Pre-application Cover Page

Proposal to be Submitted to **DE-FOA-0000536**

Is this an Exploratory Application (**Yes** or **No**)? **No.** Is this a **New** or **Renewal** application? **New**

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Title: "Ecosystem fluxes of CO_2, CH_4, and other greenhouse gases, and photochemical drivers of BVOCs and O_3, in the Central Amazon Basin: links between the carbon cycle and drivers of climate change"

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Requested Funding (Estimated)

	year 1	**year 2**	**year 3**
Harvard University	220k	220k	220k
University of Arizona	125k	125k	125k

"Ecosystem fluxes of CO_2, CH_4, and other greenhouse gases, and photochemical divers of BVOCs and O_3, in the Central Amazon Basin: links between the carbon cycle and drivers of climate change".

Amazon forests are potentially susceptible to climate change, and can influence the course of climate change through complex, non-linear feedback processes. Amazonia holds vast reserves of organic carbon in an extremely dynamic ecosystem, mediating enormous fluxes of CO_2, H_2O, fixed nitrogen, and highly reactive organic species (Biogenic Volatile Organic Carbon, "BVOCs"). The ecosystem provides the fuel for vast fires that release carbon and modify atmospheric radiation, precipitation and composition regionally and globally. Amazonia provides the free radical precursors that drive the most vigorous photochemistry on earth and, through deep convective inputs, the most important reactive species in the climatically crucial regions of the Tropical Tropopause Layer (TTL) and lower tropical stratosphere.

The proposed study will focus on field measurements of ecosystem fluxes of CO_2, H_2O, BVOCs, nutrients, and NO_x. We will study the interactions of these fluxes and budgets with global climate drivers, regional climate, climate-related photochemical species (e.g. O_3), and secondary aerosols. The work will leverage the upcoming Manaus study of the DOE ARM Climate Research Facility (ACRF), which aims to elucidate the interaction between urban emissions, natural cycles, and climate on the effluxes, and fate of CO_2, BVOCs, nutrients, and NO_x. The ACRF study will emphasize processes that affect aerosol extinction and cloud condensation nuclei (CCN). We intend to provide a crucial complement to the ACRF program by defining the ecological fluxes and their controls and interactions with climate, upwind of the Manaus site and absent significant urban emissions.

Science questions/hypotheses

Our proposed work will address the following scientific questions:

1. Carbon cycle and ecosystem processes, interaction with climate: What are the responses to long term trends in climate, episodic events (droughts), and recovery from prior and contemporary disturbance (wind throw, harvesting) in an Amazonian forest? Particular focus will be on ecosystem fluxes of CO_2, greenhouse gases (CH_4, N_2O), and latent heat, and on corresponding changes in ecosystem structure.

2. BVOCs and ecosystem processes, interaction with climate: What are the ecosystem BVOC emissions and what controls them, for the range of environmental conditions (precipitation, temperature, radiation, soil moisture) that represent scenarios of Amazon change?

3. Biomass burning, photochemical ozone, and ecosystem process and carbon flux: How does biomass burning aerosols influence the quality of radiation and hence CO_2 uptake and BVOC emissions? What are the effects of pollutant stressors such as elevated ozone or NO_x on the forest carbon budget and BVOC emissions? How does the response of Amazonian ecosystems to ozone and NOx, influence its responses to climate variability and change (modeling analysis using the ED-2 model)?

Science Program

We will propose a three-year measurement program at the "Km 67" tower and ecological study site in the Tapajos forest south of Santarem, Brazil. In the NASA-LBA program, ecological measurements started at this site in 1999 (eddy flux in 2001), continued to the present in the NSF "Partnerships in International Research and Education (Amazon PIRE)/INPA-LBA program. The PI on this proposal was a PI in both of these programs.

Eddy flux measurements of CO_2, H_2O, sensible heat, and momentum, plus measurements of weather and climate will be carried out collaboratively. Ecological surveys of our permanent plots, comprising 75 ha in the vicinity of the tower, will determine above-ground biomass and growth, changes in CWD stocks, and shifts in plant composition, all in the context of data extending back more than a decade. High-sensitivity NO_x and NO_y data, along with soil nutrient measurements, will be used to track nutrient cycle and their interaction with atmospheric oxidants. Carbon monoxide will be measured to define the influence of biomass-burning. BVOC emissions will be tracked in real-time using proton-transfer mass spectrometry (PTR-MS), as well as with gas canisters analyzed by gas chromatography mass spectrometry. Ozone will be measured to track episodes of anthropogenic influence and photochemical process relevant for trace gases and aerosol formation. Particle chemistry will be monitored using an Aerosol Mass Spectrometer (AMS), analysis of filter samples, and optical measurements. A cloud condensation nucleus counter (CCNC) will be used to track climate-relevant properties. We plan to deploy the new COSMOS ecosystem-scale soil moisture sensor (based on attenuation of cosmic-ray

