2nd Ocean Carbon from Space workshop
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Can we constrain the biological C pump by nudging a biogeochemical model towards satellite observations of phytoplankton size classes?

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Introduction

Marine ecosystems transfer POC from the surface to the deep ocean through the Biological Carbon Pump (BCP).

- **The efficiency of the BCP** depends on the production, transformation and export of POC → depend on the structures of phytoplankton communities.
- **Earth System Models (ESMs)** like NEMO-PISCES exhibit inconsistent in phytoplankton size classes biomass (PSCs)
- **Projections** show declining diatom populations due to ocean warming, → affects POC export predictions
- **Challenge**: PSC uncertainties between models limit our ability to predict BCP responses to climate change

Figure 1. Particulate Organic Carbon (POC) dynamics in the water column. Phytoplankton (green organisms), zooplankton (orange organisms), and detritus (purple particles) are tracers in PISCES model. Fish are represented as an infinite chain of predators. Black downward arrows represent gravitational sinking flux, and purple upward arrows represent the time C is stored in the deep ocean.

Objective

To address PSC-related biases in the NEMO-PISCES model and quantify the impact of these biases on the global biological carbon pump during the satellite era.
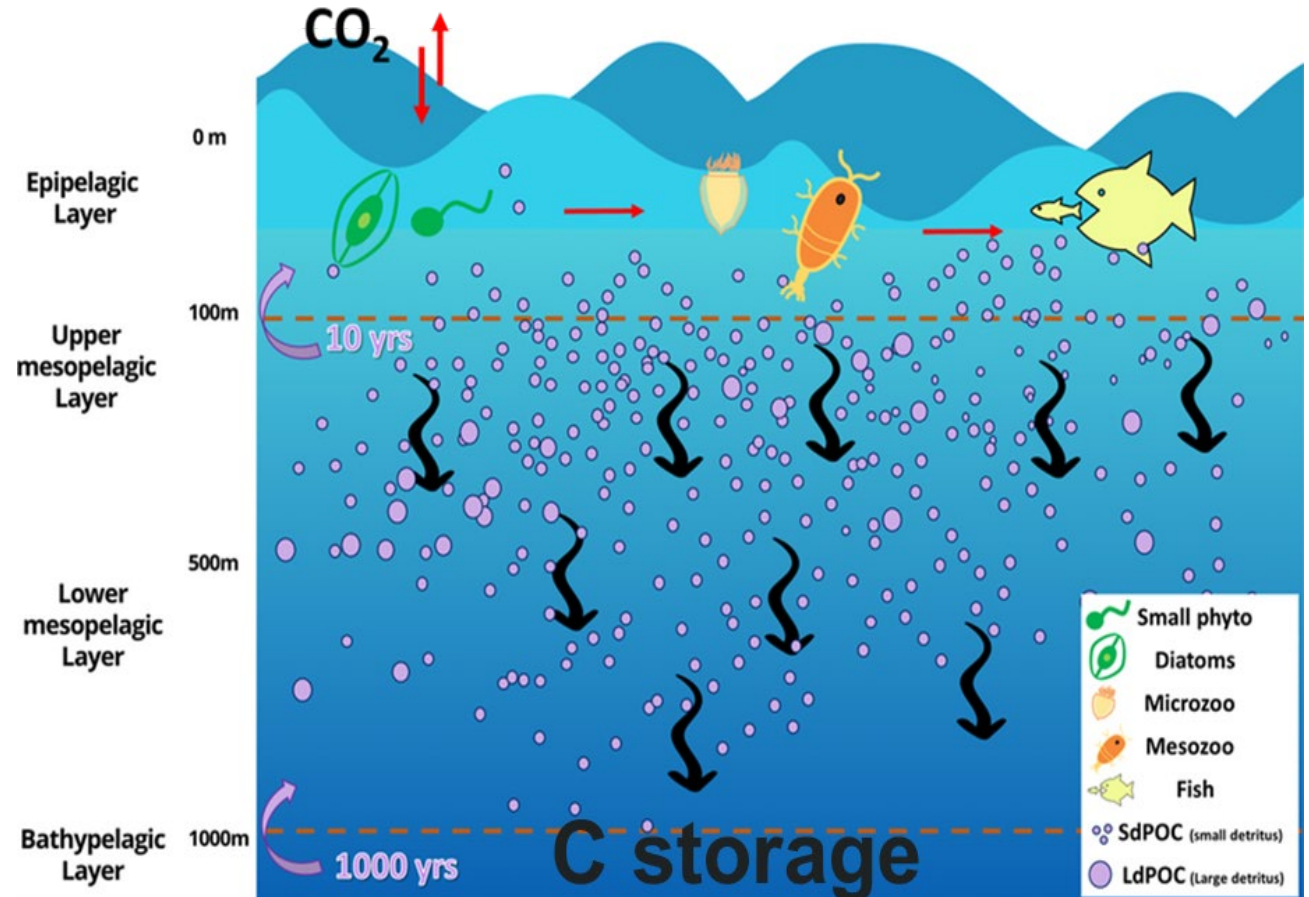
Methodology

