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Modeling water quality and phytoplankton blooms in Florida Bay and Florida Keys

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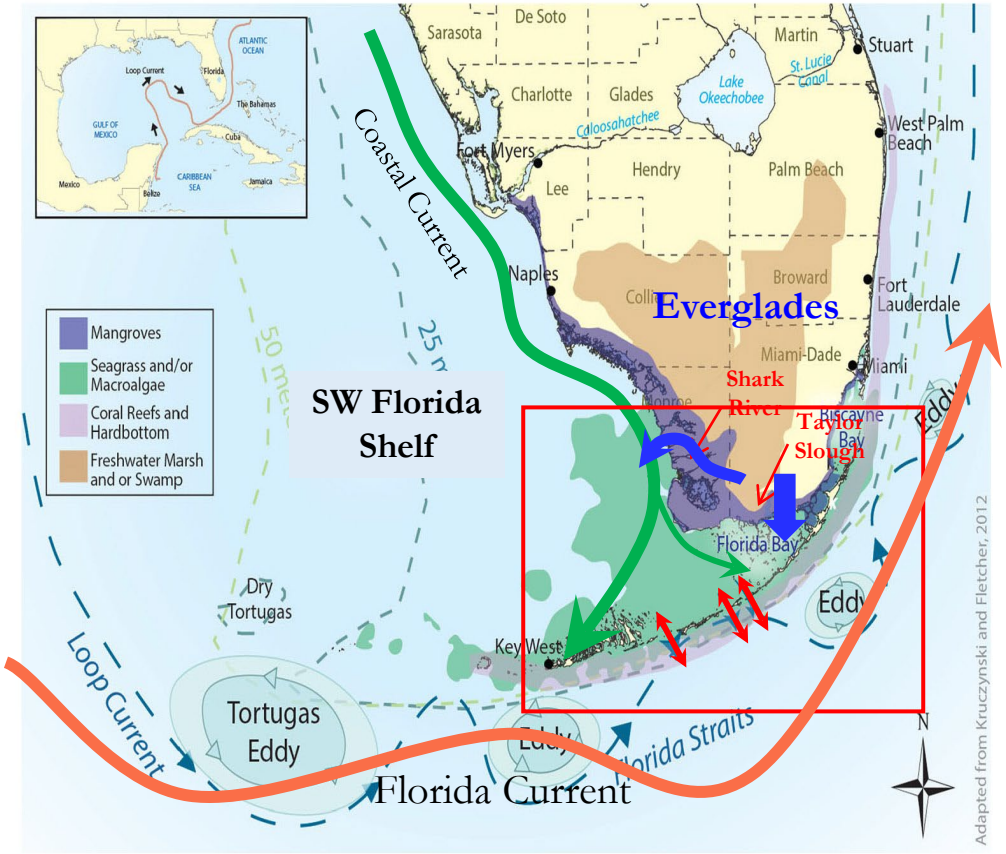
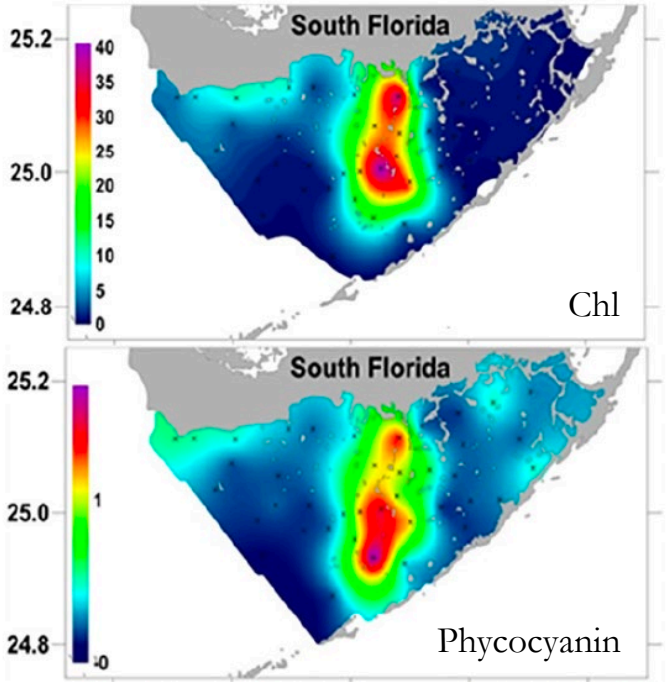
Background

- Greater Fbay: Abundant seagrass & mangroves; Major cyanobacteria blooms
- Complex benthic biology & biogeochemistry
- Affected by west Florida shelf, upstream coasts & Everglades
- Important to Florida Reef Tract & Other downstream ecosystems

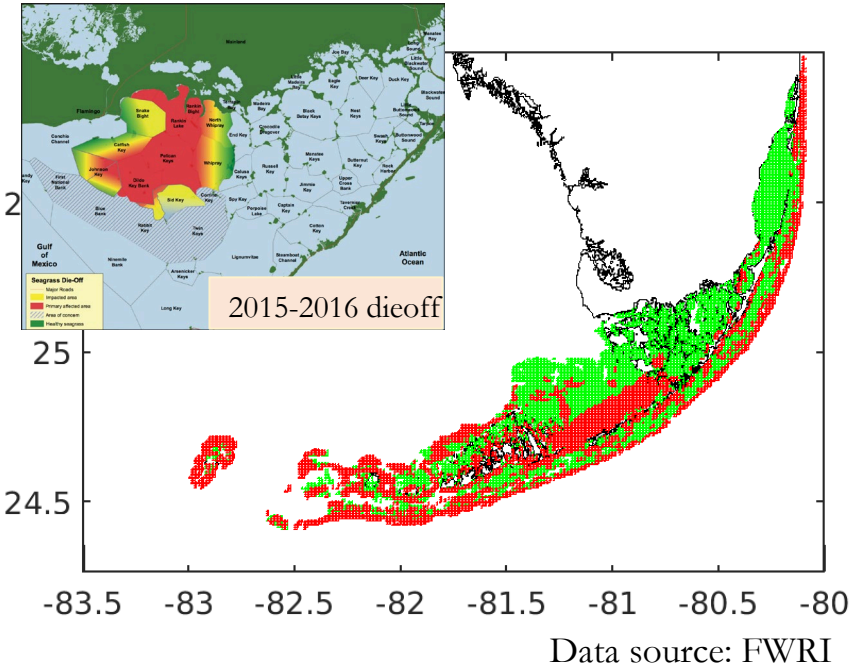


Adapted from Koch et al. 2014

Q1: What drive the cyanobacteria blooms and why focus on Central Florida Bay?
Q2: What are the potential effects on seagrass and corals?



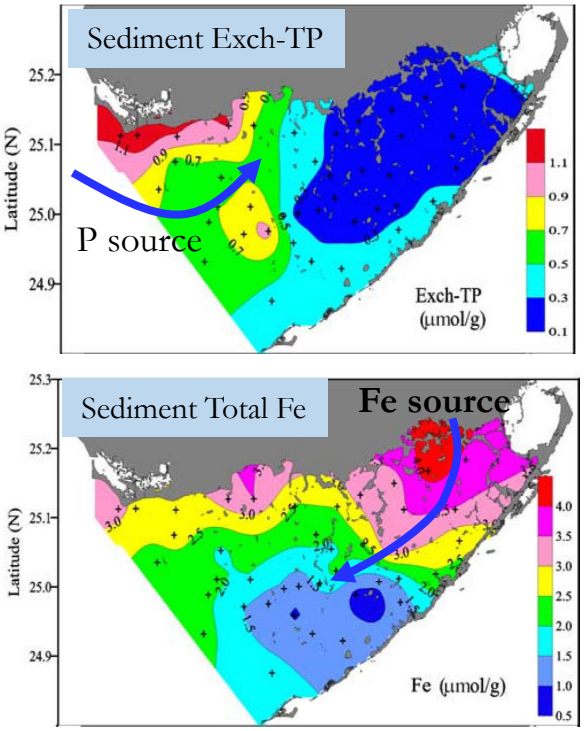
Cannizzaro et al. (2019)



