A DECREASING TREND IN NORTHERN HEMISPHERE CARBON UPTAKE SINCE 1992

J.B. Miller[1,2], P.P. Tans[1], J.W.C. White[3], K.A. Masarie[1], T.J. Conway[1], B.H. Vaughn[3], N. S. Suits[4], and J.T. Randerson[5]

[1]*NOAA Climate Monitoring and Diagnostics Laboratory, Boulder, CO, 80305 USA; john.b.miller@noaa.gov; Pieter.tans@noaa.gov; Kenneth.masarie@noaa.gov; Thomas.j.conway@noaa.gov*

[2]*Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder, CO 80309, USA*

[3] *Institute for Arctic and Alpine Research, University of Colorado, Boulder, CO 80309, USA; james.white@colorado.edu; bruce.vaughn@colorado.edu*

[4] *Department of Atmospheric Sciences, Colorado State University, Fort Collins, CO, 80523, USA; nsuits@atmos.colostate.edu*

[5] *Department of Earth System Science, University of California, Irvine, CA 92697, USA; jranders@uci.edu*

ABSTRACT

Increases in the north-south gradient of atmospheric CO_2 at Northern Hemisphere measurement sites of the NOAA/CMDL Global Air Sampling Network reveal a shrinking carbon sink. 14 of 16 low altitude sites show differences with South Pole increasing at a faster rate than can be explained by fossil fuel emissions, resulting in an average north-south difference at remote marine sites nearly 1 ppm larger in 2003 than in 1992. Regardless of whether this trend will persist, it shows that large changes in the carbon cycle can occur rapidly and is a strong indication of the tenuous nature of terrestrial carbon sinks.

INTRODUCTION

In atmospheric approaches to the carbon cycle, the latitudinal gradient of CO_2 at the Earth's surface is the fundamental constraint on the size of the mid-latitude carbon sink [*Keeling et al.*, 1989; *Tans et al.*, 1990]. The annual mean latitudinal gradient is caused primarily by the combustion of fossil fuels in the temperate Northern Hemisphere (TNH: 18°-53°N), where more than 90% of fossil fuel emissions occur [*Marland et al.*, 2003]. Simulations of the transport of fossil emissions across a suite of models [*Gurney et al.*, 2002] show differences between the TNH and the South Pole (SPO) averaging about 5 ppm. The second contributor to the annual mean gradient, and then the one in which we are interested in this study, is the net annual addition or removal of CO_2 from either the oceans or the terrestrial biosphere. The 'rectifier effect' also contributes to the gradient, but it is unlikely this would be the source of a trend.

We compute the annual mean difference between a given measurement site and SPO for each year of the measurement record and calculate its linear trend (Figure 1). SPO is chosen as the reference site because it is the furthest removed from sources and sinks of CO_2. Thus, changes in the difference between any other site and SPO likely reflect source/sink changes near the site. The time span for our study is 1992 – 2003, which reflects the time over which we have widespread measurements of both CO_2 and $\delta^{13}C$ in our network. Figure 1 shows that from 1992 – 2003, every site except one (MID; see Table S1), shows a positive trend. The average trend of all sites located in the marine boundary layer (MBL) is about 0.07 ppm yr^{-1}, which amounts to an aggregate change in the SPO difference of about 0.8 ppm over the entire period. Furthermore, the average trend at our continental sites is 0.17 ppm yr^{-1}, corresponding to a 2 ppm aggregate change. Most sites (10/16) show trends that are significantly different from zero at the two

sigma level, and all but two of the rest show trends significant at one sigma. Furthermore, the chance of randomly obtaining the distribution of slopes we observe, given an expectation of a slope of 0.04 ppm yr^{-1} due to just fossil fuel combustion, is less than 1% (based on a χ^2 goodness of fit test). Averaged across all our northern extra-tropical MBL sites, the difference from SPO increased from 2.8 to 3.6 ppm, between 1992 and 2003.

