Biogeochemical Parameter and State Estimation MITgcm - BLING

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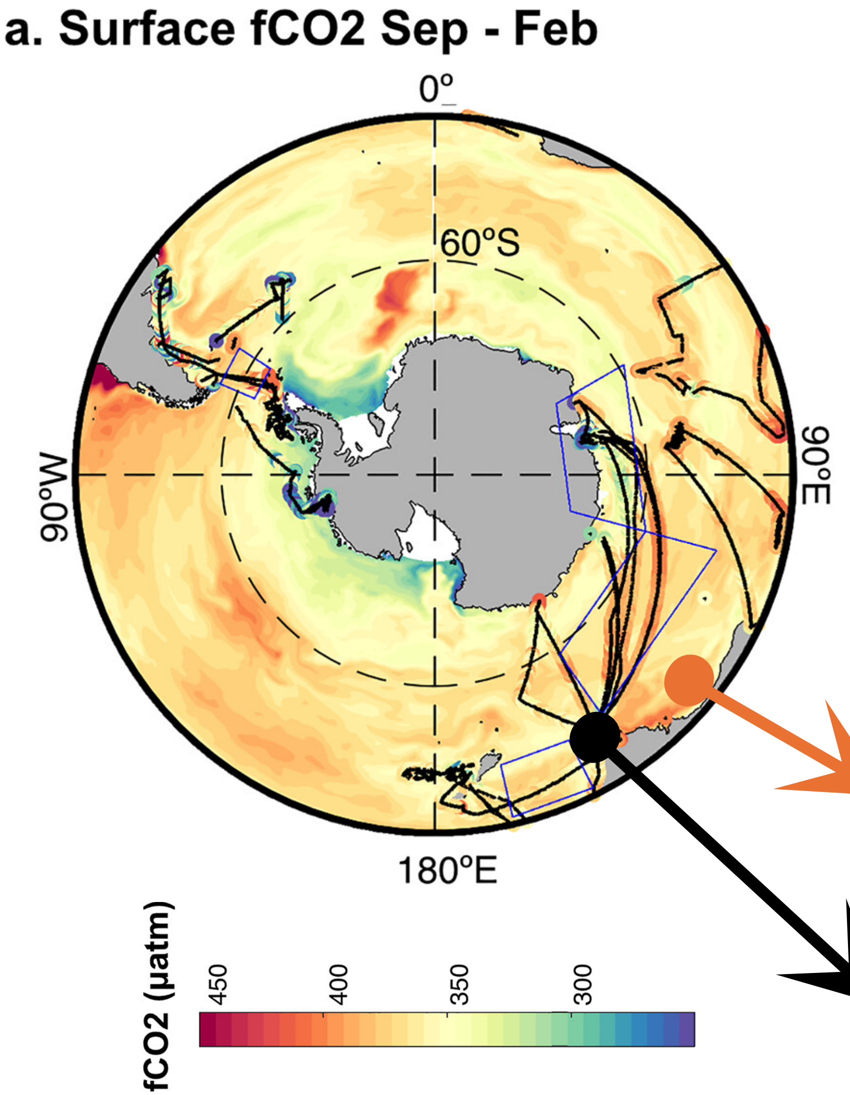
Schmidt Sciences

Biogeochemical Parameter and State Estimation MITgcm - BLING

1. Parameter estimation to improve pCO_2 model biases
2. Regional state estimation
3. Proposed work

BGC parameter estimation: pCO_2 model biases



JGR Biogeosciences

Research Article | Full Access

Understanding Regional *p*CO_2 Model Biases and Uncertainties in the Biogeochemical Southern Ocean State Estimate (B-SOSE)

Angela M. Kuhn, Matthew R. Mazloff, Sarah T. Gille, Ariane Verdy

First published: 21 May 2026 | https://doi.org/10.1029/2025JG009491 | VIEW METRICS

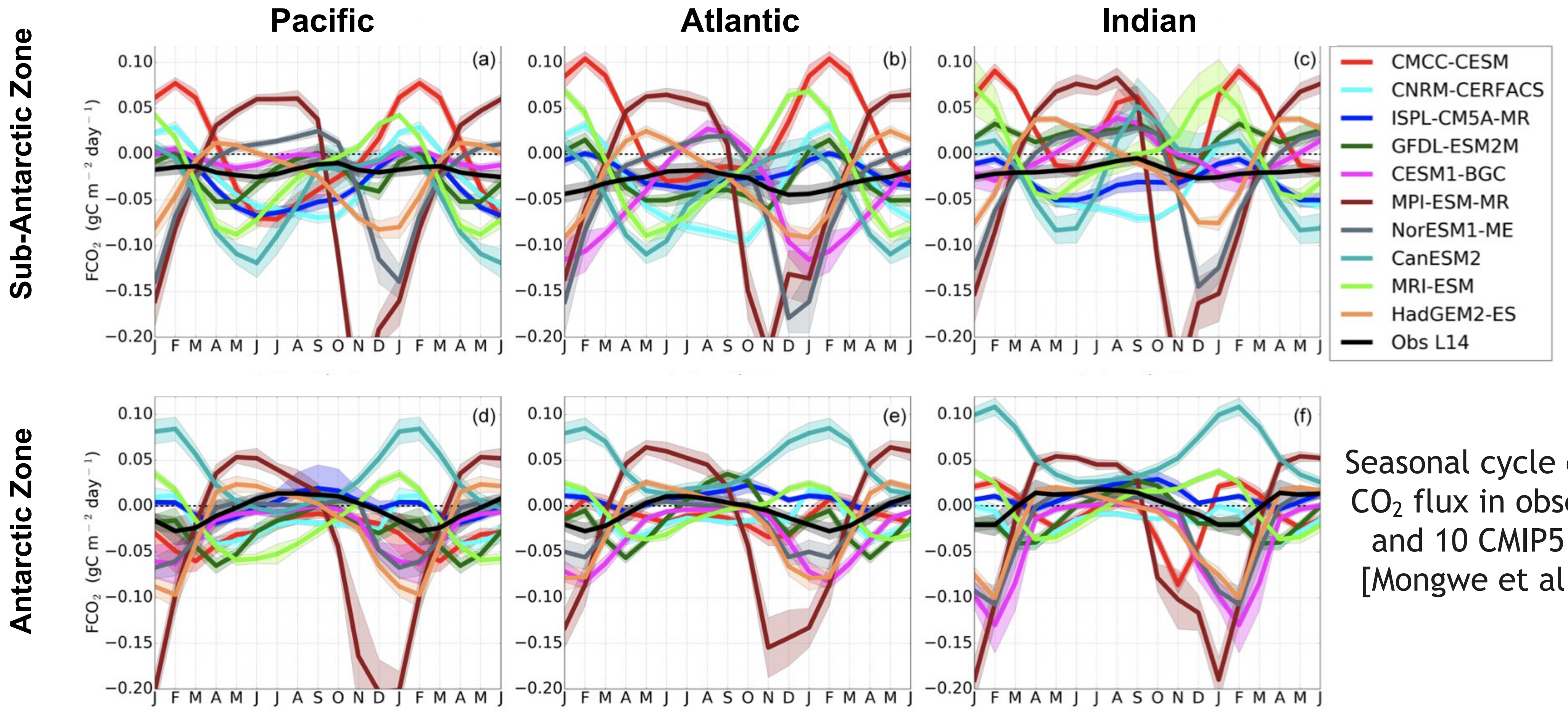
Get it at UC

B-SOSE
(control run 2019 - 2020)

SOCAT fCO_2

BGC parameter estimation: pCO_2 model biases

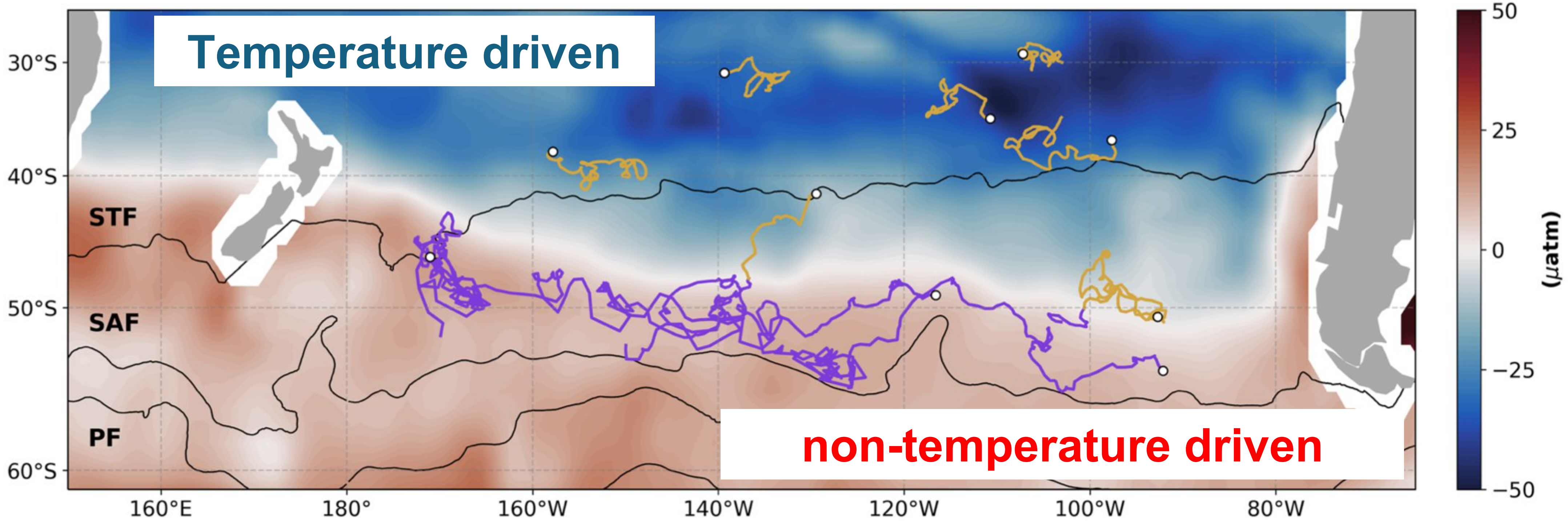
Climate models often **poorly represent the phasing air-sea CO_2 flux** in the Southern Ocean



