$\Delta^{14}C$ of Atmospheric CO_2 at Point Barrow, Alaska

Xiaomei XU (xxu@uci.edu) **and Susan E. TRUMBORE**
Earth System Science Department, University of California, Irvine, CA 92697/USA

INTRODUCTION

$\Delta^{14}C$ is a useful tracer for studying the carbon cycle, especially for discriminating between fossil and biosphere carbon emissions. However observations of $\Delta^{14}C$ variation in atmospheric CO_2 are available for only a few locations. We report here a high precision and high temporal resolution $\Delta^{14}CO_2$ record obtained at the Point Barrow Observatory, Alaska (71.3° N, 156.5° W) from July 2003 to present. These data will enhance our understanding of the patterns of atmospheric $^{14}CO_2$ distribution and its seasonal variation and provide observational constraints for the roles of ^{14}C isotope disequilibirum among its various sources and sinks.

SAMPLE COLLECTION AND MEASUREMENT

Sample collection was through the NOAA/ESRL flask network program where many other trace gases and isotopes were also measured, such as CO, CO_2 mixing ratios and $\delta^{13}C$ and $\delta^{18}O$ of CO_2. Two biweekly samples were collected before 2008, and after that, one sample was collected weekly. Air samples were collected into a pre-evacuated 6L canister which was then pressurized to ~ 2 atms by an oil free pump.

Upon returning to the lab, CO_2 was cryogenically purified on a vacuum line (see Fig. 1), subsampled for $\delta^{13}C$ analysis, and then reduced to graphite using zinc reduction method [1]. The graphite was analyzed for $\Delta^{14}C$ at the W.M. Keck AMS facility at UC Irvine with a high precision of ~2 ‰ at the current atmospheric ^{14}C level (see Table 1). The use of in-situ AMS-$\delta^{13}C$ for fractionation correction has helped to achieve the high precision.

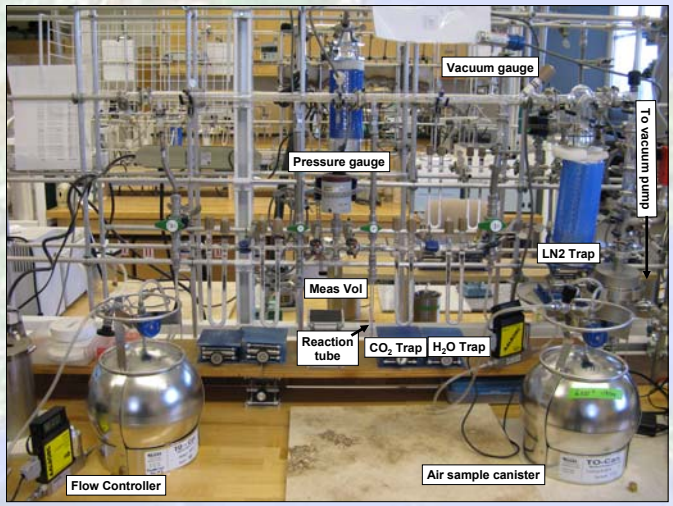


Fig. 1 Vacuum system for extracting CO2 from air samples. Two samples can be processed simultaneously.

Quality Control: In our 40-position wheel, we routinely use 7 OXIs as our primary standard, and 2 OXIIs, 1 ANU and 1 FIRI J as secondary standards for quality check. Table 1 shows the standards run in all 15 Barrow air sample wheels without outliers removal. The secondary standards agree well with the consensus values [2]. The reproducibility of all OXIs is ~ 2 ‰ (1 σ standard deviation). The relative error is about 0.2 to 0.25%. The precision is generally better than our regular wheels[2] because we pick a good AMS performing time to run the air sample wheels and normally run them for longer time to get better statistics. In order to minimize possible wheel to wheel offset on the time series, we also run some samples collected earlier together with the samples collected later.

Table 1 Results of standards

OXI	Fraction Modern
Consensus Value	1.0398
Lab Average	1.0398
Standard Deviation	0.0021
% Error	0.20
n	105

OXII	Fraction Modern
Consensus Value	1.3407±0.0019
Lab Average	1.3395
Standard Deviation	0.0025
% Error	0.19
n	25

Firi J	Fraction Modern
Consensus Value	1.1069±0.0004
Lab Average	1.1078
Standard Deviation	0.0026
% Error	0.23
n	15

Acknowledgement: We thank J.R. Southon and G.M. Santos for their help in AMS measurements, and the W. M. Keck foundation, the NSF Carbon Cycle Program, and UC Irvine for financial support.

