What can Atmospheric Potential Oxygen tell us about the Ocean Carbon Sink?

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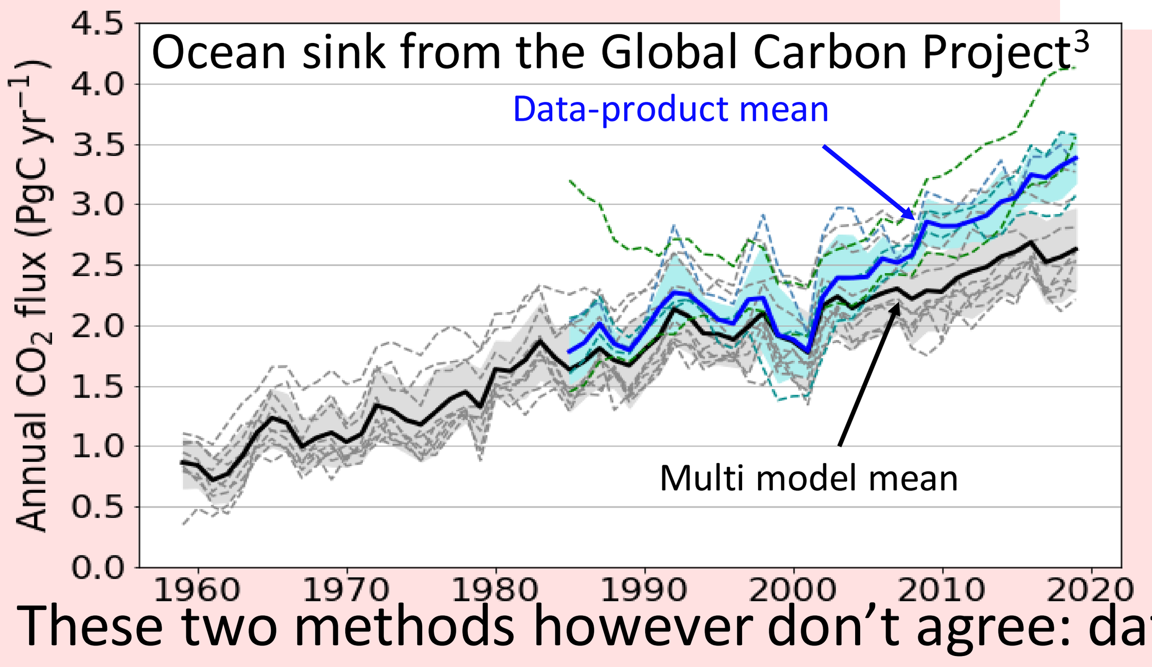
Motivation: trouble with the Global Carbon Budget