Seasonal cycle of sea-air CO_2 flux in observations and 10 CMIP5 models [Mongwe et al., 2018]

BGC parameter estimation: pCO_2 drivers

Model limitations may arise from **misrepresentation of** the spatial distribution of **pCO_2 drivers**



Winter minus summer mean surface ocean pCO_2 from Landschützer climatology. Blue = thermally driven. Red = non-thermally driven [Prendt et al. 2022]

BGC parameter estimation: B-SOSE (BLING)

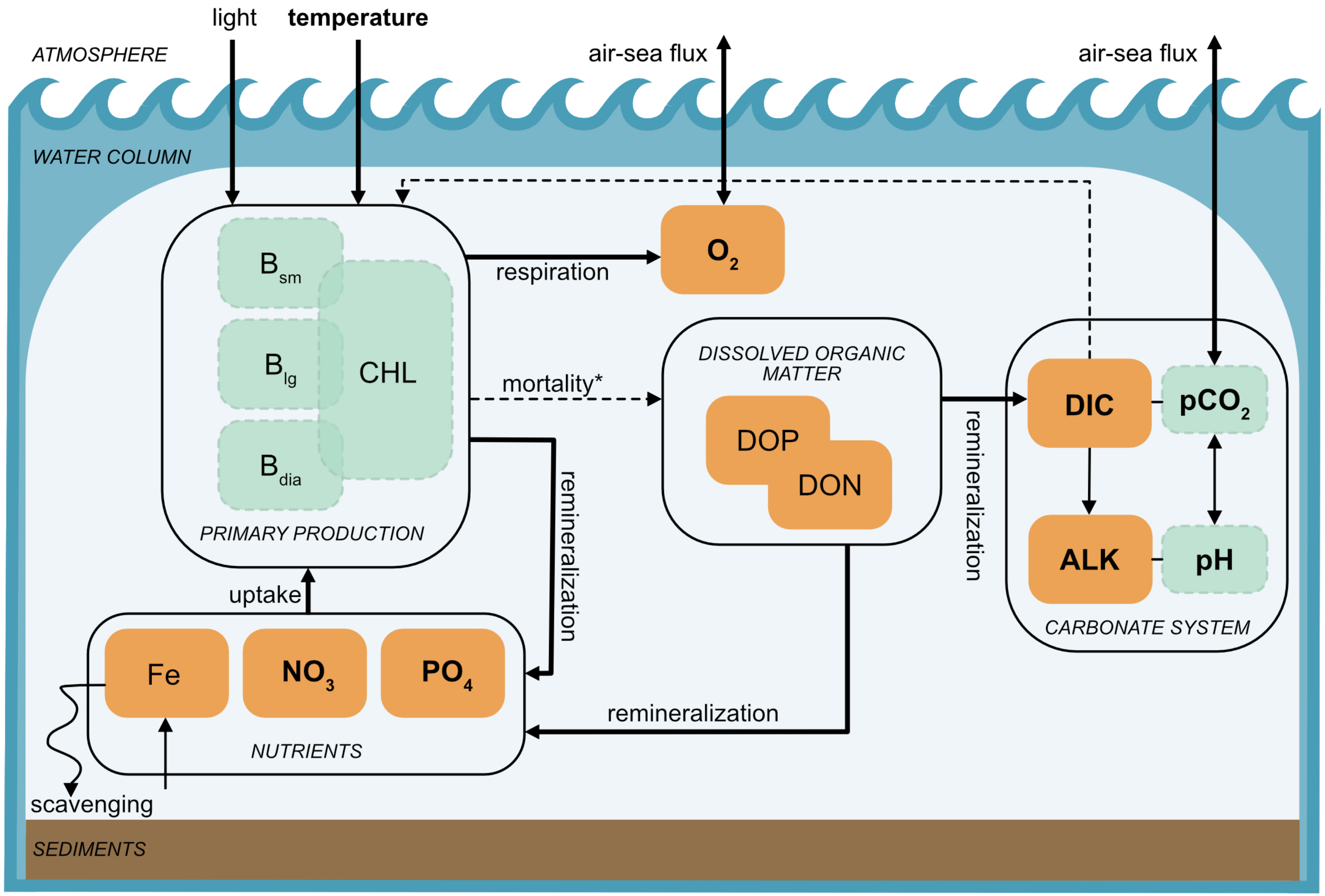
B-SOSE

Physics:

- MITgcm + ECCO configuration
- Resolution of 1/3° and 52 vertical levels

Biogeochemistry: N-BLING

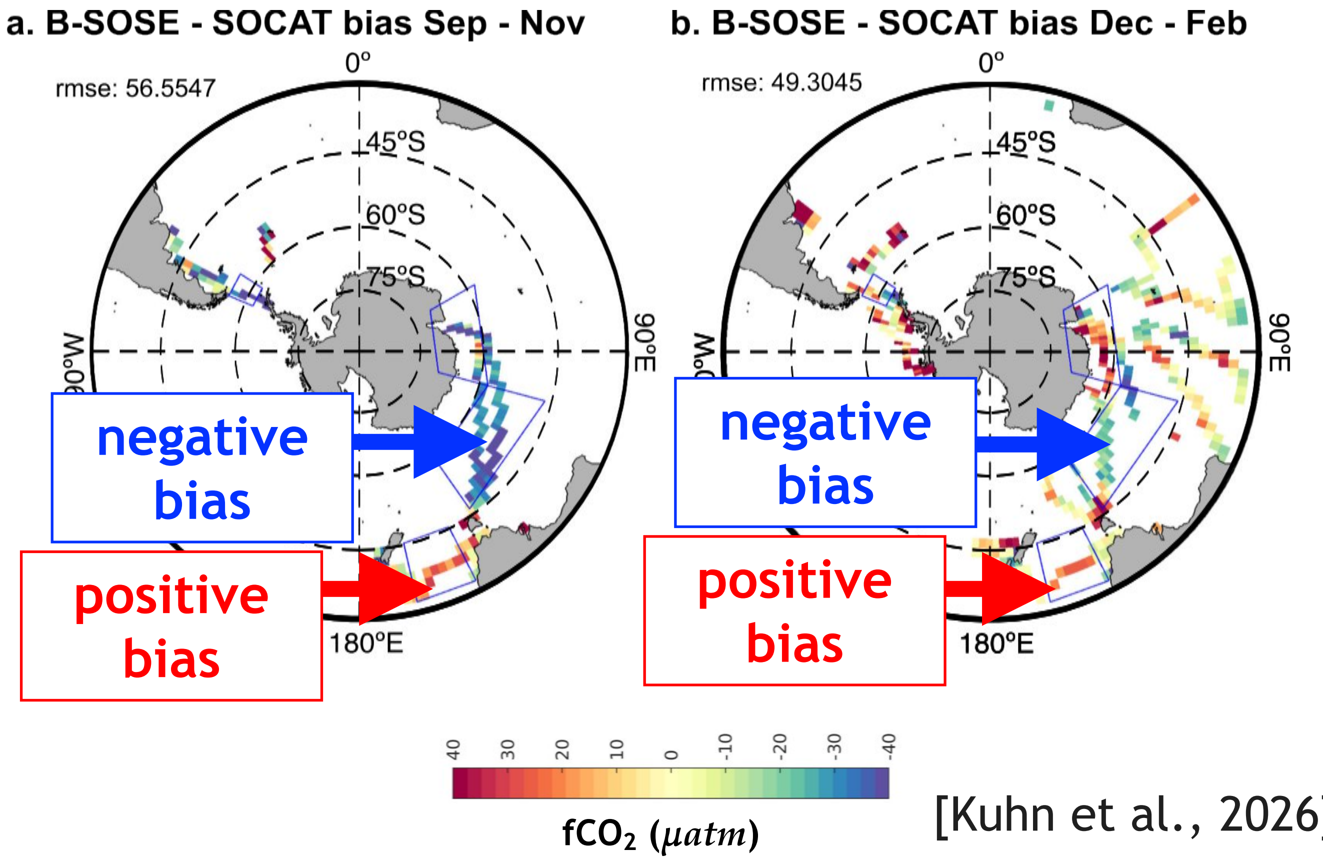
- Intermediate-complexity model
- 9 prognostic tracers
- Total phytoplankton biomass divided into 3 groups



BGC parameter estimation: pCO_2 model biases

- **Distinct temporal and spatial structure** related to latitudinal gradients and coastal features.

Sep. 2019 – Aug. 2020 simulations



[Kuhn et al., 2026]

BGC parameter estimation: pCO_2 model biases

- Distinct temporal and spatial structure related to latitudinal gradients and coastal features.
- **Biases flip from negative to positive** between seasons in some areas.

