HyspIRI Preparatory Airborne Activities and Associated Science and Applications Research

Abstracts of selected proposals

(NNH11ZDA001N - HYSPIRI)

The National Aeronautics and Space Administration (NASA) Earth Science Division within the Science Mission Directorate solicited proposals using airborne measurements resulting from planned airborne campaigns in FY2013 and FY2014. For these campaigns, NASA plans to fly the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER) instruments on a NASA high-altitude aircraft to collect precursor datasets in advance of the Hyperspectral Infrared Imager (HyspIRI) mission. NASA solicited proposals that would use these airborne data to address one, or more, science or applications research topic aligned with the science questions for the HyspIRI Mission. A goal of this solicitation was to generate important science and applications research results that are uniquely enabled by HyspIRI-like data, taking advantage of the contiguous spectroscopic measurements of the AVIRIS, the full suite of MASTER TIR bands, or combinations of measurements from both instruments.

NASA received a total of 49 proposals and has selected 14 for funding at this time. The total funding to be provided for these investigations is approximately $6.3 million over three years.

The investigations selected are listed below. The Principal Investigator, institution, investigation title and abstract are provided. Co-investigators are not listed here.

Wendy Calvin/University of Nevada - Reno
Energy and Mineral Resources: Surface Composition Mapping that Identifies Resources and the Changes and Impacts Associated with Their Development

Threats to the availability of strategic mineral resources from foreign countries and the need for new resources linked to the renewable energy economy (e.g. battery technologies) has lead to current focus on identification and understanding of geotectonic controls on strategic or critical mineral-bearing deposits and their host rocks. Our reliance on fossil fuels has led to their consumption at unprecedented rates that has depleted the most accessible and largest of these deposits. Future resource development, coupled with a national push toward energy independence, will encourage the development of renewable energy resources (solar, wind and geothermal), exploitation of abundant domestic fossil fuel resources (coal and natural gas), and production of minerals needed for energy efficient technologies. Extraction of natural gas at large scales has already altered the landscape of the Western U.S., and the development of utility-scale solar and wind farms has the potential to do the same. The Deep Water Horizon oil spill catastrophe highlights potential risks associated with extraction of petroleum resources in more difficult and inaccessible locations. It is essential to encourage intelligent exploitation of our domestic natural resources while cautiously avoiding unnecessary landscape alteration, contamination, and environment disruption.

The proposed research addresses these issues with modern energy and mineral resources through specific sites and selected studies to 1) identify new systems linked to critical or strategic minerals, 2) identify high priority sites for geothermal energy development, 3) assess the land surface changes associated with large scale energy development (solar, wind, or natural gas), and 4) map and monitor the impacts associated with energy and mineral resource extraction. These tasks will be accomplished through surface compositional mapping in both the VNIR/SWIR and TIR, following on our past work with the AVIRIS, HyMAP, MASTER and SEBASS sensors. Proposed sites are within the broad flight corridors identified in the proposal call. We also propose potential additional sites that are nearby and could readily be included are also discussed. This research addresses fundamental HyspIRI questions on land surface composition and change (CQ5, TQ5, VQ6), and will provide an assessment of how a satellite system can address these issues in a global context.

Matthew Clark/Sonoma State University
Spectral and Temporal Discrimination of Vegetation Cover Across California with Simulated HyspIRI Imagery

Land cover is an essential global climate variable and important for understanding coupled natural and socio-economic processes at work on a landscape. The science, policy, management, conservation, and development communities need recent land-cover information, with sufficient class detail, accuracy and wall-to-wall spatial coverage to analyze the multiple drivers of change that operate at different spatial and temporal scales. However, there is a surprising lack of land-cover data that meet these requirements at regional to global scales, partially due to our reliance on low- to medium-resolution multispectral satellites for mapping.

With its high spectral resolution, moderate pixel size, and multiple acquisitions within a year, the planned HyspIRI satellite will offer an unprecedented image stream at global scales. Studies with field spectrometers and imaging spectrometers have demonstrated how vegetation chemical-structural effects on hyperspectral properties can be used to discriminate land cover at leaf, crown and broader scales of floristic organization. The seasonal chemical-structural changes in vegetation types due to phenology, such as leaf flush, expansion and senescence, can have profound effects on spectral variation but have not been deeply explored in hyperspectral studies. In our proposed research, we ask two fundamental science-based questions: 1) Can simulated HyspIRI imagery and associated hyperspectral processing techniques produce better maps of natural vegetation than possible with imagery from a traditional, multispectral sensor? 2) How does seasonal spectral variation in natural vegetation types relate to underlying abiotic and phenological factors, and can this variation be harnessed to aid vegetation discrimination?

