Terrestrial Ecosystem Science

Summary of projects awarded in spring 2012 under Funding Opportunity Announcement DE-FOA-0000536.

Funding Opportunity Announcement Overview

The Office of Biological and Environmental Research's (BER) Terrestrial Ecosystem Science (TES) program is the result of the consolidation of its former Terrestrial Carbon Processes (TCP) program and Program in Ecological Research (PER). The goal of the TES program is to provide scientific knowledge of terrestrial ecosystems to:

- Provide accurate predictions of their roles in influencing the atmospheric concentration of greenhouse gases;
- Quantify terrestrial carbon sources and sinks and how they are changing in relation to other atmospheric, climatologic and hydrologic influences; and
- Assess terrestrial feedbacks on carbon cycle and climate change.

The Funding Opportunity Announcement **DE-FOA-0000536**, released in the summer of 2011, considered applications on measurements, experiments, modeling and synthesis that provide improved quantitative and predictive understanding of the terrestrial ecosystem that can affect atmospheric greenhouse gas concentration changes and thereby affect the anthropogenic forcing of climate. The emphasis of this FOA was to understand the impacts of, and feedbacks from a changing climate on non-managed terrestrial ecosystems. Authors were required to pose their research applications in the context of representing terrestrial ecosystem processes in Earth system models. Authors were encouraged to consider utilization of, or collaboration with, sites that have existing support (e.g., former FACE or existing AmeriFlux projects) thereby leveraging existing investments, archived samples and long-term data sets.

While the program supports a broad spectrum of fundamental research in terrestrial ecosystem science and considered research applications within this scope, this FOA particularly encouraged applications in the following Science Areas:

- The role of natural disturbances in carbon cycling, particularly disturbances associated with changing climate (e.g., changes in atmospheric carbon, precipitation, nutrients)
- The role of belowground processes and mechanisms across scales (e.g., soil carbon transformation, root dynamics, mycorrhizal interactions, and plant mediated (e.g. root exudates) biogeochemical transformations) associated with a changing climate.
- Factors controlling belowground processes associated with transformation of biomass into soil organic matter and stabilization mechanisms of the long-lived carbon components in soil as well as the results of those processes in the context of a changing climate.
- Responses and feedbacks of coupled biogeochemical cycles to climate change, including coupled trace element cycling (e.g. Mo, Fe).

- New and improved understanding of carbon pathways, fluxes and ecosystem function with particular emphasis on Arctic and tropical ecosystems

This FOA highlighted belowground processes since they are a critical component to carbon cycling, yet our understanding of the specific processes has been over simplified or ignored. This “black box” approach to belowground systems will not lead to a mechanistic and predictive understanding of these systems as potential long-term terrestrial sinks for carbon. The goals of belowground ecosystem research are to quantify rates and magnitudes of carbon accretion, and to understand processes and properties that control transformation of biomass into organic matter, including studies of stabilization mechanisms of the long residence time components, their fate, and ecosystem feedbacks. Research is needed on these processes for different climate and vegetation conditions (e.g., as represented by AmeriFlux research sites) where results can be spatially scaled to estimate carbon changes across climate zones and bioregions. Products of research that focus on belowground carbon processes (e.g., organic matter stabilization and dynamics, carbon turnover rates, root and microbial respiration, carbon/nitrogen/other relationships) should provide new insights and model representation opportunities for coupled interactions, residence time and other carbon source or sink properties of belowground ecosystem components.

Overall, proposed research was intended to fill critical knowledge gaps, including the exploration of high-risk approaches. BER encouraged the submission of innovative exploratory applications with potential for future high impact on terrestrial ecosystem science.

Twelve awards (three of which were exploratory awards) were made through this Funding Opportunity Announcement in FY 2013 totaling $8,601,966 over three years.

