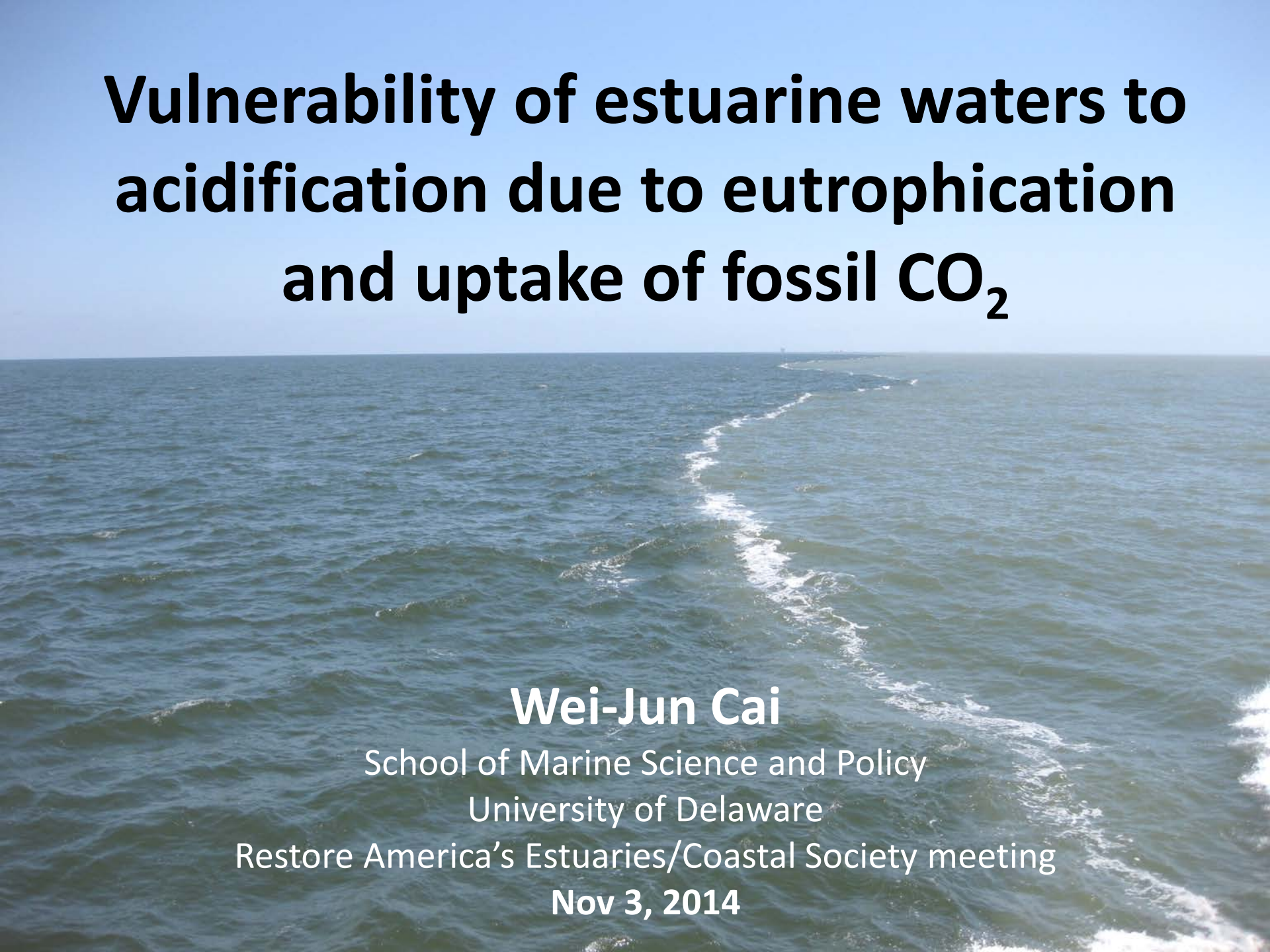
Vulnerability of estuarine waters to acidification due to eutrophication and uptake of fossil CO_2



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Restore America's Estuaries/Coastal Society meeting
Nov 3, 2014

Outline

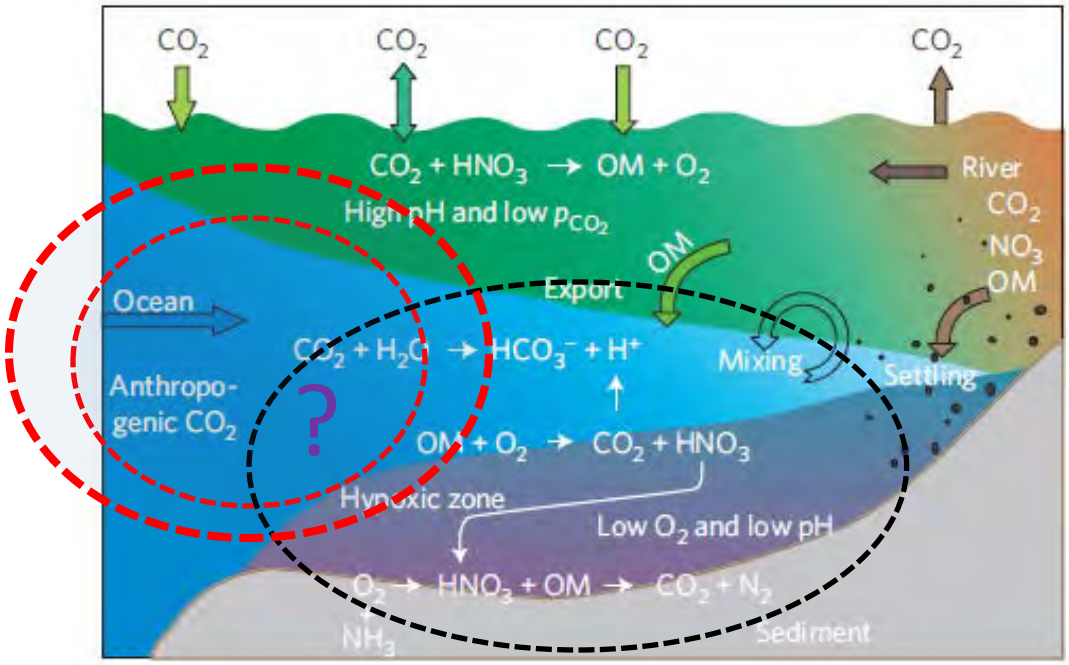
- Introduction
- Examples
- Predicting responses from first principles
- Summary

