Characteristics and Mechanisms of Atmospheric CO_2 Variations during Summer Frontal Passages

Sha Feng

Arkayan Samaddar, Sandip Pal, Lily Campbell,
Andrew Schuh, Thomas Lauvaux, Kenneth Davis,
and ACT-America Science Team

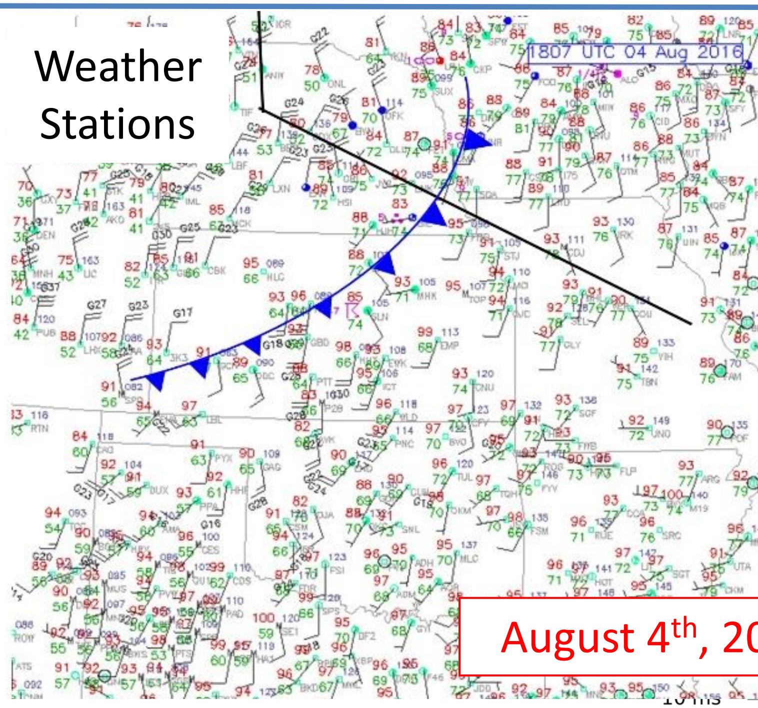
Outline

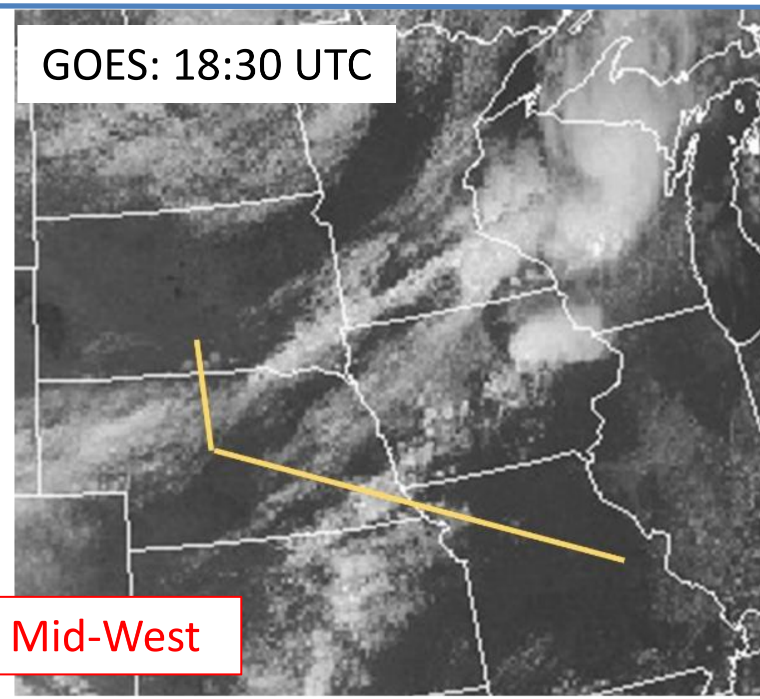
- Characteristics and mechanisms of atmospheric CO_2 variations across fronts
  - Case study: August 4th front
  - All summer frontal cases
- Summary
- ACT-America Flight Overview
- Data Availability

Outline

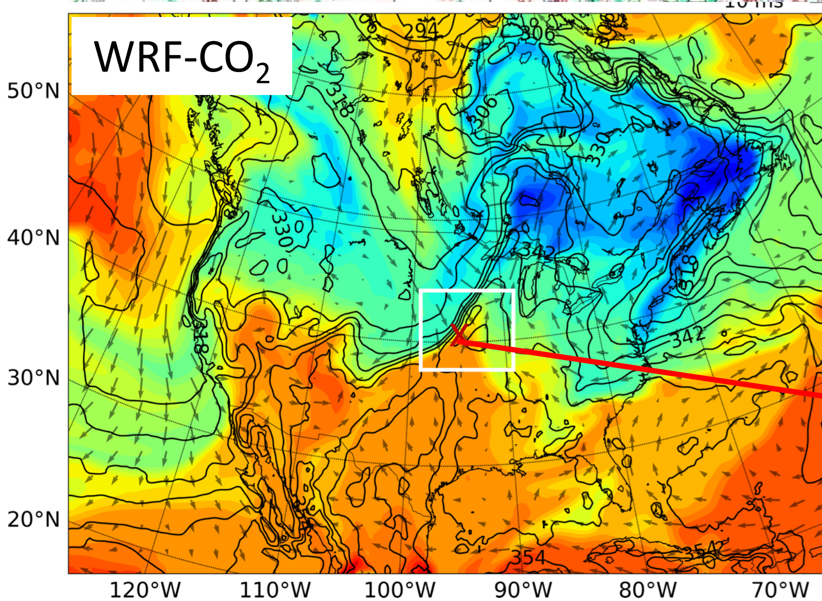
- Characteristics and mechanisms of atmospheric CO_2 gradients across fronts
  - ➢ Case study: August 4th front
  - ➢ All summer frontal cases
- Summary
- ACT-America Flight Overview
- Data Availability

