The Chesapeake Carbon and Alkalinity Study (CHALK)

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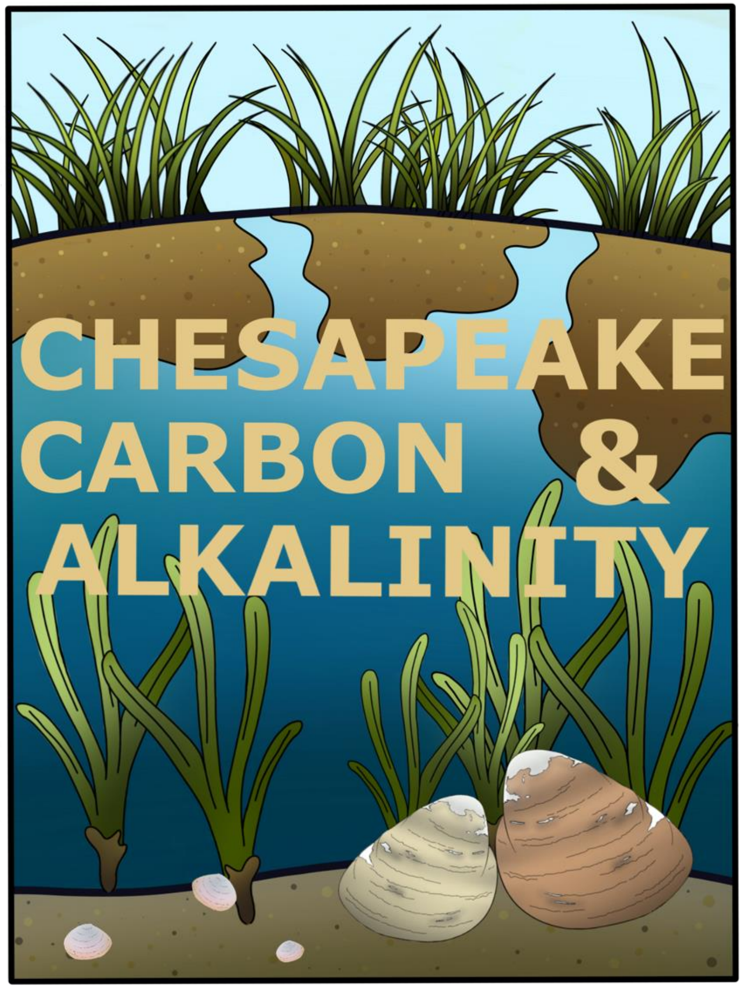
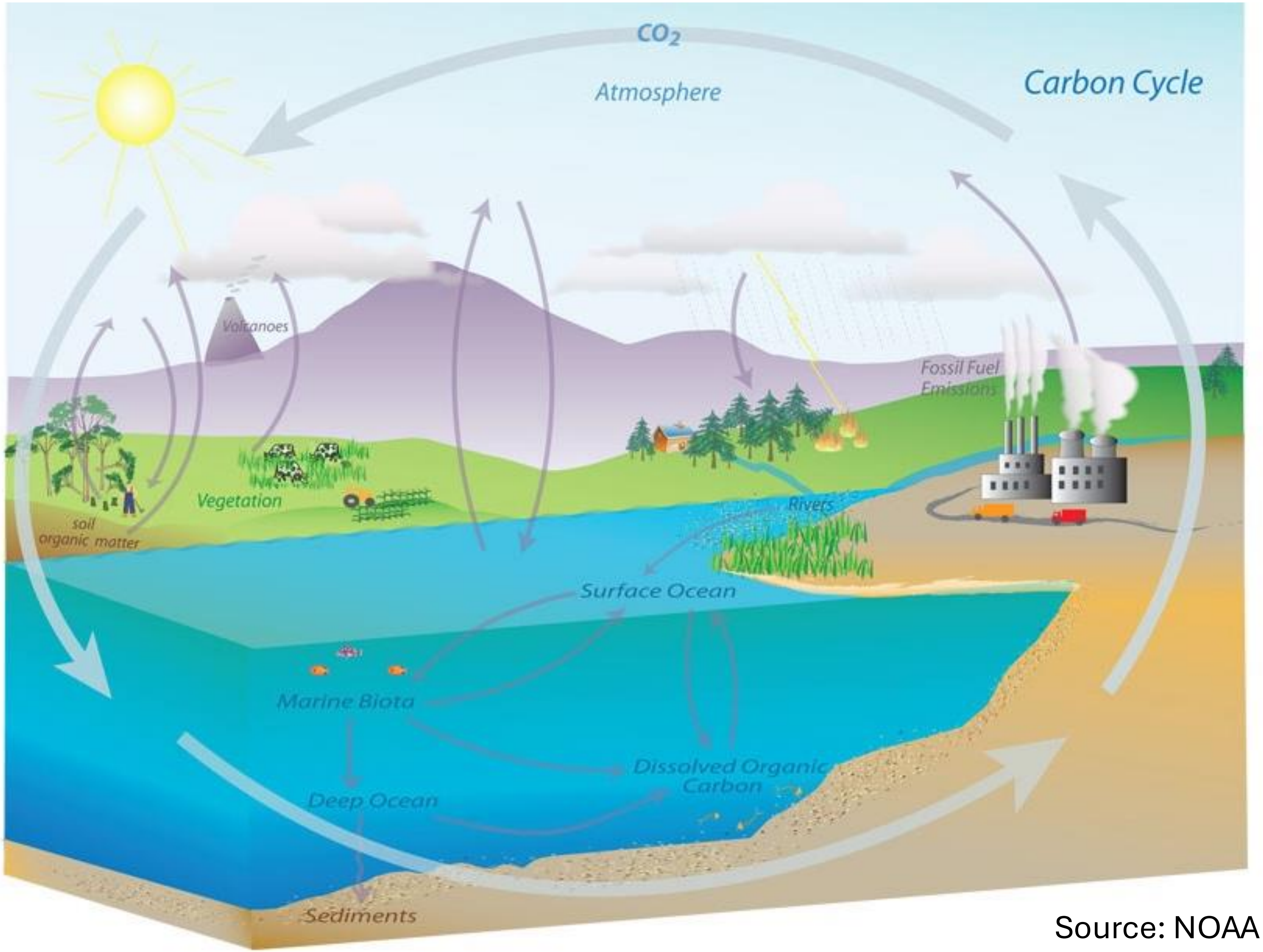