An examination of the trends in the differences from SPO reveals that the strongest part of the trends has occurred since 1997. From 1997 – 2003, the average trend among MBL sites was 0.09 ppm yr^{-1}, but most dramatically, non-MBL sites showed an average trend of 0.27 ppm yr^{-1}. Many new continental sites were added to the network between 1992 and 1997, and they contributed to the doubling in the average slope of the SPO differences. Nonetheless, the large difference in trends between MBL and non-MBL sites since 1997 suggests that the change in sink strength originated on land. We have also "corrected" the time series at our continental sites for fossil fuel emissions by using the elevation of carbon monoxide over the MBL average (interpolated at the same latitude) and a constant CO:CO_2 emission ratio of 20 ppb CO/ppm CO_2. We find that none of the observed trend at continental sites is attributable to local fossil fuel influences.

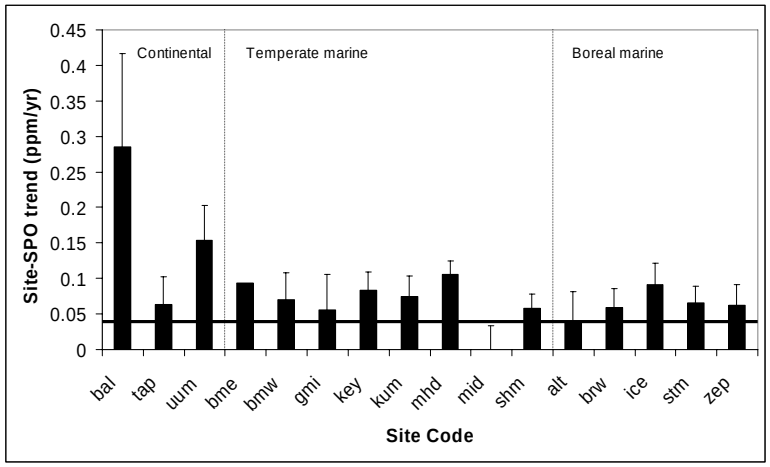

Fig. 1. Trends in annual mean CO_2 differences from South Pole (SPO) at low altitude extra-tropical measurement sites in the NOAA/CMDL Global Cooperative Air Sampling Network. Sites are divided into three categories: continental, temperate marine and boreal marine. The error bars represent the one-sigma uncertainty in the slope, and the line at 0.02 ppm yr^{-1} represents the simulated trend in the CO_2 difference between 18 – 53°N and SPO due to fossil fuel emissions.

REFERENCES

Gurney, K.R., R.M. Law, A.S. Denning, P.J. Rayner, D. Baker, P. Bousquet, L. Bruhwiler, Y.H. Chen, P. Clais, S. Fan, I.Y. Fung, M. Gloor, M. Helmann, K. Higuchi, J. John, T. Maki, S. Maksyutov, K. Marsarie, P. Peylin, M. Prather, B.C. Pak, J. Randerson, J. Sarmiento, S. Taguchi, T. Takahashi, and C.W. Yuen (2002), Towards robust regional estimates of CO_2 sources and sinks using atmospheric transport models, *Nature*, *415* (6872), 4.

Keeling, C.D., R.B. Bacastow, A.F. Carter, S.C. Piper, T.P. Whorf, M. Heimann, W.G. Mook, and H. Roeloffzen (1989), A three-dimensional model of atmospheric CO_2 transport based on observed winds, 1: Analysis of observational data, in *Aspects of Climate Variability in the Pacific and the Western Americas*, edited by D.H. Peterson, pp. 363, AGU, Washington, D.C.

Marland, G., T.A. Boden, and R.J. Andres (2003), Global, regional, and national fossil fuel CO_2 emissions, in *Trends: A compendium of data on global change*, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn.

Tans, P.P., I.Y. Fung, and T. Takahashi (1990), Observational constraints on the global atmospheric CO_2 budget, *Science*, *247* (4949), 1431-1438.