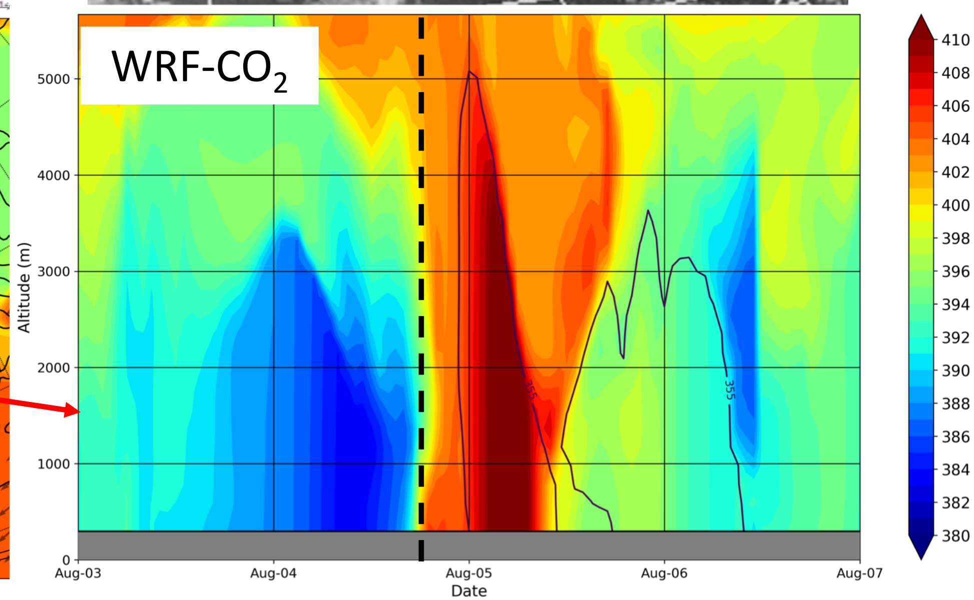
Synoptic Weather&CO_2 Conditions



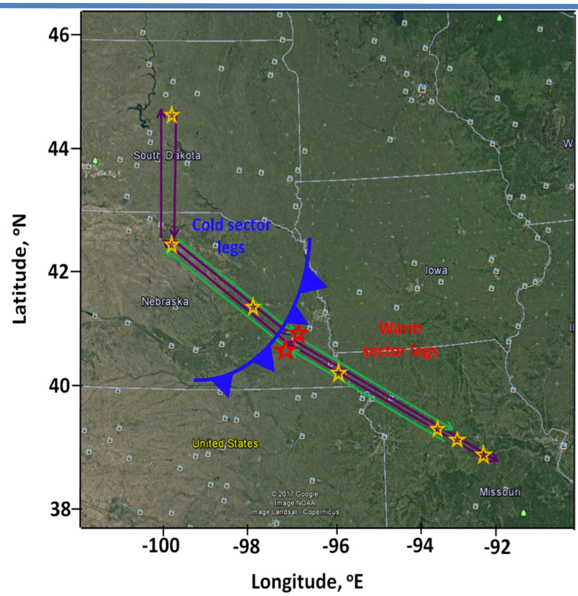


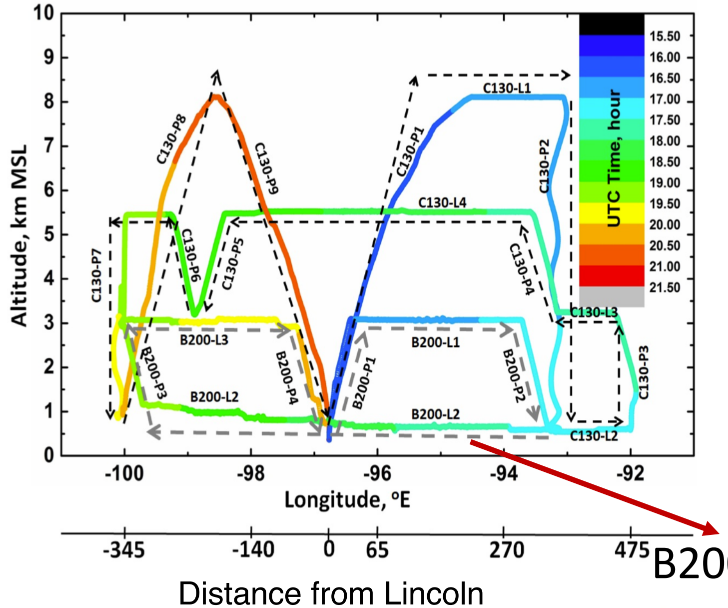
August 4th, 2016 Mid-West





Aircraft Measurements

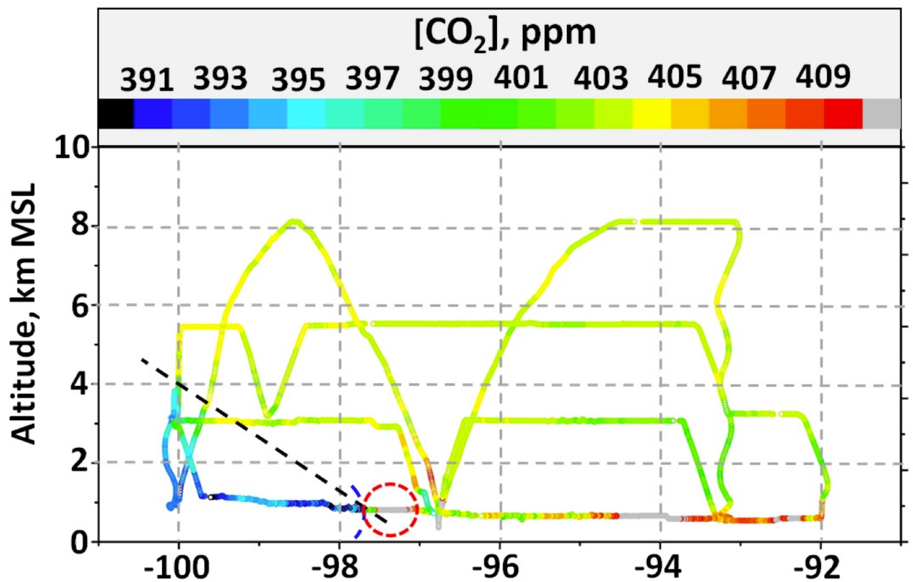


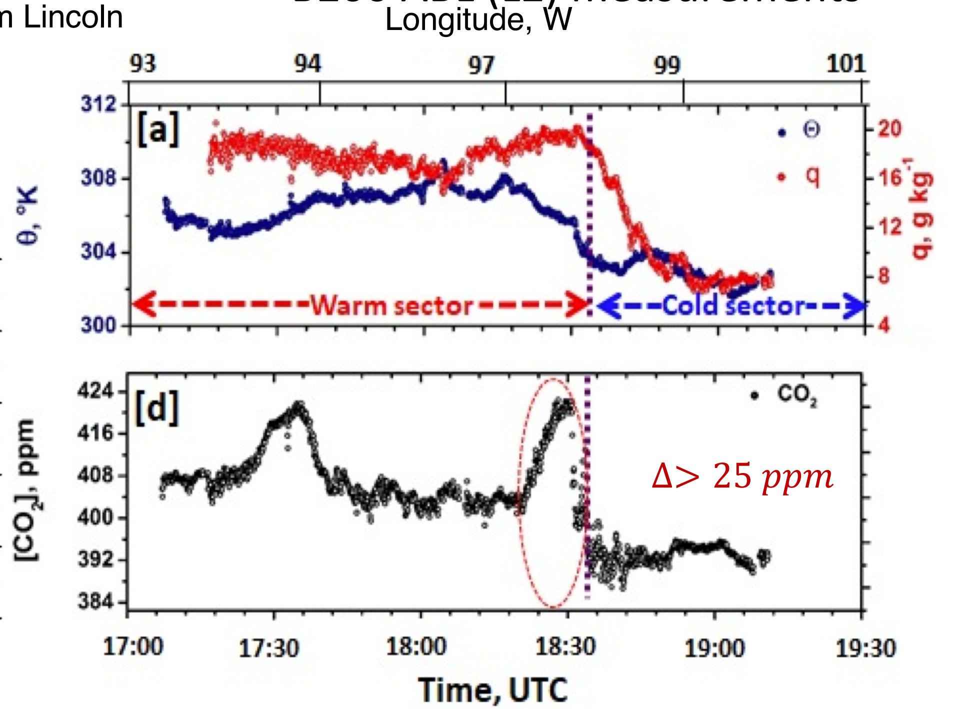


B200: lower level legs