This project is based in California, a global biodiversity hotspot. It uses simulated HyspIRI and Landsat imagery derived from AVIRIS images covering three broad transects, with three seasons of imagery per year, over two years. We investigate spectral-based discrimination of natural vegetation at two levels of floristic organization, following the National Vegetation Classification scheme: formations at a broad scale covering all AVIRIS collections and finer-scale alliances in two core research sites. Reference data are collected by photo-interpretation of formation-level samples within an automated web-based tool and by sampling of alliances in the field. We use simulated HyspIRI imagery to generate a suite of hyperspectral metrics related to vegetation chemical absorptions, structure and physiology from the visible to shortwave infrared parts of the spectrum. Techniques include narrowband indices, absorption-feature fitting, derivative analysis and multiple-endmember spectral mixture analysis (MESMA). The Random Forests and MESMA classifiers are compared for mapping natural vegetation using seasonal and between-year HyspIRI data. We also explore spectral-temporal variation within and among natural vegetation classes and its relationship to underlying environmental and phenological factors.

Our project provides a quantitative assessment of the potential of HyspIRI for mapping natural vegetation at levels of floristic organization needed by regional- to global-scale applications. As a cost-benefit analysis, we compare HyspIRI and Landsat map class and spatial detail, accuracy and temporal stability. Our proposed activities, questions and results will develop the foundation upon which we can ask broader HyspIRI Mission science questions, such as those related to the pattern, spatial distribution and seasonal activity of global biomes and their ecosystems. The project also has implications for assessing how spaceborne hyperspectral sensors can improve land-cover data needed by land-change science and national and international policies related to climate change.

Bo-Cai Gao/Naval Research Laboratory

Characterization and Atmospheric Corrections to the AVIRIS-Classic and AVIRISng Data to Support the HyspIRI Preparatory Airborne Activities

In response to the NASA research announcement - A.26 HyspIRI Preparatory Airborne Activities and Associated Science and Applications Research, we propose to further develop and enhance atmospheric correction and spectrum-matching techniques for the characterization and analysis of hyperspectral imaging data to be acquired with the present AVIRIS instrument (referred as AVIRIS-Classic) and the next generation AVIRIS (referred as AVIRISng) operating in the solar spectral region between approximately 0.35 and 2.5 micron. The atmosphere-corrected hyperspectral imaging data will be most useful for research and a variety of applications, and to answer many key science questions originally identified in the National Research Council Decadal Survey and refined recently by the HyspIRI Science Study Groups and research community. These questions include, but not limited to: What is the composition, function, and health of land and water ecosystems? How are these ecosystems being altered by human activities and natural causes? How do these changes affect fundamental ecosystem processes upon which life on Earth depends?

The solar radiation on the sun-surface-sensor path is affected by absorption and scattering effects from atmospheric gases and aerosols. Accurate modeling of these effects is required in order to derive surface reflectance spectra from imaging spectrometer data. Previously, we developed radiative transfer modeling algorithms for atmospheric corrections over land and water surfaces. We propose to use these algorithms to derive the surface reflectance spectra from AVIRIS-Classic and AVIRISng data to be acquired through the HyspIRI preparatory Airborne Activities in the near future. The retrieved reflectance spectra using these algorithms can still contain residual atmospheric absorption and scattering effects. We plan to use field-measured surface reflectance spectra, such as those collected over a large playa during a calibration experiment, to renormalize the retrieved reflectance spectra and to remove the residual errors.

Since the early 1990s, accurate radiometric calibrations of any imaging spectrometer data below 0.45 micron have remained to be a problem using NIST-traceable calibration lamps. Because the lamps operate at a temperature of approximately 2000 K, they do not emit sufficient amount of photons in the blue to permit accurate radiometric calibrations in the blue spectral region. We propose to derive additional gain curves for AVIRIS-Classic and AVIRISng bands below 0.45 micron based on modeling the spectrally flat reflectance spectra of white clouds in the 0.35 - 0.9 micron wavelength range. This empirical technique has recently been used successfully in radiometric calibration of hyperspectral imaging data collected with HICO (Hyperspectral Imaging for the Coastal Ocean) onboard the International Space Station.

AVIRISng is equipped with arrays of area detectors. Small artifacts, such as spectral smile in the spectral domain, will likely be present in the measured data. We propose to upgrade our present versions of spectrum-matching algorithms for wavelength and spectral resolution calibrations. We will apply the updated algorithms to characterize and verify the wavelength and spectral resolution calibrations of AVIRIS and AVIRISng data for every pixel in the cross track direction, and to monitor the stability of the instruments with time.

Bernard Hubbard/U. S. Geological Survey
Using Simulated HySpiri Data for Soil Mineral Mapping, Relative Dating and Flood Hazard Assessment of Alluvial Fans in the Salton Sea Basin, Southern California

The Salton Sea basin of Southern California is located within a tectonically active basin between the San Andreas, San Jacinto and Imperial Fault zones. It is flanked by alluvial fans derived from the Santa Rosa and San Jacinto Mountains to the west and the Little San Bernandino and Chocolate Mountains to the east. The basin also contains the economically important Imperial and Coachella valleys, which produces more than 75% of the irrigated winter vegetable crops consumed in the U.S. Also, a number of popular resort towns such as Palm Springs, Palm Desert and Borrego Springs, are situated near active alluvial washes.

