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Quantifying the added value of underway pCO₂ data from sailboats

Jacqueline Behncke^{1,2}

Peter Landschützer^{1,3}

¹ Max Planck Institute for Meteorology

² International Max Planck Research School on Earth System Modelling

³ Flanders Marine Institute

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INTERNATIONAL MAX PLANCK
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FÜR METEOROLOGIE



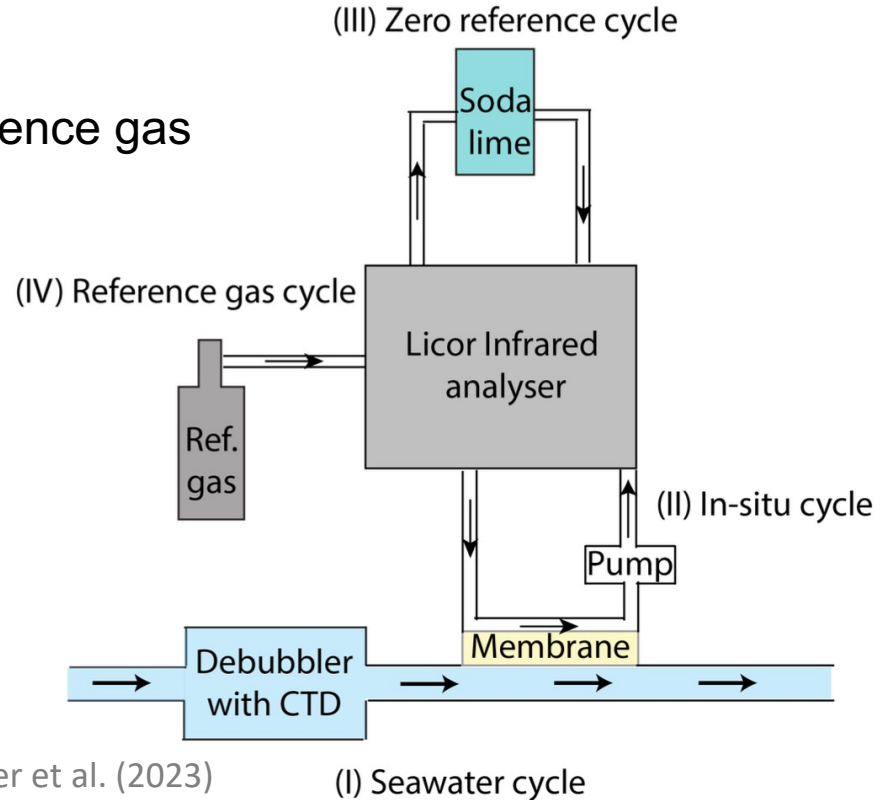
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Supplementary material

- Measurement system
- Overview about sailboat pCO₂ observations
- How to reconstruct missing pCO₂ values?
- Relative difference between flux estimates (w./wo sailboat data)
- Sensitivity of air-sea CO₂ flux to measurement uncertainty

Measurement system

- OceanPack™ RACE system
- Two point calibration: zero CO₂ and reference gas
- Expected measurement accuracy within $\pm 5 \mu\text{atm}$ (flags C and D in SOCAT)



Landschützer et al. (2023)
forthcoming

(I) Seawater cycle

Overview about sailboat pCO₂ observations



- 5 races with high-performance sailyacht
- incl. Antarctic circumnavigation
- 5 transfers

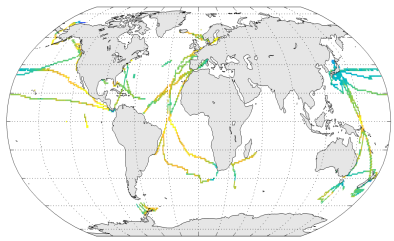


- 2018 - 2022
- 129 days
- (recurrent races)

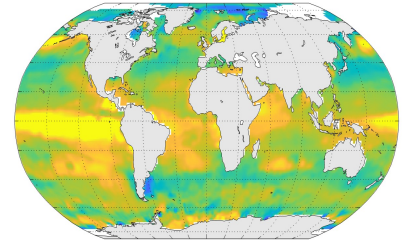


- Sailboat route covered
- ... 7.0 % in the North Atlantic
 - ... 2.6 % in the Southern Ocean
 - ... 10.5 % along Subantarctic Front
 - ... 9.1 % along Northern Boundary
 - ... 2.0 % along Polar Front

How to reconstruct missing pCO₂ values?

