Application of Observations from the Summer 2016 ACT-America Campaign to Constrain Modeled Regional CO_2 Concentrations and Fluxes

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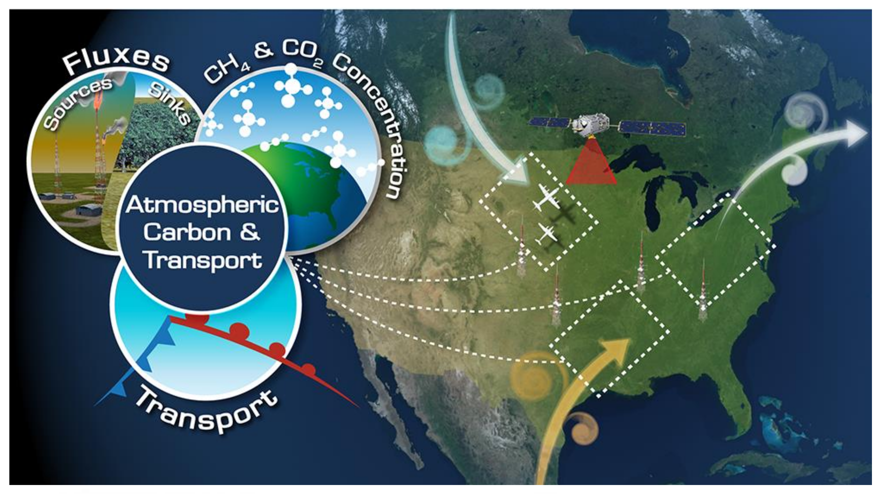
1. INTRODUCTION

While observational constraints on greenhouse gas (GHG) fluxes exist on the local scale (via eddy-covariance flux towers) and the global scale (via remote-site concentration measurements and the conservation of mass), regional-scale observational constraints are relatively deficient. One of the primary goals of the Atmospheric Carbon and Transport – America (ACT-America) project is to increase the understanding of regional-scale GHG fluxes through the use of aircraft, tower and satellite-based measurements over three focus regions (Mid-Atlantic, Midwest and Gulf Coast) during all four seasons.

Here we will compare CO_2 concentration observations from the initial ACT-America campaign during the summer of 2016 ACT-America campaign to those produced by the CarbonTracker (CT) atmospheric CO_2 inversion system in order to: 1) evaluate the accuracy of the modeled concentrations at various spatial scales; and 2) where practical from the meteorology, infer the accuracy of regional-scale CO_2 flux estimates. We make use of the CarbonTracker Near-Realtime (CT-NRT) product, which uses priors derived from the optimized fluxes of regular CT along with provisional observations to reduce the time required to produce an analysis. We will also compare the observations to concentrations simulated with the Weather Research and Forecasting (WRF) model, which uses CT-NRTv2017 surface fluxes as a lower boundary condition.



Airborne Platforms

(in situ Picarro CO_2, CH_4, and CO)

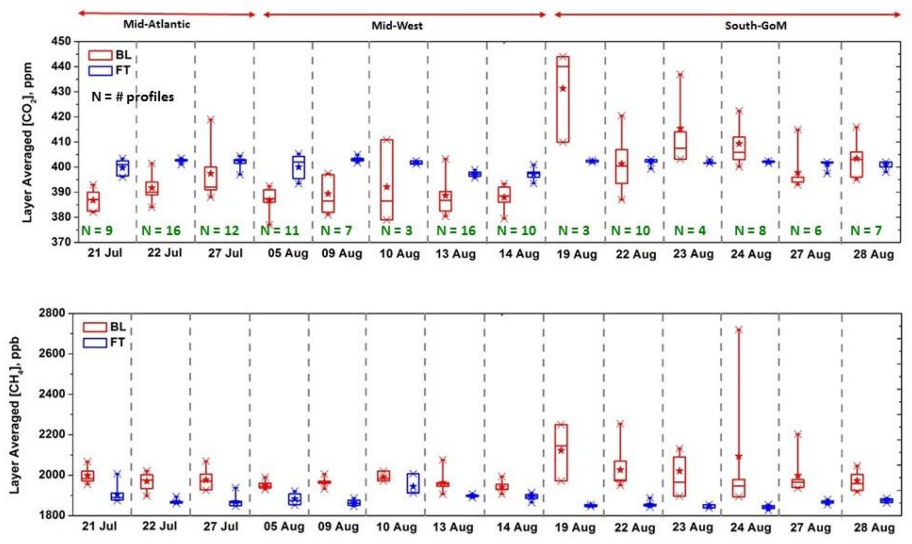
- **C-130 Hercules**
- **B-200 King Air**

