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Carbon fluxes and transport in North America: A new perspective from three-dimensional CO_2 sampling

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By yielding a three-dimensional coverage of the continent, the new sampling strategy of atmospheric CO_2 vertical profiles over North America from the NOAA/ESRL Global Monitoring Division aircraft network gives a unique opportunity to study mass exchange pathways in the troposphere across North America and to design new methods for estimating surface fluxes.

We use regular aircraft measurements of vertical CO_2 profiles (0-8km) performed by NOAA/ESRL Global Monitoring Division at 19 locations, covering most of North America, once to twice a month since 2004, in the framework of the North American Carbon Program. Their analysis reveals strong signatures of CO_2 exchanges over the continent: strong CO_2 gradient between the boundary layer and the free troposphere, South to North and West to East CO_2 gradients due to transport and flux distribution vegetation uptake and respiration, and fossil fuel emissions. Based on the clear coherence of the spatial patterns in the data, we use analyzed wind fields to estimate the transport and surface fluxes creating this mole fraction difference and to highlight mass exchange pathways over North America.

By balancing air mass in- and outflows into a control volume put on top of North America and solving for the surface fluxes, we find a moderate sink of $0.51 \pm 0.39 PgC.yr^{-1}$ for the period 2004-2006 for the coterminous US, in excellent agreement with forest-inventories based estimates of the first North American State of the Carbon Cycle Report (SOCCR), and averaged climate conditions. We find that the highest uptake occurs in the Midwest states and in the Southeast. This partitioning is in good agreement with estimates of crop uptake, which proves to be a significant part of the US atmospheric sink, and of secondary forest regrowth in the East.

Provided that vertical profile measurements are continued, our study offers an independent means to study interannual variation of the tropospheric CO_2 across North America and to link regional carbon fluxes to climate drivers.