Lamont-Doherty Earth Observatory
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The observing system and air-sea carbon flux

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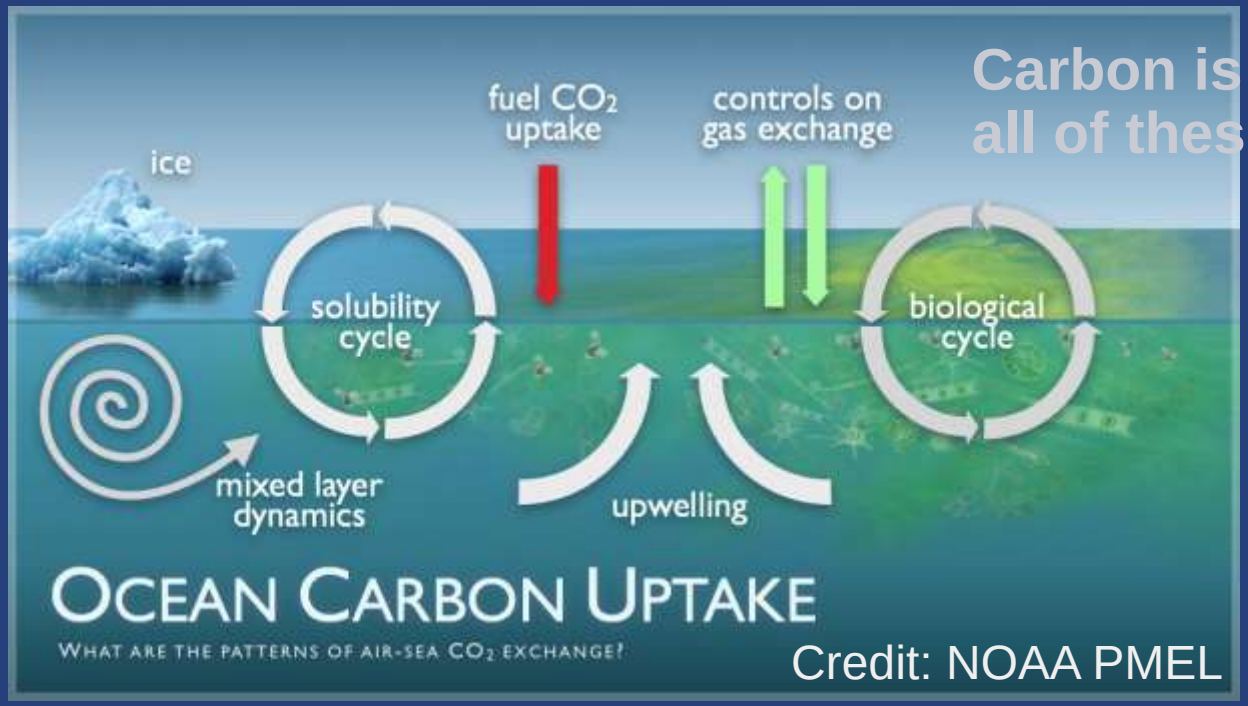
GOMO Community Workshop 2023

Many thanks to collaborators: Dave Munro, Rik Wanninkhof, Colm Sweeney, Adrienne Sutton, Thea Heimdal, Galen McKinley

Why do we care about the uptake of carbon?