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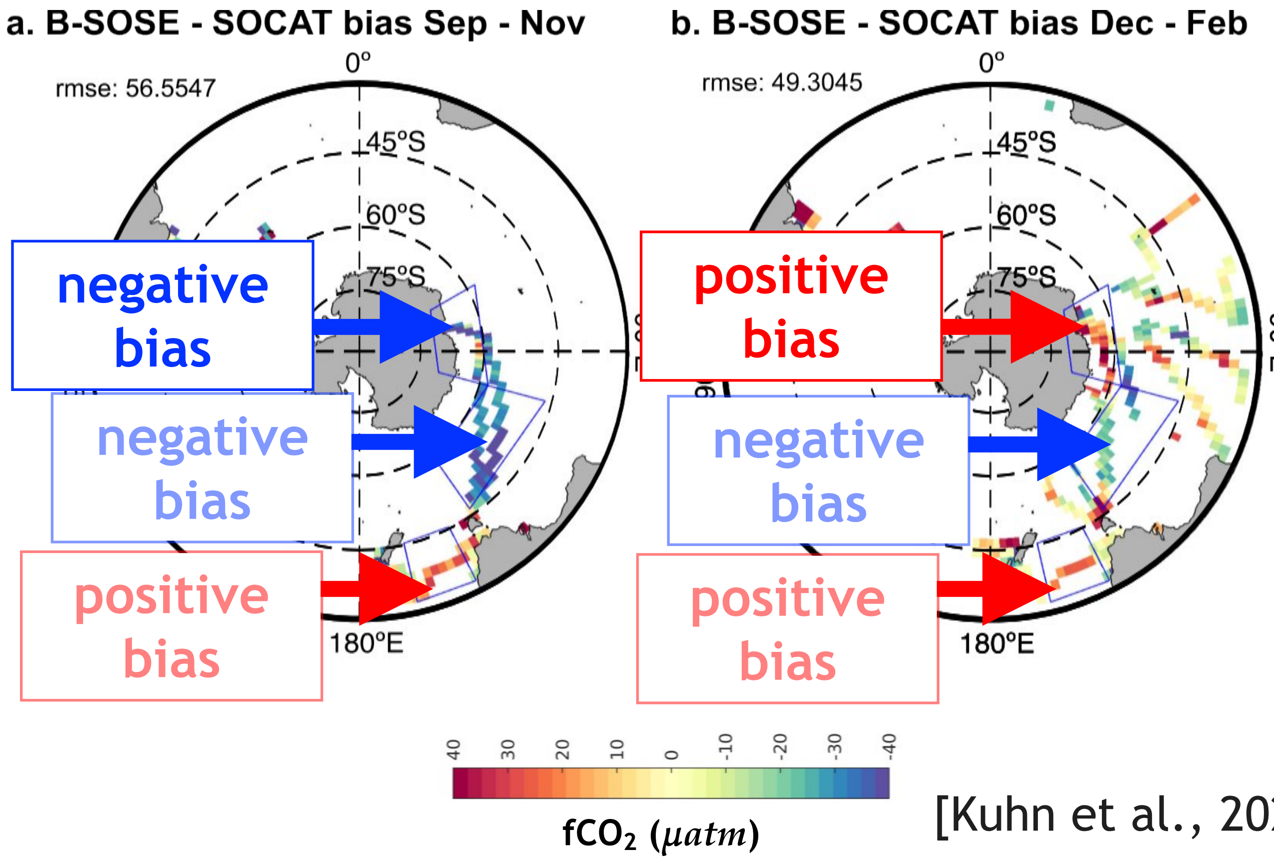
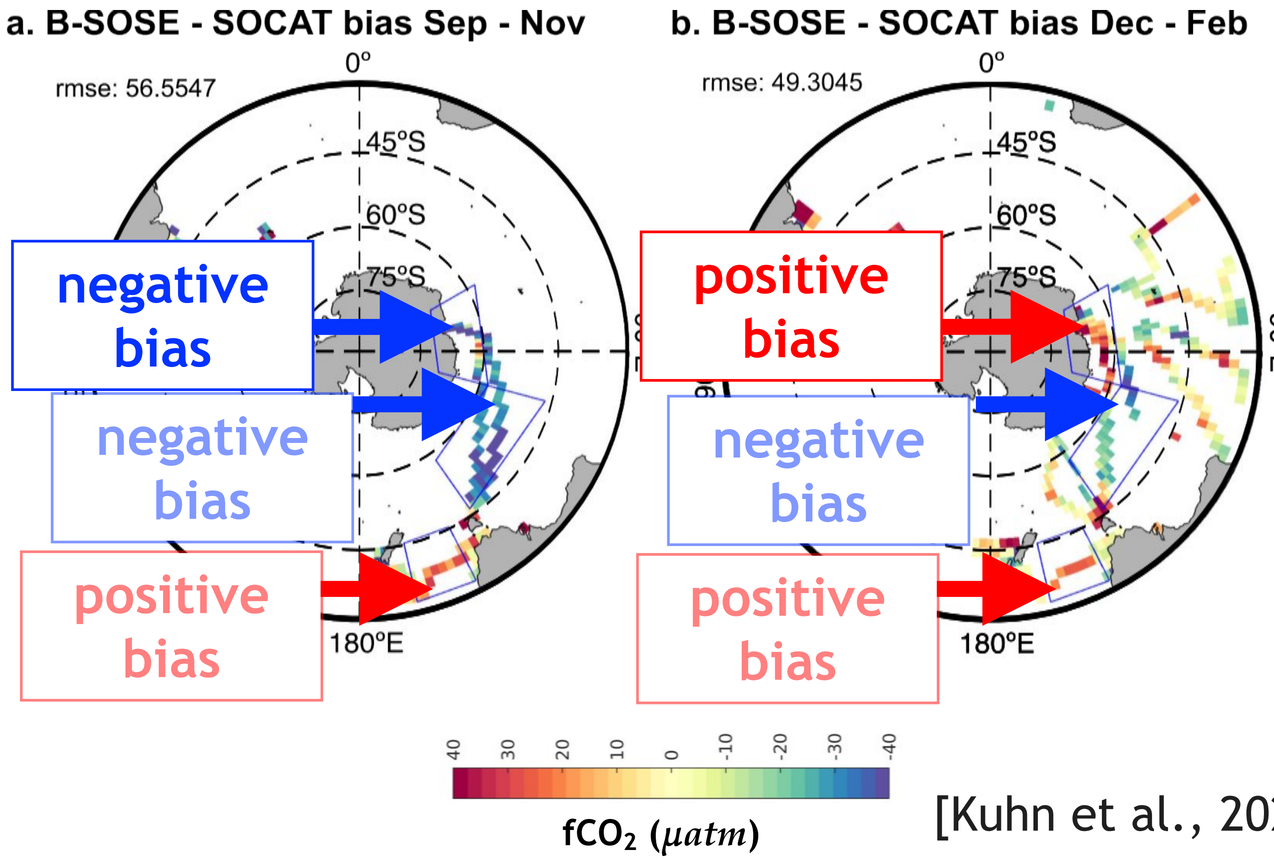


[Kuhn et al., 2026]

BGC parameter estimation: pCO_2 model biases

- **Distinct temporal and spatial structure** related to latitudinal gradients and coastal features.
- **Biases flip from negative to positive** between seasons in some areas.
- **Temporal and spatial offsets.**

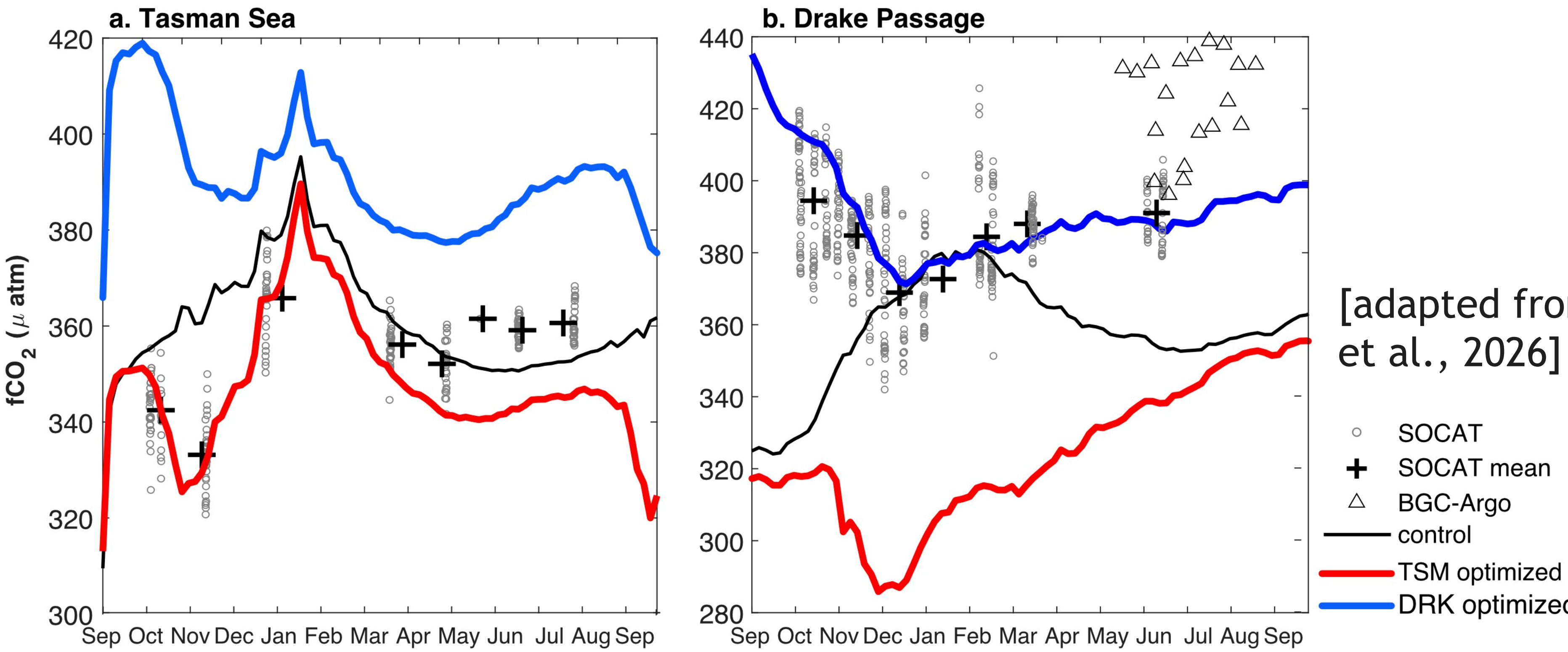
Sep. 2019 – Aug. 2020 simulations



[Kuhn et al., 2026]

