U.S. Department of Energy Office of Science
Office of Biological and Environmental Research
Climate and Environmental Sciences Division

Carbon Cycle Science

2014 NASA Research Opportunity in Space and Earth Sciences (ROSES) (Joint NASA-DOE-USDA-NOAA Funding Opportunity)

Summary of projects awarded in spring 2014 under NASA Research Opportunity in Space and Earth Sciences (ROSES) Carbon Cycle Science Funding Opportunity.

Funding Opportunity Announcement Overview

The Office of Biological and Environmental Research's (BER) Terrestrial Ecosystem Science (TES) program seeks to improve the representation of terrestrial ecosystem processes in Earth system models thereby improving the quality of climate model projections and providing the scientific foundation needed to inform DOE's energy decisions. TES uses a systems approach to understand ecosystems over multiple scales that can be represented in models (e.g., single process models, ecosystem models, and coupled Earth system models). This emphasis on the capture of advanced understanding in models has two goals. First, it seeks to improve the representation of these processes in coupled models, thereby increasing the sophistication of the projections from those models. Second, it encourages the community to exercise those models and to compare the results against observations or other data sets to inform future research directions.

Within DOE's Office of Science, the Climate and Environmental Sciences Division (CESD) seeks to advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the nation's energy and environmental challenges. Among CESD's goals, the following three pertain to the Terrestrial Ecosystems Science (TES) program and to this solicitation:

- Develop, test, and simulate process-level understanding of terrestrial ecosystems.
- Advance fundamental understanding of coupled biogeochemical processes in complex subsurface environments to enable systems-level environmental prediction and decision support.
- Synthesize new process knowledge to advance next-generation, integrated models of the human-Earth system.

TES focuses its research on ecosystems that are globally important, climatically sensitive, and comparatively understudied or underrepresented in Earth system models.

TES coordinates its research direction and activities with the rest of the Federal government through the US Global Change Research Program's (USGCRP) Carbon Cycle Interagency Working Group (CCIWG). The CCIWG agreed to support an interagency call for proposals through the NASA Research Opportunities in Space and Earth Sciences (ROSES) funding opportunity. ROSES was released in the fall of 2013 and offered opportunities for carbon cycle science funding from the NASA Earth Science Program, the U.S.

Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) Agriculture and Food Research Initiative Competitive Grants Program (AFRI), the U.S. Department of Energy (DOE) Terrestrial Ecosystem Science Program, and the Atmospheric Chemistry, Carbon Cycle, and Climate (AC4) Program within NOAA's Climate Program Office. NASA, USDA, DOE, and National Oceanic and Atmospheric Administration (NOAA) sought proposals to improve understanding of changes in the distribution and cycling of carbon among the land, ocean, and atmospheric reservoirs and how that understanding can be used to establish a scientific foundation for societal responses to global environmental change.

In this joint agency solicitation, research proposals aimed at three carbon cycle science questions and conducting research focused on integrated scientific-societal issues were requested. Six specific research themes were solicited including:

1. Carbon research in critical regions, specifically: Arctic-boreal regions, tropics, and high latitude oceans (NASA, DOE, USDA);
2. Carbon dynamics along terrestrial-aquatic interfaces, including land-ocean, land-freshwater, and coastal ocean regions (USDA, DOE, NASA);
3. Belowground carbon processes and soil carbon (USDA, DOE);
4. Carbon dynamics within urban-suburban-forested-agricultural landscapes (NOAA, USDA, DOE, NASA);
5. The impact of rising CO2 on aquatic ecology (NASA); and
6. Carbon cycle science synthesis research (NASA, USDA, DOE)

Representatives from the four agencies collectively wrote the solicitation, organized and managed the review panels and made selected proposals for funding. Almost all of the funded projects were supported by a single agency. DOE and USDA did collaborate to co-fund one project. In total, nine awards were supported by DOE through this Funding Opportunity Announcement in FY 2014 totaling $8,179,748 over three years.

