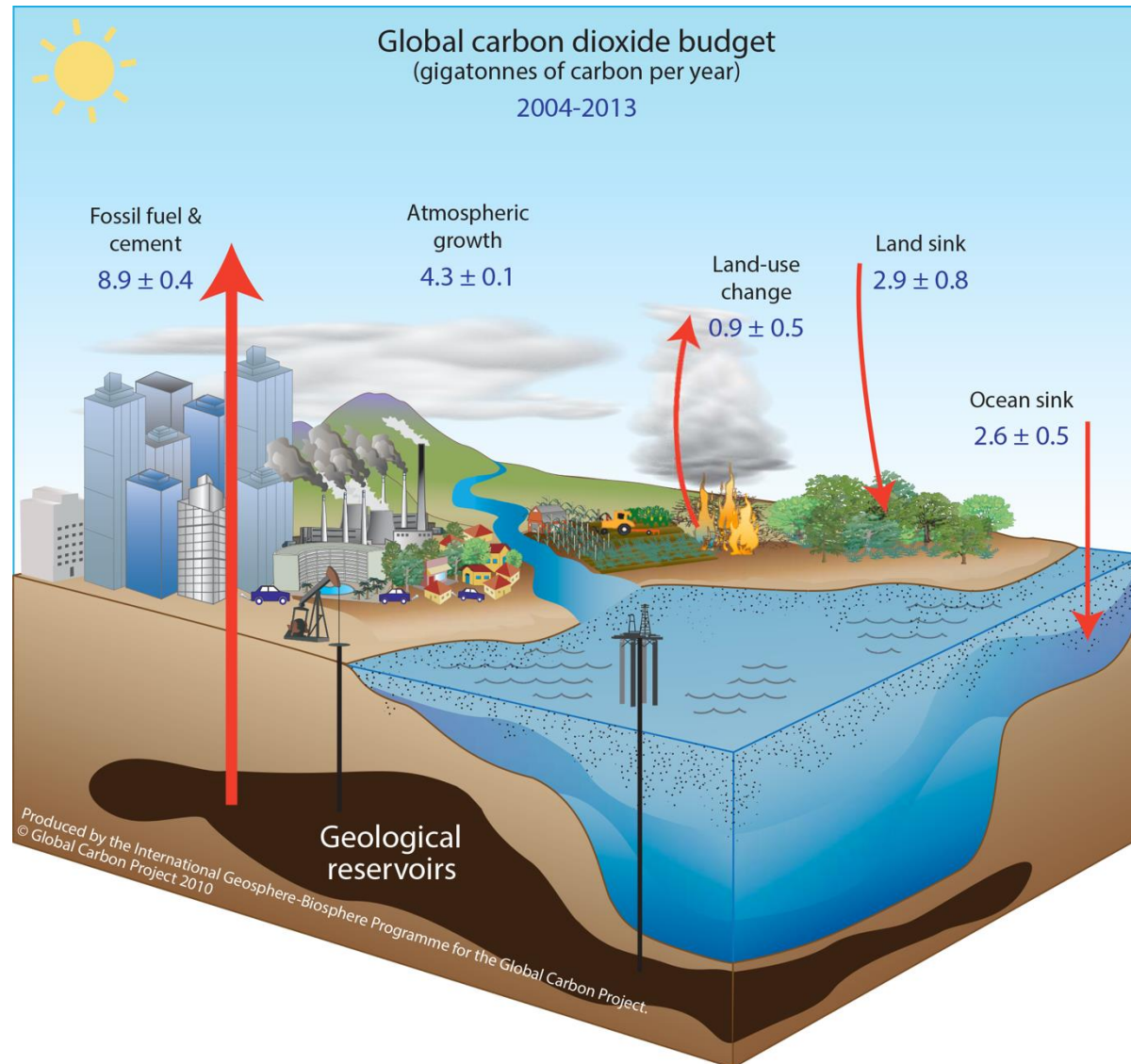


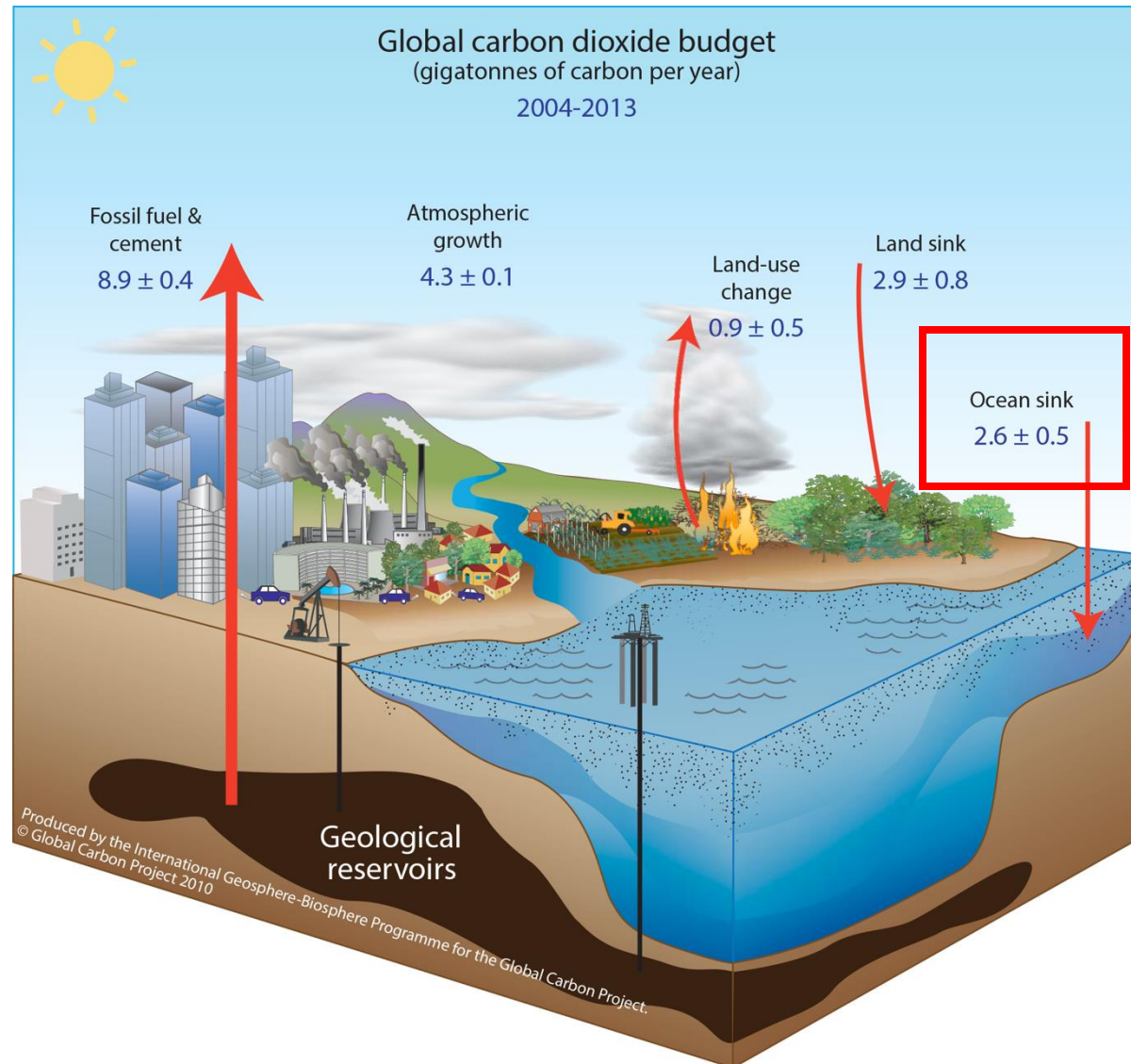
Peter Landschützer

From global to regional marine carbon budgets - Are we ready to monitor a decarbonizing society?

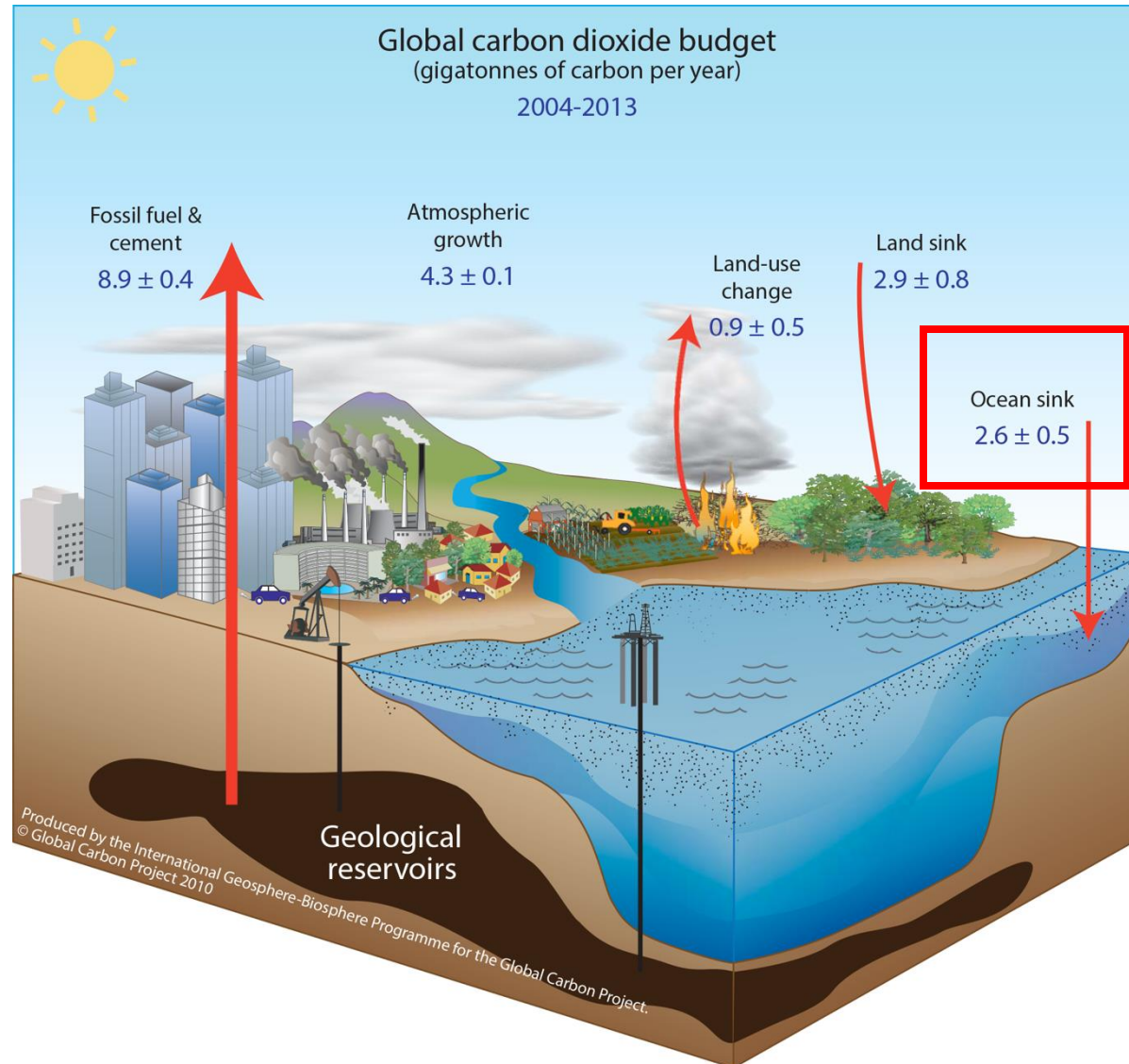
The global carbon cycle in 2013



The global carbon cycle in 2013



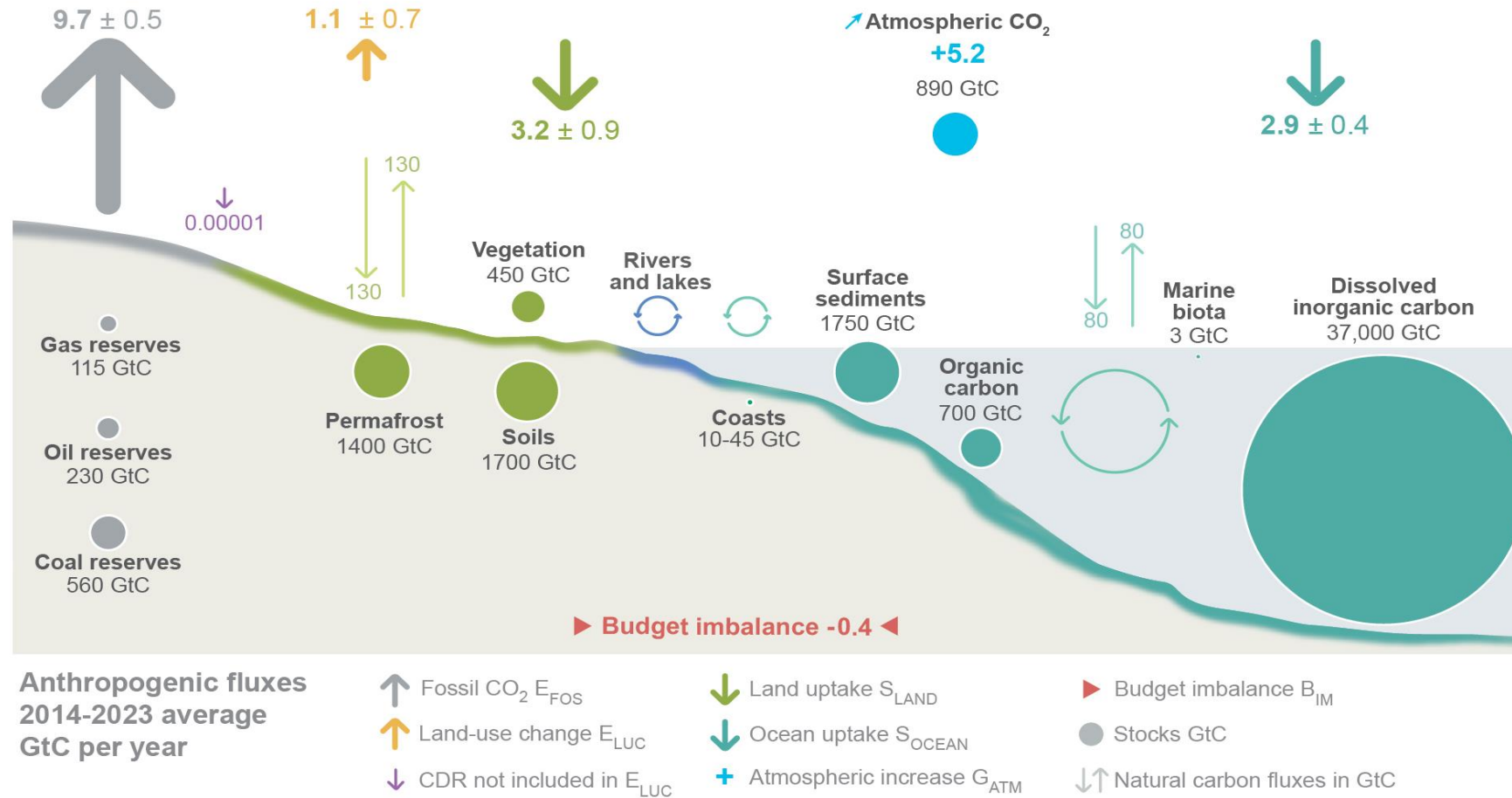
The global carbon cycle in 2013



~China±India (in 2013)

