Gradients of Column CO\textsubscript{2} Across North America from Aircraft and Tall Tower Measurements in the NOAA/ESRL Global Greenhouse Gas Reference Network

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This study analyzes seasonal and spatial patterns of column CO\textsubscript{2} over the North America using \textit{in situ} aircraft and tall tower measurements from the NOAA/ESRL Global Greenhouse Gas Reference Network over the period of 2004 to 2015. The long-term trend of background CO\textsubscript{2} from Mauna Loa Observatory is first subtracted from all measurements before comparisons. We found that the largest spatial gradients of CO\textsubscript{2} among the seven regions we defined across North America appear below 2km during summer time, while upper layer data (above 5km) show little contribution to spatial gradients. Although individual CO\textsubscript{2} profiles have relatively large variability across different heights, the long-term mean profiles show clear seasonal propagations of surface signals to levels above. Strong seasonality also exists on the time series of column averaged CO\textsubscript{2} from aircraft measurements. Large spatial gradients of long-term mean column CO\textsubscript{2} mainly occurred during June to August with strong summer drawdowns. Since Carbon Tracker modeled CO\textsubscript{2} agrees well with our aircraft measurements and AirCore measurements, modeled CO\textsubscript{2} from upper layer (~ 340 mbar to 0 mbar) are utilized with aircraft and tall tower data to produce the whole atmospheric column CO\textsubscript{2} (XCO\textsubscript{2}). We found that the XCO\textsubscript{2} gradients across North America mainly reflect the large-scale circulation patterns instead of only surface source and sink. The long-term mean summer drawdowns at the northern regions are stronger by ~ 3ppm than the southern regions. This spatial gradient of XCO\textsubscript{2} is only half of the amount reported in a recent study in Europe (Reuter et al., 2014).

**Figure 1.** Aircraft and Tall Tower Sites in the NOAA/ESRL Global Greenhouse Gas Reference Network that are analyzed in this study. Seven regions are defined for spatial comparisons.

**Figure 2.** Long-term mean XCO\textsubscript{2} calculated from aircraft and tall tower measurements combined with upper levels Carbon Tracker modeled data. B1 to B7 in figure legend represent the regions in Figure 1.