DOE Funded Projects

Scaling from Flux Towers to Ecosystem Models: Regional Constraints on Carbon Cycle Processes from Atmospheric Carbonyl Sulfide

- **Principle Investigator:** J. Elliott Campbell (University of California, Merced)
- **Collaborators:** Joe Berry (Carnegie Institution), Tomas Domingues (University of São Paulo), Antonio Manzi (Instituto Nacional de Pesquisa Amazônicas), Kadmiel Maseyk (University of California, Los Angeles), Ulrike Seibt (University of California, Los Angeles), Margaret Torn (Lawrence Berkeley National Laboratory)
- **Award:** $1,045,721 over 3 years

Recent work suggests that gross primary productivity (GPP) is largely underestimated by global earth system models, reflecting the persistent challenge in extrapolating from local process observations to earth system models. This poor understanding of GPP at large spatial scales is of particular concern in tropical forests. In tropical forests, some earth systems models forecast a powerful feedback between a warming climate and a decline in GPP resulting in forest dieback. While this simulated feedback is intensely debated, we lack robust large-scale constraints on GPP that are needed to resolve this debate. Here we propose an integrated measurement and modeling study of regional-scale GPP in the Amazon rainforest using atmospheric carbonyl sulfide to provide a new constraint on GPP mechanisms in earth system models. Project activities include three inter-related components: (1) a field campaign in the

Brazilian Amazon will provide the first tropical measurements of COS using two state-of-the-art laser spectrometers with eddy covariance, chamber, and airborne platforms in order to assess the relationship between CO_2 GPP fluxes and ecosystem COS fluxes; (2) eddy covariance and chamber data will be used in the development and calibration of ecosystem models of COS and CO_2 fluxes; (3) these ecosystem flux simulations and the airborne observations will be used in a mesoscale inverse model to provide top-down constrains on regional GPP and an assessment of the GPP representation in earth systems models. The project applies a unique analysis system field tested by the U.S. investigators on our team and the complementary major research instrumentation available from the Brazilian investigators on our team. This project will provide the fundamental ecosystem measurements needed to extend the COS-GPP tracer approach to the tropics and an application to a critical uncertainty for carbon-climate feedbacks. In addition to the carbon cycle, the new understanding of COS resulting from this project may have broad impacts in related scientific disciplines including its use as a conservative tracer of convection in the biophysical climate investigations of the GOAmazon campaign.

Effects of warming on tropical forest carbon cycling: investigating temperature regulation of key tropical tree and soil processes

- **Principle Investigator:** Molly Cavaleri (Michigan Technological University)
- **Collaborators:** Tana Wood (Fundación Puertorriqueña de Conservación); Sasha Reed (U.S. Geological Survey); Eoin Brodie (Lawrence Berkeley National Laboratory)
- **Award:** $869,000 over 3 years

Although tropical forests make up only 15% of the planet's terrestrial surface, they account for over 2/3 of live terrestrial biomass, store 1/3 of the planet's soil carbon, and exchange more carbon dioxide (CO_2) with the atmosphere than any other biome. In light of these large pools and fluxes, even subtle changes to the way tropical forests take in and release CO_2 (via photosynthesis and respiration, respectively) could have dramatic effects on atmospheric CO_2 concentrations and thus future climate. At the same time, current modeling predictions suggest that the tropics will experience unprecedented changes in temperature in the coming decades. In the context of these changes and the large amounts of carbon the forests store and cycle, understanding how tropical forests respond to climate warming has substantial implications for our understanding of future climate and carbon cycling at the global-scale. Nevertheless, forecasting the vulnerability of tropical forests to climate change is a topic of much debate and there is a notably poor understanding of tropical forest responses to a changing climate. This poor understanding is not only due to a striking lack of data, but also results from the diversity of tropical forested ecosystems themselves: the forests span broad gradients in climate, soil type, and species composition, and many tropical forests maintain hundreds of tree species per hectare.