Graphic by Javi Pujols

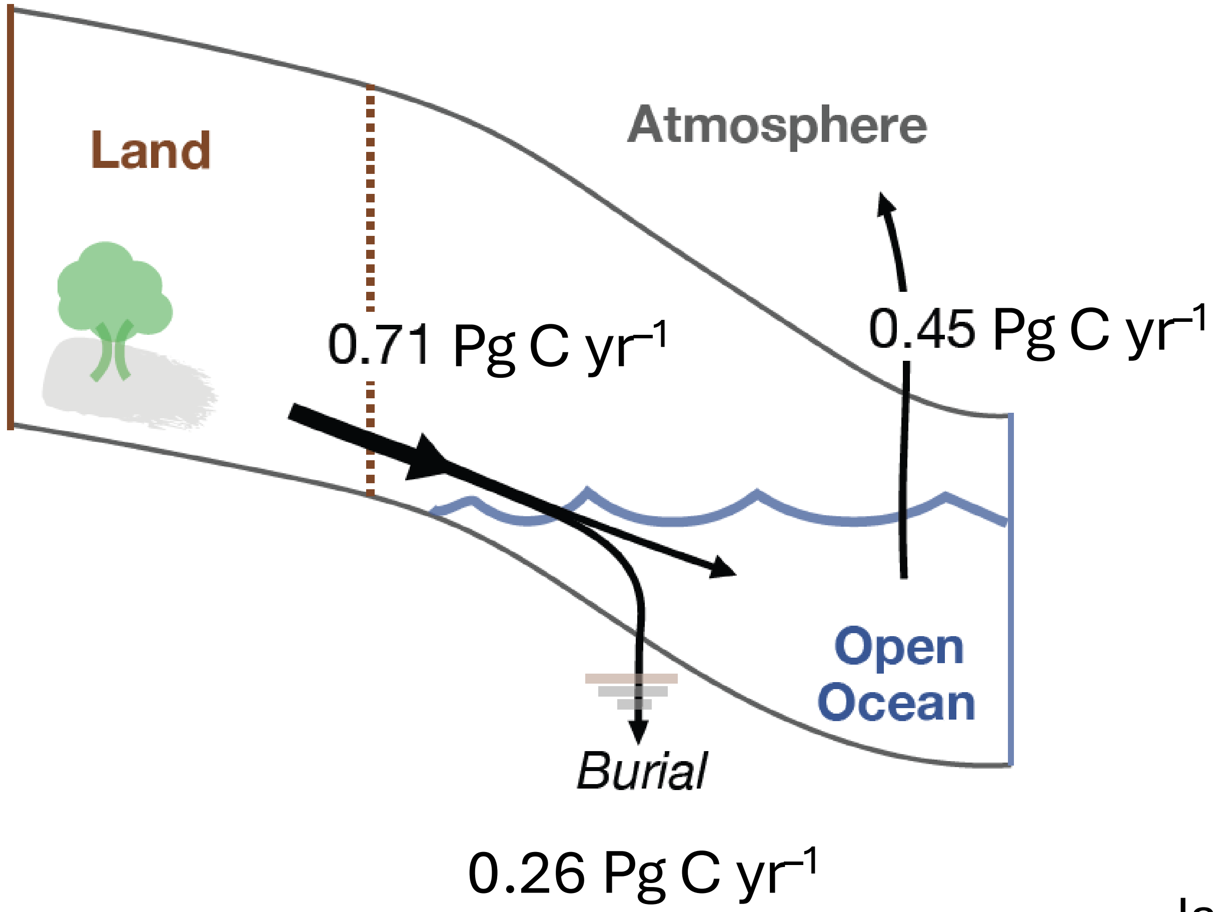


Source: NOAA

Why is the carbon cycle important?

- Carbon is the main currency for quantifying the productivity of the biosphere
- CO_2 stimulates plant growth
- Anthropogenic CO_2 acidifies the ocean
- CO_2 is an extremely important greenhouse gas

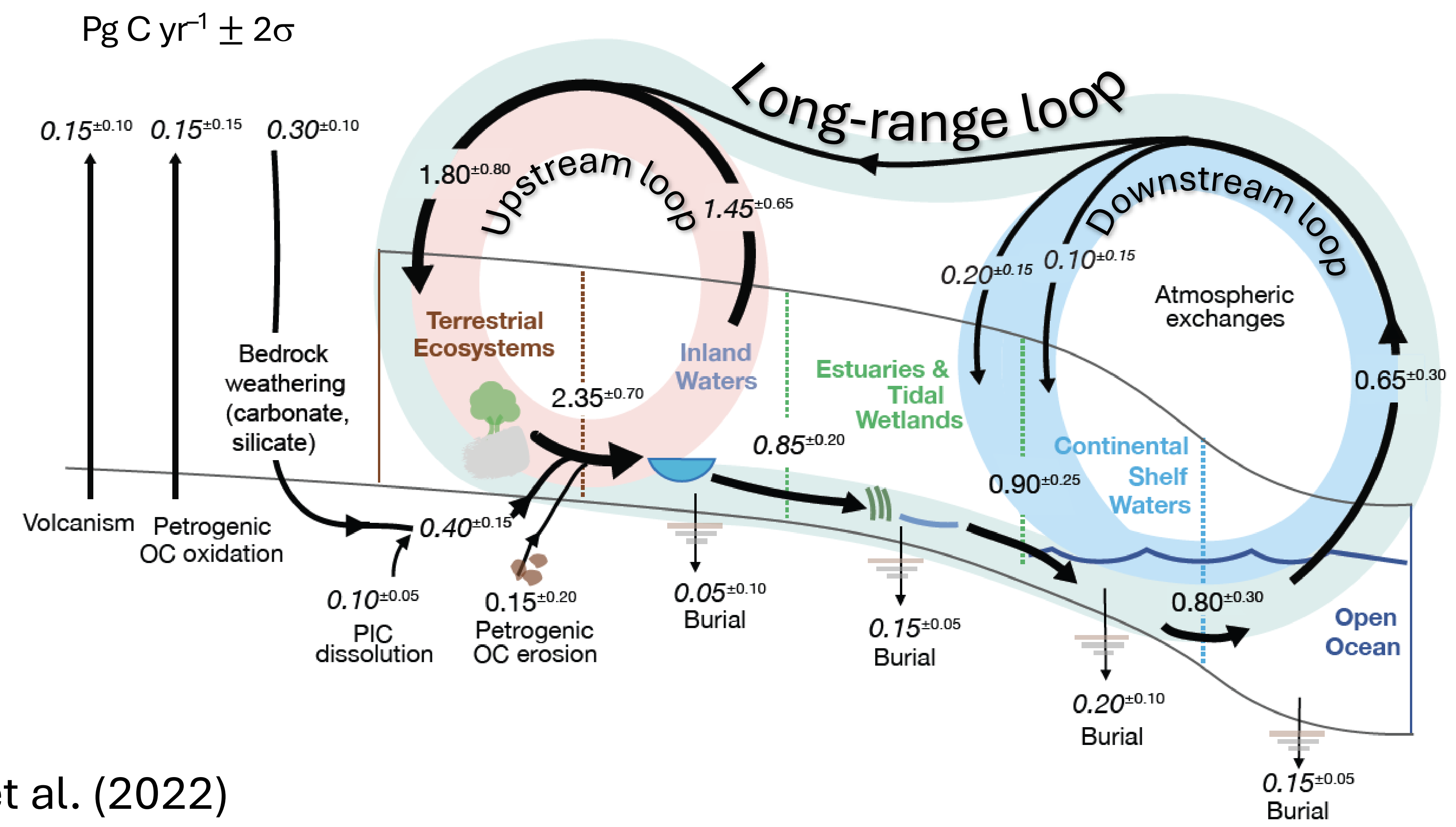
Land-to-ocean carbon transfer is a key component of the modern carbon cycle



- Old "single pipe" view of the natural carbon cycle
- Widely used in global budgeting exercises of the Intergovernmental Panel on Climate Change and the Global Carbon Project

Jacobson et al. (2007) and Resplandy et al. (2018)

