Sedimentcontrol of summer hypoxia development in the Pearl River Estuary

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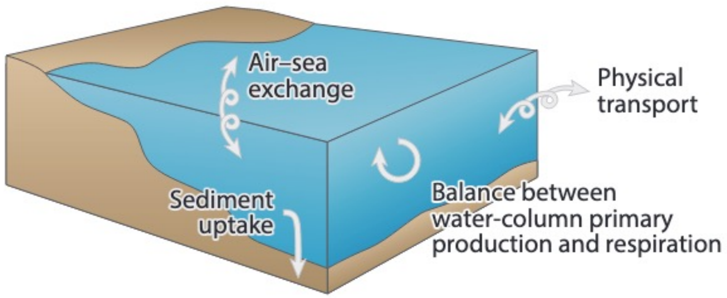
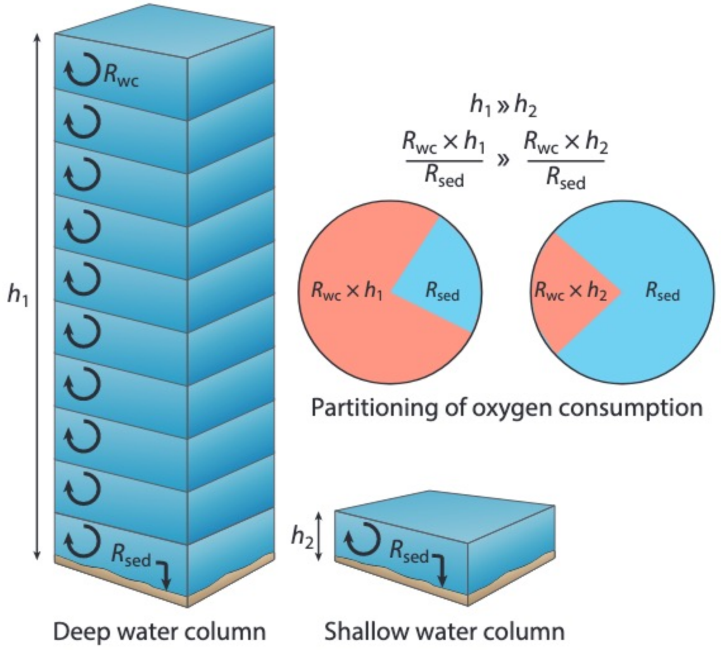
EOAS
Earth, Ocean and Atmospheric Sciences

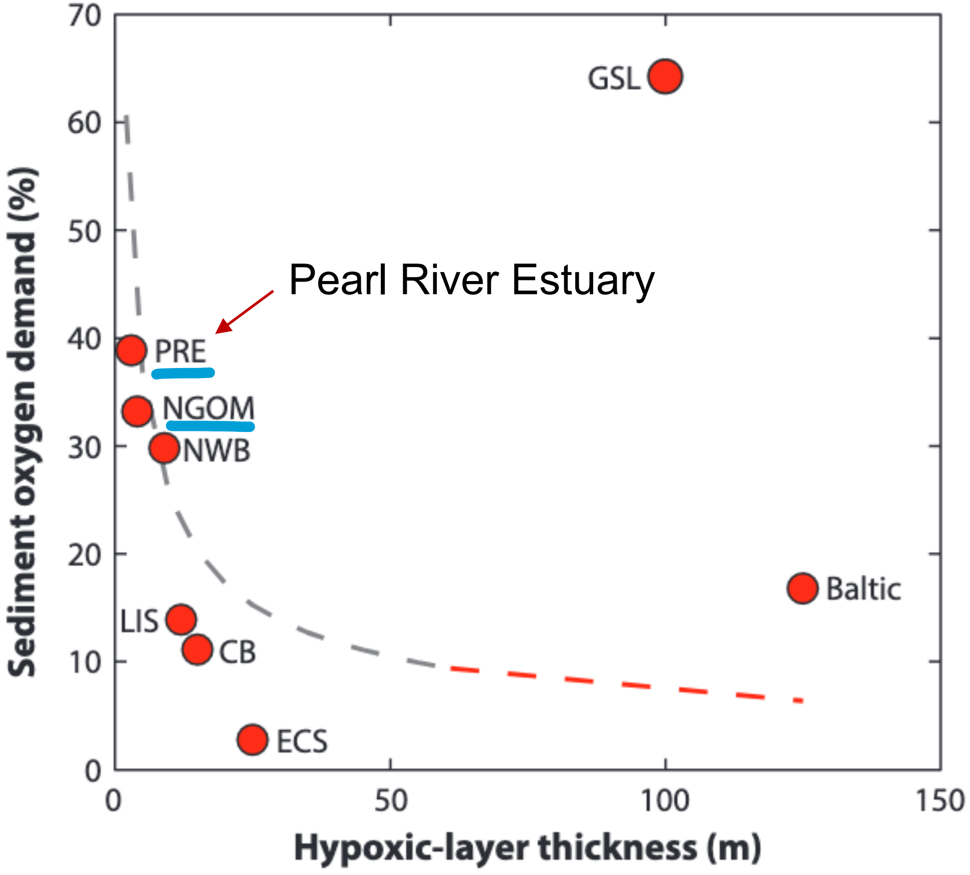
Sediment O_2 uptake is critical to hypoxia formation



Relative importance of **water-column** VS **sediment** consumption

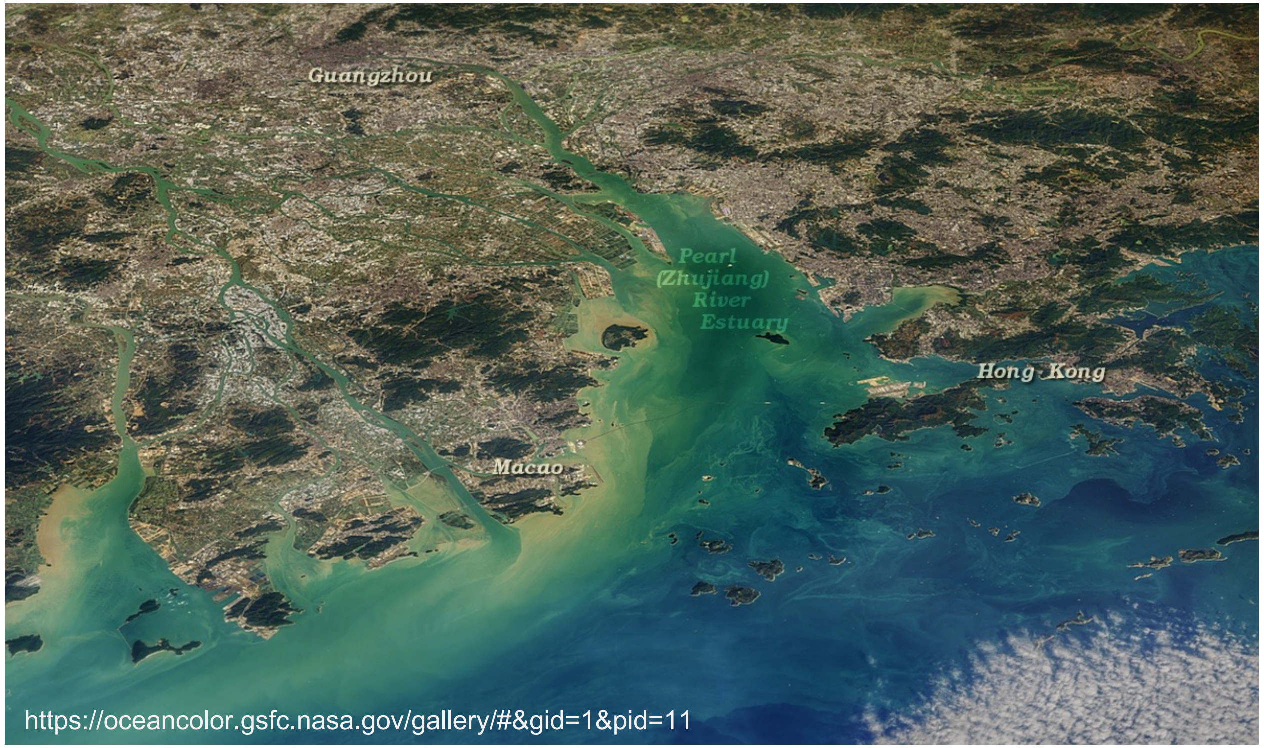


Sediment contribution to total consumption (%) **increases** with decreasing hypoxic-layer thickness