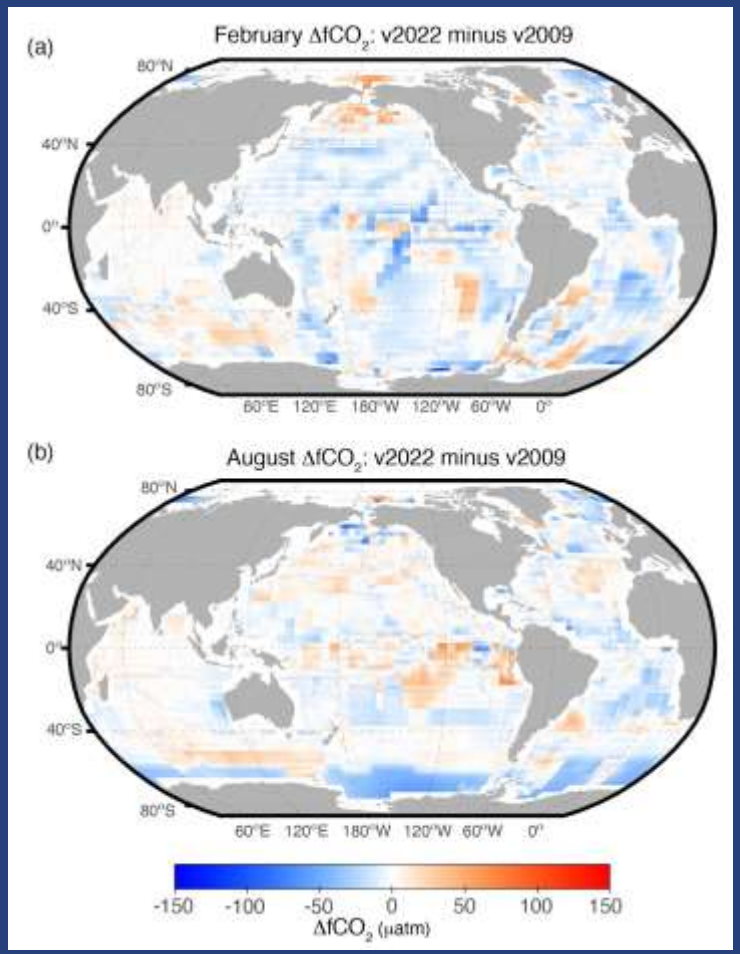


Credit: NOAA PMEL

Carbon is associated with all of these processes.

- **Ocean absorbs ~25% of CO_2 emissions**
- **Climate change is impacting both biological and physical processes that determine this ocean uptake**
- **The ocean uptake uncertainty/interannual/regional variability is more poorly constrained than previously known/acknowledged**

Takahashi climatology update (in prep)