C130: larger vertical span

B200 ABL (L2) measurements

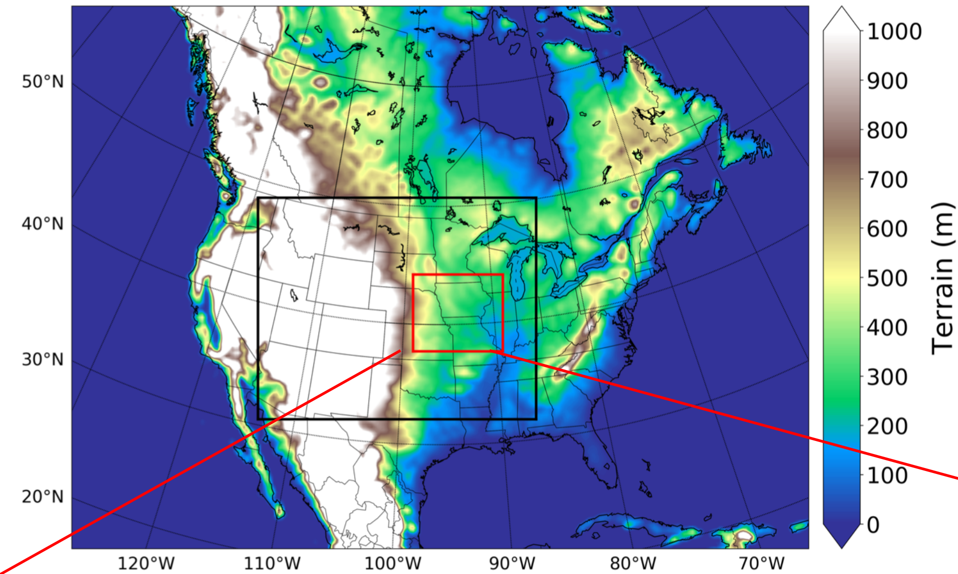




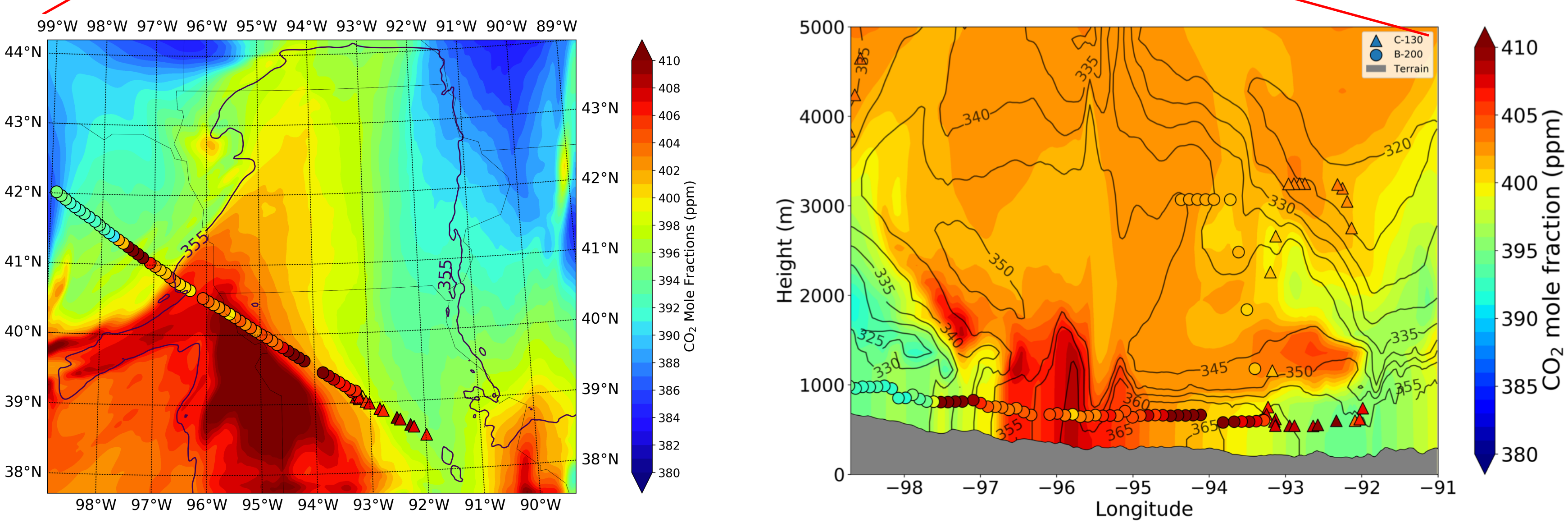
Questions

- What sources and sinks cause the CO_2 gradients along the frontal boundaries?
- What govern the atmospheric CO_2 transport during the summer frontal passages?