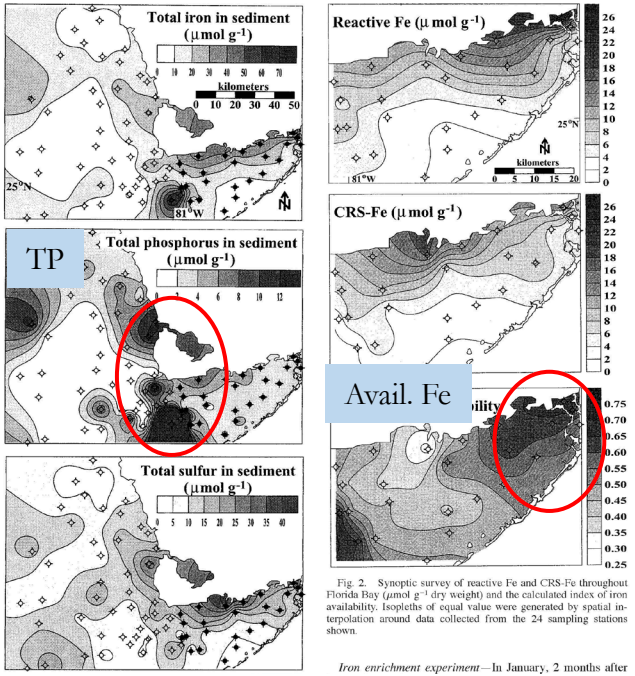
Data source: FWRI

Q3: Where are the nutrients from?

- High leachable P in western bay sediment
- Fe and N inputs from the northeastern bay
- High P in upstream coastal waters



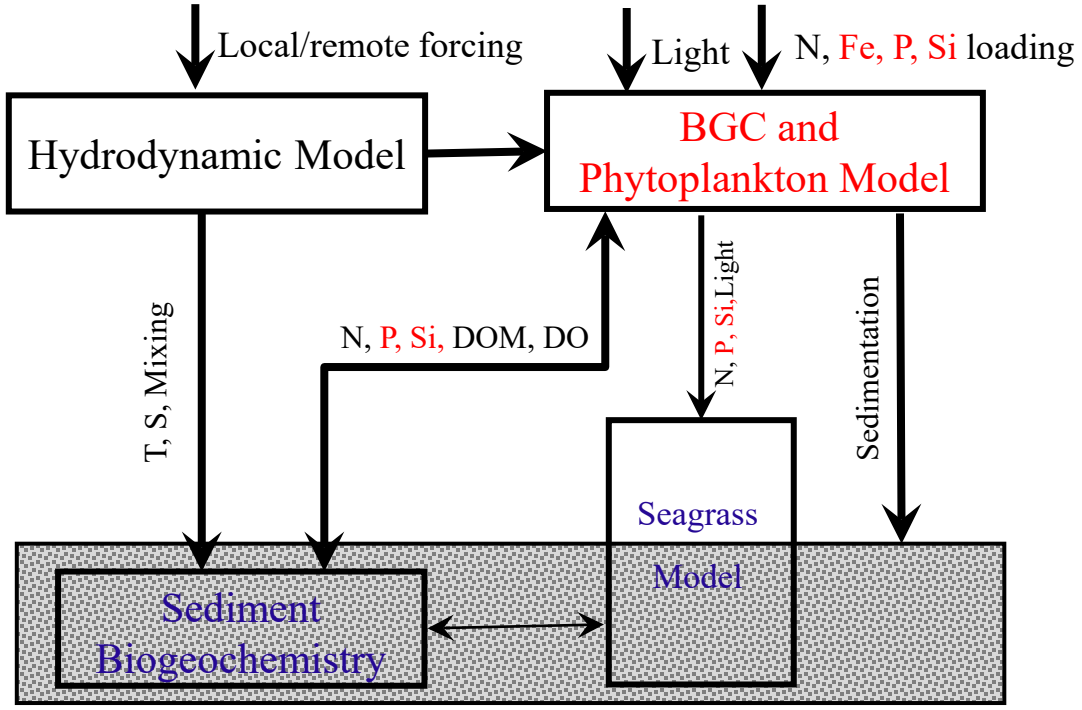
Zhang et al. (2004)



Chambers et al. (2001)

Model Framework & Research Objectives

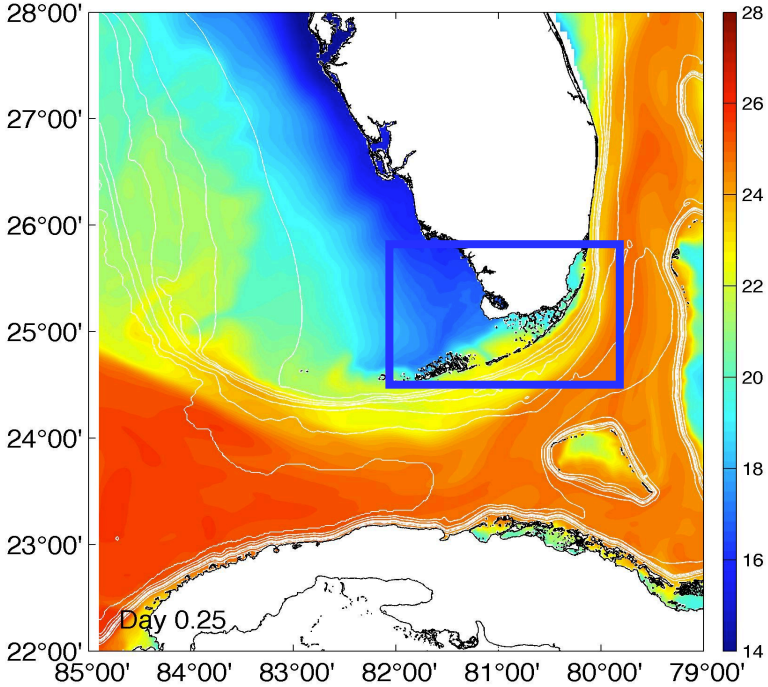
- Development of a coupled hydrodynamic-biogeochemical-SAV model
- Simulate and understand the dynamics of water quality, phytoplankton blooms and seagrass
- Climate projection and management applications



This talk will focus on phytoplankton-seagrass processes

Hydrodynamic Model – Regional Ocean Modeling System (ROMS)

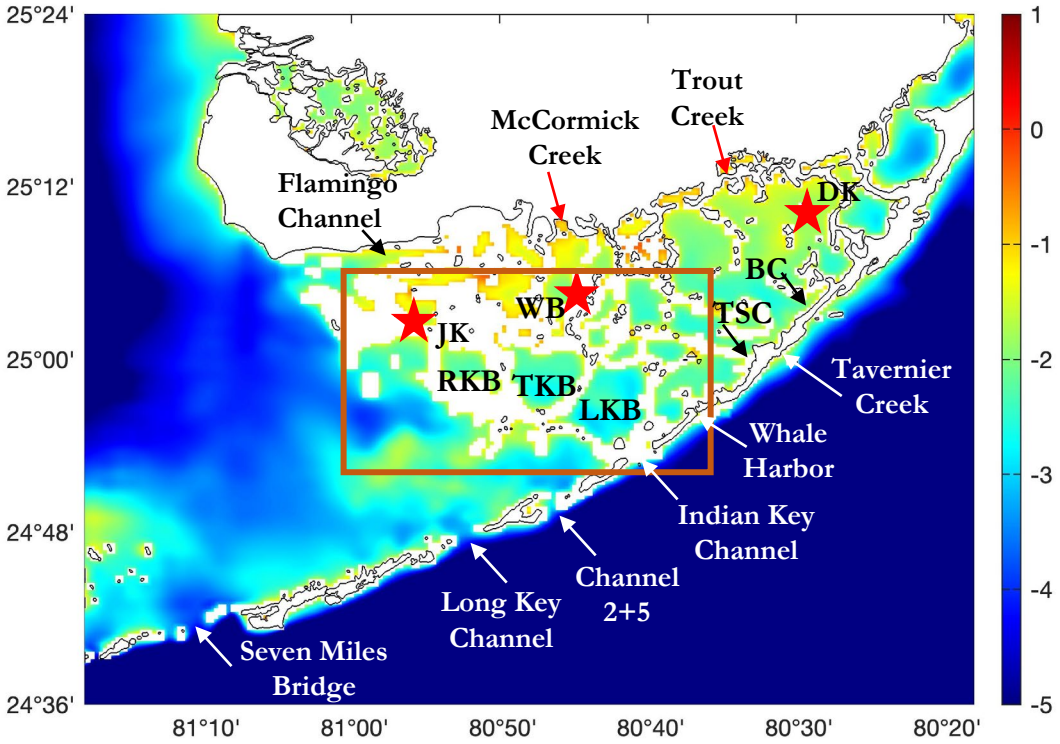
- Spatial Resolution 1.5 km (child domain 500m)
- Momentum: 3rd order upstream
- Tracer: 3rd order upstream
- Turbulent closure: MY2.5
- Vertical structure: S-coordinate
- Initial conditions: Gulf of Mexico HYCOM 1/25° (GOMex)
- Boundary conditions: HYCOM/GOMex
- Surface forcing: NARR and SST
- Bottom friction: Quadratic form drag
- Two-year (2011-2012) simulation