Fennel & Testa 2019

Mississippi River Delta		Pearl River Estuary



	Mississippi River Delta	Pearl River Estuary	
Discharge (m^3/s)	17,000	10,000	
N load (10^6 mol/d)	190	77	
Residence time (d)	30	10	← shallower; stronger tidal mixing…
Hypoxic layer thickness (m)	4	3	
Max hypoxic area (km^2)	23,000 (mean 15,000)	~1000	

Data source: Fennel & Testa 2019; Li et al. 2020; Yu et al. 2021

Mississippi River Delta

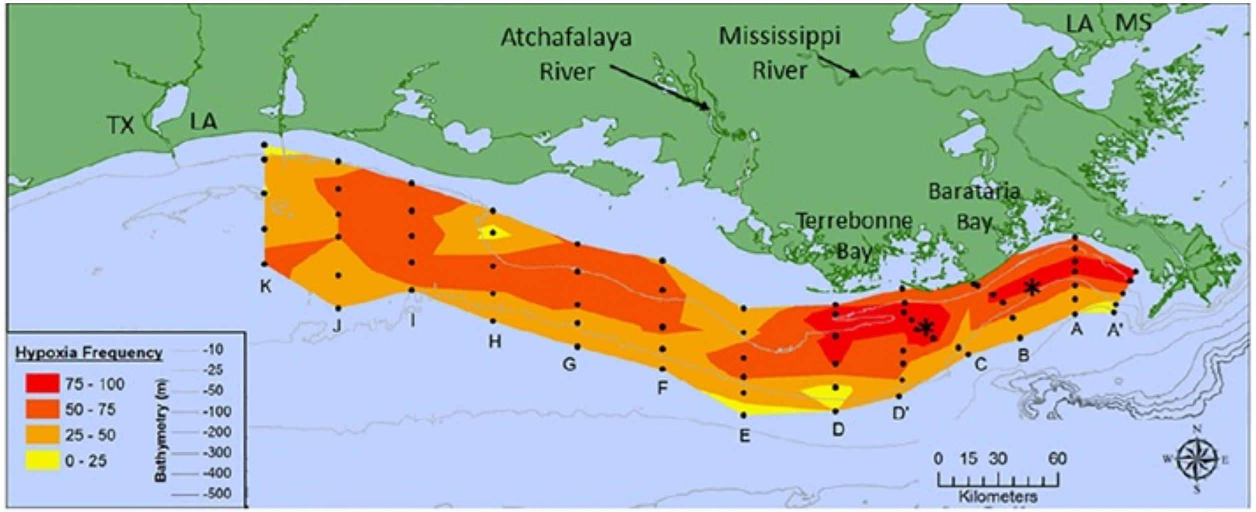
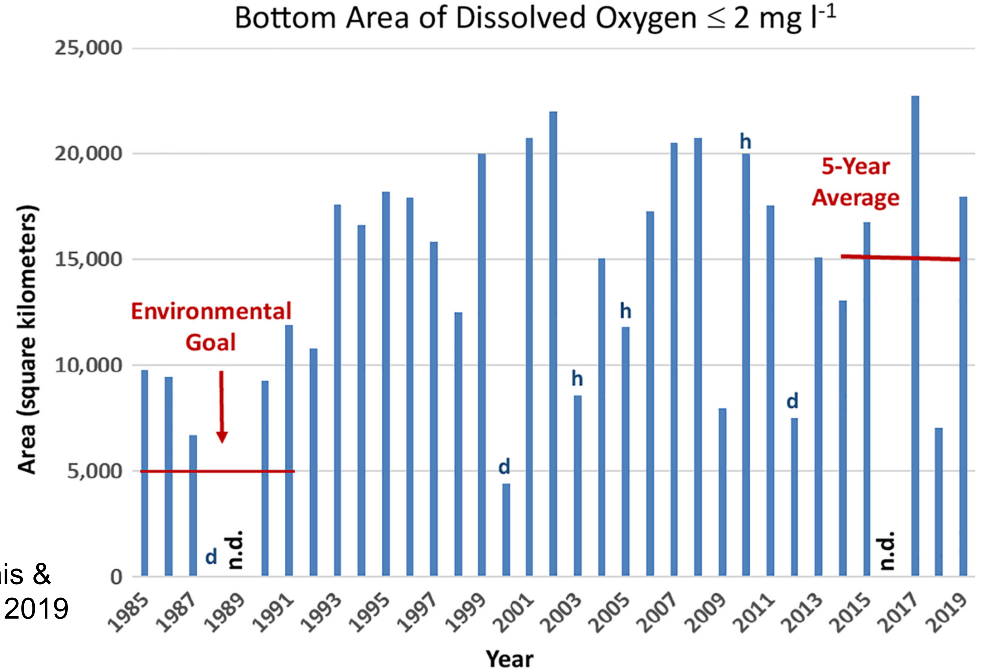
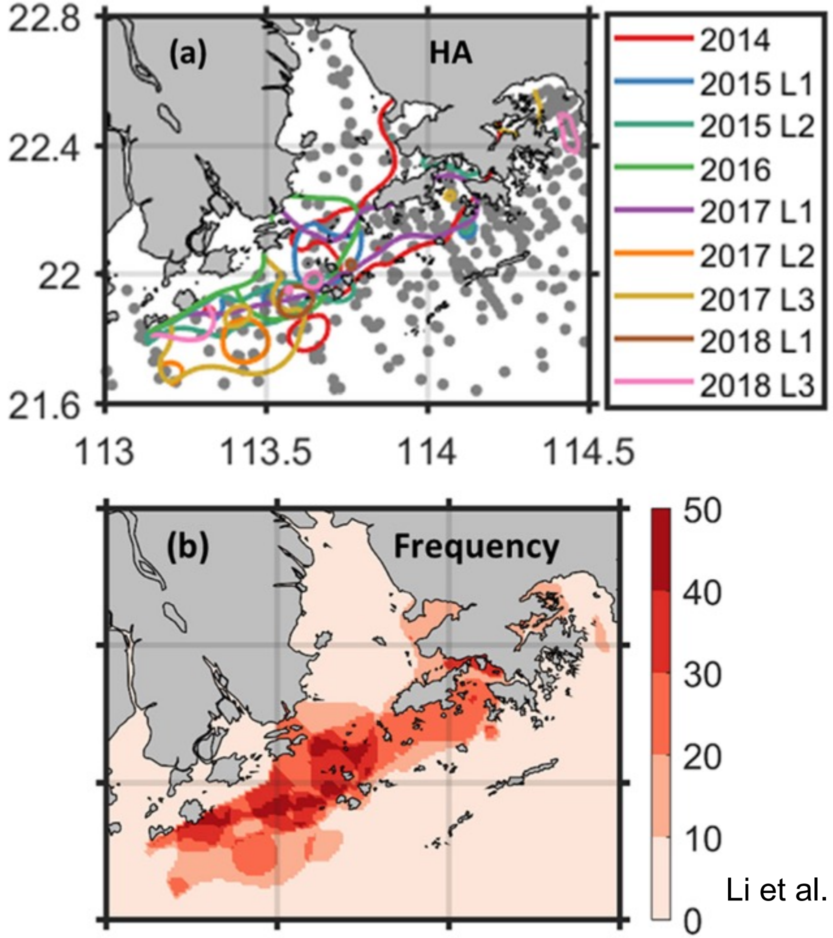


FIG. 1. The frequency of bottom-water hypoxia from shelf-wide hypoxia mapping (1985–2014) (updated from Rabalais et al. (2007b); frequency is determined from stations for which there are data for at least half of all cruises. Asterisks (*) indicate locations of near-bottom oxygen meters; transects C and F identified. Data source: N. N. Rabalais and R. E. Turner.