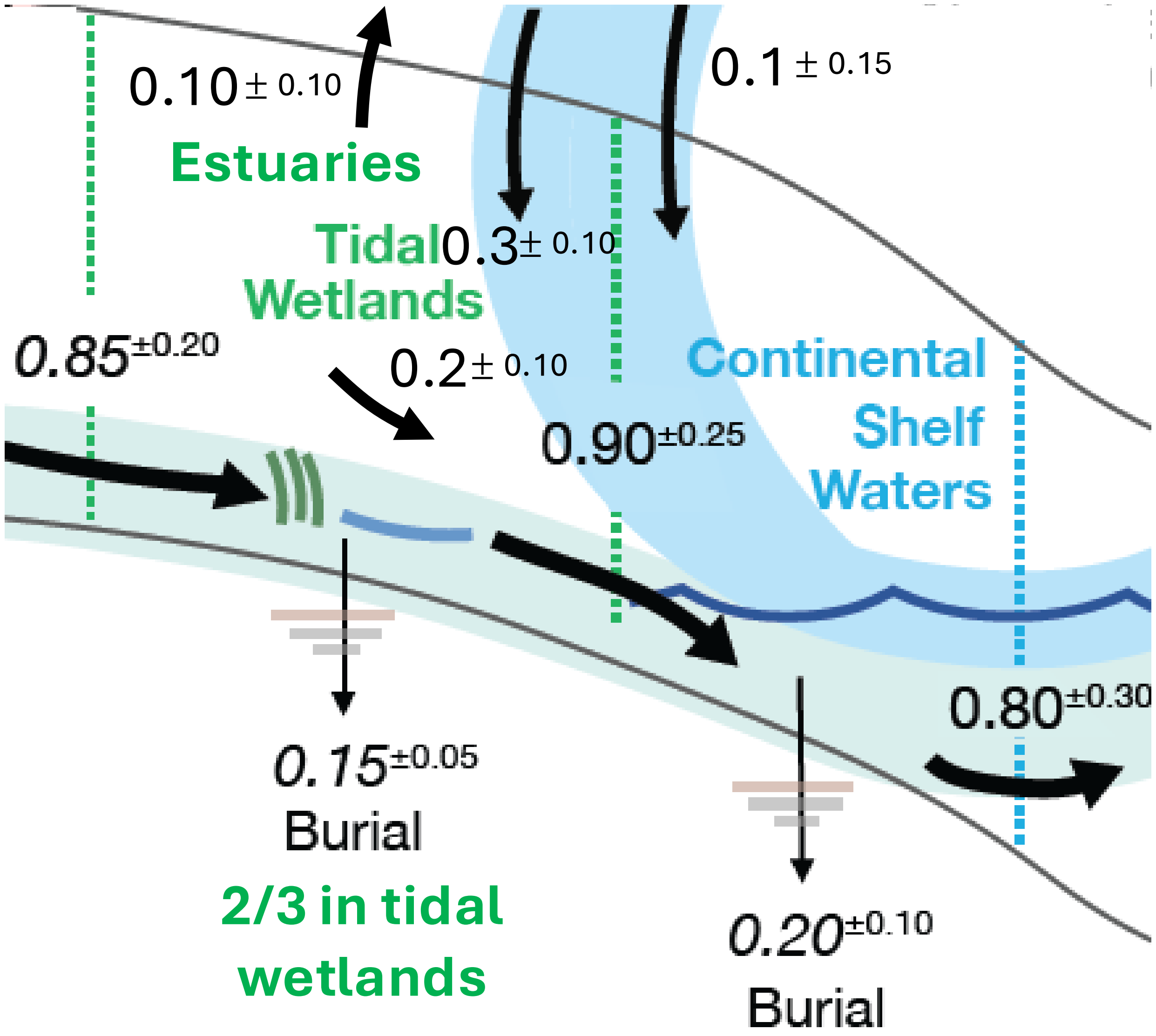
Updated view of pre-industrial carbon cycle shows two prominent loops of CO_2 exchange with the land–ocean aquatic continuum



Regnier et al. (2022)

Riverine carbon does not reach the open ocean unhindered but rather passes through highly productive estuaries and is profoundly transformed by metabolic processes, burial, and outgassing

Zoom-in on pre-industrial coastal fluxes ($Pg\ C\ yr^{-1} \pm 2\sigma$)



Regnier et al. (2022)

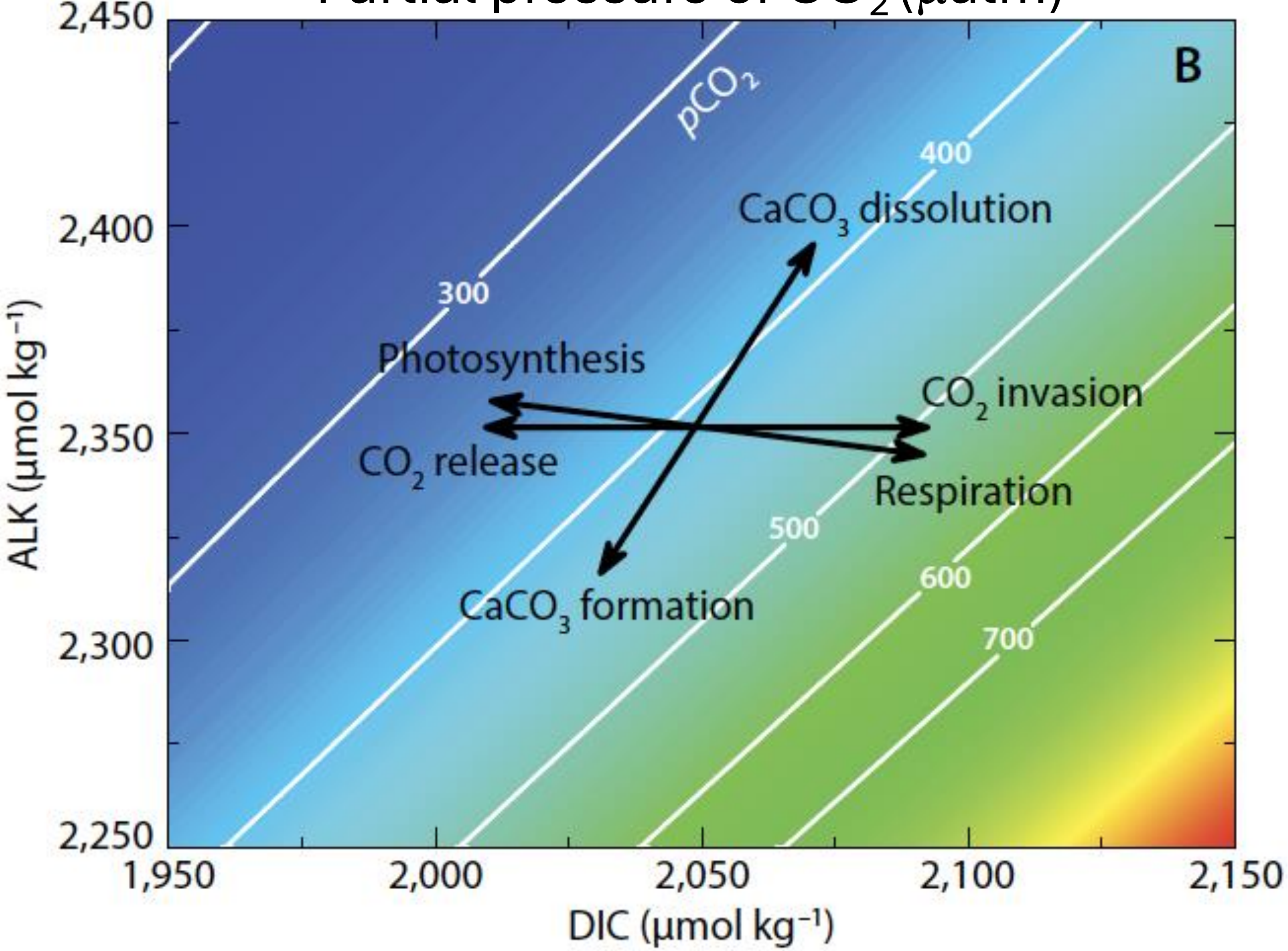
Aquatic carbonate system background and motivation

$$\mathbf{CO_2 + H_2O \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-}}$$

- There are 2 more unknowns than equations, so 2 variables need to be specified
- Best variables are **dissolved inorganic carbon (DIC) and alkalinity** because they are conservative with respect to changes in temperature, salinity, and pressure
- DIC = $CO_2 + HCO_3^- + CO_3^{2-}$
  - Tracer for photosynthesis, respiration, and CO_2 exchange with atmosphere
- Alkalinity
  - The acid-neutralizing capacity of a water body
  - Regulates speciation of inorganic carbon among CO_2, HCO_3^-, and CO_3^{2-}
  - Tracer for estuarine processes involving Ca, N, and S

