The New (Early Career) Investigator Program (NIP) in Earth Science is designed to support outstanding scientific research and career development of scientists and engineers at the early stage of their professional careers. The program aims to encourage innovative research initiatives and cultivate scientific leadership in Earth system science. The Earth Science Division (ESD) places particular emphasis on the investigators' ability to promote and increase the use of space-based remote sensing through the proposed research.

The NIP supports all aspects of scientific and technological research aimed to advance NASA’s mission in Earth system science (http://science.nasa.gov/about-us/science-strategy/).

In basic research and analysis, the Focus Areas include: Carbon Cycle and Ecosystems, Climate Variability and Change, Water and Energy Cycle, Atmospheric Composition, Weather, and Earth Surface and Interior. In applied scientific research, the ESD encourages efforts to discover and demonstrate practical uses of NASA Earth science data, knowledge, and technology (see http://appliedsciences.nasa.gov). In technological research, the ESD aims to foster the creation and infusion of new technologies into space missions in order to enable new scientific observations of the Earth system or reduce the cost of current observations (see http://esto.nasa.gov). The ESD also promotes innovative development in computing and information science and engineering of direct relevance to ESD.

Of the 131 proposals received for the NIP program element in ROSES 2013, 22 proposals have been selected for awards upon verification of eligibility; they are:

**Ryan Abernathey/Columbia University**

Quantifying Surface Diapycnal Mixing by Mesoscale Eddies Using Satellite Observations

Physical processes which modify the density of water are of central importance in the ocean circulation. This proposal seeks to investigate the physical process of diapycnal mixing by horizontal mesoscale eddy stirring in the surface mixed layer, using satellite observations and high-resolution numerical models. In the ocean interior, mesoscale eddies stir properties mostly along isopycnals and therefore produce little or no diapycnal flux. In contrast, lateral eddy stirring in the mixed layer irreversibly mixes density, leading to water mass transformation. We argue that this type of transformation is potentially significant in mode-and intermediate water formation regions and therefore has implications for climate change and climate variability. We also demonstrate that it has not been studied adequately in the past and is therefore a source of uncertainty in our
understanding of the upper ocean meridional overturning circulation. The proposal puts forth a powerful new technique for estimating transformation by mesoscale eddy stirring in the surface layer by combining the transformation framework of Walin (1982) with the modified-Lagrangian-mean framework of Nakamura (1996). We propose applying this framework to high-resolution satellite sea-surface temperature observations, specifically the MODIS, GOES, and MUR products in order to make a global estimate of the transformation rate due to mesoscale eddy diapycnal mixing. Three primary challenges are discussed, and potential solutions proposed: the need to extrapolate high-resolution sea-surface salinity, the need for a grid-scale diffusivity, and the need for mixed-layer depths. Overcoming these challenges constitutes the bulk of the proposed work, after which the transformation calculation itself is straightforward. We also propose diagnosing the mesoscale eddy diapycnal-mixing-induced transformation rate in a high-resolution numerical model (ECCO2). This will serve to test the methods and assumptions used in analyzing the data and to provide context for the transformation rates in comparison to other processes such as air-sea fluxes. The proposed research has the potential to greatly advance our understanding of how mode and intermediate waters are formed and also to deepen our understanding of the role of mesoscale eddies in the ocean circulation. It also represents a novel and innovative application of satellite data to an important problem.

Ali Behrangi/Jet Propulsion Laboratory
Improving High Latitude Precipitation Observation Climatology Using Advanced Space-Borne Sensors: A Critical Step Towards Evaluation of Reanalysis and Climate Models

We propose to use the strengths offered by recent space-borne sensors: CloudSat-CPR, Aqua-AMSRE, and GRACE, to improve the quantification of high latitude precipitation (e.g., poleward of 55° latitude bands) and its uncertainty. The outcomes will be used to set guidelines to update commonly used precipitation observation records, i.e., GPCP, which is known to be highly uncertain at such regions (Adler et al., 2012). With the improved results on the quantification of precipitation and its uncertainty at such climate-sensitive regions, we will then evaluate reanalyses and climate models, which are critical to understand the current and future states of the Earth's climate.

We propose to achieve the following practical objectives:

- Deliver independent high-latitude seasonal precipitation climatology maps using the strengths offered by the recent advanced sensors (e.g., CloudSat CPR, AMSR-E, and GRACE) and use them to quantify precipitation observation uncertainties.

- Determine GPCP discrepancies and errors, trace them back to the GPCP's level 2 inputs, and set a guideline for future update of the product through collaborative efforts with the GPCP team.
Utilize GPCP, the new high-latitude precipitation maps, and the improved uncertainty analysis to evaluate the skills of reanalyses and models: the Modern Era Retrospective-Analysis for Research and Applications (MERRA), widely used to study global water and energy cycle, and the Coupled Model Intercomparison Project Phase 5 (CMIP5) models.

Jennifer Bonin/University of South Florida
Using Satellite Laser Ranging to Fill the Gap Between GRACE and GRACE Follow-On Over the Polar Regions

The Gravity Recovery And Climate Experiment (GRACE) has produced high-quality information concerning mass transport since 2002, specifically improving our understanding of ice mass change in Greenland and Antarctica over the past decade - an understanding closely connected with the more general questions of modern day climate change and sea level rise. It is the only direct measurement of mass change over the full extent of these large, remote regions. Furthermore, it provides a crucial cross-check to ice height measurements of satellite altimetry as well as GPS or in situ ice velocity measurements, which are more spatially limited. Unfortunately, GRACE is coming to the end of its lifetime, either due to simple deorbiting or exhausted battery life, and will not be replaced by GRACE Follow-On until approximately 2017. The likely gap between the two missions is undesirable for two reasons. First, polar mass changes are critical to understanding global climate change, especially accelerations. Second, a gap will make it difficult to link GRACE Follow-On data with that of the original GRACE if there is a significant acceleration or long time between the two record sets.