Funded Projects

Understanding the Mechanisms Underlying Heterotrophic CO_2 and CH_4 Fluxes in a Peatland with Deep Soil Warming and Atmospheric CO_2 Enrichment

- **Principle Investigator:** Scott Bridgham (University of Oregon)
- **Collaborators:** Jason K. Keller (Chapman University) and Qianlai (Charlie) Zhuang (Purdue University)
- **Award:** $1,047,425 over 3 years

The overall objectives of this proposal are to provide a mechanistic understanding of how deep warming of peat and carbon dioxide (CO_2) enrichment in a peatland affect carbon mineralization and methane (CH_4) production, consumption, and transport and to incorporate that understanding into a biogeochemistry model, the Terrestrial Ecosystem Model (TEM). The proposed work will compliment ongoing DOE research at the Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) experiment taking place in a black spruce-Sphagnum bog located at the Marcell Experimental Forest (MEF) in northern Minnesota. Porewater from all treatment plots will be collected monthly throughout the soil profile to determine seasonal depth dynamics of key electron donors and acceptors and fermentation products that together regulate anaerobic carbon mineralization and CH_4 dynamics. We will also measure the stable isotope composition (δ13C and δD) in dissolved CH_4, CO_2 and acetate in porewater and in emitted CH_4 and CO_2 to explore, in situ, the dominant methanogenic pathway, the importance of recently fixed carbon in anaerobic carbon mineralization, and the degree of CH_4 oxidation in the unsaturated zone. Periodic measurements of $14CH_4$ and $14\ CO_2$ will be used to determine the age of respired carbon and to determine if deep, older peat is more heavily mineralized in response to warming. Initial laboratory experiments will explore the potential temperature response of carbon mineralization in shallow, relatively labile, and deep, relatively recalcitrant, peat soils as well as the importance of priming in regulating the temperature response of peatland carbon mineralization. This increased mechanistic understanding of the complex set of controls that regulate CH_4 dynamics, and how they respond to key global changes, will be explicitly incorporated into TEM.

Hydraulic Redistribution of Water Through Plant Roots - Implications for Carbon Cycling and Energy Flux at Multiple Sites

- **Principle Investigator:** Zoe Cardon (Marine Biological Laboratory)
- **Collaborators:** Rebecca Neumann (University of Washington), Guiling Wang (University of Connecticut) and Daniel Gage (University of Connecticut)
- **Award:** $1,048,327 over 3 years

This project will advance quantitative and predictive understanding of belowground processes, particularly the well-known, but poorly understood, phenomenon of “hydraulic redistribution” (HR). During HR, soil water moves upward, downward, or horizontally from moist to dry soil through plant roots, which serve as conduits connecting soil volumes. Field measurements and regional scale modeling indicate that HR enhances overall moisture availability to plants, leading to increased stomatal conductance (and thus enhanced carbon assimilation). In addition to this direct effect of HR on plant productivity, it has been hypothesized for decades that “hydraulic lift” (upward HR of deep soil water to dry, nutrient-rich surface soil) may also stimulate enhanced soil microbial activity, thus indirectly affecting plant productivity via soil nutrient availability. In combination, these direct and indirect effects of HR on ecosystem processes have large biogeochemical implications, however the current generation of terrestrial ecosystem models and earth system models do not include a representation of HR. Using a linked suite of empirical experiments, small-scale mechanistic modeling, and terrestrial ecosystem and earth system modeling, we will explore HR’s impact on terrestrial carbon, nitrogen, water, and energy cycles through both the direct and indirect pathways. Greenhouse experiments will assess the effect of HR on plants and soil microbes, as a function of soil moisture, texture, and plant transpiration patterns. Root-scale mechanistic modeling will capture both hydraulic and biogeochemical aspects of HR’s influence belowground, aiming to reveal dominant controllers of HR and soil microbial response. Large scale modeling will draw from greenhouse and field data (from 4 Ameriflux sites), and incorporate information from mechanistic modeling in order to improve the representation of HR in earth system models and to quantify the effects of HR on terrestrial ecosystems in past and future regional climates. The work addresses two major questions: 1) How do HR-related belowground processes influence the past and future regional climate in North America? 2) How does the feedback from the atmosphere modify the strength of HR’s impact on the terrestrial carbon, nitrogen, water and energy cycles?

