Characteristics and Mechanisms of Atmospheric CO_2 Variations during Summer Frontal Passages

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Mid-latitude cyclones and the associated frontal passages mix long-distance transport of atmospheric CO_2 with local sources and sinks via horizontal advection, convergent lifting, and cumulus convection. These synoptic scale weather phenomena create sharp gradients in atmospheric CO_2 mole fractions along frontal boundaries. The quantitative studies of the net transport of CO_2 by these weather systems have been limited. The Atmospheric Carbon and Transport (ACT) – America aircraft campaigns were designed to sample the horizontal and vertical distributions of greenhouse gas across frontal boundaries and within midlatitude cyclones in three regions of the eastern United States. These data are enabling a careful observational and numerical study of the atmospheric CO_2 transport associated with frontal passages.

Here we use aircraft data and atmospheric transport models to examine CO_2 transport along frontal boundaries observed during the summer of 2016. The airborne *in situ* measurements show 5–30 ppm difference in the atmospheric boundary layer and up to 5 ppm in the free troposphere across the frontal boundaries. Using a high-resolution regional model, we further investigate the mechanisms of the CO_2 transport during these summer cold fronts. The sign of the large-scale mole fraction gradients is simulated reliably, and appears to be caused by a combination of advection of the seasonal latitudinal gradient in CO_2, and regional fluxes, mainly biological but with fossil contributions, that reinforce this gradient. Biogenic fluxes appear to play a major role in the high CO_2 band found in advance of the front, suggesting that observations of this phenomenon could provide a strong constraint on regional biological CO_2 fluxes. The majority of CO_2 transport is attributed to horizontal advection, but cumulus-permitting simulations show an increased contribution to vertical advection. Additional future analyses will explore the ability of airborne lidar and polar-orbiting satellites to capture these frontal CO_2 structures.

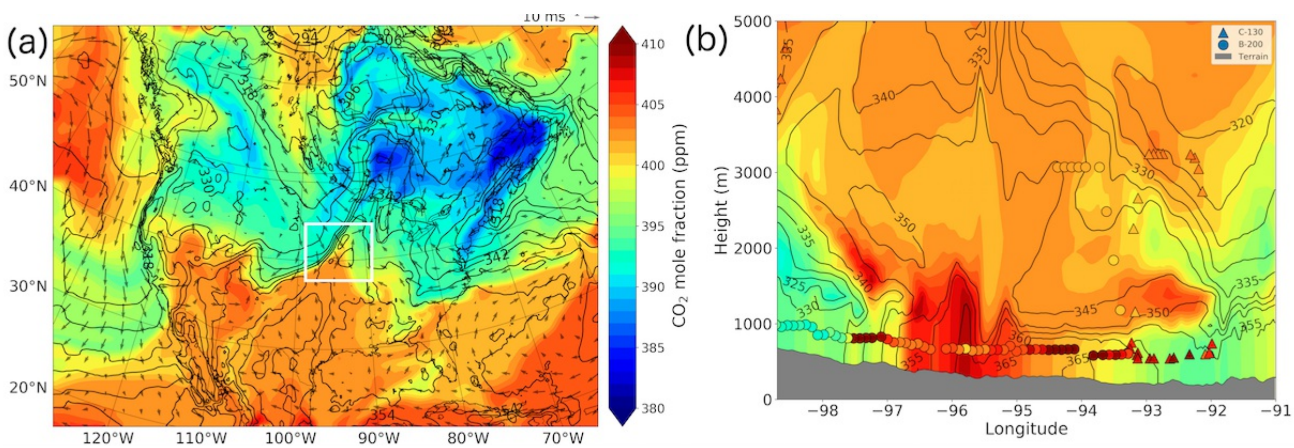

Figure 1. CO_2 distributions along a summer cold front over the Midwest region. (a) Synoptic view of the atmospheric boundary layer CO_2 mole fractions (shaded), winds (vectors), and equivalent potential temperature (contours) generated by a 27-km resolution WRF-Chem simulation. (b) Cross-section of the CO_2 mole fractions (shaded) and equivalent potential temperature (contours) generated by a three-km resolution WRF-Chem simulations nested within (white box) the 27-km resolution simulation. Aircraft observations are overlaid on the vertical cross-section.