We wish to study an alternative time series of Greenland and Antarctic mass changes, to bridge the gap between GRACE and GRACE Follow-On using the Satellite Laser Ranging (SLR) series of Cheng, Ries, and Tapley (http://grace.jpl.nasa.gov/data/weekly5x5gravityharmonicsdata). We will test a least squares inversion method to fit the very long-wavelength gravity signal available from the SLR series (to degree and order 5 in spherical harmonics) into very large global basins, including one or more over Greenland and the surrounding icy regions, and two or more basins for Antarctica. We will first use a simulation to test whether a 5x5 harmonic series is sufficient to retrieve a reliable mass change signal over broad polar regions, and learn how to best optimize the process. We will then assess errors in the technique by comparing the inversion of the 5x5 SLR results with the inversion of the full GRACE data for the period 2003 to the present.
This proposal is to develop (1) an orbit planning and lifetime configuration management tool, (2) an observation scheduling and data downlink latency minimization tool for the constellation, and (3) tools for rapid data retrieval, calibration assessment, quality management, and low-latency distribution to forecasting systems for a low-Earth orbiting (LEO) constellation of nanosatellite passive microwave radiometers. While the passive microwave radiometer payloads are of particular interest given our group's upcoming flight projects, these tools could easily be tailored to support studies of other Earth observing payloads. Prof. Cahoy is currently leading a graduate student team at MIT to build the Microsized Microwave Atmospheric Satellite, a nanosatellite (< 5 kg) which carries a 118 GHz passive microwave radiometer whose development was led by Dr. Bill Blackwell at MIT Lincoln Laboratory. MicroMAS is currently scheduled for launch in December 2013 from the International Space Station. In addition, Prof. Cahoy and Dr. Blackwell are collaborating on the Microwave Radiometer Technology Acceleration Satellite (MiRaTA), a recently selected NASA ESTO nanosatellite scheduled for launch in 2015. In addition to demonstrating proof-of-concept for a miniaturized microwave radiometer, we envision the MicroMAS CubeSat to be a pathfinder towards a future LEO constellation of nanosatellite microwave radiometers. Such a constellation would greatly improve revisit rates and geographic coverage of tropical storms and hurricanes. The goal of this proposal is to develop tools to plan an optimal constellation design, maintain and manage the constellation, schedule observations that minimize downlink latency (using both ground and space data links) and management of data from the constellation such that these key temperature, precipitation, and water vapor observations can be incorporated with minimal latency into forecasting systems. This work has significance for society in that it develops tools to enable paradigm-shifting improvements in the monitoring and tracking of severe weather systems such as tropical storms, hurricanes, and cyclones. It would provide game-changing advances by reducing costs by at least an order of magnitude for the constellation as a whole (each nanosatellite costs about $1M) while increasing robustness to launch and sensor failures as individual units could be easily replaced. Additionally, this work will support the education of graduate students in science and engineering, and Prof. Cahoy will also mentor undergraduate students to contribute to this effort through independent research for credit. Significance to NASA: This work directly meets the NASA 2011 Strategic Goal 2 of: Expand scientific understanding of the Earth and the universe in which we live. Specifically, Outcome 2.1: Advance Earth system science to meet the challenges of climate and environmental change, Objective 2.1.2: Enable improved predictive capability for weather and extreme weather events. This work complements and supports the expanded use of a NASA ESTO-funded nanosatellite microwave radiometer project, MiRaTA, as well as MicroMAS, which themselves leverage previous NASA investment in miniaturized radiometer technologies as well as nanosatellite technologies.
The contribution of the ocean biological pump to the global carbon cycle is currently poorly-constrained, in part because we lack observations of: 1) processes controlling carbon export from the euphotic zone; and 2) attenuation of carbon fluxes below the euphotic zone, in the upper ~1000 m. Autonomous, profiling floats carrying beam transmissometers act as "optical sediment traps", drifting at depth while measuring the accumulation of sinking particles on the upward-facing window of the transmissometer. Optical sediment traps have the potential to greatly increase the number and spatiotemporal density of particle flux measurements in this critically-undersampled "twilight zone". Field calibrations versus co-deployed, neutrally-buoyant sediment traps (NBSTs) are currently underway.

To fully exploit the unique, high-resolution carbon flux data that can be acquired using transmissometers on profiling floats, the flux observations must be interpreted in the context of upper ocean biological production and ecosystem function. Satellite ocean color-based estimates of net primary productivity (NPP), ecosystem structure metrics, and export provide our only global view of the processes controlling particle flux out of the euphotic zone. Similarly, autonomous platforms able to measure flux at depth are at present the only way to remotely observe particle flux attenuation, and make inferences about its driving processes, in the twilight zone beyond the view of satellites.

Float-based measurements of particle flux just beneath the euphotic zone, and down to depths of 1 km, will be analyzed in the context of corresponding satellite-based, surface ocean estimates of NPP, export, and ecosystem metrics. Long-term deployments of bio-optically instrumented profiling floats with transmissometers have been underway since mid-2011, and data from several sources have been made available for the proposed analysis.

The following questions will drive the analysis:

- How tightly coupled are profiles of bio-optical properties and derived NPP, measured in situ by optical proxy, to integrated estimates from satellite models?

- What relationships exist among satellite-derived surface ecosystem metrics (e.g., chlorophyll, phytoplankton carbon, and particle size), temperature, and the observed rate of flux attenuation with depth?

- How variable are export and flux attenuation over the spatiotemporal scales resolved by ocean color satellites and OSTs?

Previously collected datasets will be leveraged to answer the above questions. We will use best-available ocean state estimates of horizontal velocities to locate the approximate source regions for the settling particle flux detected by floats. Additional deployments
This project specifically addresses the Ocean Biology and Biogeochemistry program goals of: 1) "Understanding and quantifying the impacts and feedbacks of Earth System processes, particularly oceanographic mechanisms, on the global and regional spatial and temporal variability of ocean biogeochemistry, including carbon sources and sinks […] in the ocean"; and 2) "Exploring the development of new biological, ecological, and biogeochemical observations beyond traditional ocean color (e.g., phytoplankton chlorophyll a) from space-based assets […]".

Lyndon Estes/Princeton University

**Integrating Crowdsourcing, In Situ Sensing, and Spaceborne Observation to Understand the Sustainability of Smallholder Agriculture in African Wet Savannas**

Livelihoods in Sub-Saharan Africa (SSA) rely heavily on small-scale farming. This dependence could deepen, as SSA's wetter savannas will be increasingly farmed to meet growing food demand, while economic growth strategies promote the expansion of smallholder farming. This large-scale, smallholder-based agricultural development in a region with a highly variable climate raises important sustainability questions: 1) Do strategies for increasing smallholders' productivity increase or decrease their resilience to climatic variability? 2) Will productivity gains minimize the amount of new land needed for agriculture? To answer these questions, fine-scale, sequential maps of crop yield and cropland are needed. RS is the best tool for providing these data, but using RS to map smallholders' fields and yields is difficult because their field sizes are smaller than the resolution of the most commonly used sensors (e.g. MODIS). To overcome this scale-related challenge, this project will use a novel approach that integrates crowd-sourcing, in situ environmental sensing, and Earth Observing satellites. The research has 3 main objectives: 1 - Identify patterns of cropland change in smallholder farms; 2 - Identify landscape-scale trends in smallholder productivity; 3 - Understand the relationships between changes in crop productivity, landcover, and climatic variability. Three tasks will be completed to meet these objectives. Task 1 - Develop and use a new landcover mapping system to accurately map how smallholders' fields have changed over time; Task 2 - Develop a crop yield estimation system that can accurately map how smallholder yields have changed over time; Task 3 - Use the landcover and yield change data to investigate the relationships between cropland changes and yield changes, and to see whether higher yields increase or decrease climatic variability. The project focuses on maize farming in Zambia, a bellwether for regional agricultural development that has seen recent maize yield increases and farmland expansion. To achieve Task 1, a novel landcover mapping technique that combines crowd-sourced field boundary mapping with image pattern recognition techniques will be applied to high resolution, publicly available satellite imagery and Landsat and ASTER data. The resulting maps will track Zambian cropland from 2000-2016. Task 2 will use novel low cost environmental sensors, deployed in smallholder maize fields at 4 study sites in Zambia, to provide information
on crop reflectance and micro-meteorology, as well as farmer-reported yields. These data will calibrate Landsat and MODIS-based yield models and a mechanistic crop simulator, which will be jointly used to map annual Zambian maize yields between 2000-2016. The resulting maps will be used to calculate the trends in maize yields, planted maize area, and total cropland, and to identify where these trends are occurring at a landscape scale (Task 3). Of particular interest will be analyses testing whether maize yield increases are correlated with cropland expansion or contraction, whether yield increases precede cropland changes, and whether yield gains are correlated with increasing inter-annual yield variability. These results will provide valuable insight into this study's two sustainability questions, which are directly related to key questions in the NASA Carbon Cycle and Ecosystems Focus Area: "What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?", and "What changes are occurring in global land cover and land use, and what are their causes?" This project's direct involvement of citizens and communities in the research effort broadens the societal relevance of the science and Earth Observation that will be conducted.