Advancing Understanding of the Role of Belowground Processes in Terrestrial Carbon Sinks Through Ground-Penetrating Radar

- **Principle Investigator:** Frank Day (Old Dominion University)
- **Collaborators:** John Butnor (US Forest Service)
- **Award:** $149,999 over 2 years

Understanding the role of belowground processes in the carbon cycle under disturbance regimes such as increased CO_2 will lead to more accurate prediction of global carbon uptake and storage. Several studies have demonstrated that roots are the primary sinks for new carbon in some ecosystems, but methodological limitations have made it difficult to accurately quantify belowground carbon pools, especially through time. Newer technologies must be thoroughly explored, refined and tested prior to their use in testing hypotheses in long-term experiments. Coarse roots, unlike their aboveground counterparts, often persist for long periods after tree harvest or disturbances such as fire. The recent application of ground-penetrating radar (GPR) to imaging belowground plant structures provides a potential means to address major deficiencies quantifying belowground carbon sinks. The goal of the proposed research is to advance the application of ground-penetrating radar (GPR) in quantifying belowground carbon pools with special focus on the sensitivity of GPR in detecting change through time (roots as C sinks), live versus dead belowground structures (critical in evaluating the dynamics of belowground C pools), and legacy effects of vegetation loss and CO_2 fertilization on root C pools. Results of the proposed research will contribute to the Long Term Performance Measure of DOE‟s climate change research by providing improved methods for obtaining critical quantitative measures of the largest and least understood carbon sink in forested ecosystems. Quantification of roots with GPR will refine carbon budgets and estimates of belowground C- sequestration in temperate ecosystems, enhance understanding of the role of forested ecosystems in the global carbon cycle, and improve the accuracy of global carbon models. The first year of the proposed research will be devoted to experiments and tests conducted at Blackwater Ecologic Preserve in Virginia to further shape and refine GPR applications. Experiments conducted in one-meter square pits excavated to a depth of 60-cm will include tests on sensitivity of GPR for detecting change in root mass over time, the capability for detecting live versus dead roots, the effects of soil moisture levels, the impact of potential object shadowing and detection of roots of varied size and water content, and the capability to accurately portray the spatial distribution of root mass. In year two, the protocols and thresholds established in year one will be tested on independent sites in Florida – a former DOE sponsored elevated CO_2 experiment site at Kennedy Space Center and a large scale evaluation of carbon pools and climate change in the Everglades watershed (Disney Wilderness Preserve NEON Satellite Site).

Climate Change Feedbacks from Interactions Between New and Old Carbon

- **Principle Investigator:** Jeffery Dukes (Purdue University)
- **Collaborators:** Richard P. Phillips (Indiana University)
- **Award:** $149,981 over 2 years

By storing and releasing carbon, ecosystems on land influence the rate of climate change. However, in the models used to project future climates, some of the important processes affecting carbon storage are coarsely represented or omitted. This project will examine an omitted process: how plants can affect carbon storage through releases of easily decomposed materials from their roots, and how future conditions could affect the way these "exudates" interact with the carbon compounds already present in soil. The project will assess how changes in soil moisture and temperature affect inputs of new carbon to the soil from plant communities, and the rate of decomposition of older soil carbon once new carbon has been added. The project will take place at the Boston-Area Climate Experiment. At this site, plots of a meadow-like plant community with tree seedlings are grown under twelve different climatic conditions, with four different amounts of warming and three levels of precipitation. New carbon inputs will be assessed using mesh cylinders of soil that will be placed into the ground at the beginning of the experiment, so that roots and fungi (or fungi only, or neither) can grow in, and removed at the end. Decomposition of carbon inputs will be examined by slowly injecting known carbon-containing solutions (or water) into the soil at known rates and monitoring the carbon dioxide released by the soil microbes. This exploratory project will test the feasibility of these seldomtried experimental approaches, and produce initial results indicating how climatic changes can affect interactions between new and old carbon. Results from the project will inform the design of more comprehensive experiments that will improve our models of the exchange of carbon between the land and atmosphere in a changing world.