With the project titled 'Effects of warming on tropical forest carbon cycling: investigating temperature regulation of key tropical tree and soil processes' we propose to address this challenge and important research need by taking a mechanistic, multi-disciplinary approach to determining how plants and soils of the El Yunque National Forest in Puerto Rico respond to warming. Our goal is to directly assess the effects of increasing temperature on tropical plant and soil carbon fluxes and storage over a range of time scales in order to reduce uncertainty and increase the confidence with which we can make global predictions of future climate. The proposed set of experiments will focus on both above- and belowground processes, and will mechanistically explore temperature controls over critical aspects of carbon and nutrient cycling for tropical plants, soil, and microbes. In a wet tropical forest in

Puerto Rico (El Yunque National Forest), we will use canopy access towers, novel leaf and branch warming techniques, micro-meteorological monitoring, and leaf chamber gas exchange measurements to assess the temperature sensitivity of mature tree foliage physiology. We will employ both field and laboratory manipulations to determine how plant roots and soil microbes respond to increased temperature, as well as assessing the mechanisms controlling these responses. The field soil warming experiment will be the first of its kind in any tropical forest.

Taken as a whole, this work will make significant advances in our understanding of forest responses to climate change in a globally important and relatively poorly understood biome. In addition, because we will focus not only on documenting responses but also on assessing the mechanisms regulating change, this work will allow us to extrapolate results beyond that of a single tropical forest site. This work will also provide critical information regarding the vulnerability and adaptation potential of the only tropical forest in the U.S. National Forest System. The results of this research will represent a significant step forward in our understanding and ability to effectively forecast tropical forest responses to a warmer world.

Linking topographic variation in belowground C processes with hydrological processes to improve Earth system models

- **Principle Investigator:** David Eissenstat (Pennsylvania State University)
- **Collaborators:** Jason Kaye (Pennsylvania State University); Yuning Shi (Pennsylvania State University); Henrey Lin (Pennsylvania State University); Christopher Duffy (Pennsylvania State University); Kusum Naithani (Pennsylvania State University); Luke McCormack (Pennsylvania State University)
- **Award:** $1,050,000over 3 years

Belowground processes are strongly affected by soil moisture. Current studies are generally limited to sites with relatively uniform topography, and seldom connect the impacts of natural variation in soil moisture associated with topography to multiple C cycle processes. Current Earth system models cannot resolve topographically driven hill-slope scale soil moisture patterns, and cannot simulate the nonlinear effect of soil moisture on soil respiration, especially under high soil moisture. In this project we will assess the influence of topography on multiple belowground processes (soil CO_2 flux, soil C, root density, root production, and root turnover) and develop a coupled modeling system capable of simulating the water and carbon dynamics of this complex system.

The study site is the Susquehanna/Shale Hills critical zone observatory (SSHCZO), which has been intensively studied from a hydrologic, geochemical and geophysical perspective. We will measure the vertical root distribution, soil respiration and root turnover in relation to topography at the SSHCZO to address the hypotheses. We will sample 50 macro-sites across the watershed with 4 micro-sites nested within each macro-site (total 200 points). We will also add a spatially-distributed land surface hydrologic model, Flux-PIHM (Flux Penn State Integrated Hydrologic Model), which accounts for horizontal groundwater flow, to the Biome-BGC, which is the current carbon and nitrogen biogeochemistry model in the latest version of the Community Land Model (CLM4), to improve the representation of the land surface and subsurface heterogeneities caused by topography. Numerical experiments using the coupled model (referred to as Flux-PIHM-BBGC) will be performed to examine if the coupled model performs better than a one dimension biogeochemistry model. The proposed high-resolution measurements of soil respiration, soil C, root density distribution, and root turnover at the SSHCZO will provide important spatially distributed a priori parameter values and boundary conditions for modeling, and provide an unprecedented chance to comprehensively evaluate the coupled model fidelity (Flux-PIHM-BBGC), improve our modeling skills at high resolution and low-order watersheds, and investigate the impacts of landscape variation on belowground C processes.

