Observations of Greenhouse Gas Changes across Summer Frontal Boundaries in the Eastern United States

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Objectives:

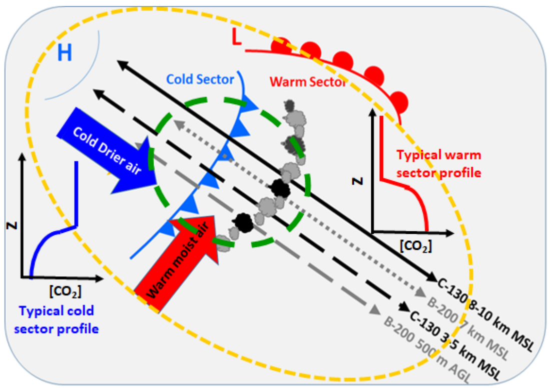
- ❖ Quantify the GHG structure of summer, mid-latitude frontal passages using measurements from ACT-America (Atmospheric Carbon and Transport-America) 2016 summer field experiment
- ❖ Investigate the similarity of these GHG structures across events and regions of the country
- ❖ Define new metrics that can be used to evaluate numerical simulations of GHG-weather interactions and the associated atmospheric transport.

Why is this important:

- Large uncertainty in atmospheric inversions exists due to sparse atmospheric observations, uncertainty in atmospheric transport, and uncertain prior flux estimates.
- All midlatitude atmospheric observations exist within the context of synoptic weather systems, but no prior observations of the GHG structure within these weather systems existed.
- This study provides benchmark metrics of GHG weather that can be used to evaluate the atmospheric transport and carbon flux simulations used to interpret long-term atmospheric carbon observations and conduct atmospheric inverse flux estimates.

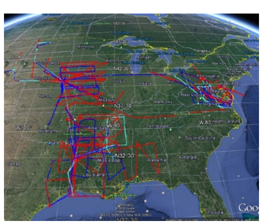
Methods:

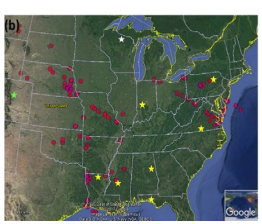
Schematic illustrating ACT research flight patterns for frontal passage cases crossing cold front boundaries at 3-4 different altitudes around a classical mid-latitude cold front passage and collecting high-resolution measurements of greenhouse gases and meteorological variables.



We conducted eleven, two-aircraft, multi-level frontal crossing flights spanning the central and eastern United States in the summer of 2016. We introduced three metrics to describe these observations,

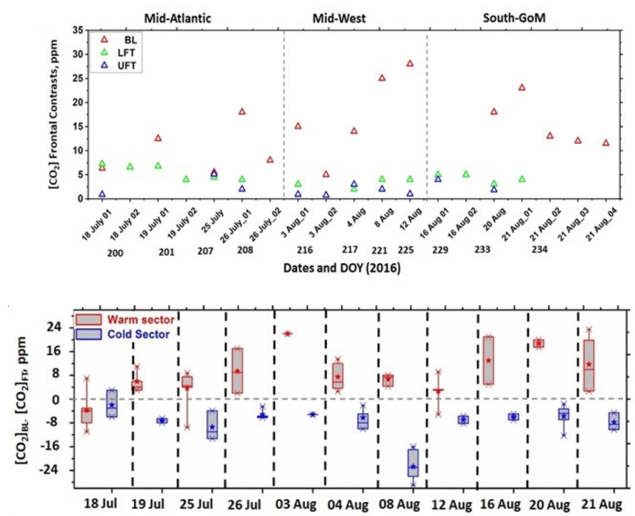
- the differences in the GHG mole fractions across frontal boundaries in the atmospheric boundary layer and free troposphere
- differences in the vertical contrasts in GHGs in warm and cold sectors,
- the size and magnitude of enhanced-CO2 along the frontal-boundary.





Tracks of NASA B200 (blue and cyan) and NASA C130 (red) aircraft between 15 July and 28 Aug, 2016 over the three ACT regions during the summer 2016 field campaign (left). Locations of 84 vertical profiles over the three ACT regions (red circles) obtained during frontal flights. Stars mark the locations of towers (right). Photographs of C-130 and B-200 taken during the ACT campaign.

Key findings:



$[CO_2]$ frontal contrasts (warm minus cold sector averaged, in ppm) in the boundary layer and free troposphere observed during 11 frontal research flights (upper panel). Box and whisker analyses ABL-to-FT CO_2 differences for warm (red) and cold (blue) sectors yielding mainly positive and negative ABL-to-FT $[CO_2]$ differences in warm and cold sectors, respectively. Total number of profiles available for warm and cold sectors were 48 and 36, respectively

- ✓ All fronts sampled showed lower $[CO_2]$ in the cold sector (north/west) and higher $[CO_2]$ in the warm sector (south/east) throughout the entire troposphere, with larger differences in boundary layer than in free troposphere. This suggests that during this campaign, continental fluxes reinforced the differences imposed by continental boundary inflow.
- ✓ Warm sector boundary layer $[CO_2]$ was higher than free tropospheric $[CO_2]$. The opposite was true in the cold sector. This suggests a net biogenic source of CO_2 in the warm sector, and a net biogenic sink of CO_2 in the cold sector.
- ✓ Cold fronts include a coherent, narrow band of enhanced CO_2 along the frontal boundary.
- ✓ CH_4 frontal contrasts in the free troposphere yielded higher concentrations in warm sector than in cold sector, but the sign of the differences varied in the boundary layer.