Estuarine/Coastal Ocean Acidification?

- Global ocean uptake of atm-CO_2 (ΔpH = -0.1)
- Source water with a higher DIC/TA ratio moves onshore and mix with low S coastal waters
- This water is further acidified by mineralization of OM from the eutrophic surface water

Less known is how do they interact?

spatial differences;
diel and seasonal variations.

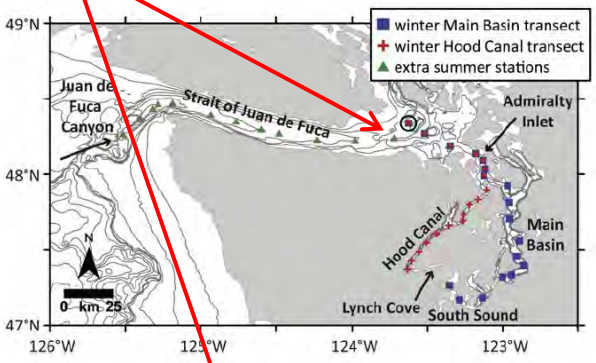


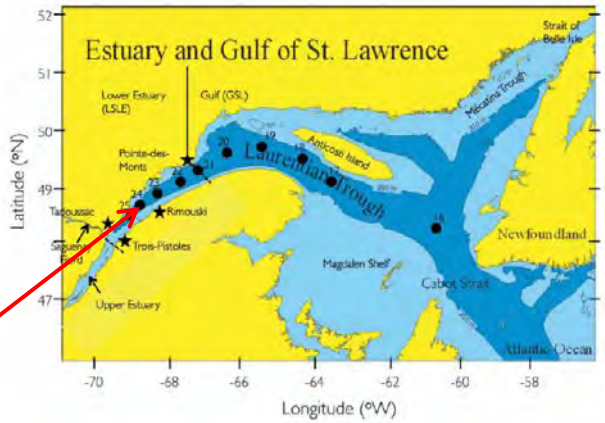
Outline

- Introduction
- Examples of acidification and low O_2 events in coastal oceans
- Responses of coastal ocean CO_2 system to multiple stressors: prediction from first principles
- Summary