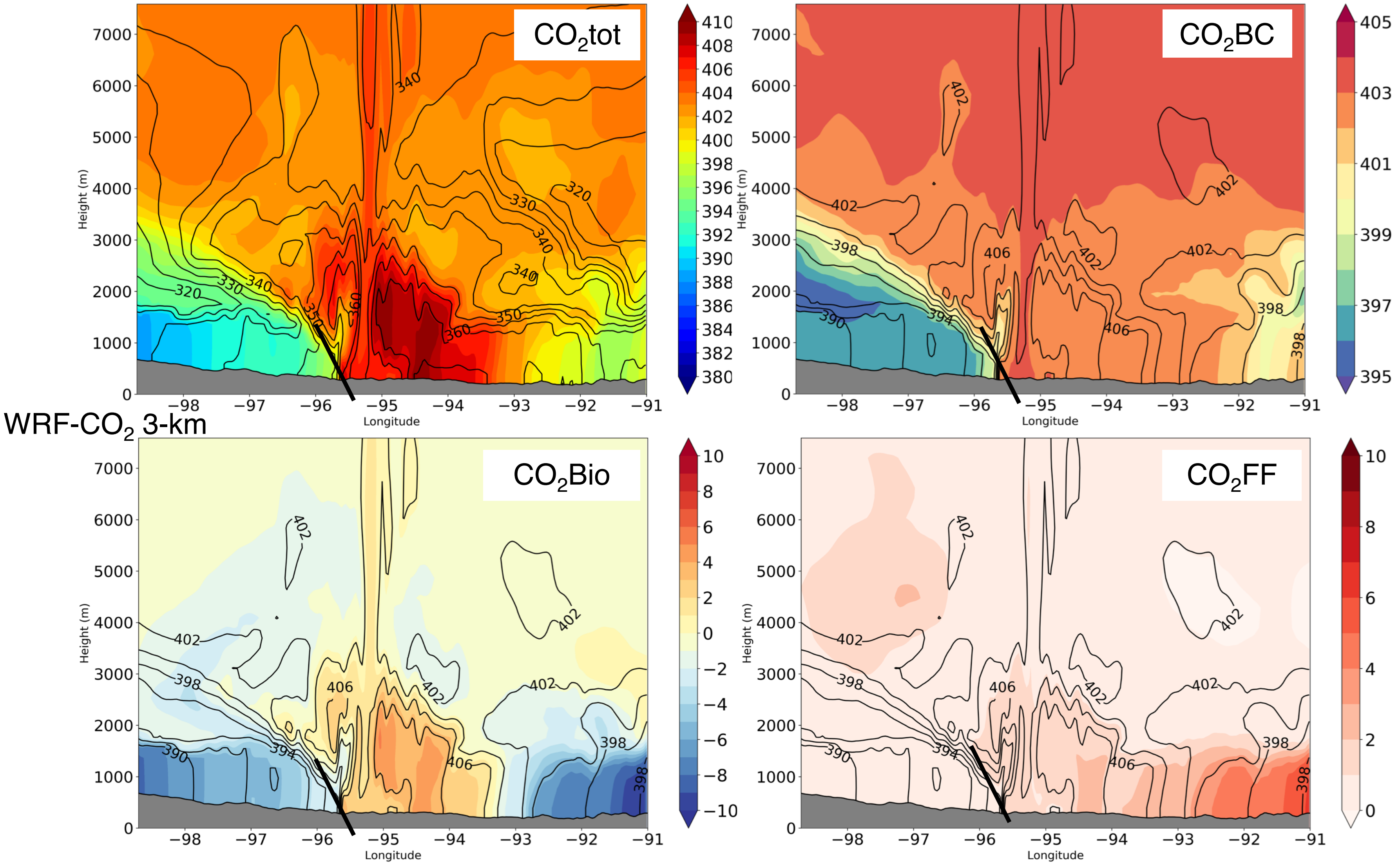
Model Setup for August 4th Front



- Three nested domains
- CT2017 for boundary conditions
- CT2017 fluxes



Modeled Atmospheric CO_2

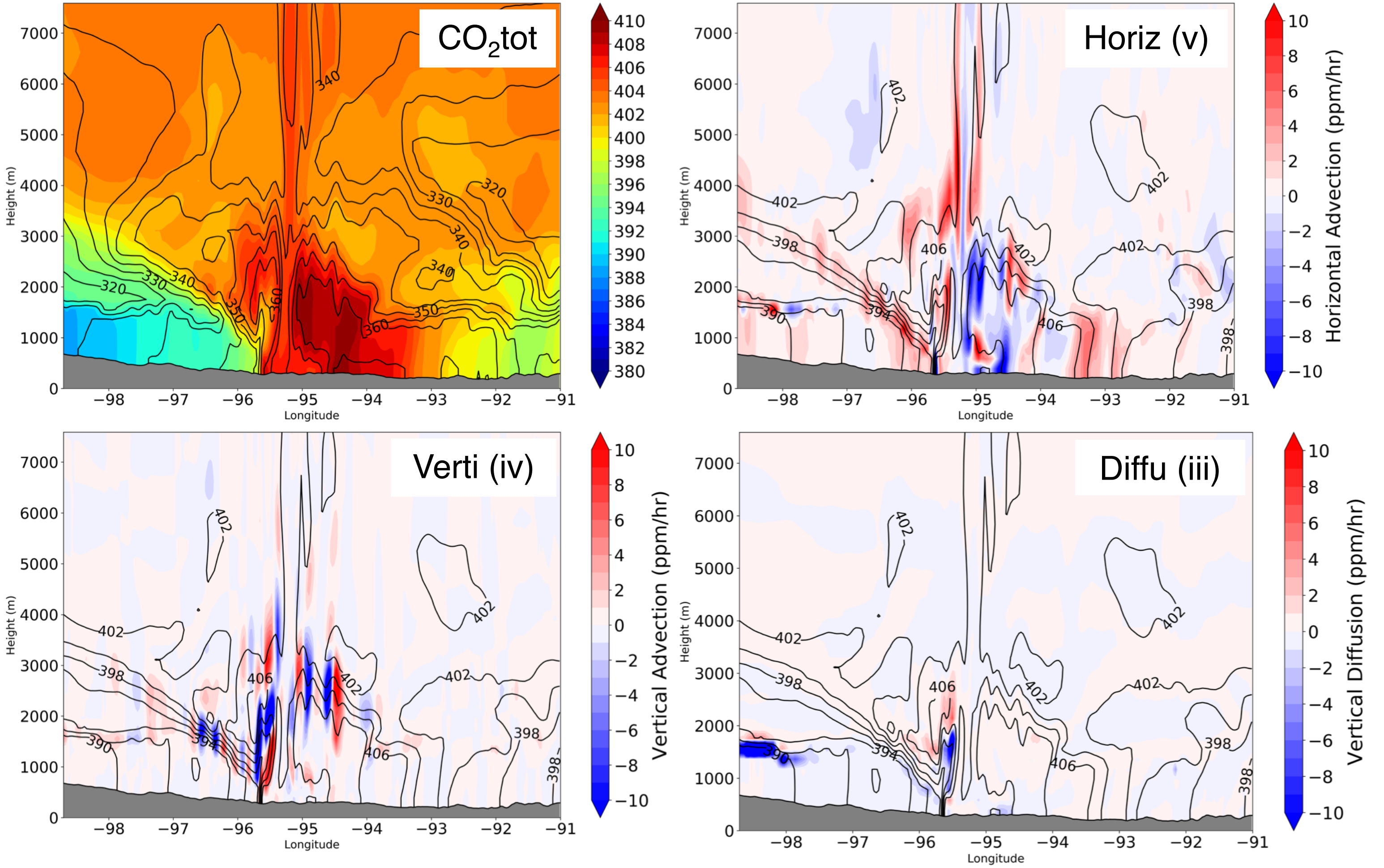


- Higher CO_2 in warm sector, lower CO_2 in cold sector
- CO_2 gradients across fronts largely caused by large-scale air movement
- In-domain surface sources and sinks modulate finer details of CO_2 distribution

