NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences – 2013
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The National Aeronautics and Space Administration (NASA) solicited proposals for Terrestrial Ecology investigations within the NASA Earth Science Program. The following types of research investigations were requested:

- Analyses of the vulnerability to and responses of terrestrial ecosystems to global environmental changes.

- Science investigations to advance the development and utilization of new and/or multisensor remote sensing approaches to address important terrestrial ecosystem and biogeochemical cycling questions. Studies using new, advanced airborne sensors to apply and evaluate approaches relevant to future satellite missions were of special interest.

- Successor studies that offer to significantly advance the results of prior NASA Terrestrial Ecology research toward meaningful answers to important NASA and USGCRP carbon cycle and ecosystems research questions.

A total of 56 compliant proposals was received, and 6 have been selected for funding. The total funding to be provided for these investigations is approximately $3.6 million over three years. The investigations selected are listed below. The Principal Investigator, institution, investigation title, and a project summary are provided. Co-investigators are not listed here.

Jennifer Balch/Pennsylvania State University
Understanding Climate and Land Use Drivers of Invasive-Grass Fueled Fires Across the Western U.S.

Invasive grasses are increasing fire activity globally, yet the mechanisms driving the initiation and perpetuation of these novel fire regimes remain largely unknown. Our proposed work will compare how short-term climate, long-term climate and land use interact with land cover across the intermountain west to alter the probability and behavior of fires. Climate interactions with wildfires in forested lands of the western U.S. are well studied, with forest fires generally promoted by short-term drought and warmer temperatures which lead to fuel desiccation and increased flammability. Fires in arid ecosystems dominated by invasive cheatgrass (Bromus tectorum) are thought to be largely driven by long-term moisture availability, which increases fuel biomass and cover. However, at a regional scale, this association has not been empirically tested despite ongoing concern about cheatgrass fires, which we have shown to be larger, faster spreading and more frequent than fires in native land cover. Current predictive models of fire risk, based on climatic conditions that drive forest fires, are insufficient for predicting fires in the intermountain west because they neglect both the presence of cheatgrass and the unique climatic and land use conditions that influence cheatgrass fires.

This research will address: How do climate and land use influence fire likelihood and behavior in native and invaded ecosystems across the intermountain west? Using novel techniques that we have developed to detect cheatgrass and derive fire regime metrics from remote sensing data, we will explore this major question. We hypothesize that cheatgrass fires will be related primarily to coupled extreme wet-dry climate conditions and strongly associated with human ignitions, compared with native forest fires. Burn probability and fire behavior will be derived from the MODIS burned area and active fire products. Regional meteorological and land use maps will be used to assess climate and land use. A regional, updated map of cheatgrass will be created from MODIS time series to differentiate invaded land cover. Using these spatial layers, we will develop an integrated model framework that predicts burn probability and fire behavior based on short-term climate, long-term climate, land cover, and proximity to land use. This analysis will: i) assess fire dynamics in the intermountain west in relation to preceding climate conditions and proximity to anthropogenic ignition sources; and ii) model current and mid-century fire risk in ecosystems and developed areas across the western U.S under future climate change and land use scenarios.

A predictive framework for understanding how climate and land use interact with land cover to promote fires will improve assessments of vulnerability of intermountain west terrestrial ecosystems to global and regional environmental change. We will integrate Earth observations from satellites into statistical models to create spatial predictions of wildfire vulnerability. These analyses are critically needed given that cheatgrass doubles the likelihood of fire and played a prominent role in the largest fire events in the intermountain west during the last decade. Assessing the relative influence of climate and anthropogenic drivers will also provide insights into how the cheatgrass-fire cycle can be prevented or reversed. While climate-induced shifts in fire activity have already been observed and predicted in forest ecosystems, little is known about how invasive grass fuels will concurrently change fire activity on regional to global scales. Our study will provide new mechanistic insights and foundational methods to characterize and quantify the current and future influence of feedbacks between climate, land use, and invasive grasses on native fire regimes.