Rabalais & Turner 2019

Pearl River Estuary



Li et al. 2020 JGR

“Regular” summer survey in PRE only started since 2010s

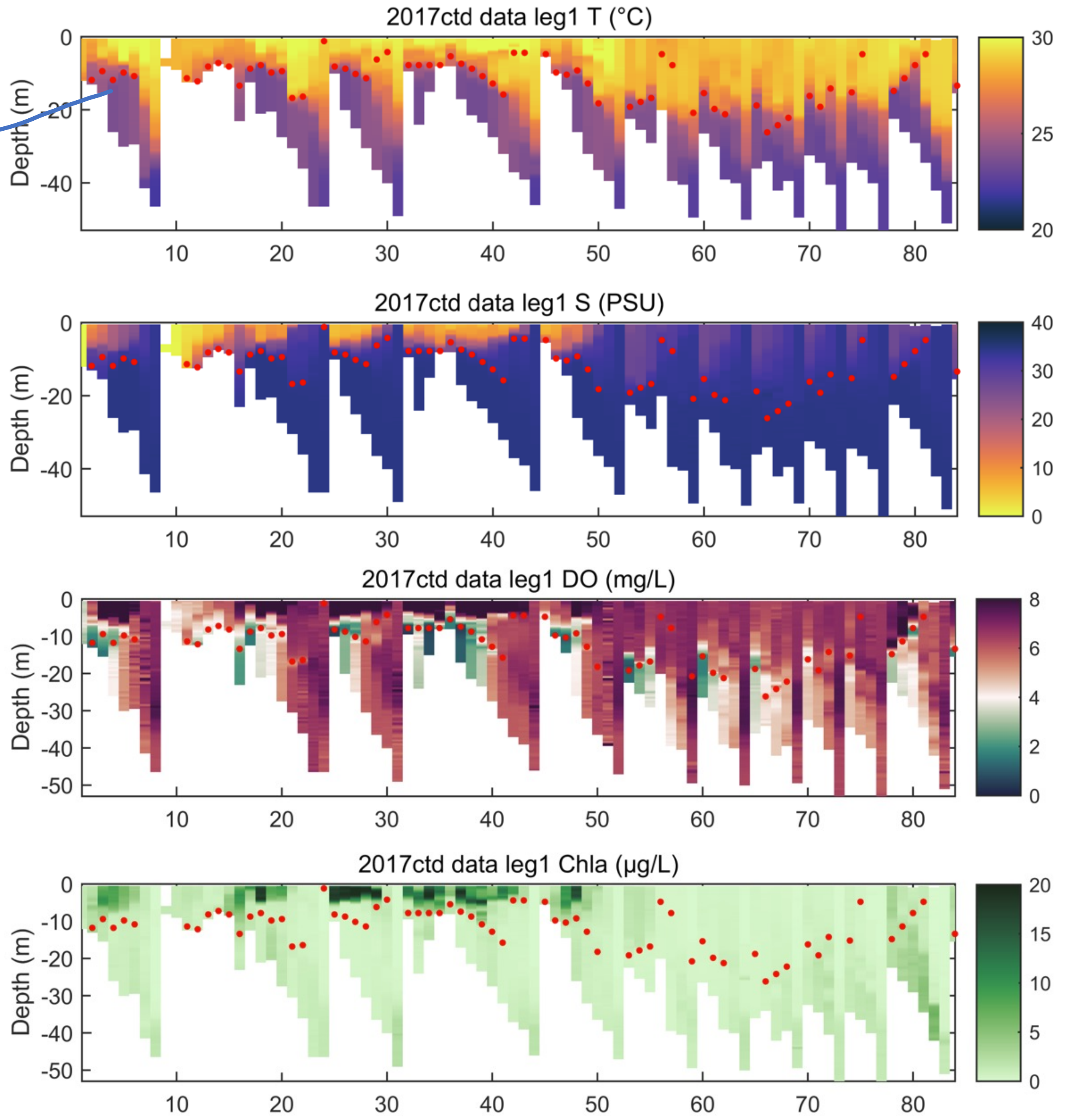
Gain insights from

- comparisons with other hypoxic systems (e.g., NGOM)
- combining observations and model simulations

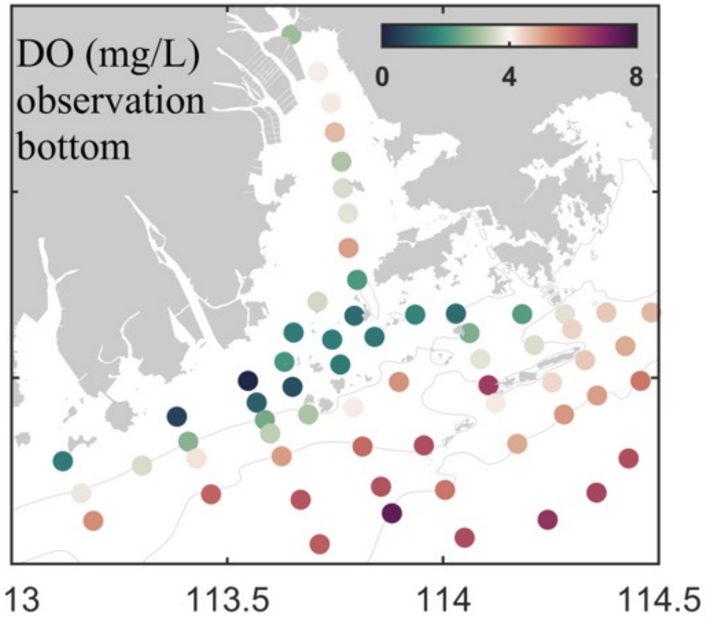
Summer cruise survey

➔ Hypoxia is mostly limited to the bottom boundary layer

(upper boundary of BBL – depth where buoyancy frequency $N^2 > 0.01/s$)