RESULTS AND DISCUSSION

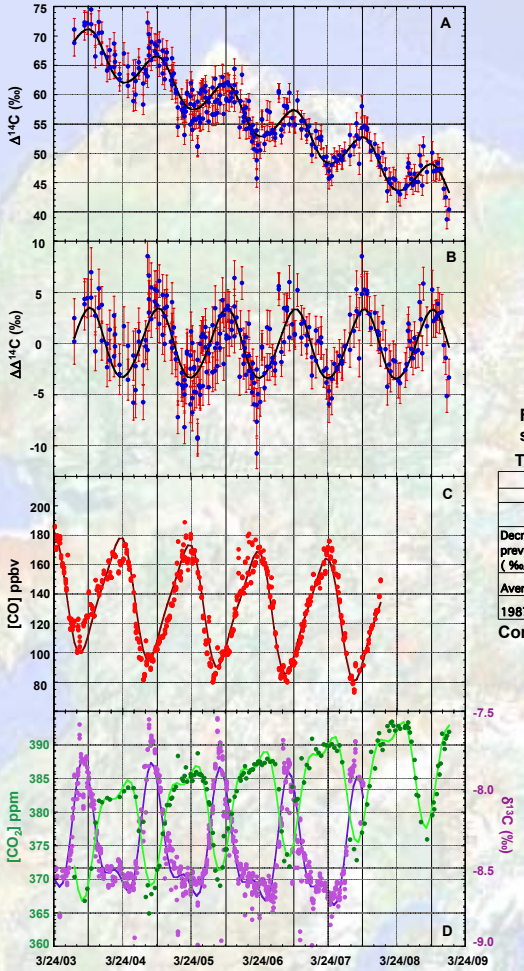


Fig. 2 A: $\Delta^{14}C$ time series from 2003 to 2008 at Pt. Barrow; B: Detrended $\Delta^{14}C$ time series; C: CO mixing ratio (main source from fossil fuel burning) time series; D: CO_2 mixing ratio and $\delta^{13}C$ records (NOAA ESRL DATA). Lines are unweighted least squares fits to a quadratic polynomial (which represents the long-term trend) and additional harmonic terms (which represent the average seasonal cycle) [3].

During the collection period, $\Delta^{14}C$ decreased by ~5‰/year, to a final value of ~42‰ in Dec-2008. We find distinct seasonal cycles for $\Delta^{14}CO_2$, with a broad minimum around Mar-Apr and a maximum in Sep-Oct with an amplitude of ~10‰. This seasonal pattern is variable from year to year. Increasing ^{14}C values may reflect injection of stratospheric air in April and May, and higher soil respiration with enriched $^{14}CO_2$ between May to Aug; rapid declines may be due to reduction in soil respiration and changes in the poleward advection of fossil fuel burned in the winter months. $^{14}CO_2$ seasonal cycle lags those of CO (Fig. 2) and CO_2 by ~ one month and half month respectively. A summary of the average seasonality of $\Delta^{14}CO_2$ is shown in Table 3. The Barrow ^{14}C record compares well with that from Niwot Ridge (NWR [4], Fig. 3).

Comparing to other NH $\Delta^{14}CO_2$ records

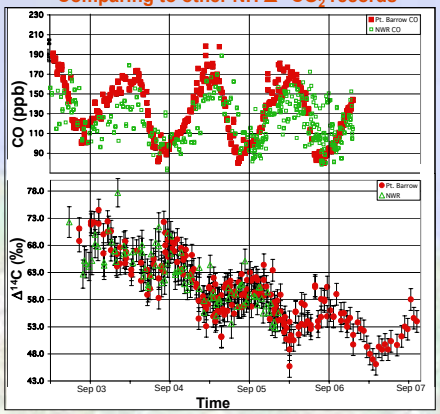


Fig. 3 Comparison of $\Delta^{14}CO_2$ record at Barrow with that in Niwot Ridge (NWR)[4]. The $\Delta^{14}CO_2$ seasonal cycles are more distinct at Barrow, and so are the CO cycles.