Mark Friedl/Boston University

Using Three Decades of Landsat Data to Characterize Changes and Vulnerability of Temperate and Boreal Forest Phenology to Climate Change

Climate change is creating well-documented impacts on terrestrial ecosystems. Among the best known of these impacts are changes to the growing season of temperate and boreal forests. Changes in phenology provide useful diagnostics of climate change impacts in these biomes, influence coupled biosphere-atmosphere interactions, and also affect regional-to-global carbon budgets. Extreme events and climate variability complicate the response of ecosystems and increase vulnerability by inducing large phenological responses that affect ecosystem function at seasonal (and longer) time scales. Studies using in-situ measurements have suggested that the growing season of temperate and boreal ecosystems is changing, and remote sensing-based research using time series imagery from coarse resolution sensors appear to confirm this trend. Specifically, studies using AVHRR NDVI data have documented changes in growing

season NDVI that indicate widespread perturbations to boreal and temperate forests in response to climate change. However, the coarse spatial resolution and other limitations of AVHRR data constrain the types of inferences that can be drawn from these data. Sub-pixel contamination of AVHRR time series by snow and disturbance events introduce sources of variation unrelated to phenology, and challenges associated with instrument calibration, atmospheric correction, and geo-location uncertainty further reduce the utility of these data for long-term phenology studies. In this proposal we describe research to address these challenges using Landsat data. Specifically, we propose to use a new methodology that exploits dense time series of Landsat images to quantify spatio-temporal patterns in North American temperate and boreal forest growing season dynamics. Our proposed methodology uses a sampling strategy designed to capture geographic variation in temperate and boreal forest properties, and focuses on regions of overlap between adjacent Landsat scenes, thereby significantly increasing the temporal sampling of Landsat images. Because temperate and boreal ecosystems are characterized by frequent disturbance and have snow on the ground at times of the year that are especially important for detecting changes in phenology, our methodology will exploit datasets related to fire disturbance such as the Canadian and Alaskan Large Fire databases, and will include strategies to screen and remove snow-contaminated pixels. Results from this research will yield methods and datasets for retrospective characterization of changes to temperate and boreal forest growing seasons spanning 30+ years at 30-meter spatial resolution. In doing so, this research will (1) dramatically improve information about how temperate and boreal forests have changed in response to climate change, and (2) improve understanding regarding the sensitivity and vulnerability of these forests to climate change.

Nancy Glenn/Boise State University
Scalable Vegetation Structure for Ecosystem Modeling in the Western US (Boise State University)

Dryland systems cover over 40% of the global terrestrial area and accommodate roughly 35% of the total human population. Changes in climate are likely to have significant impacts on these regions. Short and long-term impacts of population growth and climate variability are revealed in the changing vegetation composition and structure of dryland systems. Altered fire regimes are transforming native shrub-dominated landscapes to annual invasive grasses, thus perpetuating the fire cycle. Woody plant expansion can lead to changes in landscape ecohydrology, degradation of soil nutrients, and increased fire risk at the urban fringe. Consequently, techniques to quantify vegetation structure and predict changing vegetation structural patterns in dryland system under future scenarios are necessary to address numerous questions related to quantifying vulnerabilities to and responses of global environmental changes. For example, will warmer temperatures and higher intensity and frequency fires in California's Mediterranean ecosystem cause an irreversible shift from a shrubland-dominated ecosystem to one of non-native annual grasses and exotic weeds? Similarly will the shrubland-dominated Great Basin be converted to annual grasses and how will the conversion rate vary with interannual precipitation and climate? Current and upcoming NASA missions with observations at

multiple spectral, spatial, and temporal scales, coupled with robust calibrations and validations, have the potential to help solve these globally relevant questions.

We address Subelement 2.2 of the NASA Terrestrial Ecology program by developing new approaches to combining LiDAR and hyperspectral datasets for the purpose of quantifying vegetation structure and function in dryland terrestrial ecosystems using ecosystem modeling. Our research approach is to collect new airborne LiDAR and hyperspectral datasets over a climate and elevation gradient of the Great Basin where the researchers have existing field, hyperspectral, and LiDAR datasets. The overall goal of the proposed investigation is to synthesize existing and new ground and airborne datasets to quantify metrics such as height, cover, biomass and LAI. Results will be used to parameterize ecosystem productivity modeling in dryland systems and will provide a basis for investigating feedback mechanisms related to changing climate conditions, fire regimes and patterns of non-native plant invasion. Specifically, we will initialize the ecosystem demography model with ecological information retrieved from the remotely sensed datasets in a way that explicitly accounts for the uncertainty in the retrieved information. The overarching questions we seek to answer in this study are: 1) What are the best data fusion approaches to quantify ecosystem structure and what are the errors associated with these approaches across multiple scales? 2) To what extent do LiDAR and hyperspectral sensors reveal the same plant structure information and to what extent are they complementary? 3) What are the compositional and spatial changes in vegetation structure with disturbance regimes of climate, fire and invasive species?