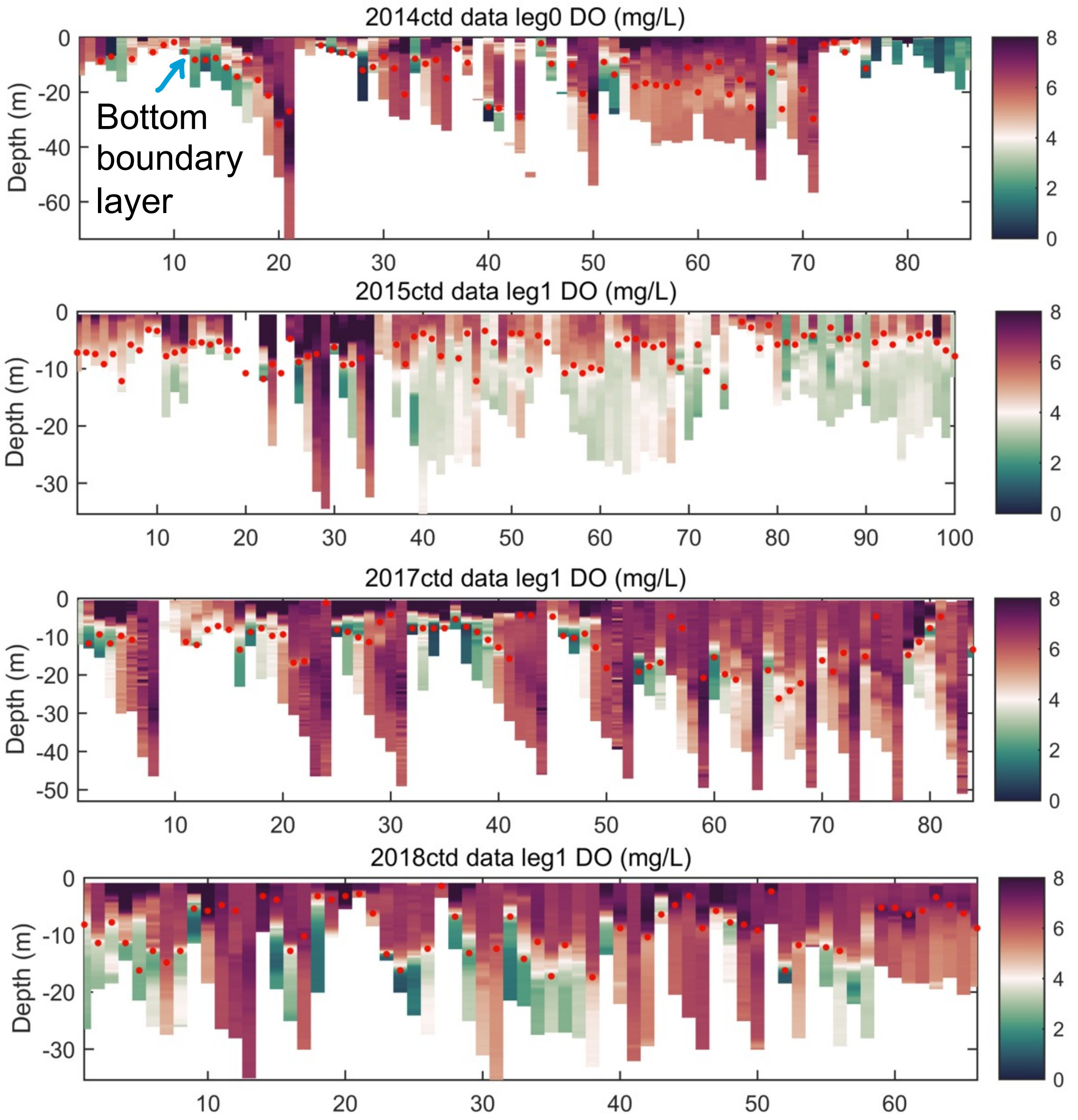


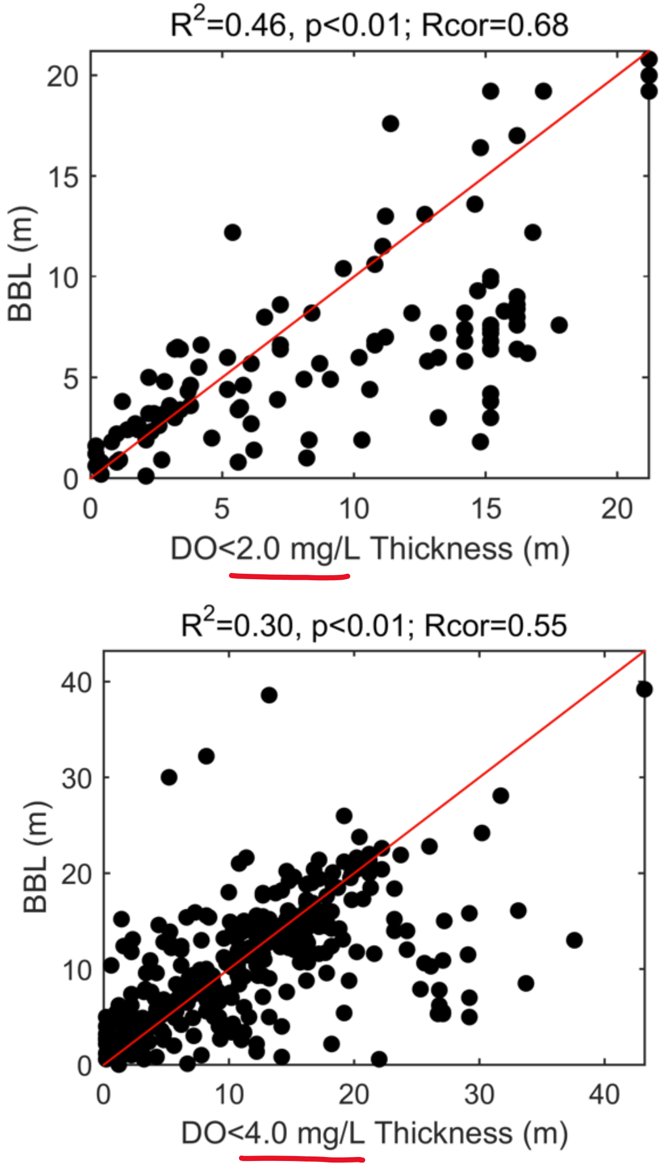
2017 summer cruise survey



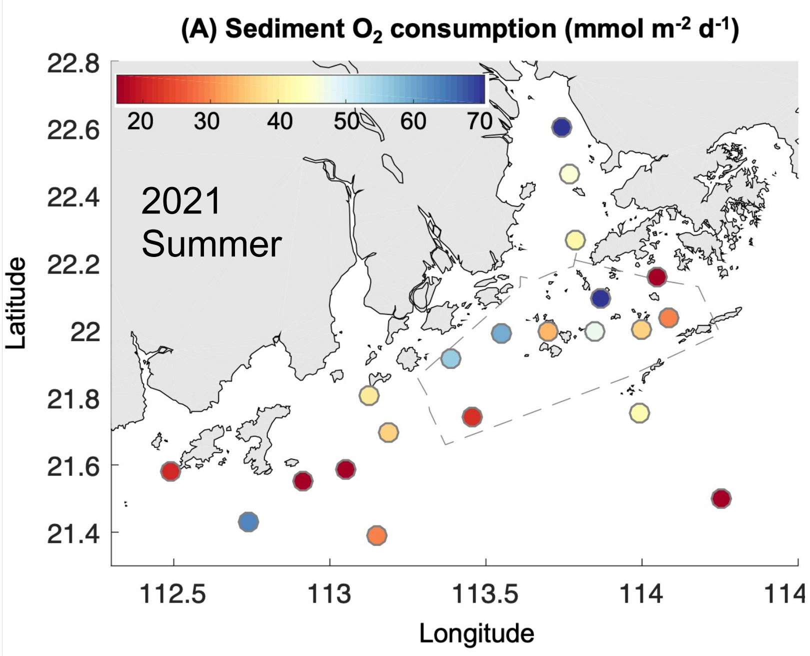
Tight correlation between bottom boundary layer (BBL) and hypoxic layer thickness

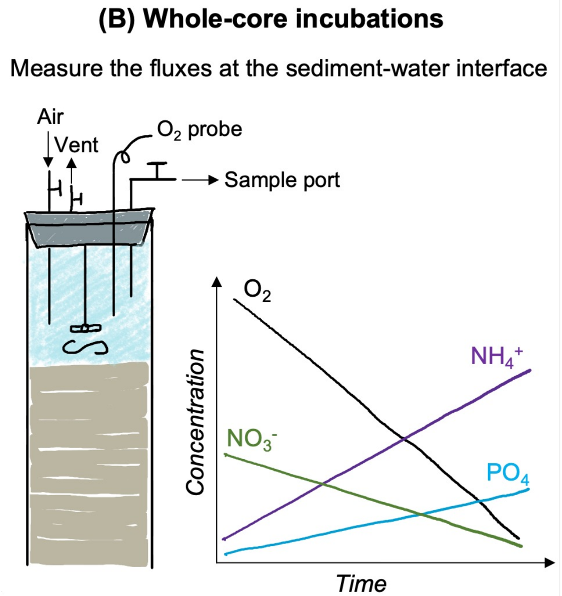
Hypoxia is mostly limited to the bottom boundary layer