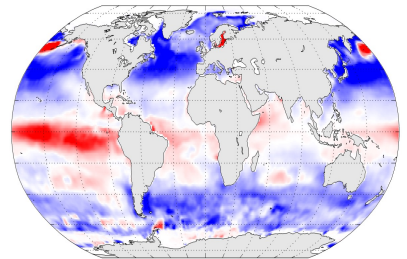


SOM-FFN



SOM = self-organizing-map (classification)

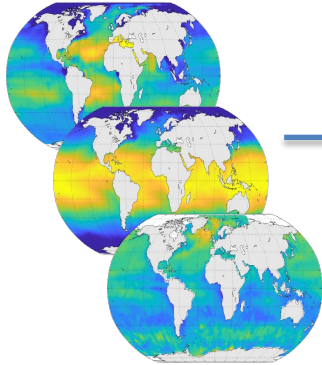
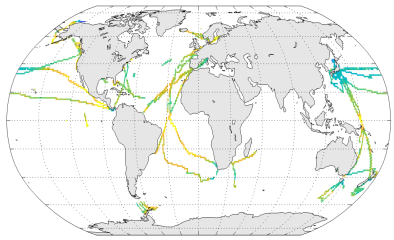
FFN = feed-forward neural network (regression)



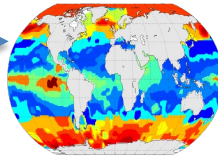
SOM clusters the ocean

1. SOM based clustering of driver variables

pCO₂ observations

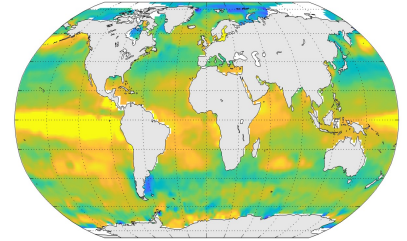


Biogeochemically similar provinces



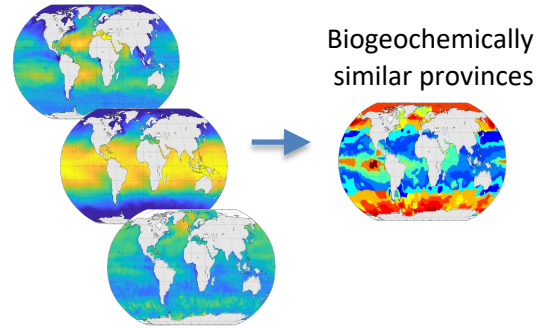
...