This study will determine the effects of topographic and hydrologic variation on root and soil respiration as well as their subsequent contributions to ecosystem NPP. The study will also link aboveground drivers, such as tree species composition, litter fall and aboveground tree growth to belowground processes such as soil respiration, root standing crop, root production and root lifespan. It is expected that the key drivers of variation in belowground processes will be identified by this study, which will enable more efficient characterizations of C processes in sites that lack the wealth of data available in the SSHCZO. One of the primary products of the study will be the coupled Flux-PIHM-BBGC model, a high-resolution coupled biogeochemical land surface and hydrologic model. These crucial data and model will be publically available for future work investigating both short- and long-term processes of the Earth system.

Toward a predictive understanding of the response of belowground microbial carbon turnover to climate change drivers in a boreal peatland

- **Principle Investigator:** Joel Kostka (Georgia Institute of Technology)
- **Collaborators:** Jeffery Chanton (Florida State University); William Cooper (Florida State University); Christopher Schadt (Oak Ridge National Laboratory)
- **Award:** $1,019,995 over 3 years

High latitude peatlands cover only 3% of the Earth's land surface but store approximately 1/3 of all soil carbon (C), and act as sinks for atmospheric C. Despite their significance, wetland-specific processes are not included in global climate models, including the land component (CLM4) of the Community Earth System Model. Soil organic matter (SOM) pools and decomposition rates used in these models are derived from mineral soils, which are likely to respond very differently to climate change drivers compared to the saturated organic soils of peatland systems. The flux of C from terrestrial soils to the atmosphere is projected to increase with climate change, but acceleration of the terrestrial C cycle does not necessarily mean that soils will lose a greater proportion of their large C stores to the atmosphere.

The proposed research will address the question of whether changes in soil carbon in peatlands are driven by higher C inputs to the soil from plants or rather by the mobilization of stored older C through increased microbial activity, or both, thereby shedding light on a critical positive feedback loop. This proposal is inspired by research conducted under a previous DOE award. We will leverage the infrastructure and site characterization conducted at the Marcell Experimental Forest (MEF), northern Minnesota, where the Oak Ridge National Lab (ORNL) has established an experimental site known as Spruce and Peatland Response Under Climatic and Environmental Change (SPRUCE). Using advanced analytical chemistry and next generation gene sequencing, the proposed project will quantify the response of SOM storage and reactivity, decomposition, and the functional diversity of microorganisms to climate change manipulation at the ecosystem scale. Through a close collaboration with SPRUCE investigators at ORNL, these new insights will be embodied into the CLM4 model to improve climate projections. For example, we propose to develop carbohydrate content (O-alkyl-C content) as a better and more efficient predictor of soil decomposition rate than the operationally-defined SOM fractions currently in use. Carbohydrates predominate over the plant-derived SOM pools in peatlands and microbes use these carbon compounds to produce greenhouse gases.

We will test the following hypotheses: 1.) warming and elevated CO_2 (eCO_2) will increase growth and transpiration of vascular plants and decrease the productivity of Sphagnum and other bryophytes. These changes will alter the reactivity of SOM and microbial dynamics; 2.) warming and eCO_2 will result in the instability of buried peat C, thereby accelerating microbial respiration rates and greenhouse gas production; 3.) accelerated microbial metabolism will result in changes in the functional diversity of microbial communities leading to changes in the pathways of SOM mineralization and the ratio CH_4/CO_2; 4.) CO_2 enrichment will lead to increased delivery of labile C substrates from enhanced primary production and root exudation, resulting in increased decomposition, mobilization and export of ancient peat C as dissolved organic carbon (DOC) from extensive belowground reservoirs; 5.) mobilization of ancient peat C in response to climate change drivers will be dependent upon interactions between microbial populations and the C-use efficiency of the microbial groups that degrade labile and/or recalcitrant SOM pools.