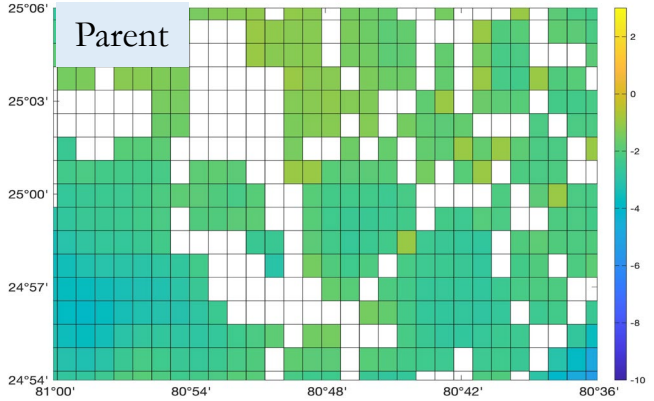


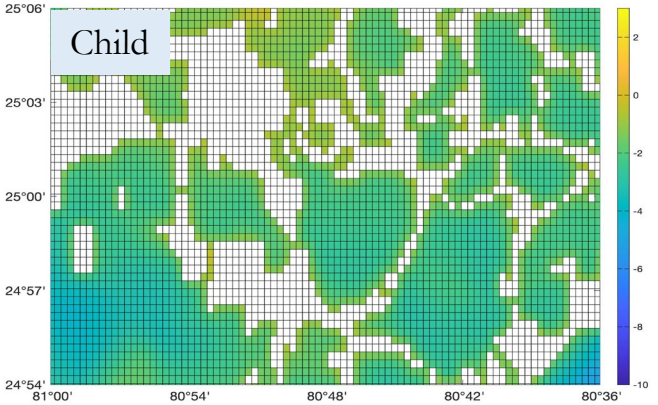
Sea Surface Temperature

Pan et al. 2017; Jiang et al. 2020

Nested modeling allows better resolution of complex bathymetry

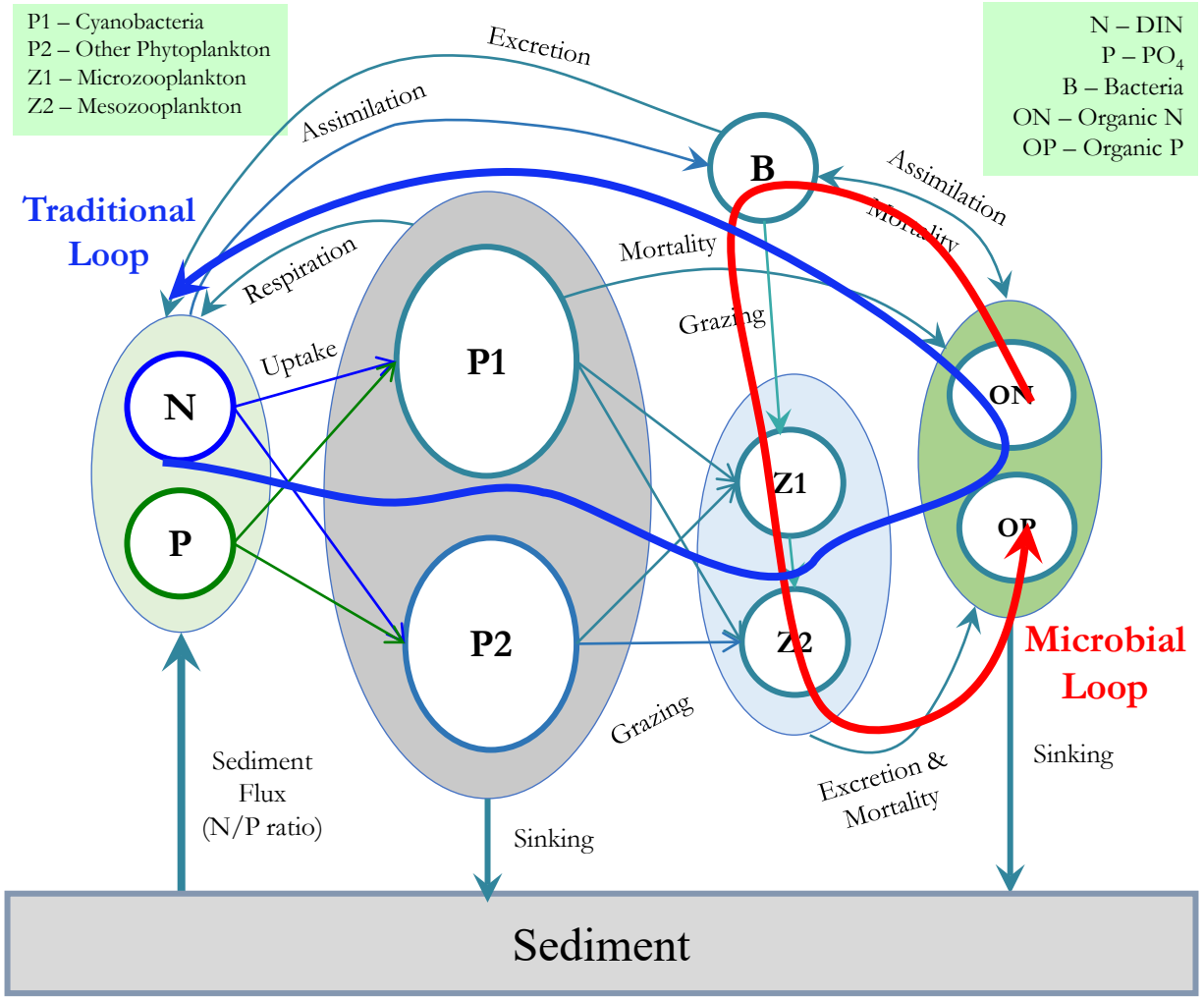






Biogeochemical Model – A multi-functional group model

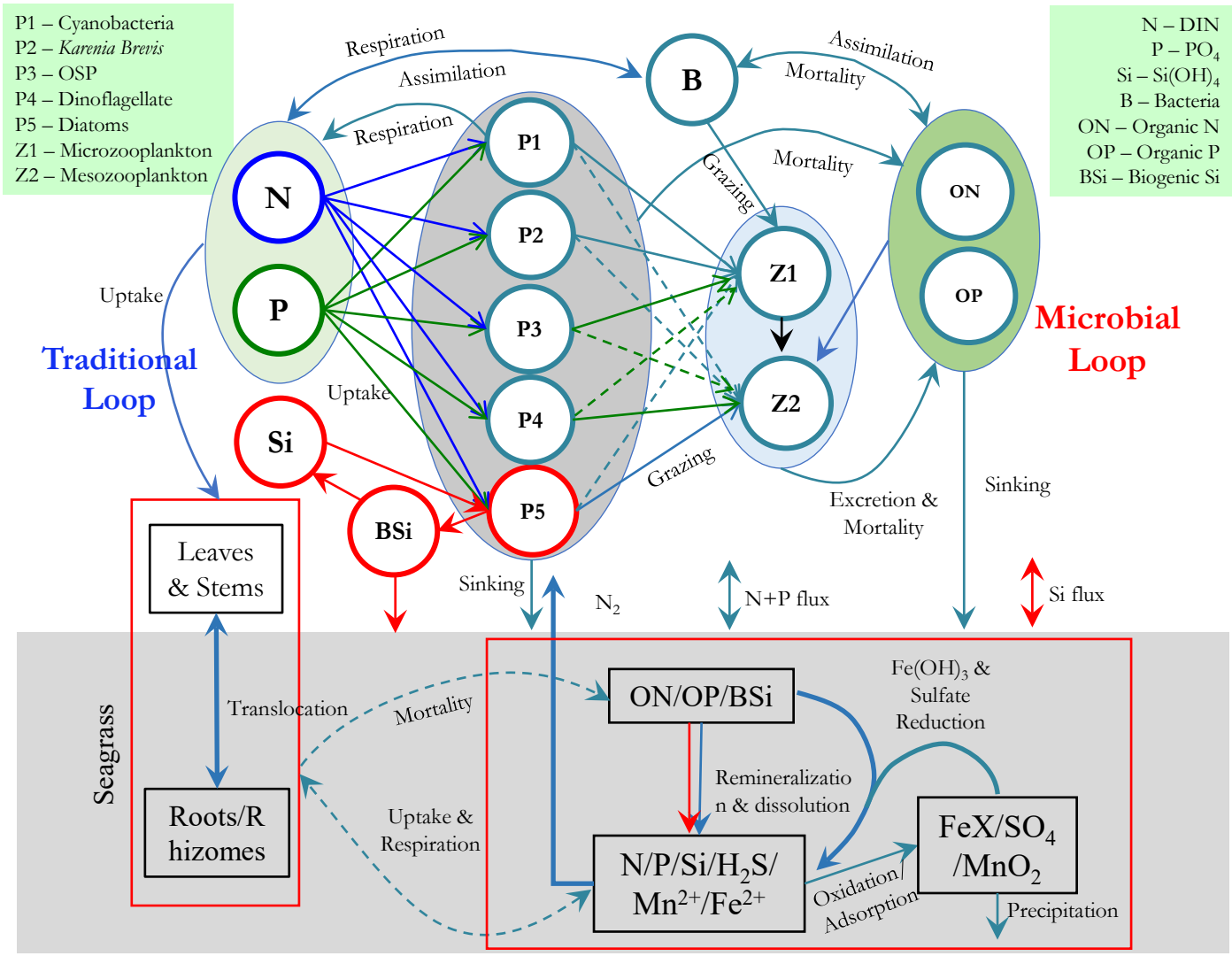
- Two nutrients (N, P)
- Two phytoplankton groups (cyanobacteria and all other P.)
- Two zooplankton groups
- Organics split between dissolved and particulate
- Including bacteria to simulate microbial loop
- Variable Chl/C ratios
- Light attenuation depends on Chl (plus background, no TSS)