reconstructed pCO₂ maps

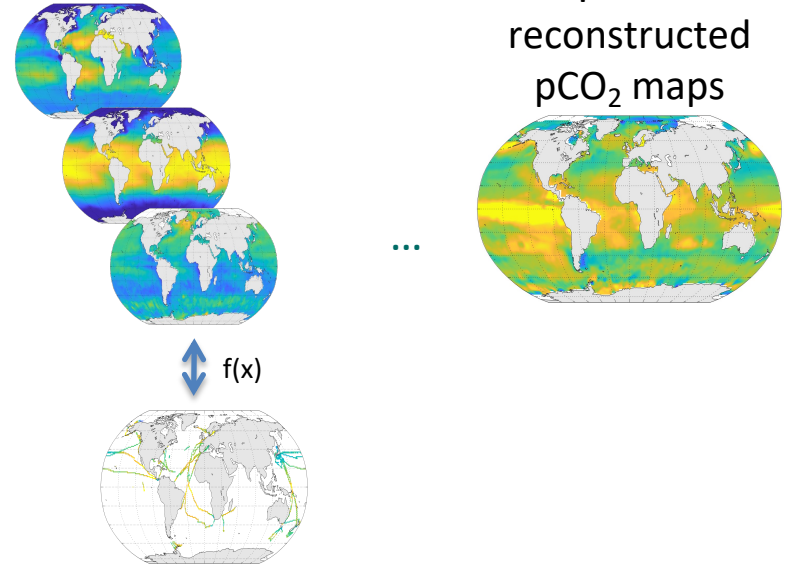


FFN estimates missing pCO₂ values

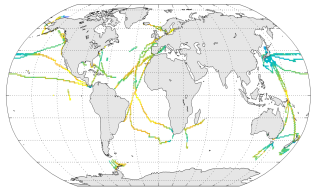
1. SOM based clustering of driver variables



2. FFN: interpolation using relationships between drivers and observed pCO₂

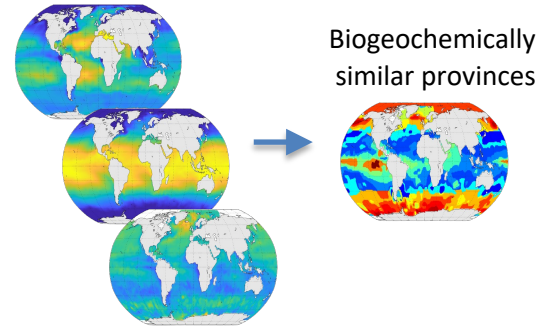


pCO₂ observations

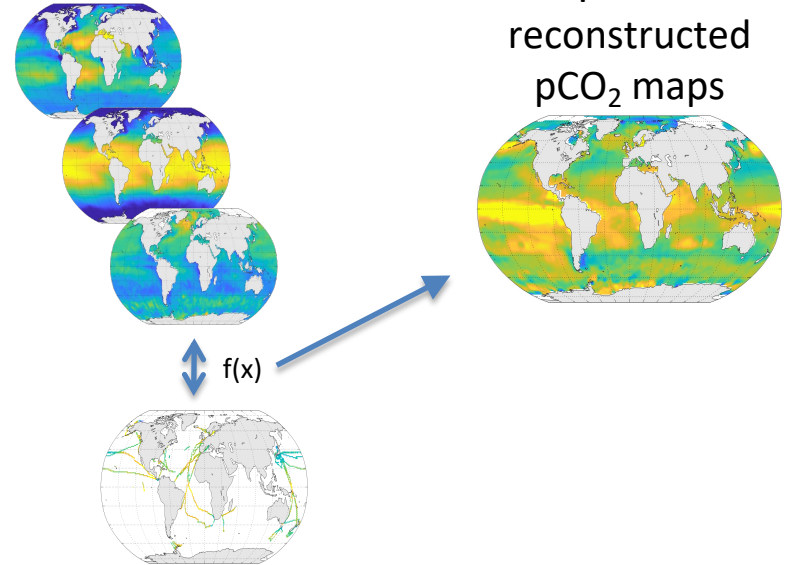


FFN estimates missing pCO₂ values

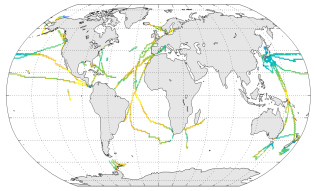
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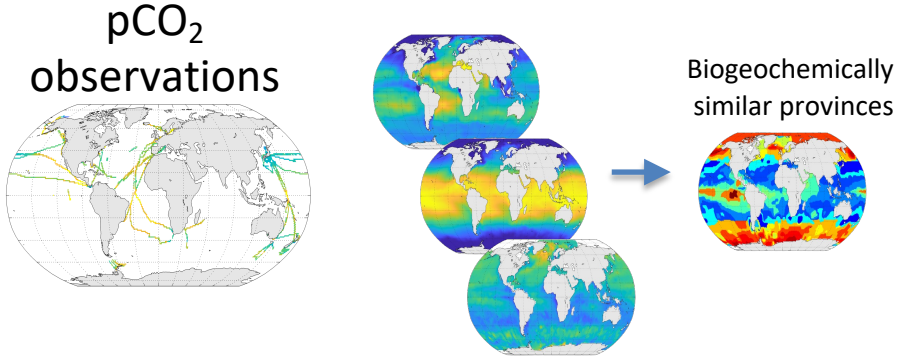