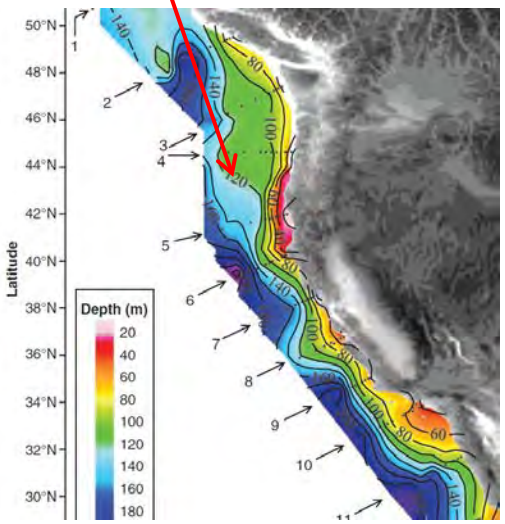
Examples of coastal ocean acidification

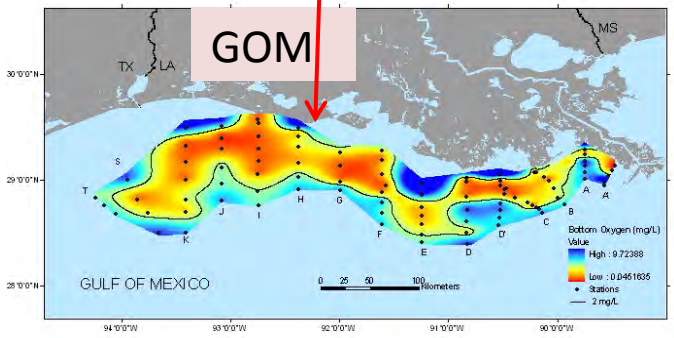
Major upwelling impacted waters



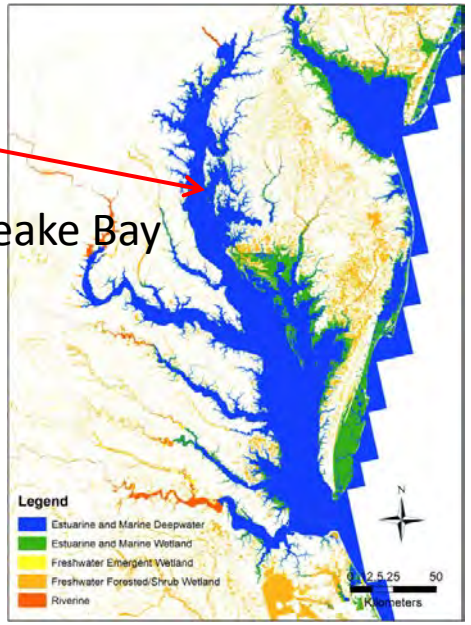


Within and under eutrophic river plumes

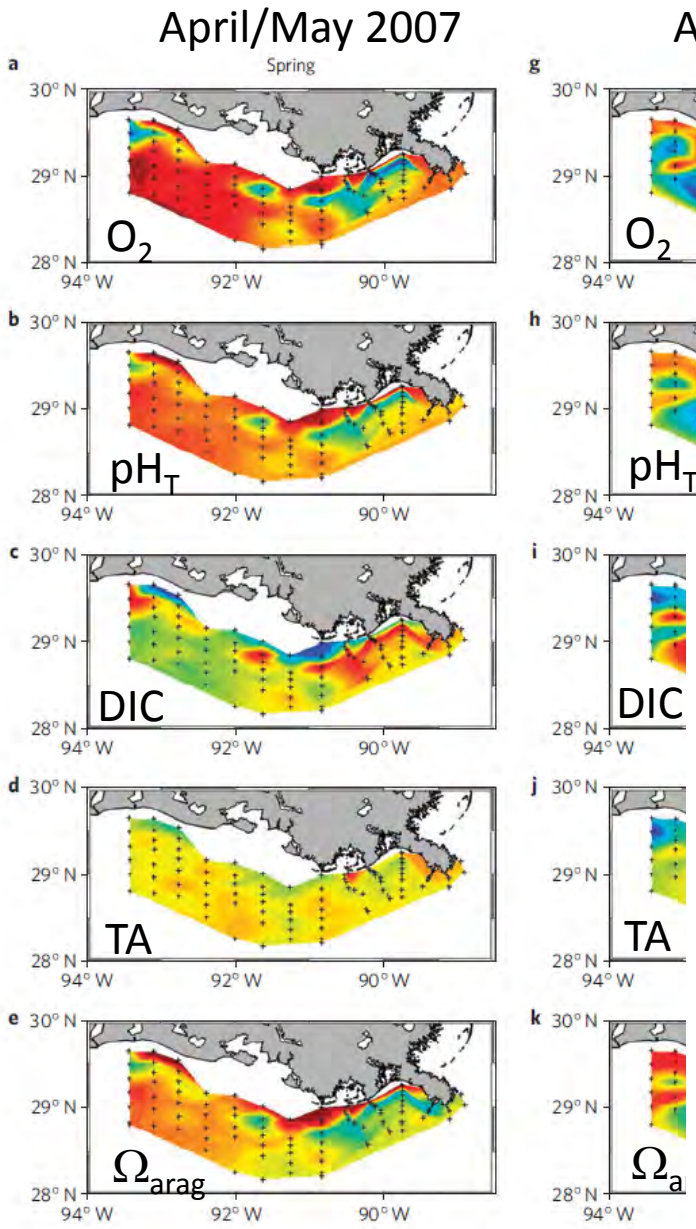




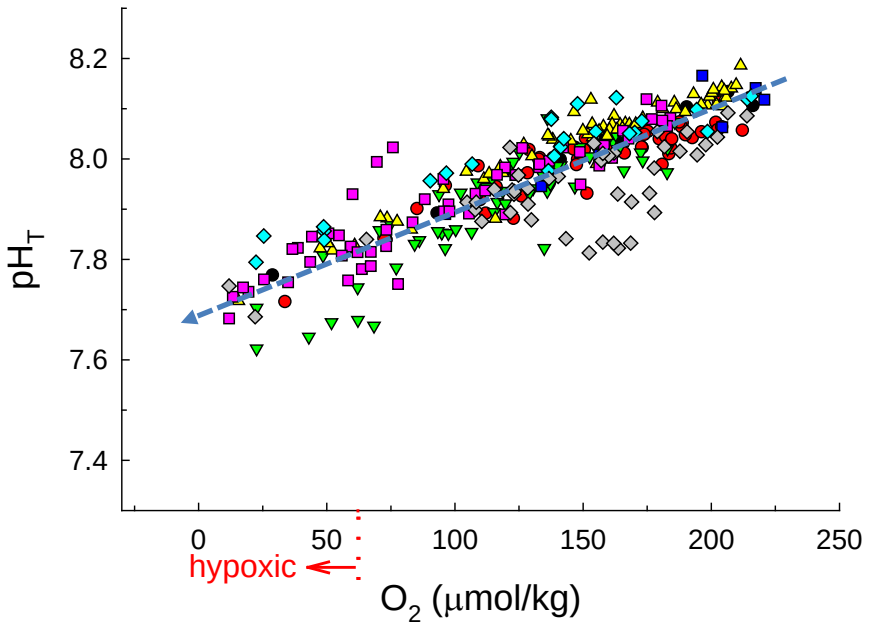
Chesapeake Bay



Acidification and low O_2 events in coastal water--4.

