CD-01

Spatial Integration of Regional Carbon Balance in Amazônia

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Abstract

We propose a 3-year continuation of our investigation of processes that control land-atmosphere CO_2 exchange in Amazônia, using a suite of numerical models to extrapolate local results to regional and Basin scale. We emphasize three key areas of research: (1) evaluation of our models across a range of spatial and temporal scales, from local fluxes and isotope ratios to field campaigns in the area of the Flona Tapajos, to large regions sampled by airborne experiments; (2) a collaborative investigation of the effects of surface water and seasonally inundated land on exchanges of energy, water, and CO_2; and (3) estimation of regional and Basin-scale carbon balance on seasonal, annual, and interannual time scales by inversion of atmospheric data using tracer transport modeling.

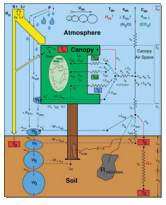
Evaluation of a new version of the ecophysiology model SiB will be by direct comparison to measured fluxes of heat, water, and carbon; canopy profiles of CO_2; and the stable isotope ratios of fluxes and stored carbon. The model has been coupled to a mesoscale atmospheric model (RAMS), and will also be evaluated by comparison to observed weather and to concentrations and $\delta^{13}C$ of CO_2 in the regional atmosphere, as measured by other teams from towers and airborne platforms. The evasion of CO_2 from the Tapajos River will be investigated in a set of collaborative field campaigns in which other teams will document local fluxes and isotope ratios of CO_2 from the River and from soils and vegetation in different ecosystems. We will then use the coupled SiB2-RAMS model to propagate these fluxes through the regional atmosphere and predict variations in concentrations in space and time and compare to measurements made by other teams from boats and aircraft. At the larger regional and Basin scales, the influence of surface water and inundated land will be investigated by prescribing the areal extent of these surfaces in RAMS from products developed by other teams using radar and microwave imagery. Energy, water, and CO_2 fields simulated using these fields will be compared to those simulated in a control experiment using classifications based on AVHRR imagery, and to observed meteorology and trace gas concentration measured during the COBRA-BRAZIL campaigns. We have developed a synthesis inversion method for estimation of area-averaged surface fluxes from measured CO_2 at regional scales by including lateral inflow fluxes and initial conditions in the calculation. We will extend these methods to use multiple tracers (CO, $\delta^{13}C$) and apply them in the Tapajos intensives, over large regions for COBRA-BRAZIL, and to the entire Basin using a suite of global transport models. These methods yield quantitative estimates of both the area-averaged flxu and the uncertainty in these fluxes.

This investigation directly addresses LBA-E questions CD-Q1 ("What is the (climatically driven) seasonal and interannual variability of the carbon dioxide flux between the atmosphere and different land cover/use types?"); CD-Q3 ("What are the relative contributions of fluxes from natural and disturbed ecosystems to the net Amazônia-wide flux?"); and ND-Q5 ("What is the importance of periodically "wet" environments for the land and atmospheric balances of nutrients, carbon dioxide, trace gases, and water and energy on multiple scales?"). The proposed research addresses NASA Earth Science Enterprise questions of variability in the carbon fluxes across Amazônia in space and time; forcing of these variations by climate and land use, the response of terrestrial ecosystems and the atmosphere to this forcing, and prediction of the consequences for CO_2 concentrations and stale isotope ratios.

Objectives

1. **Evaluation of ecophysiological model simulations** of ecosystem fluxes of heat, water, momentum, CO_2, and $^{13}CO_2$ at flux towers in primary forest, logged forest, and pasture. Further evaluation of vertical structure in CO_2 and $\delta^{13}C$ from data collected by other teams. Focus on diurnal variability, rainy-season/dry-season controls, and interannual variability.
2. **Evaluation of coupled ecophysiology-mesoscale atmosphere model simulations** for case studies across Amazônia using COBRA data, radiosondes, and other atmospheric data;
3. **Quantify the impact of surface water, wetlands, and seasonally-flooded ecosystems** on local and regional energy budgets, climate, and carbon cycling.
4. **Quantify regional fluxes and their uncertainty** over well-defined spatial domains for intensive observing periods from data collected during COBRA experiments
5. Document **influences of advective transport, diurnal PBL dynamics and deep cumulus convection** on regional distribution of free-tropospheric CO_2, $\delta^{13}C$, and CO
6. **Estimate magnitude and uncertainty of basin-wide carbon flux** using inversion of atmospheric observations and transport at global scale.