pCO₂ observations

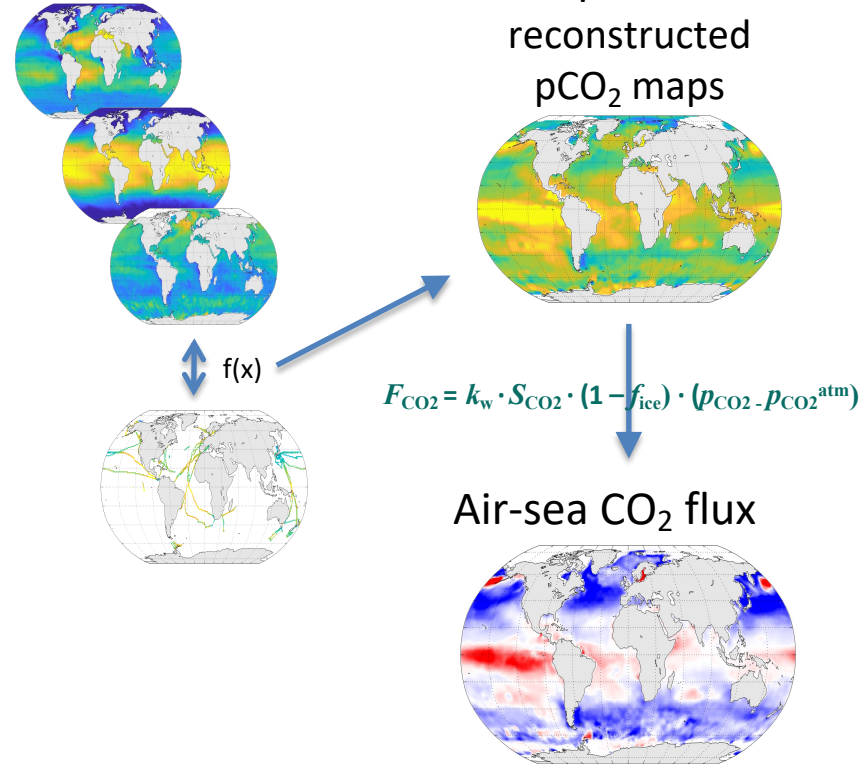


Air-sea CO₂ flux calculation

1. SOM based clustering of driver variables

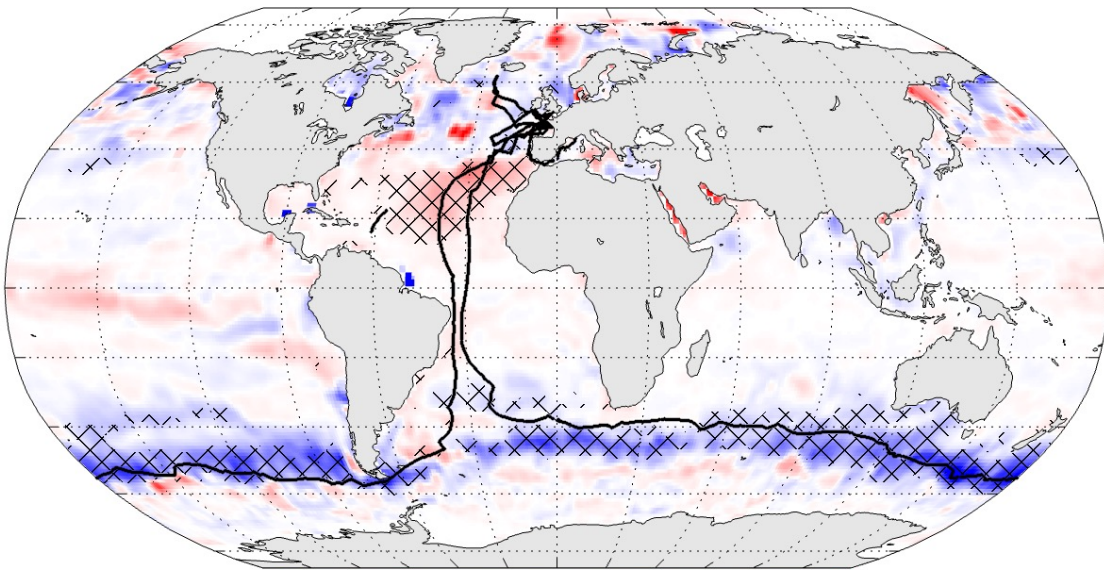


2. FFN: interpolation using relationships between drivers and observed pCO₂