In response to the climate change manipulation, we will determine: 1.)changes in the reactivity of solid peat, DOC, and microbial respiration products (CO_2, CH_4); 2.)changes in the abundance, community structure, and function of soil microbial communities; 3.)compositional and ^{14}C isotopic changes in the exported DOC of peatland and enclosure outflow; 4.)the response of SOM lability as indicated by infrared spectroscopy determined humification indices, the function of specific microbial groups, and the efficiency of organic matter decay to climate change manipulation under controlled conditions in the laboratory using microcosm experiments.

Effects of Experimental Warming and Elevated CO_2 on CO_2 and CH_4 Fluxes in an Ombrotrophic Black-Spruce

- **Principle Investigator:** Adrien Finzi (Boston University)
- **Award:** $390,825 over 3 years

High latitude peatlands represent a particularly significant terrestrial carbon sink for atmospheric CO_2, containing nearly half of the soil carbon pool on Earth. As result of anoxic conditions, however, peatlands are simultaneously a major source of CH_4 to the atmosphere. The greatest rates of global warming are occurring at high latitudes and warming is predicted to accelerate the loss of the C stored in peat as a result of faster rates of decomposition. The magnitude of these effects remains uncertain, as does the balance between C loss as CO_2 and CH_4. Methane is a powerful greenhouse gas with ~25 times the warming potential of CO_2, thus it is critical to develop a robust understanding of the patterns and processes regulating climate-change associated changes in C cycling in northern peatlands. The overarching objective of this research is to characterize the response of CO_2 and CH_4 emissions from a boreal peatland to experimental warming and atmospheric CO_2 enrichment (eCO_2). This research will be conducted at the Spruce and Peatland Responses Under Climatic and Environmental Change (herein SPRUCE) experimental facility, which is located in the USDA's Marcell Experimental Forest in northern Minnesota. By focusing on peatland responses to multiple levels of warming at ambient or eCO_2 and our deployment of state-of-the-art technology to make continuous measurements of CO_2 and CH_4 emissions and isotopic signatures from the peat surface, the proposed research will enable the development of robust models relating trace gas emissions to changes in temperature and moisture regimes in peatlands and changes in C cycling imposed by potential increases in plant productivity at eCO_2.

By collecting first-ever data on CO_2 and CH_4 fluxes from intact peatlands exposed to experimental warming and eCO_2, this research will provide important data constraints on model structure and parameter estimation in a high-latitude boreal peatland. The proposed research therefore contributes to understanding the responses and feedbacks of carbon rich, high latitude ecosystems to climate warming and atmospheric change. The proposal's focus on belowground processes is fundamental to this understanding. The proposed data collection and collaboration with modeling groups will enable the refinement of Earth System Models, thus contributing to research that will aid in projecting the future state of the Earth's climate system mediated by changes in land-surface processes. This research leverages existing federal investments in high-latitude, multifactor global change experiments and provides unique data of importance to the need for adaptation and mitigation in response to climate change in US.

Connecting AmeriFlux to the Globe, Extending the Partnership with Global Flux Network FLUXNET

- **Principle Investigator:** Dennis Baldocchi (University of California, Berkeley)
- **Collaborators:** Deg Agarwal (Lawrence Berkeley National Laboratory); Margaret Torn (Lawrence Berkeley National Laboratory); Marty Humphrey (University of Virginia); Dario Papale (University of Tuscia, Viterbo, Italy); Markus Reichstein (Max Planck Institute for Biogeochemistry, Jena, Germany); Helen Cleugh (CSIRO, Canberra, Australia); Joon Kim (Seoul National University, Seoul, South Korea); Rodrigo Vargas (University of Delaware); Gui-Ru Yu (Chinese Academy of Science); Laszlo Nagy (INPE, Manaus, Brazil); Sebastian Wolf (University of California, Berkeley)
- **Award:** $882,078 over 3 years