Once you understand DIC and alkalinity, you can understand the rest of the carbonate system, like pCO_2

Partial pressure of CO_2 (μatm)

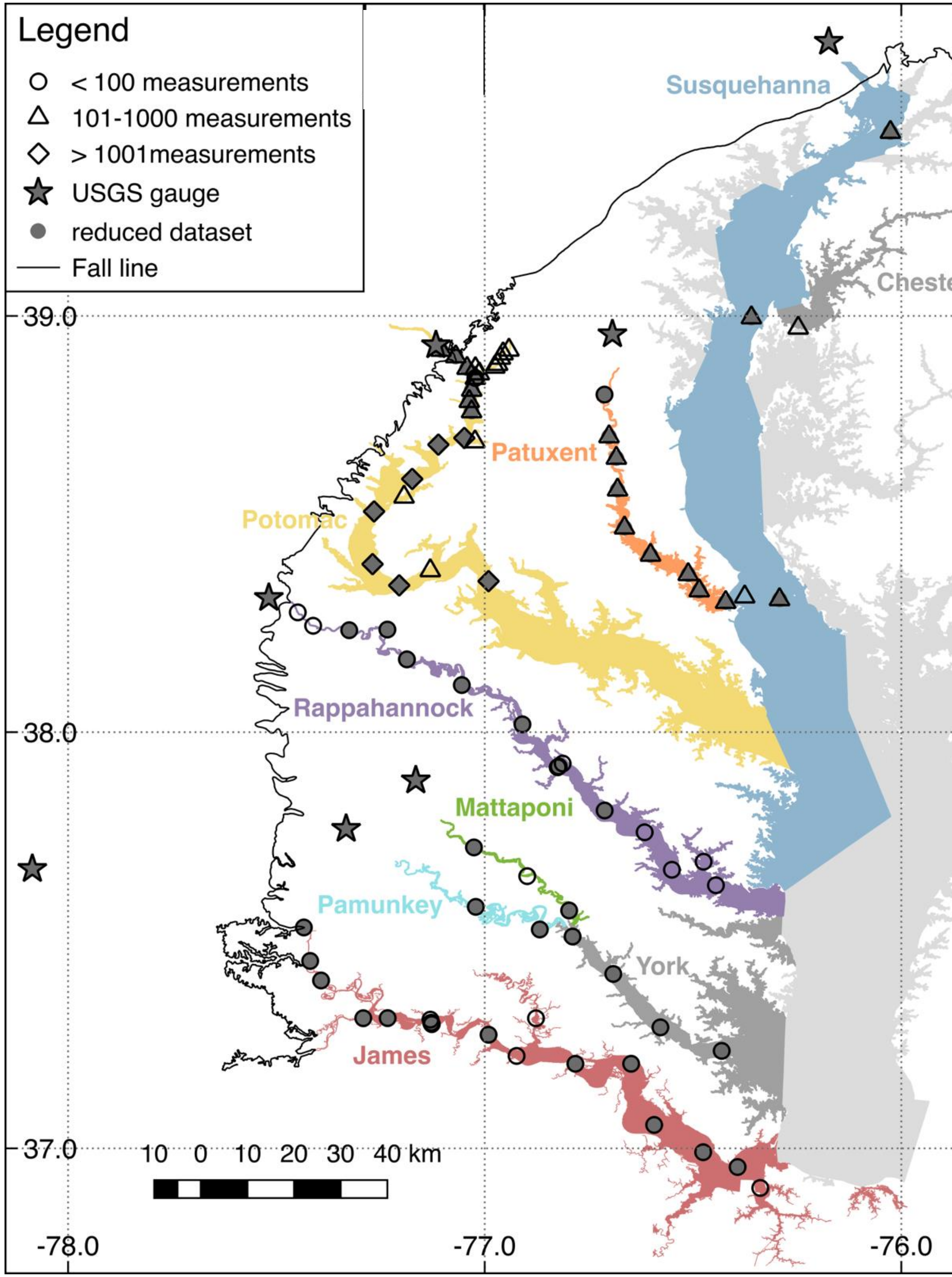


Source: Yu et al. (2014)

Pre-CHALK alkalinity study

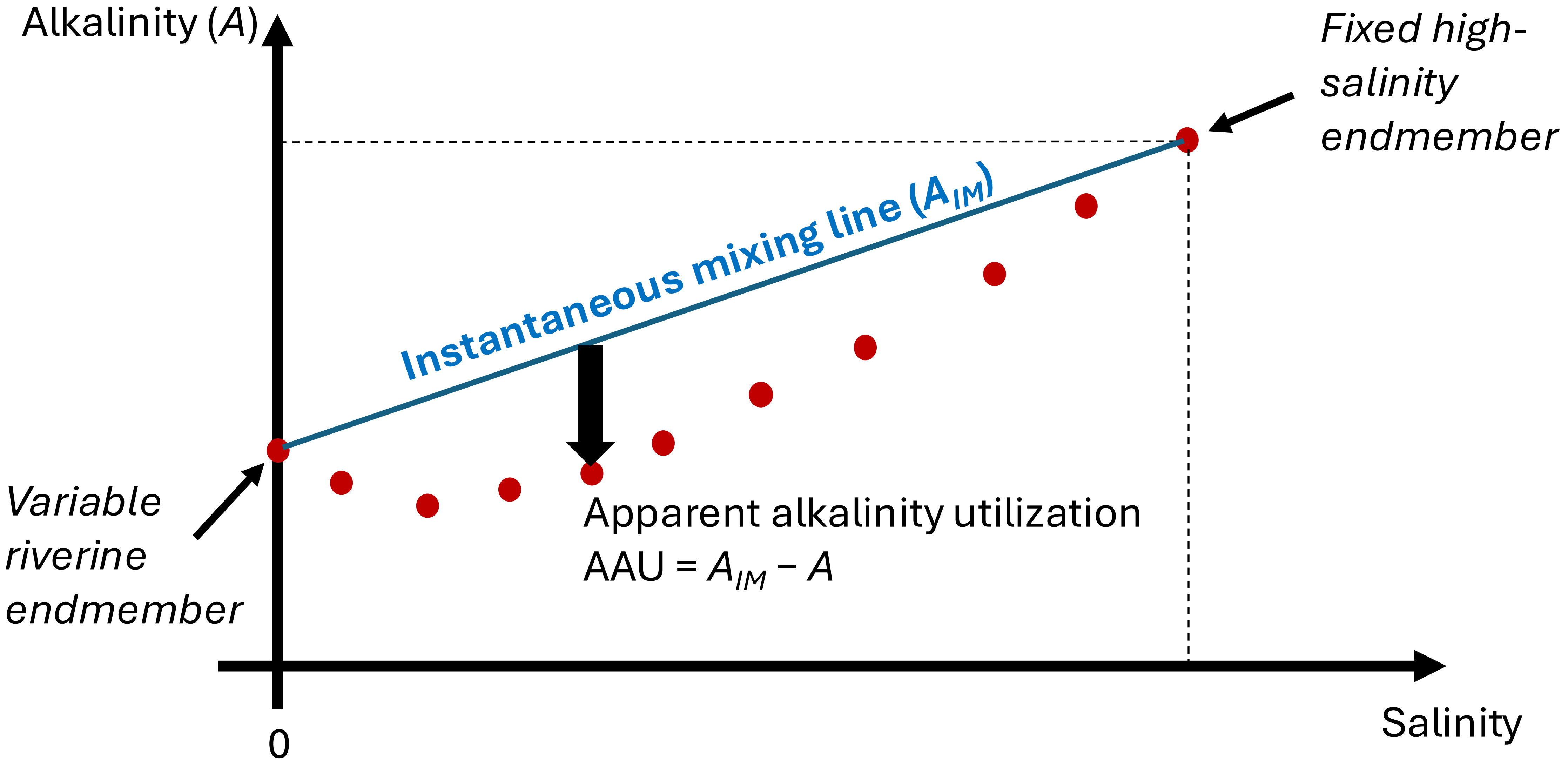
- Document variability of alkalinity in major tidal tributaries of Chesapeake Bay
- Quantify alkalinity sources and sinks
- Tidal data:
    - Chesapeake Bay Program
    - >25,000 measurements
    - 1986 to 2018
- Non-tidal data from United States Geological Survey