Barton Forman/University of Maryland

Multisensor Assimilation of Satellite-Based Passive Microwave Brightness Temperatures and Gravimetric Terrestrial Water Storage Retrievals in Snow-Dominated Regions

Quantification of global snow water is important for improving flood and drought prediction, freshwater resource characterization, oceanic circulation, and terrestrial water storage. The overarching goal of this proposal is to test the hypothesis that passive microwave and gravimetric measurements collected by satellite-based instrumentation can be systematically merged with an advanced land surface model to increase accuracy and reduce uncertainty in snow water equivalent (SWE) and terrestrial water storage (TWS) estimates at regional and continental scales. En route to this goal, the research approach includes distinct milestones that will be addressed by testing the following three hypotheses:

1. A support vector machine (SVM) can serve as an effective and computationally efficient, passive microwave (PMW) brightness temperature (Tb) measurement model within a land data assimilation system (LDAS) in order to optimally merge satellite-derived PMW Tb measurements with a land surface model.
2. PMW Tb measurements and gravimetric retrievals can be simultaneously merged to reduce uncertainty in modeled estimates of SWE, soil moisture, groundwater, runoff, latent heat flux, and sensible heat flux.
3. The simultaneous merger of PMW Tb measurements and gravimetric TWS retrievals within a LDAS will effectively downscale TWS retrievals in space/time thereby adding spatial and temporal resolution to the gravimetric retrievals that currently does not exist.

The increased utility associated with multisensor assimilation of TWS + PMW Tb will be proven via a series of experiments in North America. PMW Tb assimilation only will
quantify the improvements to regional and continental SWE estimation associated with SVM-based prediction of PMW Tb. SWE estimates from the NASA GEOS-5 model with and without PMW Tb assimilation will be compared against independent, ground-based SWE measurements. Additional ground-based observational networks that measure soil moisture, runoff, groundwater, and surface turbulent fluxes will also be employed in order to study the impact on hydrologic states and fluxes other than SWE. Multisensor assimilation of TWS + PMW Tb will then be conducted in order to investigate and quantify the synergistic effects of assimilating PMW Tb and gravimetric-based TWS retrievals on the performance of the NASA GEOS-5 model.

It is hypothesized that PMW Tb assimilation over snow covered regions will not only improve the characterization of SWE across regional scales, but will also enhance estimates of melt runoff during the subsequent ablation season. Multisensor assimilation offers the additional promise of improved soil moisture and groundwater characterization due to the integrated nature of the TWS retrievals. The synergistic effect of multisensor assimilation will provide a holistic estimate of the integrated basin response while providing an unprecedented opportunity to leverage multiple data sources in order to enhance our understanding of the spatiotemporal variability and uncertainty of the hydrologic cycle.

Experiments will systematically highlight measureable model improvements associated with the incorporation of SVM-based PMW Tb prediction as well as improvements associated with the combined, synergistic effects of multisensor assimilation. Integration of this multisensor assimilation framework within the GEOS-5 model will ultimately improve model accuracy and reduce model uncertainty at regional, continental, and global scales thereby increasing the utility of NASA data products that are based on modeling and data assimilation.

Pierre Gentine/Columbia University
A Unified Parameterization of Dry and Moist Convection

Low-level clouds contribute significantly to earth's radiative balance and to the vertical transport of heat and moisture. The representation of low-level clouds and convection in climate models is tied to an accurate representation of the mixed layer and moist convection. However, deficiencies in current model representation of low-level clouds and convection persist; among the outstanding challenges are: 1) the representation of subgrid processes and heterogeneities in the state properties and cloud cover; 2) the unification of moist convective processes within a single framework comprehensively validated against observations; and 3) the transition between different types of convection (stratocumulus to shallow convection, shallow to deep convection, dry to shallow convection), despite some recent advances.

In prior work, we developed a semi-analytic bulk model of the coupled mixed-layer and moist convection, denoted the probabilistic bulk convection model (PBCM), which is
based on a probability distribution function (pdf) of plumes. These advances appear promising to address the deficiencies noted above. The proposed work ultimately aims to incorporate PBCM into the NASA Goddard Institute for Space Studies (GISS) GCM model E. To achieve this, the proposed work will further test and validate the extension of PBCM to account for stratocumulus. PBCM will next be embedded into the NASA GISS Single Column Model (SCM) and validated across a wide array of test cases and data sets, i.e., BOMEX, ATEX, ARM, CGILS: CFMIP-GCSS Intercomparison of Large-Eddy and Single-Column Models. Concurrent with these activities, we will evaluate a new formulation of entrainment using a stochastic entraining plume model and the extension of the model to represent stratocumuli with the inclusion of a pdf of downdrafts. Lastly we will use the coupled PBCM-SCM framework to develop a convection parameterization that can be incorporated into NASA GISS model E. We anticipate that the new coupling between the mixed layer and moist convection and the pdf approach will substantially improve the representation of moist convection in the model by, for example, enhancing the model's ability to simulate transitions between the different convection regimes.

Brett Hoover/University of Wisconsin, Madison  
Dynamical Sensitivity Analysis of Weather Forecast Challenges Using the GEOS-5 Adjoint System

Significant forecast challenges exist for numerical weather prediction (NWP) in which suspected physical mechanisms at work in the modeled atmosphere create high uncertainty, resulting in potentially poor forecasts. Examples include the forecast of the intensity or track of tropical cyclones (TCs), and the uncertainty surrounding the development of midlatitude waves downstream of a recurving TC (so called "downstream development"). The evolution and eventual landfall location of Hurricane ("Superstorm") Sandy (2012) is an especially poignant example of such a forecasting challenge, where complex interactions between the hurricane and a developing midlatitude wave created uncertainty several days in advance for a forecast with important risk-analysis implications. Despite a priori knowledge about the likely interaction between these two features, forecasts from operational centers in the United States had difficulty in resolving the eventual westward turning of the hurricane and landfall along the east coast. Even though Sandy did not suffer incredibly large uncertainties, its impact was significant enough for the existing uncertainty to carry large risks.

The adjoint models of an NWP data assimilation and forecasting system provide the opportunity to investigate the sensitivity of specific aspects of the forecast to small changes to the initial condition model analysis, as well as its constituent parts - the observations and background state used to create the analysis. We wish to use the adjoints of the GEOS-5 and its data assimilation system to objectively define the sensitivity of these forecast challenges in select case studies. Sensitivity information provides an opportunity for deep, objective analysis of the dynamical processes most important to a specific forecast challenge, and how individual observations contribute to
this forecast at both short and medium range. Such a project would be a unique opportunity to apply these adjoint tools (GMAO being one of only two places in the US employing these systems operationally) in unique ways to address some of the most challenging issues faced by modern weather prediction.

While application of adjoint models to these kinds of forecast challenges has historically suffered from simplified (or absent) moisture and convective physics, the GEOS-5 currently employs an adjoint model employing sophisticated linear moist physics and gravity wave drag, making it uniquely qualified to address these scientific questions. The capability to quantitatively assess the impact of individual observations allows us to investigate both the atmospheric dynamics and impact of various portions of the observing network on prediction of extreme weather events. We expect to discover opportunities for innovative use of NASA's remote sensing observations to improve predictive capability.