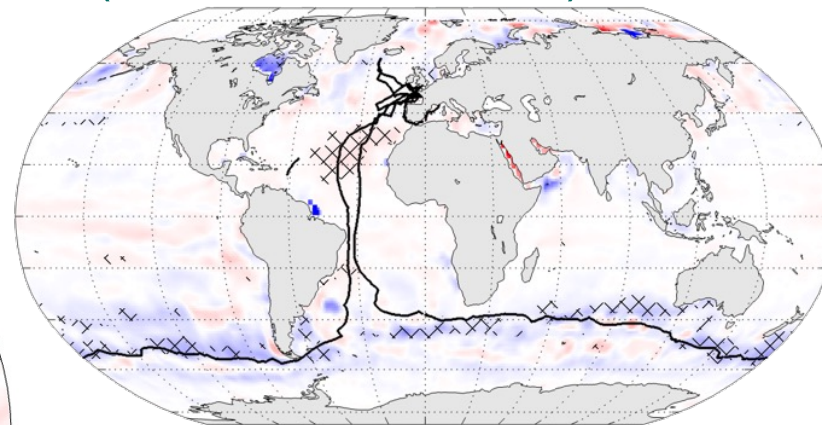


Relative difference between flux estimates (w./wo sailboat data)

Nov 2020 – Jan 2021



Difference between flux estimates [$\text{mol C m}^{-2} \text{ yr}^{-1}$]