Restoring technique:

Cphy experiment with PISCESv2.0–NEMO4.0.4 coupled model.

We constrain C from surface phytoplankton biomass in NEMO – PISCES using ESA satellite observations, distinguishing:

→ Small phytoplankton (pico- and nano-)

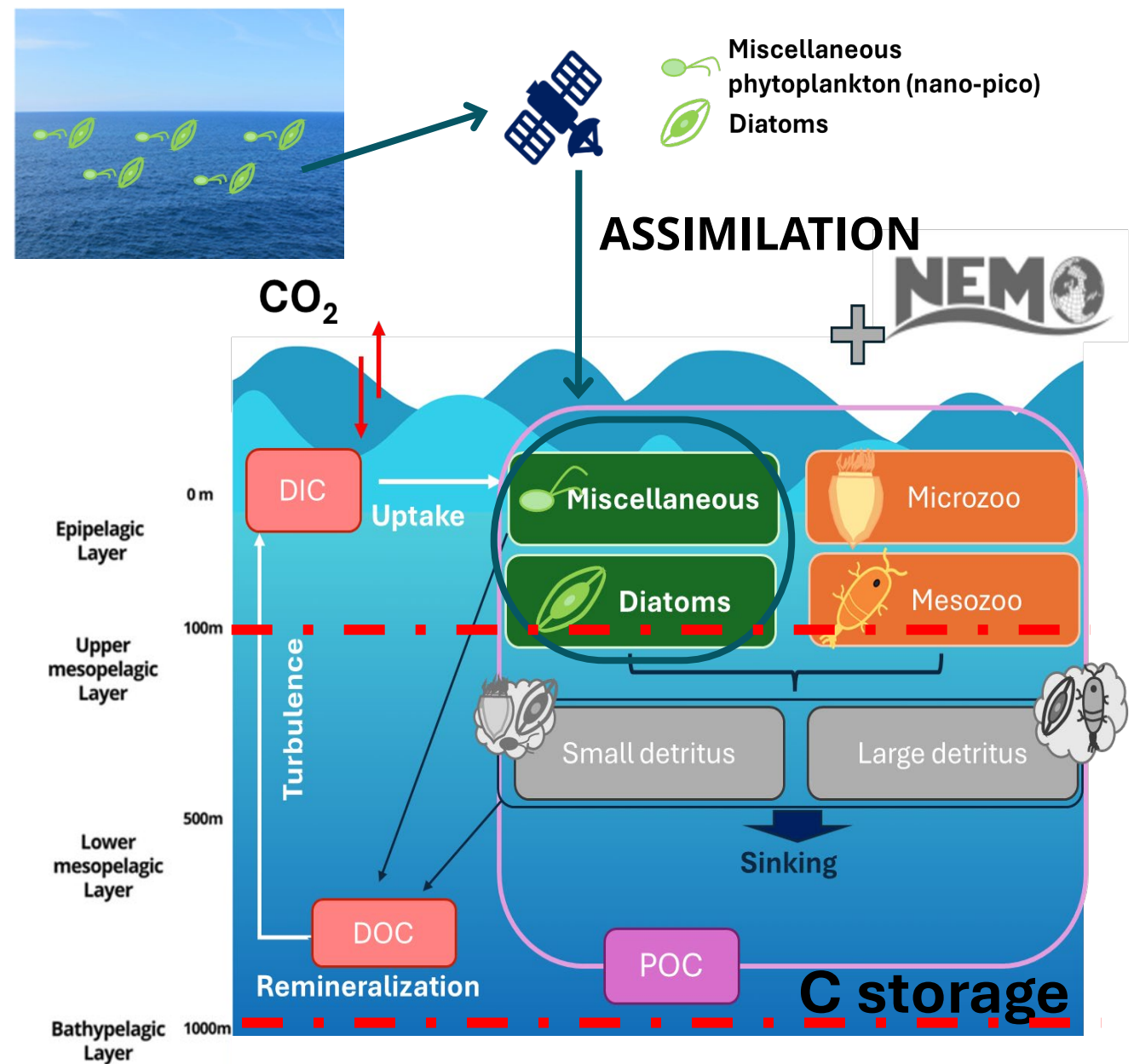→ Large phytoplankton (diatoms)