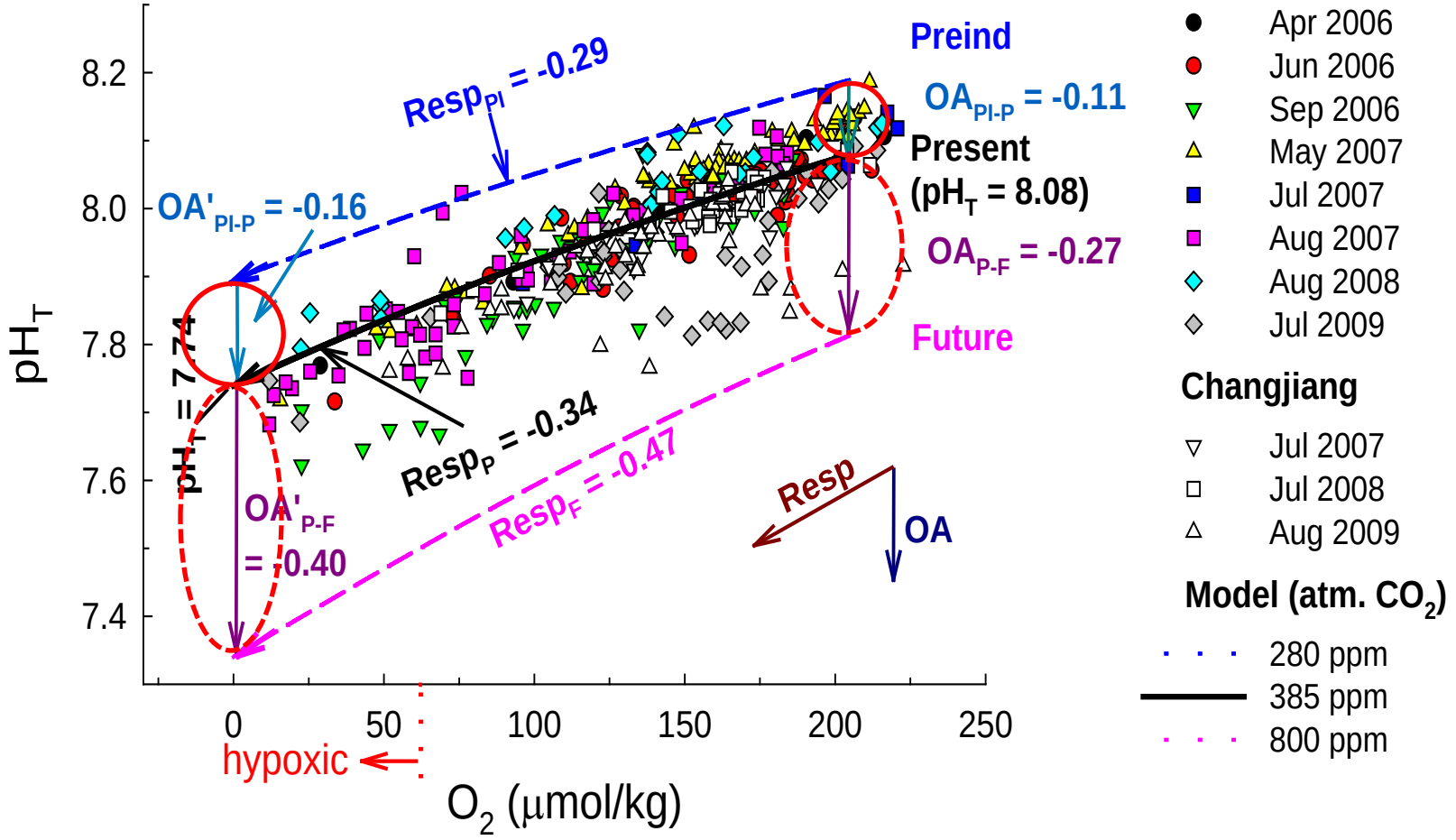


- Gulf of Mexico hypoxic water



How do anthropogenic CO_2 and CO_2 from respiration interact?