BGC parameter estimation: pCO_2 optimized results

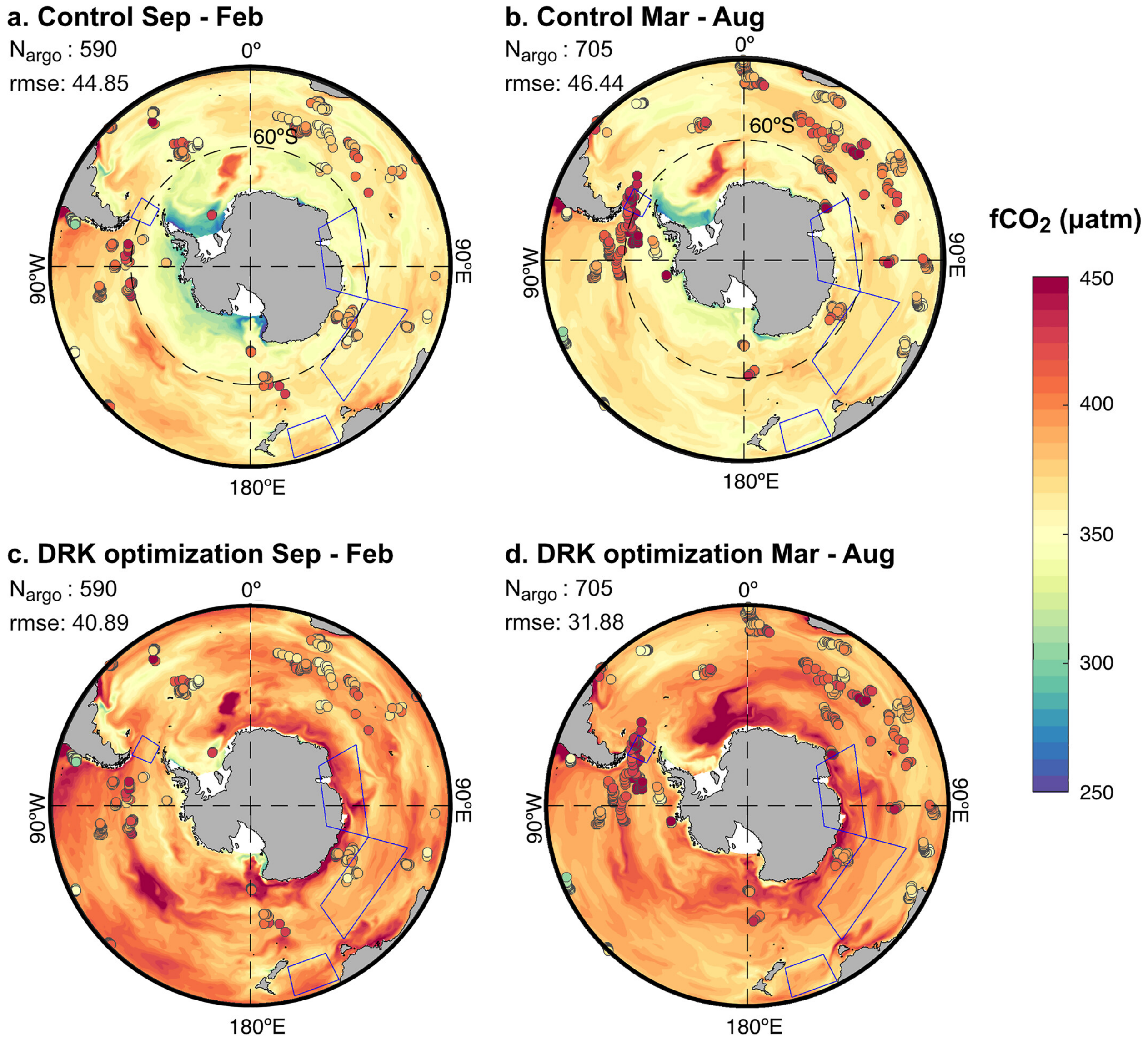
- Optimization for individual sub-regions obtained **1. similar** changes in **bgc parameters** and 2. **different** changes to **alkalinity initial conditions**.
- BGC **parameters and initial conditions control different aspects** of the fCO_2 model response.



[adapted from Kuhn et al., 2026]

BGC parameter estimation: pCO_2 optimized results

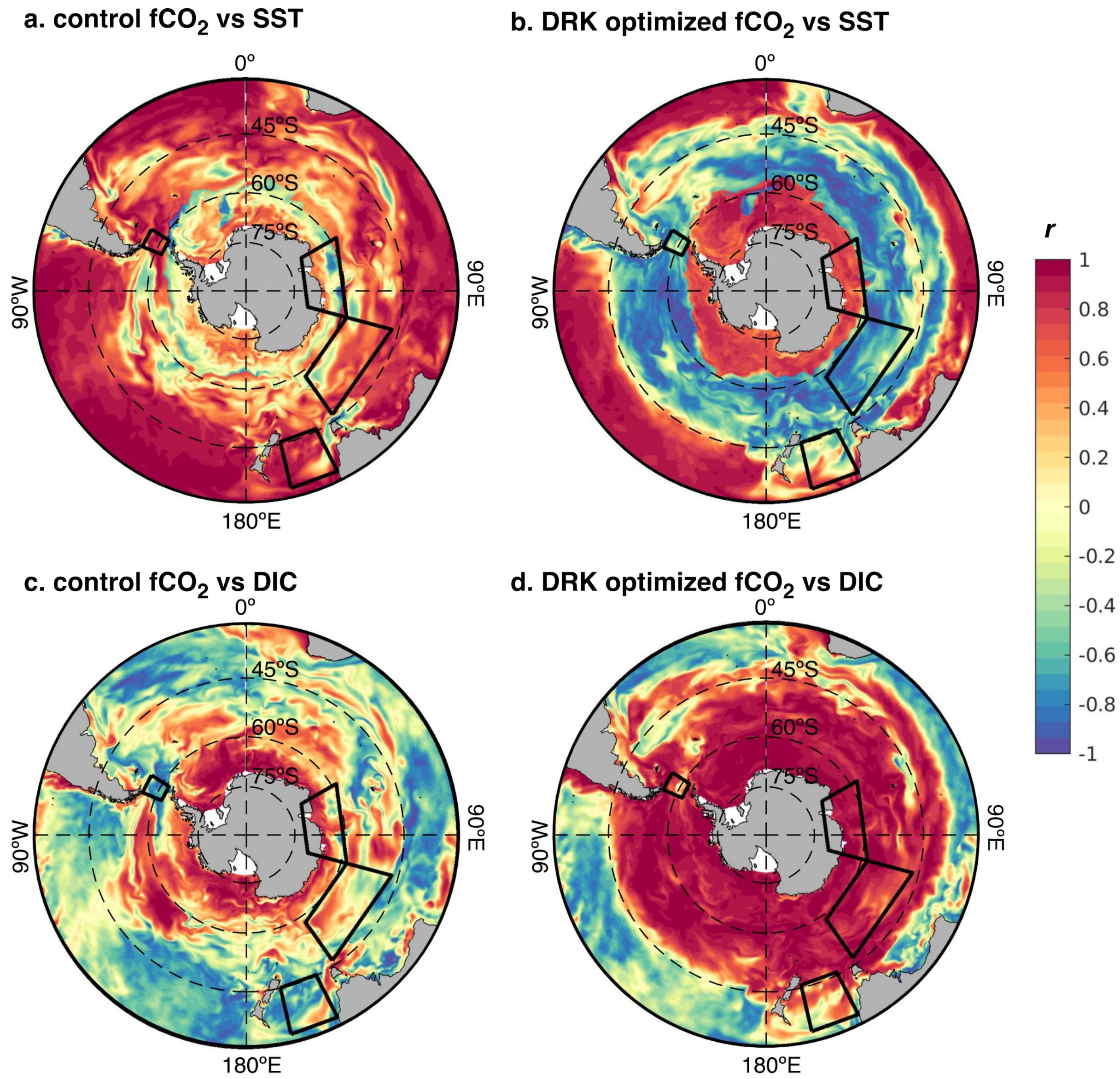
- **Increased fCO_2** throughout the entire domain.
- Increased the **similarity to BGC-Argo** observations with high fCO_2



BGC parameter estimation: pCO_2 optimized drivers

Emergent spatial patterns of **pCO_2 drivers** agree with observational studies:

- pCO_2 strongly **correlated with SST in subtropical areas.**
- pCO_2 strongly **correlated with DIC in subpolar areas.**



BGC Parameter estimation: summary

- **Improved B-SOSE fCO_2** results; 18%–79% rmse reduction & 67%-92% correlation improvement.
- **Improved spatial patterns of fCO_2 drivers** of seasonal variability.
- **BGC parameters and initial conditions control different aspects** of the fCO_2 model response in the Southern Ocean:
- **BGC parameters affect the phasing** of the fCO_2 seasonal cycle; BGC optimization improves correlation to observations.
- **Alkalinity initial conditions affect sub-regional mean** fCO_2 differences; uncertainties still affect model solution.

Regional State Estimation

Matthew R. Mazloff & ECCO@Scripps group

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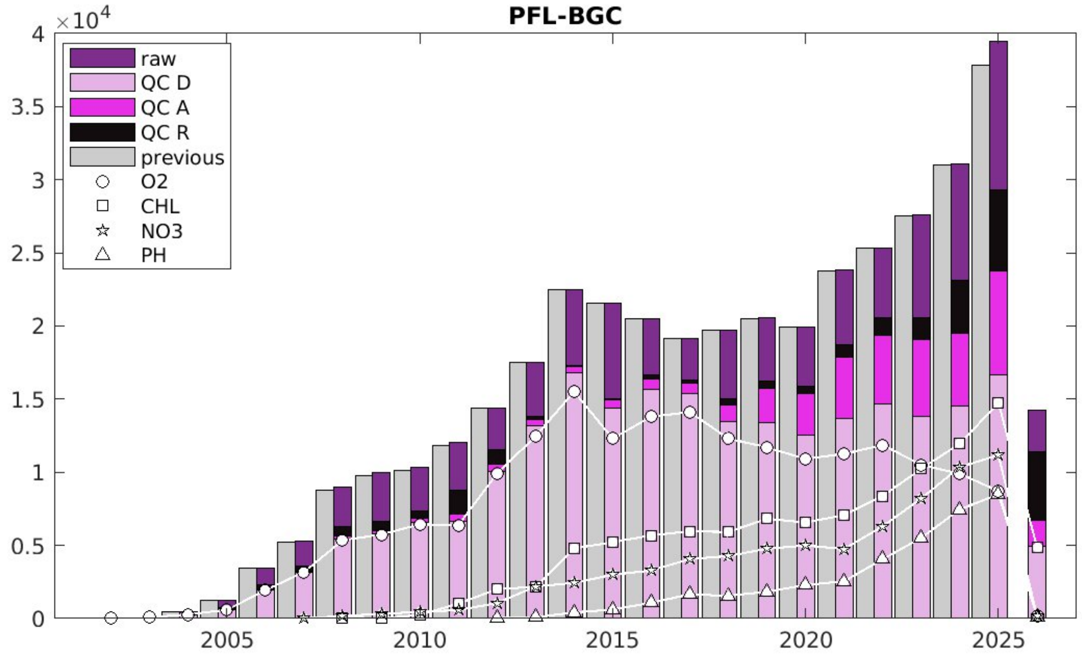
SOCCOM NSF NOAA Schmidt Sciences OCEAN MARGINS INITIATIVE ACCRA, GHANA 2024-2029

