BIOLOGICALLY DRIVEN SOUTHERN OCEAN CARBON FLUXES AS OBSERVED BY ATMOSPHERIC O_2 AND CO_2 CONCENTRATIONS

B.B. Stephens[1], D.F. Baker[1], M. Battle[2], R.F. Keeling[3], A.C. Manning[4], and P.P. Tans[5]

[1]*National Center for Atmospheric Research, 1850 Table Mesa Dr., Boulder, CO 80307-3000, USA; stephens@ucar.edu*

[2]*Bowdoin College, Brunswick, ME, USA*

[3]*Scripps Institution of Oceanography, La Jolla, CA, USA*

[4]*Max Planck Institute for Biogeochemistry, Jena, Germany*

[5]*NOAA Climate Monitoring and Diagnostics Laboratory, Boulder, CO, USA*

ABSTRACT

Our understanding of biogeochemical and physical processes in the Southern Ocean, which are critically important to future anthropogenic CO_2 uptake and global climate, is limited by the sparse spatial and temporal coverage of existing oceanographic and atmospheric measurements. We will present high-precision horizontal atmospheric O_2 and CO_2 concentration gradients over the Southern Ocean from three independent observing networks. These measurements reveal that, relative to southern mid-latitudes and Antarctica, CO_2 concentrations over the Southern Ocean are high during winter and low during summer (Fig. 1). This suggests a seasonal variation between net CO_2 summertime uptake and wintertime release that is in disagreement with the T99 [*Takahashi et al.*, 2002] dissolved pCO_2 climatology, which predicts year-round CO_2 uptake, and with the OCMIP-2 biological ocean general circulation models [BOGCMs, *Doney et al.*, 2004], which either predict year-round CO_2 uptake or opposite seasonality with wintertime uptake and summertime release.

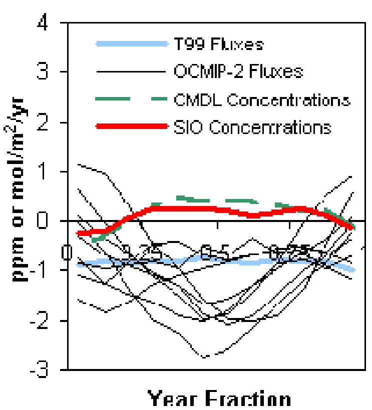

Fig. 1. Observed Southern Ocean CO_2 concentration gradients as defined in text, compared to CO_2 fluxes south of 40 S as predicted by the OCMIP-2 models and the T99 pCO_2 climatology.

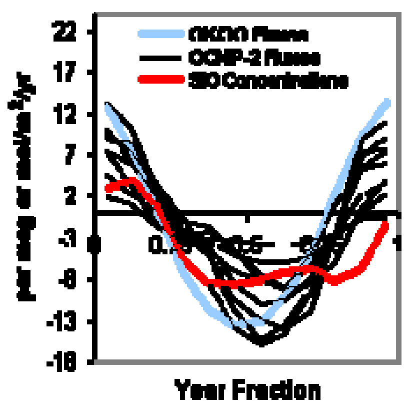

Fig. 2. Observed Southern Ocean O_2 concentration gradients, compared to O_2 fluxes south of 40 S as predicted by the OCMIP-2 models and the Garcia and Keeling dissolved O_2 climatology inverted by Gruber and Gloor.

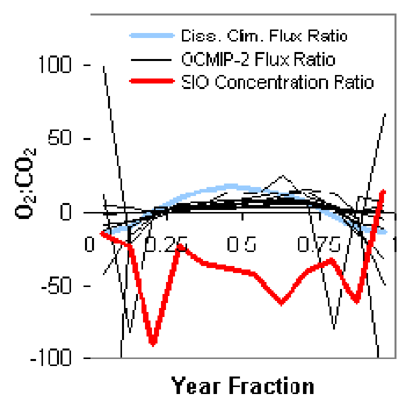

Fig. 3. Ratios between observed Southern Ocean O_2 and CO_2 concentrations compared to ratios between O_2 and CO_2 fluxes south of 40 S as predicted by the OCMIP-2 models and by the dissolved climatologies.

Atmospheric O_2 measurements can provide unique insights into the processes responsible for air-sea CO_2 exchange. Over the Southern Ocean, atmospheric O_2 gradients oppose those of CO_2, with elevated concentrations during summer and reduced concentrations during winter (Fig. 2). This combination suggests that Southern Ocean O_2 and CO_2 fluxes are dominated by photosynthesis during summer and by ventilation of respiration-influenced waters during winter. In contrast to CO_2, the seasonal atmospheric O_2 variations are well-matched by predictions of both dissolved O_2 climatologies [*Garcia and Keeling*, 2001; *Gruber and Gloor*, 2001] and the OCMIP-2 models. Most notably, atmospheric observations over the Southern Ocean show anti-correlated O_2 and CO_2 variations at all times of year, whereas dissolved gas climatologies and ocean models predict positively-correlated O_2 and CO_2 uptake for over six months during winter (Fig. 3). As others have suggested, the pCO_2 dataset likely suffers in the Southern Ocean from a lack of wintertime data. In the case of the OCMIP-2 models, it appears that errors in either physical or biological parameterizations may lead to a dominance of thermal forcing over biological forcing of Southern Ocean carbon fluxes.

To facilitate intercomparison, the biological parameterizations in the OCMIP-2 models were held constant across models to a simple PO_4 restoring scheme, so we will examine output from models with more sophisticated parameterizations. We will also present atmospheric transport modeling to identify regions influencing the observed concentration gradients, comparisons of these gradients to recently acquired wintertime pCO_2 measurements, and a discussion of the implications of the observations for global carbon budgeting.

METHODS

We define the concentration gradients shown in Figures 1-3 by comparing stations over the high-latitude Southern Ocean to stations immediately north and south. We include data from the following sites: South Pole (SPO), Halley Bay (HBA), Syowa (SYO), Palmer Station (PSA), Tierra del Fuego (TDF), Crozet Island (CRZ), Cape Grim (CGO), and Easter Island (EIC). For the SIO data, we plot monthly averages for the quantity PSA - mean(SPO,CGO) over the period 1998 through 2001. For the CMDL data, we plot monthly averages of the quantity mean(HBA,SYO,PSA,TDF,CRZ) - mean(SPO,CGO,EIC) over the period 1995 through 2002.

REFERENCES

Doney, S. C., et al. (2004), Evaluating global ocean carbon models: The importance of realistic physics, *Global Biogeochem. Cycles*, *18*, GB3017, doi:10.1029/2003GB002150.

Garcia, H.E. and R.F. Keeling (2001), On the global oxygen anomaly and air-sea flux, *J. Geophys. Res.*, *106(C12)*, 31155-31166, 10.1029/1999JC000200.

Gruber, N., M. Gloor, S.-M. Fan, and J. L. Sarmiento (2001), Air-sea flux of oxygen estimated from bulk data: Implications for the marine and atmospheric oxygen cycles, *Global Biogeochem. Cycles*, *15(4)*, 783-804, 10.1029/2000GB001302.

Takahashi, T., R.H. Wanninkhof, R.A. Feely, R.F. Weiss, D.W. Chipman, N. Bates, J. Olafsson, C. Sabine, and S.C. Sutherland (1999), Net sea–air CO2 flux over the global oceans: An improved estimate based on the sea–air pCO_2 difference, in: Yukihiro Nojiri (Ed.), Proceedings of the Second International Symposium, CO_2 in the Oceans (ISSN 1341-4356), Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Japan, pp. 9–14.