LBA-ECO TG-05:
Modeling the Effects of Land Use Change and Surface Hydrology on Carbon and Trace Gas Fluxes over the Amazon Region

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ABSTRACT

The fundamental approach we propose for LBA-ECO II research involves integrated studies and predictive modeling for Amazon carbon, water, and nutrient cycles using a regional ecosystem model called NASA-CASA (Carnegie-Ames Stanford Approach), which has been uniquely developed and applied using satellite data drivers as a component of the NASA LBA-ECO I program. Our proposed work thereby builds upon over four years of coordinated data assimilation and model development, as part of the LBA Science Team. The research plan we now propose is designed to extend the value of new LBA site (tower and small plot flux) data and remote sensing products by up-scaling with NASA-CASA to the regional level using a variety of different land cover products available for the Amazon region. In this manner, we propose to make new linkages in LBA-ECO project science between site-based investigation and regional scale modeling and remote sensing.

A unique aspect of our study approach is to treat land cover inputs to our ecosystem carbon modeling as *variable* according to time, spatial scale, and spatial resolution. In the proposed research plan, the NASA-CASA ecosystem model will make a series of simulation runs using multiple sequences of land cover change for the entire Amazon regional extent. The simulations will include the following land cover/land use class settings -- moist primary forest, dry primary forest, drought-deciduous forest, savanna, disturbed (burned), secondary forest, pasture, and annual crop. Nominal spatial resolution for hydro-meteorologic inputs to our LBA regional simulations will be 8x8 km pixel size. The percentage cover-weighted results from these individual model runs for land cover change sequences will be aggregated to reconstruct a history of regional heterogeneity in Amazon ecosystem dynamics. Trace gas fluxes (e.g., CO_2, N_2O) will be weighted by land cover change frequency distributions derived from the highest spatial resolution data available (e.g., from MODIS and Landsat sensors) for the entire region and for selected smaller areas around intensive LBA studies. High resolution (< 1-km) land cover images for 'footprint' areas of LBA tower sites will be used to define the proportions of each land cover class with which to weight ecosystem model estimates and validate against measured tower fluxes of carbon and water exchange. Particular emphasis will be placed on Tapajós National Forest (TNF) tower sites, where our Brazilian co-investigators are actively making field measurements of energy, water, and carbon exchange, which are vital to ecosystem model evaluation.

A second integrative aspect of this study will be to extend NASA-CASA model predictions of carbon and trace gas fluxes to (seasonally) inundated areas of the region. Through close collaboration with other LBA investigator teams whose studies have developed or used radar remote sensing products or surface water models, we will adapt our CASA model to include Amazon mainstem and floodplain dynamics, with focus on up-scaling wetland ecosystem methane and CO_2 emission fluxes. At the smaller scale of the TNF watershed, we will complete the development of a new parameterization scheme within the NASA-CASA model for coupling a surface water routing model called HYDRA (Univ. Wisconsin), and validating simulations of surface water flow against measured flow and dissolved carbon chemistry of the Rio Moju discharge network from the TNF.

STUDY OBJECTIVES

- Quantify the respective contributions of land cover change (e.g., its spatial resolution and heterogeneity) and disturbance (i,e., deforestation) to the overall uncertainty associated with regional source/sink estimates produced by Amazon ecosystem modeling for carbon, water and trace gas exchange.
- Validate Amazon ecosystem model predictions and their land cover inputs by comparison to tower-based measurements of net ecosystem production (NEP) and other field data sets.
- Extend and validate ecosystem model predictions for trace gas exchange into the floodplain, major tributaries, and inundated areas of the Amazon River mainstem.
- Recommend/prioritize improvements to Amazon ecosystem carbon models which will incorporate surface hydrologic flows, and to better constrain source/sink estimates for atmospheric CO_2 and other trace gases (N_2O, CH_4) of importance in LBA.