We will develop regionally scaled LiDAR / hyperspectral vegetation products in anticipation of a need to determine how best to assimilate the growing number of these site-level collections (G-LiHT (GSFC), Carnegie Airborne Observatory, NEON AOP), which will ultimately be linked to satellite observations. This foundational work will provide a basis for evaluating the extent to which new and future satellite missions are suitable for characterizing dryland vegetation structure (i.e., LDCM, NPP-VIIRS, HyspIRI, LIST, Icesat-2). Importantly, the effect of changes in ecosystem composition and function on resource management and 3D vegetation structure have been identified by Science Study Groups (e.g., HyspIRI mission) and scientific panels (e.g., NRC Decadal Survey) as high science priorities.

Izaya Numata/South Dakota State University
Assessing Vulnerability and Responses of Forest Edges to Drought in Amazonia

Recent severe droughts in Amazonia (2005 and 2010) have led to extensive damages to forest canopies and increased rate of tree mortality. After the 2005 drought, considered a once in century extreme event, the Amazon forest experienced another even more severe and extensive drought in 2010, with more than 600,000 km2 of forest area affected by both droughts. In addition to drought, the Amazon forest has been disturbed by deforestation over the past decades, and remnant forests are continuously fragmented into smaller habitats. Fragmented forests suffer several biological and ecological changes due to edge effects, including desiccation, that exacerbate regional forest degradation. As of 2010, 34% of the remaining forest outside protected areas is within 1 km of forest edges

in the Amazon Basin, but much larger proportions are found in highly fragmented regions such as RondÃ´nia (> 90%). Drought impacts should be larger and more severe in fragmented forest landscapes, especially within forest edges that dry more rapidly and intensely, however, the spatial scale of this phenomenon has not yet been quantified. As more frequent and intense extreme drought events are predicted in the future, more severe and extensive damages in regional ecosystems are expected as the remnant forests become increasingly fragmented with future land cover change in the Amazon. In this context, forest edges may serve as early warning indicators of potential tipping points at which climate change-triggered drought conditions could cause serious ecological changes to Amazonian ecosystems.

This proposal addresses â€œVulnerability and responses of terrestrial ecosystemsâ€ , one of the research topics solicited by the 2013 NASA Terrestrial Ecology Program. We propose to investigate the vulnerability and responses of forest edges to drought in the southern Brazilian Amazon that was most severely affected by the recent droughts. Our approach is the following: 1) determine drought intensity and forest fragmentation metrics (landscape metrics) across the southern Brazilian Amazon (1998-2014); 2) conduct field studies of forest edges determined by drought intensity and forest fragmentation to examine vulnerability and responses of forest edges; 3) generate time series data of ET and vegetation indices from Landsat to assess regional canopy desiccation and its recovery from drought impacts; and 4) predict the future vulnerability of forest edges to drought based upon simulated future climate and land cover change scenarios.

Marc Simard/California Institute of Technology/Jet Propulsion Laboratory
Estimating Canopy Height Using Repeat-Pass Polarimetric Interferometric (PolinSAR) Data from UAVSAR

This is a successor proposal addressing the use of repeat-pass polinSAR (polarimetric and interferometric synthetic aperture radar) to estimate forest canopy height, structure and biomass as well as their respective accuracy. We propose to exploit the polinSAR potential of a rich UAVSAR dataset (L-band polarimetric repeat-pass interferometry) generated during a TE-funded project (2009-2012) over 6 sites covering boreal, temperate and tropical forests. Those sites are located in QuÃ©bec, Maine, New Hampshire, Massachussets, California and Costa Rica. We quantified the impact of temporal decorrelation on interferometric coherence (Simard et al., 2012) and developed forward models for temporal decorrelation (Lavalle et al, 2012).

One of the Carbon Cycle and Ecosystem new observations priority is the â€œmeasurements of vegetation height and profiles of three-dimensional ecosystem structure to estimate above-ground biomass and carbon stocks with greatly reduced uncertainties and to characterize species habitats in ways that will enable exploration of fundamental controls on biodiversityâ€ .

