Mid-Continental Intensive Field Campaign Atmospheric CO2 Observations Compared to Forward Models

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B51E-0338

Support: This research was supported by the Department of Energy's Terrestrial Carbon Processes program and fellowships (L. Diaz) from Penn State's Earth and Environmental Sciences Institute and Bunton-Waller Program.

Motivation for the MCI

- Improve regional estimates of CO2 sources and sinks.
- Compare "top-down" (atmospheric inversion) and "bottom-up" (agricultural inventory) flux estimates in densely instrumented region.
- Improve regional atmospheric inversions by quantifying flux uncertainty as a function of observational density and uncertainty in fluxes due to atmospheric transport uncertainty.

Objectives of this study

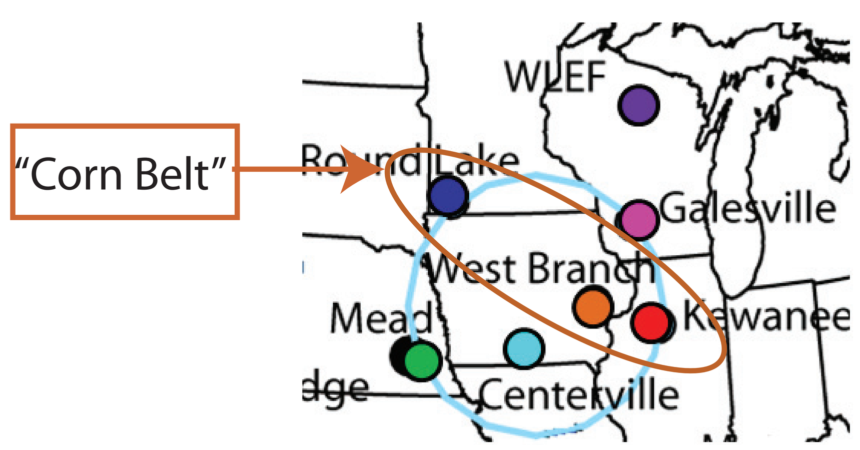
- Understand the statistical structure of the model-data mismatch in atmospheric CO2 in the MCI region.
- Evaluate the statistical assumptions typically used in atmospheric inversions.
- Assess the potential for the MCI observations to improve regional flux estimates using atmospheric inversions.

Methods

- Model-data mismatch is evaluated in time at several locations.
- Two time periods are compared: June through December, 2007, and the growing season of 2007.
- Output from two models (Carbon Tracker - optimized; WRF-SiBcrop - unoptimized) are evaluated.
- Comparisons are limited to midday, well mixed conditions.
- The following analyses are performed to characterize the model-data mismatch:
  1. Time Series Differences
  2. Taylor Diagrams
  3. Distribution of the Residuals

Data

- In-situ measurements are collected from seven communications towers, enveloping the U.S. "corn belt".



- The seven sites and sample levels used for this study are:
  1. Centerville, IA (110 m)
  2. Galesville, WI (120 m)
  3. Kewanee, IL (140 m)
  4. Mead, NE (120 m)
  5. Round Lake, MN (110 m)
  6. LEF, WI (122 m)
  7. West Branch (WBI), IA (99 m)

Models

Carbon Tracker:

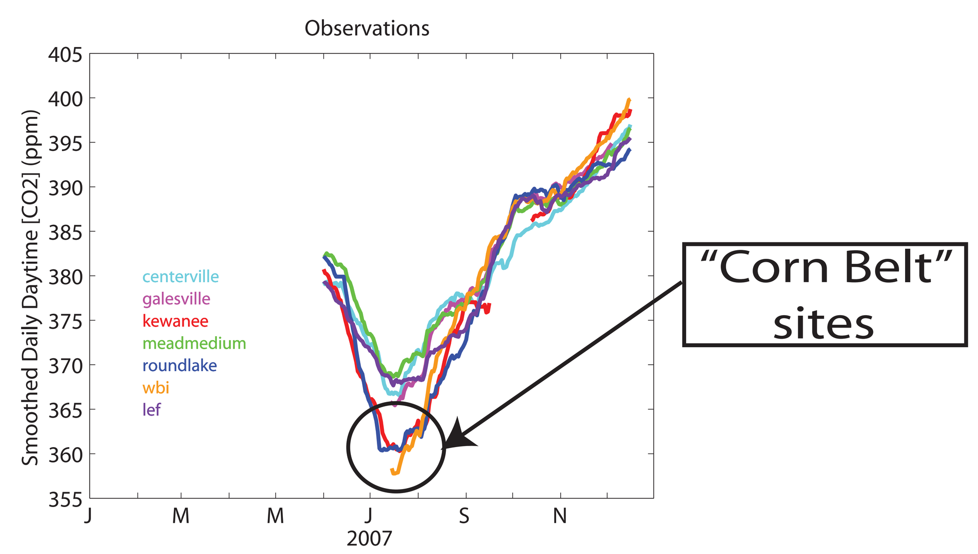
- Global Transport Model 5 (TM5) is coupled with the biospheric model Carnegie-Ames Stanford Approach (CASA) Model to predict CO2 concentration.
- CO2 mixing ratios are predicted using optimzed ecoregion fluxes. WBI and LEF are used in the Carbon Tracker optimization (Peters et al., 2007)
- CO2 from the third model level, representing a geopotential height of approximately 390m, is used. This level is the best available match to the mixed layer.

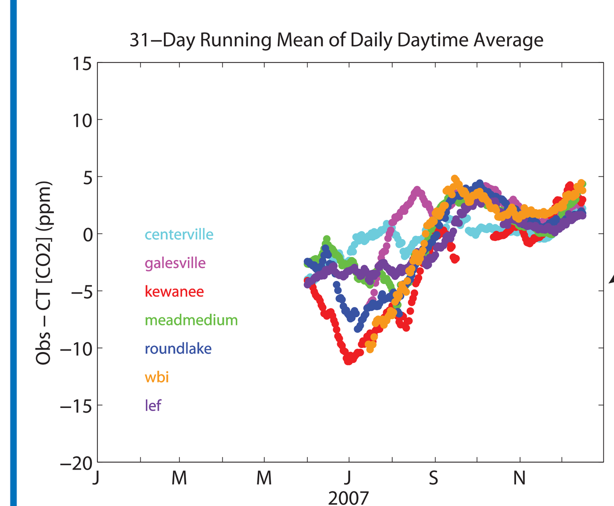
WRF-SiBcrop:

- Mesoscale model Weather Research and Forecasting (WRF) is merged with fluxes from Simple Biosphere (SiBcrop) model.
- SiB model is supplemented with a phenology model for a better parameterization of the three main crop types (Lokupitiya et al., 2009).
- Boundary and initial are provied by Carbon Tracker.
- The third model level (160 m) is used in this study.

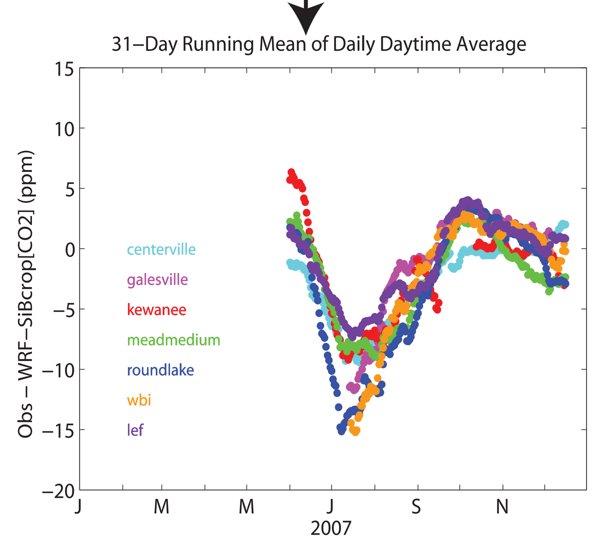
Seasonal Cycle Comparison

- Plots below shoe 31-day running means of daily daytime average CO2 mixing ratios.