Focus Regions

- **Mid-Atlantic**
  - **Operations base: Wallops Island and NASA / Langley, VA**
- **Midwest**
  - **Operations base: Lincoln, NE**
- **Gulf Coast**
  - **Operations base: Shreveport LA**

Types of Flight Patterns

- **Fair Weather Pattern (see right)**
  - Two-day box patterns (second day downwind of first) in conditions of homogeneous meteorology and quiescent atmospheric boundary layers
  - One-day box pattern variant in Gulf Coast region when upwind conditions should be temporally constant (e.g., in the Gulf)
  - Chosen to maximize chances of observing modification of GHG concentrations from local fluxes
  - Intent includes improving our understanding of seasonal-scale GHG fluxes over spatial scales of order 10^5 km^2
- **Frontal Weather Pattern**
  - Same-day sampling of synoptic weather systems at multiple levels and / or locations
  - Intent to quantify concentrations and their spatial and temporal variability across these systems (e.g., between the warm sector and the cold sector)
- **OCO-2 Underflight**
  - Underflight of OCO-2 track in clear weather conditions
  - Intent to help validate OCO-2 measurements of CO_2



(Above) chart of fair-weather days during the summer 2016 ACT-America campaign, including Gulf Coast variant, and OCO-2 days. BL and FT indicate box-and-whiskers plot of boundary layer and free troposphere average concentrations, respectively, over the set of all aircraft profiles.

2. DESCRIPTION OF MODELS

CarbonTracker Near-Real-time (CT-NRT)

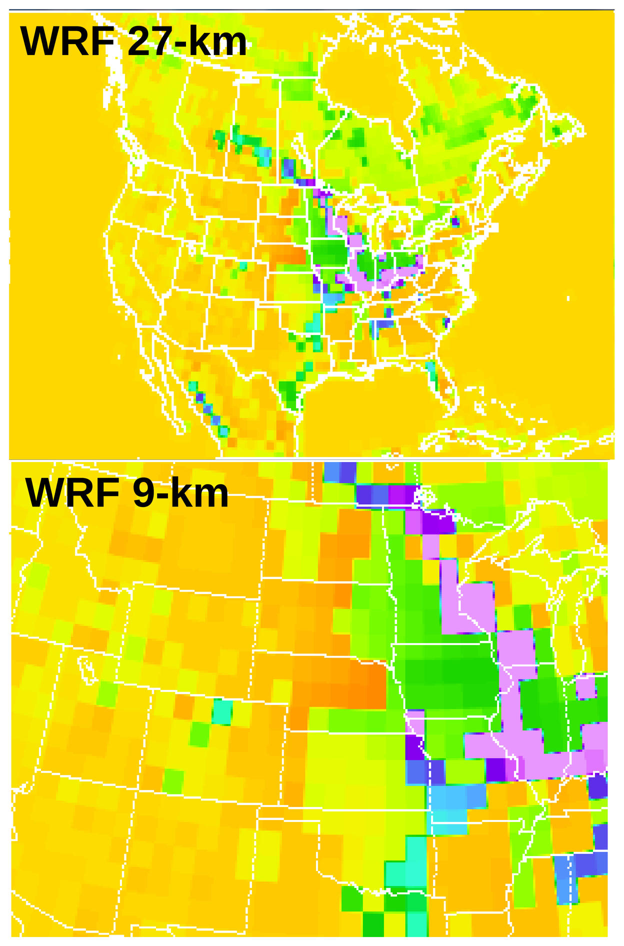
- Version CT-NRTv2017
- Extension of regular CarbonTracker (CT2016) global CO_2 analysis system (Peters et al. 2007)
- CT-NRT uses a set of provisional observations and prior CO_2 fluxes from regular CT in order to produce a more timely product than regular CT
- Like CT, CT-NRT models transport over North America on 1 x 1 degree grid

Weather Regional and Forecasting Model with Chemistry (WRF-Chem)

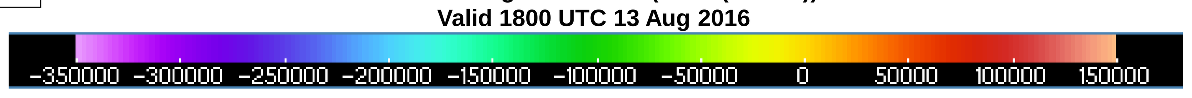
- State-of-the science local-to-global atmospheric model (Skamarock et al. 2008)
- Chemistry extension allows prediction of emission, transport, deposition, and interaction of multiple species (Grell et al. 2005)