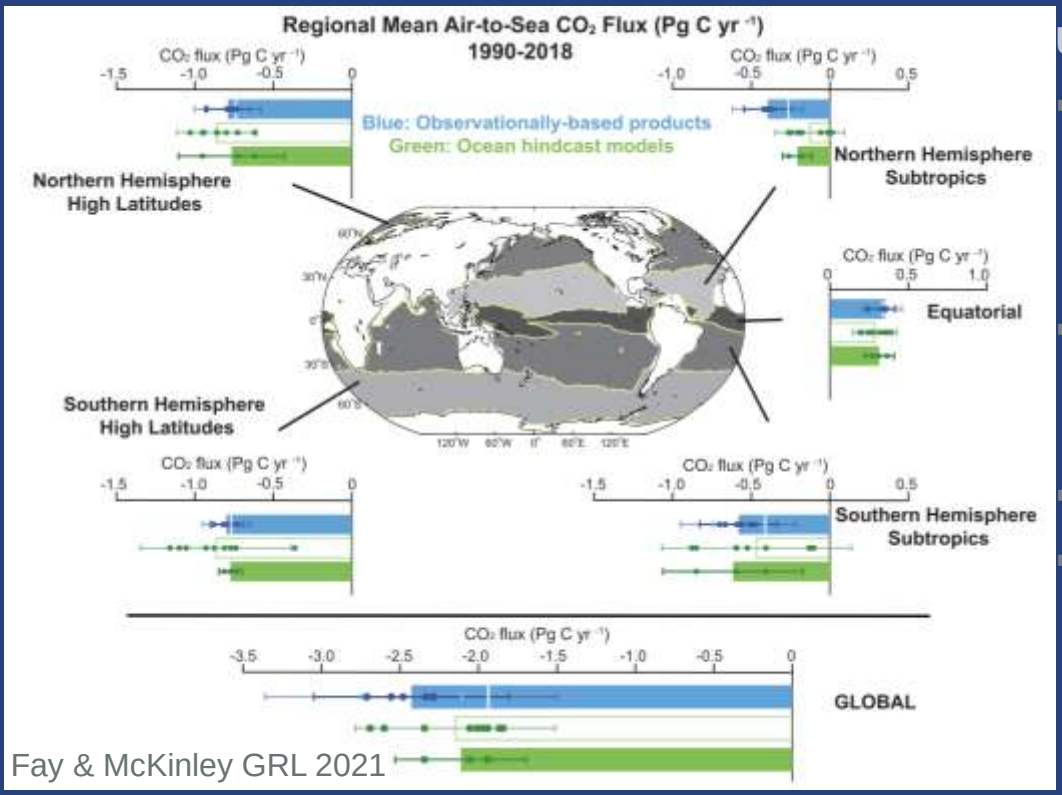
Fay et al. in prep

Source	Time period	Flux estimate (contemporary) PgC yr^{-1}
Takahashi climatology Fay et al. 2023, in prep	1980-2021	-1.79 ± 0.6
Takahashi climatology Takahashi et al. 2009	2000 (1970-2007)	-1.67 ± 0.9
GCB 2022* Friedlingstein et al. 2022	2012-2021	-2.25 ± 0.4
SeaFlux Fay & Gregor et al. 2021	1990-2019	−1.97 ± 0.45

*When contemporary estimate is not reported, we utilize a riverine flux estimate of 0.65 PgC yr^{-1}

Current state of the air- sea CO_2 flux estimate

The Global Carbon Budget (GCB) shows a discrepancy between the different methods (models vs products) on the strength of the ocean sink over the last decade.