Priorities include: (1) test appropriateness of response functions meant to define forecast challenges of interest, and perform analysis of resulting sensitivity gradients to investigate the most important dynamical processes; (2) objectively analyze the impact of observations on forecast challenges through the data assimilation adjoint, and perform data-denial of high-impact observations to determine physical mechanisms responsible for their impact; (3) compare sensitivities between high-predictability and low-predictability cases.

Kirk Knobelspiesse/Ames Research Center
Quantitative Simulation of Polarimetric Instruments Using Radiative Transfer Simulations and Bayesian Statistical Methods for the Remote Sensing of Aerosols and Clouds

My postdoctoral research primarily concerned the development of an instrument simulator that tested retrieval uncertainty assessments of existing aerosol remote sensing instruments. I propose to refocus this work to directly address future instrument development needs. A primary goal is to clarify the ACE and PACE Science Traceability Matrix (STM) to find the ideal instrument configurations for those missions. Furthermore, I will use these methods to consider more compact small-sat and cube-sat instruments. Validation with field observations will also be a component of the proposed research. Three airborne polarimeters were recently deployed as part of the Polarimeter Definition Experiment (PODEX). The variety of observed scenes from PODEX provide a wealth of validation potential and will test the predictive capability of the instrument simulator.

Aerosols, which are suspended particulate matter in the atmosphere, are an important yet highly uncertain component of the global climate, because they have a variety of sources, sinks, lifetimes and means of interacting with climate drivers. Global observations of aerosols remain limited, because the constrained information content from current
instrument designs provide for the retrieval of only a portion of aerosol descriptive parameters relevant to climate.

The National Research Council (NRC) identified these issues in its first decadal survey for Earth science, and called for a multispectral, multiple view-angle polarimeter to be one of the instruments on the proposed Aerosol, Cloud and Ecosystems (ACE) mission. Subsequent proposals, such as the Pre-Aerosol, Clouds and ocean Ecosystem (PACE) mission, also include polarimeters. It is therefore widely recognized that the aerosol remote sensing community needs instruments with these characteristics. Observations from such instruments would furnish a more complete description of aerosols and their climate impacts.

There is, however, considerable variability in aerosol polarimeter designs, and a lack of consensus about the best configuration for aerosol remote sensing. Instrument complexity also makes it difficult to connect conclusively an individual design characteristic to the ability to retrieve a specific aerosol parameter from the observations. Fortunately, the optimal instrument design can be determined in a more quantitative manner by employing radiative transfer simulations and statistical techniques to link instrument measurement uncertainty to retrieval success. When coupled with validation from prototype instrument observations, instrument simulation techniques such as these can be a powerful tool to help meet scientific goals at minimal engineering cost.

The proposed research directly applies to the Atmospheric Composition and Climate Variability and Change focus areas of the Earth Science Division (ESD) by attempting to clarify the definition of instruments that will be part of future NASA missions. It will also help identify possible design simplifications that can be employed by small and cube satellites while still meeting scientific goals. In the broadest sense, however, I hope to bring cutting-edge information theory techniques to the design of future NASA aerosol polarimeters.

Eric Kort/University of Michigan
Using Space-Based Remote Sensing & In-Situ Observations to Solve the North American Methane Conundrum: Towards Resolving the 12Tg Gap

Methane is a crucial atmospheric trace gas, playing significant roles both in climate as a potent radiative agent (second behind CO2 as a contributor to post-industrial radiative forcing, Butler J [2012]) and in air quality as a precursor for tropospheric ozone [Fiore AM et al, 2002]. In spite of methane's importance, we still have poor constraints on regional emissions, and the relative role of different contributing sources. Given these poor constraints, it is unsurprising that emissions inventory estimates for methane come with high uncertainty, and are frequently found to be greatly in error. Prior studies using ground and airborne observations are consistent with US anthropogenic emissions of ~40 Tg CH4 yr-1 [Kort et al., 2008, 2010]. This stands in stark contrast to inventories reported by the US EPA for the same year (28.1 Tg CH4 yr-1). What source or sources
are responsible for this 30% discrepancy? To address this major question, we intend to propose a research approach that combines space-based remote sensing with ground-based observations to identify and attribute major unaccounted for methane sources in North America. The approach will use space-based atmospheric observations of methane made by SCIAMACHY and GOSAT. Using these two observational data sets, regions exhibiting anomalous methane enhancements will be identified as candidate contributors to the 12Tg atmosphere-inventory discrepancy. Analysis of ongoing GOSAT observations in these selected regions will enable the assessment of net regional emissions and emissions trends from 2010 onwards. The ability to assess trends from strong source regions has particular relevance now given the rapidly changing natural gas economy with its potentially significant repercussions for fugitive emissions. Pushing beyond the regional assessments made from space, ground-based ethane-methane observations will be evaluated, providing critical attribution information. Ethane is a powerful attributive tracer for methane studies, because in the absence of biomass burning, enhancement of ethane with methane unequivocally identifies a thermogenic source. Tracer-tracer analysis of the ethane:methane ratio in observed plumes will be used to quantitatively assess the relative contribution from different source sectors, helping observationally identify the emission sectors responsible for the 12 Tg gap. Helping resolve the North American methane budget question directly improves understanding and predictive capability for climate forcing and air quality (addressing Atmospheric Composition goals), as well as improving our understanding of methane cycling (addressing Carbon Cycle & Ecosystems goals). With the useful combination of multiple space-based instruments with in-situ observations this proposed research will promote and increase the use of existing space-based remote sensing, as well as demonstrate the potential value of improving methane sensing from space in the future.


Hyongki Lee/University Of Houston

Estimating Two-Dimensional Surface Water Depths in the Congo Wetlands Using Multiple Remote Sensing Measurements

Scientific Rationale. The Congo Basin is the world's third largest in size (~3.7 million km2), and second only to the Amazon River in discharge (~40,200 m3 s-1 annual average). The impact and connections of this hydrologic flux with the region's and
globe's climate, biogeochemical cycling, and terrestrial water storage is clearly of great importance. However, little is known about the hydrology and hydraulics of the Congo Basin. The Congo Basin has not experienced the same degree of new research compared to the Amazon in spite of its enormous size because the lack of in situ has limited our hydrologic understanding of the basin. As a consequence, estimates of the magnitude of other processes driven by such dynamics, such as methane emissions from flooded wetlands that form a significant contribution to global atmospheric methane, also cannot be well estimated. A few studies have only recently attempted to investigate Congo's terrestrial water dynamics using remote sensing measurements and modeling.