3. WRF CONFIGURATION

- Domains
  - 27-km over most of North America
  - 9-km on regional scale
- Fluxes of CO_2 through Domain 1 lateral boundaries, and surface fluxes, derived from CT-NRT
- Separate WRF tracers used to track regional surface fluxes due to the different CT modes of production (biogenic, fossil fuel, oceanic, fire)
- Simulation performed as series of segments throughout 2016 to 'spin-up' concentration fields



Surface Biogenic Fluxes (mol / (km^2-hr))
Valid 1800 UTC 13 Aug 2016



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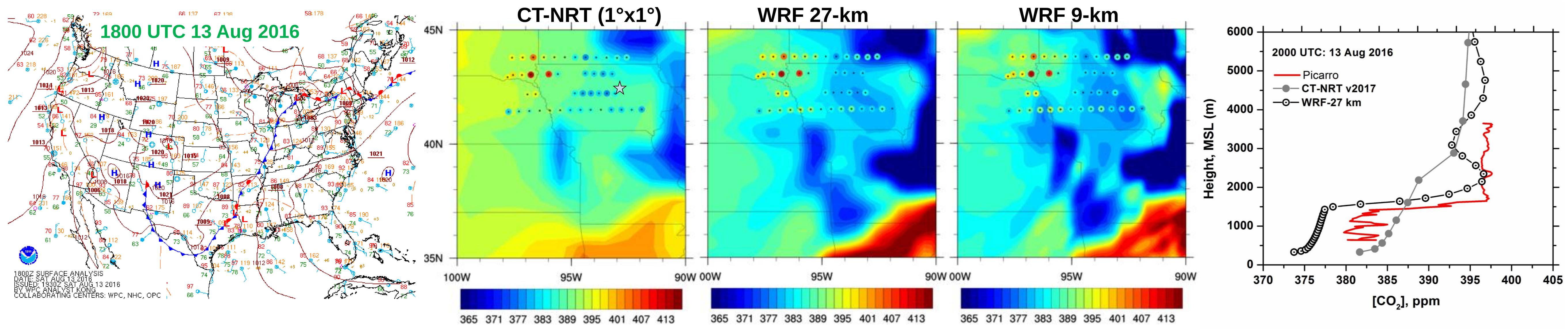
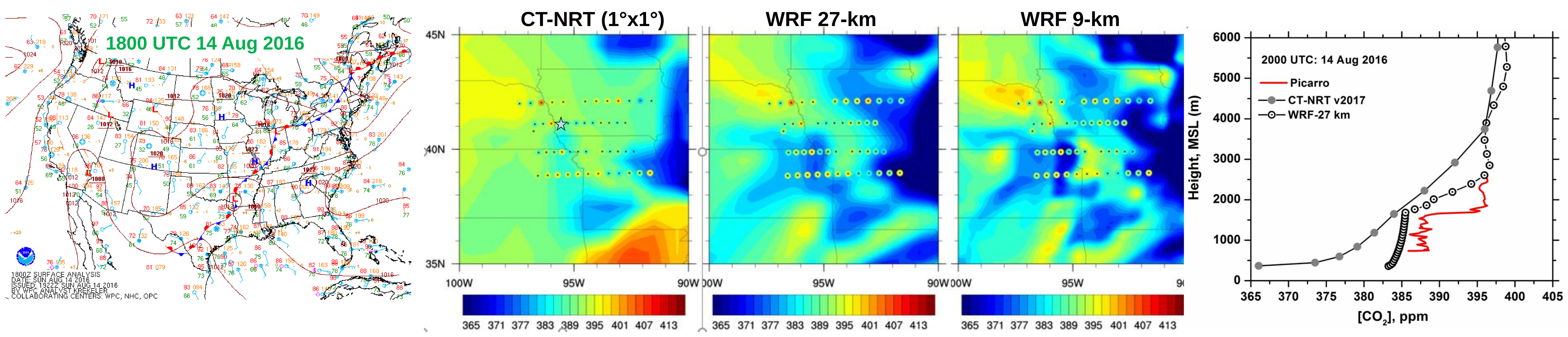
4. FAIR WEATHER CASES – MIDWEST REGION EXAMPLES