Precipitation patterns in this part of the Sonoran Desert are influenced by the longer term (~20 30 years) Pacific Decadal Oscillation (PDO) and the shorter term (< 5 years) El Niño Southern Oscillation (ENSO); the latter of which produces above average precipitation during strong El Niño years, while drought and wildfires are most common during the strongest La Niña years. Population and economic growth in the last few decades has lead to an expansion of agricultural and urban land-use patterns upstream into active and inactive parts of alluvial fans. Recently active distributary channels of alluvial fans are the focus of catastrophic flooding, erosion, hyper-concentrated and/or debris flow hazards. Modeled climate projections by the U.S. Global Change Research Program, suggest that future droughts and wildfires in the southwest will become more severe as a result of reduced spring snowpack and soil moisture in the mountains. Conversely, flood frequency and erosion along alluvial washes will increase as more winter precipitation falls as rain rather than snow, while increased sea surface temperatures will lead to enhanced tropical cyclone activity and more frequent summer monsoonal convective thunderstorms. Also, alluvial fans are modified with time by differential erosion (both fluvial and aeolian), weathering, soil formation, scrub vegetation growth, desert varnish coating, caliche deposition and desert pavement formation processes. Variable textural surfaces such as montmorillonite-rich crusts and quartz rich sands affect overland flow rates differently during storms. Therefore, this exemplifies the need for distinguishing recently flooded areas from those that have not been inundated in hundreds or thousands of years.

We propose to evaluate the utility of HyspIRI data simulated from planned higher resolution AVIRIS and MASTER datasets for mapping mineralogical and textural differences between alluvial fan surfaces of various ages using a combination of both VSWIR and TIR data. For example, HyspIRI VSWIR data can be used to distinguish impermeable clay minerals, such as montmorillonite (common in arid soils), from hydrothermally formed clay minerals, such as kaolinite (associated with upstream mineral deposits) and illite (associated with nearby mud volcanoes and geothermal areas). For recent alluvial fans derived from lithologically diverse bedrock source areas, we plan to test the utility of simulated HyspIRI TIR multispectral data (i.e., 7 bands planned between 7.5 and 12 microns, excluding the one band planned at 4 microns) for measuring and unmixing of silicic, mafic and carbonate sediments, which (along with vegetation growth and related soil moisture characteristics) can be used as a basis for change detection after high precipitation storm events.

Finally, our research will address several HyspIRI Science Group questions, such as: (TQ5) What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability? (CQ5) What is the composition of the exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non-anthropogenic drivers? (VQ6) What are the land surface soil/rock, snow/ice and shallow-water benthic compositions?

George Jenerette/University of California Riverside

Assessing Relationships Between Urban Land Cover, Surface Temperature, and Transpiration Along a Coastal to Desert Climate Gradient

We propose to use the HyspIRI preparatory airborne data collection over the Los Angeles, CA metropolitan region (Los Angeles) to better identify interacting relationships between climate, land cover, surface energy balance variables including temperature and evaporation, and demographic patterns across the dramatic coastal to desert climate gradient. Key components of this proposal are the (1) extensive in-situ measurements planned in connection with the airborne campaigns, (2) application of data-model assimilation tools to couple diverse measurements with process models, and

(3) evaluation of societal correlates with energy balance patterns with direct influence on urban sustainability. Our project will address fundamental science and broad societal challenges associated with the coupling between urban heat islands and rates of evaporation. We will provide detailed understanding of urban surface temperature regulation, interactions of surface temperatures with evapotranspiration, and relationships between these energy balance components and neighborhood socioeconomic condition across the strong climate gradient within this region. We will evaluate the relative importance of land cover, meteorology, irrigation, and adjacent landscape patterns on the regulation of land surface temperature and evaporation across throughout the coastal to desert climate gradient using a combination of HyspIRI preparatory airborne data and in-situ measurements. We will quantify how land surface relationships essential to improving the sustainability of dryland cities, notably surface temperature and ET, interact with socio-economic neighborhood segregation.

In answering the research questions, the project objectives are: (1) Process imagery data to generate LST, emissivity, and land cover patterns at sub-regional and regional scales. (2) Conduct in-situ measurements of and energy balance of net radiation, sensible heat, and latent heat (evaporation) and high resolution surface temperature dynamics. (3) Use data-model assimilation approaches to couple surface temperature, meteorology, and land cover patterns with airborne and in-situ data for parameterization of models to scale surface temperature and evapotranspiration rates from diel to annual scales. (4) Identify spatio-temporal variation in correlates between neighborhood land surface temperature for the 2013-2014 airborne campaigns and conduct scenarios of neighborhood suface temperature and evapotranspiration responses to potential climate, vegetation, and irrigation changes. By meeting these objectives we will answer our research questions, evaluate the contribution of multiple hypothesized sources of urban heat island and evapotranspiration regulation, and extended the biophysical findings to better understand potential societal consequences of current and alternative future conditions. This work will provide a strong case-study of HyspIRI-like data to better understand land surface processes within cities.