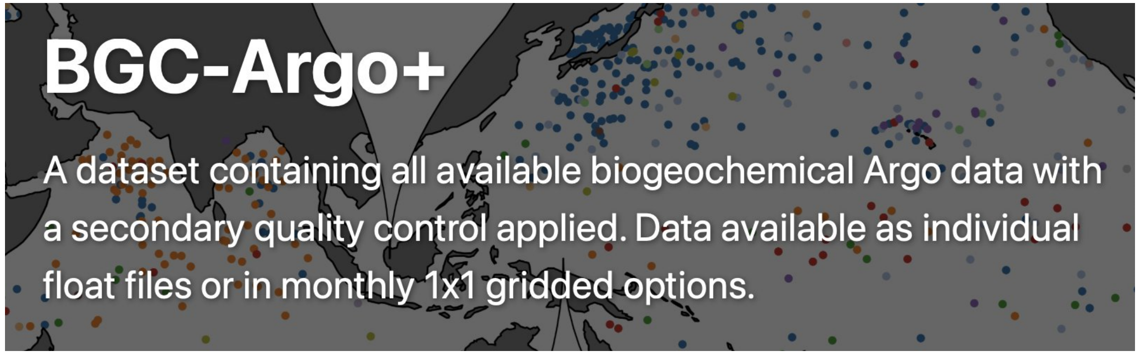
in situ BGC constraints processing

- bgc-Argo 2005-2026
- WOD 1992-2026
- SOCATv2025 2012-2024
- GLODAPv2 1992-2021

ecco.ucsd.edu/assim.html



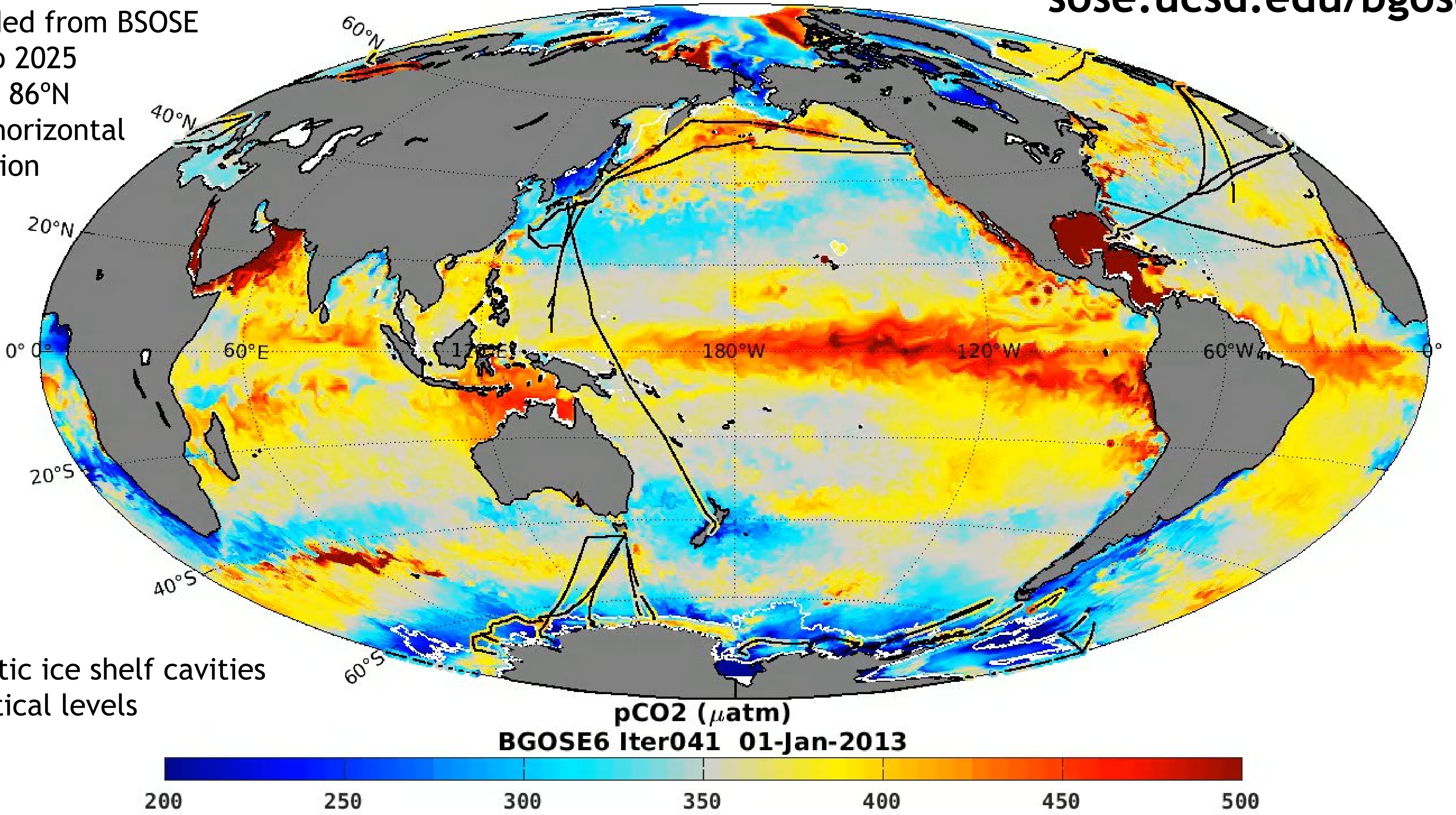
In progress:
Improved QC, BGC-Argo+ (Bushinski, Nashod)



Biogeochemical Global Ocean State Estimate (BGOSE)