- Sediment fluxes & atmospheric loading pre-defined



Jiang et al. (2025a, b)

New BGC-SAV Model

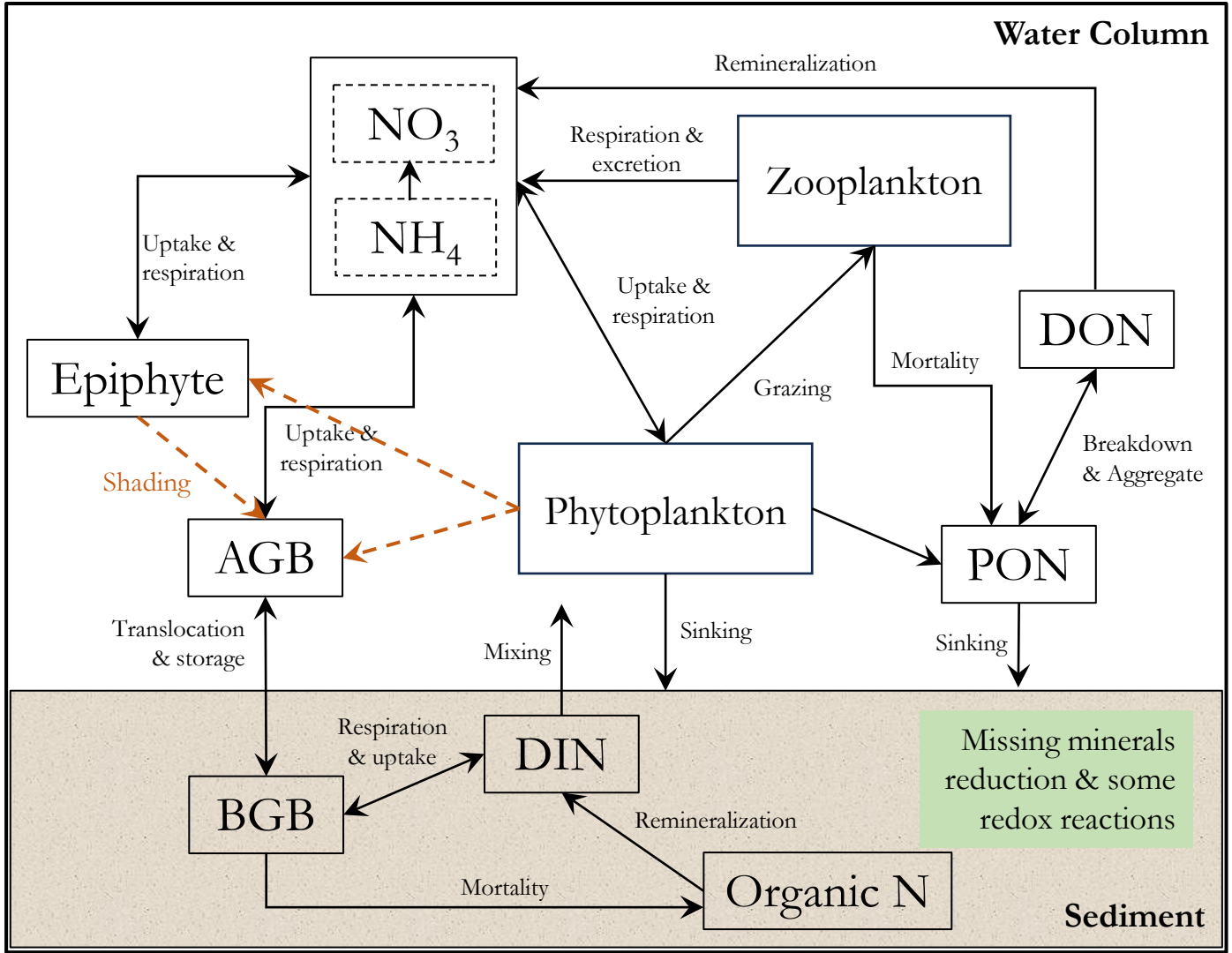
- Three nutrients (N, P, Si)
- Five phytoplankton groups (cyanobacteria, and 4 other groups)
- Two zooplankton groups
- Organics split between dissolved and particulate
- Including bacteria to simulate microbial loop
- Variable Chl/C ratios
- Light attenuation depends on Chl (plus background, no TSS)
- Sediment fluxes internally computed by the model
- Sediment biogeochemistry incl. (but misses processes)
- Ignoring N_2 fixation & denitrification



