Constraints on Global Carbon and Heat Exchanges from Measurements of Atmospheric O_2 and Related Tracers

R. Keeling[1], E. Morgan[1], B. Paplawsky[1], A. Cox[1] and L. Resplandy[2]

[1]Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92037; 858-534-7582, E-mail: rkeeling@ucsd.edu
[2]Princeton University, Princeton, NJ 08540

The Scripps O_2 program sustains measurements of changes in the O_2/N_2 ratio begun in 1990 using the interferometric method. The measurements track a long-term decrease in O_2/N_2 caused mostly by uptake of O_2 during fossil burning, but also strongly influenced by processes impacting the land sink carbon sink, such as photosynthesis and respiration. The O_2 measurements, in conjunction with measurements of atmospheric CO_2, continue to provide strong constraints on the global land and ocean carbon sinks. A principle limitation of the method involves the need to correct for long-term release of O_2 from the oceans associated with ocean warming and stratification. The method is nevertheless an important complement to other methods, which have similarly large limitations.

As alternate methods of resolving ocean carbon sinks have improved in parallel, an additional application for the O_2 measurements has emerged, involving tracking changes in ocean global heat uptake. The global heat uptake remains a primary measure of global warming, and quantifying the rate of heat uptake is critical to improving estimates Earth's climate sensitivity to excess CO_2, and thereby forecasts of future warming. Previous estimates of ocean heat uptake rely on thermometer measurements of ocean temperature in combination with data-filling methods for extrapolating the sparse temperature database to the entire ocean. By combining atmospheric O_2 and CO_2 to compute the tracer "atmospheric potential oxygen" (APO ~ $O_2 + CO_2$) an independent estimate of ocean heat uptake can be formulated. APO is decreasing over time as the O_2 decrease exceeds the CO_2 increase. This APO decrease is insensitive to land exchanges because impacts on O_2 and CO_2 cancel. It is sensitive mainly to fossil-fuel burning, ocean uptake of "anthropogenic CO_2", and climate driven exchanges of O_2 and CO_2. The latter influence can be isolated because the other influences are quite well known. The climate-drive exchanges of O_2 and O_2 in principle include both physically (e.g. solubility) and biologically-driven exchanges, but it turns out that the solubility effects strongly dominate. This can be shown both from hydrographic data and across ocean climate models. The climate-driven APO trend thus directly constrains global ocean heat uptake, providing an alternate method that is completely independent of ocean hydrographic data and places estimates of ocean warming on a more secure footing.

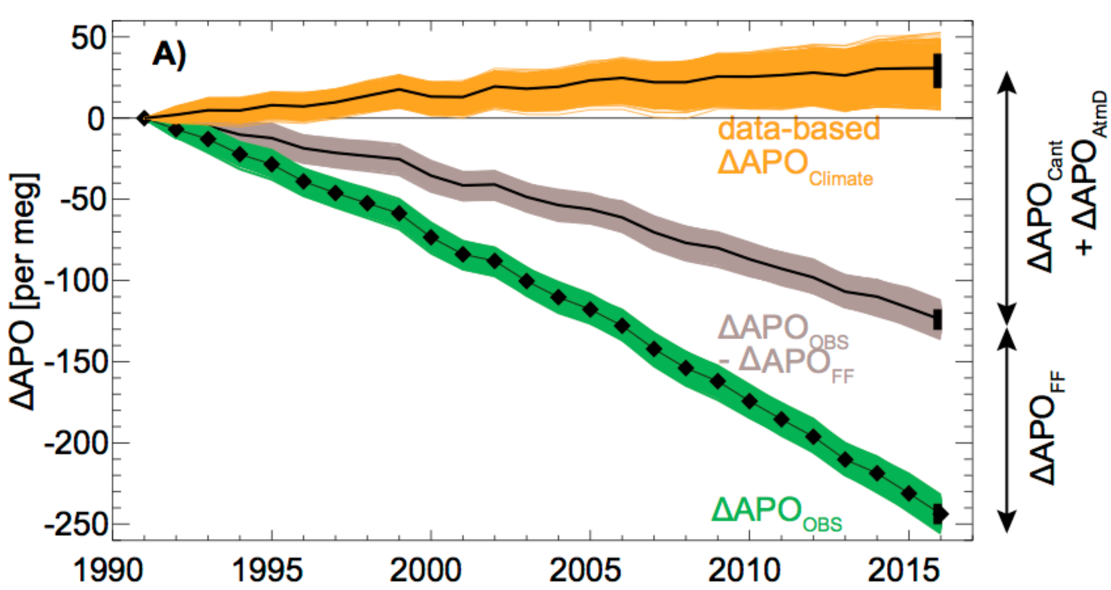

Figure 1. Residual change in APO (orange) after correcting raw signal (green) for fossil-fuel contribution (grey) and anthropogenic CO_2 uptake by the oceans. From Resplandy et al. (in prep, 2018).