Nutrient Cycle Impacts on Forest Ecosystem Carbon Cycling: Improved Prediction of Climate Feedbacks From Coupled C–Nutrient Dynamics From Ecosystem to Regional Scales

- **Principle Investigator:** Joshua Fisher (University of California Los Angeles)
- **Collaborators:** Richard Phillips (Indiana University), Danilo Dragoni (Indiana University) and Tom Evans (Indiana University)
- **Award:** $1,044,839 over 3 years

Understanding the role of terrestrial ecosystems in removing CO_2 from the atmosphere remains one of the fundamental challenges to predicting future changes in climate. Will forests continue to sequester carbon indefinitely under rising atmospheric CO_2 or will their capacity to build new biomass be constrained by a lack of nutrients? Currently, plant–soil interactions and their impact on nutrient cycling are largely absent or poorly represented in the computer models that form the basis of much of our predictive capacity to estimate changes in the Earth's climate. The goal of our proposed research is to develop a predictive framework for improving and integrating plant–soil interactions and carbon–nutrient dynamics into Earth system models. This project will integrate experimental plot-level data with models and satellite imagery to determine how trees and their belowground interactions with soil microbes influence carbon–nutrient interactions in mixed hardwood forests. A predictive framework for scaling plot-level data of carbon and nutrient cycling will be developed using a land cover classification from remotely sensed data and a nutrient uptake model which can be integrated into the land surface model of one of the world's leading climate models. The integration of these components will provide empirical grounding for investigations of the role of belowground processes in shaping carbon–nutrient dynamics at ecosystem, regional and global scales.

Carbon Dynamics of the Greater Everglades Watershed and Implications of Climate Change

- **Principle Investigator:** C. Ross Hinkle (University of Central Florida)
- **Collaborators:** Brian Benscoter (Florida Atlantic University), Xavier Comas (Florida Atlantic University), David Sumner (US Geological Survey), Donald DeAngelis (US Geological Survey)
- **Award:** $845,554 over 3 years

Studies investigating watershed carbon cycling have traditionally focused on high and middle latitude riparian watersheds. As a result, little information is currently available regarding watershed carbon dynamics of low-latitude watersheds dominated by peat-forming wetlands, such as the Florida Everglades, or the vulnerability of their extensive carbon stocks in a changing climate. In this three year project we will quantify above- and below-ground stocks and exchanges of carbon from terrestrial ecosystems along a seasonal hydrologic gradient in the headwaters region of the Greater Everglades watershed. Additionally, we will investigate the response of ecosystem carbon cycling to climate drivers to facilitate integration of our research findings with climate-driven terrestrial ecosystem carbon models to examine the potential influence of projected future climate change on regional carbon cycling. We will use a multidisciplinary array of ecological, hydrological, and geophysical sampling techniques combined with modeling at multiple spatial scales of measurement. Enhancement and expansion of current infrastructure for observation of regional carbon cycling coupled with initiation of new manipulative and process-oriented investigations of ecosystem carbon dynamics and their response to climate-related environmental drivers not only address near-term goals of understanding terrestrial carbon cycling in understudied subtropical and peatland ecosystems but also provides data products for integration with regional and global Earth Systems and Terrestrial Ecosystem Carbon models. Additionally, the proposed activities provide a research platform and baseline data for future investigation of the role of disturbance and climate forcing feedbacks on ecosystem carbon cycling in these vital components of the terrestrial carbon cycle. The infrastructure and data products developed by the proposed research will be leveraged with other regional AmeriFlux and NEON data networks and will be made openly available through the USGS SOFIA web data portal to promote the long-term objective of developing a comprehensive understanding of carbon cycling in the Greater Everglades watershed in a changing climate.

Can Microbial Ecology and Mycorrhizal Functioning Inform Climate Change Models?