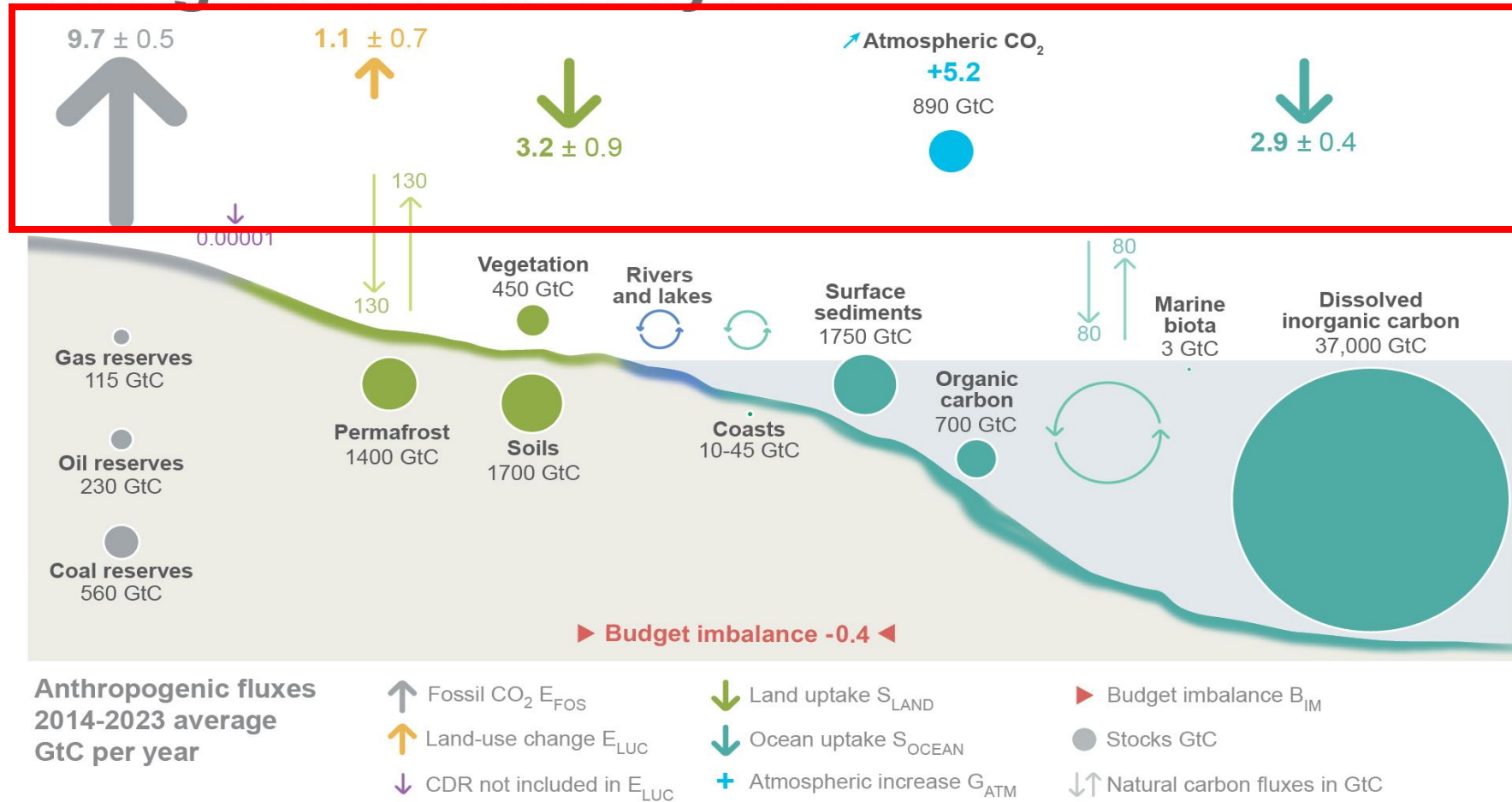
The global carbon cycle 2014-2023

The global carbon cycle



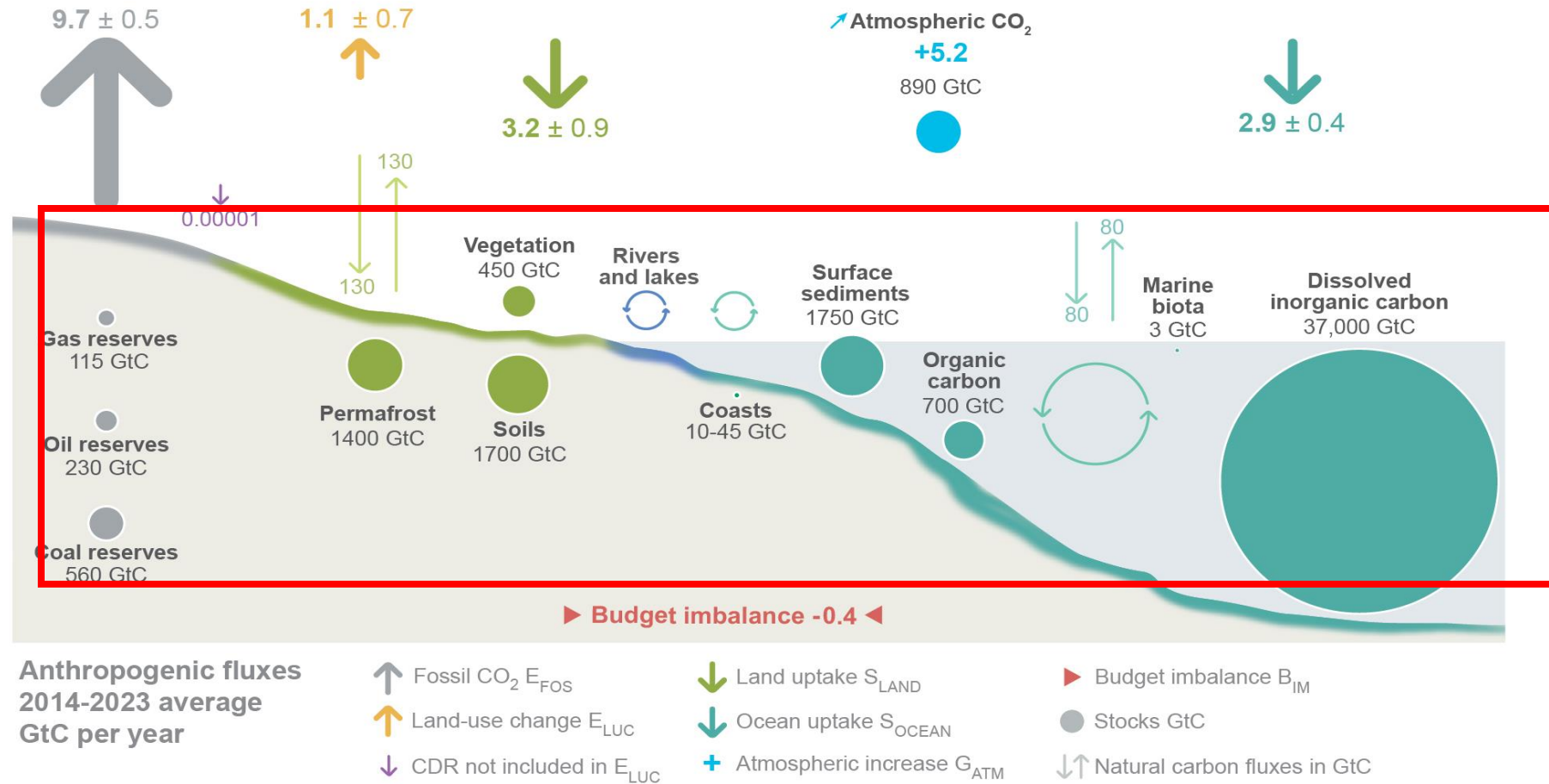
The global carbon cycle 2014-2023

The global carbon cycle



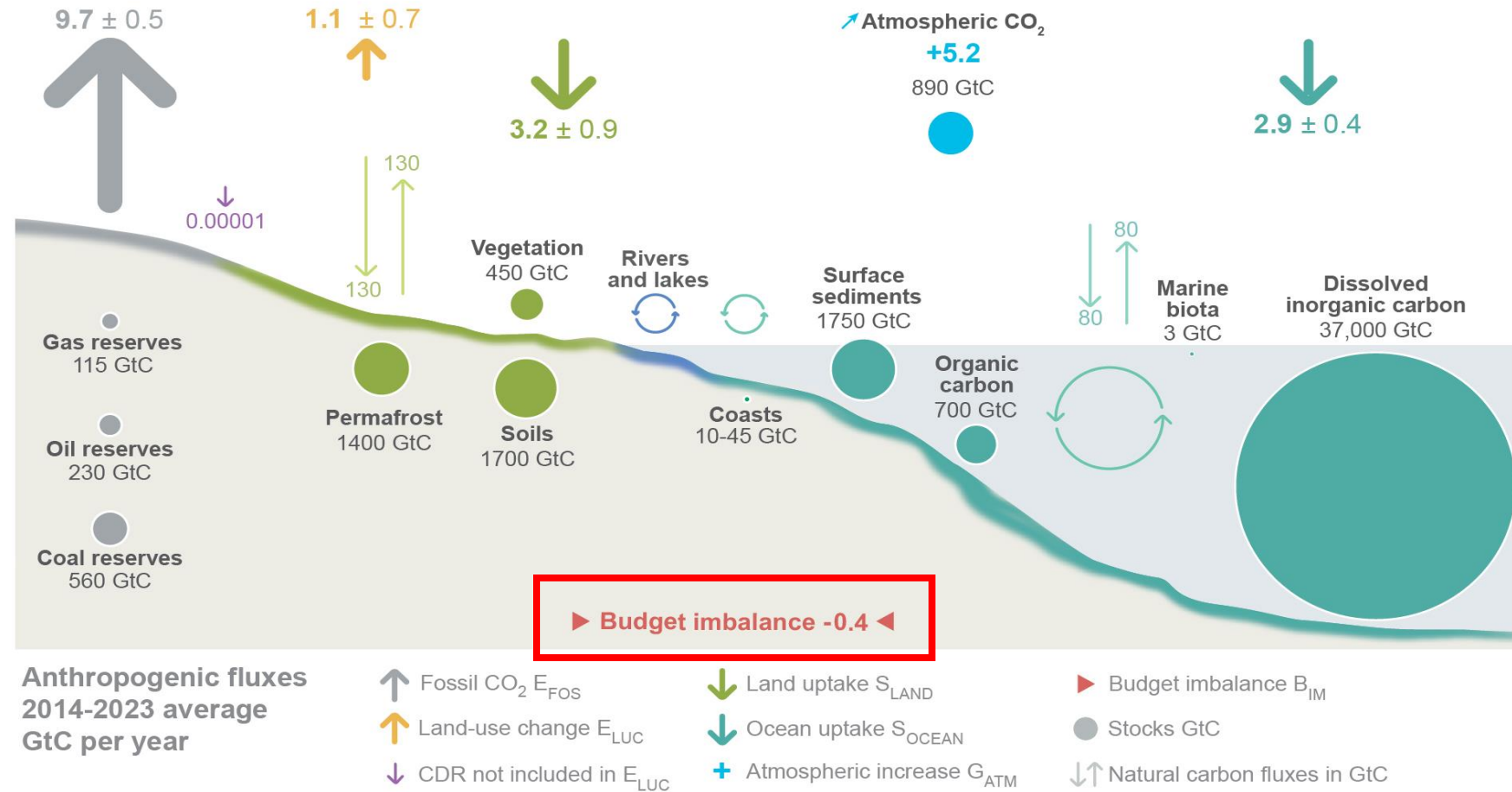
The global carbon cycle 2014-2023

The global carbon cycle



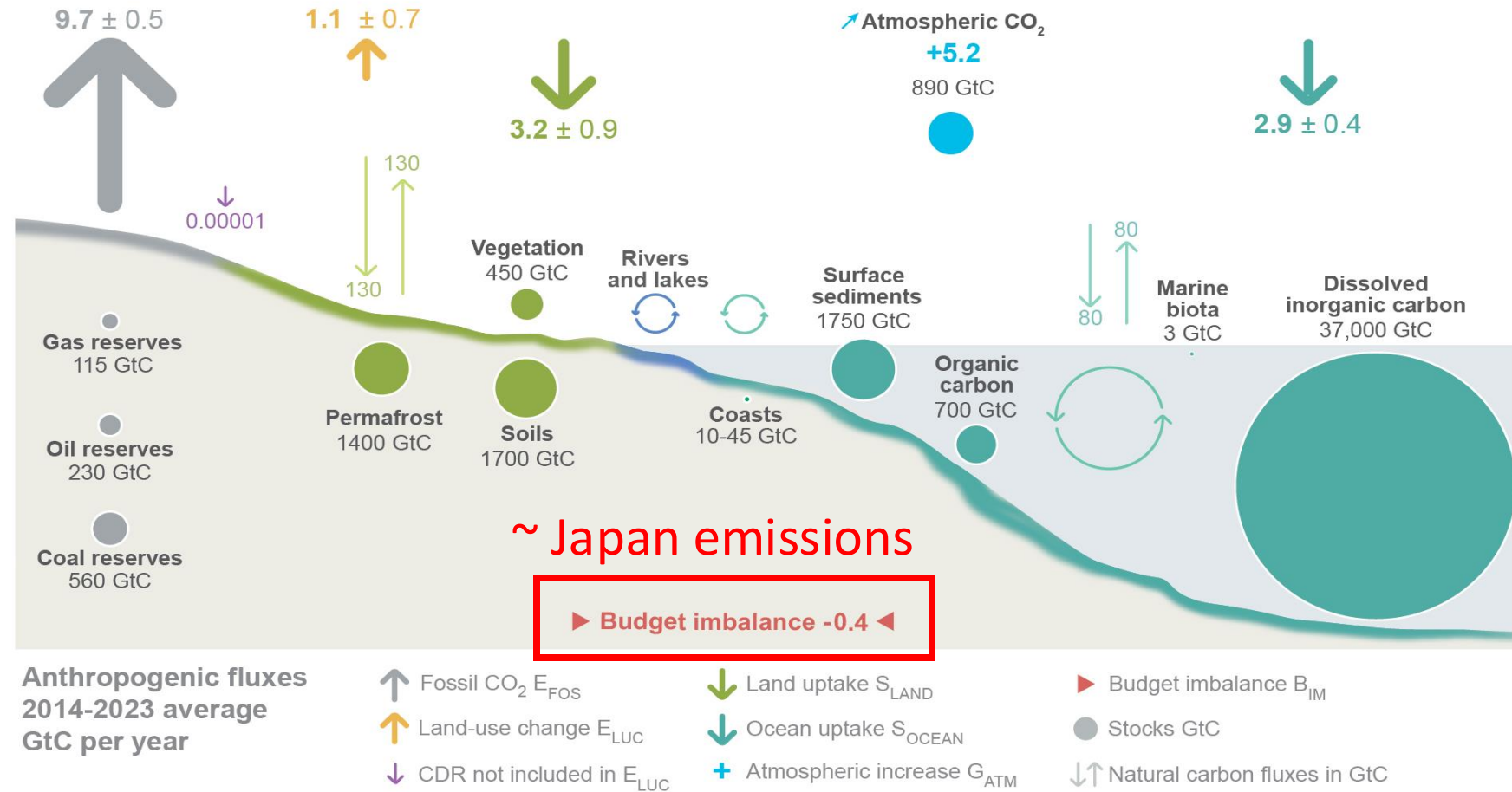
The global carbon cycle 2014-2023

The global carbon cycle

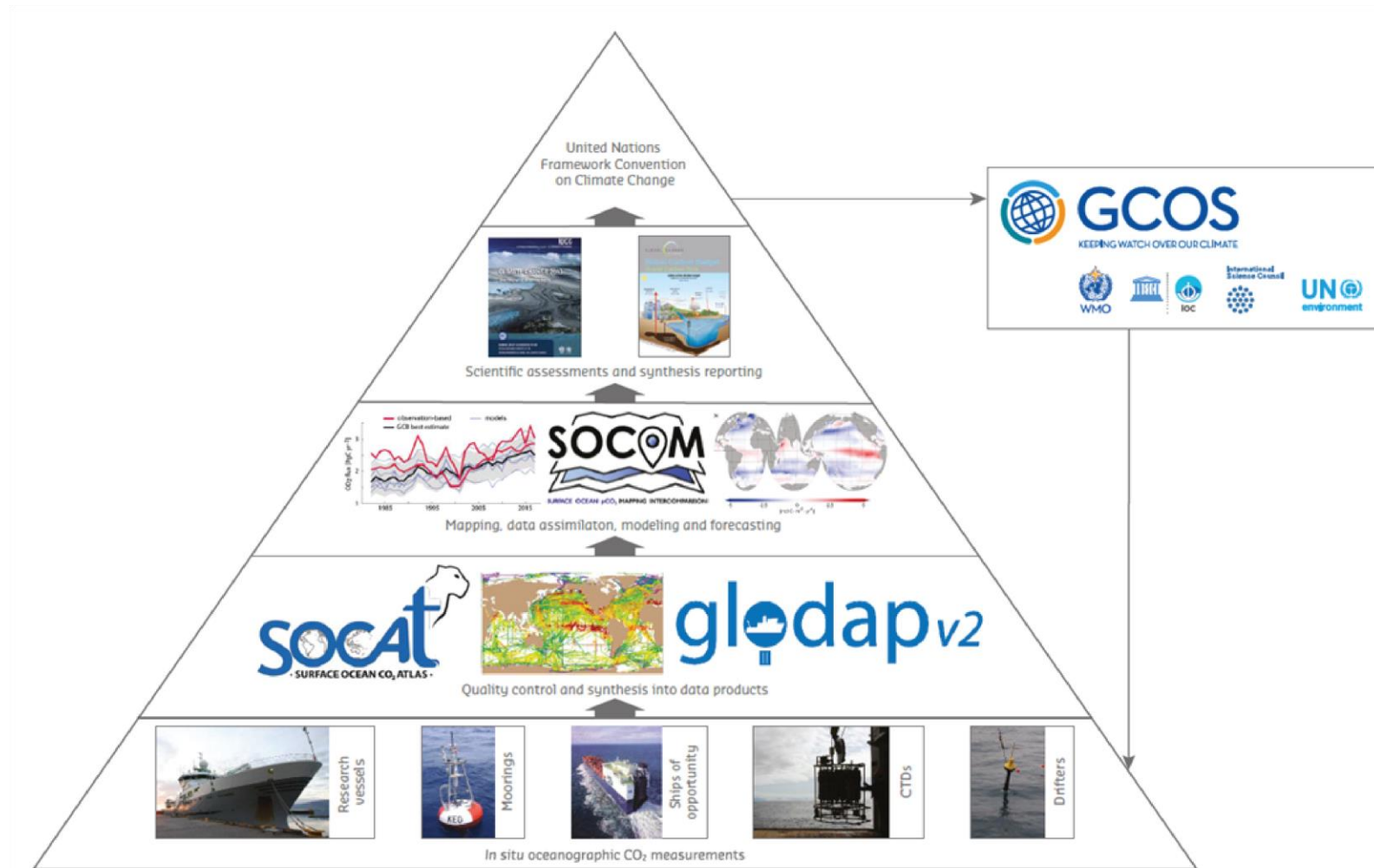


The global carbon cycle 2014-2023