The project targets the combined need for VSWIR and TIR data, as we will use the VSWIR data to develop a land cover classification and vegetation indices and TIR to evaluate surface emissivity and temperature. A major justification for TIR data from HyspIRI is for improved understanding of UHI dynamics and our project directly addresses questions directed toward this goal. A second justification is for improved estimates of total evaporation and our project will provide field estimates of ET in conjunction with airborne data collection in the urban ecosystem.

Thomas Kampe/National Ecological Observatory Network Incorporation
Synergistic High-Resolution Airborne Measurements of Ecosystem Structure and Process at NEON Sites in California

The National Ecological Observatory Network (NEON) aims to conduct overflights of its sites within the NEON Pacific Southwest domain with the first Airborne Observatory Platform (AOP) at the same time as the planned Airborne Visible/Infrared Imaging

Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER) flights onboard the NASA ER-2 aircraft. The NEON sites fall within one of the wide area transects being planned as part of the HyspIRI Preparatory Airborne Activities and Associated Science and Application Research program. NEON will fly a high fidelity VSWIR imaging spectrometer identical to AVIRIS-ng, a high-resolution digital camera, and a waveform LiDAR to collect information on ecosystem chemistry and structure at high spatial resolution (~1 m) over areas of approximately 300 sq. km around the NEON sites. These synergistic flights will provide a multi-scale data set for a range of terrestrial ecosystems well suited for the development and evaluation of science data products under development by HyspIRI science investigators. In parallel, these data sets will prove useful for developing the NEON strategy for the spatial scaling of structural ecosystem data and their processes (either implied by foliar chemistry or implicit through direct flux measurements). Data will be collected from the organismal scale of individual trees/plants, to flux scales, to the scale of hundreds of kilometers and to the continental scale which necessitates the use of satellite remote sensing. All data acquired by NEON, including in-situ spectral measurements of vegetation species at the NEON sites, will be made available to HyspIRI investigators via the NEON web portal. More information on the NEON project is available at www.neoninc.org.

Raphael Kudela/University of California Santa Cruz

Using HyspIRI at the Land/Sea Interface to Identify Phytoplankton Functional Types

There are many properties of biological interest in the coastal ocean, e.g., river plumes, kelp beds, and phytoplankton including harmful algal blooms (HABs), and similar targets at the land/sea interface (e.g. estuaries, coastal lakes). These properties are associated with salinity, temperature and radiation gradients but are spatially aliased with conventional 1 km resolution data. With funding from past NASA projects we have demonstrated that hyperspectral airborne data can be inverted to identify phytoplankton functional types, including discriminating between dinoflagellates and diatoms, a distinction that has been difficult to make using past algorithms and data sets. HyspIRI has the potential to greatly improve our understanding of ecological processes at the land-sea interface due to both improved spatial and spectral resolution. We propose to directly assess whether it can provide adequate signal in these complex systems to address questions of algal bloom dynamics, water quality, and transient responses to (e.g.) human disturbance, river runoff, and red tides.

Our objective is to directly test the capabilities of HyspIRI (using AVIRIS or similar) by providing an end-to-end assessment of image acquisition, atmospheric correction, algorithm application, and ground truthing. This will build on ~5 years of airborne campaigns in the Monterey Bay region as part of the NOAA COAST program, NASA COAST-HOPE, and NASA SARP. We will also build on preliminary data collections (COAST-HOPE and SARP) that demonstrated our ability to detect and quantify cyanoHAB events in coastal lakes. Finally, we propose to make the data collected available to partners working on the South Bay Salt Pond Restoration Projects so they can evaluate the utility of HyspIRI for monitoring benthic algal mats and habitat restoration in the greater San Francisco Bay area.

Monterey Bay is well characterized oceanographically, provides rich historical and ongoing observations, and has been used in the past for both cal/val and science airborne operations including the October 2011 Coastal and Ocean Airborne Science Testbed (COAST) mission conducted using similar parameters as proposed herein. Based on past experience and typical conditions, we expect that an autumn (October) mission will maximize the likelihood of data collection days, minimize cloud cover, and will provide a range of scientifically interesting features, including tidal exchange with Elkhorn Slough, red tides, fall transition, upwelling versus oceanic conditions, and, potentially, a first flush rain event. This is also the peak cyanoHAB period in local lakes and reservoirs. Complementary data collection in other seasons would provide an opportunity to document diatom-dominated upwelling in the coastal ocean (spring), and low biomass (low signal) conditions in winter.

This proposal directly builds on the expertise and experience of previous NASA airborne remote sensing programs, including the NASA COAST project. The PIs have a strong track record utilizing the MAS, MASTER, and JPL AVIRIS instruments, and UCSC hosted the HES-CW risk reduction activities prior to the cancellation (by NOAA) of the mission. Data processing, QA/QC, and archive/distribution tasks will heavily leverage the existing ASTL infrastructure as well as separate funding through UARC to develop end-to-end data management for remote sensing, providing exceptional capabilities at modest cost. We will leverage this rich historical data set and ongoing field campaigns funded by other agencies to maximize data and science return for the HyspIRI simulations. This includes access to ship time in both Monterey and Southern California funded by an existing NOAA project.