Sebastian Cintron Del Valle, 2016 Research Experiences for Undergraduates Participant



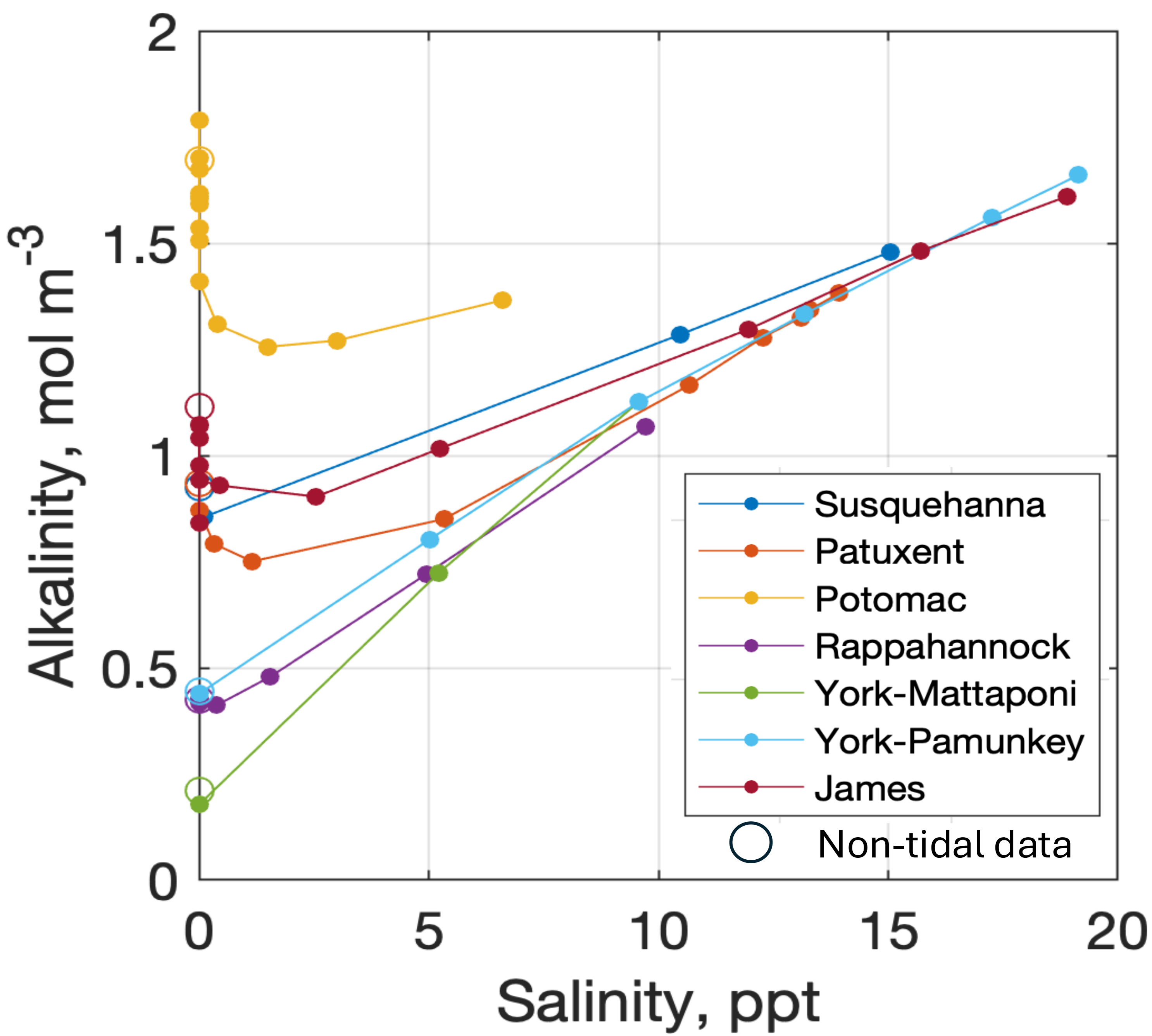
Najjar et al. (2020)

Interpreting estuarine water chemistry data: Alkalinity example



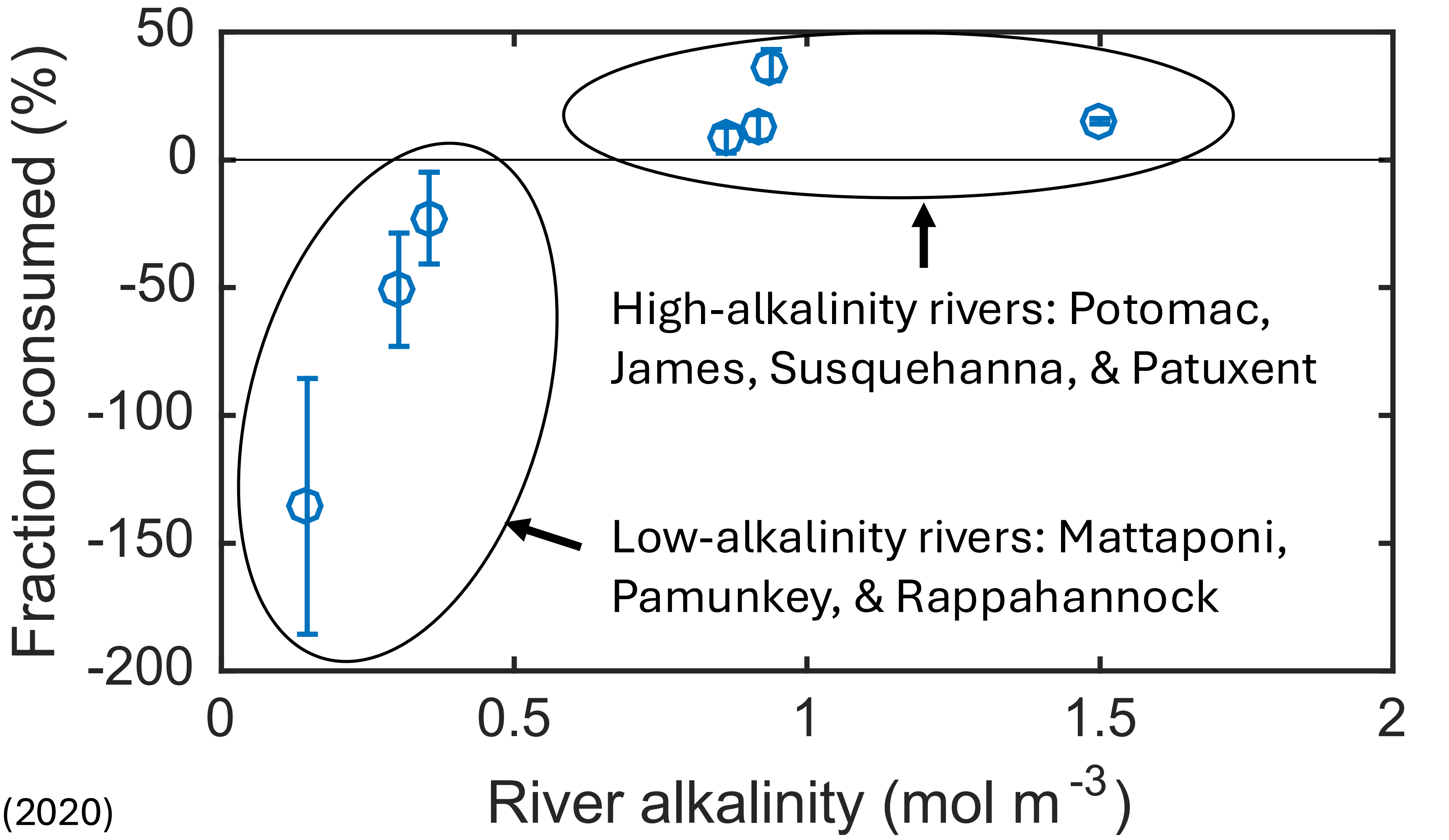
Summary figure shows differences among the seven tidal tributaries in:

- Fresh-water endmember
- Source/sink behavior



Najjar et al. (2020)

Tidal tributaries fed by high-alkalinity rivers have alkalinity sinks and those fed by low-alkalinity rivers have alkalinity sources



Najjar et al. (2020)

Macrobiota—benthic fauna, tidal wetlands, and SAV—may be responsible for much non-conservative carbon and alkalinity behavior in estuaries

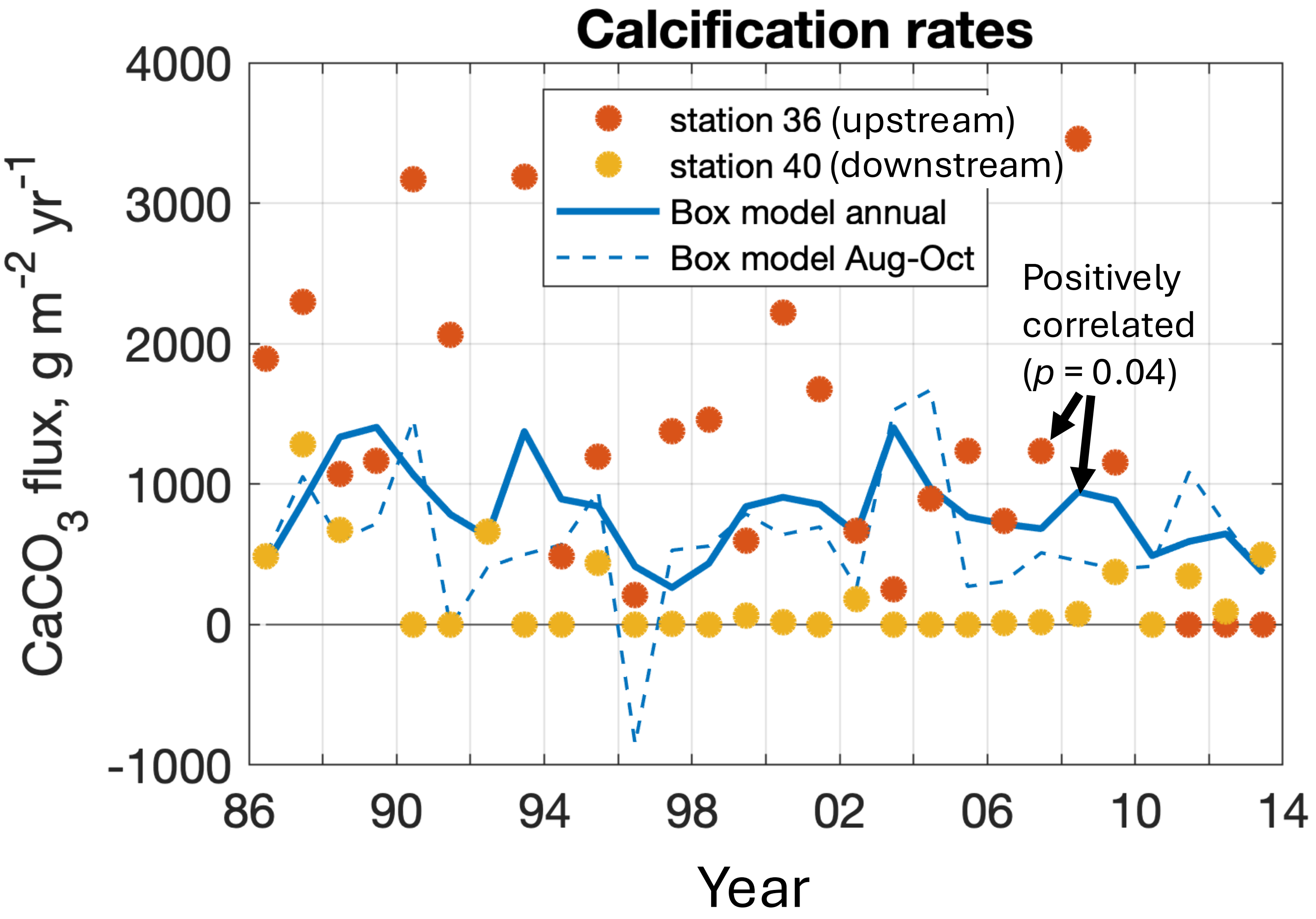
benthic fauna

tidal wetlands

submersed aquatic vegetation

Example of bivalves in the upper Potomac River Estuary

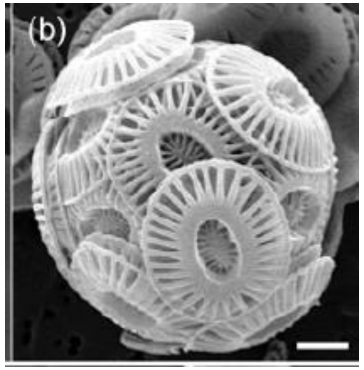
Calcification rates estimated from bivalve biomass are large enough to account for the Ca^{2+} sink estimated from an alkalinity mass balance box model

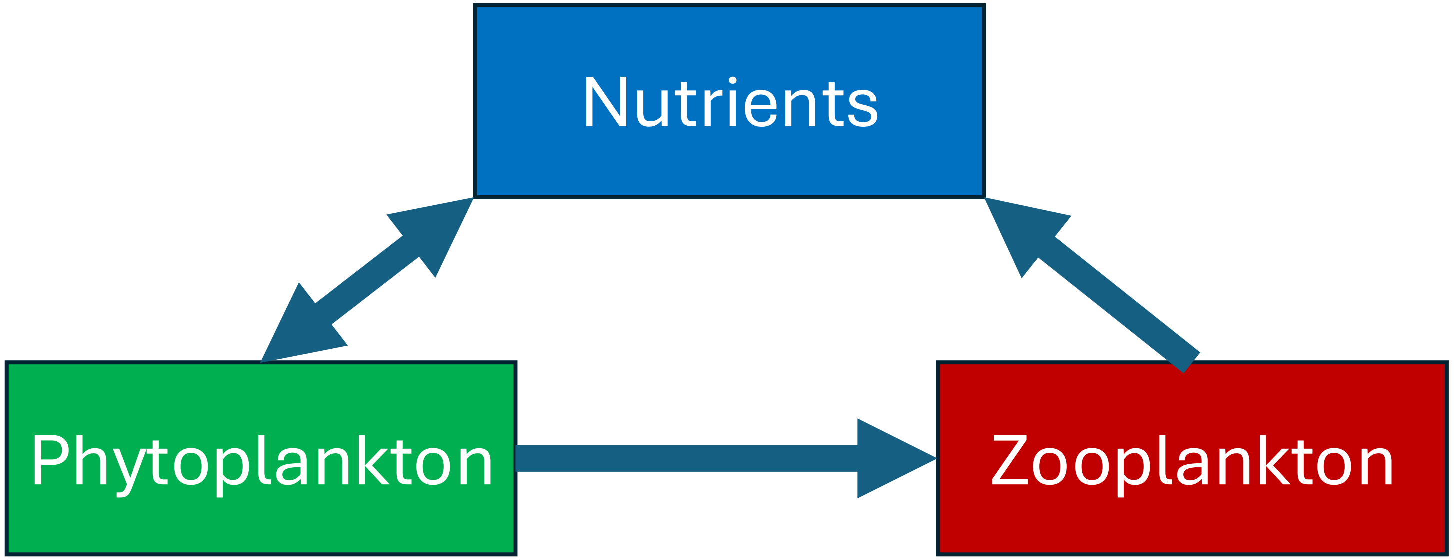


Najjar et al. (2020)