Dynamic Mechanisms of CO_2 Transport

$$\underbrace{\frac{\partial C}{\partial t}}_{i} = -\underbrace{K_m \frac{\partial^2 C}{\partial z^2}}_{iii} - \underbrace{w \frac{\partial C}{\partial z}}_{iv} - \underbrace{\overrightarrow{V_H} \cdot \nabla_H C}_{v}$$

WRF-CO_2 3-km



- Horizontal advection the main driver of the increase of CO_2 along frontal boundaries
- Vertical advection plays a role where clouds form along frontal boundaries
- Diffusion hardly impact the CO_2 variations along fronts

Summary 1

- What sources and sinks cause the CO_2 gradients along the frontal boundaries?
  - ➢ Sharp CO_2 gradients appear across fronts between warm and cold sectors in ABL, up to 25 ppm
  - ➢ Detailed structures of the CO_2 distribution modulated by in-domain surface CO_2 fluxes mainly from biosphere for the August 4^{th} front
- What govern the atmospheric CO_2 transport during the summer frontal passages?
  - ➢ CO_2 enhancement observed along frontal boundaries mainly due to large-scale horizontal advection

❖ Those features are repeatable for all summer fronts and vary with seasons

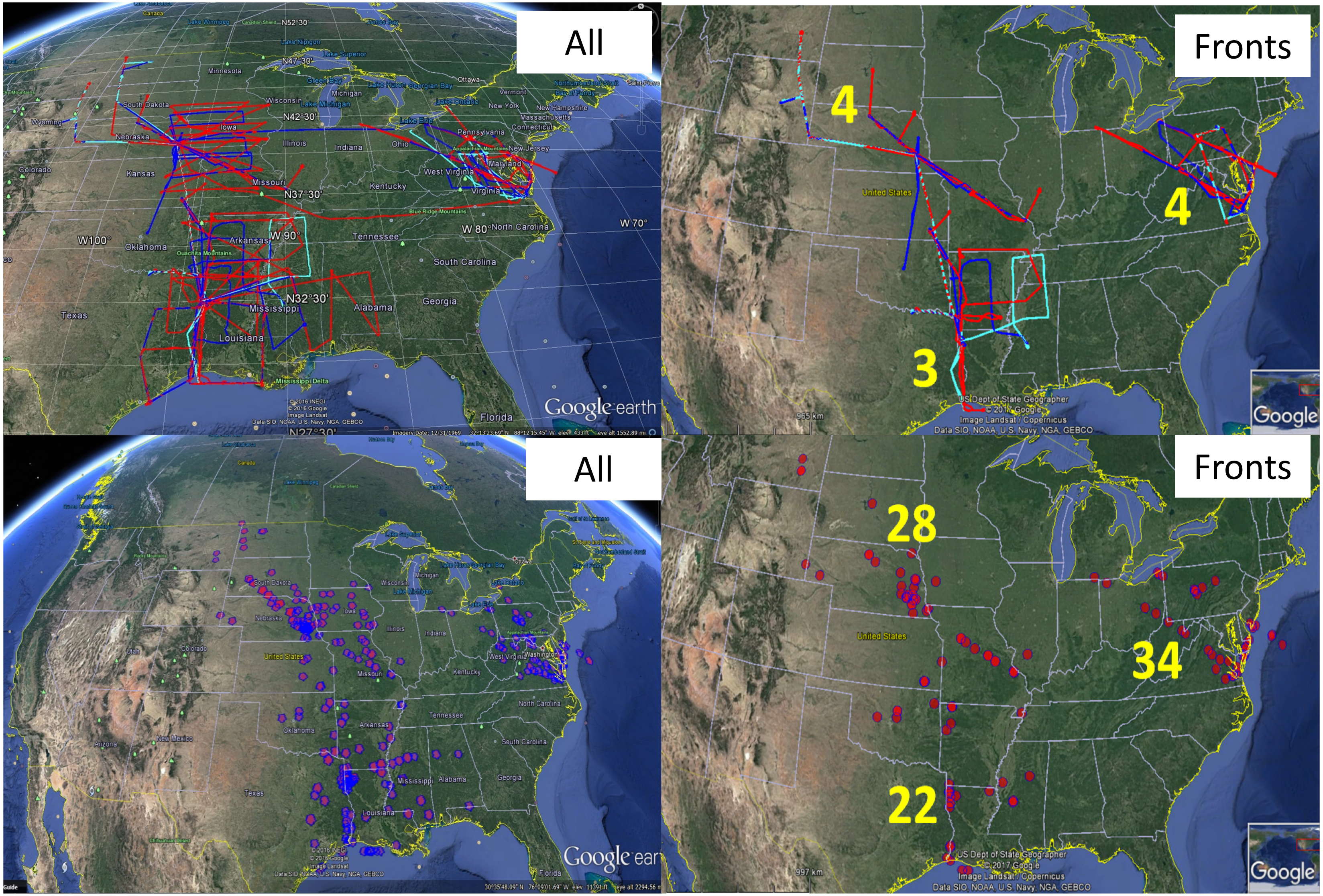
Outline

- Characteristics and mechanisms of atmospheric CO_2 gradients across fronts
  - ➢ Case study: August 4th
  - ➢ All summer frontal cases
- Summary
- ACT-America Flight Overview
- Data Availability