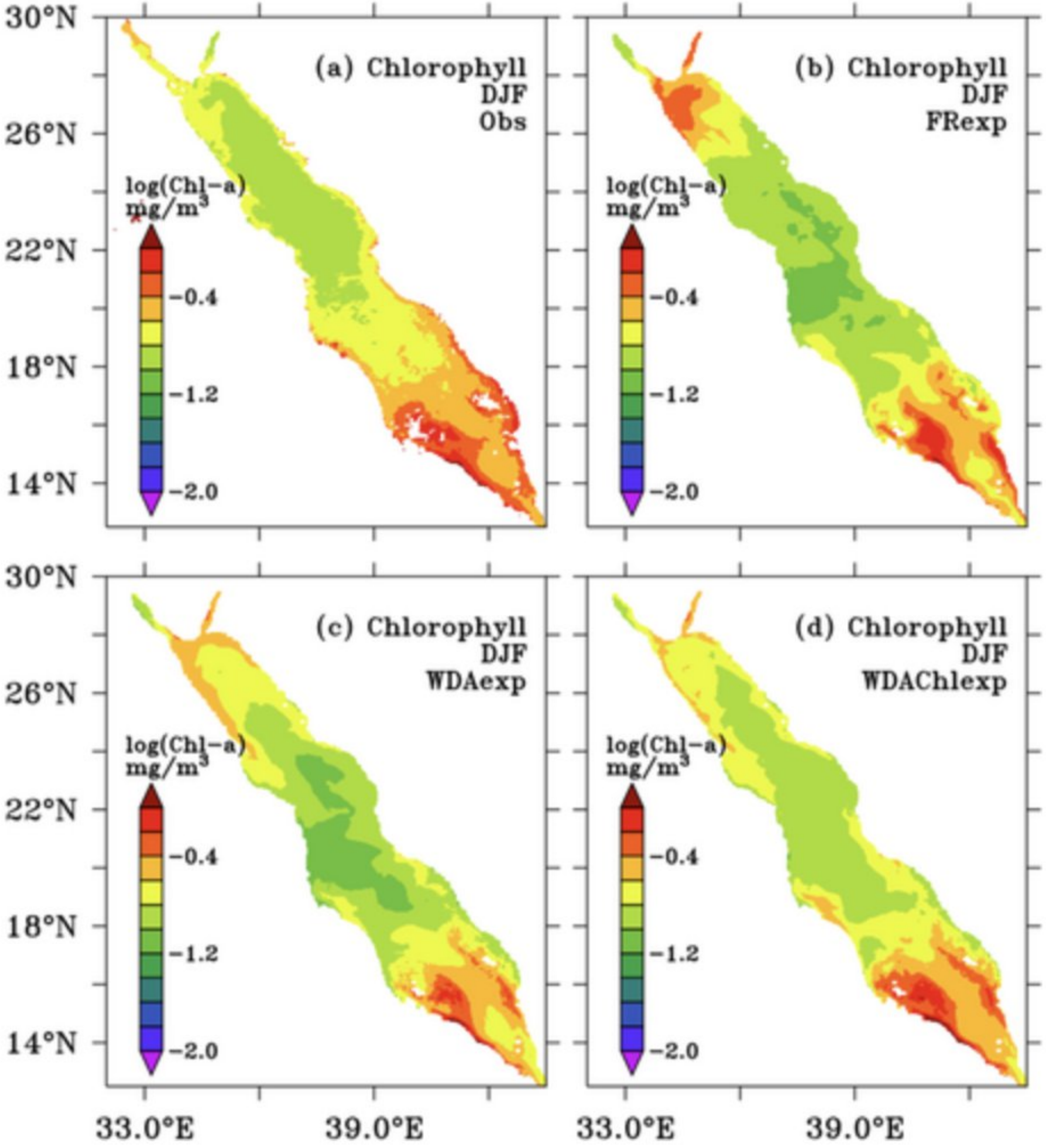
sose.ucsd.edu/bgose.html

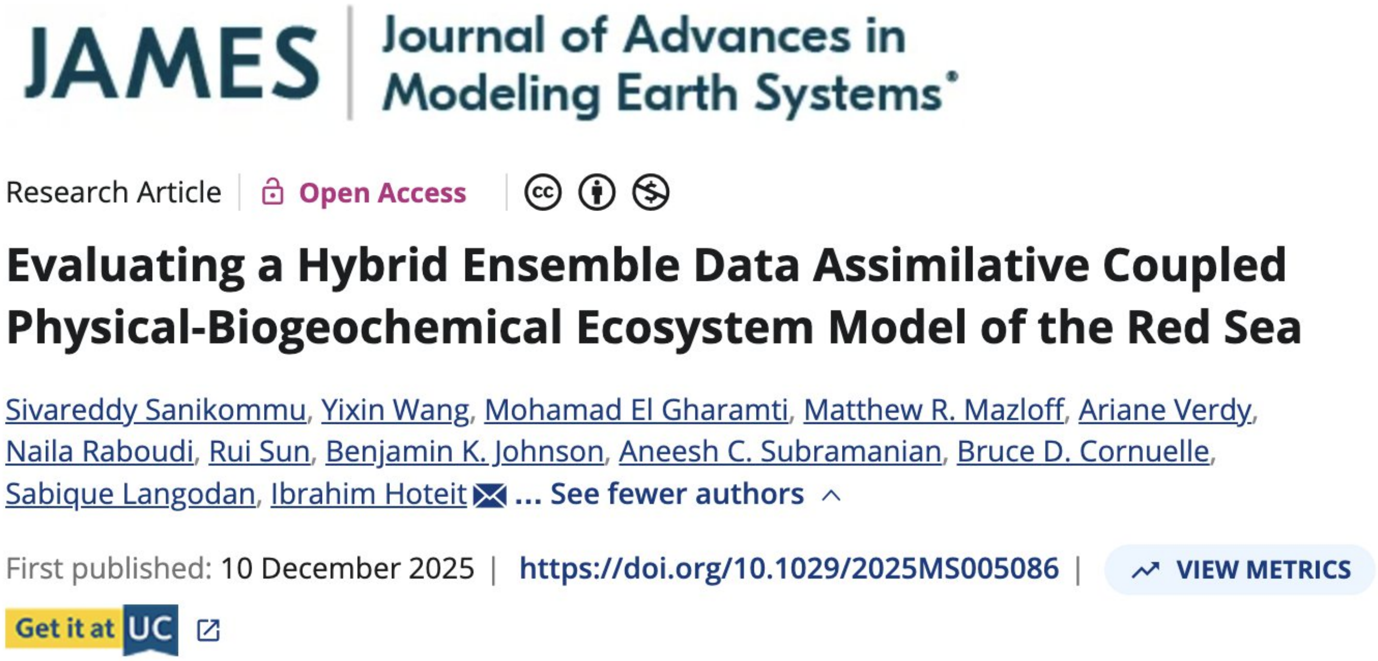
- Expanded from BSOSE
- 2013 to 2025
- 83ºS to 86ºN
- 1/6th horizontal resolution



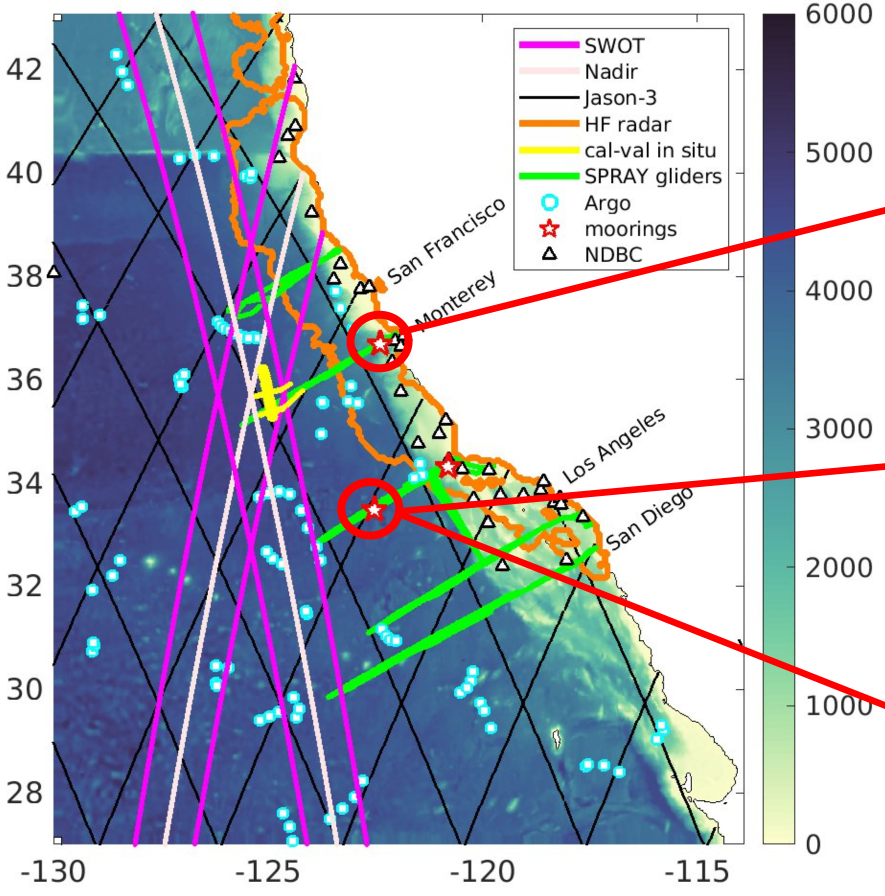
- Antarctic ice shelf cavities
- 52 vertical levels

BGC in the Red Sea

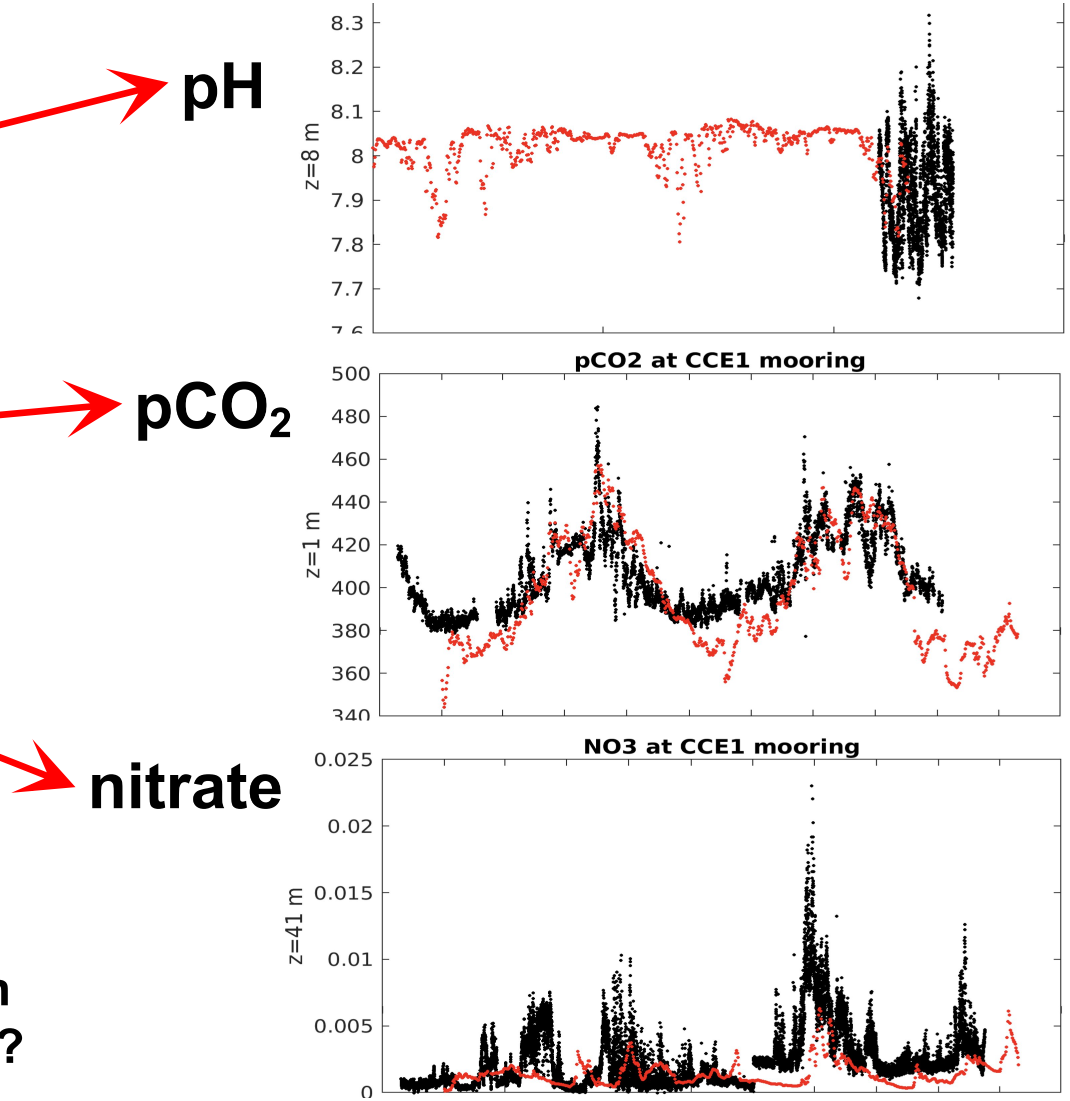




BGC in the California Current System (CCS)