- **Principle Investigator:** Kirsten Hofmockel (Iowa State University)
- **Collaborators:** Erik Hobbie (University of New Hampshire), Kate Orwin (Lancaster University) and Jack Gilbert (Argonne National Laboratory)
- **Award:** $707,704 over 3 years

Feedbacks between forest ecosystems and global climate are regulated in part by the coupled cycling of carbon and nitrogen throughout the atmosphere-plant-soil continuum. However, the current generation of models that link the terrestrial carbon cycle to climate neglect many fundamental plant-microbe interactions that regulate this coupling. One critical link in coupled carbon-nitrogen cycling is the role of organic nitrogen in providing plant nutrition and in contributing to forest carbon storage. This research will investigate the consequences for ecosystem carbon cycling in climate change experiments of microbial decomposition of organic nitrogen and its subsequent uptake by mycorrhizal (plant associated) fungi. Using archived samples and data from the Duke Forest and Oak Ridge National Laboratory Free Air CO_2 Enrichment (FACE) experiments, we will use stable isotope methods to estimate the source and quantify the use of organic nitrogen in different mycorrhizal taxa. Using fresh samples from the Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) experiment we will trace carbon from the atmosphere through plants and into the microbial community. Data generated from the three field experiments will be used in conjunction with the newly developed MySCaN (Mycorrhizal Status, Carbon and Nutrient cycling) model to explore how organic nitrogen uptake by mycorrhizal fungi affects forest carbon cycling under different climate scenarios. The model explicitly incorporates organic nitrogen movement and key microbial components to predict organic nitrogen changes and soil carbon storage. These measurements and modeling will inform global biogeochemical models by providing new insights into how carbon and nitrogen cycling are linked to plant and microbial dynamics in forest systems. This work will accordingly be useful in efforts to incorporate key processes (such as nitrogen constraints to plant growth and soil carbon storage) into the carbon dynamics of large-scale models used to predict forest-climate feedbacks.

Determining the impact of forest mortality in semi-arid woodlands on local and regional carbon dynamics.

- **Principle Investigator:** Marcy Litvak (University of New Mexico)
- **Collaborators:** Robert Sinsabaugh (University of New Mexico), Andrew Fox (National Ecological Observatory Network), and Nathan McDowell (Los Alamos National Laboratory)
- **Award:** $1,049,130 over 3 years

The southwestern United States experienced an extended drought from 1999-2002 which led to widespread coniferous tree mortality. Piñon-juniper (*PJ*) woodlands, which occupy 24 million ha throughout the Southwest, were extremely vulnerable to this drought. An abrupt die-off of 40 to 95% of piñon pine (*Pinus edulis*) and 2-25% of juniper (*Juniperus monosperma)* across 1.5 million ha triggered rapid and extensive changes in the structure of *PJ* woodlands with potentially large, yet unknown, consequences for ecosystem services and feedbacks between the carbon cycle and climate system. Our overarching hypothesis is that coniferous mortality events in *PJ* woodlands have significant carbon and climate forcing consequences which persist for many decades following mortality. We will take advantage of an existing large-scale manipulation experiment in central New Mexico using paired eddy covariance towers that are directly measuring carbon, water and energy simultaneously over an intact *PJ* woodland and a disturbed *PJ* woodland < 5 km away in which ~1600 piñon trees were girdled in 2009 to simulate the mortality observed in 2001-2004. We will augment this experiment and incorporate these findings into a land surface model, DOE's Community Land Model (CLM) to understand the long term carbon dynamics of these mortality events and use remote sensing maps of mortality in *PJ* woodlands in NM to scale the implications of these events to regional carbon dynamics and atmospheric CO_2. Our specific objectives are: 1) Determine the carbon, water and energy exchange trajectory after mortality in *PJ* woodlands; 2) Determine the mechanisms controlling the response and recovery of ecosystem production and respiration processes following piñon mortality; 3) Test and improve CLM to work in semiarid ecosystems and represent widespread coniferous mortality; 4) Use CLM to determine long term impacts of widespread mortality on regional level C fluxes and atmospheric CO_2. The proposed project has multiple values to science and to DOE. First, one of the glaring questions we face internationally is the climate forcing consequences of vegetation mortality. The estimates from models and observations are currently widespread, which makes modeling the implications of widespread mortality on future carbon and climate forcing difficult. Second, this project is highly cost efficient due to the value-added of the existing three years of data on the results of girdled pine trees, and the wealth of collaborative options with existing remote sensing and modeling efforts on vegetation mortality and its consequences supported at both UNM and LANL. Third, a direct path for input of the results of the experimental and observational data into DOE's Community Land Model (CLM) is outlined in the proposal.