Questions

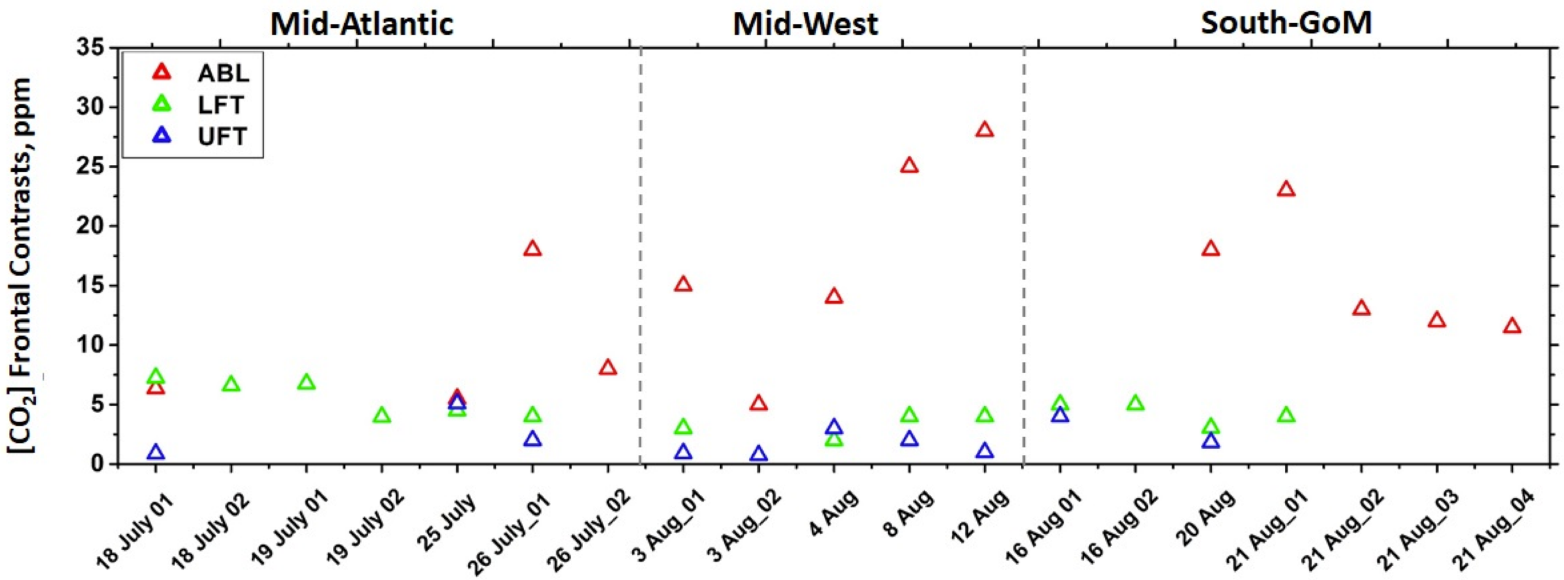
- What are the CO_2 gradients across fronts (between warm and cold sectors)?
- What are the vertical gradients of CO_2 in warm and cold sectors in summer?