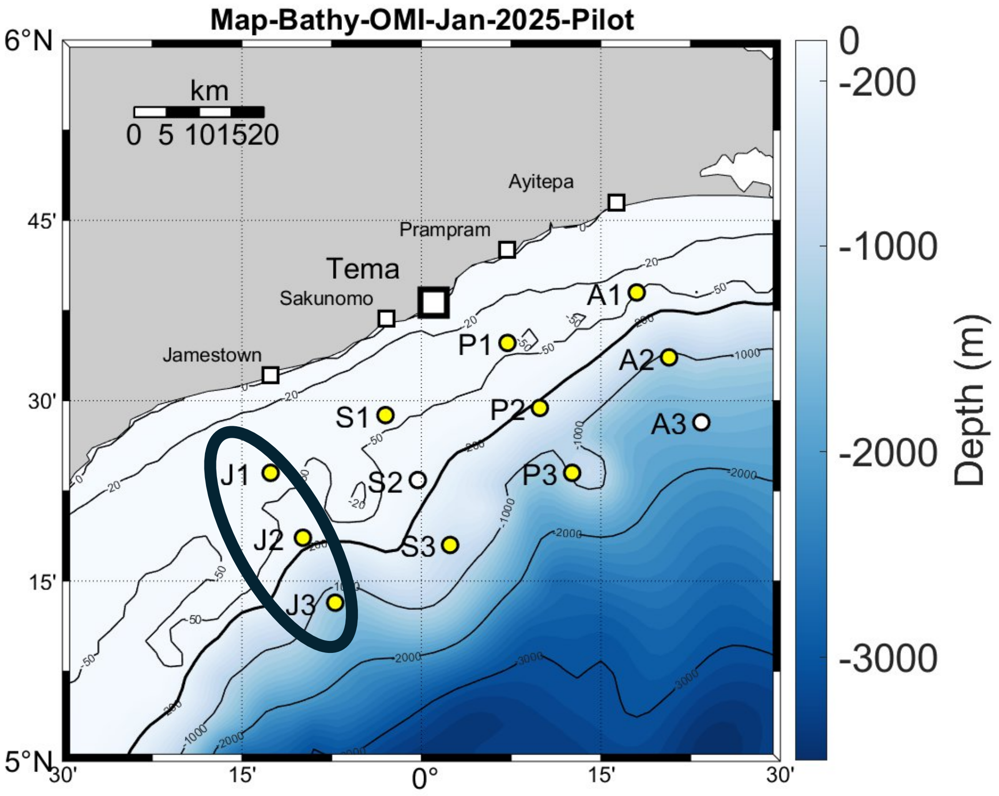
Mooring data vs BLING forward run

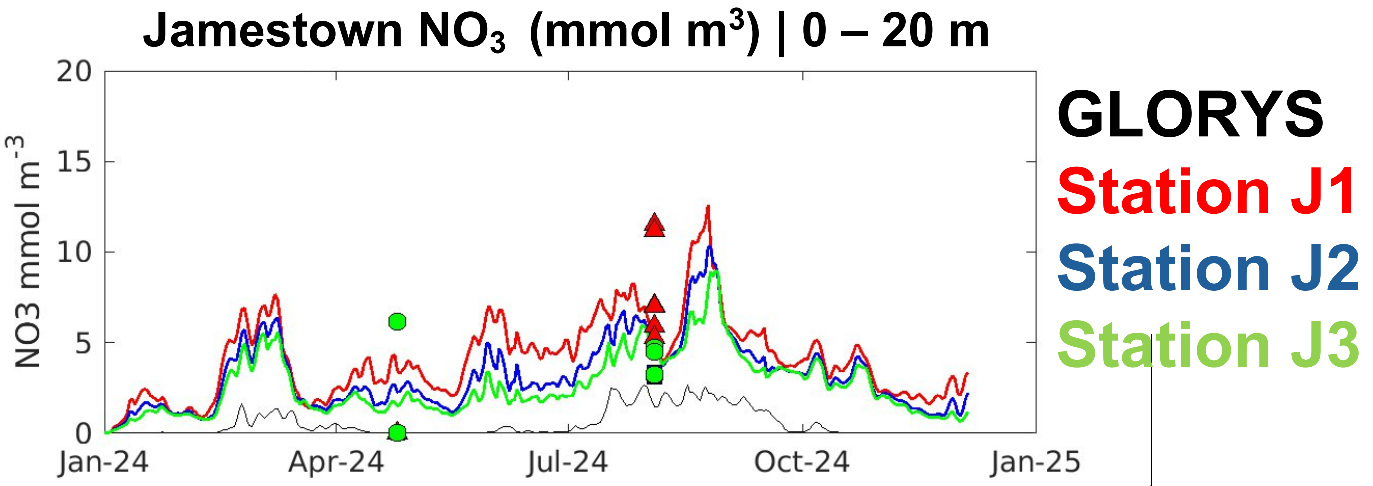


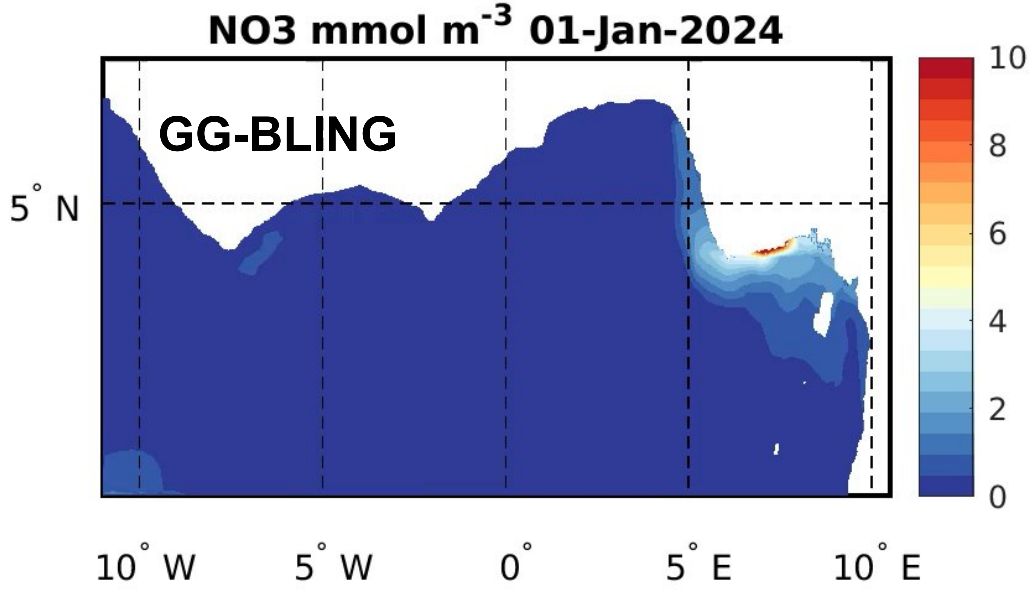
In progress:

How does data assimilation impact vertical motion simulation, and what are the implications for BGC?

BGC in the Gulf of Guinea (GG)







In progress:
Cross-shelf heat, carbon and nutrient fluxes

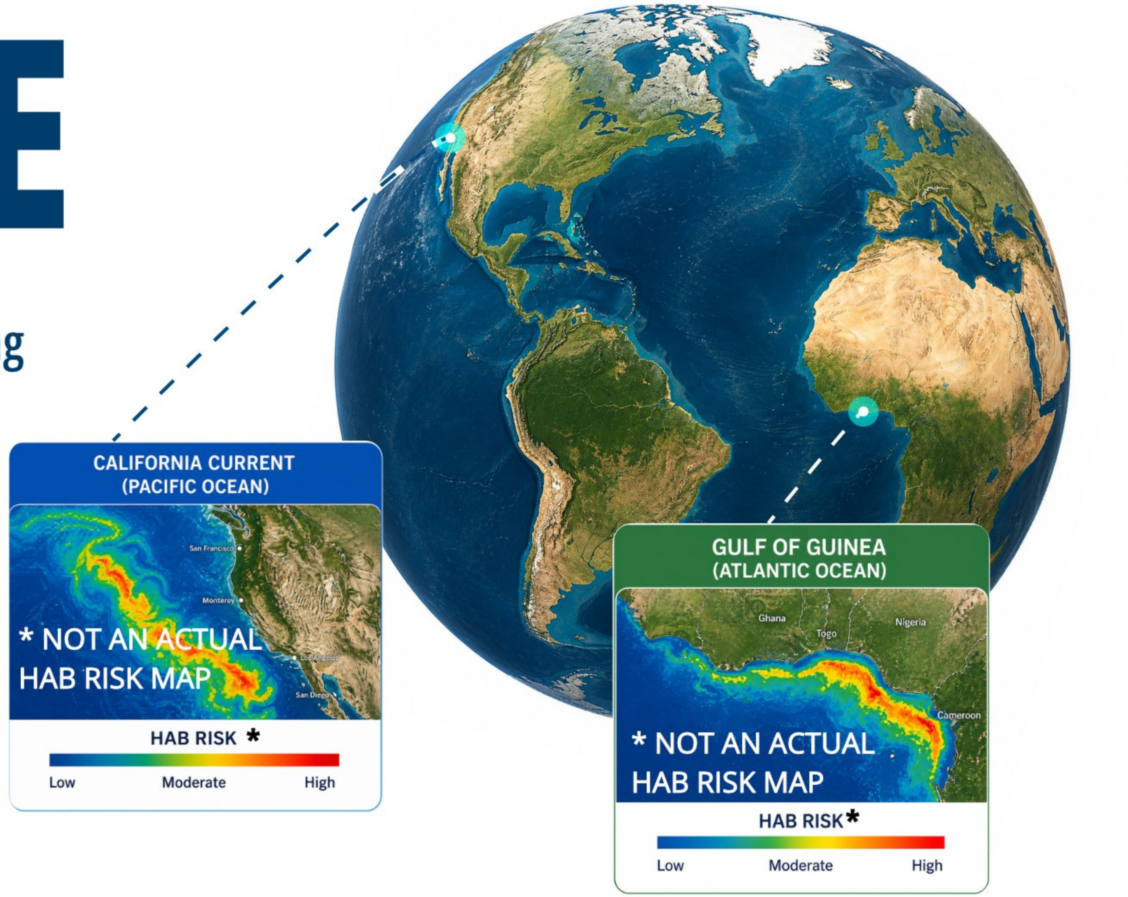
Proposed Work

Proposed: “mechanistic- AI” forecasting

HABWISE

Harmful **A**lgal **B**loom **W**arning through
Integrated **S**tate **E**stimation and Machine Learning

HABWISE combines artificial intelligence, advanced ocean modeling, satellite and in situ observations to deliver accurate, low-latency regional HAB forecasts



SCALABLE

A **roadmap** to ocean biogeochemical **AI-powered forecasting**, scalable worldwide