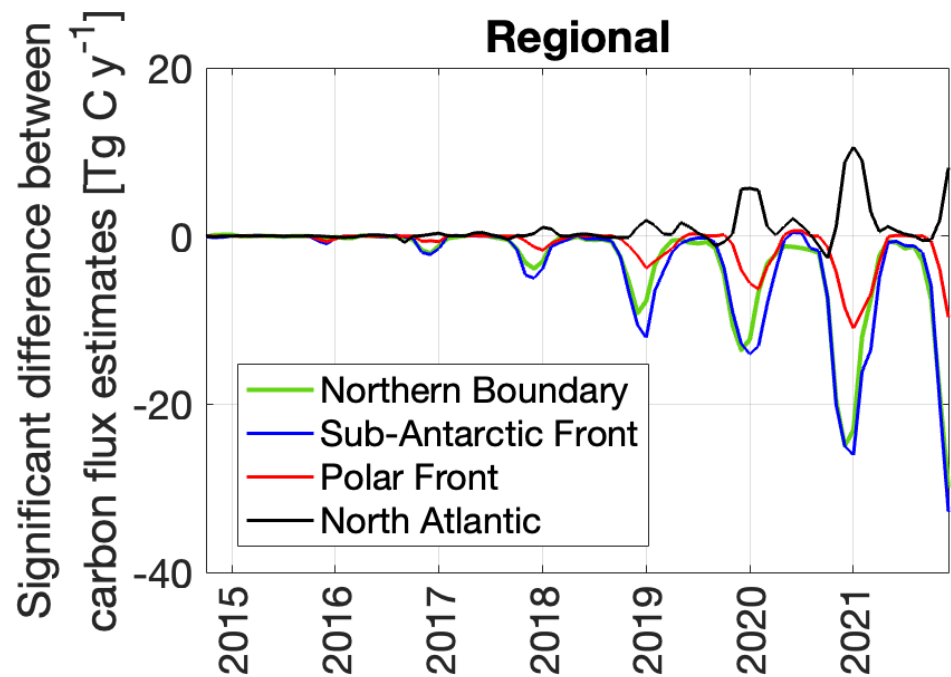
2018 - 2021

Increased uptake in Southern Ocean,
reduced uptake in North Atlantic

Red: $\text{Flux}_{\text{SOCAT+sailboat data}} > \text{flux}_{\text{SOCAT-sailboat data}}$

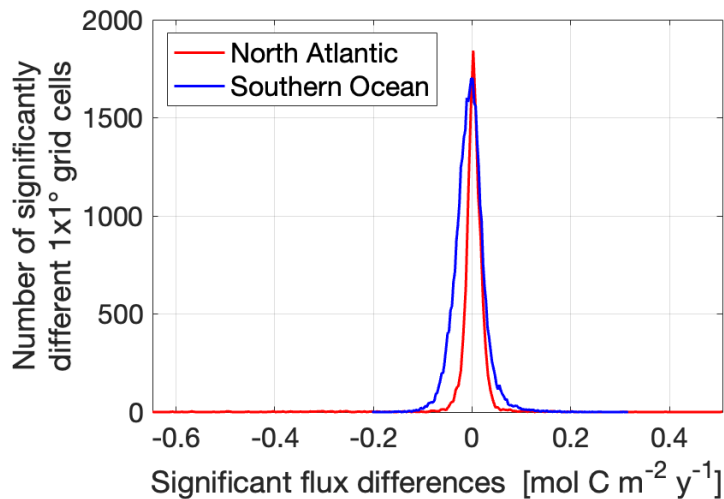
Blue: $\text{Flux}_{\text{SOCAT+sailboat data}} < \text{flux}_{\text{SOCAT-sailboat data}}$

Relative difference between flux estimates (w./wo sailboat data)



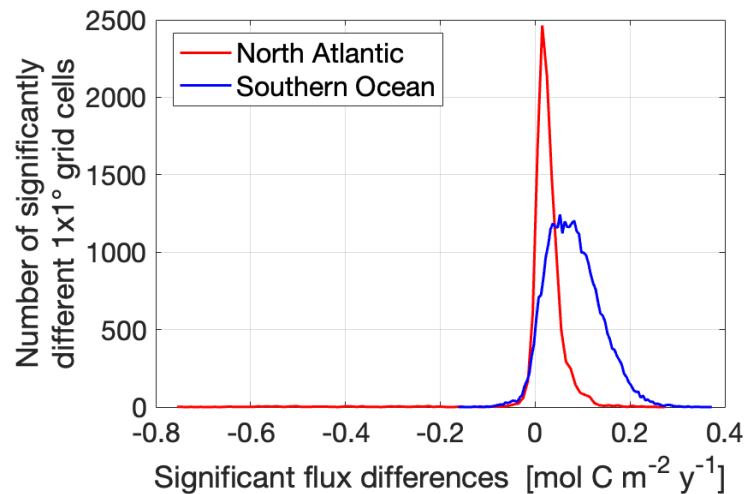
Sensitivity of air-sea CO₂ flux to measurement uncertainty

Random measurement accuracy ($\pm 5 \mu\text{atm}$)



- no significant effect basin-wide
- effect on high-frequency local fluxes

Measurement offset ($5 \mu\text{atm}$)



- causes a bias of up to 0.06 PgC y⁻¹ (2021) = 2.4 % of global uptake of 2.51 PgC y⁻¹ (2021)

North Atlantic mean: 0.02 mol C m⁻² y⁻¹
Southern Ocean mean: 0.08 mol C m⁻² y⁻¹