N cycle & SAV module

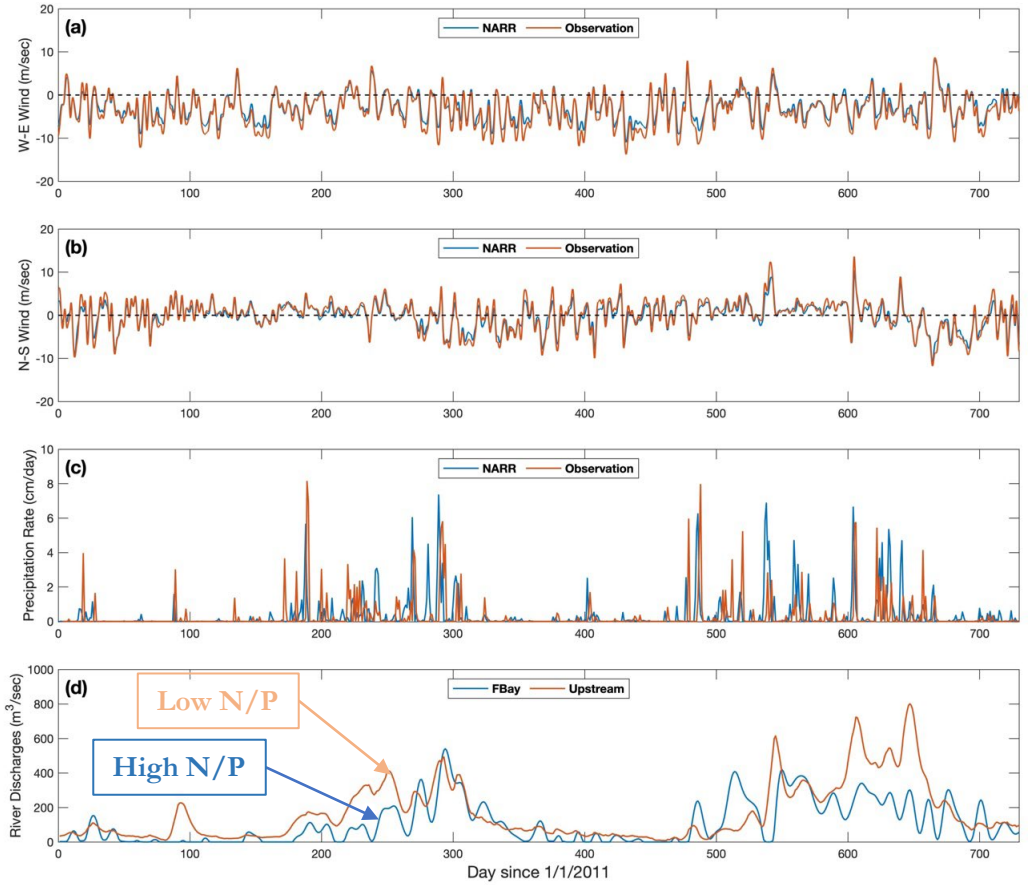
- One group for epiphyte & one for SAV
- SAV split into above ground biomass (AGB) and below ground biomass (BGB)
- Shading by phytoplankton & epiphytes
- SAV uptakes nutrients from waters and sediment
- Translocation exchanges biomass between AGB & BGB
- Temperature & salinity dependences

Madden & Kemp (1996) & Kalra et al. (2020)



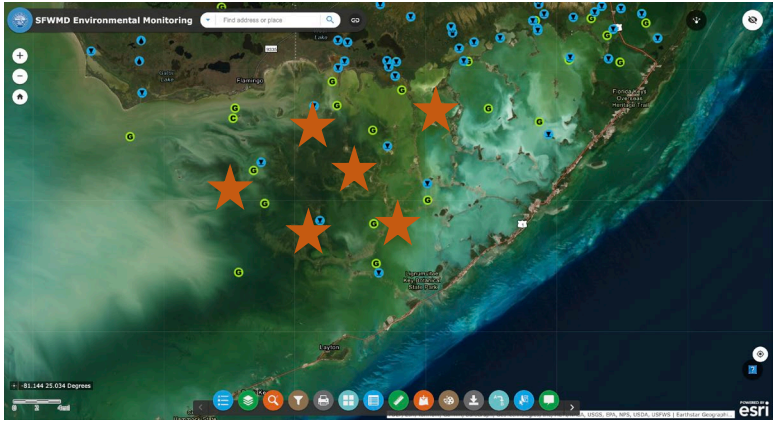
Winds & Rivers

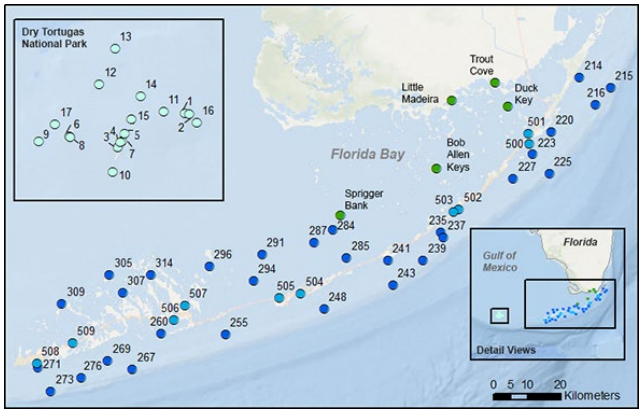
- Surface winds are derived from meteorological model (NARR, 30 km)
  - ➢ largely out of NE/SE
- River flows are from USGS/SFWMD gauges
  - ➢ about same amount from upstream and local watersheds
- Nutrients and organics are from multi-year means
  - ➢ Upstream: low N/P
  - ➢ Taylor slough: high N/P



Water quality and Seagrass Data

- Water quality data (T, S, nutrients, Chl, DO): ENP, SFWMD, AOML & FIU
- Seagrass data
  - FWRI/SFWMD: Florida Bay
  - FIU: FKNMS
- Conversion: Seagrass abundance to biomass (Fourqurean et al. 2001; Kaldy & Dunton, 2000)