The proposed objectives are to:

1. Develop a robust and efficient method to correct polinSAR products for temporal decorrelation
a. Compare temporal decorrelation compensation methods
b. Develop an iterative procedure to adaptively correct for temporal decorrelation with observed canopy structure parameters
c. Estimate microwave extinction using polinSAR inversion and known canopy heights from lidar data
d. Estimate coarse canopy layer using single baseline data through Legendre Decomposition

2. Distribute and discuss polinSAR products to the science community at large
a. Provide access to polinSAR data through a website interface for all sites
b. Organize a UAVSAR polinSAR workshop with a course, presentations and discussions.

Through this polinSAR analysis, we will produce validated maps of canopy height, structure (e.g. coarse vertical layers) and biomass. We will investigate the role of canopy structure and microwave extinction in driving canopy height estimation accuracy. All polinSAR products, with documentation and support, will be distributed through http://lidarradar.jpl.nasa.gov

The proposed UAVSAR polinSAR workshop will be held in conjonction with the annual UAVSAR workshop.

Philip Townsend/University of Wisconsin-Madison
Assimilation of Imaging Spectroscopy Data to Improve the Representation of Vegetation Dynamics in Ecosystem Models

The ability to seamlessly integrate information on forest function across a continuum of scales, from field to satellite observations, greatly enhances our ability to understand how terrestrial vegetation-atmosphere interactions change over time and in response to anthropogenic and natural disturbances. This proposal focuses on the use of field (spectroscopy) and high-spectral resolution remote sensing observations (i.e. imaging spectroscopy, IS), within an efficient model-data assimilation framework, to improve the characterization of vegetation dynamics in terrestrial ecosystem models. Our primary objective is to comprehensively examine the potential for direct assimilation of optical remote sensing observations into sophisticated ecosystem models to better constrain projections of energy balance, vegetation composition, and carbon pools and fluxes. This proposed work would be a novel step toward improving our ability to better diagnose ecosystem vulnerability to environmental change and predict responses to climatic and other perturbations. This effort comes at a crucial time because the experimental, remote sensing, and modeling communities have entered into an increasingly data-rich era; however the tools needed to make use of the numerous but disparate data for model improvements are currently lacking. For example, remote sensing can provide detailed spatial and temporal information on a number of important biophysical and biochemical properties of ecosystems, such as leaf optical properties, leaf chemistry, morphology,

vegetation composition and structure. State-of-the-art dynamic vegetation ecosystem models, such as the Ecosystem Demography (ED v2.2) model (Medvigy et al., 2009), a physiologically-based forest community model, can potentially use this information to improve model representation of vegetation dynamics. ED is especially relevant to these efforts because it contains a sophisticated structure for scaling ecological processes across a range of spatial scales: from tree-level physiology to stand demography to landscape heterogeneity to regional carbon, water, and energy fluxes, which allows for the direct use of remotely sensed data at the appropriate spatial scale. The proposed research will leverage within an ecosystem modeling framework extensive existing field and imaging spectroscopy (IS) data that have been collected by Serbin and Townsend in the upper Midwest US, as well as from California as part of the ongoing NASA HyspIRI Airborne Campaign, and other from other sites in the eastern US with extensive data records. We propose to utilize a radiative transfer modeling (RTM) module being developed by Serbin and Dietze for use with the ED2 model and Predictive Ecosystem Analyzer (PEcAn, LeBauer et al., 2012) workflow system (www.pecanproject.org) to enable efficient assimilation of spectral reflectance observations from IS data (and eventually any optical remote sensing observations, such as Landsat and MODIS/VIIRS). This open-source workflow system directly ingests spectral observations rather than derived products. This will improve the models parameterization of canopy optical properties and the surface energy balance. Through state-variable data assimilation we will fuse AVIRIS (or other IS data), flux towers, forest inventories, and model projections to reconcile estimates of vegetation composition and carbon pools and fluxes. The resulting data product will provide the basis to develop a better understanding of the drivers of spatial and temporal variability in the carbon cycle and the sources of uncertainty in these estimates. This project is an important step toward the operational capacity to assimilate reflectance observations, uniformly, within sophisticated ecosystem models with the goal to accurately constraining model projections of carbon pools and fluxes of terrestrial ecosystems.