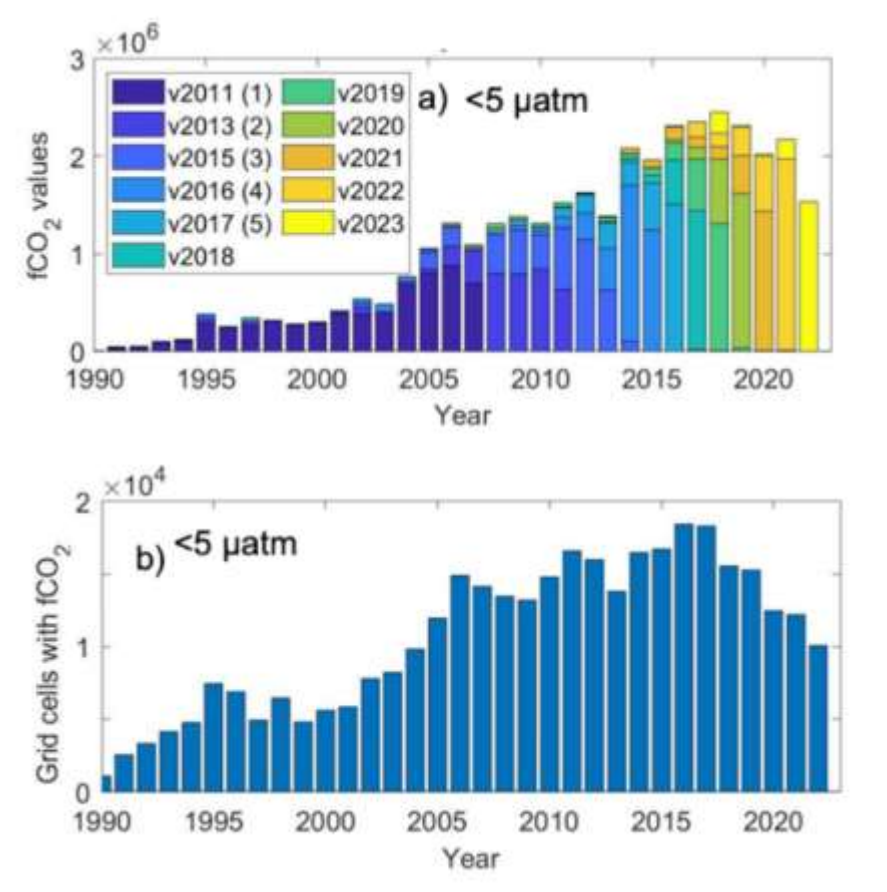


Fay & McKinley GRL 2021

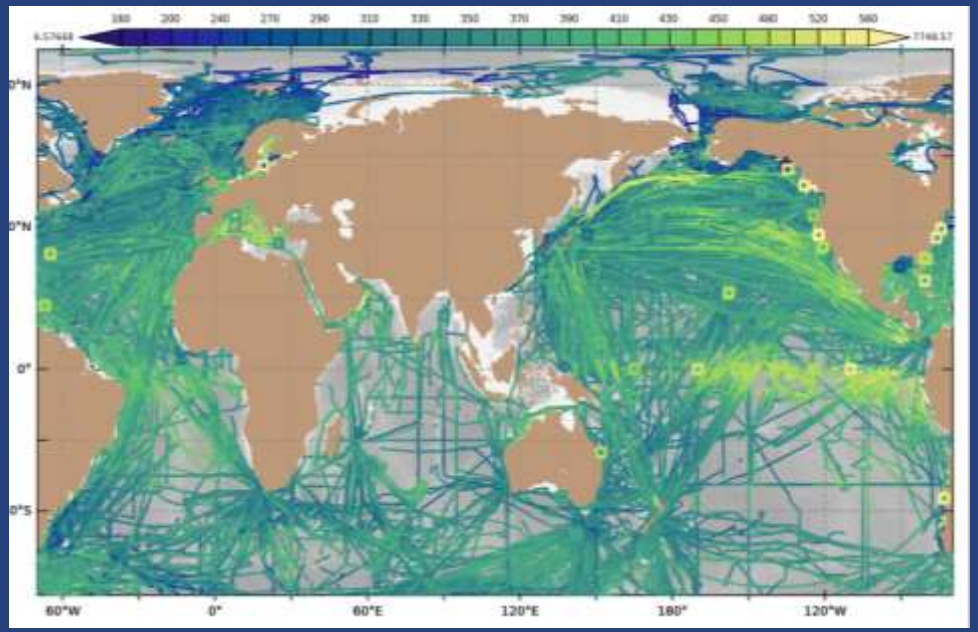
Uncertainties still to be researched…

- Riverine flux.
  - Needed for comparison of observation-based products and models.
  - Current estimates range from 0.21 to 0.78 PgC yr^{-1}
- Skin temperature effect.
  - It is understood that the SOCAT database has a warm bias due to intake collection depth
- Not all estimates are giving a global estimate
- Interaction of climate change with the different flux estimates: e.g., anthropogenic vs natural plus riverine, etc.

