Modeling Amazonian Carbon Release with Calibrated Soil-Vegetation-Atmosphere Transfer Models (CD-18)

PIs: Jim Shuttleworth[1] (shuttle@hwr.arizona.edu), Carlos Nobre[2], and John Gash[3]

CoIs: Eleanor Burke[1] (eleanor@hwr.arizona.edu), Luis Bastidas[4], Antonio Manzi[2], Humberto R da Rocha[5], and Chris Huntingford[3]

[1] Department of Hydrology & Water Resources, University of Arizona, Tucson, Arizona 85721, USA
[2] CPTEC-INPE, 12630 Cachoeira Paulista, Sao Paulo, Brazil
[3] Centre for Ecology and Hydrology, Wallingford OX10 8BB, UK
[4] Utah State University, Civil and Environmental Engineering, 4110 Old Main Hill, Logan, Utah 84322, USA
[5] Departamento de Ciencias Atmosfericas-IAG Universidade Sao Paulo, Sao Paulo, CEP 05508-900 , Brazil

Abstract

This proposal is motivated by the question "How do ecosystems respond to and affect global environmental change and the carbon cycle?" for the Amazônian forest ecosystem. Over the last decade, description of carbon exchange processes has been introduced into some of the more realistic and important Soil-Vegetation-Atmosphere Transfer (SVAT) models used in General Circulation Models (GCMs). In addition, important progress has been made in developing state-of-the-art multi-parameter estimation techniques that can provide values of preferred sets of the (often many) model parameters used in complex SVAT models by optimizing against the (often multiple) measurements collected in present-day field experiments. The LBA Experiment is providing a uniquely rich source of long-term field data for Amazon forest sites in different climatic conditions and for a range of soils and disturbance regimes. We propose to use these data to calibrate the description of the carbon and energy-water exchange processes represented in two advanced SVAT models (SiB2C and MOSES-TRIFFID) using advanced multi-parameter estimation techniques. Further, we will investigate whether and how the preferred sets of model parameters in the two SVAT models change with season, the nature of the underlying soil, and/or disturbance regimes, and explore relationships between the preferred parameters found at individual LBA sites and relevant remotely sensed (e.g., TERRA) data products. The National Centers for Environmental prediction (NCEP) and the European Centre for Medium-Range Weather Forecasting (ECMWF) are both currently preparing long (50-year and 40-year, respectively) time series of atmospheric variables (including near-surface atmospheric forcing variables) from historical atmospheric and remotely sensed observations using data assimilation techniques. These time series will become available for scientific use within the lifetime of this proposal. We propose to compare these new model-calculated re-analysis data with Amazônian climate records and with field data obtained during LBA and earlier studies to investigate their reliability within Amazônia. Assuming these data are reasonably realistic (or that simple corrections can be made to make them so), we then propose to use these historical data to force two-dimensional arrays of calibrated versions of SiB2C and MOSES-TRIFFID to investigate model-to-model differences and the spatial and temporal variability in carbon exchange of and within the Amazônian region. When doing so, we will exploit any relationships we have previously found between calibrated parameters and seasonal climate, forest disturbance, underlying soil type, and remotely sensed variables, as appropriate.

Goal and Objectives

The overall goal of this proposal is:

To investigate temporal and spatial variations and model-to-model differences in the calculated carbon exchange of the Amazônian forest ecosystem over the last 40-50 years using models of soil-vegetation atmosphere interactions which have been calibrated against field data from the LBA field sites using modern multi-parameter estimation techniques.

This will be addressed through the following objectives:

1. Obtain the available data from the LBA field sites relevant to the calibration of SVAT models and carry out a multi-parameter calibration of SiB2 and MOSES-TRIFFID using these data
2. Explore the variation in optimized parameters obtained by calibrating SiB2 and MOSES-TRIFFID against LBA data, to determine if and how these parameters are related to site-specific seasonal climate, disturbance regimes, underlying soil, and appropriate remotely sensed geophysical variables
3. Obtain the time series of near-surface forcing variables available from the re-analysis data sets from ECMWF and/or NCEP and validate these time-series against climate records for Amazônia and data from past and ongoing Amazonian field studies (e.g., LBA, ABRACOS, ARME, etc.)
4. Investigate the temporal and spatial variations and model-to-model differences in the calculated carbon exchange of the Amazônian forest ecosystem over the last 40-50 years by using the time series of meteorological variables [validated in (3)], to force two-dimensional arrays of calibrated SVAT models [specified from (1) and (2)]