This project will extend and expand the functioning of the global FLUXNET database, which consists of data on carbon dioxide, water and energy fluxes, meteorological conditions and the structure and function of the ecosystems to beyond a decade. The production of the next FLUXNET database is critical to the activities of DOE/BER because these data will drive many of the carbon cycle synthesis activities and the model parameterization and validation activities. This data system will enable the broader biogeoscience user community to discover new information about the 'breathing' of terrestrial ecosystems across a spectrum of time and space scales.

FLUXNET will construct a new database with over 2000 site-years of trace gas flux measurements, supporting meteorological and site meta-data from over 400 sites world-wide. They will create a next-generation, data-system that will process raw data and produce value-added data products. These value-added data will be integrated or averaged on daily and annual time scales. Net carbon fluxes will be partitioned into their constituent components, ecosystem respiration and canopy photosynthesis. Uncertainty analysis and quality control metrics will be produced in coordination with AmeriFlux and ICOS. The data system will also house, distribute and query these data. The team will use the resulting data in synthesis activities that improve our understanding on how climate, weather, ecological, physiological and soil factors govern the exchange of carbon, water and energy between vegetation and the atmosphere at multiple time and space scales.

FLUXNET intends to foster collaboration and interactions with national and international partners and the recruitment of data by: 1) continuing the periodic publication of the newsletter, FLUXLETTER; 2) hosting an international conference; 3) coordinating and launching multi-investigator data synthesis activities; and 4) developing tools that coordinate the development and tracking of research papers, through production to publication.

Measurements and modeling of CO_2 concentration and isotopes to improve process-level understanding of Arctic and boreal carbon cycling

- **Principle Investigator:** Ralph Keeling (University of California, La Jolla)
- **Collaborators:** Stephen Piper (Scripps Institution of Oceanography)
- **Award:** $1,050,000 over 3 years

This project seeks to understand the processes that control the exchanges of CO_2 between the atmosphere and the land biosphere on decadal and longer time scales. The approach involves measuring the changes in atmospheric CO_2 concentration and the isotopes of CO_2 ($^{13}C/^{12}C$ and $^{18}O/^{16}O$) at background stations and uses these and other datasets to challenge and improve numerical models of the Earth System. The project particularly emphasizes the use of these data to improve understanding of changes occurring in boreal and arctic ecosystems over the past 50 years and to seek from these data improved understanding of large-scale processes impacting carbon uptake, such as the responses to warming and CO_2 fertilization. This project is responsive to the need for improved understanding of carbon cycling in Arctic and boreal regions and to the need for improved observational capability, by providing an archive of CO_2 samples extracted from flasks that may promote the development of novel isotopic applications related to land carbon cycling (e.g. radiocarbon).

A core thrust of this project involves providing partial support for continuing measurements of CO_2 concentrations and isotopes from the Scripps CO_2 program, initiated by C. D. Keeling in the 1960s. This program includes analysis of flasks collected at an array of ten stations distributed from the Arctic to the Antarctic, and it sustains the iconic Mauna Loa CO_2 record.

A second thrust of this project is to carry out interpretive work to help understand the origins of the large ~50% increase in the amplitude of the atmospheric CO_2 cycle detected at high northern latitudes between 1960 and present. This cycle is mainly caused by the photosynthetic uptake of CO_2 by land ecosystems in the spring and summer and the corresponding release of CO_2 from respiration in the fall and winter. While the cycle itself is relatively well understood, it's less clear why it should be getting larger with time. The amplitude increase is not well accounted for in current earth system models, even though these models do include a representation of the main known agents of change, including the effects of climate warming ecosystems and the direct effect of rising CO_2 on photosynthesis. Something is clearly missing in these models. This amplitude increase stands out as perhaps the most compelling evidence to date for wide-spread changes in land carbon cycling relevant for the global CO_2 balance and climate change. Understanding its causes and improving terrestrial ecosystem models to depict the relevant processes is therefore clearly a high priority. This project focuses on key questions: 1) How is the amplitude increase related to changes in net carbon flux in boreal and arctic systems? 2) What processes are responsible for the amplitude increase? 3) How can the models be improved to incorporate the relevant processes?