The global carbon cycle



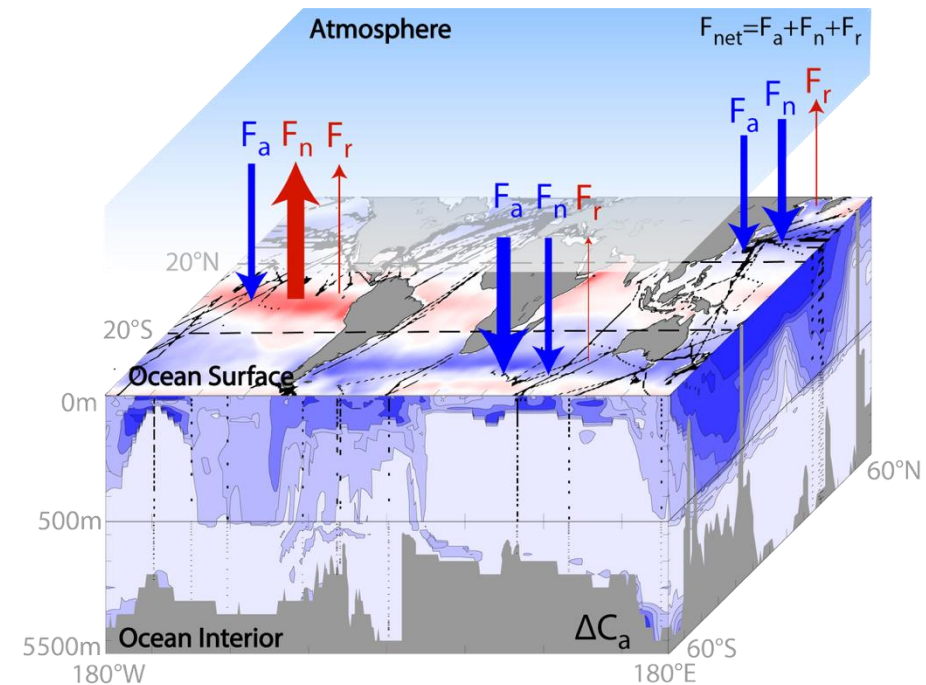
The Value chain of ocean carbon observations

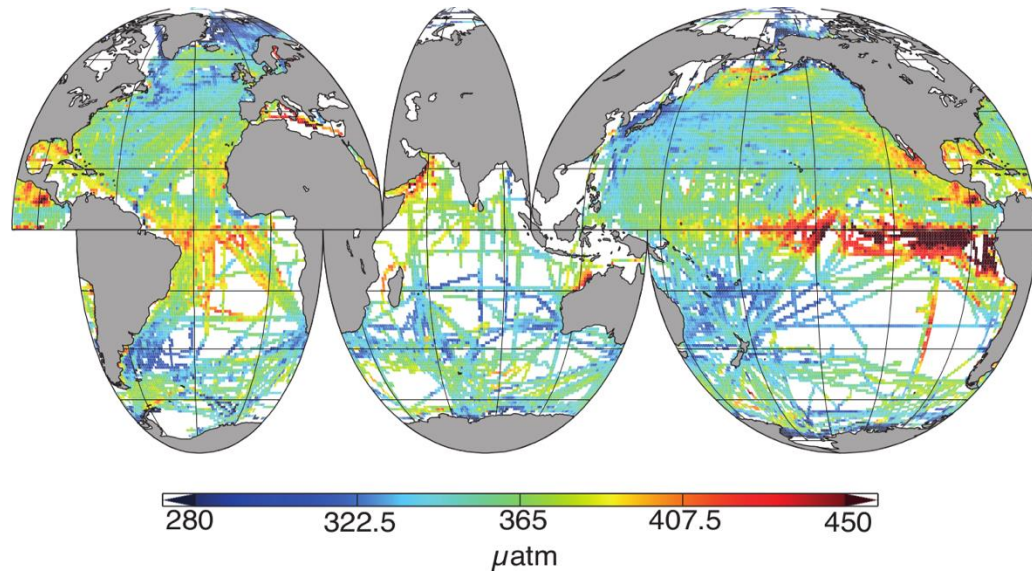


The contemporary ocean carbon cycle - assumptions

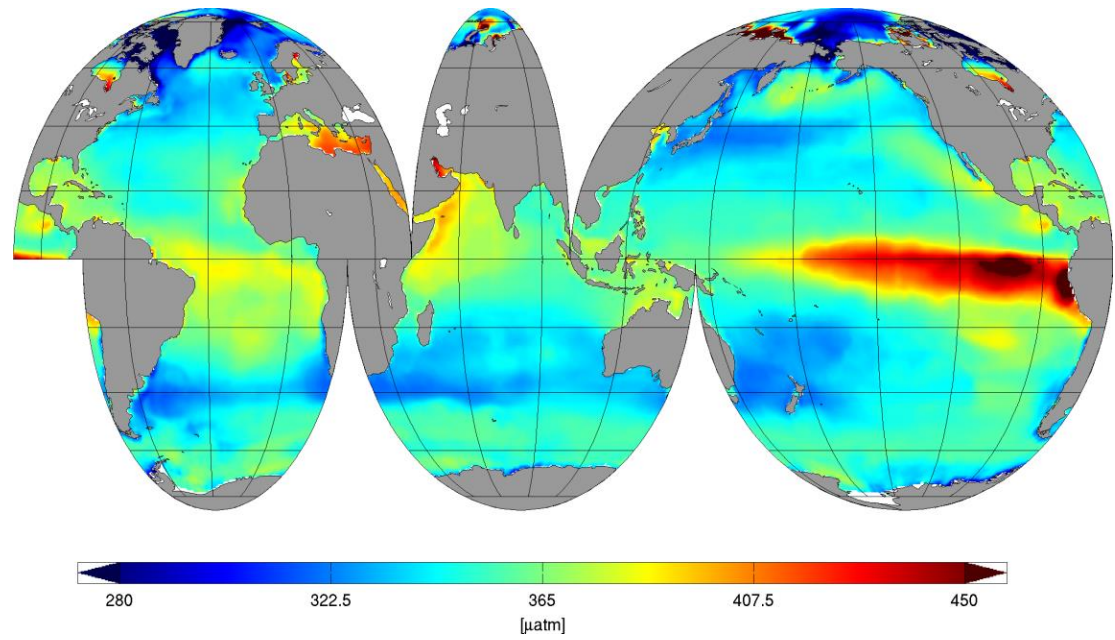
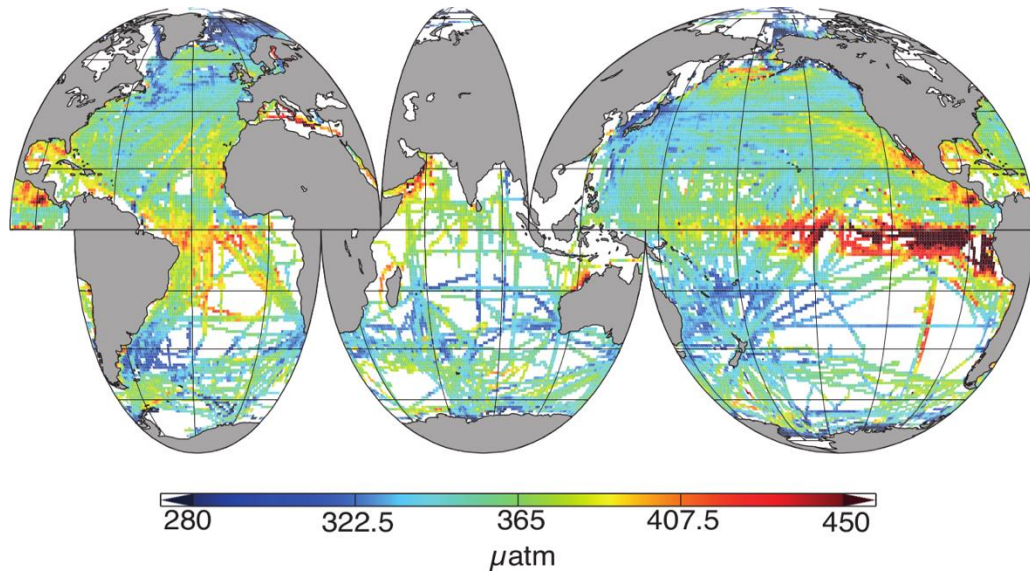
The contemporary (annual) perspective

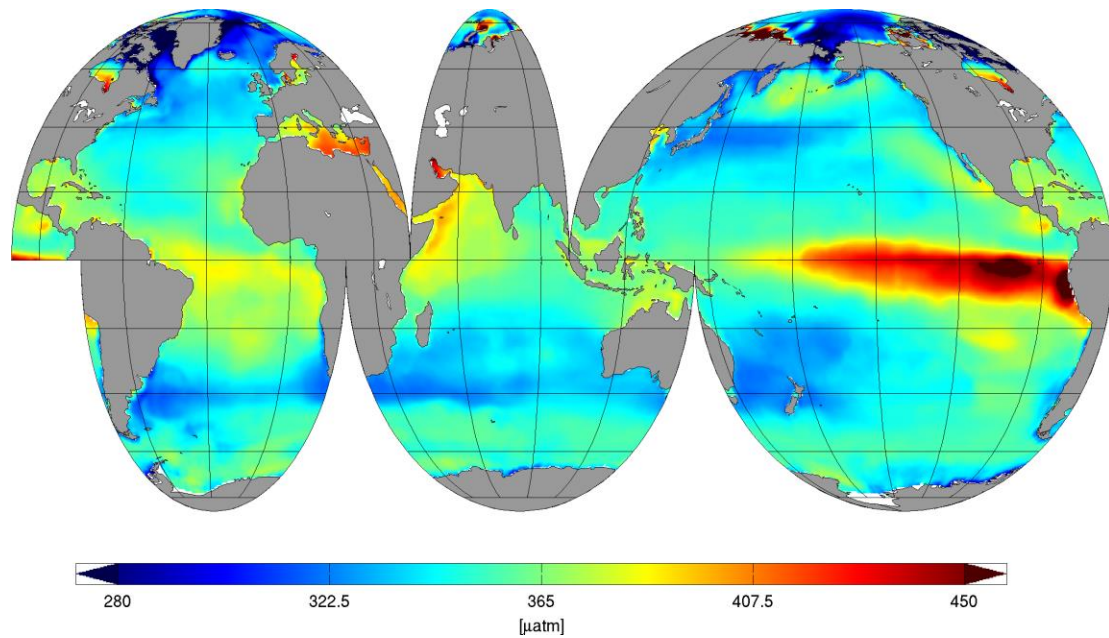
- $\int F_n \sim 0$
- $\int F_r \sim 0.65 \text{ PgC/yr}$
- $\int F_a \sim -2.8 \text{ PgC/yr}$