Factors controlling the present short-term atmospheric $\Delta^{14}CO_2$:

Sources of high $\Delta^{14}C$
- Stratosphere injection
- Exchange with terrestrial biosphere

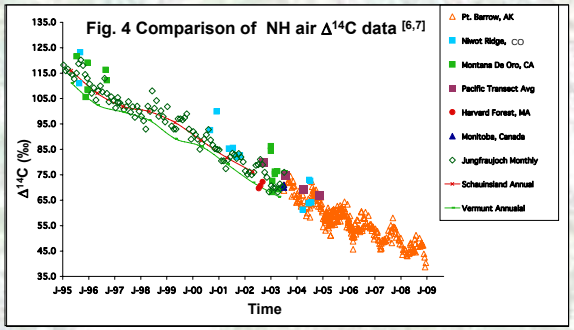
Sources of low $\Delta^{14}C$
- Fossil fuel burning
- Exchange with the ocean

Other influence
- Atmospheric circulation

Table 3 Annual decrease in $\Delta^{14}CO_2$ and the characteristics of the fitted average seasonal cycles

	Average $\Delta^{14}C$ (‰)						Fitted Average Seasonal Cycle			
	2003	2004	2005	2006	2007	2008	2 x Amplitude (‰)	Max Date	Min Date	Ref
	70.8±2.2	65.1±2.9	58.5±2.8	54.4±3.0	50.9±2.8	45.9±2.6	7.1±0.2	Sep28 ± 8 d	Mar24 ± 5 d	This work
Decrease from previous year (‰/yr)		5.7	6.6	4.1	3.5	5				
Average annual decrease (‰/yr):				5.0 ± 1.1						
1987 to 1989 annual decrease (‰/yr):				9.2 [5]			12.0 ± 1.5	Aug23 ± 7 d	Apr 17 ± 5 d	Meijer et al., 2006

Comparing to the earlier record, the current cycles have smaller amplitudes and later max date.



CONCLUSIONS

1. Our $^{14}CO_2$ results at Pt. Barrow are consistent with published records from North America [4, 5] and from Europe [6,7] (Fig. 4).
2. The high precision and high resolution time series from Point Barrow displays distinct seasonal cycles of $^{14}CO_2$, and allows us to analyze the seasonality change over time. This may help us to understand the various sources and sinks of $^{14}CO_2$.
3. Our record adds to the few available records worldwide to provide observational constraints for the roles of ^{14}C isotope disequilibirum among different reservoirs, and hopefully can enhance our understanding of the patterns of atmospheric $^{14}CO_2$ distribution and its seasonal variation [8].

REFERENCES

1. Xu, X., S E. Trumbore, S Zheng, JR Southon, KE McDuffee, M Luttgen, JC Liu (2007) Modifying a sealed tube zinc reduction method for preparation of AMS graphite targets: Reducing background and attaining high precision. Nuclear Instruments and Methods in Physics Research B 259, 320–329.
2. Xu, X., M S. Khosh , K C. Druffel-Rodriguez, S E. Trumbore and J R. Southon (2009) Is the consensus value of ANU too high? Poster in 20th International Radiocarbon Conference, Hawaii.
3. Tyler, S C, A L Rice and H O Ajie (2007) Stale isotope ratios in atmospheric CH4: Implications for seasonal sources and sinks. JGR vol. 112, D03303.
4. Turnbull, JC, S Lehman, JB Miller, RJ Sparks, JR Southon and PP Tans (2007) A new high precison $^{14}CO_2$ time series for North American continental air. JGR vol. 112, D11310.
5. Meijer H A J. M H Pertuisot and Jvan der Plicht (2006) High-accuracy 14C measurements for atmospheric CO2 samples by AMS. Radiocarbon 48(3), 355-372.
6. Levin, I. and V. Hesshainer (2000) Radiocarbon – A unique tracer of global carbon cycle dynamics, Radiocarbon, 42(1), 69-80.
7. Levin, I. and Kromer, B. (2004) The Tropospheric $^{14}CO_2$ level in Mid-Latitudes of he northern hemisphere (1959-2003), Radiocarbon, 46(3), 1-12.
8. Randerson, J.T., I.G. Enting, E.A.G. Schuur, K. Caldeira, and I.Y. Fung (2002) Seasonal and latitudinal variability of troposphere $\Delta^{14}CO_2$: Post bomb contributions from fossil fuels, oceans, the stratosphere, and the terrestrial biosphere. Global Biogeochem. Cycle, 16(4), 1112-1130.