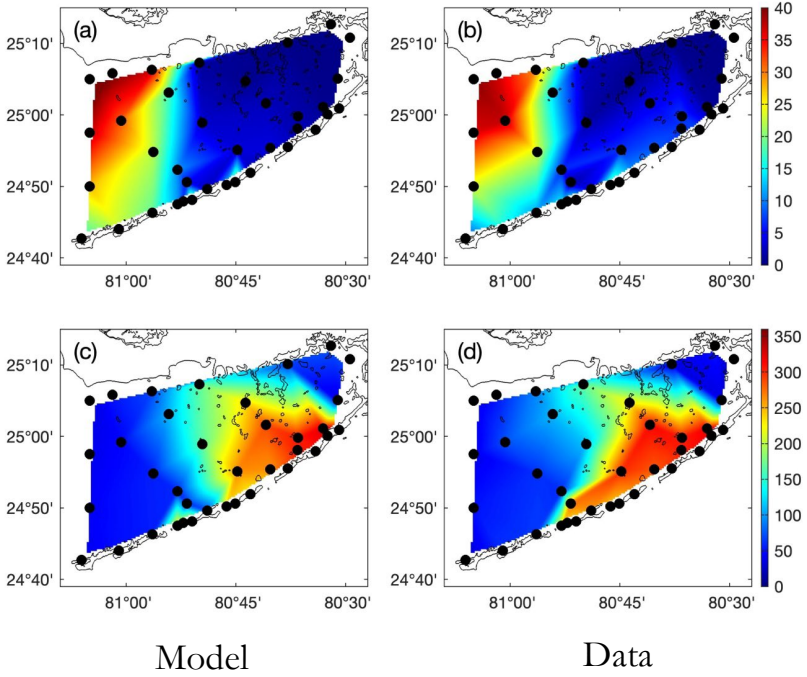




Results: Tides & salinity

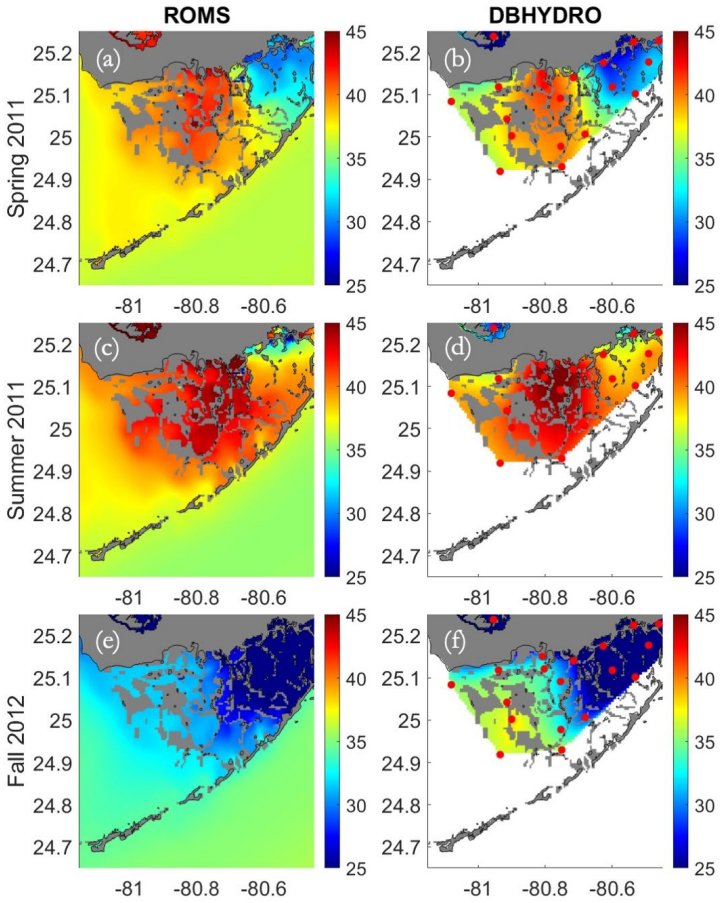
M_2 amplitude

M_2 phase



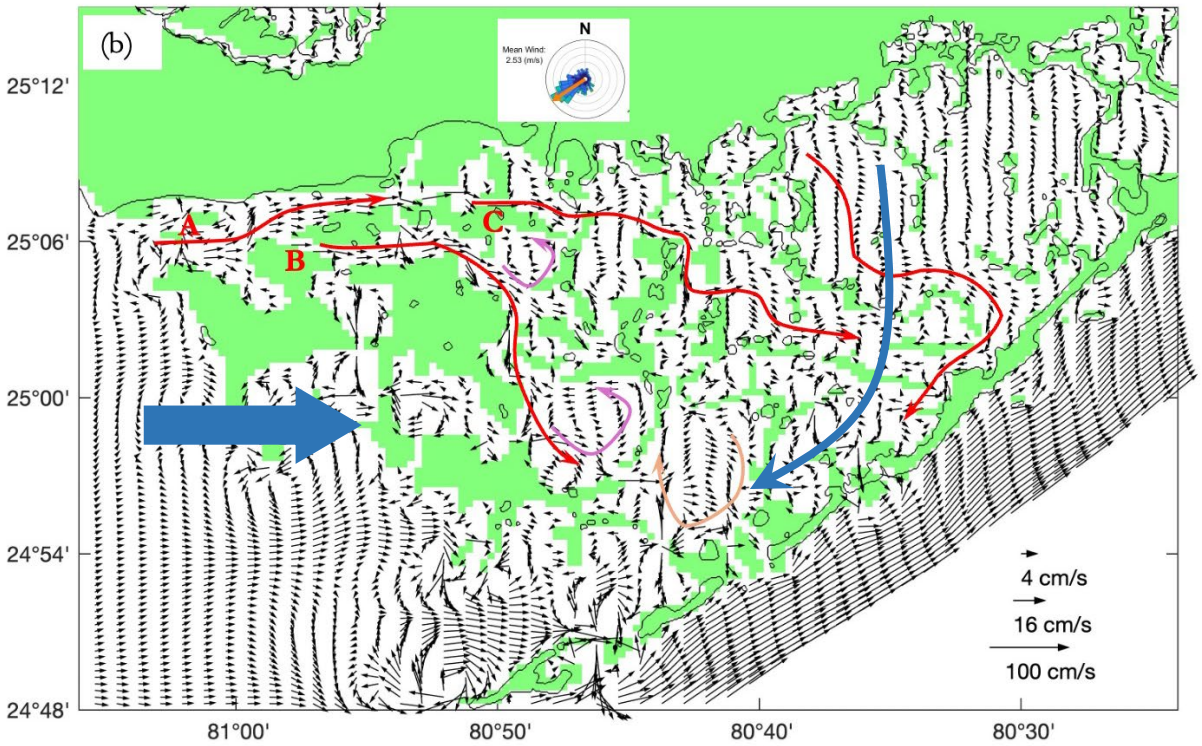
Model

Data

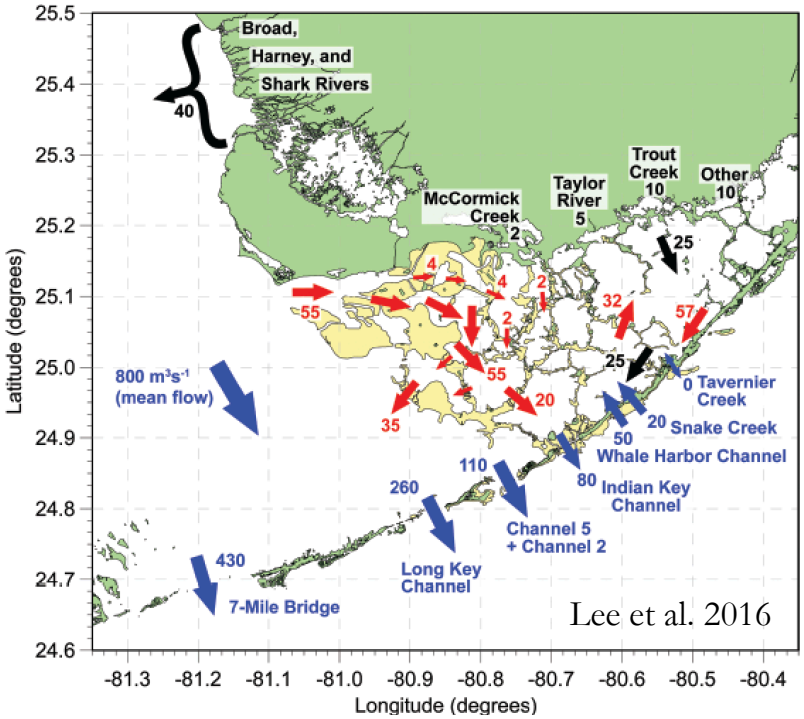


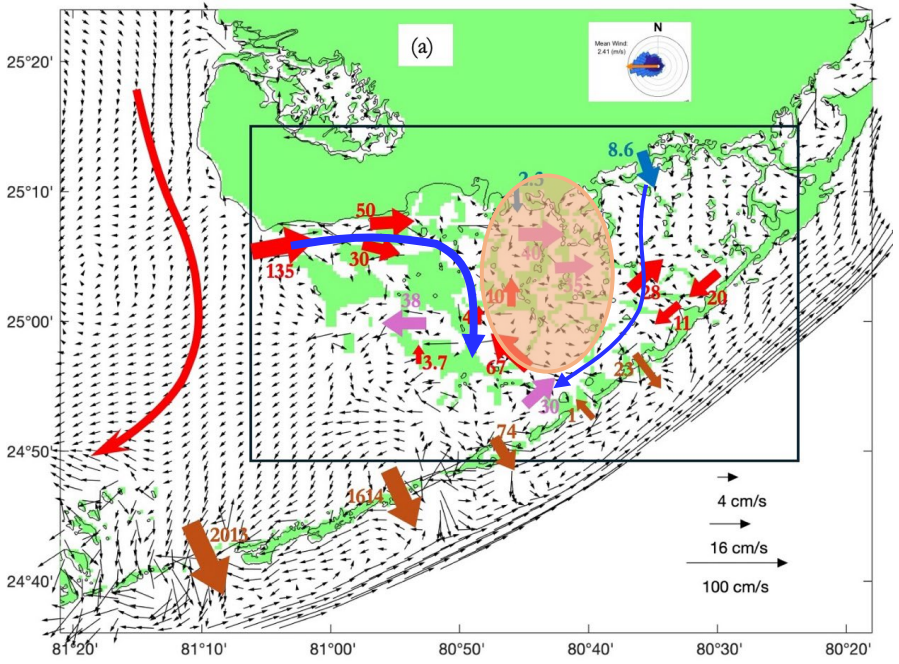
Results: Seasonal Mean Currents (summer 2012)

- Tidal rectification &upstream flow put water into the bay
- NE winds drives flow in eastern bay southward
- Many recirculation in sub-basins