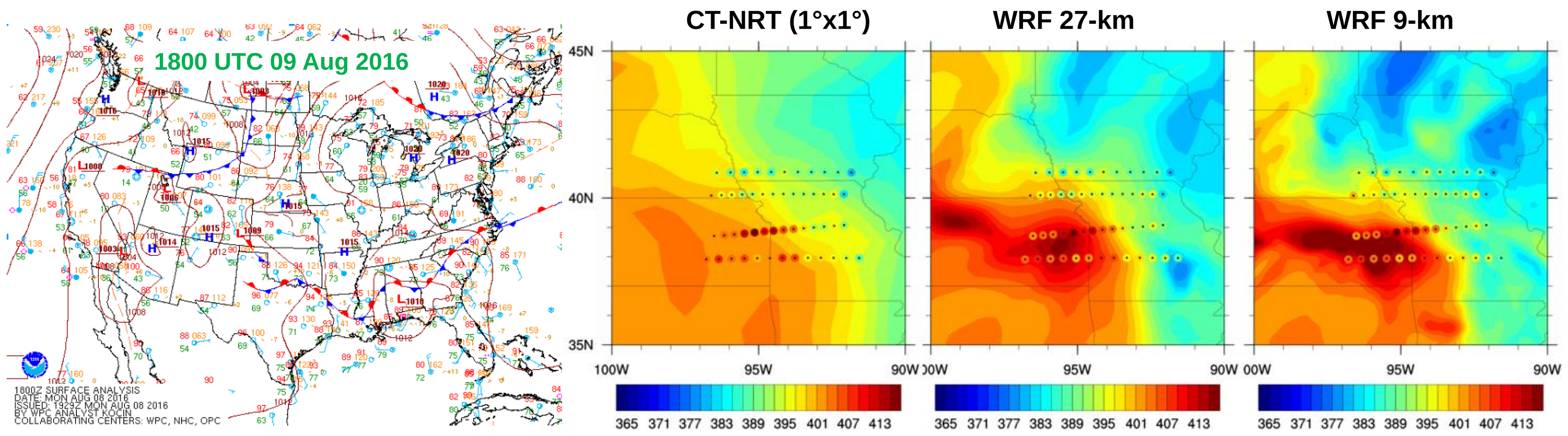
Flow from north – 13-14 Aug 2016

Averaged model boundary layer CO2 concentrations

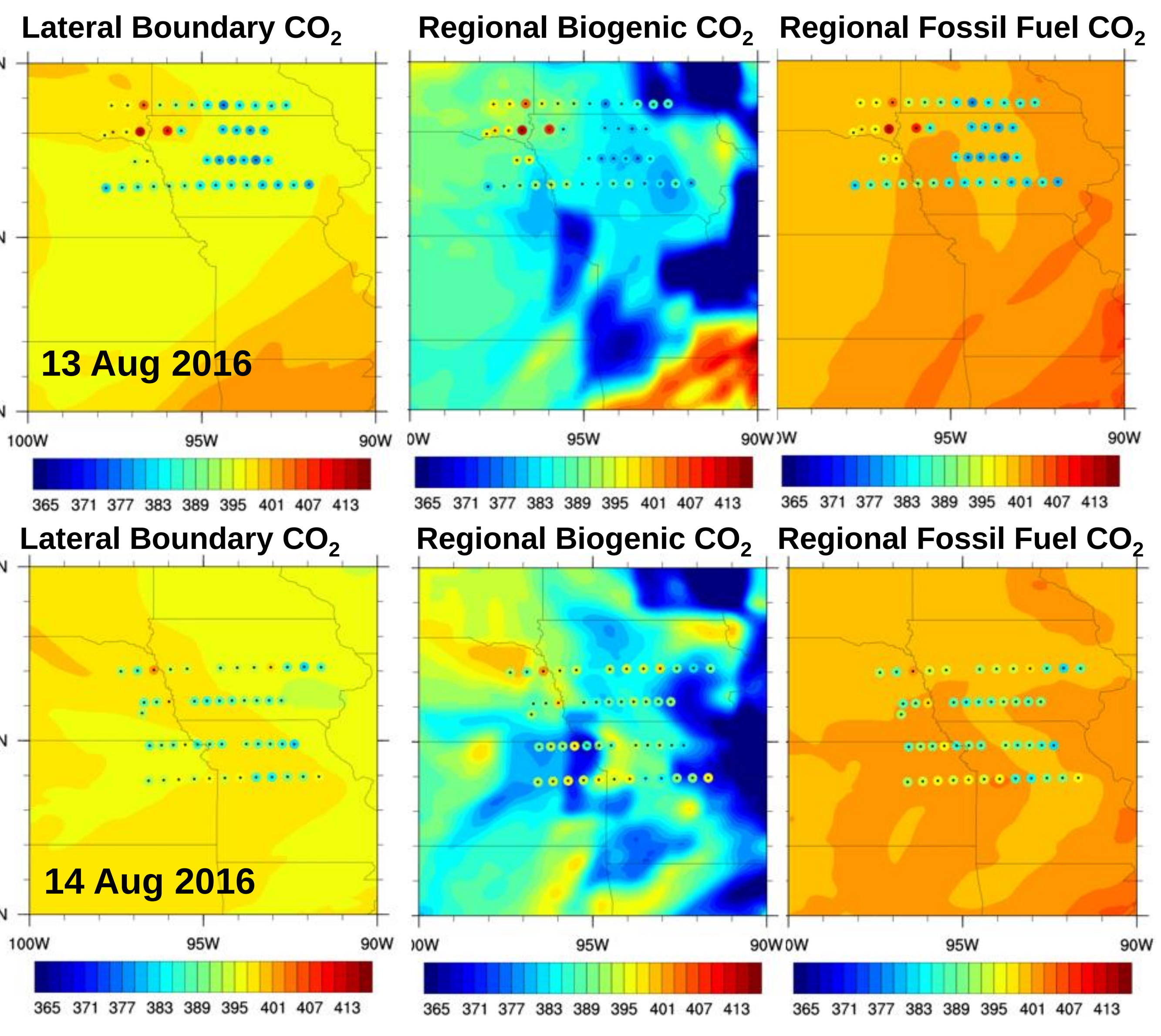




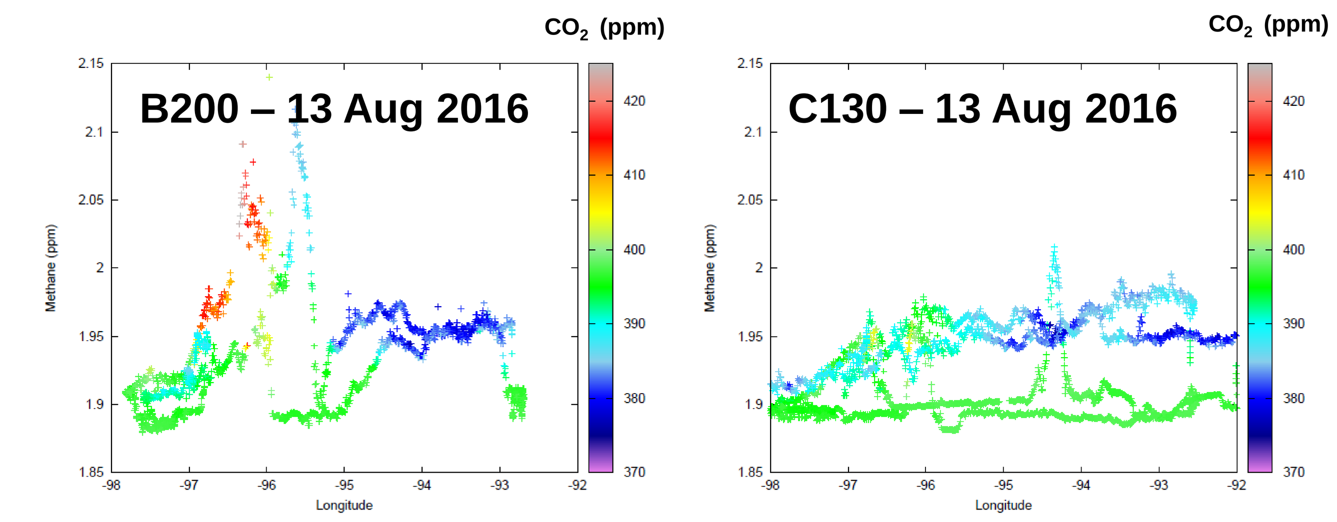
Flow from south – 9 Aug 2016



5. ANALYSIS



(Biogenic and fossil fuel contributions are relative to a uniform 400 ppm base state)



6. PRELIMINARY FINDINGS

- Regional biogenic fluxes needed to explain concentrations and gradients for summer ACT-America Midwest fair weather cases.
- The finer-scale meteorology in WRF can produce more accurate predictions of observed horizontal gradients and boundary layer structure of CO_2 concentrations.
- Substantial local variability of concentrations is present, both in the model and observations, and mismatches between the two can still be considerable.

7. FUTURE WORK

- Use measurements to help quantify biases in CarbonTracker and stratify by season and synoptic condition
- Use observations from set of fair weather cases to infer regional- and seasonal-scale biogenic fluxes
- Use these inferred surface fluxes to help evaluate model surface fluxes in inversions or flux ensemble systems.

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