Estuarine biogeochemical models generally ignore macrobiota

Typical “NPZ” model:

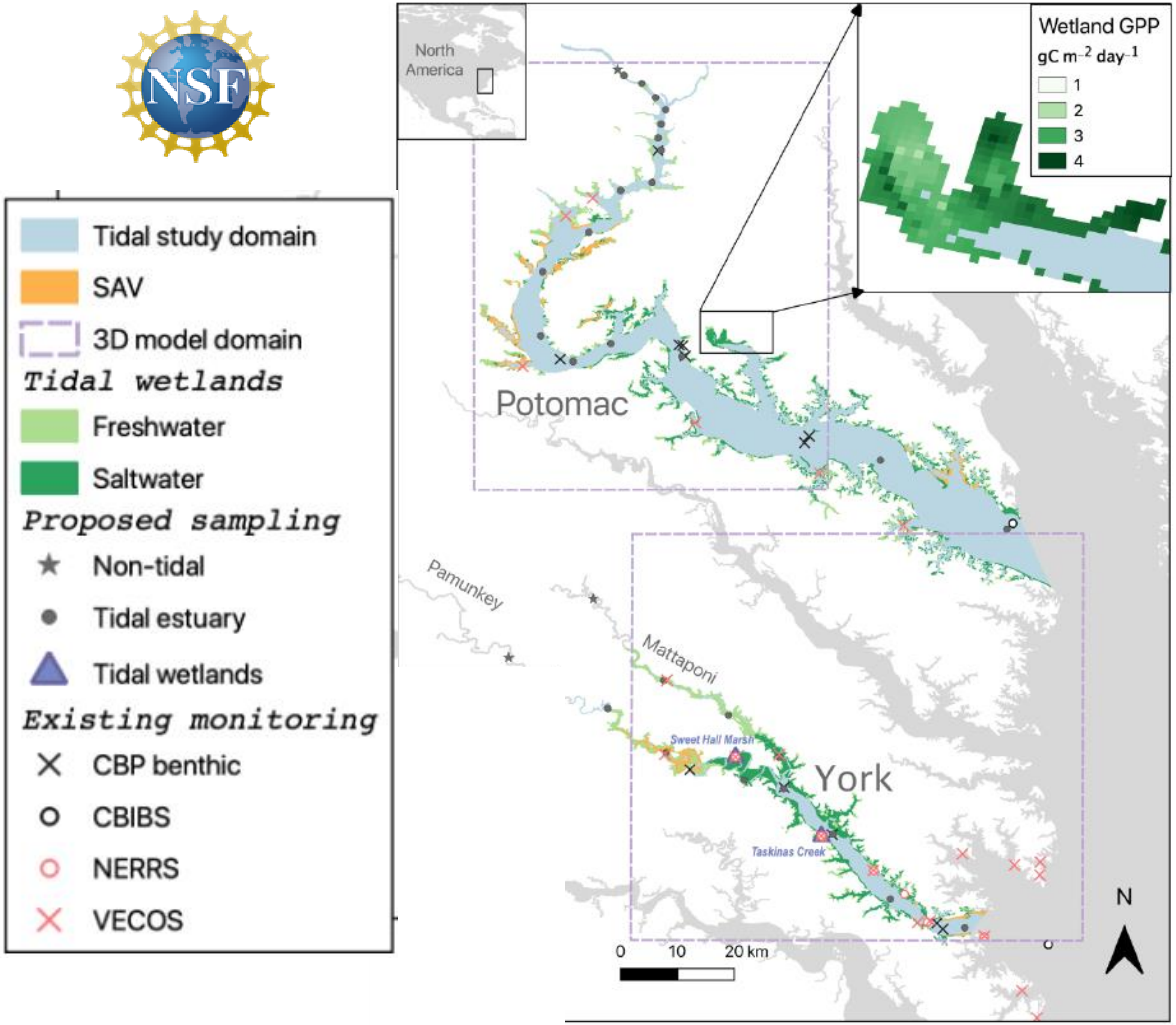




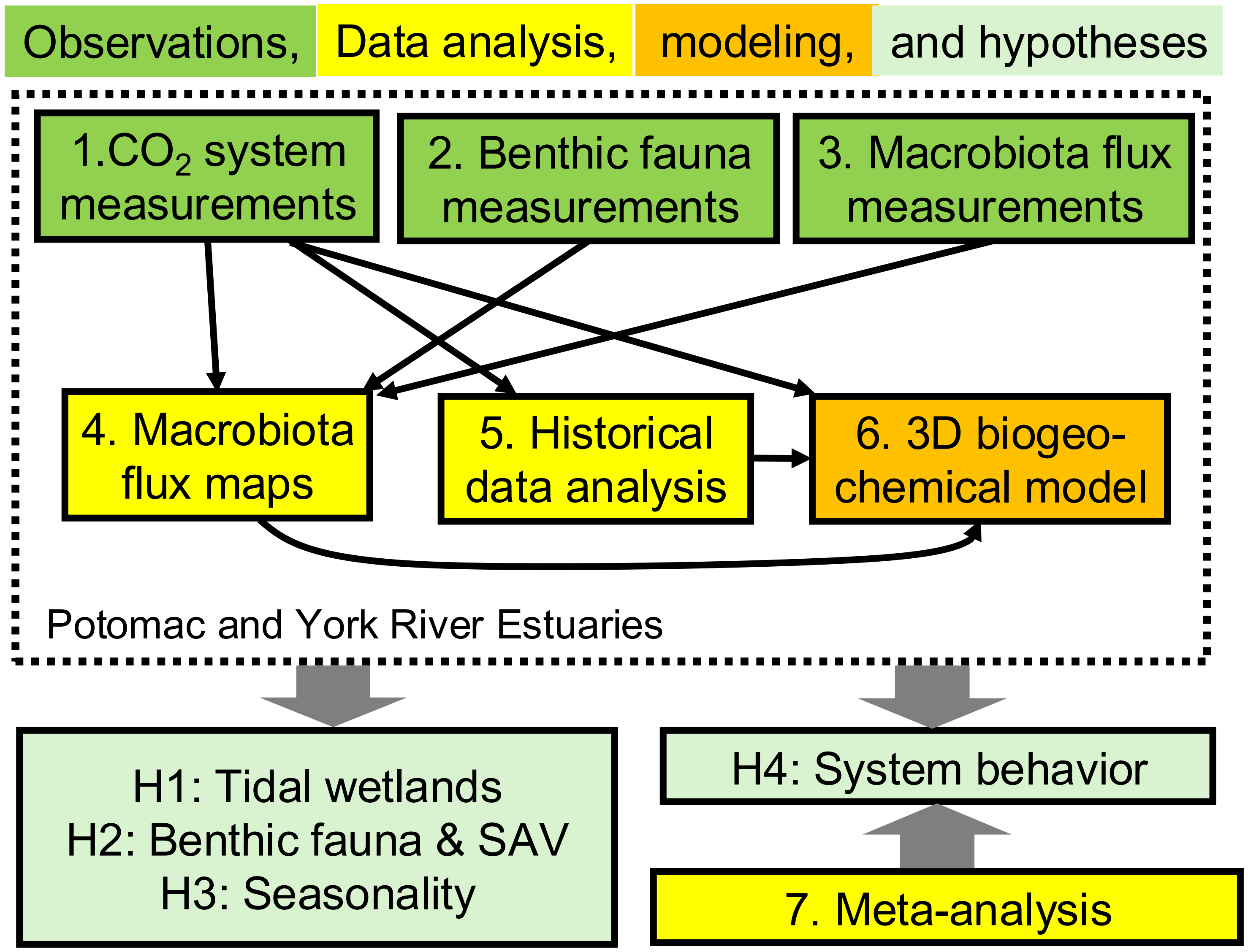
Images: Von Dassow et al. (2018) and National Oceanography Centre, Southampton