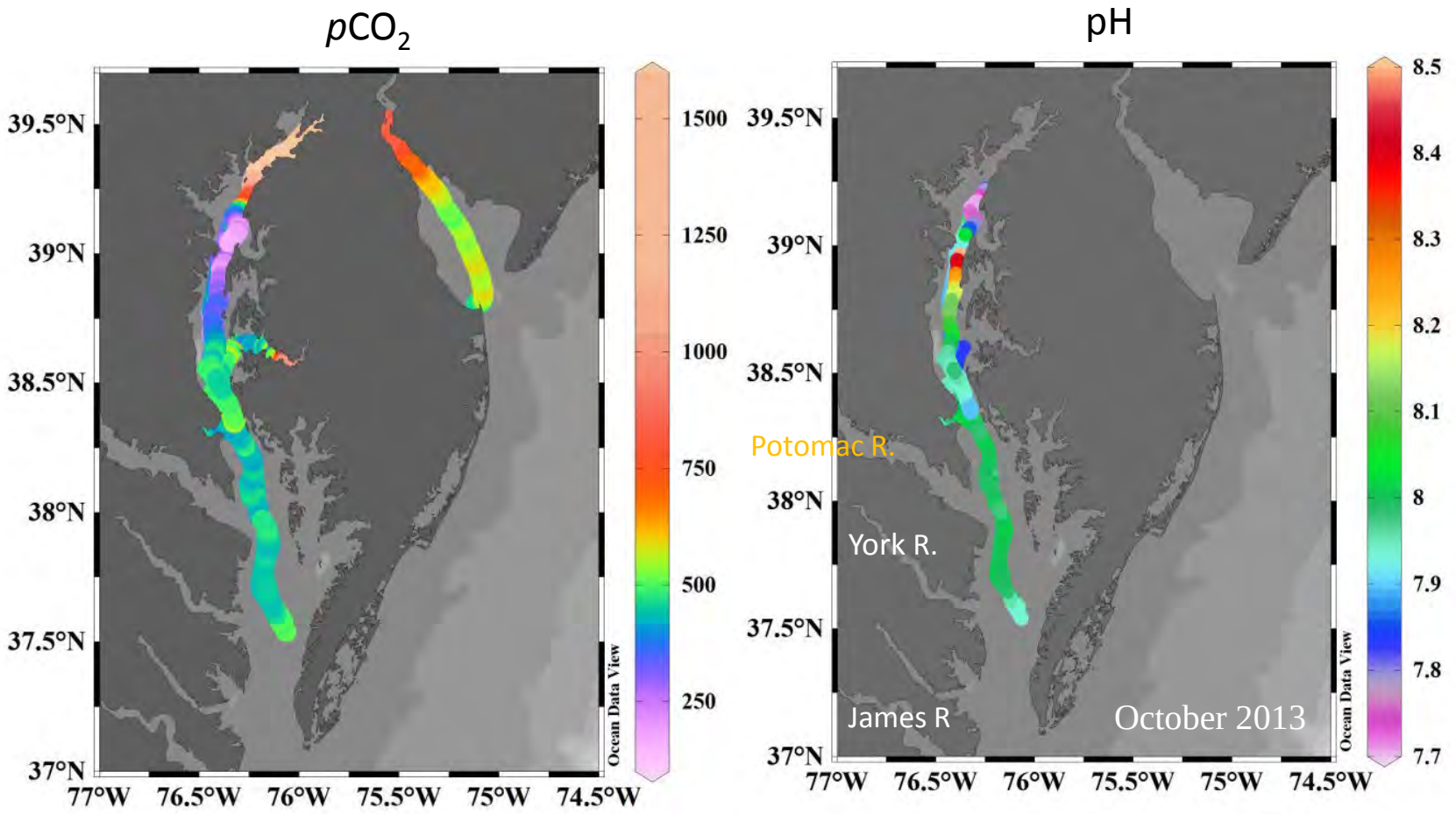
Enhanced ocean acidification!



Acidification and low O_2 events in coastal waters—5. the Chesapeake Bay

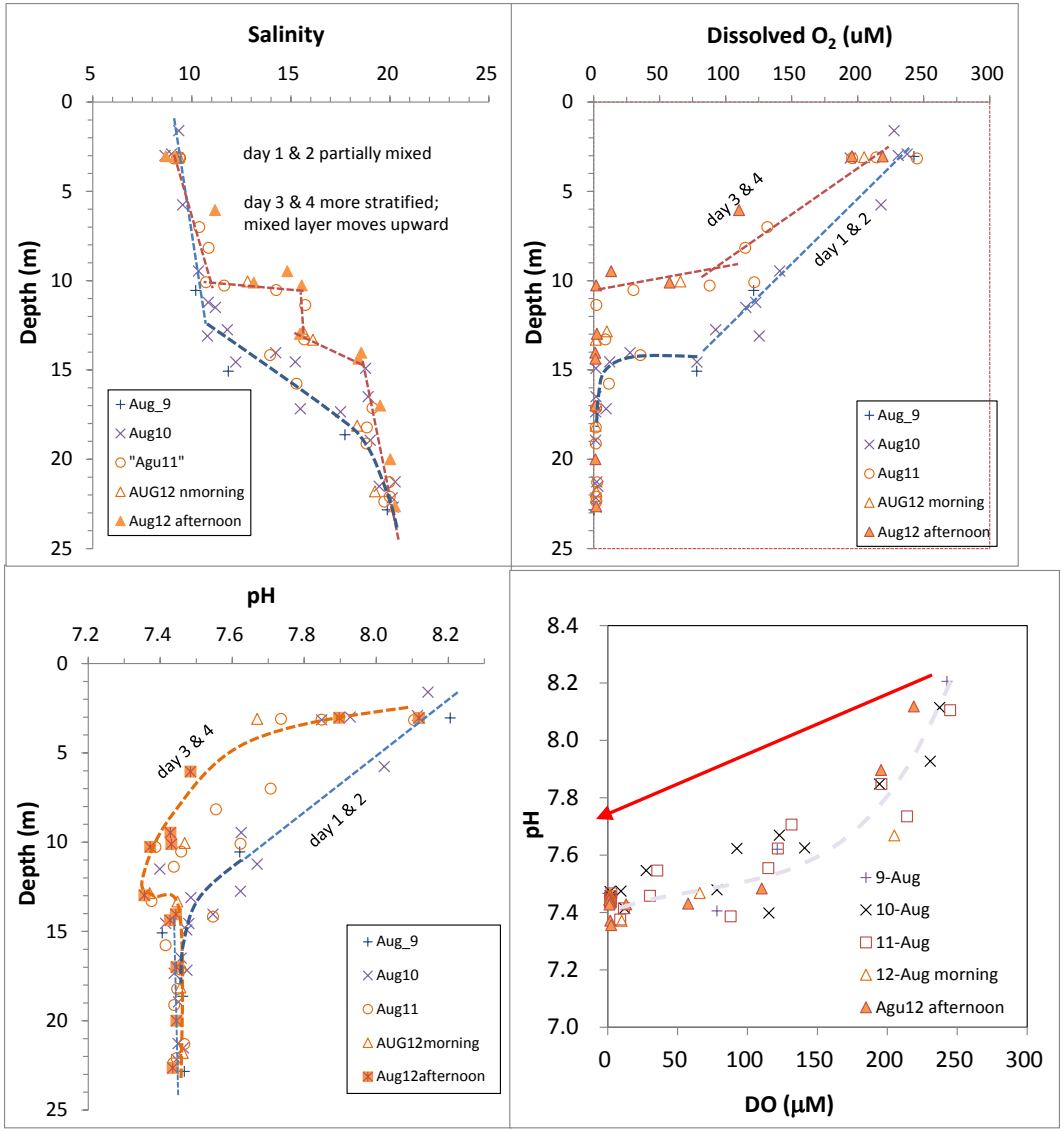
- One of the most "well" studied estuaries in the world
- We know little about its CO_2 system and acidification status