Ira Leifer/University of California, Santa Barbara
Hyperspectral Imaging Spectroscopic Investigation of California Natural and Anthropogenic Fossil Methane Emissions in the Short-Wave and Thermal Infrared

On a 20-year timescale, CH4 has a larger greenhouse effect than CO2 and its decadal lifetime makes it more amenable to regulatory approaches. Yet sources remain poorly quantified. Top-down and bottom-up regional and global CH4 budgets often disagree significantly, eg, Hsu et al (2009) found an ~40% discrepancy for the LA Basin. Much of the discrepancy could relate to fossil CH4 from fugitive industrial (FFI) and geologic sources; a recent LA Basin survey (NOAA) suggests FFI. Some studies suggest recent CH4 stabilization was from global FFI CH4 emission decreases. Recent transcontinental ground CH4 data validated SCIAMACHY & GOSAT data with similar conclusions. Others suggest an ~50% US FFI underestimate. The planned AVIRIS/MASTER flights cover significant FFI industrial activity and geologic CH4 emission sites.

The key study science question is: What are the relative California contributions of fossil geologic and FFI CH4? I.e., addressing the relationship between fossil CH4 emissions and geologic, marine, and atmospheric (eg, inversion layers, buoyant rise) controls.

This primarily is an application study using AVIRIS (eg, HyspIRI VSWIR) and MASTER (eg, HyspIRI TIR) and to a lesser extent a research study. It directly addresses the RFP by: 1) Demonstrating science applications (CH_4 emission) enabled by HyspIRI-like sensors and aids HyspIRI mission design (band selection and binning, algorithms); 2) Providing unprecedented information for resource management to resource managers though merging AVIRIS data with existing data. The study fits HyspIRI mission goals through addressing science definition team questions: cq5 (terrestrial surface composition), tq4 (urbanization and environment), and vq2 (seasonal cycles of terrestrial ecosystem and land disturbance and climate change). Our team comprises scientists and resource managers with specific expertise to assure project success.

We will study factors affecting trace gas (CH_4, CO_2) SWIR retrievals in AVIRIS SWIR data for fossil sources to characterize the effect of albedo, nadir angle, aerosols, water vapor, path radiance, vertical profiles, surface spectral non-uniformity, pixel size, spectral resolution, and spectral spacing. SWIR-derived CH_4 will be compared with MASTER TIR spectral CH_4 anomalies. Retrieval approaches including neighboring pixel normalization, band ratio, residual minimization, and statistical measures, based on radiative transfer calculations for SWIR and TIR absorption features will be investigated. Improved SWIR trace gas retrievals using TIR-derived vertical profiles will be studied. Mobil ground-reference CH_4 measurements including eddy covariance fluxes, and alkane gas chromatography of C2-C8 will provide relevant size scales and natural gas fingerprinting.

We will identify the best remote sensing and in situ plume characterization approaches, relevant CH_4 size scales, and merging of mobile in situ data with airborne and satellite remote sensing to improve flux estimation and source attribution. Regional scaling is by comparison with SCIAMACHY/GOSAT data, and maps of FFI activity and geologic structures.

We leverage planned 2013/2014 CARVE (JPL) FTIR spectrometer, California transit flights and MAKO (Aerospace Corp.) high-spectral resolution TIR airborne flights, and DISCOVER (AQ) airborne data at NO COST to the study. MAKO TIR data will enable allow evaluation of MASTER TIR spectral response characteristics.

The study focuses on the Coal Oil Point (COP) seep field (natural geologic), the Elk Hills and Kern oil fields (anthropogenic), La Brea seepage, and a range of urban cites. Prior SEBASS data from these sites and AVIRIS/MASTER COP data are available, and surface CH_4 data were collected Feb. 2012 for this proposal. Several studies have demonstrated successful AVIRIS COP CH_4 retrieval. La Brea CH_4 emissions were found to dominate other LA Basin sources. Much of this study's basis was accomplished since the 2009 proposal.

Shunlin Liang/University of Maryland
Characterizing Surface Energy Budget of Different Surface Types Under Varying Climatic Conditions from AVIRIS and MASTER Data

The land surface responds to climate variability and also modulates the climate through the exchange of energy, matter and momentum. It is well known that the response and modulation largely depend on land cover and plant functional types and their properties. The synergy of the AVIRIS and MASTER data with high spatial and spectral resolutions provides us an unprecedented data resource to study the spatial variability of the land-atmosphere exchange of water, carbon and energy at the ecosystem scale. Scheduled multiple transects at different seasons outlined in the ROSES2011 call for proposals and the high temporal refreshing frequency of the future HyspIRI data will enable us to study the temporal dynamics of such land-atmosphere exchange.

We propose to use the HyspIRI-like airborne measurements resulting from the planned campaigns in FY2013 and FY2014 to 1) map the following surface radiation and energy budget components from both AVIRIS and MASTER data: insolation/photosynthetically active radiation (PAR), albedo, net radiations, and evapotranspiration (ET); and 2) quantify the changes in the land-cover-dependent surface radiation and energy budget under varying climatic conditions.