The interpretive tasks include carrying out so-called "inverse modeling" calculations in collaboration with colleagues in Germany (MPI Jena) and Japan (JAMSTEC) to further assess the relationship between the changing atmospheric CO_2 cycles and the net CO_2 fluxes over the past 50 years. These simulations will use aircraft and surface data to provide improve estimates of the relationship between the seasonal cycles and the changing northern land sink for CO_2 since 1960. The modeling work also involves working with a suite land ecosystems models to understand how they might be improved to account for the amplitude increase and to explore the linkages between the amplitude increase and other land ecosystem processes, including the ability of these systems to serve as sustained sinks for atmospheric CO_2.

Carbon Dynamics within urban-suburban-forested-agricultural landscapes

- **Principle Investigator:** Beverly Law (Oregon State University)
- **Collaborators:** Christopher Still (Oregon State University); Thomas Hilker (Oregon State University); Andres Schmidt (Oregon State University); Philip Mote (Oregon Climate Change Research Institute); Andrew Richardson (Harvard University)
- **Award:** $877,223 over 3 years

Land management strategies and land use within urban-suburban, agricultural and forested landscapes can have significant impacts on local and regional carbon, water and energy cycles, but their gross and net effects are complex and not well understood. As a result, a better understanding of the interactions and feedbacks between ecological systems, human actions, and changes in climate is needed to drive the decision making process at local to landscape and regional scales. For example, in the western US, fire and drought and their intensification with climate change are critically important issues faced by land managers. Several states have set ambitious greenhouse gas reduction targets, including conversion of power plants to bioenergy from forests and crops, and thinning high biomass forests to reduce wildfire emissions. However, policies and management are being implemented without adequate assessment of their comprehensive environmental effects.

To address these shortcomings, an interdisciplinary team of scientists from Oregon State University proposes to study the effects of land use and land cover on the exchanges of carbon, water and energy in current and future climates across a gradient of urban-suburban agricultural and forested landscapes. Our approach integrates remote sensing observations and data from tall tower CO_2 observations and flux sites with comprehensive modeling approaches using the new version of the Community Land Model, CLM4.5. We will use artificial neural network analysis to examine current spatio-temporal patterns in carbon, water and energy exchange, and enhance CLM4.5 to improve its ability to predict these processes and carbon sequestration in the future. Our study region is Oregon, as it spans strong gradients from high population/high forest productivity/mesic climate in the west to low population/low productivity/arid climate in the east, and land use is changing to reduce GHG emissions.

The project will enrich scientific understanding of the relationship between land-use decisions and climate-induced impacts on terrestrial ecosystems. A focus of our study will be on the effects of conversion of semi-arid sagebrush to irrigated bioenergy production on carbon, water and energy cycling, and resulting heating or cooling effects. We will also study and predict the effects of afforestation of idle land and rangelands deemed suitable for forests or poplar crops on exchanges of carbon, water and energy under future climate conditions. We will address these policy-relevant questions: How do current land uses and cover affect carbon dynamics, and carbon, water and energy exchanges, including cooling/warming effects? Given possible climate trajectories, what land-use strategies will reduce carbon dioxide emissions while optimizing sustainability of native vegetation and food crops? The project will enhance scientific understanding of the relationship between carbon dynamics and land-use decisions in gradients of urban to crop and native vegetation. Our contributions to innovative assessments will be the first predictions of integrated impacts of future climate and land use (management to mitigate climate impacts on forests, land use shifts to bioenergy crops) on carbon sequestration, and carbon, water and energy fluxes at local to regional scales using new downscaled CMIP5 climate data selected for the region, a new version of CLM, and new land use/land cover maps generated from remote sensing data for the region.