ACCURATE

Physics-informed AI for reliable HAB predictions

LOW-LATENCY

Real-time forecasts for timely decisions

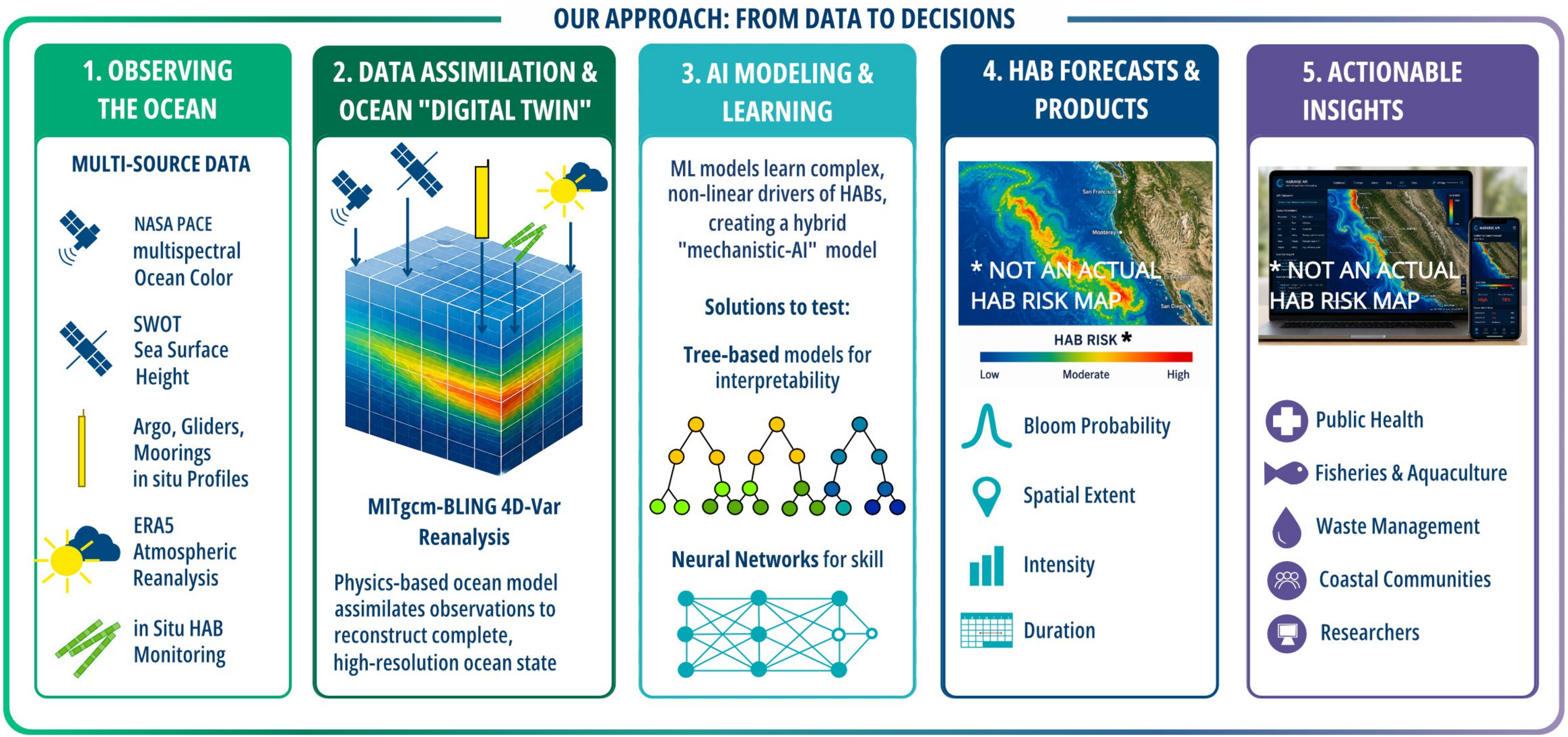
GLOBAL SCOPE

Built equitably for future **scalability** to data-rich and data-sparse regions

IMPACTFUL

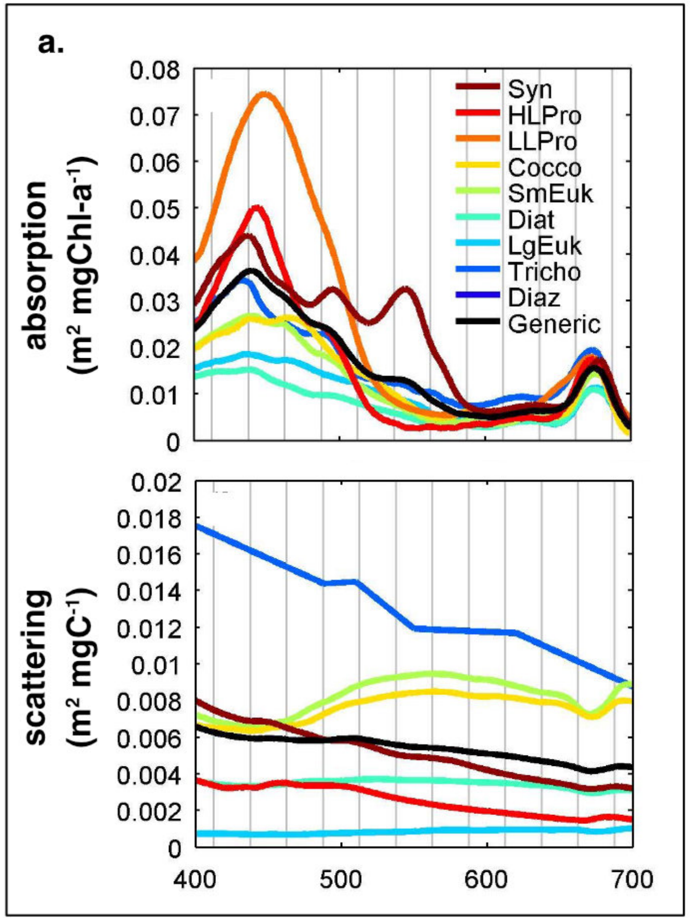
Protecting health, economies and ecosystems

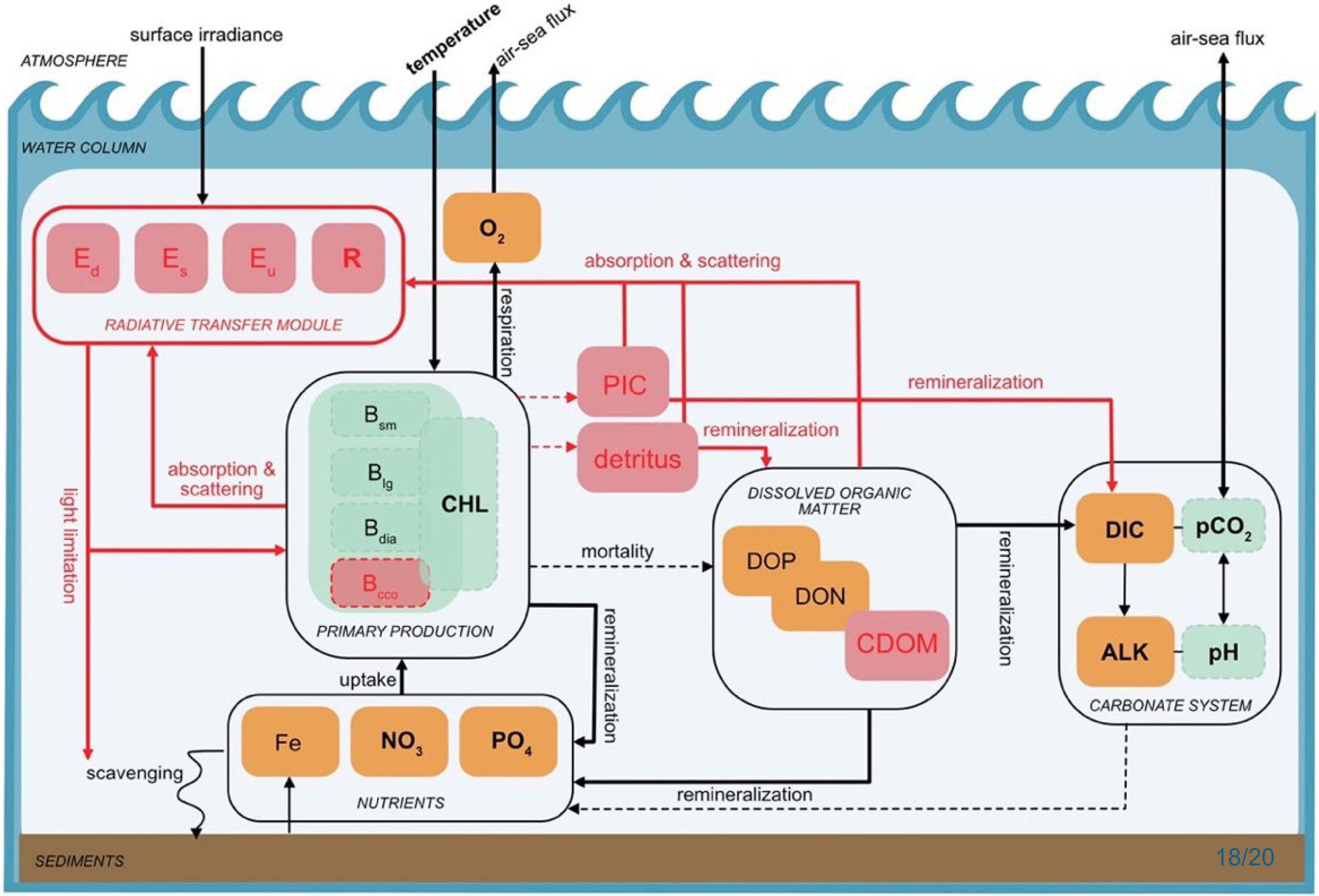
Proposed: “mechanistic- AI” forecasting



Proposed: PACE data assimilation

BLING + radiative transfer model





Proposed: pkg/D-Lite

- A simplified version of the Darwin model
  (“Darwin light”)
- Start with BLING structure (adjoint compatible)
- Add tracers: PIC, POC, 5 phytoplankton types, and 2 zooplankton types (following ECCO-Darwin)
- Couple to pkg/RadTrans for comparisons with PACE
- Run Darwin forward and D-Lite adjoint?
  (“Multi-ecosystem?”)

some AI designs…

D-Lite
OCEAN BIOGEOCHEMICAL MODEL

BGC MITgcm – BLING: Summary

- Tested cost-efficient and transferable calibration methodologies.
- Global and regional BGC state estimates products available: BGOSE, BSOSE, Red Sea, California, Gulf of Guinea
- Looking forward to new projects and collaborations (funding permitting).