We have developed the corresponding algorithms for the multispectral remotely sensed data in the recent years. In this study, these algorithms will be refined and extended to hyperspectral data, and extensively validated using the AVIRIS and MASTER data at many field stations where surface measurements are available. These products will be mainly used for addressing scientific questions in this proposal, but also provided to other investigators for many other applications. They can also be scaled up for validating other coarser resolution radiation energy products.

This is a research proposal responding to A26 calling for proposals that utilize AVIRIS measurements, MASTER measurements, or both to address one or more of the HyspIRI science questions . The scientific question we will try to answer is CQ4 How do species, functional type, and biodiversity composition within ecosystems influence the energy, water and biogeochemical cycles under varying climatic conditions?

All these algorithms developed in this study can be potentially used for generating the operational surface radiation and energy products from the VSWIR and TIR data of the HyspIRI mission in the future. Since the proposed efforts build on our algorithm development from the previous NASA projects, it is a cost-effective strategy for refining the algorithms and generating the needed products for analysis.

Paul Moorcroft/Harvard University

Linking Terrestrial Biosphere Models with Imaging Spectrometry Measurements of Ecosystem Composition, Structure, and Function

The objective of this proposal is to determine how the composition of different terrestrial ecosystems affects their interaction with the energy, water, and biogeochemical cycles of the earth. This will be achieved by linking remotely-sensed imaging spectrometry estimates of above ground ecosystem composition to ED2, a state-of-the-art terrestrial biosphere model. Successful application of these approaches will pave the way for more accurate regional- and global-scale predictions of how the earth system will change in the future one of NASA s key science questions and research objectives.

Dar Roberts/University of California, Santa Barbara
HyspIRI Discrimination of Plant Species and Functional Types Along a Strong Environmental-Temperature Gradient

Imaging spectrometry has a demonstrated capability to discriminate plant species and functional types. However, this capability has been limited in three important ways: 1) Mapping of species and measurement of species-specific properties have been restricted to local scales with relatively uniform environmental conditions; 2) Limited data availability across time has allowed only a few studies to investigate impacts of vegetation phenology on species mapping; and 3) Species and functional type discrimination has largely been restricted to reflected solar radiance, neglecting the potential of emitted radiance in the mid-infrared and thermal infrared portions of the spectrum. In order to evaluate HyspIRI s capability to discriminate plant species and functional types globally, it is first necessary to evaluate how the spectral-biophysical properties of vegetation change both seasonally and along environmental gradients, such as the precipitation and temperature gradients that occur with elevation and distance from large bodies of water.

In this research, we propose to utilize HyspIRI-like data, collected using the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) and MODIS-ASTER Airborne Simulator (MASTER) in FY2013 and 2014 to address seasonal-environmental changes in species-specific properties, focusing on the proposed Santa Barbara - Southern Sierra Nevada transect. This transect provides an elevation gradient of over 2700 m, a factor of four change in annual precipitation, and average air temperature ranging from 17.6C to less than 2C. Specific objectives include:

1) Evaluation of species-level discrimination from the coast to the interior, focusing on broadly distributed species and functional types. Targeted plants include chamise and manzanita, the genus Ceanothus, and needleleaf evergreen trees as examples. Spectral separability will be evaluated using Multiple Endmember Spectral Mixture Analysis (MESMA) and a suite of endmember selection tools, such as Iterative Endmember Selection. We will leverage off of an extensive set of existing training and validation polygons, in addition to collecting new data in the field. Separability will be evaluated across multiple seasons, and potential improvements in classification of dominant species through incorporation of phenological data will be investigated.
2) Evaluation of synergies between Visible-Shortwave Infrared (VSWIR) and Thermal Infrared (TIR) data for improved accuracy in Temperature Emissivity Separation (TES). AVIRIS-derived column water vapor will be used to constrain atmospheric correction required for separating Land Surface Temperature (LST) from emissivity using MASTER TIR data. The large elevation gradient, seasonal variation in precipitable water vapor and the gradient from the coast to interior provides an ideal test-bed to evaluate

potential synergies between VSWIR and TIR. LST will be validated using several instrumented sites.
3) Evaluation of the relationship between species composition, cover fraction and LST. Canopy temperature varies considerably depending upon species-specific water use efficiency, fractional cover and water stress. We hypothesize that LST will vary depending upon dominant plant species and available soil moisture.
4) Evaluation of full spectral properties of a subset of species from the VSWIR to TIR including measurements of water content, chlorophyll, nitrogen and lignin-cellulose.

This research specifically addresses two HyspIRI science questions, VQ1 (Pattern and Spatial Distribution of Ecosystems and their Component) and combined question CQ4 (Ecosystem Function and Diversity) with strong linkages to VQ2 (Ecosystem Function, Physiology and Seasonal Activity). To address this research we have assembled a team consisting of experts in VSWIR data including vegetation image spectroscopy and species-level discrimination (Roberts & Dennison) and in TIR data using TES (Hulley).