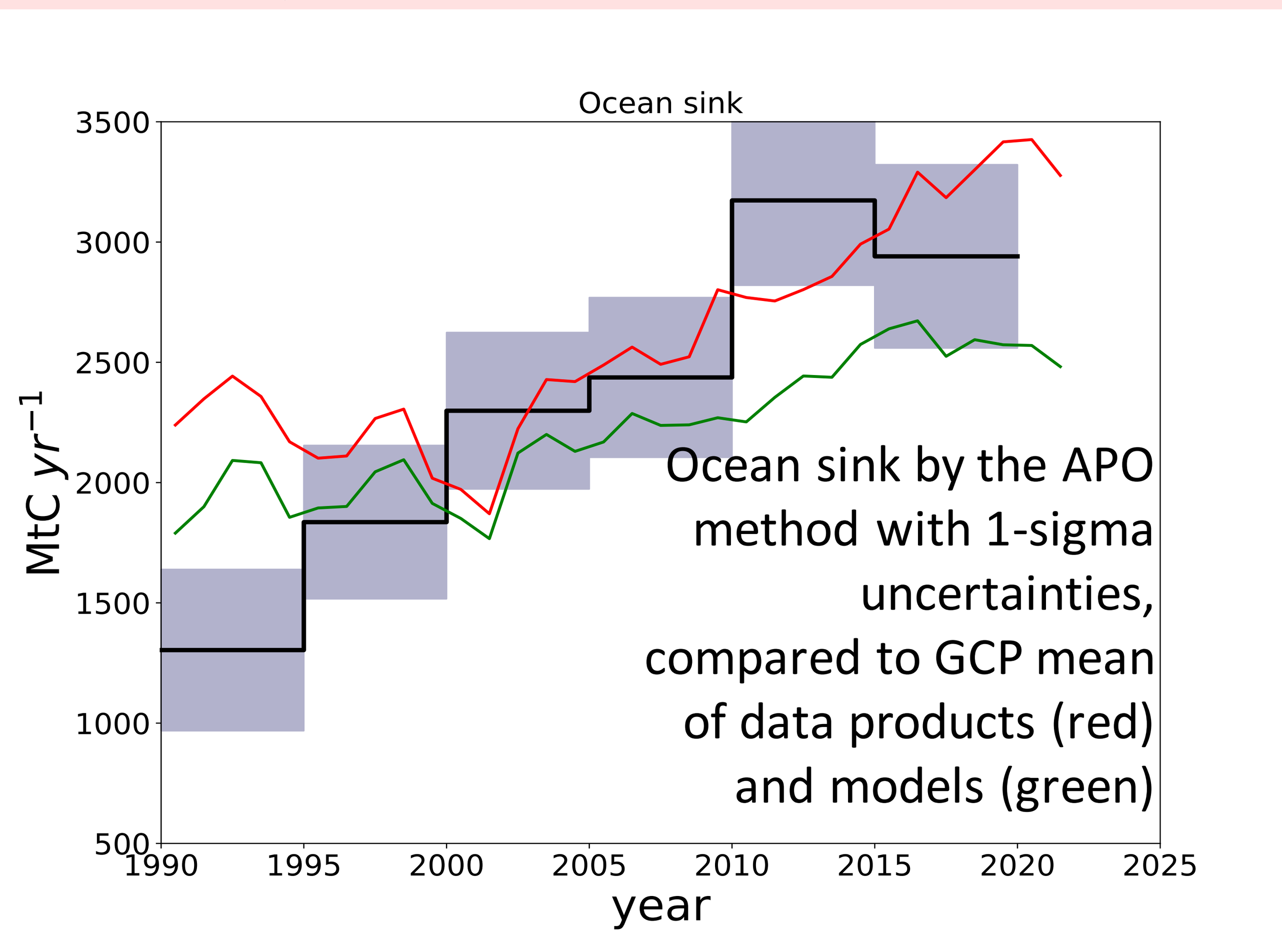
- We need to know the size of the land and ocean sinks for atmospheric CO_2, to understand current global change and to project possible futures.
- The combined size of the land and ocean sinks is well-constrained by observations, but how much is ocean and how much the land is less well-known.
- To assess the ocean sink, the Global Carbon Project budget (GCB) uses primarily two methods: ocean biogeochemical models (OBGMs) and data products[1,2] based on the SOCAT surface pCO_2 observations[3], interpolated with the aid of additional variables (surface temperature, salinity etc).



- These two methods however don't agree: data products suggest the ocean sink has grown twice as fast as the models give over the period 2000-2020.
- What does the APO-based approach say?

APO Ocean sink for anthropogenic CO_2

1. Use the method of Manning and Keeling (2006)[5].
2. Ocean outgassing of O_2 calculated using WOA heat estimates and the analysis of Ito et al[6].
3. Uncertainties propagated using Monte Carlo technique.



Ocean sink by the APO method with 1-sigma uncertainties, compared to GCP mean of data products (red) and models (green)

Conclusions

- In the period 2000-2015 the APO calculation gives a similar rate of increase of the ocean sink to GCB surface data products, and disagrees with their model estimates.
- Subsequently to 2015 it shows a levelling off of the rate of rise however.
- APO suggests a continuous rise from a low level in the 1990s – different to both surface ocean data products and models. (However, less confidence in all methods for that decade).
- The GCB models are much the same as those used in IPCC projections, so this has implications for IPCC studies.

