REGIONAL AND CONTINENTAL NORTH AMERICAN CARBON EXCHANGE IN 2003 AND 2004 USING AIRCRAFT AND SATELLITE DATA (CO_2 BUDGET AND REGIONAL AIRBORNE (COBRA) STUDIES)

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ABSTRACT

We quantify atmosphere-biosphere carbon exchange at the continental scale across North America during the summers of 2003 and 2004. The 2003 campaign features continental transects across the northern portion of North America with significant influence from biomass burning, while the 2004 study focuses on the greater New England and Quebec region. We use a Lagrangian, adjoint atmospheric model [*Gerbig et al.* 2003a,b; *Lin et al.* 2003] coupled to a biosphere model derived from the Vegetation Photosynthesis Model [*Xiao et al.,* 2004]. Our analysis of the 2004 airborne data demonstrates the progression of increasing carbon uptake through the boreal zone during the seasonal transition from early spring to late summer. Data from the coast-to-coast transects of the 2003 campaign allow us to quantify large scale carbon exchange across the continent.

FRAMEWORK

Our approach is a receptor-oriented modeling framework, consisting of a time-reversed Lagrangian particle transport model (STILT) [*Gerbig et al.* 2003a,b; *Lin et al.* 2003] coupled to a vegetation CO_2 flux model that calculates gross primary production and respiration by partitioning photosynthetic and non-photosynthetic respiration. To drive atmospheric transport, the adjoint transport model utilizes wind fields from the Colorado State Regional Atmospheric Modeling System (RAMS) with the Grell convection parameterization [*Grell and Devenyi*, 2002], the Eta Data Assimilation 40-km reanalysis product (EDAS-40), or the Weather Research and Forecasting (WRF) model. The biosphere model incorporates MODIS-derived enhanced vegetation index (EVI) and land surface water index (LSWI) together with GOES-derived shortwave radiation [*Diak et al*., 2004] to capture surface spatial heterogeneity and variations in soil moisture, canopy nutrition, solar input and phenology. Functional dependence of CO_2 flux is integrated through optimizing parameters in the biosphere model using Ameriflux eddy covariance data. We optimized corresponding Ameriflux data for eight vegetation types, based on GLCC 2.0 land cover classes. These initial biosphere parameters serve as a priori values in a Bayesian optimization method, where the adjoint atmospheric model links the atmospheric measurement at a receptor point to the appropriate footprint at high spatiotemporal resolution within the domain of the biosphere. We use a Green's function analysis of NOAA CMDL data from selected stations in the Pacific Ocean to set an upstream continental boundary condition for North America.

COBRA AIRBORNE INTENSIVES

The COBRA-2003 airborne campaign took measurements of CO_2, CO, O_3, and a suite of CFCs during May and June, 2003. Flights consisted of repeated vertical cross-sections along a route that looped North America twice, starting each loop in Boulder, CO, flying north along the West Coast to Campbell River BC, across the boreal forests of Canada to Yarmouth, NS, and returning via New England and the U.S. Midwest. Inversion of the airborne data allows calculation of carbon flux from the entire continent for a 4-week period. On the second loop, a number of large forest fires were burning in Manitoba and Ontario during June 19-23, 2003, the signal from which we saw in airborne measurements of CO and CO_2. Our measurements provide the basis of an opportunistic experiment to get a unique new regional constraint on estimates of these emissions. We have adapted our framework to incorporate MODIS-based trace gas biomass burning emissions estimates made at NOAA CMDL [*C. Wiedenmyer*, manuscript in preparation, 2005], and we use our data in an inversion to help optimize the emissions algorithm.

The primary focus of the 2004 COBRA-Maine airborne intensive was to perform repeated experiments to characterize carbon exchange in Maine and southern and central Quebec. These experiments were designed to be Lagrangian as described in *Lin et al.* [2004]. During each experiment, a contiguous airmass forecast to influence the Ameriflux Howland Forest tower or the CMDL Argyle tall tower was sampled vertically and horizontally at 8, 16, and sometimes 24 and 36 hours upstream and again at the receptor point. The upstream data, when contrasted with downstream concentrations, provide a simple differential measurement of carbon exchange from the surface landscape footprint with which the measured airmass interacted. Because the receptor point is at a tower, the tower measurements can provide an additional constraint when used in the framework. We have analyzed a selected number of these experiments in detail, yielding optimized vegetation CO_2 flux model parameters and carbon fluxes with defensible error bars. Of particular interest is a case study of June 10^{th} and 11^{th}, 2004, when a favorable high pressure synoptic system resulted in clear skies, general subsidence, and consistent northwesterly winds blowing across central Quebec, southern Quebec, and Maine. We use the relatively straightforward meteorological situation and corresponding aircraft data to demonstrate the complete, updated receptor oriented framework in its entirety to calculate regional carbon fluxes for a short time period in Maine/Quebec. Initial results from the full suite of experiments trace the northward progression of increasing carbon uptake through the boreal zone during the seasonal transition from early spring to late summer 2004.

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