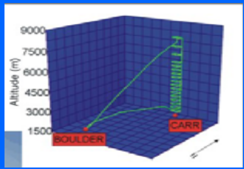

Constraining the north American sink with CO_2 measurements from the NOAA/ESRL Aircraft Network

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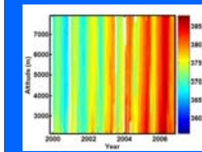
6 Year Record at Briggsdate, CO



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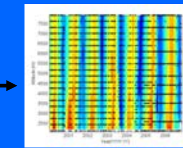

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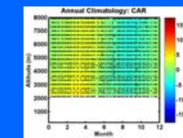


Introduction

Over the past 12 years the NOAA/ESRL Global Monitoring Division has been maintaining an aircraft network to make discrete measurements of air from 500 meters above ground to the 8000 meters. The backbone of the aircraft network is the flask packages that enable analysis CO_2, CO, SF_6, N_2O, H, CH_4, $^{13}CO_2$, and $C^{18}O_2$ of all at a common lab in Boulder, CO. At present, roughly 18 sites are being sampled every two to three weeks as a part of the North American Carbon Program.

Here, we the annual climatology developed from aircraft profiles to develop a full 3D CO_2 atmospheric distribution together with a novel budgeting approach to circumvent the traditional weaknesses of atmospheric inversions and derive an estimate of the North American sink independently from other approaches.

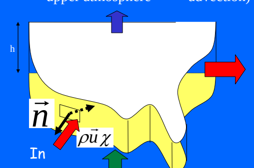
Abstract:

Profiles of CO_2 mixing rations collected from the NOAA/ESRL Aircraft Program are unique in their ability to constraint estimates of the North American carbon sink. This three dimensional dataset which reaches as far north as 65ºN and as far south as 27ºN between 500m and 8000m above ground level provides a valuable picture of the seasonal changes in CO_2 mixing rations over North America which does not rely on vertical and horizontal transport estimates typically used for inverse estimates of the North American carbon sink. The timing, amplitude and spatial distribution of CO_2 mixing ratios up to 8000 m at 19 aircraft profiles sites throughout North American not only provides an excellent benchmark for inverse flux estimates but also provides the opportunity for an independent estimates of the North American carbon sink when coupled with mean wind climatologies. Here we present a novel budgeting approach to estimate land-to-atmosphere fluxes. This approach circumvents most of the weaknesses of traditional atmospheric inversion, by relying mostly on CO_2 vertical data and wind distribution. We find a moderate sink of 0.51±0.39 GtC.yr^{-1} compared to other estimates for the period 2004-2006, with the highest uptake occurring in the South-East deciduous region, the agricultural mid-west states and the South of the boreal region.

Annual Climatology

This study uses a compilation of all the data CO_2 data from the NOAA/ESRL Aircraft Network. In order to take advantage of the fact that data collected in the NOAA/ESRL Aircraft Network has been discontinued at some sites due to lack of funding and logistics all measurements have been adjusted to one common year (2004) using the Mona Loa surface site measurements. The annual climatology has been constructed by binning each "adjusted" profile by month. The final product is an annual climatology that reflects measurements from as many years as aircraft profiles have been done at that site. Black dots in the annual climatology show the sampling density that makes up the climatology.

Direct Carbon Budgeting Approach



$$dC/dt = (F^h_{in} - F^h_{out}) - F_{vertical} + F_{surf}$$

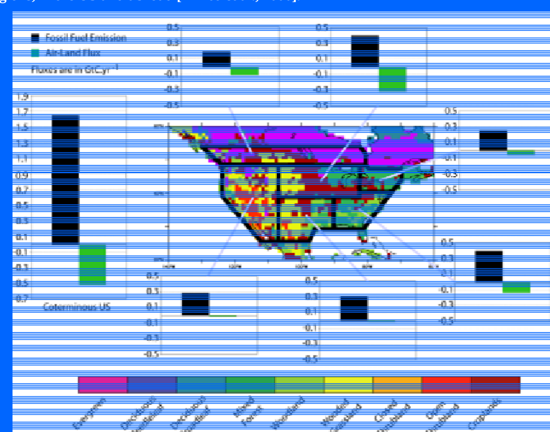
Observations aircrafts + towers.

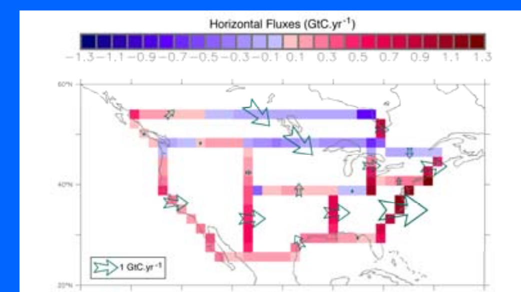
?