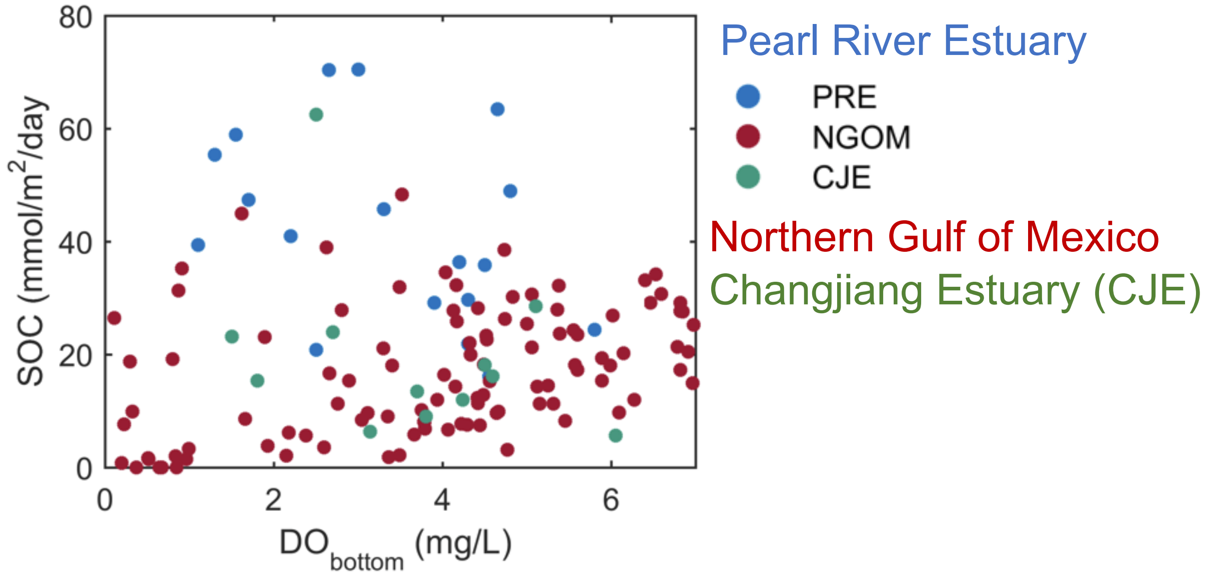
High sediment oxygen consumption

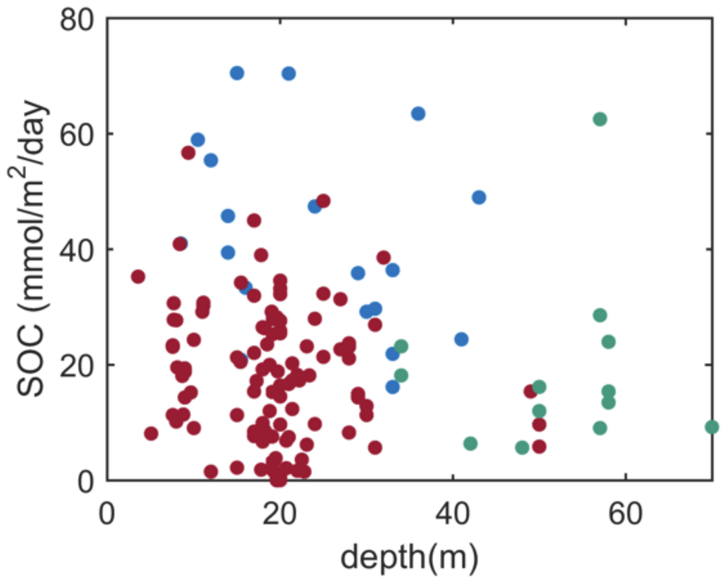




Unpublished data from Jiying Li

Overall higher than other hypoxic systems

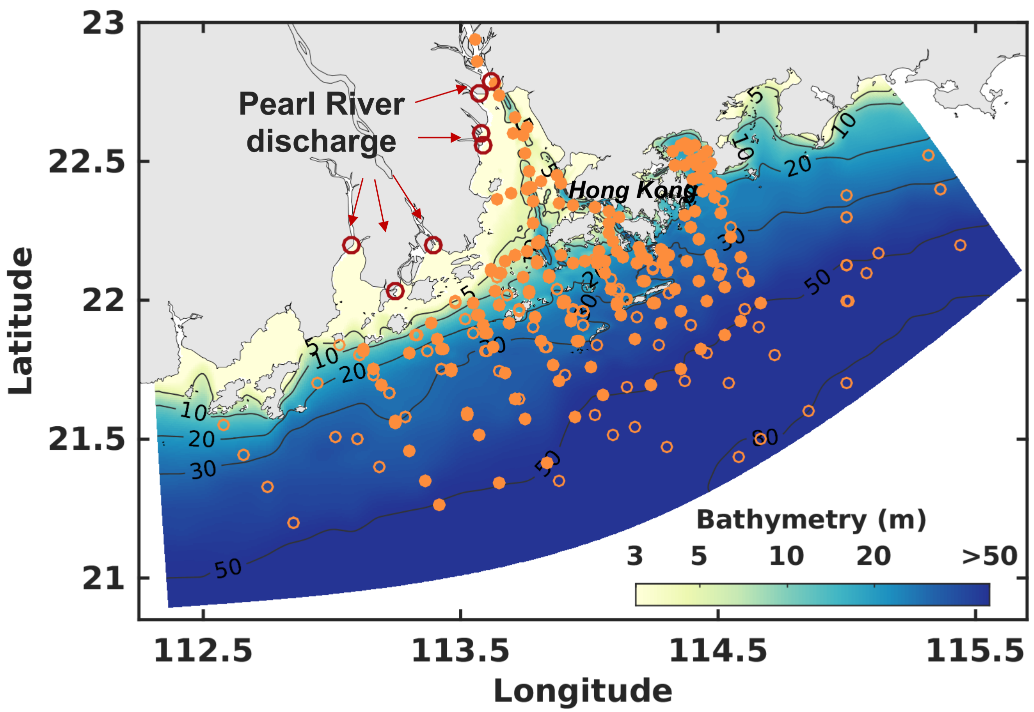


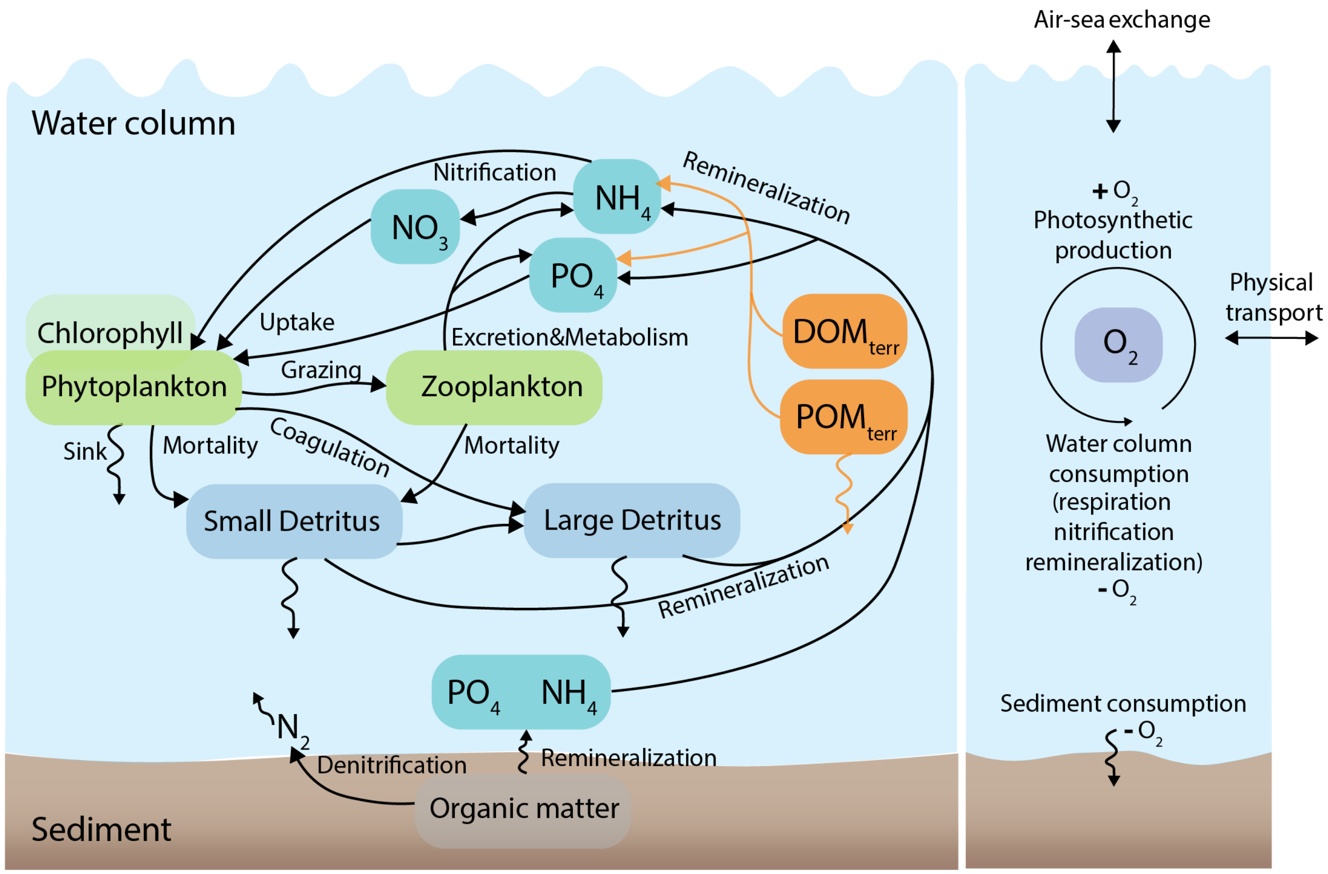


Data compiled from Yu et al. 2015; Zhang et al. 2018

Coupled physical-biogeochemical model

Regional Ocean Modelling System (ROMS)