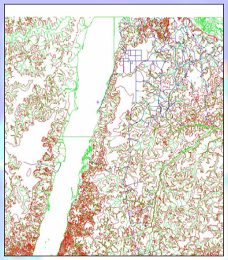
STUDY APPROACH

Field Measurements

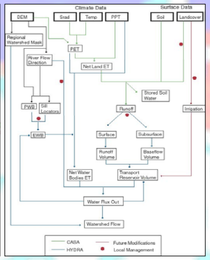
Forest Canopy Carbon and Water Fluxes. We are currently installing a new set of measurement sensors on the wooden towers at the two TNF Seca Floresta sites. We will measure profiles of radiation fluxes, humidity, leaf temperature (instrumentation from Delta-T Devices, UK), and photosynthesis rates at three canopy levels (top, middle, understory) in both the control and rainfall-excluded forest plots. Our daily and monthly process models of plant water flux and soil water content, ecosystem productivity, biogeochemical processes, trace gas emissions, and net carbon sequestration will be continuously evaluated for prediction errors and refined using these data collected at the TNF and other LBA tower study sites.

Surface Water Flow. The coupled CASA-HYDRA model is operational and can be described generally as an integrated set of computer programs to forecast runoff and flood flows for watersheds having response times ranging from one day to several weeks. The HYDRA module is a physically based simulation model of the hydrologic budget of a watershed. It represents a set of physical processes including interception, infiltration, interflow, base flow, overland routing and channel routing. Potential river discharge is calculated at each grid cell as the accumulated flow of water across the land surface. To validate the CASA-HYDRA predictions for the Rio Moju drainage of the TNF, a fixed-site sampling scheme is being established for river flow and water constituent sampling, with which we will attempt to establish a reference database for the drainage. This sampling scheme should also allow determination of the DOC flows past each sampling location in the drainage. Effects of land use on river constituent composition will be assessed.

TNF area DEM in red, hydrology in green, and roads in blue. Spatial resolution is ca. 90 meters. (Source: LC-03).



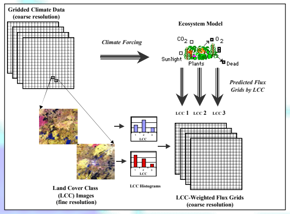
Schematic version of the CASA-HYDRA Regional water flow model



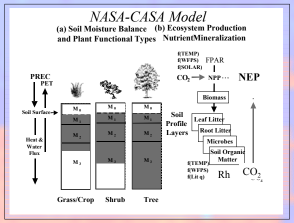
Integration and Synthesis

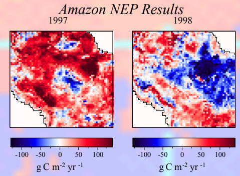
Terrestrial NPP and NEP fluxes are computed monthly (over the period 1982-Present) using the NASA-CASA (Carnegie-Ames-Stanford) Biosphere model (Potter, 1999; Potter et al., 2001). NASA-CASA is a numerical model of fluxes for water, carbon, and nitrogen in terrestrial ecosystems (see Figure above right). Our estimates of terrestrial NPP fluxes depend on inputs of global satellite observations for land surface properties and gridded climate drivers from interpolated weather station records (New et al., 2000).

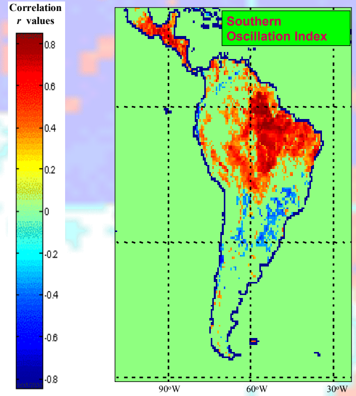
A flowchart is shown (at right) for producing regional ecosystem model estimates of net carbon exchange, weighted by area frequency distributions for multiple land cover classes (LCC). The ecosystem model is forced by a time series of relatively coarse spatial resolution climate data sets for predicted carbon fluxes using individual LCC parameters. Relatively high spatial resolution LCC histograms are derived from image classification methods for sub-grid cell areas, geo-rectified to the gridded climate data set. LCC-weighted flux grids are produced by combining modeled flux grids with the histogram distributions for each LCC in the image classification. Continental scale maps for monthly model inputs such as satellite leaf area index and FPAR will be generated for single LCCs by spatial interpolation.



MODELING RESULTS







Main Results: Predicted carbon flux (NEP) is highly correlated with SOI over practically the entire Amazon region east of 60°W, with rainfall and temperature as co-determinants of model estimates.

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