Philip Townsend/University of Wisconsin-Madison
Measurement of Ecosystem Metabolism Across Climatic and Vegetation Gradients in California for the 2013-2014 NASA AVIRIS/MASTER Airborne Campaign

Using the California transects for the proposed HyspIRI field campaign in 2013-2014, we will comprehensively assess the potential to make spatially explicit estimates of two important parameters characterizing leaf and canopy photosynthetic capacity: the maximum rate of CO2 carboxylation by RuBisCo (Vcmax), and the maximum rate of electron transport required for the regeneration of RuBP needed in Calvin Cycle processes (Jmax). These variables are typically determined using measures of leaf gas exchange, but we have identified an approach to estimate Vcmax and Jmax using spectroscopy (Serbin et al., 2012). It follows that estimation of these variables from remotely sensed hyperspectral+thermal data will facilitate prediction of seasonal canopy assimilation across large areas using similar data from the anticipated HyspIRI mission. Our proposed work relies on the simultaneous acquisition of hyperspectral and thermal infrared imagery, as estimates of canopy temperature will be crucial for an accurate characterization of Vcmax and Jmax . The research will be conducted across two climate-elevation gradients in California, and will span a vegetation gradient from coastal sage and chaparral to oak woodlands and closed-canopy conifer forests. For two years, combined hyperspectral and thermal infrared imagery will be collected at key intervals during the growing season along each climate-elevation gradient. The resulting estimates of Vcmax and Jmax will be evaluated against those derived from eddy flux-based observations of canopy gas exchange, and will be used to generate high-resolution spatio-temporal estimates of gross primary productivity (GPP) that will then be compared to concurrent measures of plot-level productivity. Specifically, we propose to:
1. Calibrate leaf-level values of Vcmax and Jmax, derived from photosynthetic CO2-responses (using the LI-6400 Portable Photosynthesis system) measured across a range of temperatures and vegetation types, to leaf-level spectroscopy using partial least-squares regression.

2. Use the 4SAIL2 radiative transfer model (Verhoef et al., 2007) to scale Vcmax and Jmax to AVIRIS via radiative transfer modeling, using ground-based measurements of canopy structure. MASTER data will be used to retrieve canopy temperature and generate temperature-normalized values of metabolic properties for each canopy (e.g. Vcmax,Jmax at 25 deg C) from the instantaneous values.
3. We will then compare our measurements of Vcmax and Jmax to estimates derived from ten eddy covariance flux towers located within the proposed footprints of the aerial campaign, using a simple ecosystem model and Bayesian parameter estimation.
4. Finally, we will apply a Farquhar-von Caemmerer-Berry (FvCB) photosynthesis model to convert airborne estimates of photosynthetic parameters and associated canopy traits to pixel-level GPP values, and compare those to vegetation productivity measured in a set of plots located near each of the ten flux towers.
If successful, this activity will demonstrate a unique capacity of the proposed HyspIRI mission, which will make comparable measurements to what we are proposing for an airborne system, but at a global scale at a 19-day repeat interval.
This research specifically addresses three HyspIRI science questions: VQ2. Ecosystem Function, Physiology and Seasonal Activity; VQ3. Biogeochemical Cycles; and especially CQ4. Ecosystem Function and Diversity. Our team includes expertise in imaging spectroscopy (Townsend and Serbin), data assimilation (Serbin and Desai), plant physiology (Kruger), and eddy covariance techniques and modeling (Desai and Goulden).

Susan Ustin/University of California, Davis
Identification of Plant Functional Types By Characterization of Canopy Chemistry Using an Automated Advanced Canopy Radiative Transfer Model

As identified as a national research priority by the NRC Decadal Survey report, key objectives of the HyspIRI mission satellite are to detect and monitor changes in physiological functioning and map changes in species composition. The expanded and related objectives are principally described in HyspIRI science Documents VQ2, VQ3, and CQ4. To address these objectives, we ask the question: to what extent are functional types consistent with biochemical diversity at the canopy scale?

Our main objective is to advance scientific understanding of the relationship between conventional plant functional types (PFT(c)), which are described by growth form and phenology, and physiologically important biochemical components at the canopy scale (Chl a, b, carotenoids, water, nitrogen, carbon); and assess the viability of a PFT definition in terms of remotely sensed canopy biochemistry. We address this objective through three sub-objectives: (1) Identify whether associations of different biochemical compositions match conventional plant functional types and their groups. (2) Evaluate the clustering of remotely sensed biophysical and biochemical properties in relation to PFT(c)s. Does biochemical variability (natural clustering in multivariate spectral space) correspond with PFT distributions? To what extent do PFT differences influence retrieved biochemical concentrations? And (3) Test the potential for complete automation of the radiative transfer model inversion to retrieve canopy chemistry products from HyspIRI spectra.

This study will significantly improve understanding of how biochemical composition varies with physiognomically identified PFTs. Results will lead to better understanding of variables related to physiological functioning for climate and ecosystem models.