Data Synthesis and Data Assimilation at Global Change Experiments and FLUXNET toward Improving Land Process Models

- **Principle Investigator:** Yiqi Luo (University of Oklahoma)
- **Collaborators:** Jianyang Xia (University of Oklahoma) and Dan Ricciuto (ORNL)
- **Award:** $1,050,000 over 3 years

Tremendous progresses have been achieved in development of land process models over the last two decades. The land models, in couple with earth system models, now simulate the land-atmosphere interactions via biophysical and biogeochemical processes. These models are now widely used assessing management and policy options for climate change mitigation and adaptation. However, model intercomparison and data-model comparison have clearly showed large uncertainties in predicted ecosystem-climate change feedbacks. To reduce uncertainties in model predictions, it is essential to continuously evaluate and improve models against experimental and observational data. The overall objective of this project is to improve land process models for predicting responses and feedback of terrestrial ecosystems to global change. We will achieve the objective via development and application of various data synthesis and data assimilation techniques at global change experiments, FLUXNET (including AmeriFlux), and other studies to identify general mechanisms and estimate parameters for model improvement. Specifically, this project will improve land models in terms of 1) temperature response functions of ecosystem processes; 2) data products to constrain modeled ecosystem feedback to climate change; 3) baseline performance of soil carbon distribution; 4) computational efficiency; 5) parameter variability under various climate change scenarios; and 6) uncertainty analysis. This project will directly support the Long Term Performance Measure (LTM) of the DOE's global change research to "Deliver improved scientific data and models about the potential response of the Earth's climate and terrestrial biosphere to increased greenhouse gas levels for policy makers to determine safe levels of greenhouse gases in the atmosphere". The project is designed to directly improve models at scales from ecosystem to regions and the globe.

Sources, Sinks and Processes Regulating Cryptic Methane Emissions from Upland Ecosystems

- **Principle Investigator:** J. Patrick Megonigal, (Smithsonian Institution)
- **Award:** $149,907 over 1 year

Most work on methane (CH_4) emissions from natural ecosystems has focused on wetlands and wetland soils because they are predictable emitters and relatively simple to quantify. Less attention has been directed toward upland ecosystems that cover far larger areas, but are assumed to be too dry to emit CH_4. There is abundant evidence that upland ecosystems emit small amounts of CH_4 during hot moments that collectively constitute a significant source in the global budget of this potent greenhouse gas. The PI proposes an exploratory study to quantify CH_4 sources in upland forests – both soils and trees – and investigate key controls on the biogeochemical processes that regulate this cryptic source. The long-term objective of the research is to refine Earth system models by quantifying CH_4 emissions from upland ecosystems, and elucidating the biogeochemical processes that govern upland CH_4 emissions. The immediate objectives of this exploratory proposal are to: 1) test the emerging paradigm that upland trees transpire CH_4, 2) test the basic biogeochemcal assumptions of an existing global model of upland CH_4 emissions, and 3) develop the suite of biogeochemical approaches that will be needed to advance research on upland CH_4 emissions.

