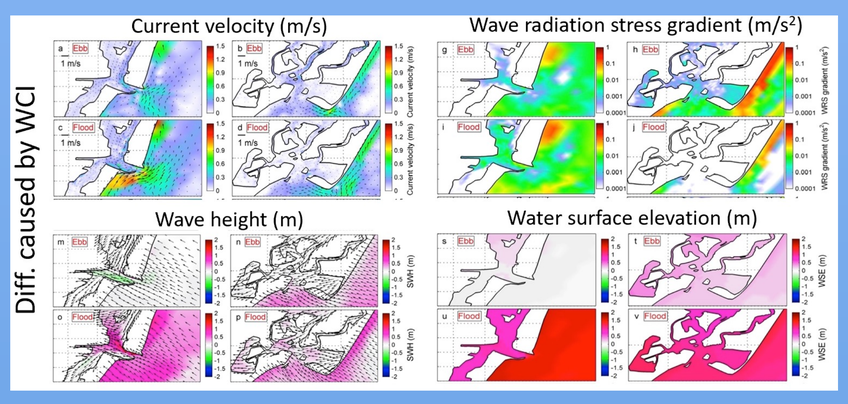
Frequent encounter of intense hurricanes, winter storms and blizzards.



Maximum surge height (a1, a2) and surge duration (b1, b2) and the differences (a3, b3) during Hurricane Sandy.

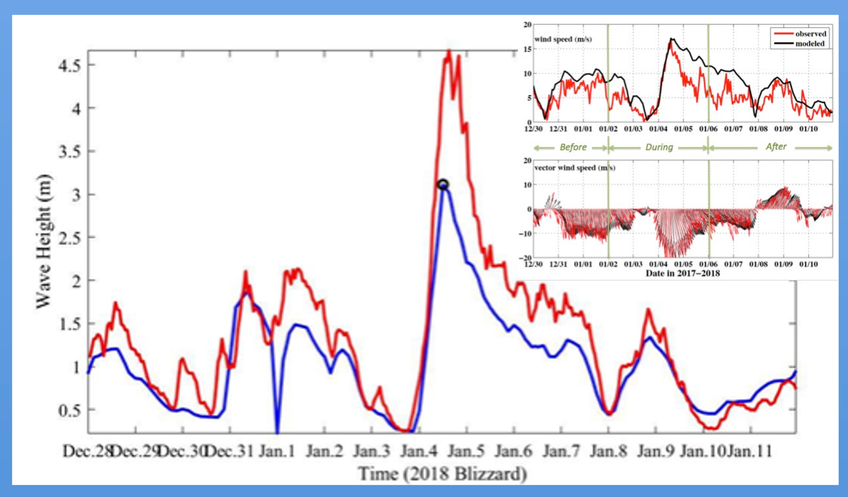
Impact of weather extremes on Maryland Coastal Bays

- Winds (> 14.5 m/s) significantly affect the coastal circulation near the inlets.
- Lee side of the inlet is impacted by the wind-induced waves.
- Wave-current interaction affect currents near inlets through wave radiation stress.
- Wave-current interaction affects wave dynamics by depth-induced breaking.



Blizzard during Jan 2-6, 2018

Only 17 m/s wind generated around 4.5 m of waves in the bays.



We are working on

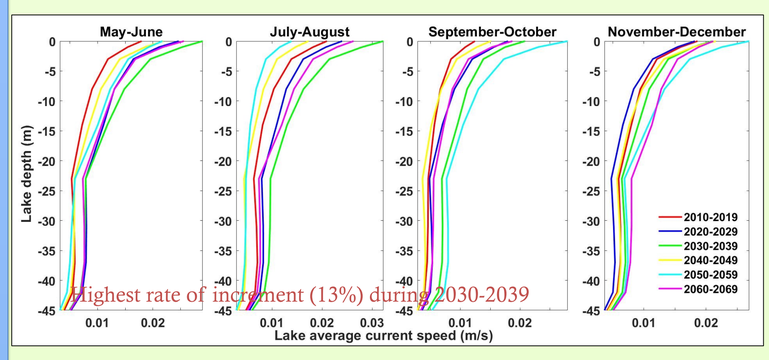
- Climate change impacts on watershed over Maryland Coastal Bays.
- Trend of productivity cycle under the changing climate.
- Impact of climate change on biodiversity of Maryland Coastal Bays.

Lake Michigan (the 3rd large Great Lakes)

