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

Liza I. Diaz1, Kenneth J. Davis1, Natasha L. Miles1, Scott J. Richardson1, Thomas Lauvaux1, Andrew E. Schuh2, A Scott Denning2, Arlyn E. Andrews3, Andrew R. Jacobson3

1The Pennsylvania State University, 2Colorado State University, 3NOAA Earth System Research Laboratory

Contact: lzd120@psu.edu  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.
- Improve regional atmospheric inversions by quantifying flux uncertainty as a function of observational density and uncertainty in fluxes due to atmospheric transport uncertainty.
- Compare "top-down" (atmospheric inversion) and "bottom-up" (agricultural inventory) flux estimates in densely instrumented region.
- Understand the statistical structure of the model-data mismatch.
- Evaluate the temporal and spatial correlations of the model-data residuals.

Objectives of this study
- 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

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".

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 optimized 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 300m, 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 provided by Carbon Tracker.
- The third model level (160 m) is used in this study.

Seasonal Cycle Comparison
- Plots below show 31-day running means of daily daytime average CO2 mixing ratios.

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.

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 transport variability, 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 optimized version of the WRF-SiBcrop model.