secondary neutron by soil water), a new Quantum Cascade Laser Spectrometer (QCLS) developed with DoE support at Arizona, Harvard and Aerodyne and capable of direct measurement of CO_2 isotopic fluxes, a hyperspectral camera for measuring canopy processes (funded secured from NASA already) and an imaging thermometer/radiometer for canopy temperature distribution and radiation balance. The measurements will be analyzed to define response drought stress, in the upper canopy, gaps, and understory. The data will be shared in real time with collaborative modeling projects headed by Prof. Paul R. Moorcroft and the present PI (based on the Ecosystem Demography Model -2), as well as being made public and promoted for use by other Earth System models.

Responsiveness to DoE-FOA-0000536 is defined by these elements of the call:

- The role of natural disturbances in carbon cycling, particularly disturbances associated with changing climate (e.g., changes in atmospheric carbon, precipitation, nutrients). *Our goal is to elucidate the relationships between ecosystem productivity, BVOCs, NO_x, O_3, and aerosols, all of which strongly respond to changes in T, precipitation, sunlight, NOx inputs, and atmospheric effects of fires.*

- New and improved understanding of carbon pathways, fluxes and ecosystem function with particular emphasis on Arctic and tropical ecosystems. *The long term measurements of eddy flux and ecosystem structure at the site (2001-2006; 2008-present) provide an unequaled opportunity to assess the ecosystem response to environmental stress, including two severe droughts (100-yr droughts occurred in 2005 and 2010 in Amazonia, mainly 2010 at km 67), building upon recent comprehensive terrestrial model developments (supported by the Moore Foundation) to help synthesize the observations into a climate-interaction modeling framework.*

Relationship with collaborators and related projects.

The proposed work is closely linked to work by collaborators in projects. However, the study design provides a stand-alone project of the highest quality by making contingency plans to cover required contributions in the event that some of the collaborations may not materialize.

The NSF Partnerships in Research and Education (PIRE) study. The new measurements will extend, complement and enhance the NSF PIRE/LBA INPA program of observations and training.

Collaboration with Prof. Paulo Artaxo (USP). The Artaxo project is planned to collaborate with measurements of BVOCs, aerosol composition and optical properties, O_3, and possibly NO_x at Santarem.

Collaboration with Prf. Rodrigo da Silva (UFOPA Santarem) and Pra. Michela Figueira (UFOPA Santarem). Prf. da Silva and Pra. Figueira have ongoing programs studying the ecological structure of the Tapajos Forest and the km 67 site in particular.

Collaboration with Prof. Paul Moorcroft. Prof. Moorcroft heads the Moore Foundation model inter-comparison for ecosystem-atmosphere models in Amazonia. We will link our measurements to this activity and its follow-on to assess the ecological mechanisms and controls for which the outcomes are observed in our study.

Collaborative proposed study of highly reactive BVOCs (Kolby Jardine, U. of Arizona). Dr. Jardine is proposing to this FOA a set of complementary measurements of BVOCs focused on understanding the ecological and physiological drivers of of hydrocarbon emissions.

Relationship to the DoE ACRF study: human activities elevate aerosol particle number and mass concentrations, and future increments in the Amazon Basin span the range where cloud properties are most sensitive. The DOE ARM Climate Research Facility (ACRF) will be deployed downwind of Manaus, Brazil (3° 6' 47" S, 60° 1' 31" W) from Jan to Dec 2014 as part of the Green Ocean Amazon (GoAmazon2014) experiment, to study this problem. The site experiences the extremes of pristine atmospheric conditions and heavy pollution from the city. The deployment will enable the study of how aerosol and cloud life cycles, including cloud-aerosol-precipitation interactions, are influenced by pollutant outflow from a tropical megacity.

The ACRF project does not measure ecosystem processes or biosphere-atmosphere exchange. The biosphere and atmosphere of the Amazon are closely coupled, with myriad processes of one affecting the other, especially in the natural Amazon Basin. We can conceptualize the aerosol processes in Amazonia, and their effects on climate, as the sequence: {plants, stressors} → BVOC emissions → atmospheric oxidation → {particle formation, ozone production} → CCN → clouds → rainfall. The proposed project will fill the critical gap {plants, stressors} → BVOC emissions. *We will study the ecosystem as a driver of the variability of the climate-relevant properties that will observed in the ACRF deployment*.