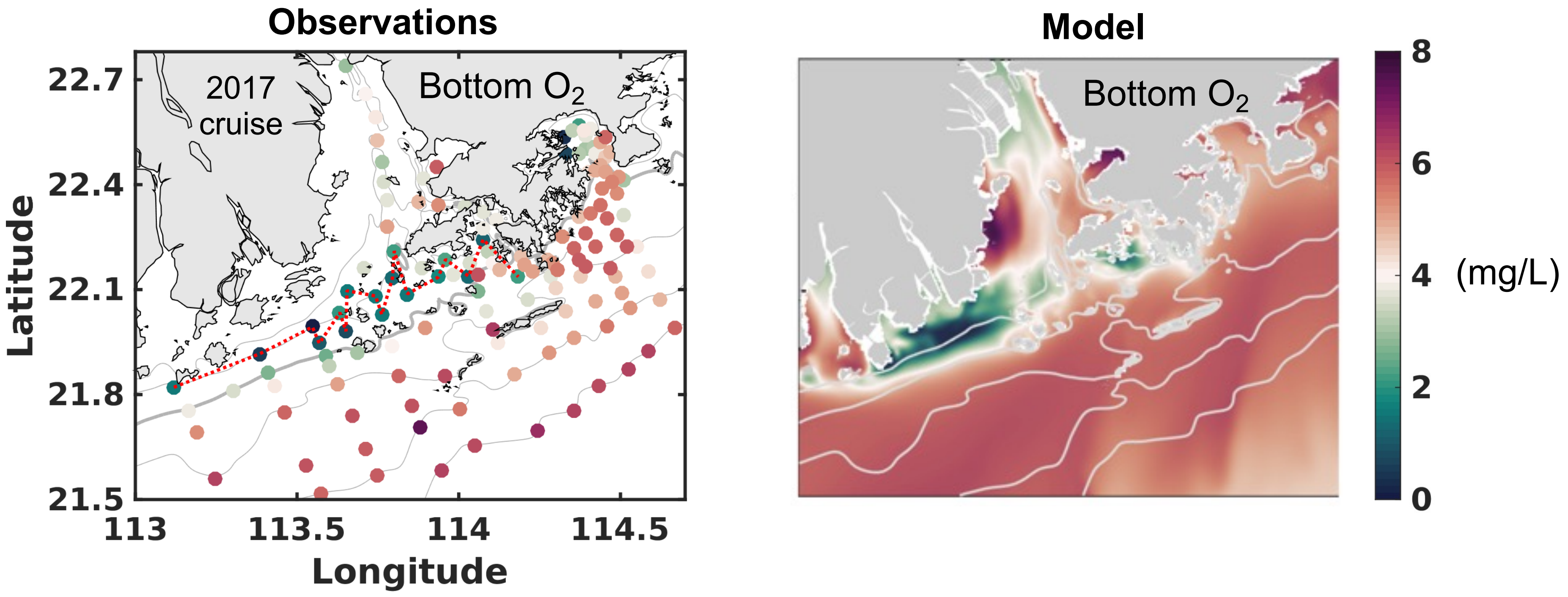




Yu & Gan 2022

- A **process-oriented** modelling framework forced by typical summer forcing

Model-data comparisons: bottom O_2 & hypoxia

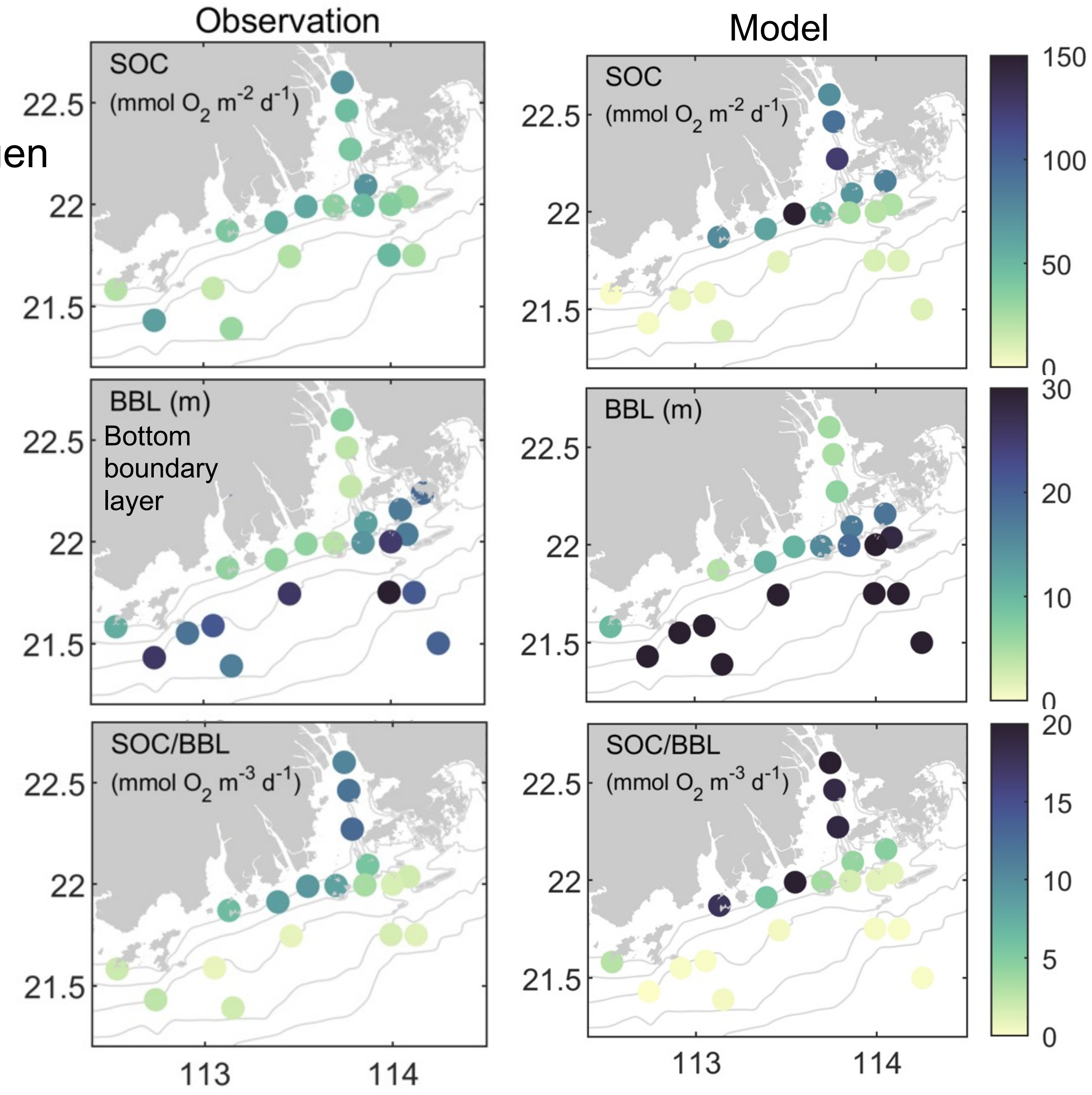


Qualitatively reproduce the observed patterns of hypoxic waters and key physical-BGC response to river discharge and wind-driven shelf current.

Yu et al. (2020); Yu & Gan (2022)