pCO_2 & pH in Chesapeake Bay (surface water)



Vertical distribution of pH and O_2

South of the Bay Bridge (8/9 -12, 2013)



There is a pH minimum at the depth where DO approaches zero

- day 1 [H_2S]=2-5 uM,
- day 4, [H_2S]=30-40 uM

$H_2S + 2O_2 = SO_4^{2-} + 2H^+$

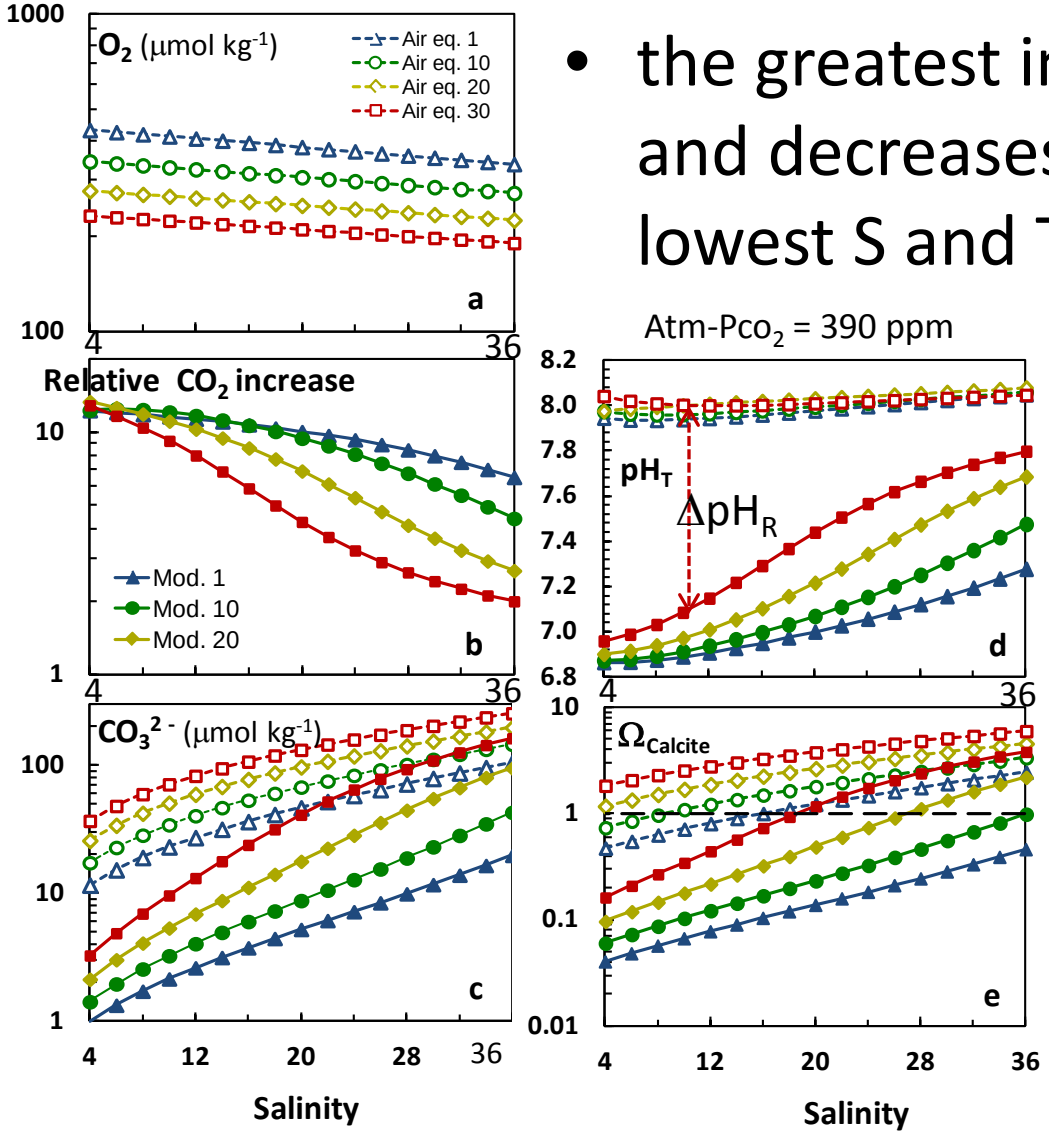
$NH_4^+ + 2O_2 = NO_3^- + 2H^+$

pH-DO relationship is very different than that in the Gulf of Mexico

Multiple stresses

- Salinity
- Temperature
- River-Ocean mixing
- More frequent storm