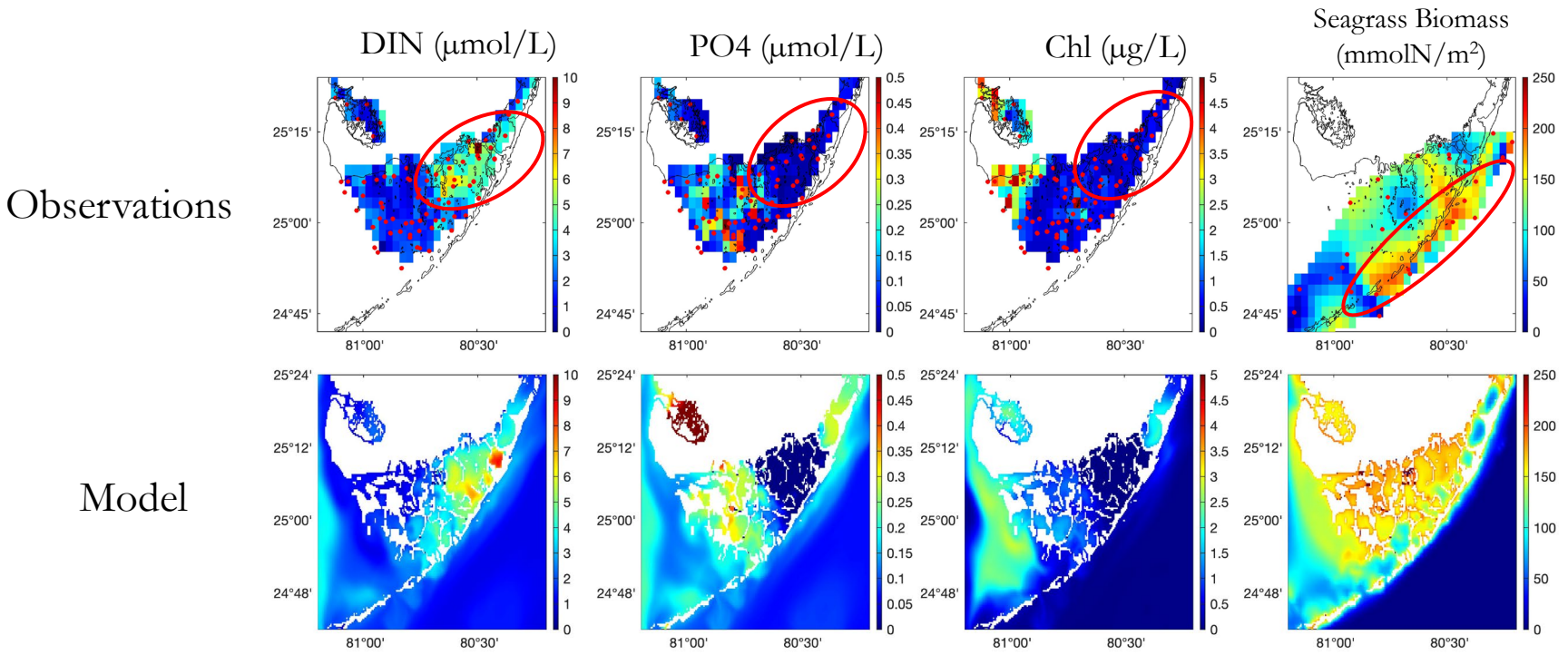
Annual Mean Circulation & Transport (2011-2012)





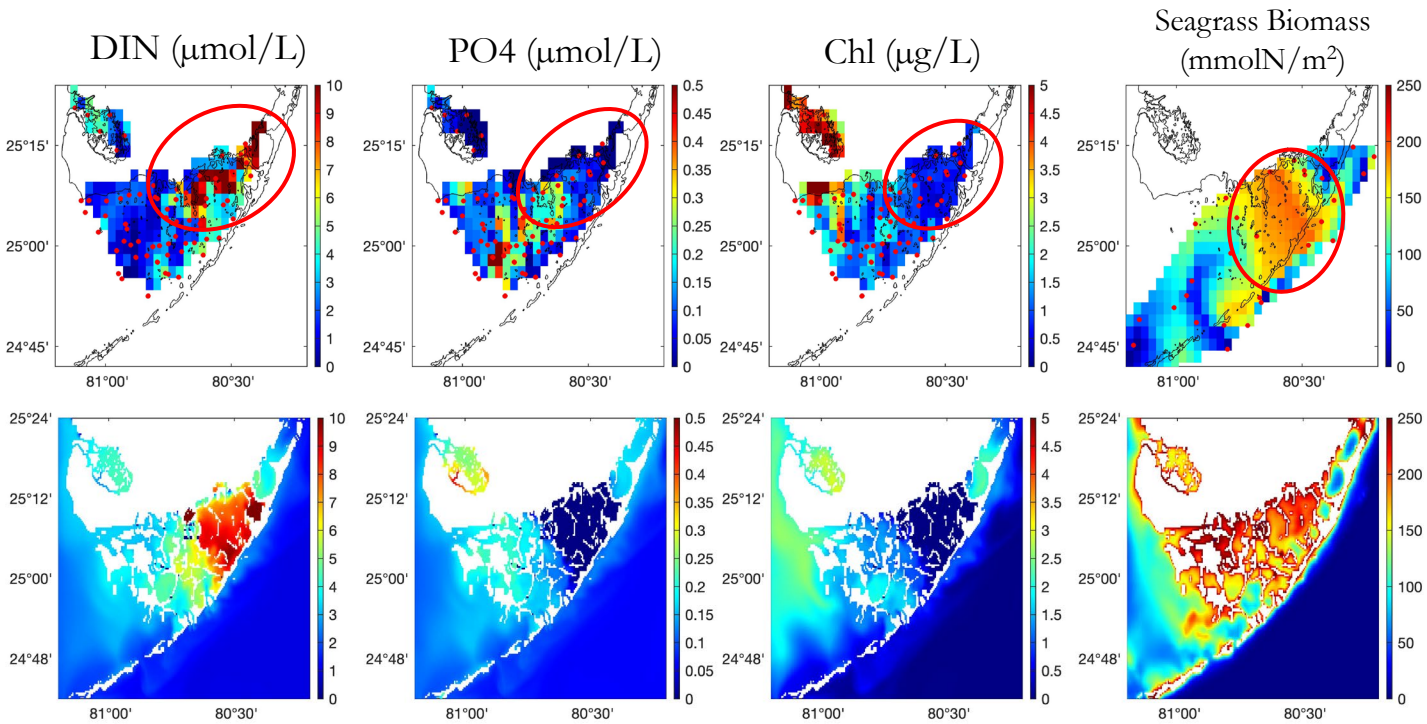
A near stagnant circulation in NE region but generally southward transport in Western Bay & across the Keys

Model vs Observations: Spatial Patterns (Spring 2011)



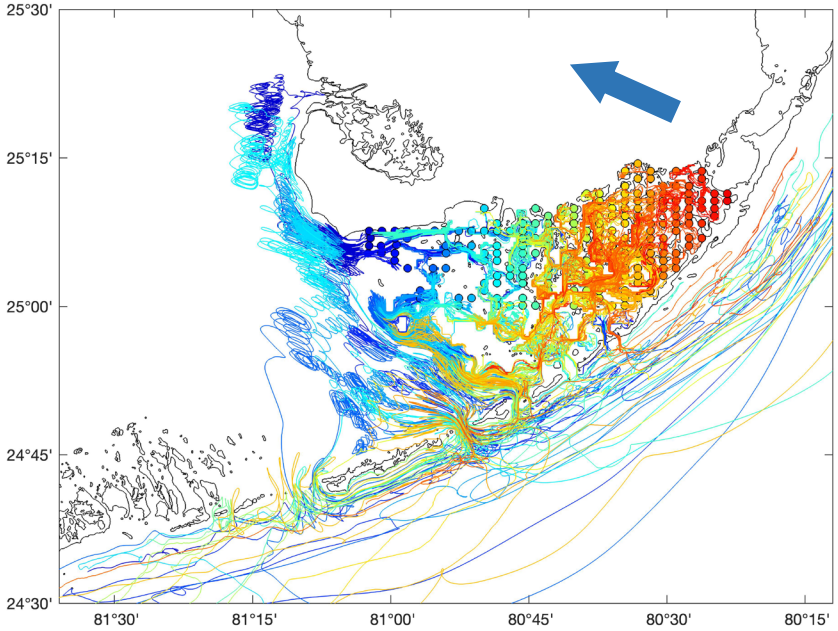
- Data and model show strong contrasting N/P spatial gradients
- Observed higher SAV around the Keys is a conversion error

Model vs Observations: Spatial Patterns (Fall 2011)