Objectives and Approach. Our proposed RESEARCH OBJECTIVES are to: (A) generate two-dimensional high-resolution (~100 m) maps of water depth over the Congo wetlands by integrating backscattering coefficients ($\sigma_0$) from ScanSAR images, water level anomalies from satellite radar altimetry, and vegetative land cover from MODIS; (B) generate two-dimensional high-resolution (~40 m) maps of centimeter-scale (spatially) relative water level changes ($\Delta h$) from interferometric SAR (using fine-beam modes); (C) generate two-dimensional high-resolution (~100 m) maps of water depth for when the ScanSAR images are not available by combining the water depth from (A) and the relative water level changes from (B); (D) construct a simple one-dimensional linear diffusion flow model to characterize the wetland storage using the hydrologic flux balances obtained from (A), (B), and (C). Specific HYPOTHESES that will be evaluated in this research are that: (1) the local upland runoff is the main source of the water in the interfluvial wetlands whereas the fluvial process of river-floodplain exchange is the main source in the floodplains adjacent to the mainstem; (2) the flow direction in the Congo floodplain that is adjacent to the mainstem is perpendicular to the mainstem flow while the flow direction in the central Amazon floodplain, located between terra-firme, is parallel to the mainstem flow; (3) the pattern of in the interfluvial Congo wetlands has clear relation with topography whereas no clear relation is observed in the Amazon floodplain.

Anticipated Results. Our anticipated results include (1) the spatio-temporal variability of water storage and its changes, and (2) the complex hydraulic processes of large channel and floodplain/wetland systems, over the central Congo Basin using multisensor remote sensing approaches. This proposal is in direct support of the specific research interest for NASA's Terrestrial Hydrology program: "particular emphasis is placed on the application of satellite based remotely sensed data for characterizing, understanding, and predicting the terrestrially linked components of the hydrologic cycle and the dynamics of large-scale river basins".
Sulfur dioxide (SO2) is an important gaseous pollutant that can have profound impacts on air quality and climate. Anthropogenic emissions of SO2 have seen significant changes in recent years, with sizable reductions in Europe and the U.S. largely offset by fast growth in China and India. Understanding these recent developments in SO2 pollution is critical for improving our ability to simulate and project the changes in the Earth's environment. This requires accurate, up-to-date estimates of SO2 sources. However, large uncertainties can exist in the emission inventories for some regions, due to inadequate temporal resolution and insufficient knowledge concerning the efficacy of pollution control measures. Global measurements of SO2 using satellite sensors, such as the Ozone Monitoring Instrument (OMI) aboard NASA’s Aura spacecraft, can provide constraints on the estimated emissions. But the applications of satellite SO2 data have been limited by issues in the operational products, instrument degradation, and also inconsistency between different instruments and algorithms.

We propose to employ multiple satellites to systematically investigate the changes in global and regional SO2 pollution over the past decade, using an innovative retrieval algorithm to produce a consistent, high quality dataset for data analysis.

Our objectives are:

To produce a consistent gridded dataset of SO2 column amount for the period of 2004-2013 with improved data quality and enhanced spatiotemporal coverage, by applying a new retrieval algorithm to multiple satellite sensors;

To quantify the changes in SO2 loading over important source regions using the new dataset and to compare the satellite observations to bottom-up emission inventories and model output;

To investigate the potential impact of the changes in SO2 emissions on the abundance of sulfate and the overall aerosol loading in selected regions.

This proposed research is based on our newly developed algorithm to be operationally implemented for the OMI SO2 retrievals. Our new algorithm combines spectral fitting and principal component analysis of the measured radiance data. It significantly reduces the artifacts and decreases the noise in the retrieved SO2 by a factor of 2-3 compared to the operational OMI product. One advantage of this algorithm is that it eliminates the need for empirical, instrument-specific data corrections, a common practice in many algorithms that can introduce artificial trends between different instruments and products. The algorithm can also be easily adapted for other instruments. These features will allow the creation of a consistent, high-quality satellite dataset, enabling more in-depth understanding of global anthropogenic SO2 pollution.

The high quality dataset resulted from this research will promote the use of space-based remote sensing in air quality and climate studies. This proposal is relevant to the ROSES-
13 solicitation (A.34, New Investigator in Earth Science) in that it will help address a key science question in the Atmospheric Composition Focus Area of NASA Earth Science: "How is atmospheric composition changing?" The proposed research will leverage and expand our separately proposed effort for NASA's Aura mission. By bridging and enhancing the important SO2 data record from OMI to OMPS (Ozone Mapping and Profiler Suite), this research will also contribute to NASA/NOAA's NPP mission and future satellite missions flying the OMPS instruments.

Jilu Li/University of Kansas
Unambiguous Determination of Ice Sheet Basal Conditions From Radio Echo Sounding Data

The next generation of ice sheet models that incorporates the full Stokes matrix is being developed to better understand recently observed fast flow dynamics in the ice sheets and to more accurately predict ice sheet contribution to global sea-level rise. These models require a wide coverage of the ice-sheet basal conditions—one of the critical boundary conditions that controls ice flow. Radio-echo sounding (RES) is the most efficient and only way to determine ice-sheet basal conditions on a large scale and at the spatial resolution required by numerical models. Previous study of ice-sheet basal conditions using RES data is more focused on East Antarctica. Our knowledge about the ice-sheet basal conditions is very limited because of the scarcity of data, especially for the Greenland Ice Sheet (GIS) and West Antarctic Ice Sheet (WAIS).

A large volume of high-quality airborne RES data has been collected during the NASA Operation IceBridge (OIB) and National Science Foundation (NSF) missions in recent years. These data sets have a dense coverage over critical coast and outlet glacial areas of GIS and WAIS and have been used to generate a new ice-bed elevation map for GIS. The goal of this proposal is to develop advanced algorithms, process and analyze these data, unambiguously determine the basal conditions of GIS and WAIS, and generate basal-condition maps that are much needed for reliable diagnostic and prognostic ice sheet modeling.

Radio echoes returned from the ice-bed interface are affected by many factors including the radar system characteristics, the roughness and dielectric contrast at the interface, and the loss of signal propagating through the overlying ice. Any improper assumptions and calibrations made about these factors may result in ambiguous basal conditions in interpreting radar data. This proposal will develop a combined model-based and signal analysis technique of data inversion for accurate radiometric calibrations to reduce the ambiguities in inferring basal conditions. Because the radars used in the OIB and NSF missions are very stable and can be characterized very well, the major ambiguities result from the uncertainties in estimating the ice loss and roughness of the ice surface and bed. We propose to combine ice core data and the specular echoes from bright internal ice layers to estimate the ice loss accurately. We also propose to analyze the echo waveforms of the ice surface and bed to estimate the interface roughness. We will verify the
determined basal conditions by comparing with ice core data, seismic data, and satellite altimetry data and by studying the correlations with ice surface, layer and flow dynamics and temperature profiles.

Multi-frequency RES data will further constrain the interpretation for basal conditions. As a part of an NSF Major Research Instrumentation grant, the Center for Remote Sensing of Ice Sheets is developing an ultra-wideband radar that operates over the frequency range from 150 to 600 MHz with a large cross-track array of 24 elements. This radar enables us to map ice basal conditions in a wide swath of 5-7 km with fine resolution. It is expected to deploy during the 2014 and 2015 field seasons. The wide-band allows four independent measurements at center frequencies separated by 150MHz, so the RES data can be inverted unambiguously. We will extend this proposed research to analyzing wideband data to facilitate unambiguous and quantitative determination of the basal conditions.

The output of the proposed research will include wide-coverage, basal-condition maps over GIS and WAIS for roughness, reflectivity, wet/dry, basal material properties and water content. These maps will present a comprehensive assessment of basal conditions of GIS for the first time and fill the knowledge gap about the basal conditions of WAIS. They will be offered to the cryospheric research community to support ice sheet modeling and geophysical studies.