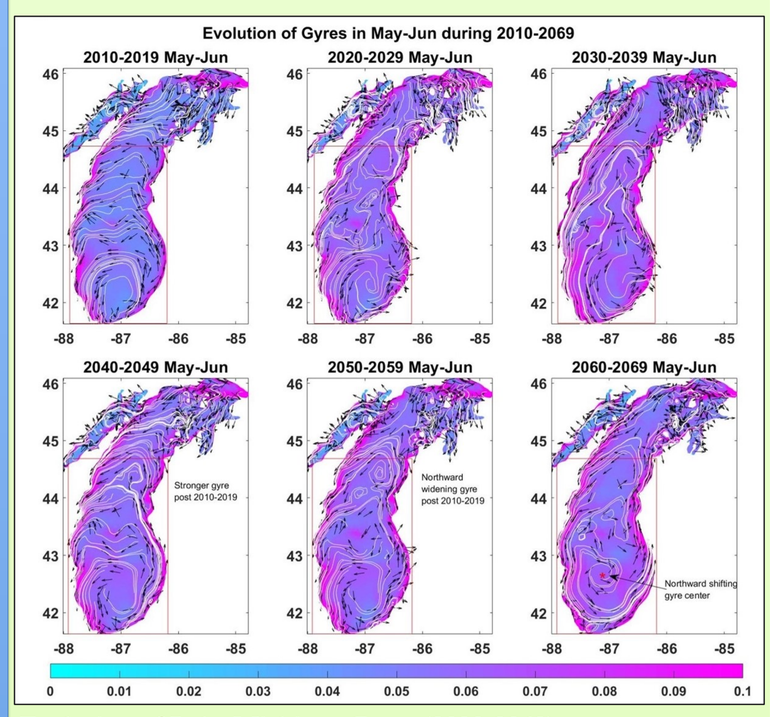
Global warming and climate change (IPCC, 2013)
Longer summer
Depletion of ice-cover
Changes in precipitation
Water level fluctuations
Increasing water and air temperatures
→ Changes in lake currents and circulation dynamics

Projections of Lake Michigan circulation (based on RCP 4.5 scenario)

- Substantial temperature gradients between southern and northern belts of Lake Michigan → stronger wind stresses → scale up the wind-driven currents.
- Lake Michigan current magnitude to increase at a relative rate of 6.5% during 2020-2050 and -1% during 2050-2069.

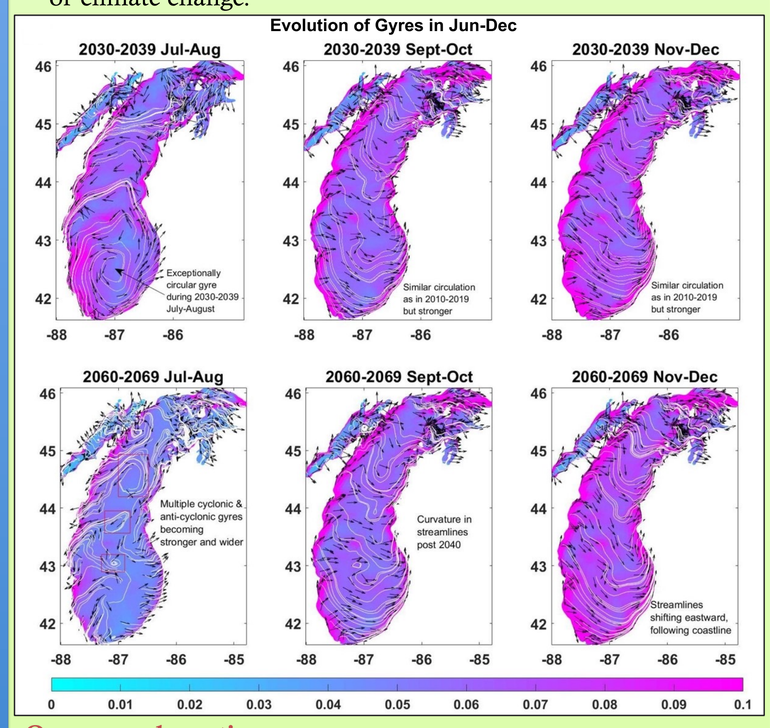


- No abrubt increase in lake current magnitude follwing the reduced thermal gradient and controled lake surface winds after 2040.



Evolution of Lake Michigan Gyres (2020-2069)

- Stronger and to wider gyres with the shift in temperature bands and modulations in wind profiles over future decades.
- A northward shift of the gyre location is noticed with a dominant rise in meridional winds.
- A delayed response of lake hydrodynamics to the declined rate of climate change.



Our research continues on

- Modeling the wave-current-surge-plume-ice interaction dynamics.
- Changes to lake hydrodynamics with depleting lake ice under global warming scenarios.

For details,
1. Xia, Meng, Mao, Miaohua, Kang, Xinyi. "Storm Surge Modeling: Influencing Factors." *Book Chapter In Press*
2. F Nimni, Nishat, and Meng, Xia, "Coupled Modeling of Storm Surge and Fluvial Flooding of the Maryland Coastal Bays." SY35B-0652 (2022): presented at 2022 Fall Meeting, *AGU,* 12-16 Dec.
3. Jiang, Long. "Characterization of the Chesapeake Bay Outflow Plume and its Response to Potential Climate Change." *Dissertation submitted to University of Maryland Eastern Shore* (2017).
4. Mao, Miaohua, and Meng Xia. "Wave–current dynamics and interactions near the two inlets of a shallow lagoon–inlet–coastal ocean system under hurricane conditions." *Ocean Modelling* 129 (2018): 124-144.
5. Kang, Xinyi, and Meng Xia. "The study of the hurricane-induced storm surge and bay-ocean exchange using a nesting model." *Estuaries and Coasts* 43.7 (2020): 1610-1624. https://doi.org/10.1007/s12237-020-00695-3
6. Sahoo, Bishnupriya, Miaohua Mao, and Meng Xia. "Projected changes of water currents and circulation in Lake Michigan under Representative Concentration Pathways scenarios." *Journal of Geophysical Research: Oceans* 126.5 (2021): e2020JC016651, http://dx.doi.org/10.1029/2020JC016651