Model-data comparisons: sediment oxygen consumption

Sediment Oxygen Consumption

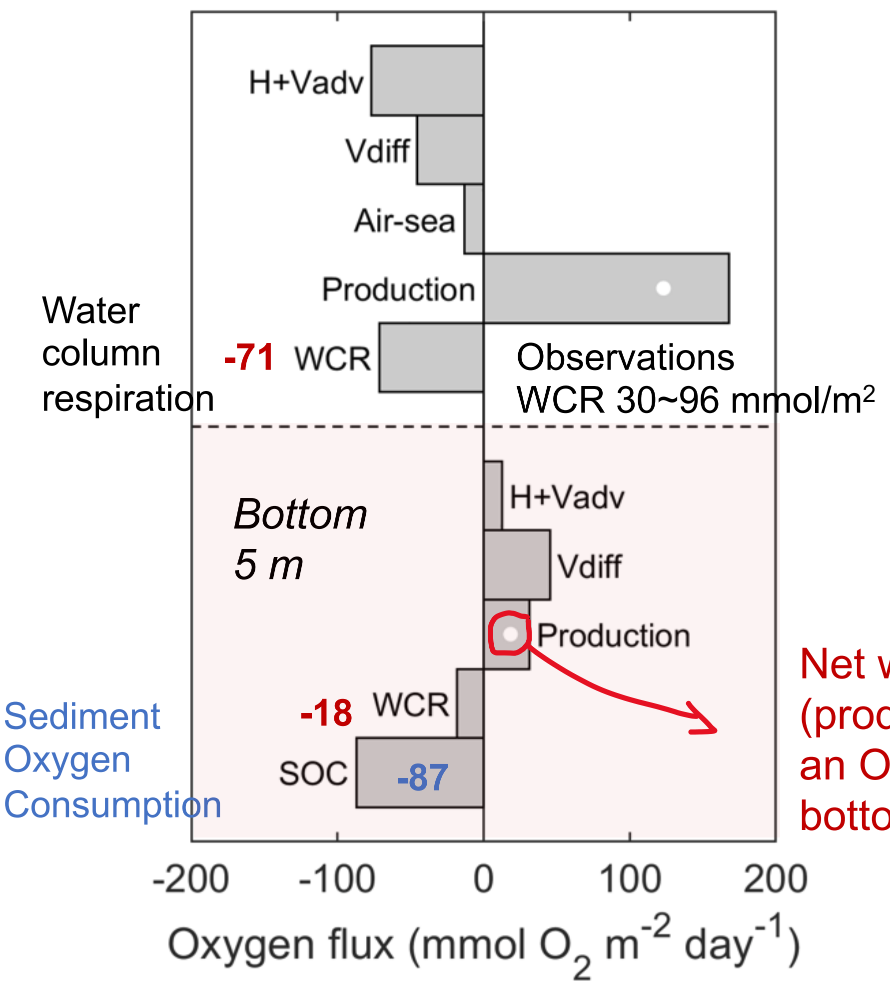


Overestimates SOC

Partially due to the overestimated BBL

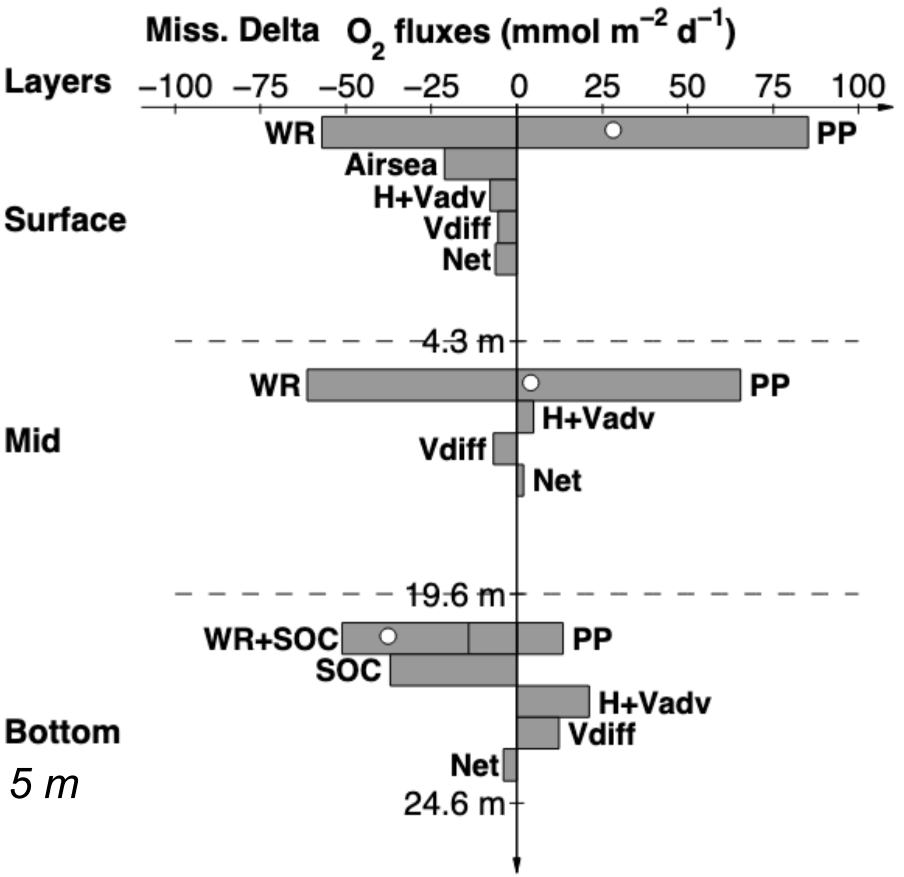
Oxygen budget → sediment dominates the total consumption

Pearl River Estuary



Net water column rate (production-WCR) is an O_2 source to bottom water

Mississippi Delta

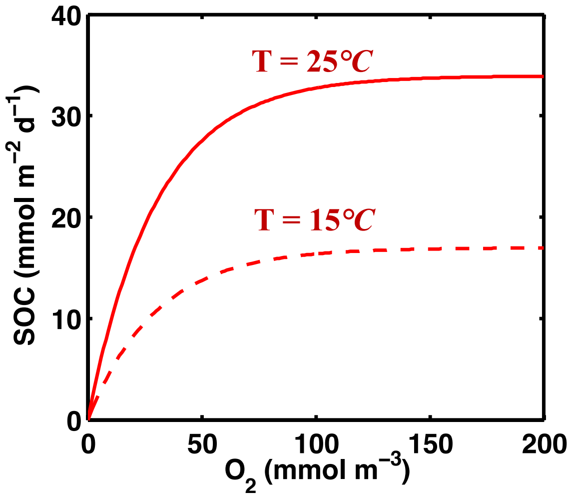


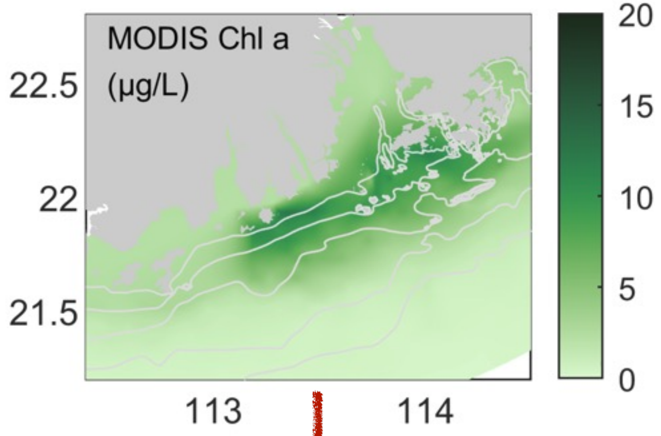
SOC also dominates, though relatively lower than in PRE

Can a simple SOC parameterization work?

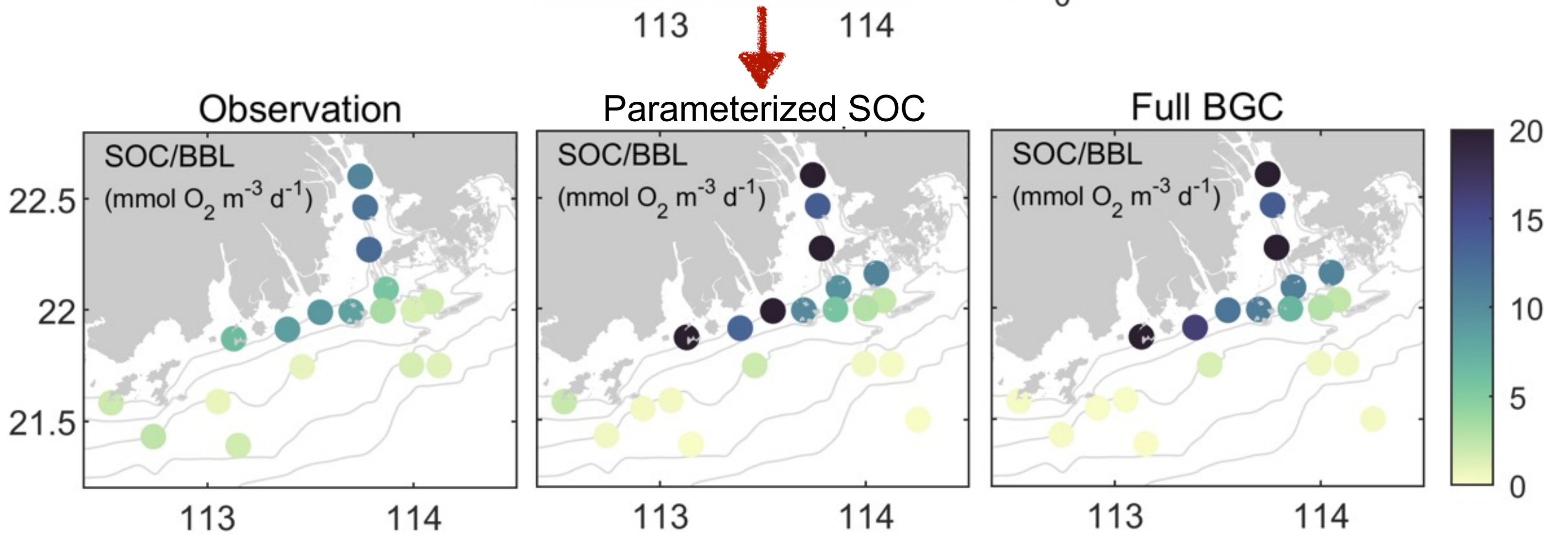
$$SOC = f(T, O_2) = 6 * 2^{\frac{T}{10}} * \left(1 - exp\left(-\frac{O_2}{30}\right)\right)$$

$$SOC = f(T, O_2, Chl) = 6 * 2^{\frac{T}{10}} * \left(1 - exp\left(-\frac{O_2}{30}\right)\right) * (0.15 * exp(-1.58 + 0.5 * Chl) + 0.43)$$