Adrian Loftus/University of Maryland, College Park
Toward Improved Representation and Understanding of Aerosol-Cloud-Precipitation Processes

Low-level stratocumulus clouds cover more of the Earth's surface than any other cloud type rendering them critical for Earth's energy balance, primarily via reflection of solar radiation, as well as their role in the global hydrological cycle. Stratocumuli are particularly sensitive to changes in aerosol loading on both microphysical and macrophysical scales, yet the complex feedbacks involved in aerosol-cloud-precipitation interactions remain poorly understood. Representing these clouds in climate models is challenging as the controlling processes (e.g., radiative cooling, turbulence, entrainment, precipitation) occur on such small scales, leading to uncertainties in future climate prediction. Moreover, research on these clouds has largely been confined to marine environments, with far fewer studies over land where major sources of anthropogenic aerosols exist.

The aerosol burden over Southeast Asia (SEA) in boreal spring, attributed to biomass burning, exhibits highly consistent spatiotemporal distribution patterns, with major variability due to changes in aerosol loading mediated by processes ranging from large-scale climate factors to diurnal meteorological events. Downwind from the smoke source regions, the aerosol-cloud system is tightly coupled and provides a unique, natural laboratory for further exploring the micro- and macro-scale relationships of the complex
interactions. Compared to other locations worldwide, studies of springtime biomass-burning aerosols and the predominately stratocumulus cloud systems over SEA and their ensuing interactions are underrepresented in scientific literature. Recent field campaigns (e.g., 7-SEAS 2010-2013) in this region have gathered vital data to help characterize the properties and interactions of aerosols and stratocumulus clouds.

Advancements in understanding aerosol impacts on clouds and precipitation are possible by employing cloud-resolving models to simulate the underlying physical processes in aerosol-cloud-precipitation interactions. The Goddard Cumulus Ensemble (GCE) cloud model has recently been enhanced with a triple-moment bulk microphysics scheme that fully predicts hydrometeor size distributions, and inclusion of aerosol microphysical sinks and sources is imminent. In addition, the Goddard Satellite Data Simulator Unit (G-SDSU), a forward radiation model coupled to the GCE, permits interfacing remote-sensing/in-situ measurements with model output. The integration of model simulations with extensive ground-based and satellite observations/retrivals will enable a thorough investigation of biomass-burning aerosols impacts on stratocumulus clouds and precipitation over this vital region. Specifically, the proposed work consists of two main components:

1) To utilize spectrally/spatially/temporally integrated data products from space-borne and ground-based platforms to evaluate the physical and statistical aspects of output from an advanced cloud-resolving model over a regional scale to ultimately improve the representation of aerosol-cloud-precipitation processes. Ground-based measurements acquired during the 7-SEAS experiments from GSFC/SMARTLabs mobile laboratories (cf. http://smartlabs.gsfc.nasa.gov) will provide critical boundary constraints.

2) To comprehensively examine relationships between aerosols modulating cloud droplet nucleation and the resulting products of warm rain processes (e.g., albedo, water content, precipitation) via cloud-resolving model simulations with respect to key physical observables (e.g., number/mass concentration, size/shape distribution). The coupled GCE/G-SDSU models will assess how aerosol-cloud-precipitation feedbacks may manifest themselves in simulated signal retrievals from both satellite and ground-based platforms. Utilizing SMARTLabs' extensive observations during 7-SEAS deployments, the proposed effort will promote unique insights into aerosol-cloud-precipitation processes over this climatically important water-cycle regime.

Saurabh Prasad/University of Houston
Novel Bayesian Image Analysis for Robust Multisensor Remote Sensing With Applications to Coastal Ecosystem Monitoring

Advances in optical remote sensing technology over the past two decades have enabled the dramatic increase in spatial, spectral, and temporal data now available to support earth science research and applications, necessitating equivalent developments in signal processing and data exploitation. Although this increase in the quality and quantity of
diverse multi-source data can potentially facilitate improved understanding of fundamental scientific questions, conventional methods that are currently available to scientists are designed for single-sensor, low dimensional data. Key challenges remain for effective utilization in an operational environment: (1) Representation and effective dimensionality reduction of high-dimensional features resulting from such datasets, (2) Designing effective classification strategies that are robust to a limited quantity of training samples in-situ data) and spatial-temporal non-stationary environments, (3) Designing and optimizing analysis algorithms that can effectively handle nonlinear, complex decision boundaries separating classes (objects of interest on ground) in the feature space. In prior and ongoing research, the research group led by the PI is generating statistical analysis models that offer robust solutions to the analysis of remotely sensed imagery, particularly hyperspectral imagery. Specifically, these methods provided robustness to the small training sample size problem (ground-truth from field campaigns is expensive, and often hard to come by), mixed pixel conditions (spaceborne imagers often do not provide a very high spatial resolution, but in prior research, the PI developed models that could detect invasive species even at coarse spatial resolutions), and additive noise (e.g. atmospheric affects, sensor overheating etc.).

On the Gulf of Mexico coast, one of the most relevant applications of these developing technologies is to quantify the character and extent of coastal wetland ecosystems. Climate change is likely to modify subtropical coastlines such as those in the Gulf of Mexico by changing them from short-stature grasslands (salt marshes) to medium-stature forests (mangroves). On the Gulf Coast, mangroves have historically expanded into salt marshes during periods with warm winters, and contracted during periods with hard freezes. In the future, however, mangrove distributions are expected to steadily expand due to rising temperatures. An area of active research focus is the investigation of the ecological implications of this shift: how will expanding mangroves alter fishery production, carbon sequestration, or endangered species? A quantitative, Gulf-wide understanding of the magnitude, rate, and “hot spots” of expansion is central to all of these ecological questions.

In this context, the central objectives of this 3-year NIP project are as follows (1) Development, optimization and validation of a novel statistical approach to Bayesian analysis of high dimensional hyperspectral and full-waveform LiDAR data, (2) Development of topology preserving feature reduction approaches to enhance the robustness of the Bayesian analysis approach, (3) Development of a statistical sensor fusion approach, to exploit hyperspectral and full-waveform LiDAR data, (4) Application of the image analysis and sensor fusion approaches to a focused set of environmental remote sensing tasks over study sites near Galveston, Corpus-Christi, and, Sabine lake, (5) Development and validation of a novel “ground-truthing” protocol using forward-looking hyperspectral cameras, for rapid field measurements. It is anticipated that this research will also serve as a stepping stone for the PI to build long-term research relationships with his academic partners and end-users, who can take this technology and analysis approach for effective remote sensing in their works.
Anita Rapp/Texas A&M University  
Detection of Precipitation Onset With Implications for Passive Microwave Rainfall Retrievals

In tropical and subtropical regions dominated by stratocumulus and shallow cumulus, rainfall is driven primarily by the warm rain process. Recent estimates in these regimes show noticeable differences in both precipitation occurrence and rates between active and passive microwave rainfall retrievals. Some of these differences may be a result of the fact that at low rain rates, the emission signatures from the cloud water and rainwater are nearly indistinguishable. Simple algorithms based on liquid water path thresholds have been previously employed to determine precipitation onset in warm rain situations, however several recent studies have shown frequent precipitation occurrence at cloud liquid water path values well below the prescribed thresholds, likely contributing to the observed differences in active and passive precipitation estimates in regions where warm, shallow convection dominates. The overall goal of the proposed research is targeted at furthering our understanding of precipitation onset and ultimately improving the detection of precipitation onset for implementation in rainfall retrievals. Measurements from A-Train instruments will be combined to study what cloud and environmental properties may be used to detect the onset of precipitation, with the focus on using auxiliary measurements and model analyses that are feasible for implementation in a passive microwave rainfall retrieval algorithm. The major proposed research tasks are to 1) determine where detection of precipitation onset is most problematic for different passive microwave rainfall retrievals, 2) determine how cloud and environmental properties are related to precipitation onset, and 3) test the sensitivity of observed microwave brightness temperatures to precipitation onset for different environments and cloud scenarios.