Figure 2. Schema of the restoring of Cphy experiment. Particulate Organic Carbon (POC) dynamics in the water column represented by PISCESv2.0–NEMO4.0.4. Phytoplankton (green organisms), zooplankton (orange organisms), and detritus (grey particles) are tracers in PISCES model. Red dashed lines represent the limits of the productive and mesopelagic layers.

Preliminary Results

1) Spatial Patterns

We decreased the PSCs bias in the North Atlantic. How does this affect the POC stock, the export fluxes, and the Biological Carbon Pump?
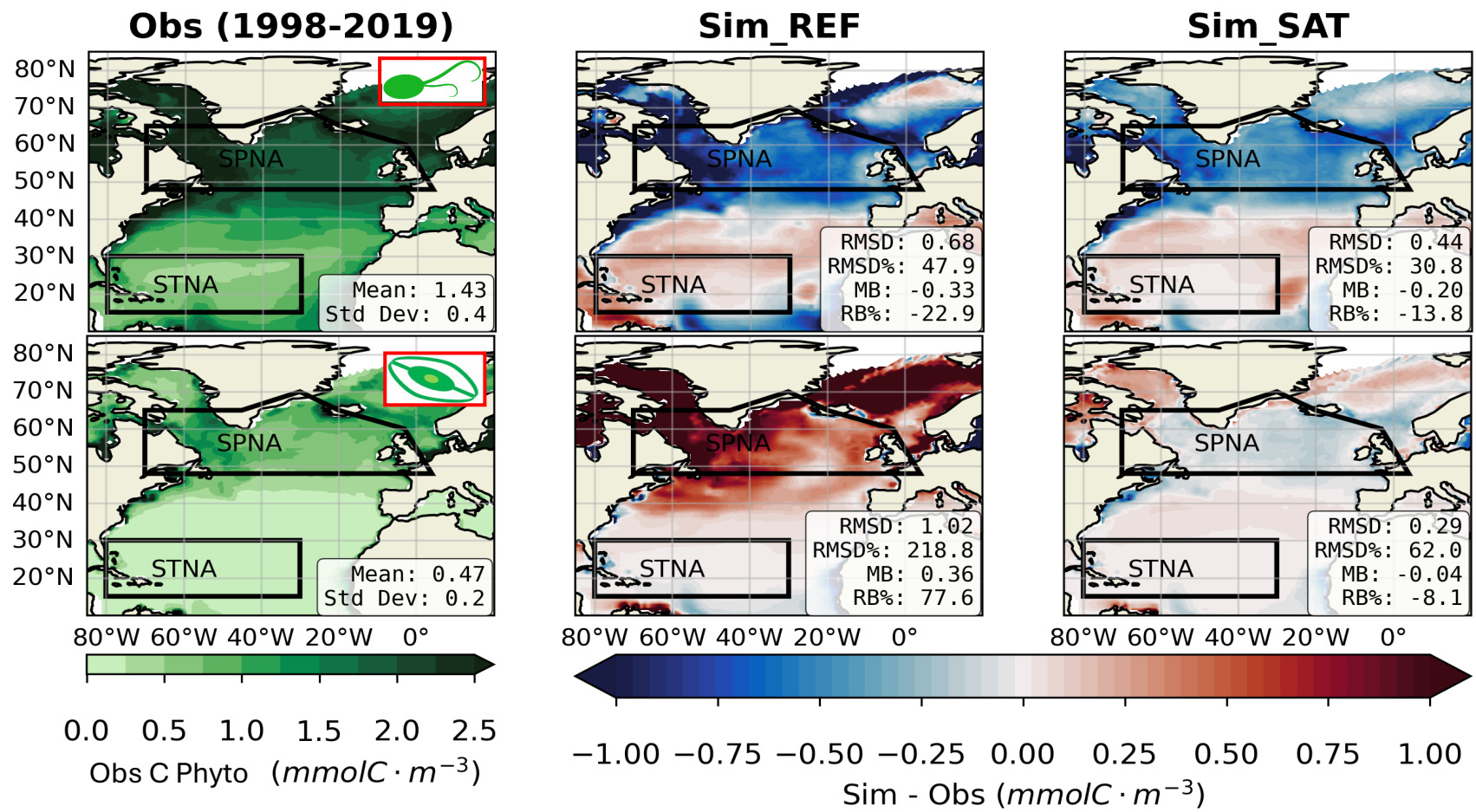