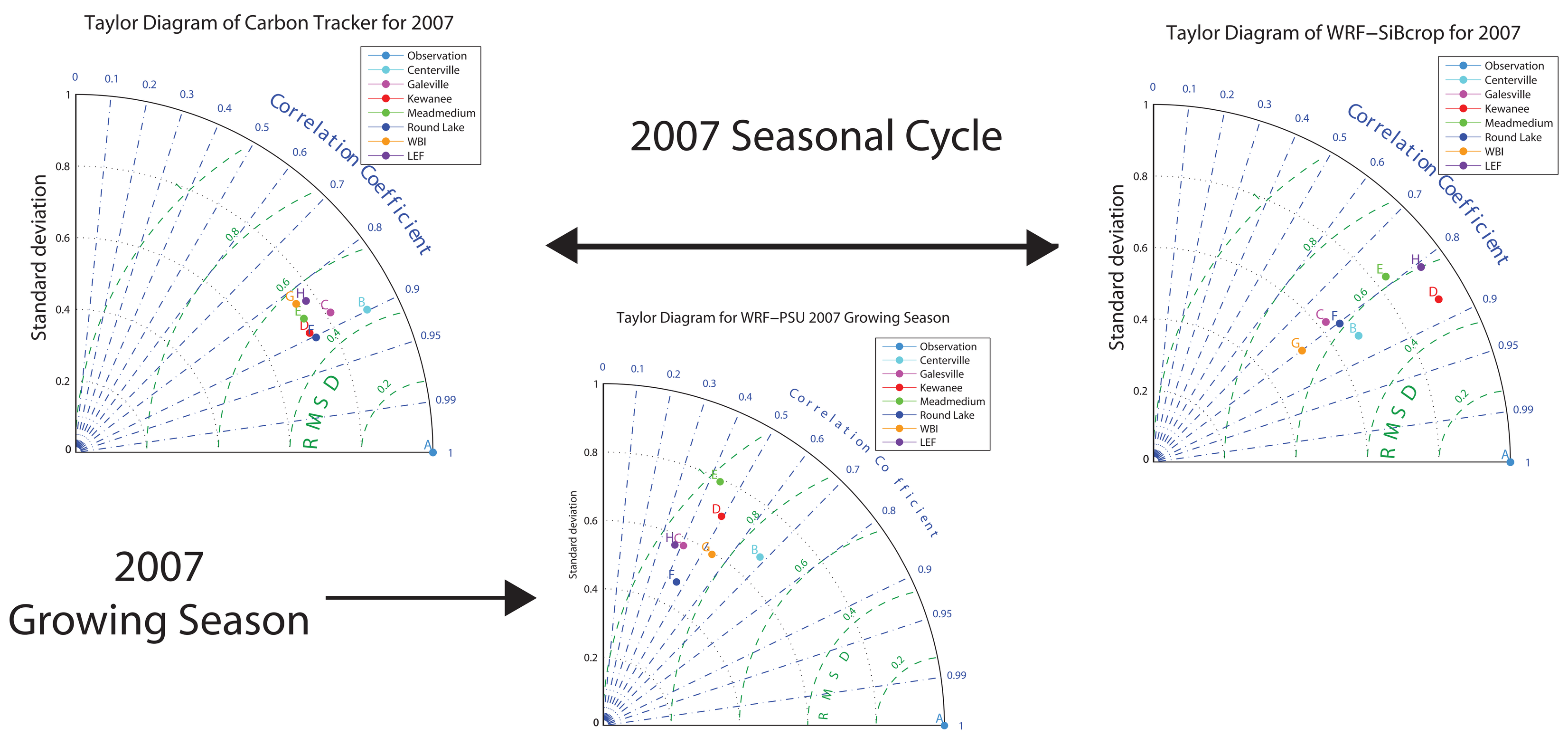




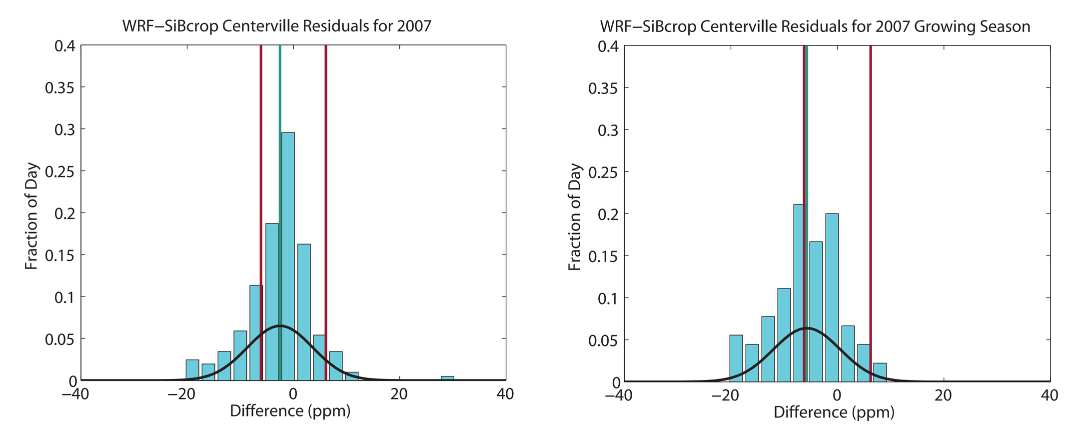
"Corn belt" sites show that modeled mixing ratios are higher than observed mixing ratios during the summer.



Taylor Plots and Probability Distributions

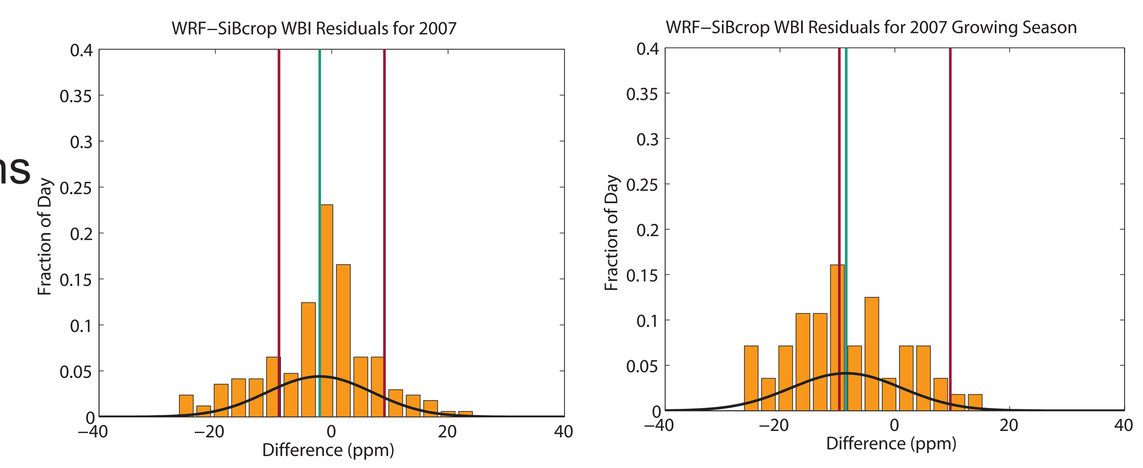


- Variability in CO2 is underestimated by both models, but more so during the growing season.
- Models are highly correlated at the seasonal time scale (correlations > 0.8) but less well correlated during the growing season (synoptic variability, correlations < 0.7).



- Distributions residuals are not Gaussian.
- The annual distribution has a larger peak of small residuals.

- Corn Belt sites for 2007 tend to show bi-modal distributions for the entire year and growimg season.



Summary

- Both models tend to underpredict CO2 concentrations during growing season, mainly "corn belt" sites consistent with low uptake in the modeled fluxes.
- Growing season is not well captured by any of the models and day-to-day variability is underestimated.
- Differences in the distributions are a combination of flux and transpor errors, which are separate elements in an inverse system.
-These results suggest that the atmospheric CO2 data contain evidence of consistent underestimation of assimilation of CO2 in the "corn belt".

Future Work

- Evaluate the temporal and spatial correlations of the model-data residuals.
- Evaluate transport model errors, by using identical flux inputs.
- Evaluate the residuals obtained from an optimzed version of the WRF-SiBcrop model.