“A Regional Atmospheric Continuous CO2 Network in the Rocky Mountains: Understanding Drivers of Flux Variability and Optimizing Regional Observations”

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Summary
The flux of carbon dioxide over the US Mountain West has an important yet inadequately quantified contribution to the total North American carbon budget. Over the first several months of work on this proposal, investigations of the drivers of CO2 flux in the Rocky Mountains using RACCOON data has involved two components: new coupled biosphere-transport model simulations of CO2 across the RACCOON domain using CarbonTracker (CT), and data mining of observed CO2 concentrations and meteorology from RACCOON towers. Below we document the activities performed by PI and staff at the University of Wisconsin over the initial reporting period.

I. Initiation of project
While the official start date on the project was May 2009, funds were not set up at UW until August 2009 due to some paperwork delays. Nevertheless, we have made great strides in our project and had already started post-doc search over summer 2009. Telephone and e-mail meetings with NCAR PI Britt Stephens ensued over the summer to being the project plan.

II. Hiring and training of post-doc
Bjorn Brooks is a recent Ph.D. student, previously working at DOE Oak Ridge National Lab, with expertise in land-atmosphere processes, statistical data-mining, and parallel programming. Dr. Brooks started in October 2009 and has been working to get up to speed on the nature of the project. In January 2009, Bjorn spent a couple of weeks at NOAA ESRL in Boulder, CO, presented initial results, and worked with CarbonTracker team on learning how to run and implement our proposed experiments in CarbonTracker.

III. Presentation of results
Several presentations of results related to this project were made at three meetings, described below. Related publications are in preparation for submission this summer.

Dr. Stephens presented this poster that focused on the Rocky RACCOON network and analysis of RACCOON tower data for signals of insect disturbance.


DOD SMART fellowship funded M.S. student Will Ahue is working on analyzing airborne CO2 data collected as part of the Airborne Carbon in the Mountains Experiment 2007 (ACME07), which complements research ongoing with the Rocky RACCOON network. Ahue presented a study at AGU of how boundary layer depth uncertainty feeds into regional carbon budget uncertainty as derived by aircraft and RACCOON tracer data. Additionally, these results were compared to CarbonTracker carbon fluxes.


As discussed previously, Dr. Brooks presented the aims of our proposed project to collaborators at NOAA ESRL, which spurred discussion on optimal ways to attack some of our experiments and hypotheses.

**IV. Observational representation analysis**

Preliminary results have provided for qualitative inferences regarding the coverage and representativeness of the RACCOON tower data. Data mining using a tower-similarity approach may also yield a more efficient method for assimilating misfit CO2 tower data into coupled biosphere-transport models such as CT while minimizing the biasing effects that transient meteorology and biology imposes on CO2 measurements.

![Figure 1. Diurnal CO2 profile of Frasier Experimental Forest illustrates a contrast between coherent and decoherent daily cycles.](image1.png)

![Figure 2. Vertical CO2 profile time series shows that coherent conditions exist regardless of season, but are constrained to moderate vertical CO2 gradients.](image2.png)
We are developing a simplified schema for identifying collections of data that are representative of regional CO\textsubscript{2} by subsetting each tower's observations into a coherent subset, in which CO\textsubscript{2} observations closely agree with those of its nearest neighbor, and a decoherent complement (Fig. 3). Coherent subsets have noticeably different diurnal profiles (Fig. 1), and are present during all times of day and seasons (Fig. 2), making this subsetting approach tenable regardless of time of day or season. Furthermore, by applying a tower-similarity approach between neighboring towers from different ecoregions (e.g. conifer forest and grassland/shrub) it may be easier to determine coherent conditions, provided that their diurnal CO\textsubscript{2} profiles differ (e.g. Fig. 1).

\textbf{V. CarbonTracker analysis}

Improved Rocky Mountain flux retrievals and RACCOON data mining are closely related. CT2009, the fourth CT release of combined model-measurement CO\textsubscript{2} flux tracking, included observations from only one of the six RACCOON towers (Fig. 3). Residual time series (Fig. 4) of simulated minus observed CO\textsubscript{2} (ΔCO\textsubscript{2} or mismatch) show mismatch discrepancies ranging from a few tenths to several PPM, with occasional mismatch above 5 PPM. Mismatch was typically larger during the daytime than at night, and was larger during the summer than winter. Niwot Ridge observations showed the smallest mismatch throughout the observational period and thus were the only RACCOON observations assimilated. A paucity of suitable RACCOON data for CT assimilation and optimization limit the ability to simulate CO\textsubscript{2} flux over those areas, which is one of the essential problems that we are addressing in this project.

To investigate our present ability to observe difference in flux retrievals between ecosystems in the US Mountain West we began a set of Observing System Simulation Experiments (OSSE) using CT using various ecosystem specifications in collaboration with Andy Jacobson at NOAA ESRL. This set of OSSE's can be thought of as threat test simulations for which only RACCOON ecoregions are specified. In these tests a large CO\textsubscript{2} flux perturbation is introduced and the retrieval of that perturbation is measured. We are presently analyzing the results from the first of these OSSE's, and its results will indicate what proportion of this large magnitude perturbation is capable of being retrieved by CT (i.e. CT sensitivity), and how that ecoregion absorbs the flux anomaly. A next set of OSSE's will assimilate the coherent subsets of data from multiple RACCOON towers. A comparison of these two sets of OSSE's will reveal whether the addition of RACCOON towers for CO\textsubscript{2} optimization will reduce model-data mismatch and improve flux retrievals.

CT CO\textsubscript{2} model-data mismatch is presently on the order of several PPM for most of the RACCOON domain. However, this may be improved by assimilating coherent subsets representative of big tower footprint conditions. The results of these OSSE simulations will indicate whether coherent-subsetting is beneficial to flux retrievals in the US Mountain West. The percentage of total flux retrieved and the model-data mismatch will provide two metrics by which we will quantify the effectiveness of control versus coherent subset assimilation.
Figure 3. Coverage of NOAA CO2 tower network (green) and RACCOON towers (red) in the ConUS.

Figure 4. CT2009 assimilated nighttime data from Niwot Ridge are shown above by the blue and black circles. The residuals, the model-data mismatch, are given by the green circles below.