- Low O_2 event
- Shift of biogeochemical conditions & processes
- ….

Effects of T & S on respiratory-driven CO_2 acidification (over a complete consumption of O_2)

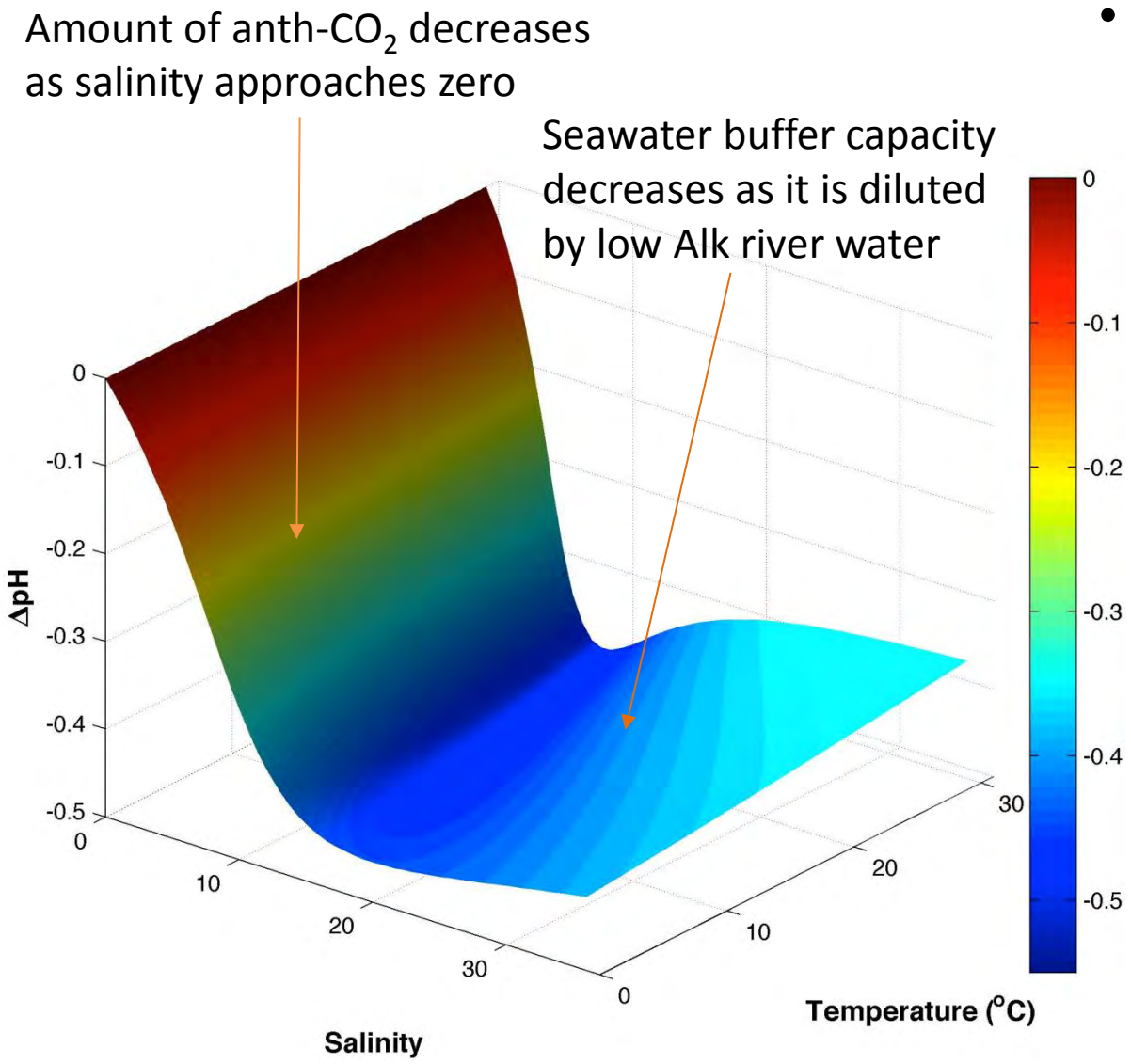


- the greatest increases in $[CO_2]$ (13-fold) and decreases in pH (~1.1) occur at the lowest S and T

- at higher S & T, less increase in Rel.$[CO_2]$ and decrease in pH (0.25–0.77 at S=36)
- $[CO_3^{2-}]$ decreases by 12-fold (low S & T) and 1.6-fold (high T &S)

(Sunda and Cai, ES&T, 2012)