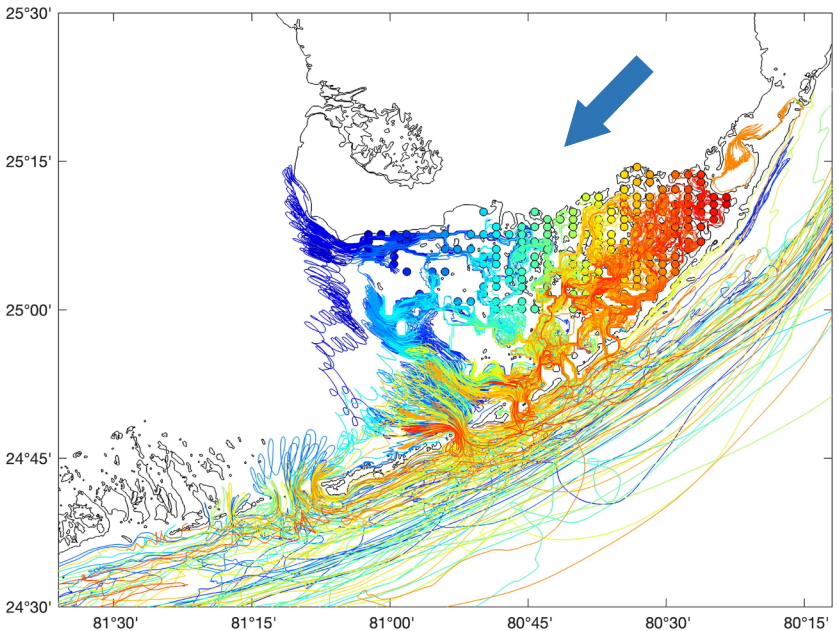


- Data and model show strong contrasting N/P spatial gradients
- Observations in this period show high SAV biomass in the NE region

Impacts on the Keys: Both winds & local discharges are important



Summer 2012: SE winds, low discharges

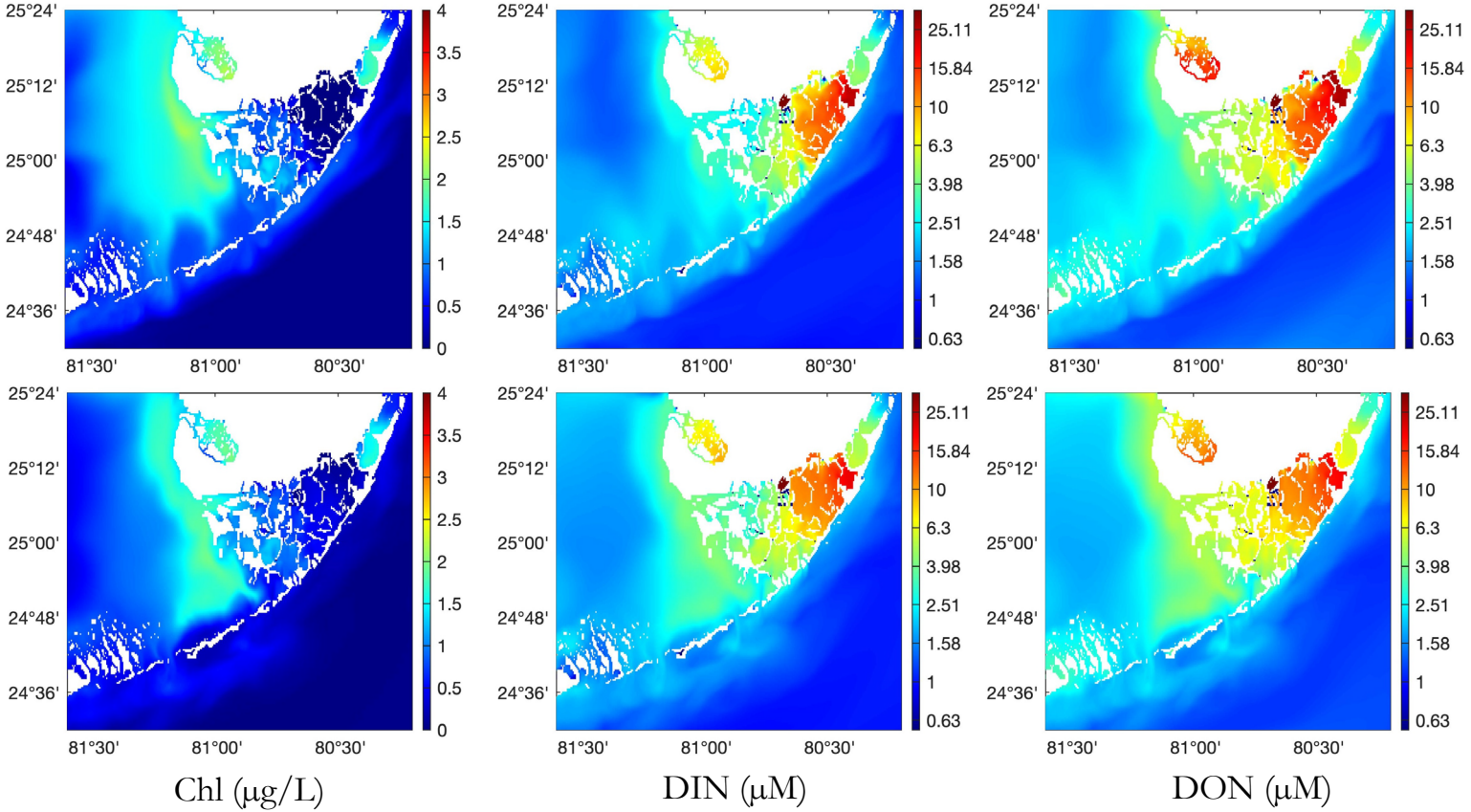


Fall 2012: NE winds, strong discharges

Impacts on the Keys: The bay is exporting both Chl & nutrients

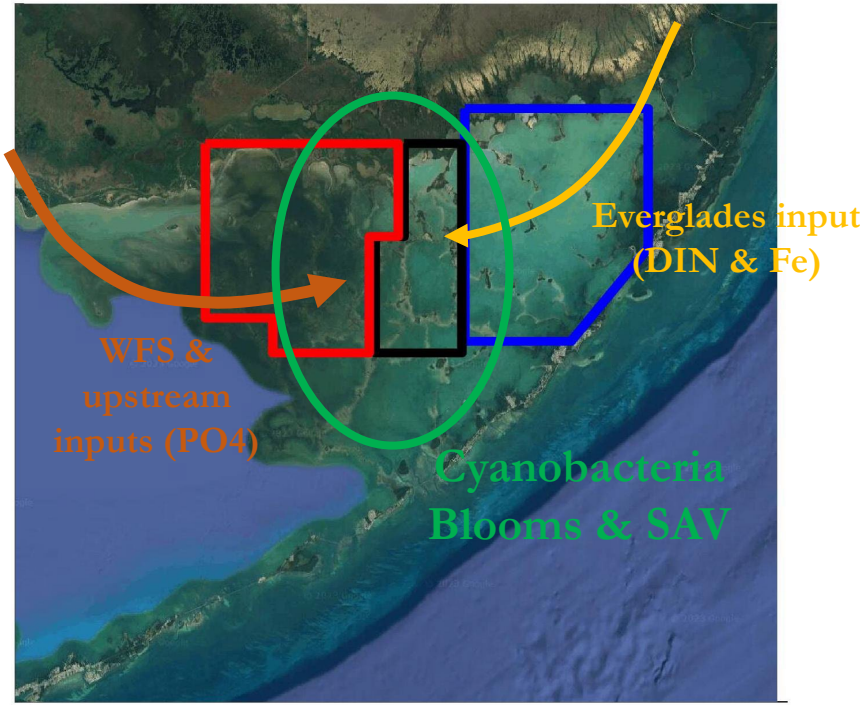
Summer 2012

Fall 2012



Summary

- A coupled physical-biogeochemical-SAV model has been developed for the greater Florida Bay; Still needs a lot of improvements especially inclusion of sediment diagenesis
- CFB features stagnant flow but moderately convergent N/P inputs from west/east (and sediment) favoring blooms
- Seagrass/epiphytes keep nutrients low; This and probably grazing controls phytoplankton blooms
- The downstream impacts depending on winds, discharges, and coastal currents



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  - NASA Water Resource Program
  - HBOI Foundation
- Collaborators
  - FAU: L. Cherubin, R. Brewton, B. Lapointe, Z. Wistort
  - J. Cannizzaro (USF), N. Wang (SFWMD), T. Frankovich (FIU)
- Water quality data are from SFWMD & FIU
- All computation is done at FAU cluster Koko/Athene