We first interpolate the profiles using a Kriging geostatistical interpolation method to obtain the 3D distribution of CO_2 across coterminous North America, up to 55°N. This northern limit comes from the location of the stations, which only cover the coterminous US and South of Canada. We then use a Direct Carbon Budgeting Approach (DCBA) [*Crevoisier* et al., 2006; above] to compute surface fluxes from the interpolated CO_2 fields. DCBA puts a control volume on top of North America, balances air mass flows into and out of the volume and solves for the surface fluxes. This method relies mostly on reanalyzed wind distribution and does not require numerical solution of the tracer transport equation (as done by atmospheric transport models) or prior flux estimates, which are used by the traditional approach to regularize the inverse calculations in an attempt to reduce the large uncertainties in flux estimates.

Regional Flux Estimates

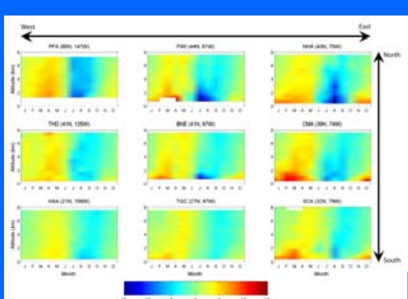
By dividing the control volume in various regions (below), we find that the sinks are mainly distributed in three regions: mid-west states (52%), which are characterized by extensive agriculture; South-East regions (22%) where most of the deciduous forests are located; and the South of the boreal region (18%). The strong sink in the agricultural region may be attributed to the differences in the spatial distribution of agricultural production and agricultural consumption: a strong atmospheric uptake by crops during the growing season in the mid-western states, while the release of carbon associated with consumption of agricultural products occurs in other regions, in the US and abroad [*Prince* et al., 2000].





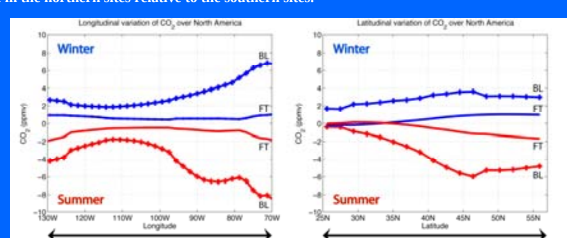
North American Fluxes of CO_2

The annual mean of carbon fluxes due to horizontal advection along the edges of the control volume and between various regions is plotted in GtC.yr^{-1} (above). On average, high horizontal outgoing fluxes are found along the East Coast. From the variation of carbon in the volume and the advective fluxes, we find a surface flux of CO_2 into the volume of 1.22±0.39 GtC.yr^{-1}. Assuming that fossil fuel emissions for the same period is 1.73±0.04 GtC.yr^{-1} [*Blasing* et al., 2007], we estimate a carbon sink in coterminous North America (up to 55°N) of 0.51±0.39 GtC.yr^{-1}, for the period January 2004-December 2006. This value does not include the outflow of CO_2 at 8 km due to convection, which is not estimated from the data. Simulations performed by various models yields an additional convective outflow of 0.10 GtC.yr^{-1}, giving a sink in the volume of 0.61 GtC.yr^{-1}. For the coterminous US only, the sink is 0.51 GtC.yr^{-1}.



Trends in CO_2 Profiles

These two figures demonstrate the variability in the seasonal cycle with latitude and longitude. The largest change in seasonal amplitude occurs between west coast and east coast sites. This is brought on by prevailing west to east transport of air masses across North America. There is also a significant increase in seasonal amplitude in the northern sites relative to the southern sites.



Conclusion

Our result confirms the existence of a moderate sink of carbon in North America, which value and location are now reaching a consensus. Comparison with previous estimates is limited by the fact that previous studies cover a different time period, generally the beginning of the 90's, hence ten years before the period considered here. However, two studies focusing on inter-annual variation of the fluxes and extended to 2006 [*Baker* et al., 2006; *Roedenbeck* et al., 2003] have shown that, even if the value of the land uptake in North America still differ substantially from one study to the other, it is similar between the Transcom period (1992-96) and our period. The absolute value of our estimate is near the lower end of the previous estimates (Table), which may indicate a more moderate sink in North America than previously estimated from traditional atmospheric inversions. Our estimate agrees well with forest-inventories based estimate of the SOCCR [*Pacala* et al., 2007], which found an atmospheric sink of 0.574 GtC.yr^{-1} in the coterminous US, with half of the sink due to the regrowth of forest in the East [*Houghton and Hackler*, 2000].

Study	Temperate NA sink	Global Sink[a]	
Pacala et al. 2001	- 0.71 to –0.37	- 0.90	1980- 1989
Fan et al. 1999	- 1.2 ± 0.4	- 2.3	1988 - 1992
Gurney et al. 2002	- 0.81 ± 0.72		
Gurney et al. 2004	- 0.89 ± 0.39	1.67	1992 - 1996
Baker et al. 2006	- 1.26 ± 0.23		
Jacobson et al. 2007	- 0.93 ± 0.71		
This Study	- 0.51 ± 0.39	-1.14	2004 - 2006