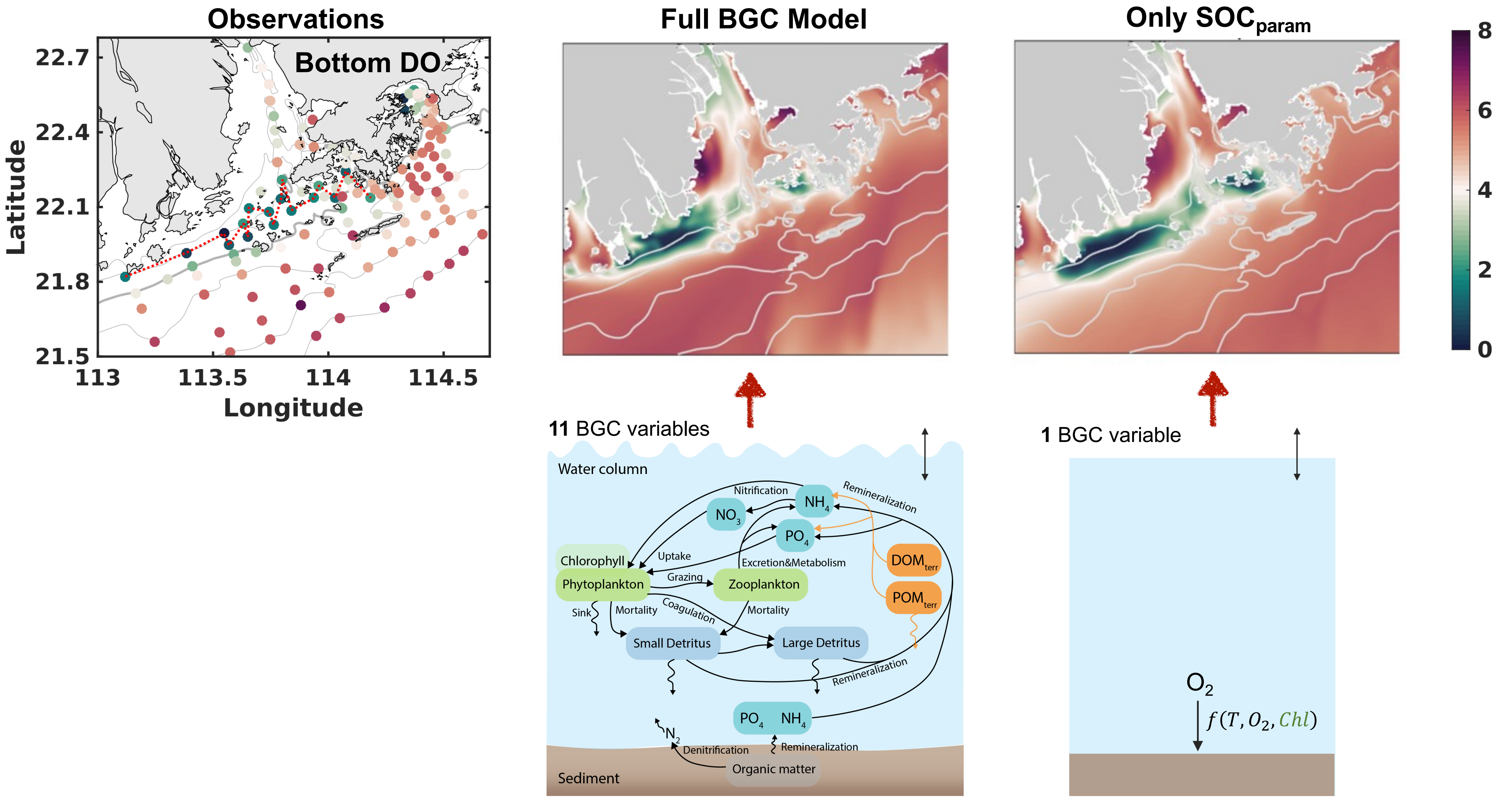
2014~2020
summer average



The equation works for

- ✔ Northern Gulf of Mexico (Hetland & DiMarco 2008; Fennel et al. 2013)
- ✔ East China Sea (Zhang et al. 2018)
- ✘ Pearl River Estuary

Can a simple SOC parameterization work?



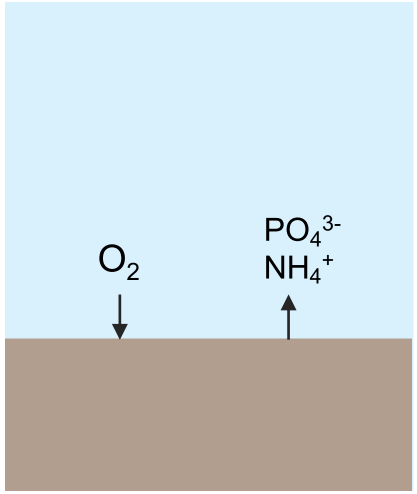
Summary

Sediment oxygen consumption is the dominant sink leading to hypoxia formation off Pearl River Estuary

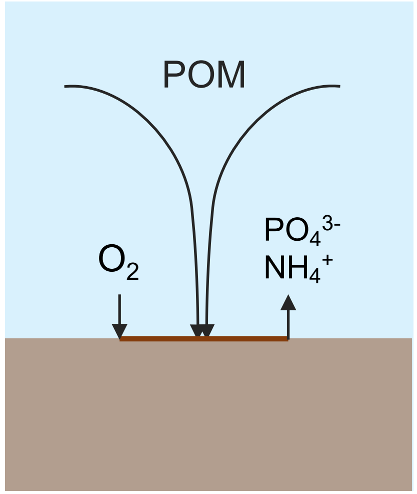
A simple oxygen model with SOC = $f(T, O_2, Chl)$ fit by observations can reasonably reproduce the observed hypoxia extent. → highlighting the importance of SOC; a computationally-cheap alternative model

Future work

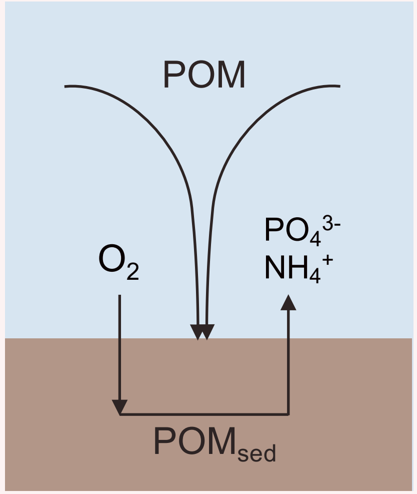
Imposed/parameterized flux
SOC = $f(T, O_2, \ldots)$
fit to measurements



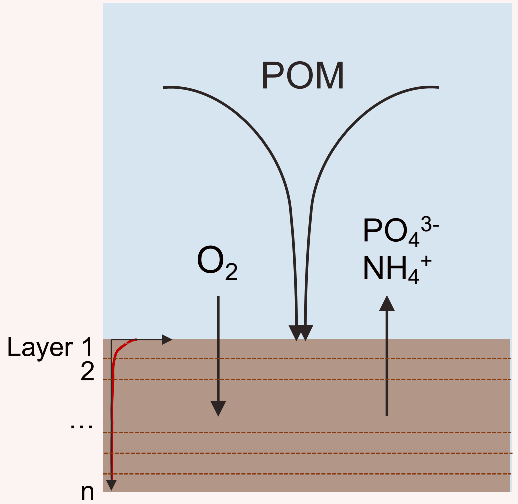
Reflective Boundary
SOC = Instant remineralization of POM



Vertically integrated
SOC ← dynamic vertically integrated model



Vertically resolved
SOC ← diagenetic model



Thank you!

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