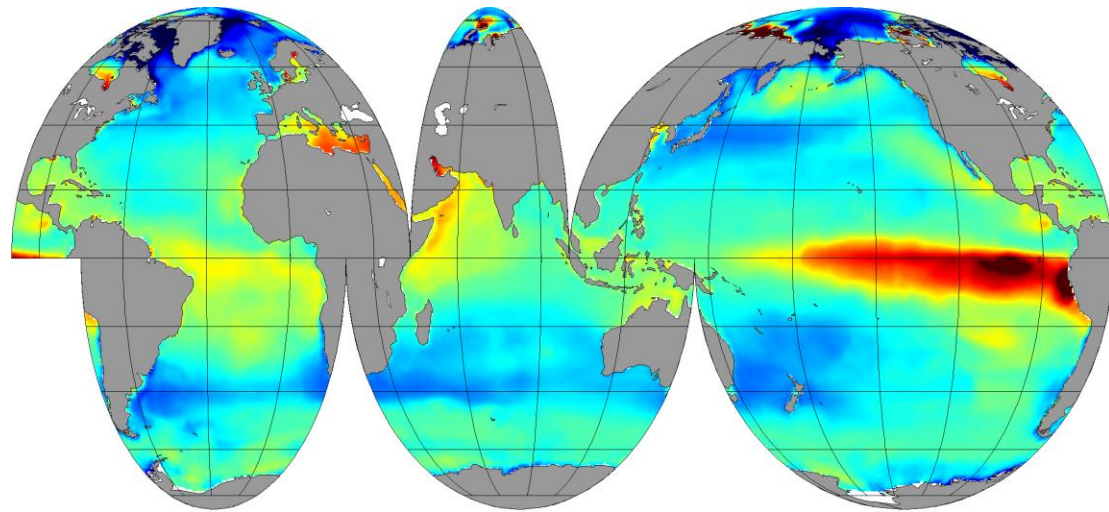




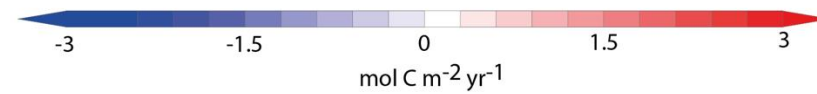
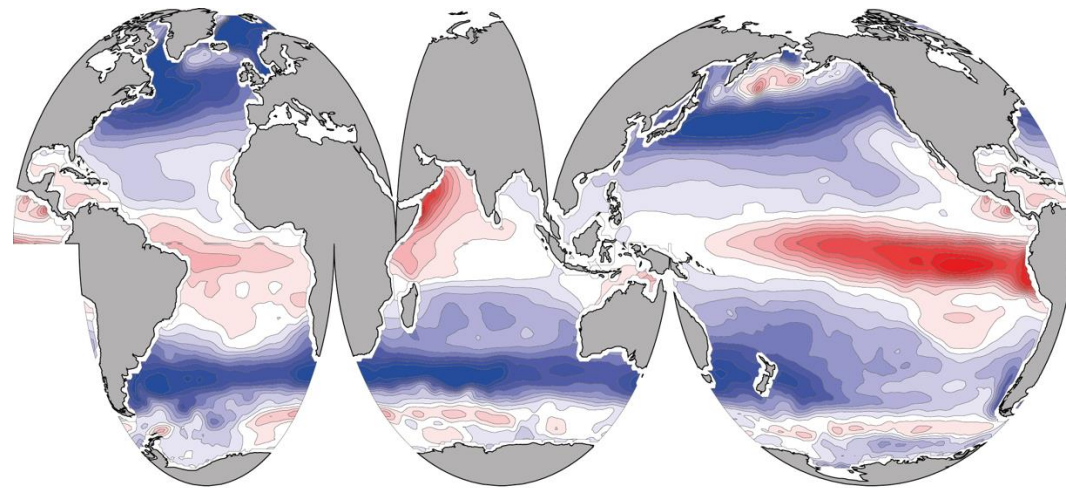
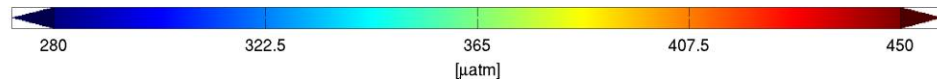
Statistical upscaling or machine learning



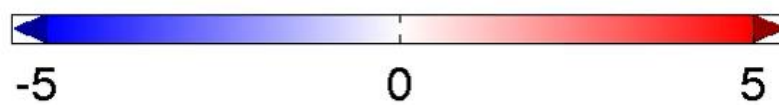
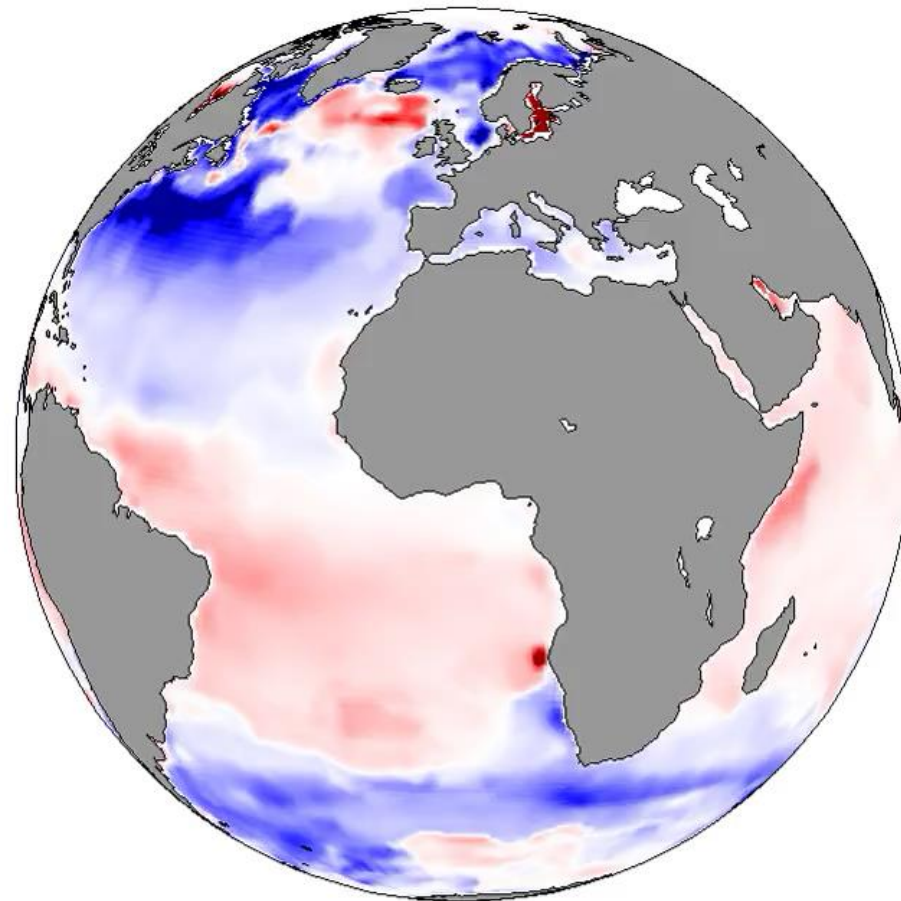




Net air-sea exchange (F_{net}) at the air-sea interface

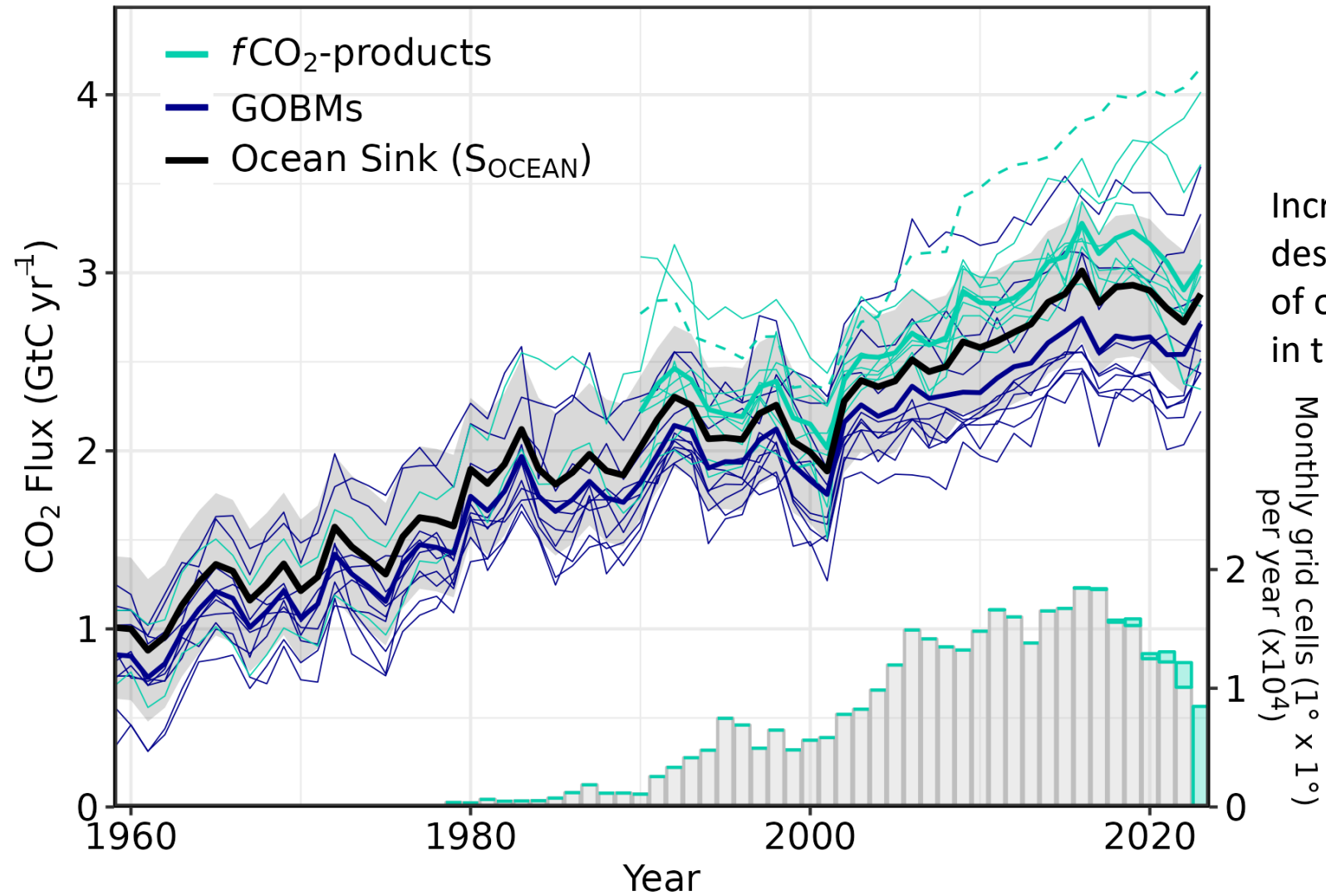


1982-1



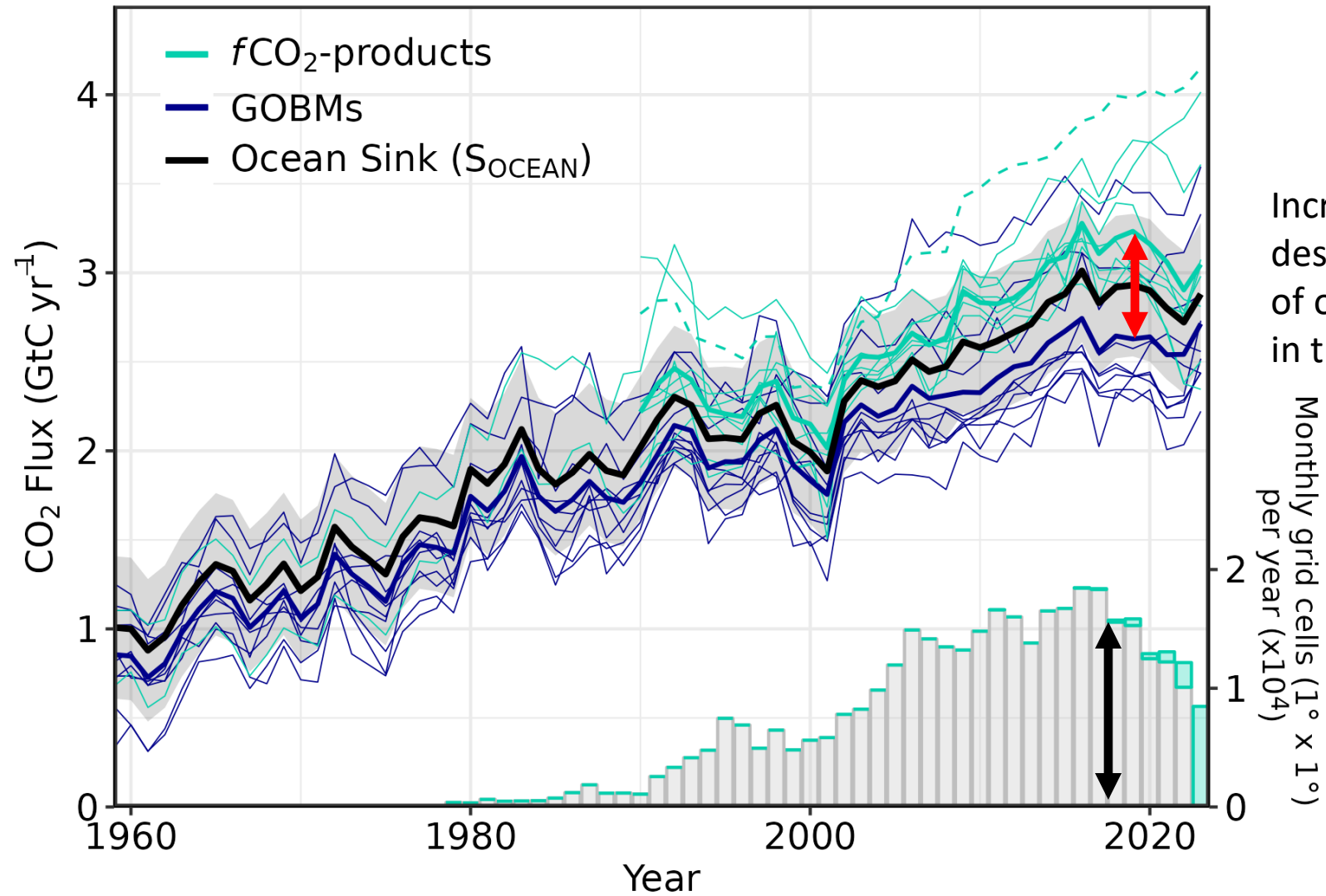
mol C/m²/yr

Ocean Sink (S_{OCEAN})

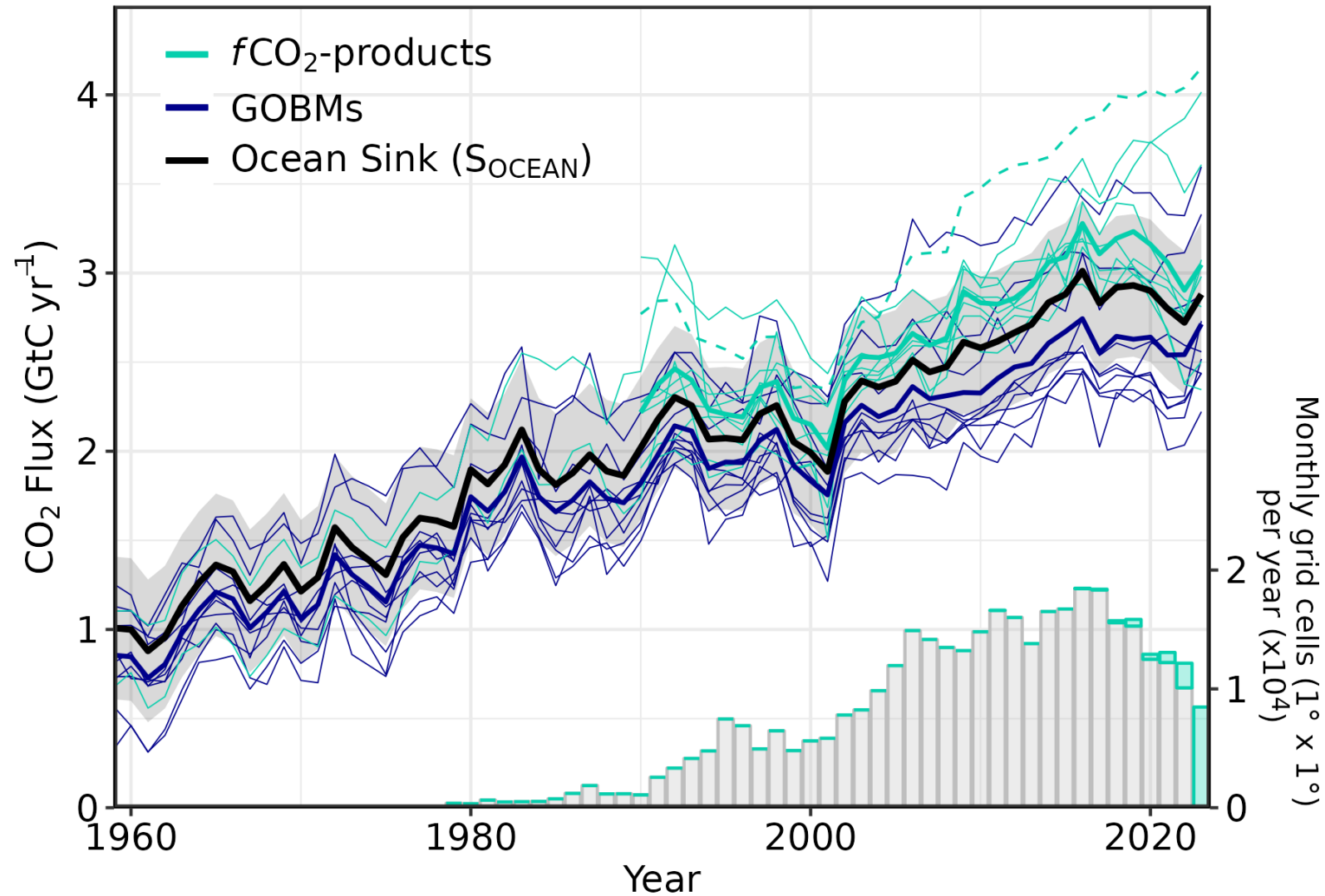


Increasing divergence despite having the majority of observations available in the latter years