Consequently, it will produce data that corresponds more accurately to realized physiological activity, leading to improved monitoring of ecosystem feedbacks to the climate system and reduced uncertainty in predicting future climate conditions.

We will evaluate retrieval of canopy chemistry using an improved version of the radiative transfer PROSPECT-5 leaf optical properties model with the SAIL family of canopy models for the three proposed HyspIRI California transects expected to be collected in different seasons in 2013 and 2014. We will concentrate on retrieval of quantitative estimates of physiologically active canopy chemistry components (chlorophyll a and b, carotenoids, water and ligno-cellulose dry matter) that are relevant for fluxes of carbon and water with the atmosphere. Additionally we will use Partial Least Squares (PLS) method for estimating nitrogen and Gitelson s 3-band method for retrieval of anthocyanin. Leaf reflectance and transmission will be made on leaves for chemical analysis using an ASD integrating sphere or the ASD leaf probe and our Fieldspec-3 spectrometers.

We will concentrate field evaluations at sites with presumed different PFTs, primarily located at flux tower sites or others where information about species composition and physiological activity are independently available and at any additional sites where concurrent HyspIRI related field activities are conducted. Field data will be used to evaluate chemistry retrieval from corresponding AVIRIS and MASTER data. Lab chemistry measured from sites crossed by the HyspIRI flightlines combined with airborne canopy temperatures will be used as independent measures of apparent canopy stress to evaluate detected chemistry.

We will test the potential for complete automation of the radiative transfer processing procedures used to retrieve canopy chemistry products. The automation of these processing procedures are necessary to ensure that canopy chemistry products can be routinely produced and made available to a broad range of HyspIRI end users.

Jan van Aardt/Rochester Institute of Technology

Investigating the Impact of Spatially-Explicit Sub-Pixel Structural Variation on the Assessment of Vegetation Structure from HyspIRI Data

Overview: The estimation of vegetation structural parameters, specifically in forest environments, has evolved from a spectral (multispectral to hyperspectral) to structural (radar to lidar) sensing modality space. All of these remote sensing modalities have their respective advantages and disadvantages. The goal of this proposal therefore is to integrate fine scale airborne and ground-based lidar assessments with the relatively coarse scale, but global coverage, HyspIRI imagery to improve HyspIRI-based vegetation structure and function assessments. We hypothesize that: (1)fine-scale, sub-pixel structural assessments can be used to improve our understanding of HyspIRI-based estimates of leaf area, leaf area index (LAI), and vegetation biomass; (2) from a systems perspective, the spatially explicit sub-pixel structural variations are quantifiable when it comes to their impact on the HyspIRI system s response (point spread function); and (3)an improved understanding of (1) and (2) will lead to proper calibration of HyspIRI-based vegetation structure estimates. Our objectives thus are to (i) assess the structural variability within HyspIRI-scale hyperspectral pixels, (ii) link that variability to structural estimates, derived from HyspIRI, and (iii) improve those estimates via a defined calibration-validation effort.

Brief methods: We propose to achieve these objectives by making use of the FY2013 and FY2014 HyspIRI-like airborne measurements over the National Ecological Observatory Network (NEON) Pacific Southwest domain, coupled to NEON Airborne Observation Platform (AOP) flights with a next-generation AVIRIS and waveform lidar onboard, and ground-based lidar and field sampling. Spatially explicit field structural measurements will be used to assess the vegetation structure models (biomass, LAI, etc.) from the HyspIRI sensor. We propose to also use a simulation-based approach, whereby we will simulate HyspIRI and structural sensing over a virtual forest scene using the MODTRAN-based Digital Imaging and Remote Sensing Image Generation tool (DIRSIG) to address hypothesis (2). The impact of the spatial distribution and variability of structure on HyspIRI parameter estimates will be assessed via correlation, sensitivity, and linear and non-linear modeling methods, e.g., Markov modeling and neural networks.

Significance: While ecosystem composition and to some degree, function , have been addressed by hyperspectral remote sensing with relative efficacy, the structural detail of many vegetation systems still present challenges. Leaf-related structural assessment approaches often saturate at high biomass levels, while it remains difficult to relate volume scattering to sub-canopy structure. This proposal therefore is aimed at an evaluation of the synergies between structure and hyperspectral remote sensing at the HyspIRI resolution/scales, in context of the HyspIRI science questions and structure-function type relationships. Specifically, we aim to address whether or not such a fusion of structural-spectral sensing could be useful in terms of
- HyspIRI cq5: What is the composition of exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non-anthropogenic drivers?
- HyspIRI vq1: What is the global spatial pattern of ecosystem and diversity distributions and how do ecosystems differ in their composition or biodiversity?
The improved LAI, vertically stratified LAI, and functional-type LAI, and its link to biodiversity in terms of "structural biodiversity" (cq 5 and vq1) are of specific interest. Finally, we believe that project outputs will contribute to the NASA Earth Science Research Program focus area of Carbon Cycle and Ecosystems and assessing (i) how these systems are changing, (ii) what causes such change, and (iii) what impact does global environmental change have on system structure.
