GLOBAL CARBON FLUXES INFERRED FROM THE CSIRO GLOBAL FLASK NETWORK: 1983-2004

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ABSTRACT
Stable isotope measurements of atmospheric carbon dioxide from the CSIRO global flask sampling program with improved traceability to the international primary reference material VPDB (Vienna Pee Dee Belemnite), and with improved uncertainty estimates, are presented. The measurements have been used with an improved time dependent inversion model to reassess terrestrial and oceanic contributions to the interannual variability in atmospheric CO_2.

INTRODUCTION
On contemporary timescales, variations of $^{13}C/^{12}C$ in atmospheric carbon dioxide ($\delta^{13}C$) primarily reflect the release of photo-synthetically fractionated carbon from respiring, combusting or decomposing terrestrial plant material, including fossil sources. Cycling of CO_2 through large carbon reservoirs ("gross exchange") introduces time-dependent modification of the atmospheric isotope perturbations through various processes. Because of this, the isotopic composition of atmospheric CO_2 provides a valuable contribution towards the understanding and management of global and regional carbon budgets.

However, isotopic measurements are susceptible to systematic bias and several studies have shown discrepancies between CO_2 isotope measurement laboratories, including the four laboratories contributing the bulk of atmospheric CO_2 isotopic measurements to global databases [*Allison, et al*, 2003, *Masarie, et al*, 2001, *Levin, et al*, 2003], that could lead to incompatible CO_2 carbon isotope data sets. An example of conflicting biogeochemical interpretation, depending on the source of CO_2 carbon isotope data, has been presented by *Le Quere et al* [2003].

MEASUREMENTS OF STABLE ISOTOPIC COMPOSITION
Traceability of atmospheric stable carbon isotope measurements is clearly a key issue, both in establishing a sufficiently precise link for $\delta^{13}C$ measurements to a primary standard, eg the VPDB scale, to allow direct comparison of isotopic measurements from different laboratories, and in propagating the calibration standards necessary to maintain high precision over long periods of time (decades). We have performed a thorough investigation of twenty years' data and developed procedures that include physically based models of systematic bias, to improve the traceability of all CSIRO stable isotope measurements to the VPDB reference material. The implementation of these procedures leads to a revision of our previously published $\delta^{13}C$ data with improved measurement uncertainty estimates for measurements from all sites in the CSIRO global flask sampling network (Fig. 1).

INVERSION OF ATMOSPHERIC CO_2 AND $\delta^{13}C$
We use the revised data and improved uncertainty estimates to reassess terrestrial and oceanic contributions to the interannual variability in atmospheric CO_2 using an updated version of the previously published time dependent inversion model [*Rayner, et al*, 1999]. Improvements to the method are: a higher resolution in both the transport model and the source functions, spatial structure in both the ^{13}C discrimination and disequilibrium and, most importantly, the treatment of dilution of ^{13}C flux anomalies by equilibration with underlying reservoirs.

Preliminary results from the inversion using $\delta^{13}C$ data from eight sites from the CSIRO global flask sampling network in combination with 69 CO_2 data records [GLOBALVIEW-CO_2, 2003] suggest the source of anomalous growth rates for atmospheric CO_2 concentration observed in 2002 and 2003 was terrestrial fluxes in both years, but 2002 was driven by the tropics and 2003 by the northern continents, with Eurasia being the main source rather than Western Europe or North America.

We have also compared the interannual variability of the net terrestrial fluxes obtained using the $\delta^{13}C$ and CO_2 concentration data from nine of the CSIRO flask sampling sites (1992-2000) with the net terrestrial ecological flux produced from a coupled atmosphere/biosphere model [Y.P. Wang, *personal communication*]. While the coupled model approach does not consider biomass burning or land-use change, there is good agreement between the two approaches in the timing and magnitude of large releases of carbon to the atmosphere (1994, 1997 and 1998).