Matched CloudSat, MODIS, AMSR-E, and ECMWF analysis data are first used to find the cloud and/or environmental regimes where passive microwave rainfall retrievals miss precipitation. These results are then used to guide a study on how cloud or environmental properties are related to precipitation onset and how they may be combined to improve the rain/no-rain detection for passive microwave rainfall retrievals. The sensitivity of the microwave brightness temperatures will also be tested across these same environmental and cloud variables to determine how this additional information can be combined with the measured microwave brightness temperatures to develop relationships suitable for algorithm implementation. The proposed research should pave the way for improving GPM-era passive microwave rainfall retrievals for warm rain clouds. This work specifically addresses the NASA Earth Science Water and Energy Cycle Focus Area and will help in "quantifying the key reservoirs and fluxes in the global water cycle and assessing water cycle change". Given recent research indicating possible trends in shallow cloud precipitation and the current shallow cloud uncertainties in climate models, better representation of precipitation from shallow clouds can also help answer these and other NASA strategic goals questions like "How is the global Earth system changing?" and "What are the sources of change in the Earth system and their magnitudes and trends?".

The role of NASA multi-angle remote sensing has been central to the retrieval of global physical characteristics, such as land cover/dynamics, albedo, burned area, as well as compositional, morphological, and structural information that facilitates addressing key climate, environmental, and ecological issues [Diner et al., 1999]. To provide accurate data input to radiative transfer models and satellite retrieval algorithms, ground-based surface directional spectral reflectance measurements (e.g., CIMEL and PARABOLA) have been used as the baseline for the discipline since the 1980s. A challenge in characterizing and assessing the accuracy of multi-angle data and products is the inability to overcome the spatial scaling errors that can produce large disagreements between satellite and field-measured values. While the empirical quality of these measurements is rarely certain, knowledge of their uncertainties is essential if a complete assessment of satellite-derived measures of key climate variables is sought.

We propose to apply a new retrieval strategy for fine-to-moderate resolution multi-angle observations based on the operational sequence used to retrieve the MODIS surface reflectance and BRDF/albedo products. The recently published and validated scheme [Román et al., 2011; 2013] makes use of a semiempirical kernel-driven bidirectional reflectance model to provide estimates of intrinsic albedo (directional-hemispherical reflectance and bihemispherical reflectance), model parameters describing the BRDF, and extensive quality assurance information. Because airborne measurements from NASA’s Cloud Absorption Radiometer (CAR) are well-calibrated, have a long temporal record, and high angular resolution, they comprise the primary dataset used in this effort. This will form the basis of the CAR Multi-Angle reference dataset (CARMA), which will be distributed to the scientific community via our website: (http://car.gsfc.nasa.gov).

These activities are directly relevant to two of the New Investigator Program’s (NIP) major research areas, Carbon Cycle and Ecosystems, and Climate Variability and Change. By accurately characterizing the spatial, spectral, and geometric characteristics of different global biomes (e.g., tundra, boreal forests, savanna, mangroves and adjacent wetland ecosystems) CARMA will enable very accurate models of land surface and ecological variables and provide the basis for new theoretical predictions of the physical properties of key terrestrial ecosystems of global importance; few of which have been previously characterized in such detail. CARMA will also provide new insights vis-à-vis the accuracy and interconsistency of different satellite retrieval algorithms applied to measurements acquired from NASA-supported sensors (e.g., MODIS, MISR, Landsat, and VIIRS).

The proposed research works towards the goals of the Global Climate Observing System (GGOS). To support measurements of terrestrial essential climate variables, GGOS has articulated a goal of 5% for the overall accuracy and stability of global surface albedo and reflectance anisotropy products [Schaaf et al., 2009]. This research contributes to enhanced GCOS accuracy and stability in two ways: 1) by providing an independent (SI-traceable) benchmark against which to validate multiple datasets and products, and, 2) by
fulfilling NASA’s international commitments, through the CEOS-Working Group on Calibration/Validation, for a globally-representative suite of reference land surface directional spectral reflectance measurements.

Daniel Steinhoff/University Corporation For Atmospheric Research (UCAR)

Global Modeling of the Climatic Suitability of Artificial Water Containers for Breeding the Dengue Vector Mosquito Aedes Aegypti Using Remotely Sensed Data for Present Day and Climate Change Applications

Dengue is the most common and important vector-borne virus in the world, being endemic to most countries in tropical and near subtropical regions. The primary dengue vector mosquito Aedes aegypti is considered an urban mosquito, exploiting artificial water containers for its immature life stages and spending its entire life cycle near human activity. Aedes aegypti is sensitive to water conditions - availability, thermal properties, and nutrition content - for immature development and survival. Direct mosquito surveys are labor intensive and necessarily limited in scope. For this reason, mosquito population estimates and dengue risk are often modeled through either statistical methods or with Dynamic Life Cycle (DLC) models. The dynamic life cycle models can be applied more confidently than regression-based models outside of the development area and are better able to simulate seasonality of population dynamics. However, a key weakness of DLC models is their use of simple regression-based estimates of water temperature and water height in containers based on atmospheric conditions. Recently, energy balance models have been developed to estimate water temperature and availability in a more physically relevant manner than the regression equations. We plan generate and apply a globally-applicable framework for assessing habitat suitability for the dengue vector mosquito Aedes aegypti by adapting a container energy balance model developed by the proposer to use atmospheric and ground data from NASA satellite and Earth science products as input. The resulting Aedes aegypti habitat suitability maps will have the advantage over previous efforts of having water temperature - the most important factor towards mosquito development and survival - simulated in a physically relevant manner. The number of mosquitos produced by a given container (e.g., productivity) for different types of containers (size, color, material, shading) will be assessed by geographic location, providing a determination of container productivity and how mosquito control efforts should be best directed.

To extend the capacity of the container modeling, the NASA/container energy balance model framework will be coupled with a dynamic life cycle mosquito population model to provide more realistic simulation of Aedes aegypti population dynamics. We will focus the coupled model simulations on several locations in North America and the Caribbean, where we have access to several observational surveillance datasets of detailed container distributions and pupal surveys. This will provide high quality estimates of the seasonality and interannual variability of Aedes aegypti population dynamics in regions where Aedes aegypti has emerged or reemerged in recent decades, including in the United States in southern Florida and along the U.S./Mexico border.
Finally, the response and sensitivity of habitat suitability and population dynamics to future climate scenarios will also be addressed by downscaling output from a NASA global climate model for use in the container and mosquito models. Changes to population dynamics in currently endemic areas and the expansion/contraction of habitat suitability will be assessed. The final products from this proposed work - habitat suitability maps and the seasonality and interannual variability of Aedes aegypti population dynamics in areas of North America and the Caribbean for both present day and future climate scenarios - will be provided to NASA/USAID SERVIR for the benefit of developing nations.

