How Observations of Atmospheric O_2 Concentration Can Inform Our Understanding of Land and Ocean Processes in a Time of Global Change

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Time series of atmospheric oxygen (O_2) concentrations from the Scripps O_2 program now span two decades. These series document a long-term decreasing O_2 trend, cycles, and gradients, and will be discussed in terms of the constraints of long-term land and ocean carbon sinks, the stability of ocean biological production, rates of ocean deoxygenation, and testing depictions of ocean processes coupled ocean/atmospheric biogeochemical models.

The importance of the O_2 data can be seen in relation to the limitations of current inverse calculations of carbon dioxide (CO_2) fluxes. Because the high variability of land carbon exchanges tends to mask the oceanic exchanges, the CO_2 inverse calculations are better equipped to resolve fluxes on land than the oceans, and are better suited resolving flux variations than their mean value. The calculations are not as well suited to estimating long-term average fluxes or interannual variations of oceanic origin. Typically, the calculations are unable to improve much upon the ocean "priors" that are tied to sparse ocean observations.

In the future, global biogeochemical data assimilation will doubtless follow the lead of physical climate data assimilation, progressing from atmospheric-based assimilation to coupled ocean/atmosphere assimilation. Inversion calculations will also progress from the goal of estimating surface fluxes to the goal of optimizing process models that depict these fluxes. Progress toward making coupled biogeochemical inverse calculations is urgently needed, not just to address improvements in CO_2 inverse calculations, but also to address a suite of important looming issues, such as ocean acidification, ocean deoxygenation, and climate impacts on ocean ecology. Coupled biogeochemical inverse calculations will require observing systems that can resolve ocean biogeochemical changes over broad space and long-time scales. The systems now deployed or planned (e.g. Argo floats, satellite systems, surface pCO_2 observations, repeat hydrography, time series, etc.) will provide essential components of this need. But a critical role will also be played by observations of atmospheric O_2.

The power of O_2 data is harnessed via the tracer Atmospheric Potential Oxygen ($APO \approx O_2 + 1.1CO_2$). The land biospheric effects on APO are near zero because of cancellation of the O_2 and CO_2 contributions. The observed trends in APO (see Figure), corrected for a small fossil-fuel effect, effectively constrain the combined exchanges of O_2 and CO_2 with the oceans. APO responds to ocean processes on the same space and time scales that influence atmospheric CO_2 concentration, but are not resolvable in CO_2 or its isotopes due to the high variability from the land. The 20-year records of APO reveal signals of ocean interannual variability not seen in other tracers or in hydrographic data. The continuity of these records will provide critically needed ocean-observing capability to aid in resolving threats to the ocean and the impacts on the carbon cycle.

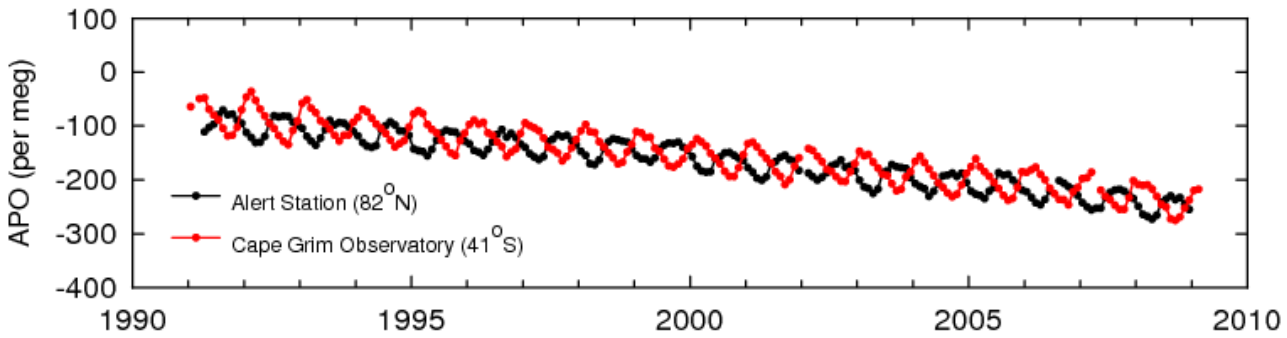

Figure 1. Observed trends in APO.