SOCAT: there has been a decline in CO_2 observing efforts in the world's ocean



Credit: SOCATv2023 release poster



Credit: SOCAT Data Viewer

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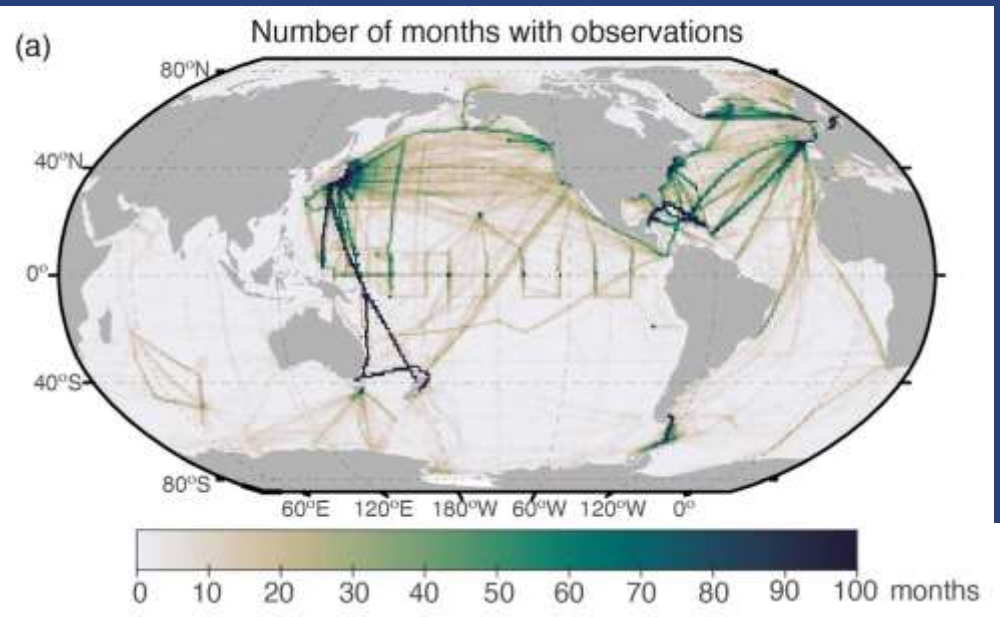
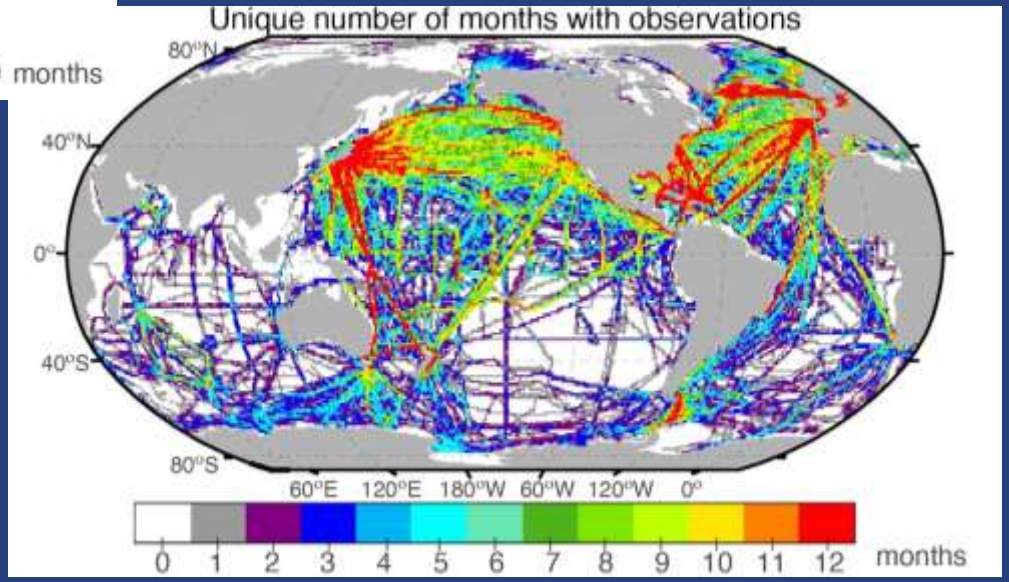
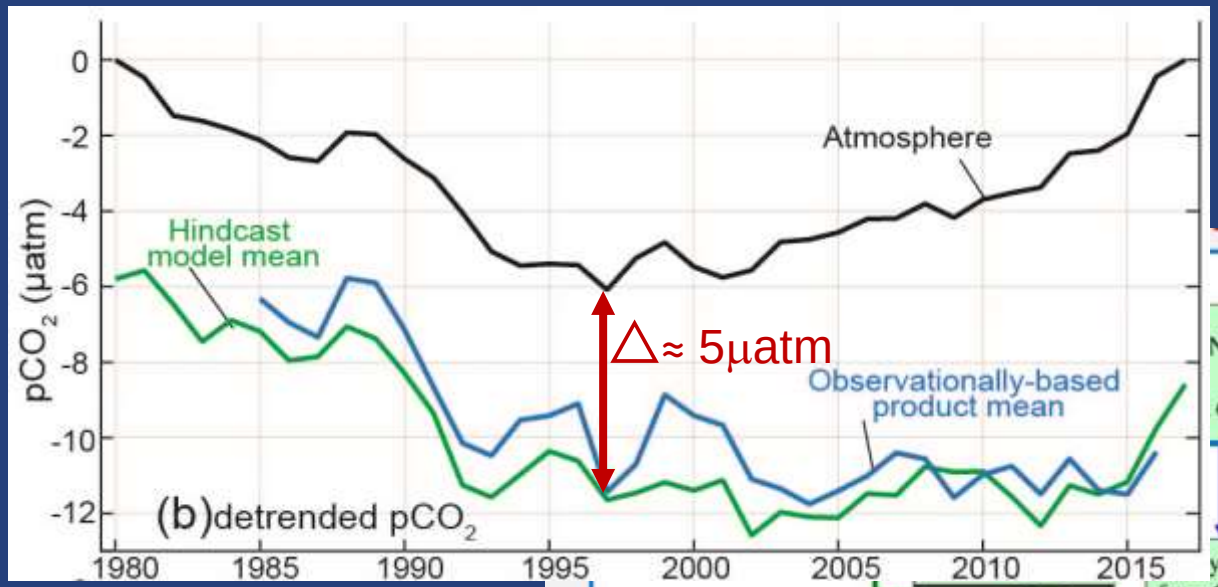