ACT-America Summer Flights



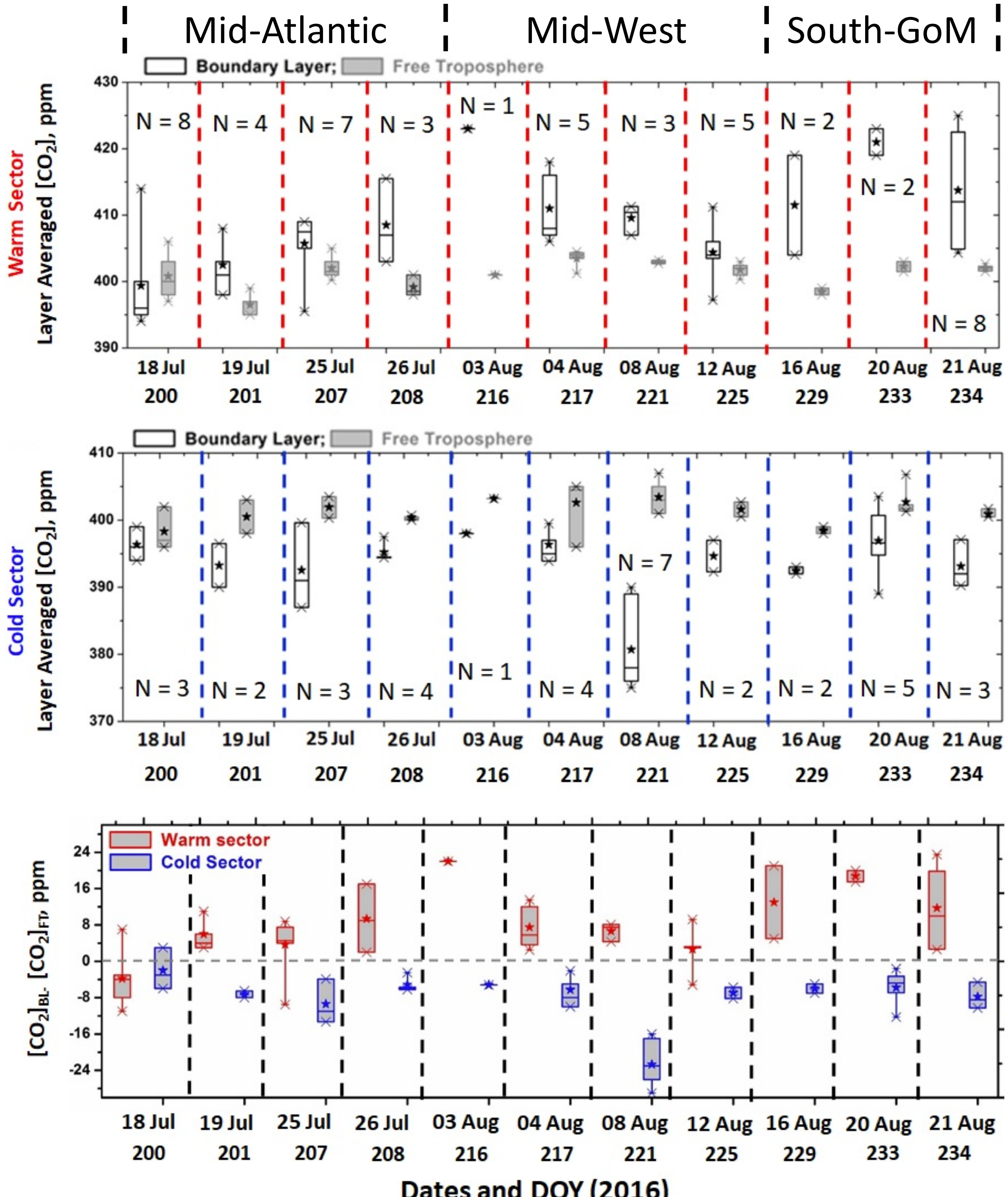
Frontal CO_2 (Horizontal) Gradients

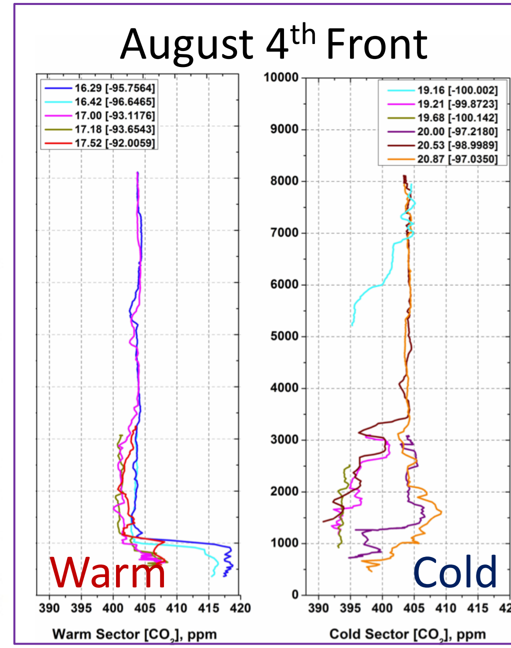
[Warm Sector – Cold Sector]



- The greatest CO_2 gradients between warm and cold sectors observed in ABL ranging from 5 ppm to 30 ppm
- About 5 ppm difference of CO_2 appears in the lower free troposphere
- The least CO_2 gradients in upper free troposphere

Frontal Gradients





- In ABL, greater CO_2 in warm sectors than cold sectors
- Vertical CO_2 gradients differ in warm and cold sectors with different sign

Summary 2

- What are the CO_2 gradients across fronts (between warm and cold sectors) in summer?
  - ➢ For summer fronts, higher CO_2 in warm sectors than cold sectors. In ABL, the difference ranges from 5 ppm to 30 ppm
- What are the vertical gradients of CO_2 in warm and cold sectors in summer?
  - ➢ With relative homogenous CO_2 concentration in the upper troposphere, the signs of vertical CO_2 gradient are opposite in warm and cold sectors

Summary

- CO_2 enhancement observed along frontal boundaries mainly due to large-scale horizontal advection
- Detailed structures of the CO_2 distribution modulated by in-domain surface CO_2 fluxes mainly from biosphere for the August 4th front
- Sharp CO_2 gradients appear across fronts between warm and cold sectors in ABL, ranging from 5 ppm to 30 ppm
- For summer fronts, higher CO_2 in warm sectors than cold sectors
- With relative homogenous CO_2 concentration in the upper troposphere, the signs of vertical CO2 gradient are opposite in warm and cold sector
- Those features are repeatable for all summer fronts and vary with seasons

References:

- Samaddar, et al., Mechanisms of CO_2 transport along a frontal boundary during summer in mid-latitudes, to be summited Journal of Geophysical Research-Atmospheres
- Pal, et al., Greenhouse gas changes across summer frontal boundaries in the eastern United States, Journal of Geophysical Research-Atmospheres, in review

Outline

- Characteristics and mechanisms of atmospheric CO_2 gradients across fronts
  - Case study: August 4th
  - All summer frontal cases
- Summary
- ACT-America Flight Overview
- Data Availability

