ESTIMATES OF ATMOSPHERIC POTENTIAL OXYGEN (APO) FLUXES BASED ON O_2/N_2 AND CO_2 CONCENTRATION MEASUREMENTS: WHAT CAN THEY TELL US ABOUT THE GLOBAL CARBON CYCLE?

C. Rödenbeck[1], C. Le Quere[1,2], R.F. Keeling[3], Y. Tohjima[4], N. Cassar[5], A. Manning[1], M. Heimann[1]

[1] *Max Planck Institute for Biogeochemistry, D-07745 Jena (Germany)*
[2] *Now at the Univ. of East Anglia and British Antarctic Survey (UK)*
[3] *Scripps Institution of Oceanography, University of California, San Diego, California (USA)*
[4] *National Institute for Environmental Studies, Atmospheric Environment Division, Atmospheric Measurement Section, 16-2 Onogawa, Tsukuba 305-8506, Ibaraki (Japan)*
[5] *Department of Geosciences, Princeton University, Princeton, NJ 08544 (USA)*

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 stochiometric ratios. In the ocean, however, several processes – carbonate chemistry (buffer effect), physical transport (dilution), and warming/cooling (solubility changes) – decouple O_2 and CO_2 exchanges. Based on a decade of atmospheric O_2/N_2 and CO_2 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

$$APO = O_2 + 1.1 \cdot CO_2 \qquad (1)$$

from the amounts of oxygen and carbon [*Stephens et al.,* 1998]. To the extent that the stochiometric ratio of O_2 and CO_2 exchange during terrestrial photosynthesis and respiration is -1.1, APO is a conservative tracer with respect to the land biosphere.

METHOD
Atmospheric O_2/N_2 and CO_2 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.

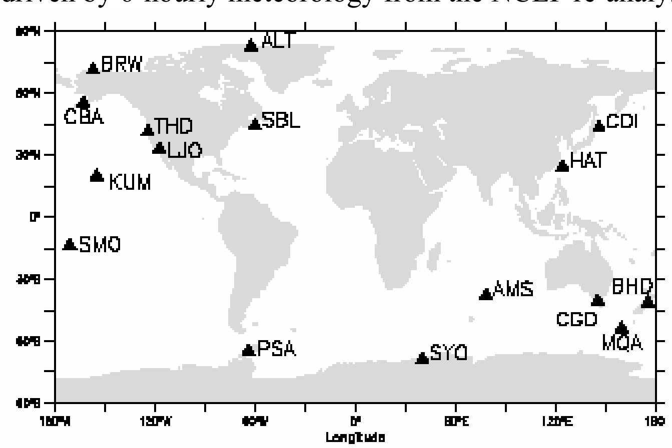

Fig. 1: Location of measurement sites for atmospheric O_2/N_2 and CO_2.

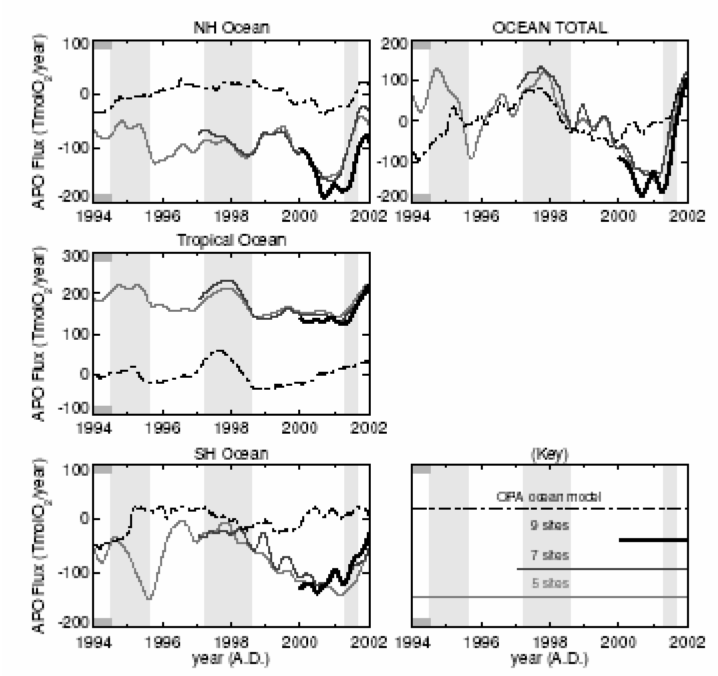

Fig. 2: Estimated fluxes based on different sets of observation sites. Fluxes are deseasonalized and filtered to highlight interannual variations. Different panels show fluxes integrated over different parts of the ocean, as well as the ocean total. Grey background stripes indicate positive El Niño phases. The results of an ocean process model are given for comparison (anomalies only).

Interannual variability in the 3 latitude bands mainly originate from the Pacific, partly because the atmospheric measurement sites are mostly located there.

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

Stephens B.B., R.F. Keeling, M. Heimann, K.D. Six, R. Murnane, and K. Caldeira, Testing global ocean carbon cycle models using measurements of atmospheric O_2 and CO_2 concentration, *Global Biogeochem. Cycles 12*, 213-230 (1998).