An important goal of the proposed research is to identify policies and management strategies that can sustain ecosystem function while addressing land use changes that are intended to reduce greenhouse gas emissions. Our observation-driven modeling approach will provide an invaluable policy analysis tool for other regions as it projects integrated impacts of land use decisions and climate change on ecosystem carbon and water processes and climate feedbacks.

Phenolic compounds and black carbon feedback controls on peat decomposition and carbon accumulation in southeastern peatlands under regimes of seasonal drought, drainage and frequent fire

- **Principle Investigator:** Curtis Richardson (Duke University)
- **Collaborators:** Neil Flanagan (Duke University); Bill Cooper (Florida State University); Jeffery Chanton (Florida State University)
- **Award:** $994,906 over 3 years

Earth System Models (ESMs) predict increased frequency of extreme wet and dry periods in the subtropics and tropics over the next century, resulting in uncertain carbon (C) budgets and greenhouse gases (GHG) fluxes. Globally, approximately 1/3 of peat stores are found in subtropical and tropical peatlands (STPs) formed from high-lignin woody biomass. These peatlands have persisted through changing climate and sea level over the last 4000 years and continue to accrete peat along the Atlantic coast from Virginia/North Carolina (VA/NC), to Florida (FL) to tropical Panama (PN), even under climate driven conditions of drought, warmer temperatures and fire. Our questions are: 1) why do these stressed non-Sphagnum subtropical and tropical peatlands continue to accumulate C, and 2) what insights can we gain from studying their natural processes and control mechanisms. We propose a 3-year experimental comparison across STPs to reveal the key process-level mechanisms controlling soil C stabilization, accumulation, and long-term carbon storage. Our main hypothesize is that STPs native-fire-adapted shrubs/trees communities produce higher polyphenol containing litter than Sphagnum/Carex communities. Polyphenols are secondary metabolites of plants involved in defense against ultraviolet radiation or attack by pathogens. High concentrations in plant tissues also prevent microbial decay of litter resulting in buildup of recalcitrant (decay resistant) organic matter in the soil and leading to the formation and long-term storage of peat. This storage difference, in conjunction with climate induced regimes of frequent low-intensity fire, creates refractory decomposition-resistant peat by a dual “latch key mechanism” consisting of high phenol and Black Carbon (i.e., the BC complex from fire forms decay resistant aromatics). Together these retardants reduce GHG flux, and C decomposition of STPs peats even under altered hydrologic conditions, higher temperatures and drought. Objectives: I: Identify and compare process-level mechanisms controlling peat accretion and C losses from Sphagnum-spruce bog sites in MN, shrub-bogs in NC, subtropical sawgrass-shrub peats in the FL Everglades, to tropical Wax Myrtle-Titi shrub bogs in PN. This never-before-studied latitudinal gradient will allow experimental quantification of biotic (plants type) and abiotic (low-intensity fire and drought) contributions to resultant high phenol/low carbon quality litter and specific BC aromatics; II: Assess the composition and origin of aromatic compounds in peat and porewater at the molecular level and the importance of fire derived aromatic compounds limiting peat decomposition using multiple advanced analytical chemistry techniques.

This research provides the first major latitudinal comparative analysis of peatland C chemistry, tests a new dual control model for sustaining C, incorporates advanced analytical methods and comprehensive C chemistry data, and uses these data for modeling in support of DOE’s climate change research program and ESMs.

More information on other projects selected through this opportunity (by NASA, USDA and NOAA), please see: http://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=408698/solicitationId=%7B2EBEDEA0-817D-D318-55C3-BC5086A4AB70%7D/viewSolicitationDocument=1/CARBON13selections.pdf

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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