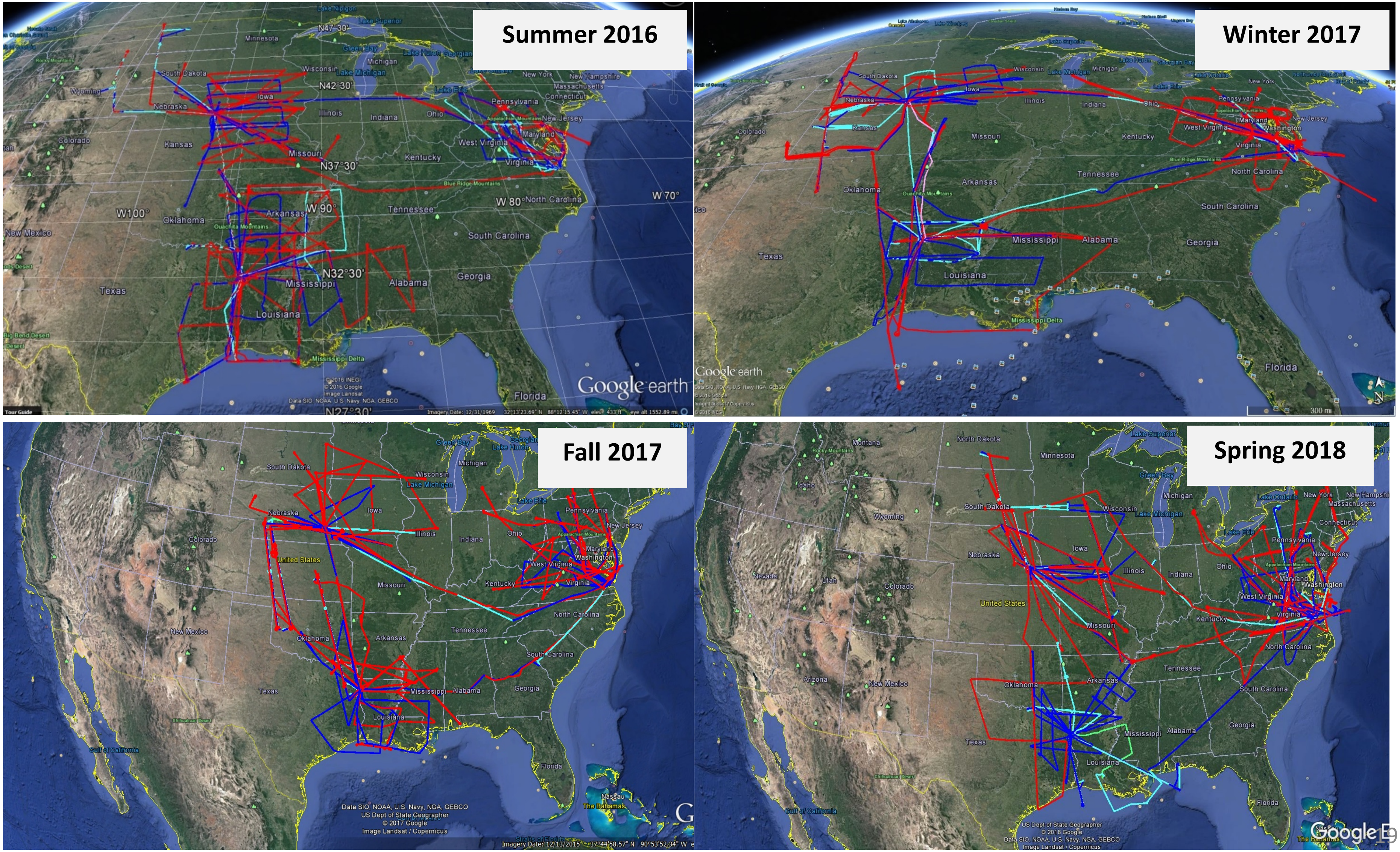
ACT- America Flight Overview

Four seasons
Three regions

99 Research flights
47 Fair weather flights

38 Stormy weather flights
14 OCO-2 under flights

1150+ Profiles

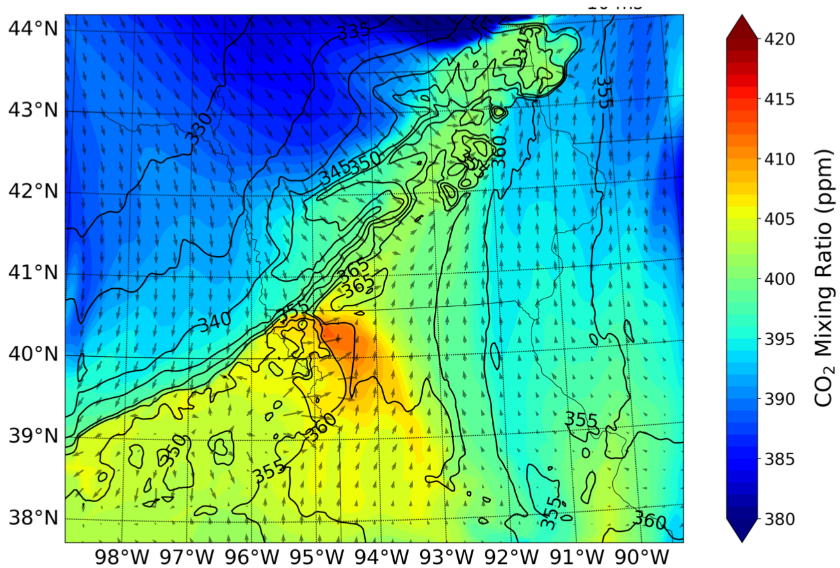


Data Availability

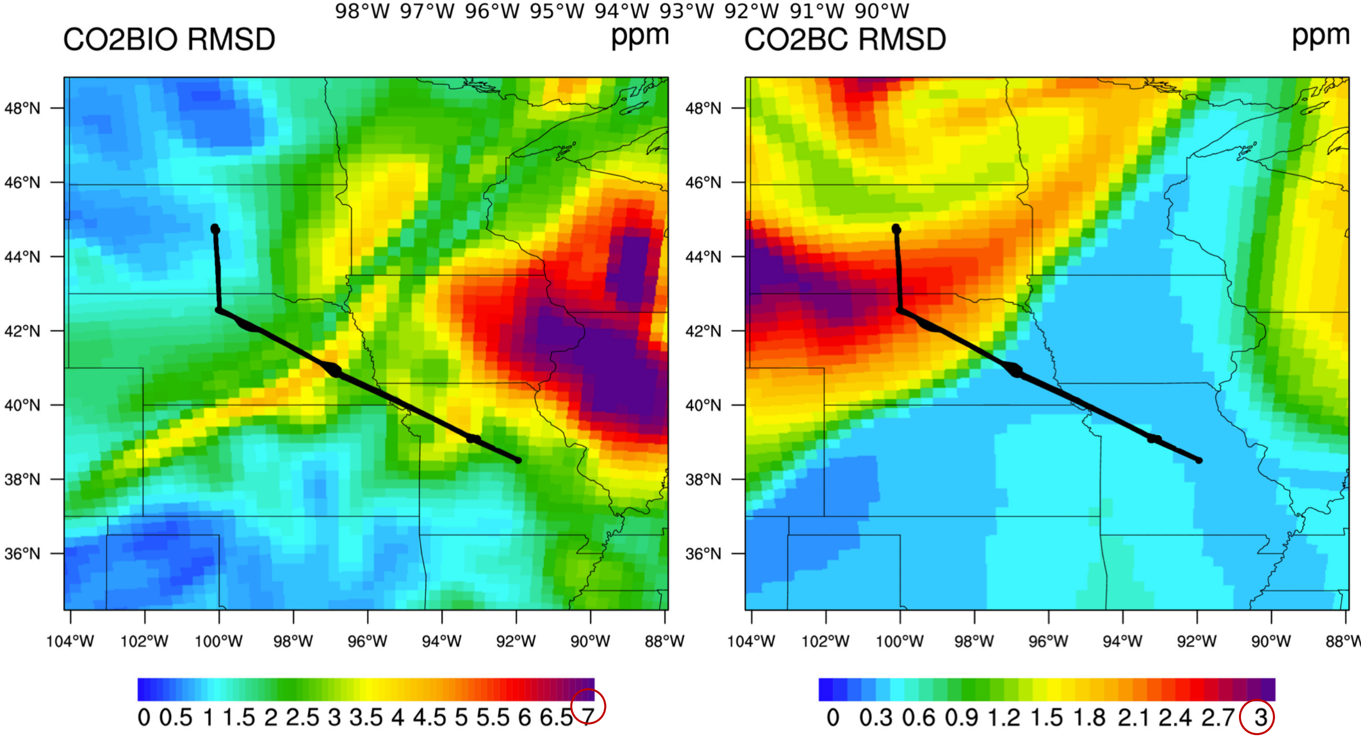
- NASA Langley Airborne Science Data for Atmospheric Composition Archive
  - https://www-air.larc.nasa.gov/missions/ACT-America/
- ORNL DAAC
  - https://daac.ornl.gov/cgi-bin/dataset_lister.pl?p=37
- NOAA ObsPack
  - https://www.esrl.noaa.gov/gmd/ccgg/obspack/release_notes.html
  - GlobalViewplus v4.2 (summer 2016 only)
  - ObsPack CO2 NRT (four seasons)
- Model output:
  - sfeng@psu.edu
  - ORNL DAAC

Backup Slides

Model Sensitivities



- Modeled CO_2 sensitive to surface fluxes along frontal boundaries
- Modeled large scale CO_2 has better agreement in warm sectors and cold sectors



CO2Bio ensemble:

- 27 CASA (C. Williams)
- SiB3 (I. Baker)
- CT2017 bioFlux

CO2BC ensemble:

- PCTM (D. Baker)
- CT2017
- GeosChem (Schuh)
- GeosChem (Liu)
- TM5 (Basu)