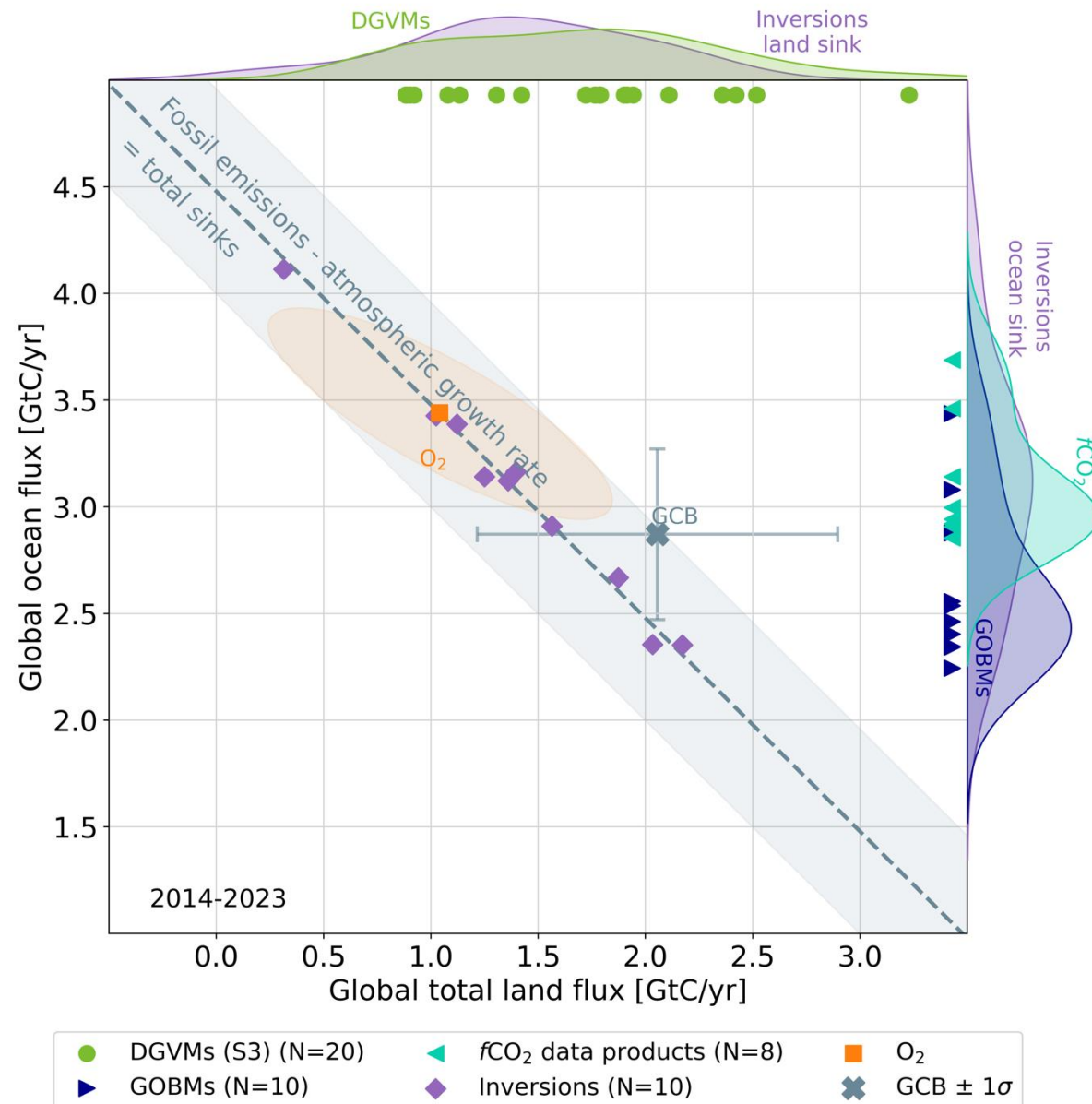
Ocean Sink (S_{OCEAN})



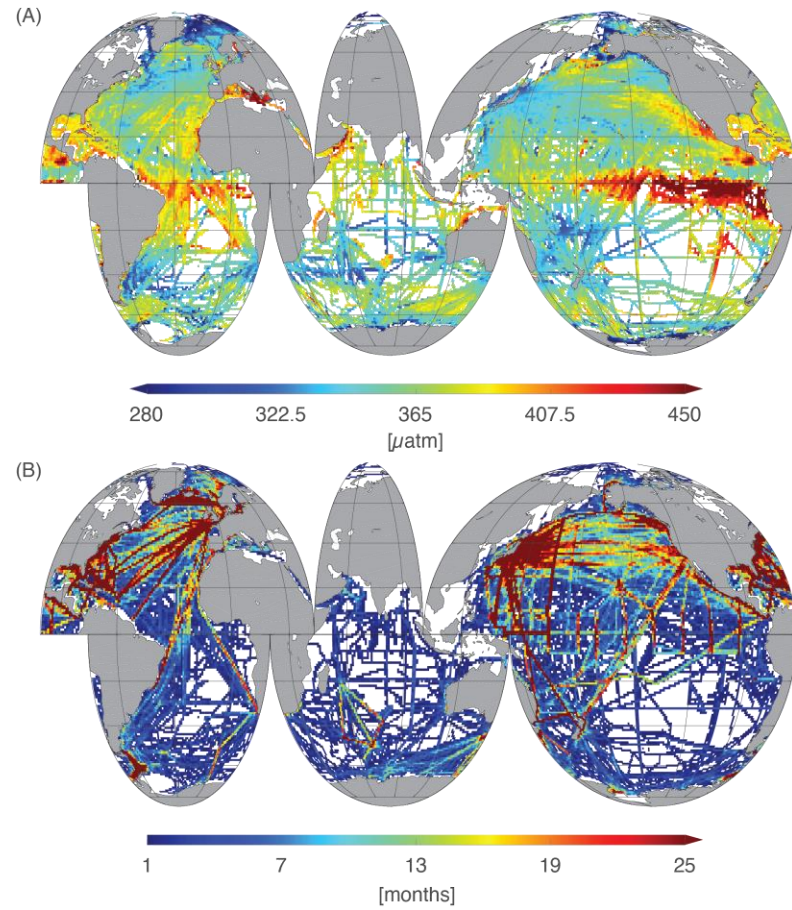
Ocean Sink (S_{OCEAN})



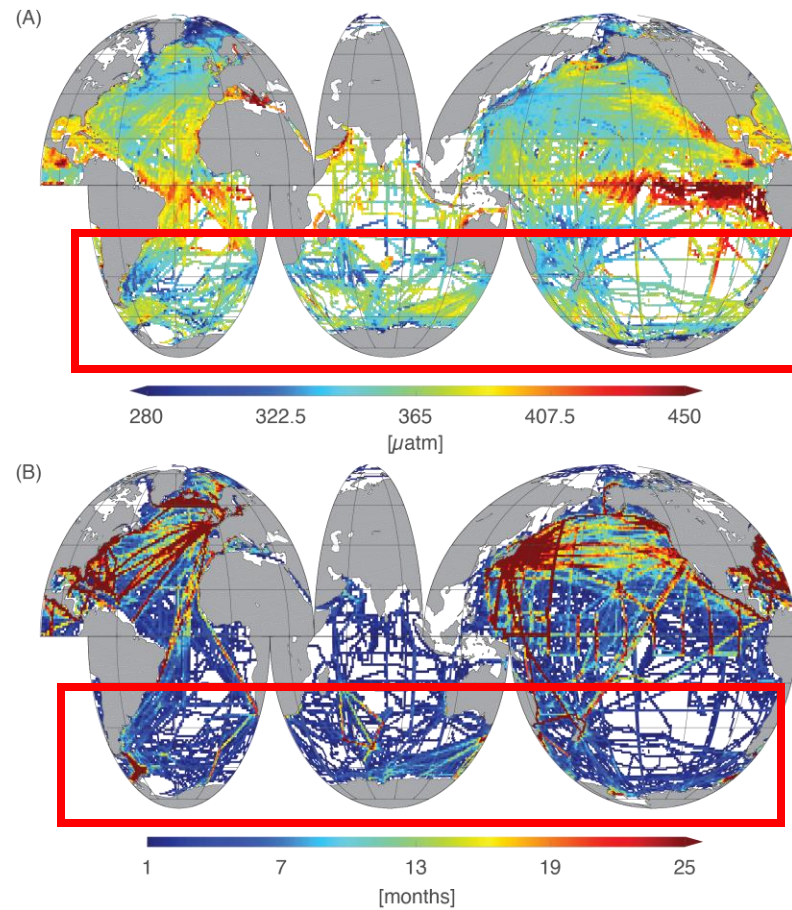
“We refrain from assigning a high confidence because of the systematic deviation between the GOBM and data product trends since around 2002.”
(Friedlingstein et al 2022)



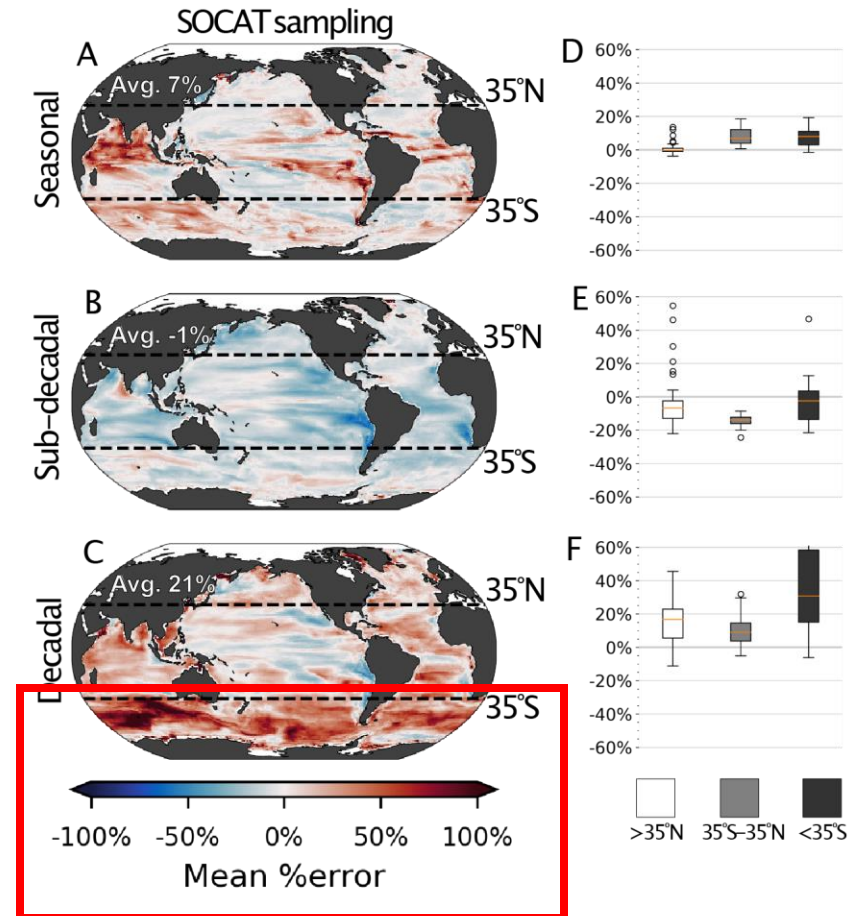
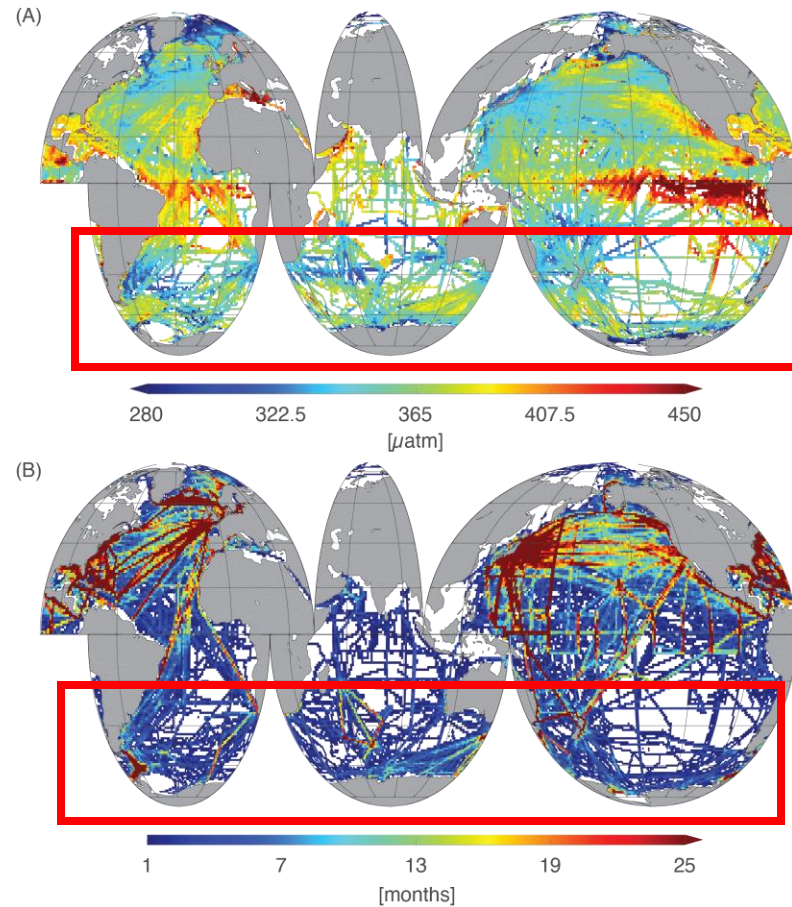
Data limitation and uncertainty



