ESTIMATES OF ATMOSPHERIC POTENTIAL OXYGEN (APO) FLUXES BASED ON O₂/N₂ AND CO₂ CONCENTRATION MEASUREMENTS: WHAT CAN THEY TELL US ABOUT THE GLOBAL CARBON CYCLE?

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ABSTRACT
The global biogeochemical cycle of oxygen is closely linked to that of carbon dioxide, because key biological processes, as well as fossil fuel burning, occur with specific stoichiometric ratios. In the ocean, however, several processes – carbonate chemistry (buffer effect), physical transport (dilution), and warming/cooling (solubility changes) – decouple O₂ and CO₂ exchanges. Based on a decade of atmospheric O₂/N₂ and CO₂ data, we estimated spatial and temporal patterns of oceanic APO fluxes, using an inversion of atmospheric transport. Seasonal and interannual variations are interpreted in the light of climate variables.

ATMOSPHERIC POTENTIAL OXYGEN
The oceanic oxygen signal can be isolated using the tracer Atmospheric Potential Oxygen (APO) defined as

\[ \text{APO} = O_2 + 1.1 \cdot CO_2 \]  

from the amounts of oxygen and carbon [Stephens et al., 1998]. To the extent that the stoichiometric ratio of O₂ and CO₂ exchange during terrestrial photosynthesis and respiration is -1.1, APO is a conservative tracer with respect to the land biosphere.

METHOD
Atmospheric O₂/N₂ and CO₂ have been measured bi-weekly, weekly, or continuously at several locations (Fig. 1), using different experimental techniques. The inversion calculation estimates the APO flux distribution and variability in 1992-2003 that best matches the atmospheric data. Fluxes and atmospheric mixing ratios are linked by the TM3 atmospheric transport model (=4° latitude ×5° longitude), which is driven by 6-hourly meteorology from the NCEP re-analysis.

Fig. 1: Location of measurement sites for atmospheric O₂/N₂ and CO₂.
RESULTS
The inversion results (Fig. 2) show global variations in APO of ±150 Tmol per year, in good agreement with the variations computed directly from the atmospheric observations. The inversion distributes this variability equally between the Northern Extratropics, Tropics (20°S-20°N), and Southern Extratropics, in spite of the fact that the oceanic area of the Northern Extratropics is half that of the other two areas. This finding is in line with higher per-area variability in the Northern hemisphere identified by CO2 inversions, but in contrast to ocean process models.

In the Tropics, the inversion shows a clear outgassing of APO during the 1997-1998 El Niño event, consistent with reduced ventilation of the oxygen minimum. This El Niño signal is not visible in the individual atmospheric APO measurements. It is retrieved by the inversion from the differences in APO between stations.

The global mean APO variability is more than twice that estimated by ocean process models, far more than can be explained by the physical model deficiencies alone. APO inversion results suggest that process models have deficiencies in their estimates of flux variability, pointing particularly at the representation of biological fluxes in the northern hemisphere.

CONCLUSION
APO inversions can identify large-scale changes in the physical and biological processes in the ocean – processes responsible for variability of the ocean carbon cycle. APO inversions show variability in oceanic fluxes in all regions of the ocean which are poorly reproduced by process models. We discuss the reliability of these first results by comparing them with known climate variations, and we provide an analysis of the error based on a series of sensitivity analyses.

REFERENCE