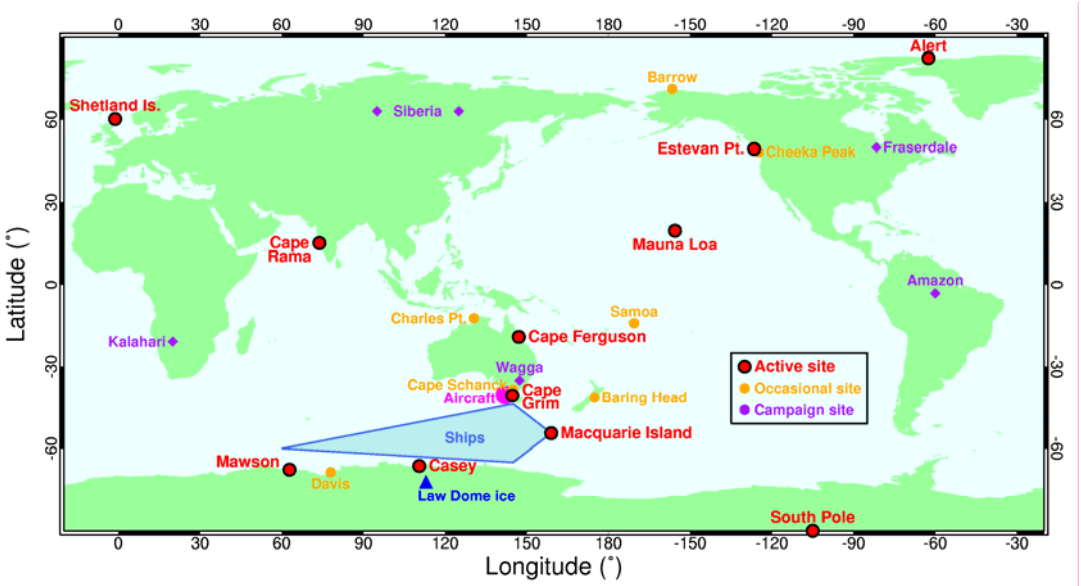

Fig. 1. Flask sample collection locations in the CSIRO global network.

REFERENCES

Allison, C.E., R.J. Francey, J.W.C. White, B. Vaughn, M. Wahlen, A. Bollenbacher, and T. Nakazawa (2003). What have we learnt about stable isotope measurement from the IAEA CLASSIC? In: Toru, S. and Kazuto, S., editors. *Report of the eleventh WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracer Measurement Techniques; Tokyo, Japan*. [Geneva]: World Meteorological Organization; 2003: 17-30. Global atmosphere watch. v. no. 148 ; WMO/TD ; no. 1138.

GLOBALVIEW-CO_2 Cooperative Atmospheric Data Integration Project - Carbon Dioxide. CD-ROM, NOAA CMDL, Boulder, Colorado (2003). [Also available on Internet via anonymous FTP to ftp.cmdl.noaa.gov, Path: ccg/co2/GLOBALVIEW].

Le Quéré, C., O. Aumont, L. Bopp, P. Bousquet, P. Ciais, R.J. Francey, M. Heimann, C.D. Keeling, R.F. Keeling, H. Kheshgi, P. Peylin, S.C. Piper, I.C. Prentice, and P.J. Rayner (2003). Two decades of ocean CO_2 sink and variability, *Tellus*, 55B, 649-656.

Levin, I., U. Langendorfer, M. Schmidt, C. Facklam, M Ramonet, C. Bourg, V. Kazan, P. Ciais, R. Langenfelds, C. Allison, R. Francey, A Jordan, W. Brand, R. Neubert, H. Meijer, and K. Holmen (2003). EuroSiberian Carbonflux – CO_2 intercomparison. *Report of the 11th WMO/IAEA Meeting of Experts on Carbon Dioxide Concentration and Related Tracers Measurement Techniques, Japan*, S. Toru, and S. Kazuto (editors) (Global Atmosphere Watch, no. 148 ; WMO/TD ; no. 1138) . [Geneva]: World Meteorological Organization. p. 37-54.

Masarie, K.A., R.L. Langenfelds, C.E. Allison, T.J. Conway, E.J. Dlugokencky, R.J. Francey, P.C. Novelli, L.P. Steele, P.P. Tans, B. Vaughn, and J.W.C. White (2001). NOAA/CSIRO Flask Air Intercomparison Experiment: A strategy for directly assessing consistency among atmospheric measurements made by independent laboratories, *J. Geophys. Res.*, 106, 20445-20464.

Rayner, P.J., I.G. Enting, R.J. Francey, and R.L. Langenfelds (1999). Reconstructing the recent carbon cycle from atmospheric CO_2, $\delta^{13}C$ and O_2/N_2 observations, *Tellus*, 51B, 213-232.