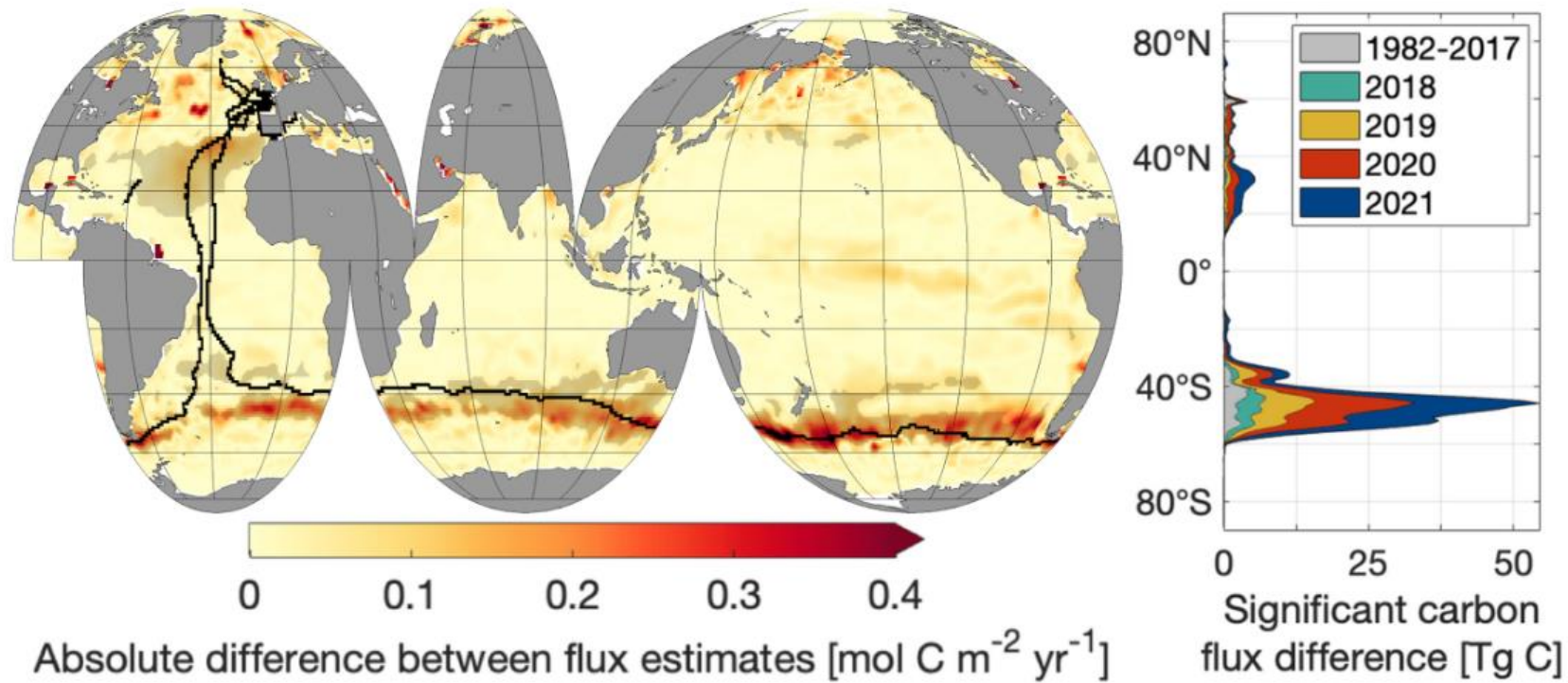
Data limitation and uncertainty



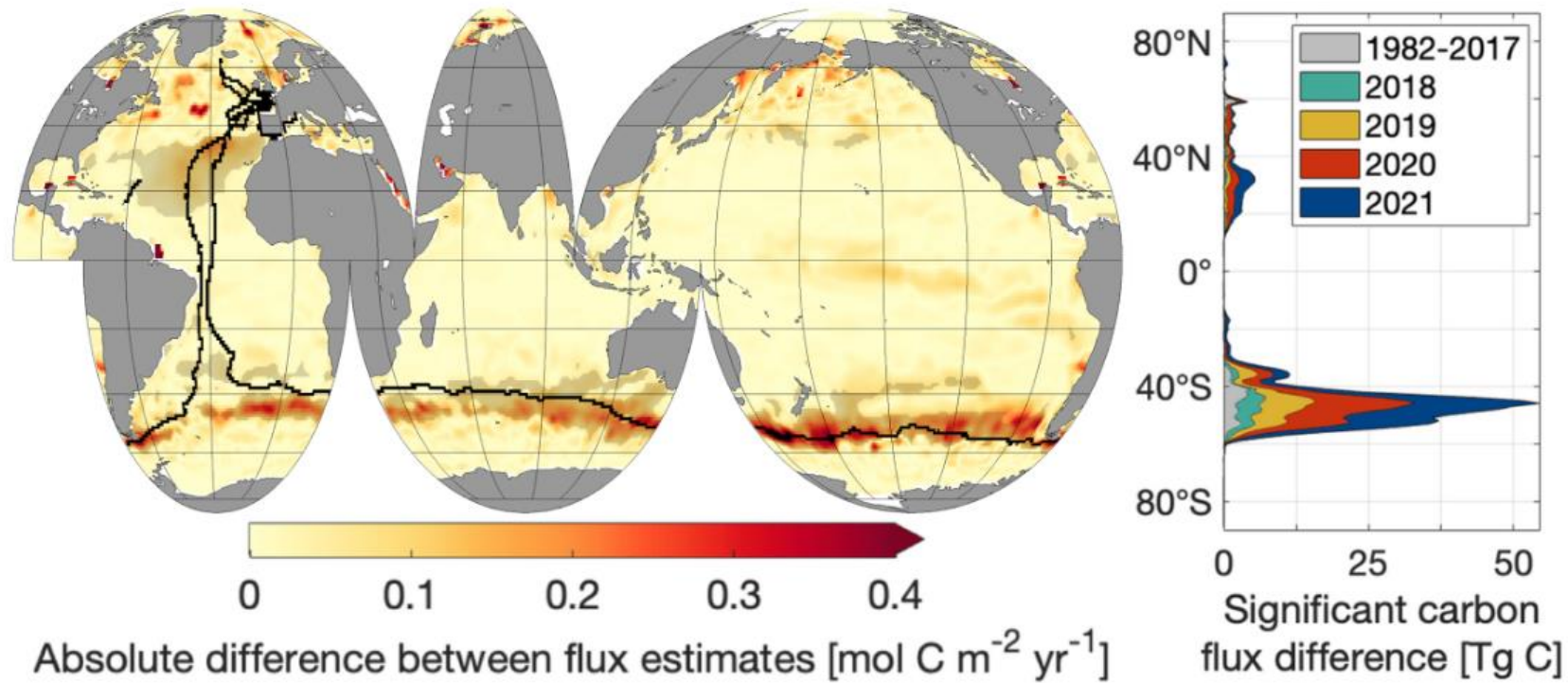
Data limitation and uncertainty



Data limitation and uncertainty



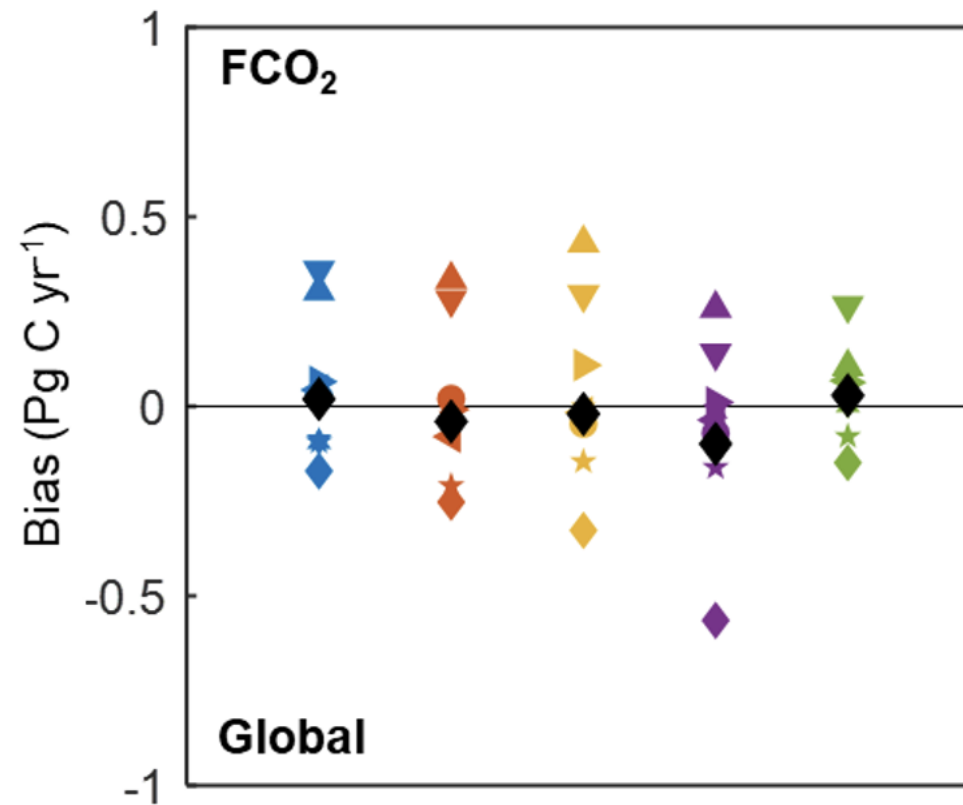
Data limitation and uncertainty



} ~1/4 of all coastal CO₂ uptake

Data limitation and uncertainty

- ◆ ensemble mean
- CarboScope
- ▼ CSIR-ML6
- ◆ JMA-MLR
- ★ OceanSODA-ETHZv2
- ★ pCO2Residual
- ▲ UExP-FNN-U
- ▶ VLIZ-SOMFFN
- ◀ NIES-ML3
- CESM ETHZ r1
- FESOM2 REcoM
- IPSL r1
- MRI ESM2
- NorESM



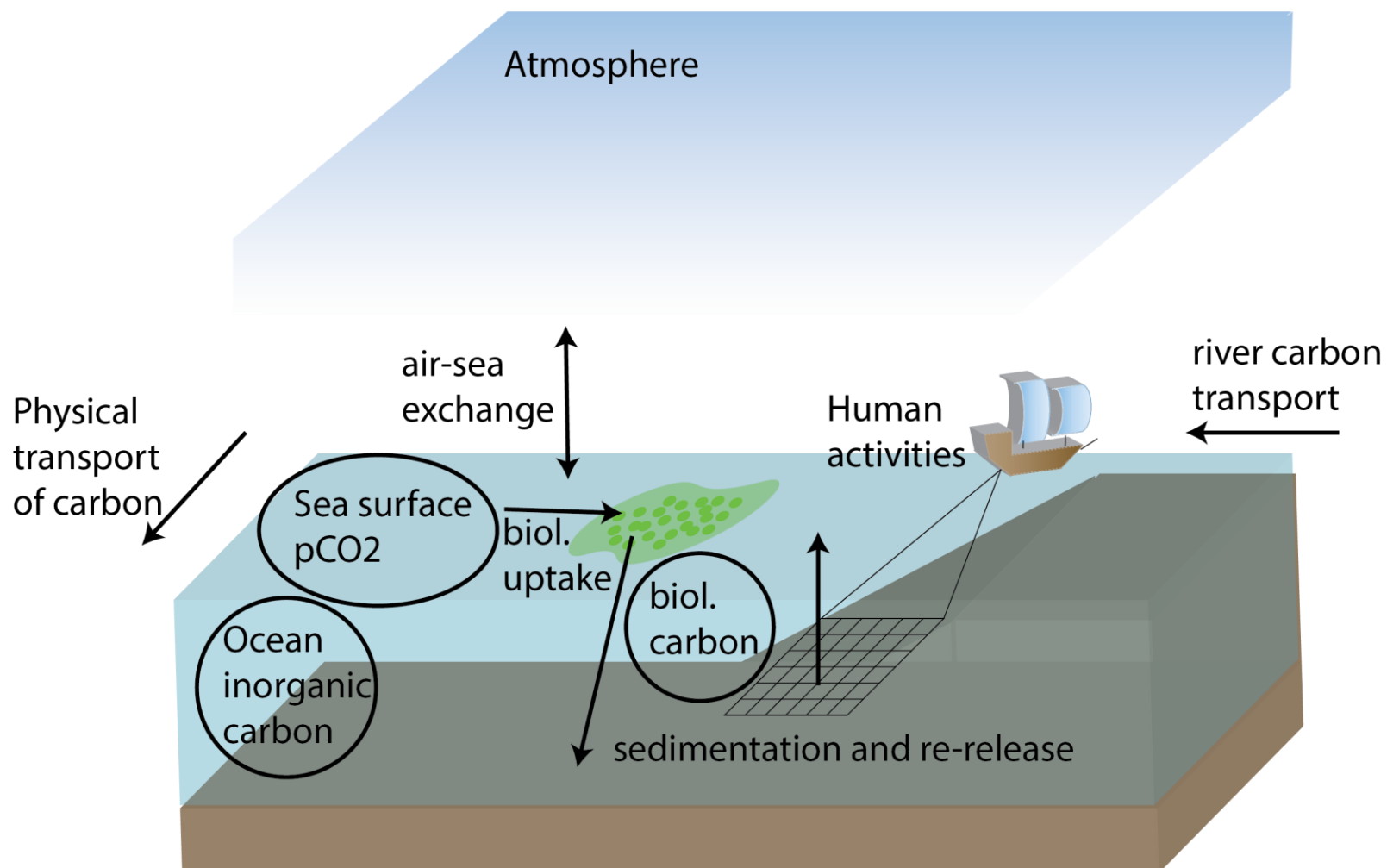
Global summary

- Human activities have altered the pre-industrial carbon cycle
- Observation-based and model constraints provide a window into this change
- Significant discrepancies still exist regarding the ocean carbon sink
- This is challenging our ability close the global carbon budget

why regional?