Estuarine minimum buffer zone or maximum acidification zone (EMAZ)



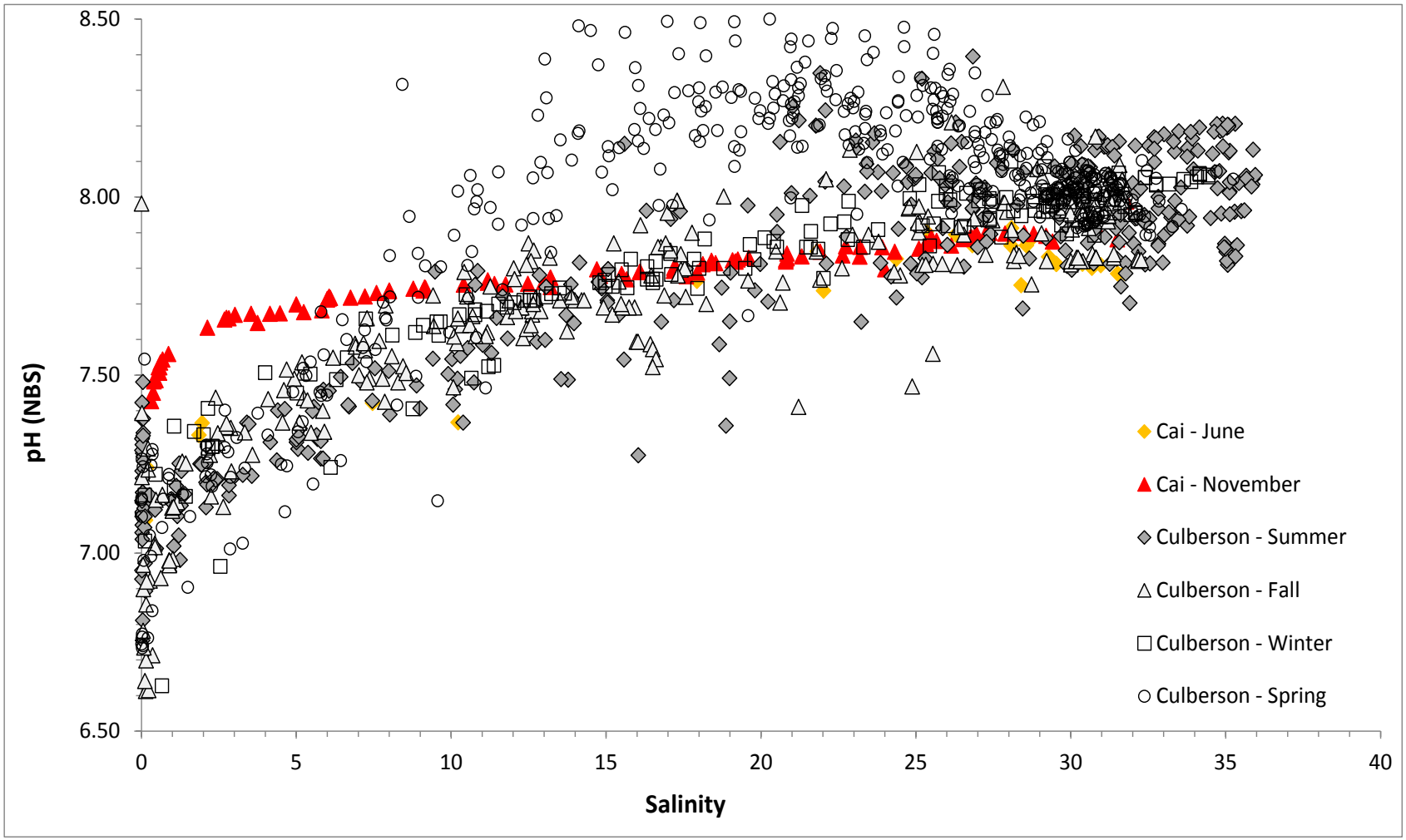
- pH difference between preindustrial era (CO_2 = 280 ppm) and future (CO_2 = 800 ppm) in an simulated estuarine water across salinity and temperature gradients. Altamaha River (TA/DIC) was used as the river endmember, and the seawater endmember TA was calculated using salinity 36 and alkalinity-salinity relationship of Atlantic surface water in Millero and DIC was calculated using TA at the two CO_2 levels.

“Coastal Ocean” Acidification? (due to primary BOD of sewage effluent)

- Oxidation of reduced C and N (i.e., OC & NH_4^+) from industrial and household sewage discharge was known for causing very low O_2 in many highly polluted rivers in the world (EU & NA 50 yrs ago and developing countries today).
- What about their impact on pH?

30 years pH data in the Delaware Bay--

Sewage discharge: an rather old and forgotten driver for coastal “ocean” acidification



Summary

- Respiration plays a more important role in acidifying coastal bottom waters today,
- Anthropogenic CO_2 uptake from the atmosphere will play an increasingly more important role in acidifying coastal ocean bottom waters.
- There is a strong enhancement of acidification in CO_2-enriched waters, and such effects vary greatly with salinity and temperature, with a greater effect in low T and S water and a smaller effect in high T and S water.
- There exists an Estuarine Maximum Acidification Zone.
- Sewage discharge is another source of acidification

Acknowledgement

NSF-CO and -Arctic program, NOAA, and NASA for funding my carbon cycle research;

However, ...