Carbon Dynamics of Forest Recovery Under a Changing Climate: Forcings, Feedbacks, and Implications for Earth System Modeling

- **Principle Investigator:** Kristina Teixeira (University of Illinois at Urbana-Champaign)
- **Collaborators:** Evan H. DeLucia (University of Illinois at Urbana-Champaign) and Benjamin D. Duval (University of Illinois at Urbana-Champaign)
- **Award:** $314,913 over 2 years

Forests recovering from disturbance (secondary forests) are strong carbon (C) sinks that play an important role in climate regulation through their influence on the global C cycle. Climate change is likely to alter forest recovery dynamics or even prevent recovery, and changes in disturbance-recovery dynamics will impact the global C cycle. To improve understanding of how forest recovery dynamics are shaped by climate and may be impacted by climate change, we will create a comprehensive database on C cycling in secondary forests and use it, together with biogeochemical process modeling, to address three questions that are key to understanding the role of secondary forests in the climate system: 1) How and why does C cycling in forests, including the net ecosystem C balance and subsidiary components of the C cycle, vary as a function of ecosystem age?; 2) How does C cycling during forest recovery vary globally with respect to climate?; 3) How will expected changes in atmospheric CO_2 and climate affect C cycling in secondary forests? Our findings will provide synthetic understanding of C flux and allocation by secondary forests in both current and future climates. Synthesis and analysis of forest C cycle data will provide improved information on C allocation patterns as forests age and the C cycle forcings associated with secondary forests, thereby improving data for validating earth system models and quantifying the role of secondary forests in global C inventories. In addition, our analyses and modeling activities will improve understanding of the mechanisms driving forest recovery and how these might best be represented in earth system models. Finally, our analyses and modeling activities will make significant headway in understanding how forest recovery might be affected by climate change—a potentially important feedback to the climate system.

Fluxes of CO_2, CH_4, CO, BVOCs, NOx and O_3 in an Old Growth Amazonian Forest: Ecosystem Processes, Carbon Cycle, Atmospheric Chemistry, and Feedbacks on Climate

- **Principle Investigator:** Steven Wofsy(Harvard University)
- **Collaborators:** J. William Munger (Harvard University), Scott R. Saleska (University of Arizona), and Paulo Artaxo (University of Sao Paulo, Brazil)
- **Award:** $1,048,187 over 3 years

We propose to measure the following at a core site in central Amazonia: 1) ecosystem productivity and processes; 2) carbon cycle and forest structure; 3) production of methane (CH_4) in upland environments; 4) environmental stresses; 5) biogenic emissions of nitric oxide (NO) radicals and of volatile organic carbon (BVOC); and 6) atmospheric consequences of biogenic NO on secondary organic aerosol (SOA) production. This will be the first set of comprehensive of ecosystem-scale fluxes, measured for an annual cycle, to provide the foundational knowledge for models to quantitatively represent coupling of basic ecosystem metabolism in tropical forests with atmospheric chemistry and to assess the response of these coupled processes with environmental forcing and climate change.

Our studies will consist of the following: 1) Ecosystem flux measurements of CO_2, H_2O, CO, CH_4, sensible heat, O_3, NO_x, NO_y, isoprene and selected other BVOCs, plus measurements of ambient concentrations of CO, NOy and NOx, (to track biomass burning and BVOC oxidation, soil moisture, soil nutrients (N, P), and weather and climate parameters. These data relate the instantaneous fluxes of carbon to the fluxes of greenhouse gases, reactive gases and aerosol precursors. These measurements will define the BVOC, CH_4, and CO components of the ecosystem carbon budget. The project will provide the first year-long observations, reported at hourly intervals, of these key fluxes in a tropical forest. 2) Ecological surveys of 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. These data provide the long-term fluxes of carbon and link to ecosystem changes on the climate time scale. 3) Soil fluxes of CO_2, NO, and CO to complement high-sensitivity NO_x and NO_y data and track nutrient interactions and their interaction with atmospheric oxidants. 4) Modeling and analysis using the Master Chemical Mechanism and the Ecosystem Demography-2 (ED-2) model.

Further information on TES objectives along with a listing of past and current funding opportunities discussed in this document, is available at http://tes.science.energy.gov/.

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