- Scale at which human activities, climate interventions etc. influence the carbon cycle
- Scale that is relevant for carbon reporting

Regional perspective

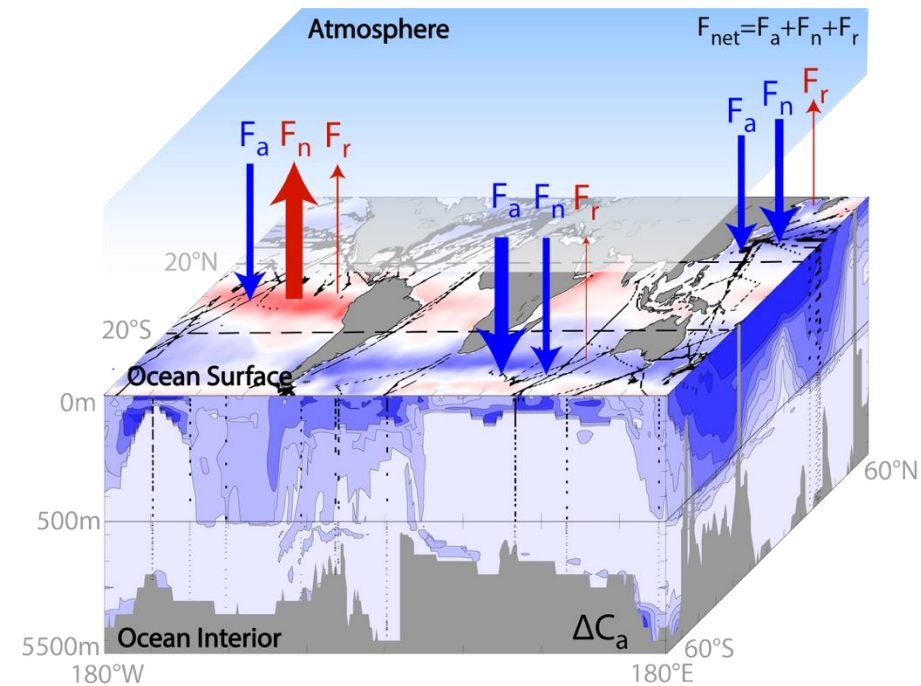


Simple schematic of the fluxes (arrows) and stocks (circles) of carbon

RECAP: The contemporary ocean carbon cycle

The contemporary (annual) perspective

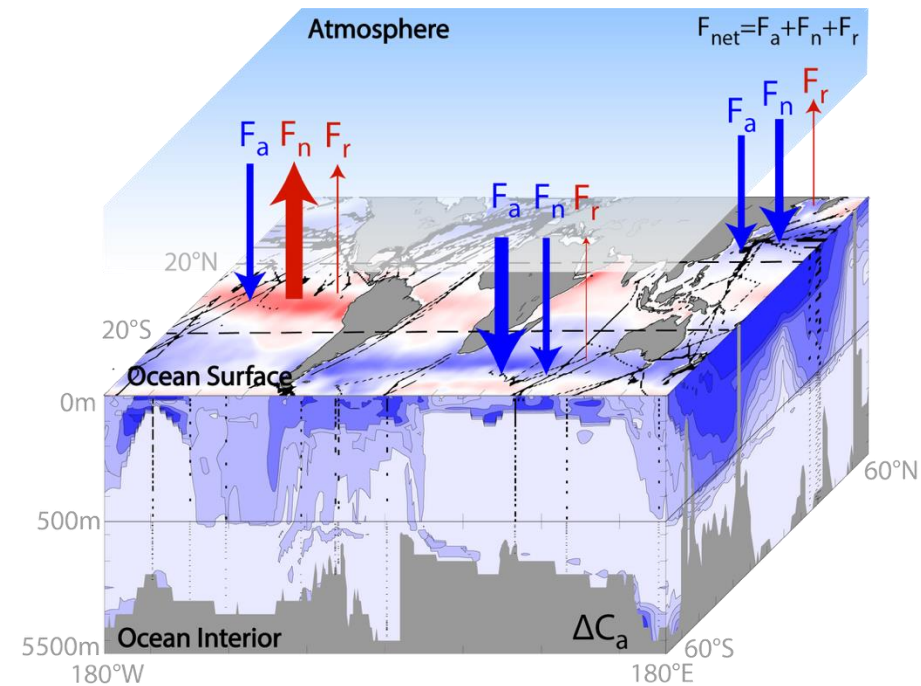
- $\int F_n \sim 0$
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RECAP: The contemporary ocean carbon cycle

The contemporary (annual) perspective

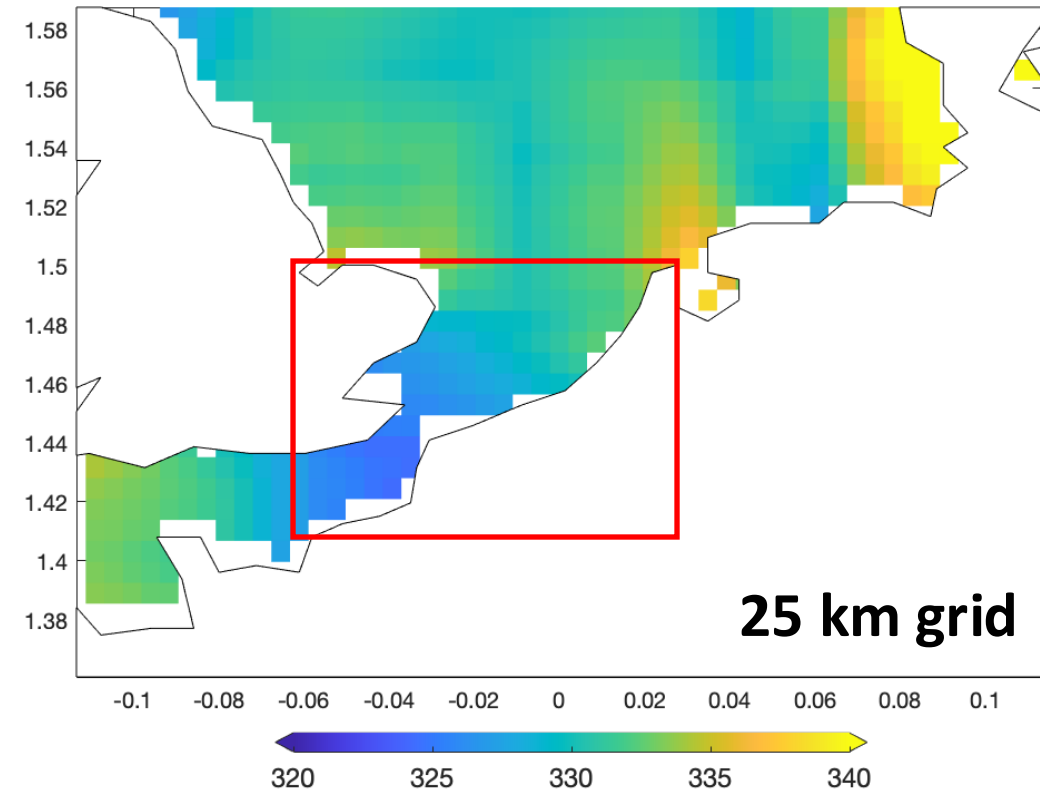
- $\int F_n \sim 0$
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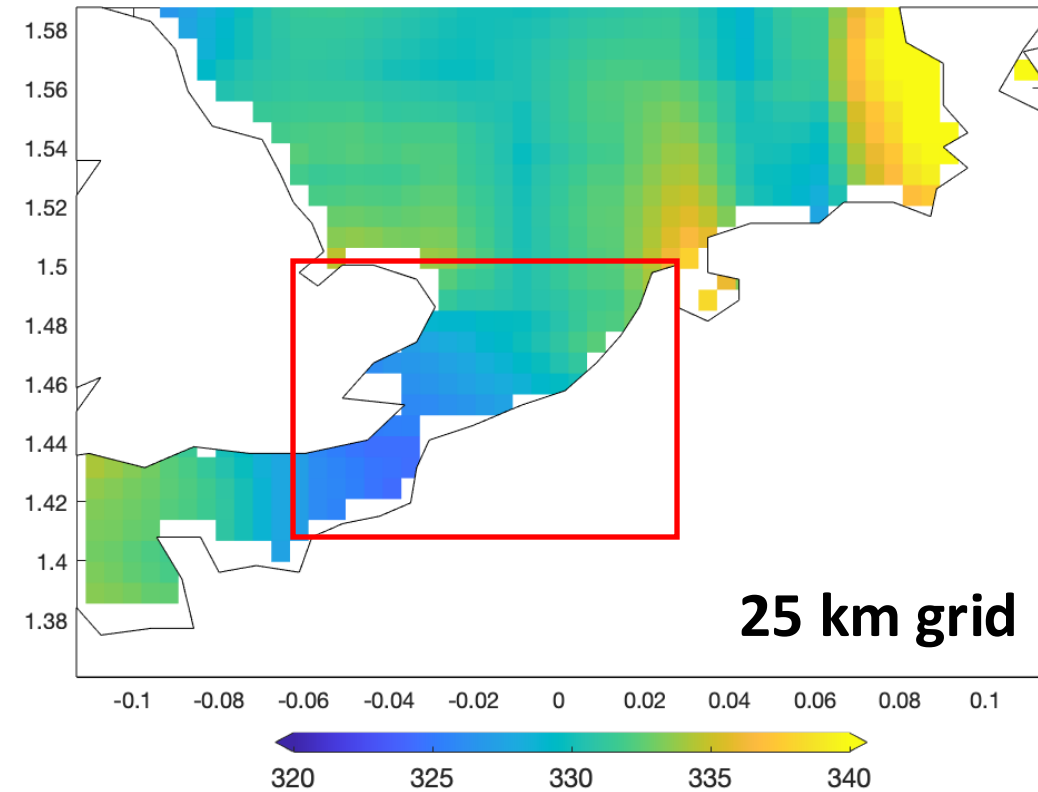
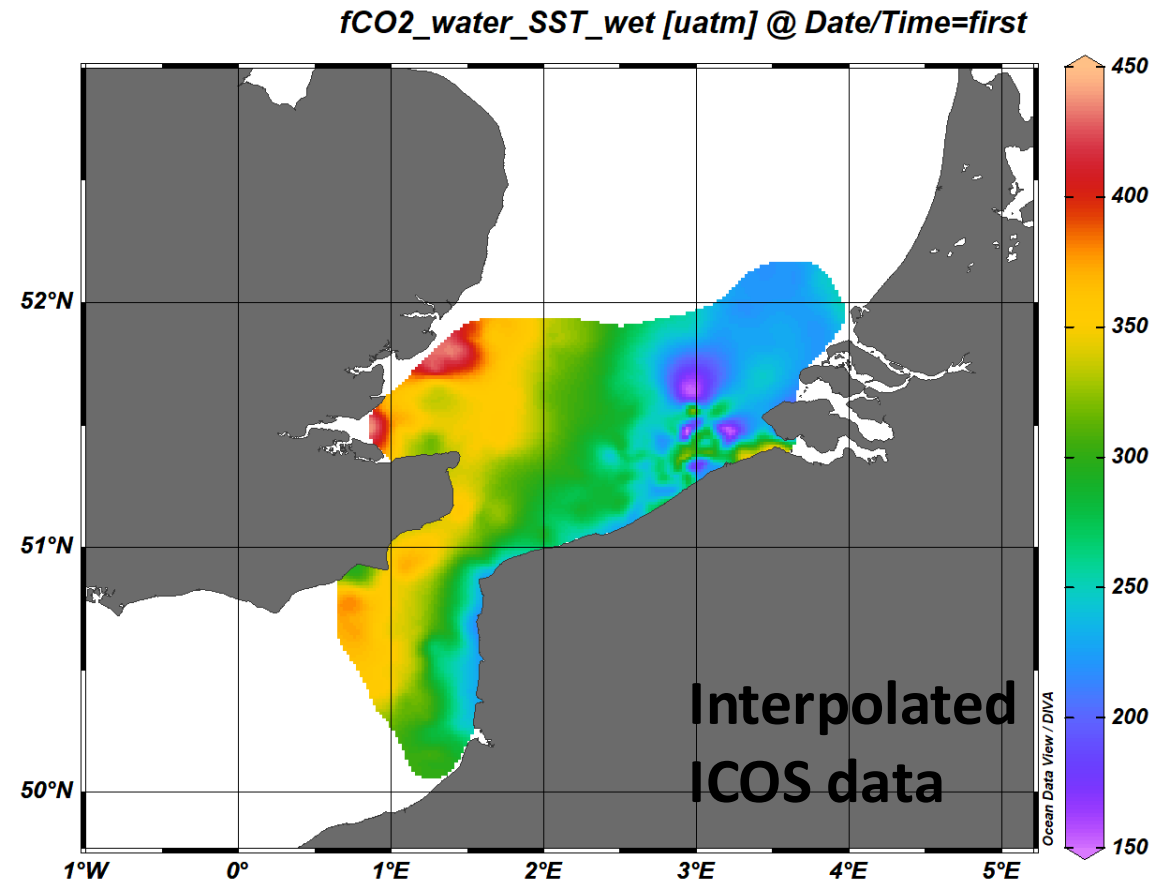
What is the baseline regionally on which additionality can be based on?

Reading suggestion: Unaccountable counting: the folly of incorporating open ocean carbon sinks in Nationally Determined Contributions by Berger, Comte, Kwiatkowski and Bopp

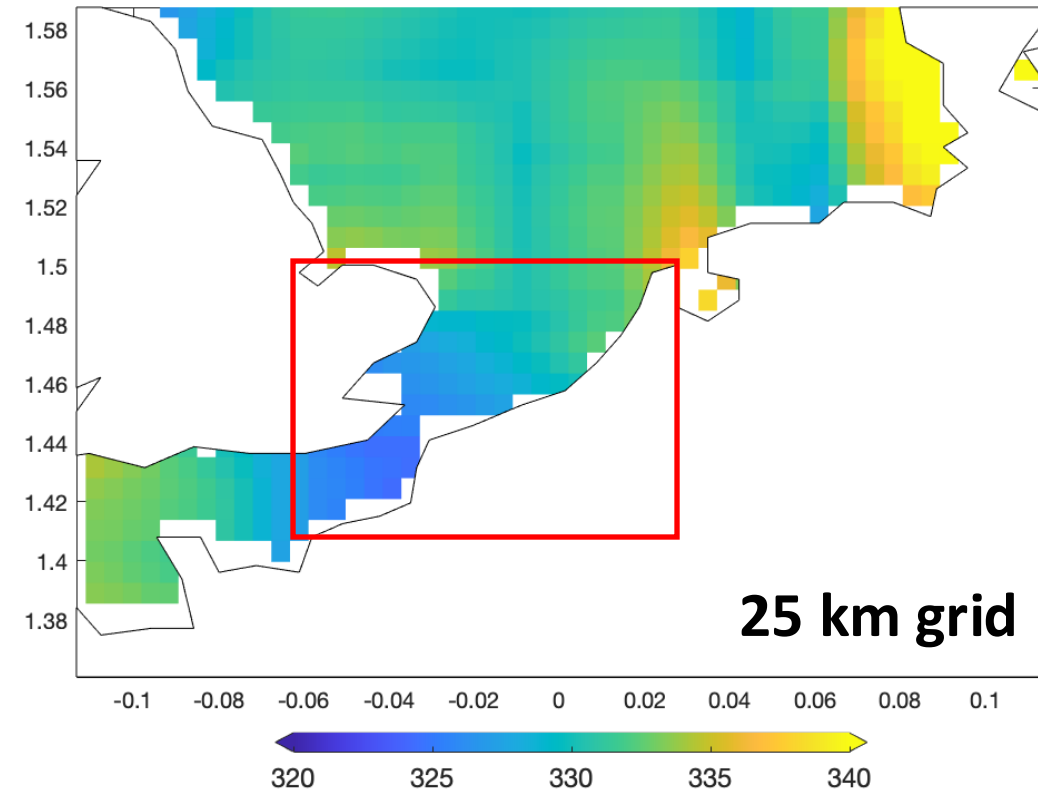
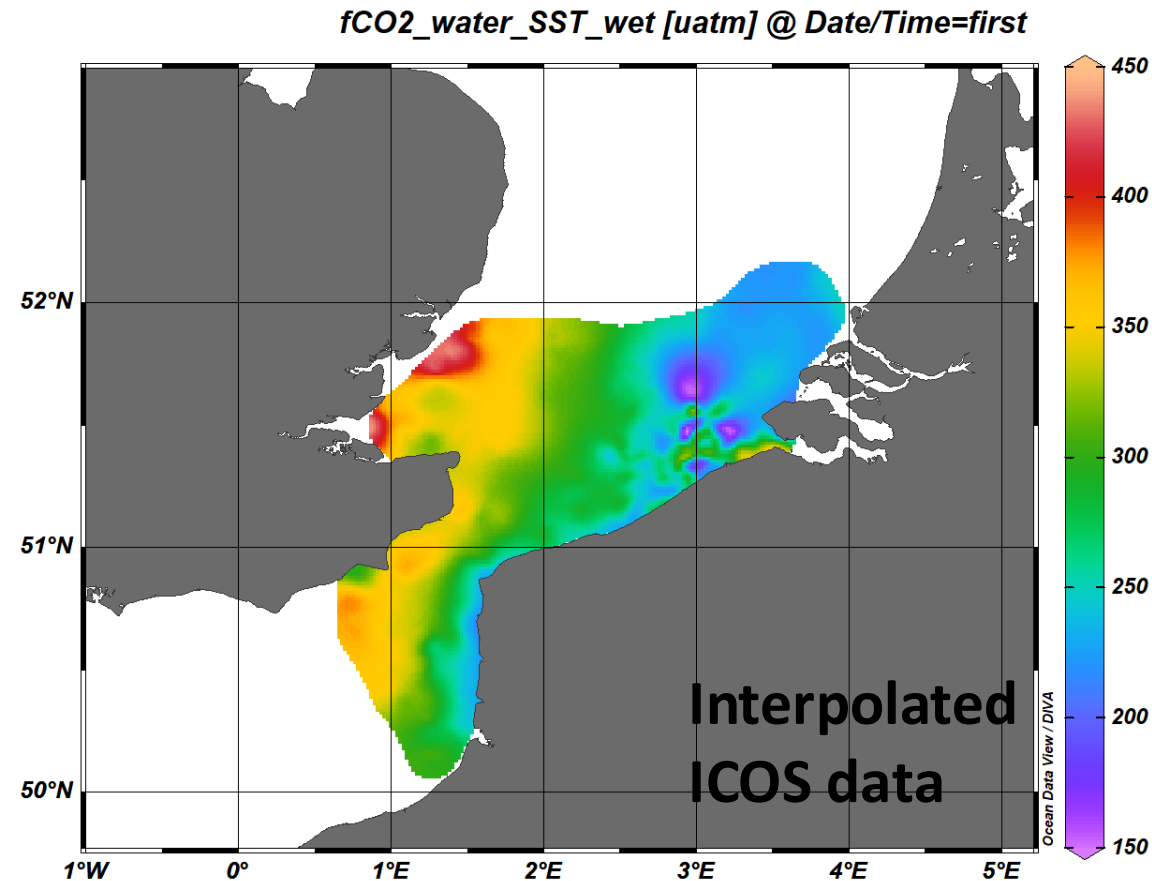
Regional vs global reconstruction of April pCO₂ at the sea surface