Figure 3. Annual maps of phytoplankton carbon from ESA satellite and model bias

2) Vertical Profiles

SPNA (Subpolar North Atlantic)
• ↑ POC (sdetoc, zmicro)
• ↑ sdetoc export
• ↓ ldetoc export

STNA (Subtropical North Atlantic)
• ↓ POC (all contributors)
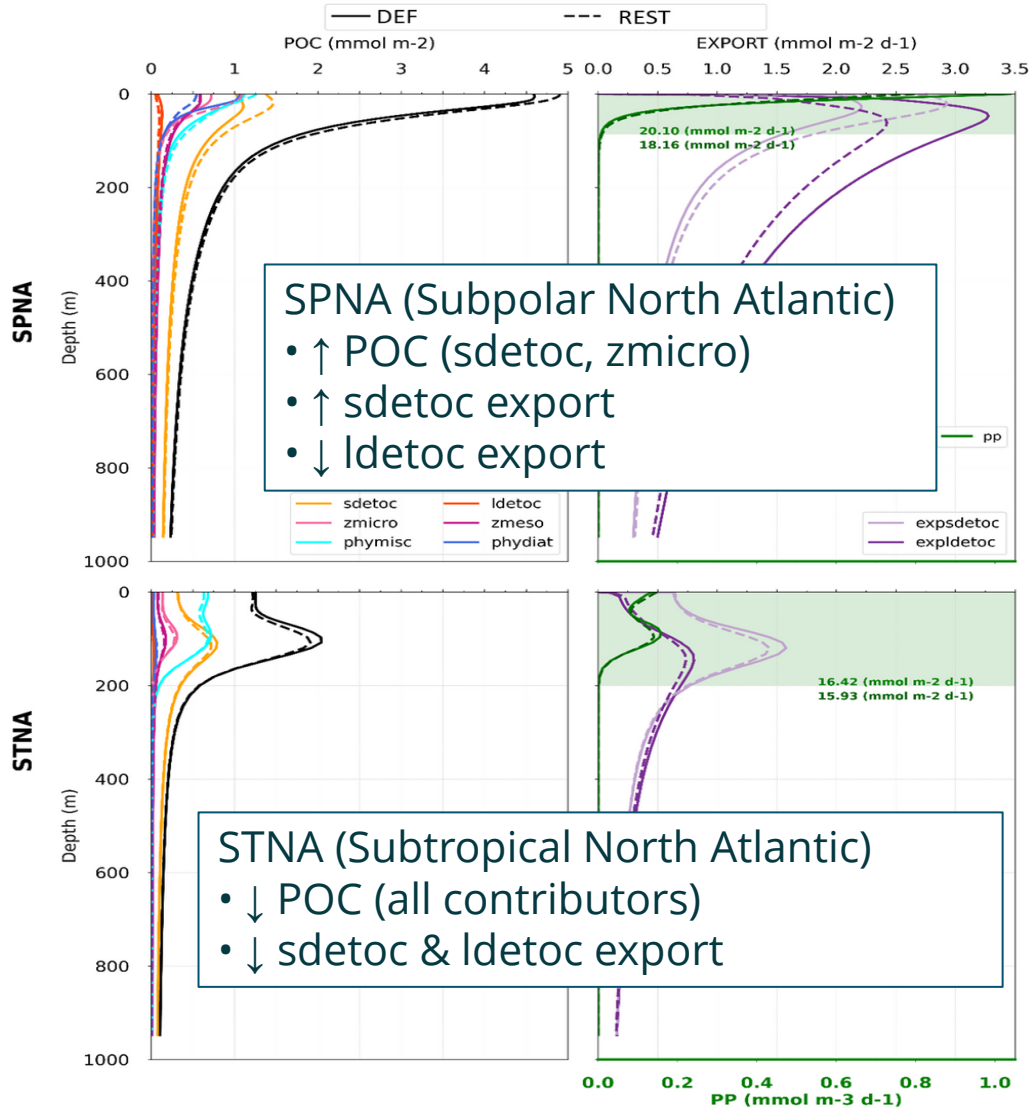• ↓ sdetoc & ldetoc export

Figure 4. Vertical profiles of POC and export fluxes in SPNA and STNA

Which is the role of the C phy in the BCP strength?

3) Transfer and Export Efficiency

BCP Strength = Transfer Efficiency × Export Efficiency
• TE = F1000/F100 (carbon reaching 1000m vs 100m)
• EE = F100/NPP (exported carbon vs net primary production)