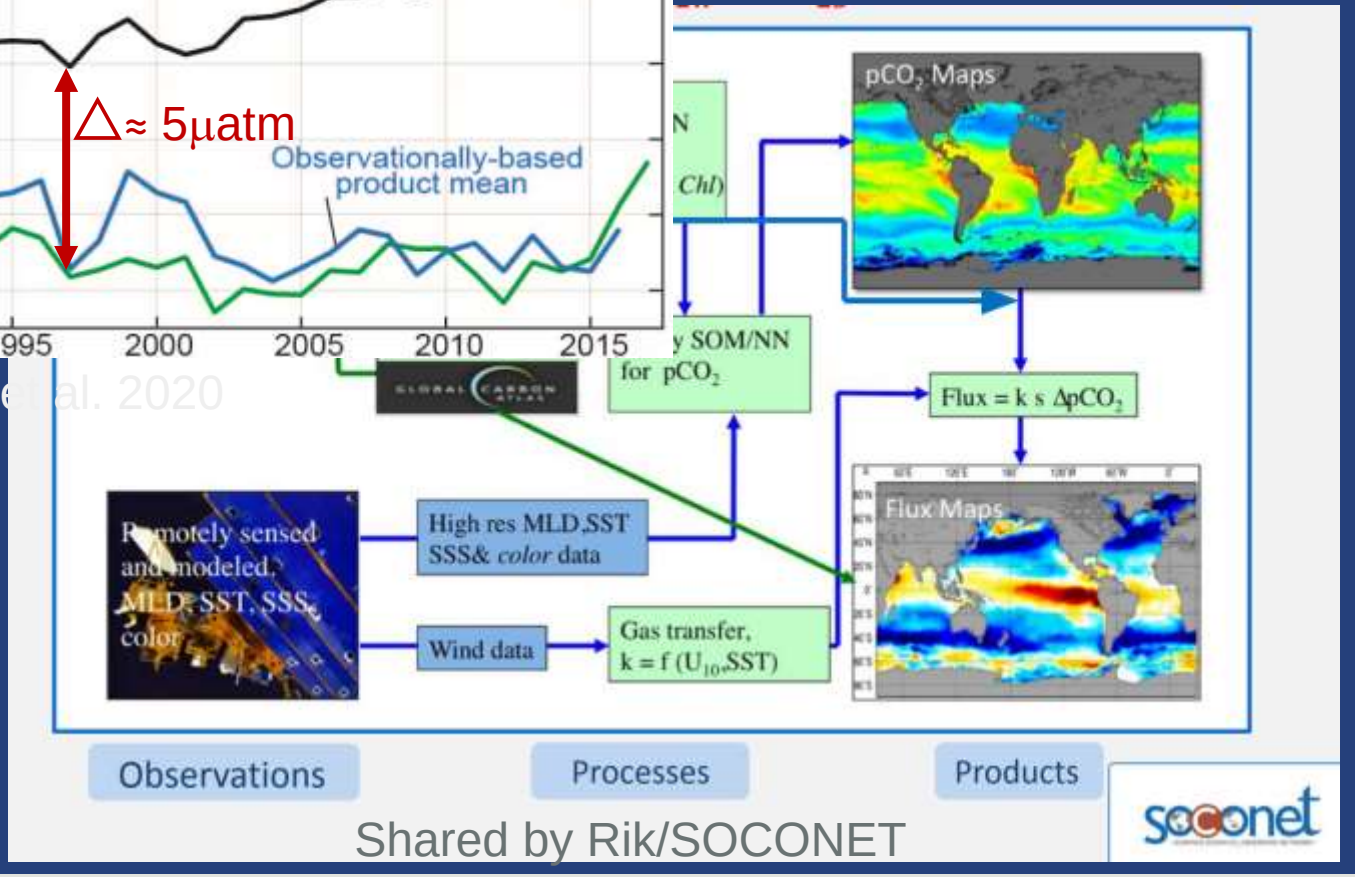
Fay et al. in prep



High quality measurements are absolutely imperative to our research

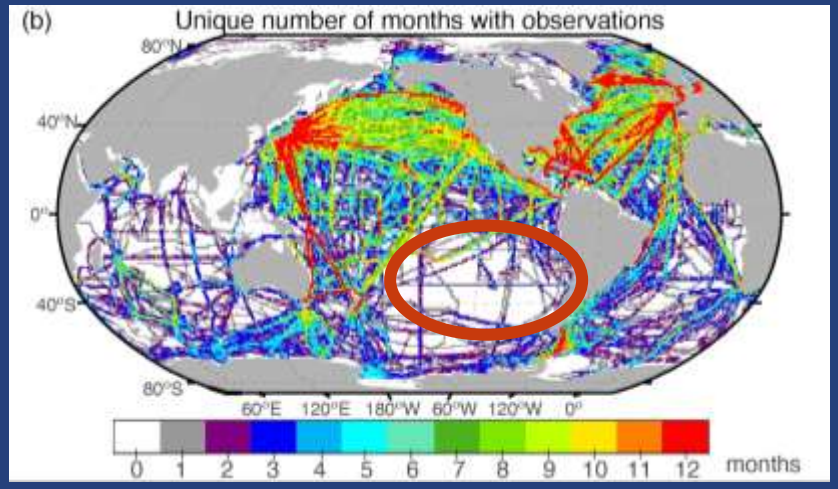


Adapted from McKinley et al. 2020



Shared by Rik/SOCONET

Assessments of data impact on poorly sampled regions

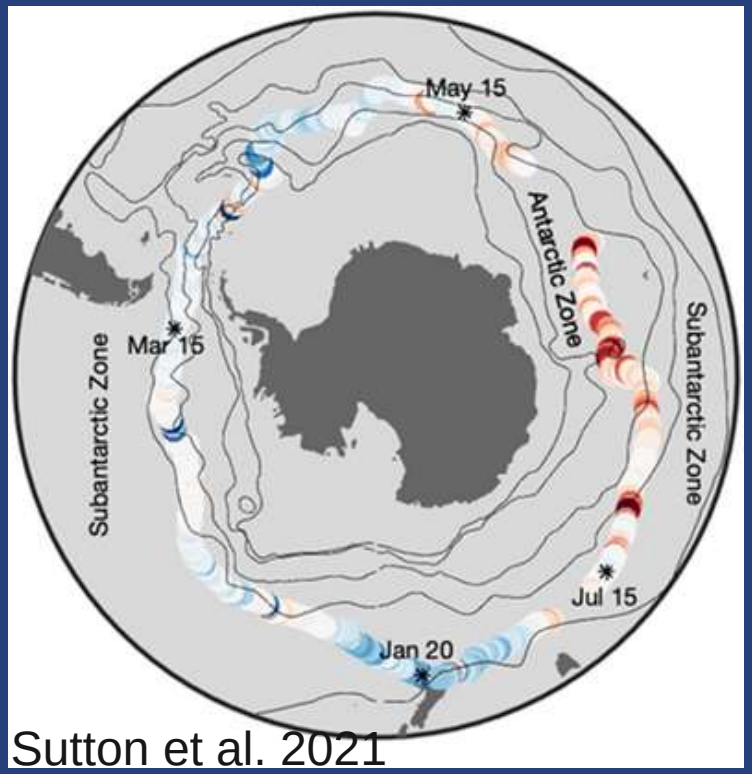


Fay et al. in prep

Automated Surface Vehicles (ASV's) have great potential to fill spatiotemporal gaps in ocean carbon observations

Climatological CO_2 air-sea flux differences with/without one individual ASV deployment in the South Pacific differ by about a tenth of a Pg yr^{-1}

Assessments of data impact on poorly sampled regions



Sutton et al. 2021

Image courtesy of NOAA's PMEL

Current work (Heimdal et al. in prep) looking at idealized sampling patterns of the Saildrone in the Southern Ocean uses a model testbed approach and find a marked improvement in capturing the "true" carbon flux in the region.

Looking forward
My thoughts on what we need

There is a need for more observations and tools in under sampled regions specifically the South Pacific, Indian Ocean, Southern Ocean, and coastal regions. Utilize models/machine learning to educated where/when sampling could be most impactful.

High quality (low uncertainty) measurements are essential. While a variety of platforms can enhance the total observing network, they are not a replacement for the high-quality measurements of pCO_2 that are obtained on ships and sail drones. There is no replacement for this type of data.

Biases in our pCO_2 data cascade to flux calculations. With the average ocean disequilibrium around 6-8 μatm, even small biases or errors can quickly affect flux estimates.