Regional vs global reconstruction of April pCO₂ at the sea surface

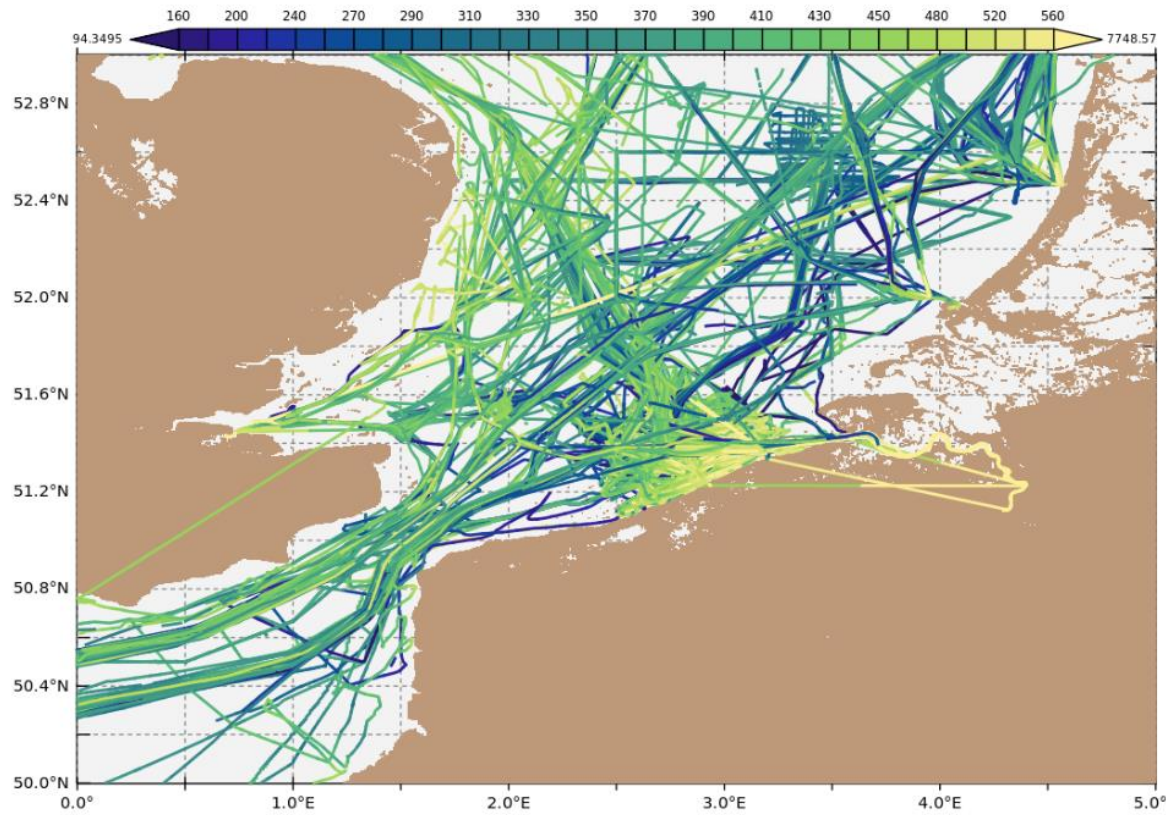


Regional vs global reconstruction of April pCO₂ at the sea surface



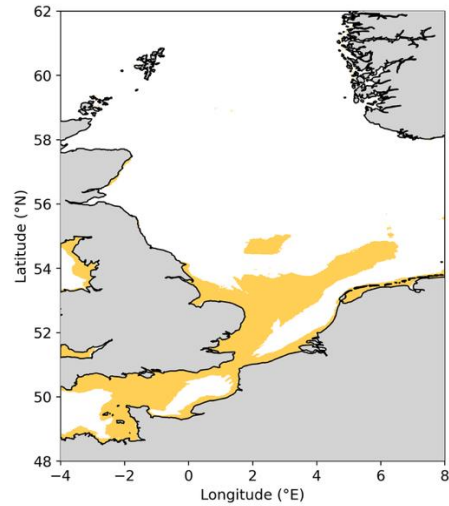
Do we resolve the required scales?

Priority #1: data collection and infrastructure strengthening

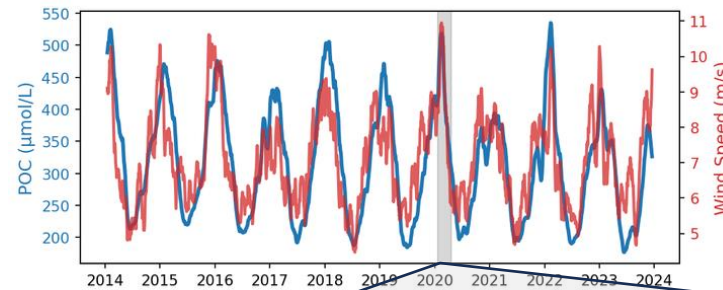


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OBSERVATION
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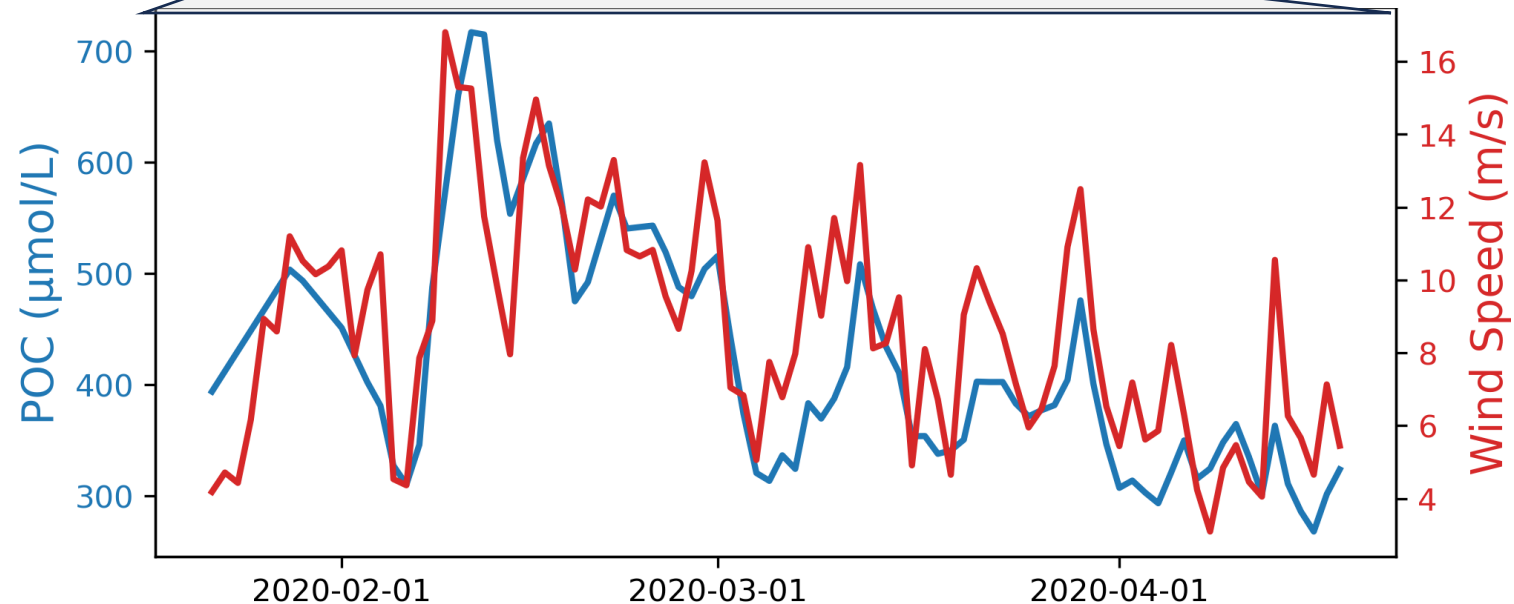
Priority #2: resolve processes at required scales



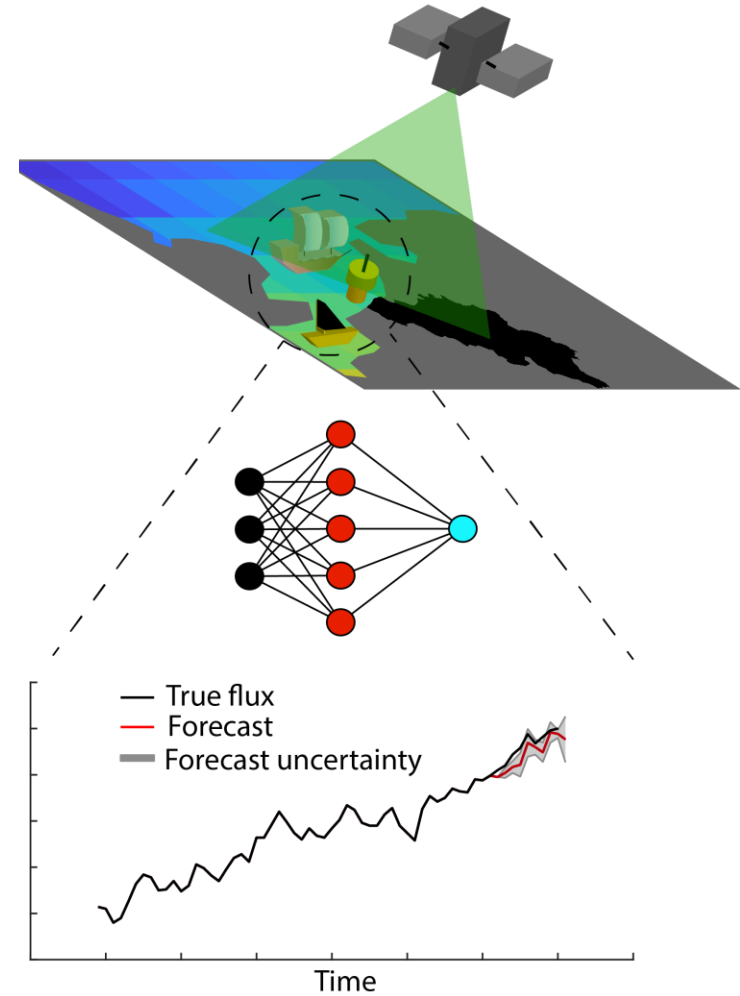
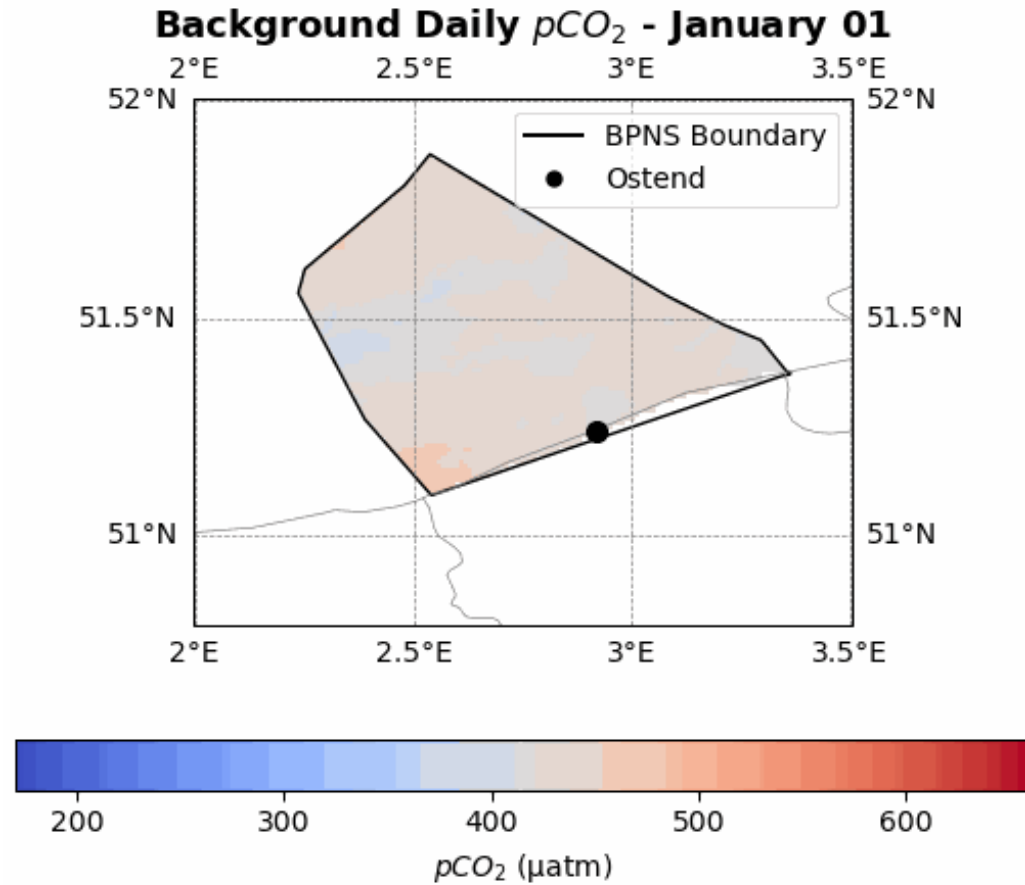
Winter storms and POC variability



Daily variability



Priority #3: set the counter to 0 and define a background



Regional summary

- Monitoring human activities, climate interventions, etc. are becoming more important in a decarbonizing society
- Our global measurement-based approaches do not cover the required scales
- Additionality will be impossible to quantify without setting a reliable “background” or “baseline”
- We need to strengthen observational capacities to eliminate “blind spots”
- And even if we don’t manage to balance regional budgets with observations, we need them to support modelling efforts

Regional summary

- “to identify the additionality of management measures ... robust assessments of the baseline carbon sink and how it would have evolved without intervention will be needed ... this is complicated by the spatially and temporally dynamic nature of ocean carbon fluxes. More fundamentally, there is no colocalization between air–sea fluxes and the subsequent sequestration of carbon in the ocean due to circulation and mixing.” (Berger, Comte, Kwiatkowski and Bopp)