SPNA: ↑ BCP strength (↑TE + ↑EE) despite ↓ large detritus export

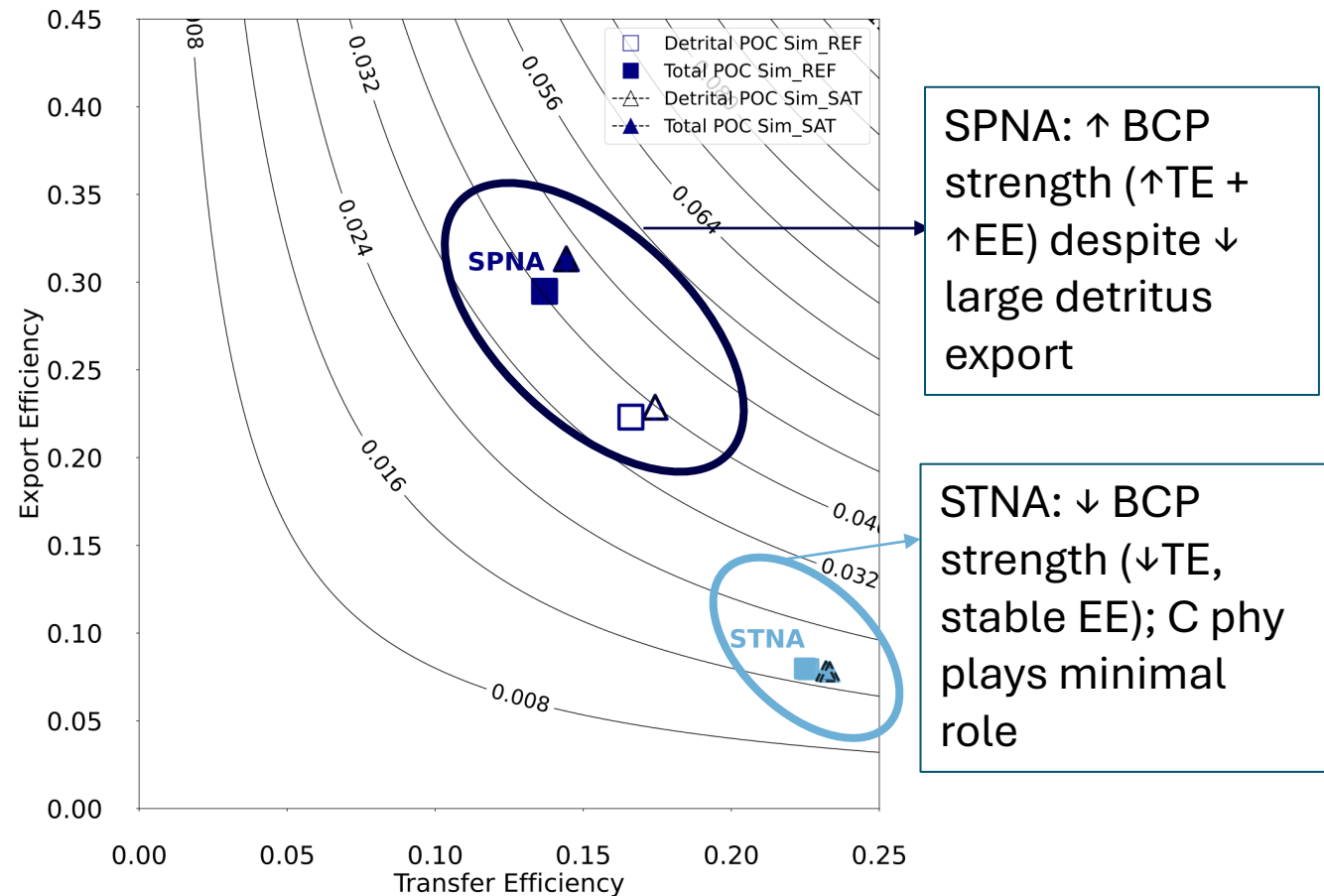STNA: ↓ BCP strength (↓TE, stable EE); C phy plays minimal role

Figure 5. Transfer efficiency and export efficiency in SPNA (dark blue) and STNA (light blue). The square markers represent the reference simulation (sim_REF, control experiment) and the triangle markers with dashed lines represent the restoring simulation (sim_SAT, C phy restoring experiment). Filled markers represent the BCP strength of total POC, including the C phy. Empty markers represent the BCP only from detritus.

Key Findings

- ✓ SPNA: Reduced Cphy bias
    - ↑ POC stock & ↑ small detritus export flux
    - ↑ BCP strength: both TE and EE increase
    - Effect enhanced when including living phytoplankton carbon (Cphy)

- ✓ STNA: Reduced bias
    - ↓ POC stock & ↓ detritus export fluxes
    - ↓ BCP strength: TE decreases while EE remains stable
    - Living phytoplankton carbon seems to play minimal role

<u>Seasonal variability influences PSC bias impact on BCP?</u>

It's an analogy for what could happen in a more stratified future (what would the BCP look like if diatoms were reduced by X%????)

Conclusions & Future Work

- Constraining PSCs with satellite data reveals regional differences in BCP.
- Model biases in PSC directly impact POC stock, export fluxes, and BCP efficiency, especially in the SPNA.
- Next step: Identify which biogeochemical processes are "buffering" the restoring effect → improve process representation in ESMs

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THANKS FOR YOUR ATTENTION

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