Mark Zelinka/Lawrence Livermore National Laboratory
Interactions Among Clouds, Radiation, and Circulation at Midlatitudes

Midlatitude clouds are a particularly important and unique component of the climate system. They are intimately coupled to the circulation associated with extratropical cyclones, which are fueled by baroclinicity (a measure of horizontal temperature gradient). Baroclinicity, in turn, is affected by the radiative perturbations caused by clouds. Despite the importance of baroclinicity in determining the location and strength of the midlatitude jet and its attendant storm track, most large-scale dynamics research focuses on dry dynamics, taking baroclinicity as something of an external parameter. Thus there is a need to understand how clouds in the vicinity of the jet impact radiation and therefore baroclinicity. Most observational studies of midlatitude clouds, however, have performed cyclone compositing. While this has been useful for understanding the structure of clouds with respect to cyclones, there remains a need to understand how clouds and their radiative impacts are related to the jet, and possibly feed back on it. Since midlatitude clouds cause a substantial radiative cooling of the planet, cloud anomalies associated with jet shifts can cause large radiative anomalies. However, the extent to which these feed back on the planet's energy budget and on the circulation shifts themselves is uncertain, and what little is known comes primarily from modeling studies. Thus, there is a need for an observational quantification of the radiative impact of changes in dynamics, and the possible feedbacks that emerge from this.

To address these needs, we propose to investigate the coupling among midlatitude clouds, radiation, baroclinicity, and circulation with state-of-the-art NASA products. We will create detailed composites of satellite-observed cloud properties as a function of latitude and height, centered on the mid-latitude jet. We will also compute jet-centric composites of clear- and all-sky radiative fluxes at the surface, top of atmosphere, and throughout the column. These will be used to quantify the role of clouds in altering radiative heating and their implications for baroclinicity. We will also assess the sensitivity of the cloud and radiation composites to jet strength and latitude. Finally, we will assess how realistically global climate models capture the observed composite cloud and radiation structures, and whether the modeled cloud-radiation-dynamics interactions behave similarly between climate variability and climate change.
Our collaboration bridges the large-scale dynamics and cloud-radiation communities, utilizes people with strengths in working with both observations and models, and capitalizes on the unique infrastructure and analysis tools at LLNL. The research will result in greater understanding of midlatitude clouds and their relationship with large-scale dynamics, quantification of the radiative impacts of clouds and their possible role in feeding back on jet shifts, and novel benchmarks for comparison with models. These fit well with the focus of NASA's Earth Science Research (ESR) Program in using "space-based measurements to provide information not available by other means, resulting in an increase in basic process knowledge" and with the objectives of the Water and Energy Cycle ESR Science Focus Area, in which "high priority is placed on understanding, observing, and modeling clouds and their interaction with energy fluxes."

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**Zhibo Zhang/University of Maryland at Baltimore County**

**Quantification of Shortwave Direct Radiative Effects of Above-Cloud Aerosols Over Global Oceans Using Multiple Satellite Data Sets**

When aerosols reside above clouds, their shortwave direct radiative effect (DRE) can be substantially different from that under clear-sky conditions. In particular, cloud reflection enhances aerosol absorption, leading to strong warming effect at the top of the atmosphere (TOA). The potential climatic implications of this coupled behavior make it both important and timely to develop a quantitative understanding of the DRE of above-cloud aerosols (ACA) on a global scale. Recent advances in satellite remote sensing have provided unprecedented and ripe opportunity for studying the ACA. Here, we propose to quantify the DRE of ACA over global oceans using satellite data sets from CALIOP, MODIS and ISCCP. Specifically, we will carry out the following research activities:

1. Continue to improve a newly developed method that utilizes a DRE look-up-table and joint histogram of cloud optical thickness vs. cloud top pressure for ACA-cloud collocation and DRE computation.
2. Derive instantaneous TOA, surface and atmospheric DREs of ACA over global oceans using multiple years of collocated daily CALIOP ACA observations and Aqua MODIS level-3 cloud product. Study the spatial and inter-annual variability of ACA DRE and their relations to aerosol and cloud properties.
3. Investigate the impact of sub-grid cloud and aerosol variability on estimating the climatological gridded mean ACA DRE.
4. Investigate the diurnal variation of ACA DREs due to the cloud diurnal cycle using CALIOP ACA observation collocated with Terra/Aqua MODIS and ISCCP 3-hourly D1 data.
5. Investigate various sources of uncertainties in ACA DRE computation.

This proposal responds to NASA's strategic goal to "advance Earth System Science to meet the challenges of climate and environmental change" by specifically addressing the climatic effects of ACA. The work proposed here will help advance our understanding of ACA's role in Earth's "Water and Energy Cycle" and "promote and increase the use of space based remote sensing."
Accurate quantification of carbon (C) cycling in the Earth system is crucial for the effective development of science-based decision tools and management strategies aimed at combating climate change. Current estimates of global CO2 fluxes consistently infer a missing terrestrial C sink that is comparable in magnitude to other major components of the global C budget (e.g. net ocean uptake). A possible mechanism contributing to this missing sink is the soil erosion / deposition process, which may induce a global C sink of ~0.12-1.5 PgC yr-1. Given the magnitude and the degree of uncertainty associated with the erosion-induced C sink, there is an urgent need to elucidate its causes and mechanisms in order to avoid unexpected consequences when developing and deploying C management strategies and policies. However, the C dynamics along terrestrial-aquatic interfaces, regulated by both biotic and abiotic processes across various temporal and spatial scales, remains poorly characterized. Therefore, the goal of this research is to develop a coupled regional watershed modeling system that integrates the best-available NASA satellite observations to improve our mechanistic understanding of particulate organic carbon (POC) cycling along terrestrial and aquatic interfaces.

To achieve this goal, we will [1] incorporate components from several public domain water quality models into the Soil and Water Assessment Tool (SWAT) to improve its representation of POC cycling in aquatic ecosystems (eSWAT); [2] extensively use NASA remote sensing products and other sources of observational data to drive, parameterize, and constrain the eSWAT model for hydrological and biogeochemical modeling along the terrestrial-aquatic interfaces in the Mississippi River Basin; and [3] conduct a suite of numerical experiments to address several compelling scientific questions: (a) what are the magnitude and spatial distribution of soil organic carbon (SOC) loss and associated implications for terrestrial C cycling? (b) what are the rate and spatial pattern of POC transport and burial in aquatic ecosystems? and (c) how can future climate change and human activities influence C stocks and fluxes along the coupled terrestrial-aquatic continuum?

The outcome of this research will directly contribute to the NASA's objective to quantify, understand, and predict changes in Earth's ecosystems and biogeochemical cycles. The proposed research also addresses the overarching scientific questions outlined in A U.S. Carbon Cycle Science Plan: how do natural processes and human actions affect C cycle on land and how are ecosystems and natural sources impacted by changes in climate and C management decisions? The proposed eSWAT model that couples ecosystem processes along terrestrial and aquatic interfaces will represent a significant advance to the existing assessments of the impacts of climate change and human actions on C cycling at the watershed scales, thereby providing more credible assessment of unintended consequences and related uncertainties of management strategies and decisions under changing climates.
The open-source eSWAT model developed here is built on public domain models and will be shared with the public through the SWAT website. The methods developed here on how to integrate NASA remote sensing data into eSWAT will be shared, facilitating sustained use of NASA remote sensing data to support societal benefits.