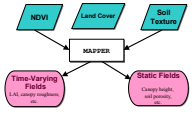
SiB2



- Ecophysiological process model describing land-air exchanges of radiation, heat, water, momentum, CO_2, and $^{13}CO_2$
- Flexible resolution, stand-alone or coupled to a range of atmospheric models
- Time steps of seconds to minutes for interaction with PBL turbulence

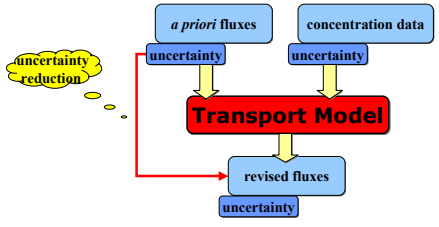
- SiB2 model is parameterized from satellite imagery and other spatial data (soils, vegetation)
- Local-scale simulations driven from observed micromet data coupled to CSU RAMS

Model Parameters



Inverse Modeling

Bayesian Synthesis

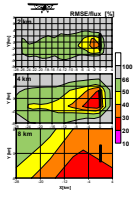


Surface exchange of CO_2 is heterogeneous in space and time, which complicates generalization from tower-based flux data across complex landscapes. Process models can be developed and tested locally against flux data. These models can be extrapolated using imagery and other spatial data products. But how can we know when and how these extrapolated models are wrong?

Variations in atmospheric concentrations and stable isotope ratios of CO_2 contain information about surface fluxes. Quantitative methods have been developed to extract this information using tracer transport models. The mixing properties of the atmosphere allow evaluation of spatially aggregated surface fluxes.

"Inverse modeling" is so named because we estimate causes (fluxes) from effects (concentrations downwind).

Regional Synthesis Inversion Of Aircraft Campaign Samples



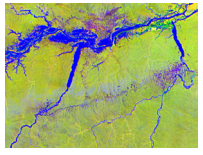
- Influence functions are calculated from RAMS for a series of samples collected on cross-wind aircraft transect
- Each sample's "footprint" is treated as a basis function for synthesis inversion
- Inversion recovers flux within quantifiable error on a grid of variable sources, even in the presence of turbulent variations

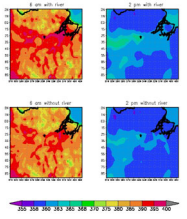
LBA Sampling Impact on Global Inversion

A posteriori uncertainty (gtC/yr) for Amazon

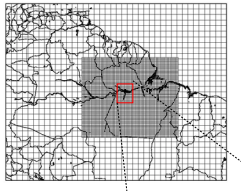
	Existing Flasks	+ Weekly LBA profiles
Model 1	0.89	0.08
Model 2	0.89	0.52
Model 3	0.92	0.73
Model 4	0.91	0.25
Model 5	0.85	0.16
Model 6	0.90	0.22
Model 7	0.89	0.47
Mean	**0.89**	**0.35**

Forward Simulations

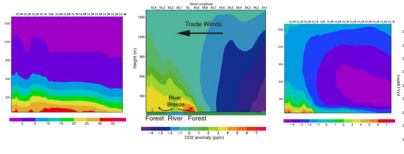




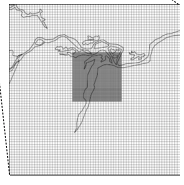
Grids 1 and 2 (Δx=125 and 25 km)



Simulated CO_2 Anomaly (Δx = 1 km)
Longitude-Height Sections Across Tapajos River: August 8



Grids 3 and 4 (Δx=5 and 1 km)



Very strong vertical gradients of $[CO_2]$ were simulated in early morning when the thermal structure is strongly stable.

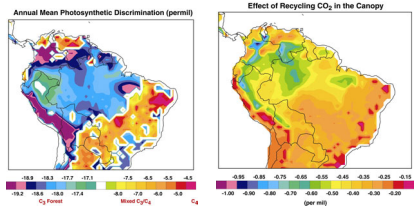
By mid-afternoon, a deep mixed layer formed, with strong drawdown over the forest. An internal boundary layer was apparent over the Tapajos River. A strong mesoscale "riverbreeze" circulation produced a convergence line along the east bank of the River. CO_2 released by evasion accumulated along this convergence zone.

At sunset, the simulated mixed layer decoupled from the surface. Elevated $[CO_2]$ began to accumulate in the newly-formed stable layer, and the CO_2-depleted residual layer advected toward the west.

CO_2 concentration measured by a continuous analyzer flown at 300 m elevation over the Amazon River (blue) and adjacent forest (green) on the morning of August 13. Two legs of over 100 km each were flown, one over the forest, and the other over the River.

Concentrations over the river were elevated by more than 10 ppm. Turbulent variations of $[CO_2]$ were much greater over the forest.

Multiyear Simulations of Ecosystem Exchange and Isotope Biogeochemistry



Isotopic fractionation simulated by SiB2 (annual mean for 1987) driven by analyzed climate, and the effect of canopy-scale recycling of respired carbon by photosynthesis

Simulated Tapajos Monthly NEE