References: 1. Landschützer, P. *et al. Biogeosciences* **10**, 7793-7815 (2013). **2.** Lefèvre, N., et al *Tellus, Series B: Chemical and Physical Meteorology* **57**, 375-384 (2005). **3.** Bakker, DCE et al, Earth syst. Sci Data 6, 69-90 (2014). **4.**Friedlingstein, P. *et al.* Global Carbon Budget 2021. *Earth System Science Data* **14**, 1917-2005 (2022). **5.** Manning, A. C. & Keeling, R. F *Tellus Series B-Chemical and Physical Meteorology* **58**, 95-116 (2006). **6.** Ito, T., Minobe, S., Long, M. C. & Deutsch, C. *Geophys. Res. Lett.* **44**, 4214-4223 (2017).

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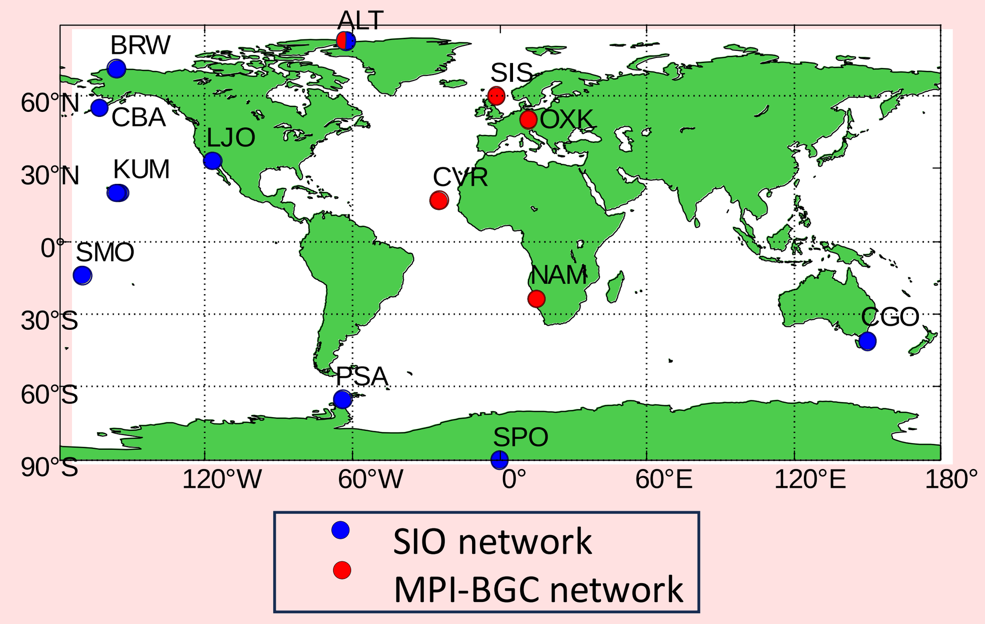
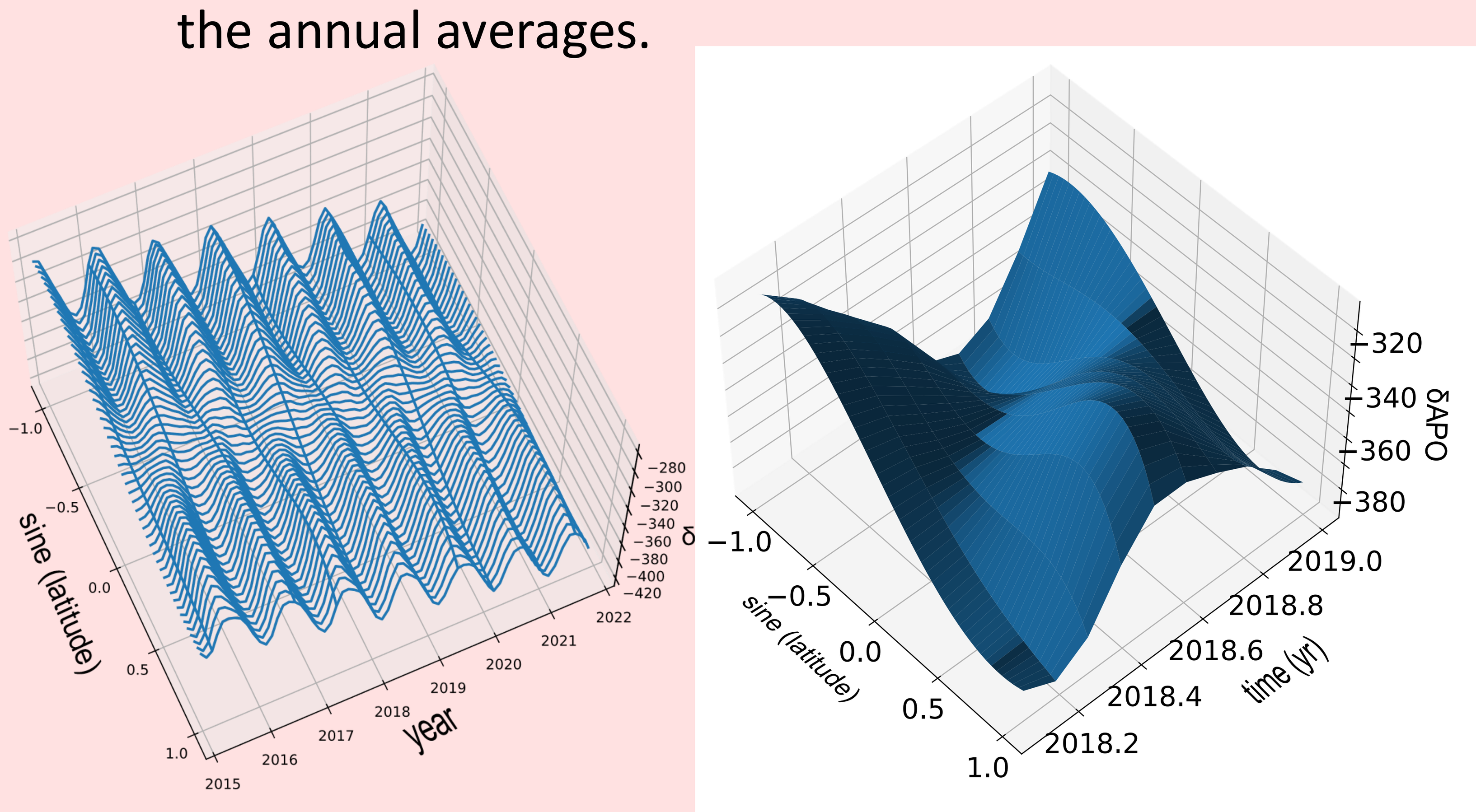
Method

1. A latitude-vs time marine boundary layer δAPO product was generated from flask measurements of O_2/N_2 and CO_2 from the Scripps and the MPI-BGC networks, excluding stations at high-altitude, with only short records, or in forest.



2. A continuous curve was fitted to each station, using a seasonal cycle of 3 harmonics, and 40-day half-width gaussian low pass filter.
3) These were then sampled at 0.1 year intervals and a 4th-order polynomial function of sine(latitude) fitted to each time slice.
4) This product was integrated over latitude (weighted by surface area of each latitude band) and annually, to generate a global annual average surface δAPO record.
5) Rate of decrease of δAPO calculated in 5-year intervals using continuous piece-wise linear fit to the annual averages.



Left: Latitude vs time "flying carpet" plot of the APO product for the period 2015-2022. **Right:** a single year (2018) in closeup

Globally and annually integrated APO product fitted with 5-year piecewise linear regression