CHALK focuses on two contrasting tidal tributaries of the Chesapeake Bay:

- Potomac River Estuary
  - High alkalinity and dissolved inorganic carbon
  - Likely alkalinity sink
- York River Estuary
  - Low alkalinity and dissolved inorganic carbon
  - Likely alkalinity source
  - Large ratio of wetland area : estuarine area



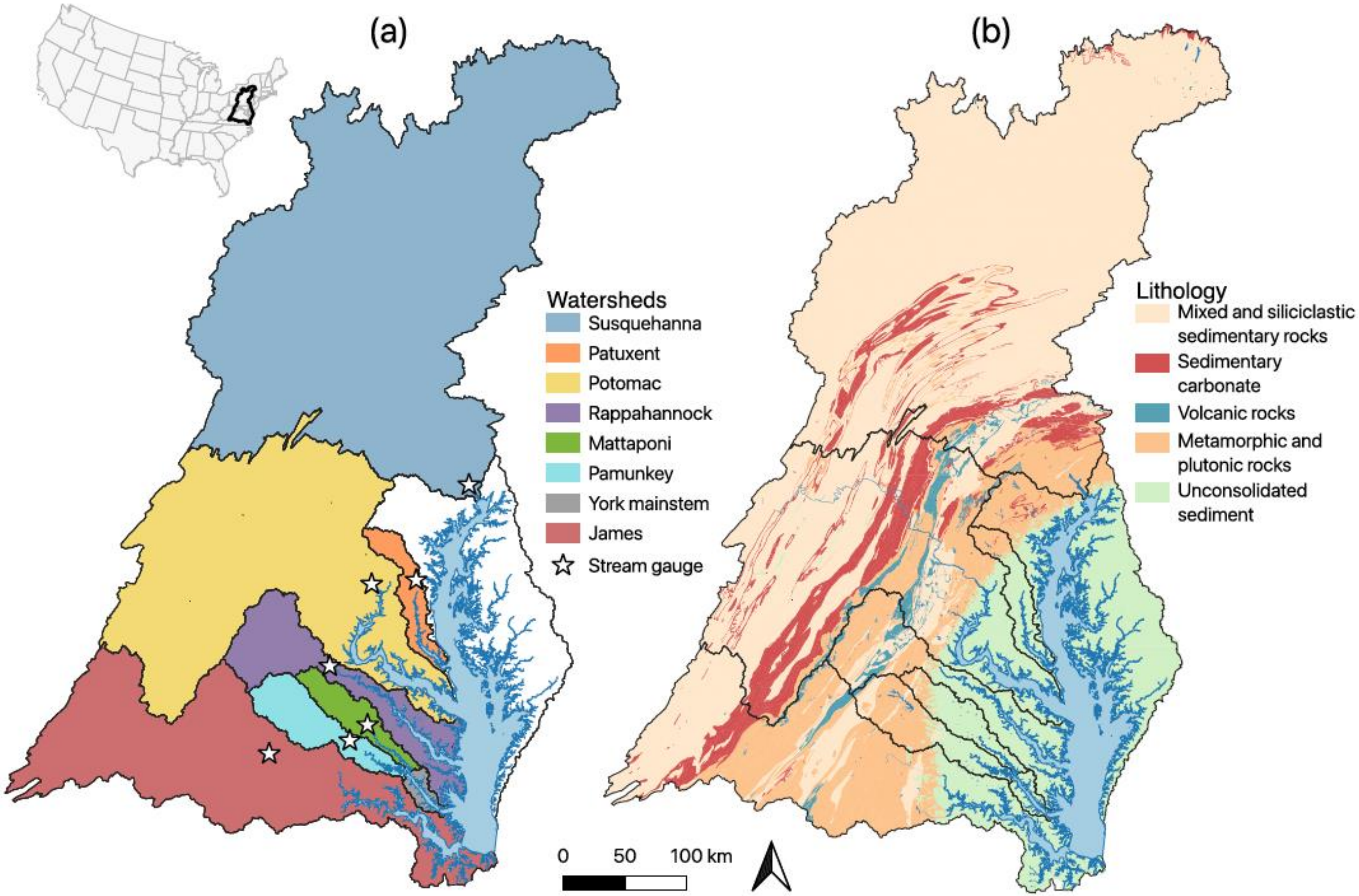
CHALK activities



CHALK overall objective

Improve understanding of the role that macrobiota play in estuarine carbon and alkalinity dynamics

Historical data analysis: Geology and hydrology drive the differences in alkalinity and DIC in the Chesapeake's rivers

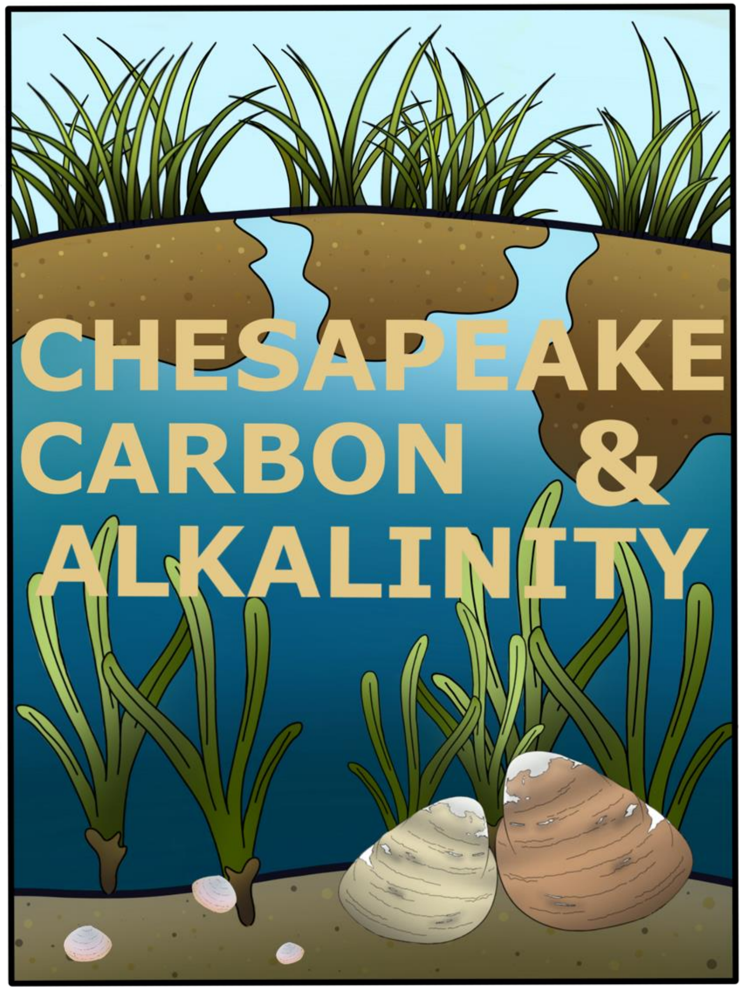


REU student
Riley Westman

Najjar et al. (2026)

Today's presentations

- Bivalve fluxes (Rivest)
- Bivalve biomass (Woodland)
- Bivalve fluxes in a 3-D model (Ajayi)
- Submerged vegetation fluxes (Gurbisz)
- DIC and alkalinity (Mann)
- Organic alkalinity (Wang)
- *p*CO_2 (Lapham)
- Calcium and other cations (Fantle)



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