Approach

1. **Multi-parameter calibration of SiB2 & MOSES using available data.**
   - Create off-line versions of the SVAT models for use with the multi-parameter optimization algorithm.
   - Obtain the available data from the LBA field sites and organize for use in the multi-parameter optimization algorithm.
   - Carry out multi-parameter optimization to obtain the preferred sets of parameters for each SVAT model for each LBA field site.
2. **Explore variations in optimized parameters between sites, seasons, disturbance regimes, and the underlying soil and their relationship with remotely sensed variables.**
   - Carry out multi-parameter optimizations for subsets of the data in different seasons to investigate the stability of optimized parameters over time.
   - Investigate the relationship between site-to-site differences in optimized parameters and:
     - the disturbance regime and soil at each site.
     - local values of relevant remotely sensed variables.
3. **Validate time-series of near-surface forcing variables available from re-analysis data sets against climate records for Amazônia and any available field data.**
   - Obtain, quality control, and synthesize all relevant field and climatological data.
   - Obtain re-analysis data and prepare relevant subsets and derivatives for comparison with climatological and field data, as required.
   - Compare model-derived re-analysis data against climatological and field data and investigate (and, if necessary, correct for) any systematic errors.
4. **Calculate carbon exchange for past 40-50 years using driving data from (3) and a 2-D array of the SVAT models defined in (1) and (2) and analyze the results.**
   - Using results from (1) and (2), set up 2-D arrays of the calibrated SVAT models across the Amazônian forest ecosystem.
   - Calculate time-dependent spatial fields of carbon exchange using driving data from (3)
   - Analyze and interpret the spatial and temporal variations in the carbon exchange of the Amazônian forest ecosystem in terms of global and regional climatological features and phenomena.

Preliminary related work

- Multi-parameter calibration of the BATS2 land surface model against long term measurements of water, heat and carbon fluxes over a natural Amazon forest ecosystem.

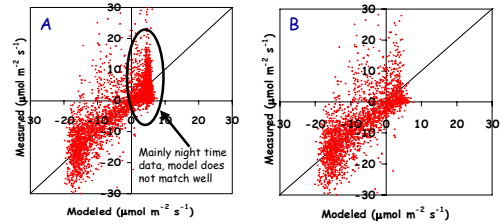

Figure 1. Comparison of modeled and measured CO_2 exchange calculated using optimized parameter sets. *A* shows the comparison with all available data included. *B* shows the comparison with the nighttime CO_2 flux data (incoming solar < 0) filtered.

- BATS2 cannot match the time dependent structure in the observed CO_2 exchange at night. It is likely that some of the structure in the observations is due to bursts of CO2 intermittently released from inside the canopy in stable, nighttime conditions.

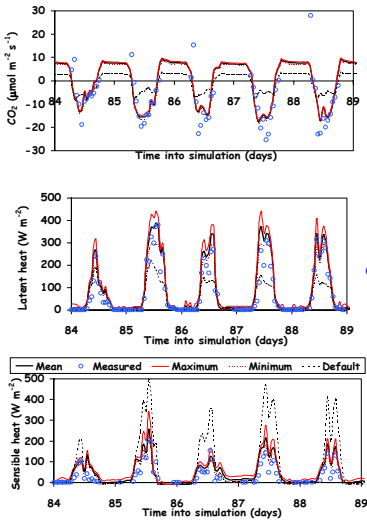

Figure 2. Time series of measured, modeled, and minimum and maximum possible fluxes for a selected 5-day period. *A* shows CO_2 flux with the night time data filtered. There are still some positive fluxes early in the morning that cannot be described by the model.

- Measured fluxes fall well within the range of the optimized simulations. Simulations made using the default parameters significantly over-estimate the sensible heat flux and under-estimate the latent heat flux and the magnitude of the CO_2 flux.

Integration and Synthesis

The LBA Experiment seeks to answer two key questions, (a) ***"how does Amazônia currently function as a regional entity?"***, and (b) ***"how will changes in land use and climate affect the biological, chemical, and physical functions of Amazônia, including the sustainability of development in the region and the influence of Amazônia on global climate?"*** This proposal will contribute towards answering these questions by providing calibrated models of carbon and surface energy exchanges for natural and disturbed Amazônian rain forest ecosystems using the field data gathered under LBA and, by using these models with historical time series of forcing data, calculating the net carbon exchange for the Amazônian region, investigating its variability in time and space, and (to the extent possible with the available LBA flux data) its response to forest disturbance. Our research is also relevant to the focus question for LBA-ECO, i.e., ***"How do tropical forest conversion, re-growth, and selective logging, influence carbon storage, nutrient dynamics, trace gas fluxes, and the prospect for sustainable land use in Amazônia?"*** and, in particular, addresses the question ***"How do [Amazônian] ecosystems respond to and affect global environmental change and the carbon cycle?"***