NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences – 2013
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The National Aeronautics and Space Administration (NASA) solicited proposals for research investigations to conduct the future work of the NASA Suomi National Polar-orbiting Partnership (NPP) Science Team (ST) and for the establishment of Science Investigator-led Processing Systems (SIPS) to produce the science data products to be developed by the Suomi NPP ST. The past work of the NASA Suomi ST focused primarily on evaluation of the sensor data records (SDRs) and environmental data records (EDRs) produced by the Joint Polar Satellite System (JPSS) Program as to their suitability for Earth system science. These evaluations have been completed, and the future work of the re-competed Suomi NPP ST will focus on developing the refined and/or alternative data products yet needed to ensure high-quality data records for Earth system science and applications that enable continuity with NASA Earth Observing System (EOS) data products.

The Suomi NPP ST has been supported in its work by five Product Evaluation and Analysis Tool Elements (PEATEs) that have provided data product testing environments. As NASA transitions to the production of standard science products from Suomi NPP, the Suomi NPP ST will need full data processing and production facilities to produce the new science products they develop. Therefore, this solicitation also requested proposals for the establishment of SIPS to produce these standard and experimental science data products. In addition, NASA requested proposals to continue applications-relevant Suomi NPP research. Specifically, NASA requested proposals for the following types of activities:

<u>Suomi NPP ST Members to</u>:

- Develop science quality standard data products using Suomi NPP measurements that will enable continuity of key standard Earth system data records from NASA's EOS Terra, Aqua, and/or Aura satellites;
- Develop and demonstrate innovative and practical applications of Suomi NPP measurements;
- Develop other new science data products from Suomi NPP measurements that will meet high-priority Earth science needs (a secondary priority); and
- Lead the Suomi NPP ST and its five Discipline Groups.

<u>Science Investigator-led Processing Systems:</u>

- A NASA Suomi NPP Land SIPS
- A NASA Suomi NPP Ocean SIPS
- A NASA Suomi NPP Atmosphere SIPS
- A NASA Suomi NPP Ozone SIPS
- A NASA Suomi NPP Sounder SIPS

NASA received a total of 119 compliant proposals in response to this NRA and recommended 45 for funding. Of the total, 6 were for SIPS and 5 were selected. The total funding to be provided by NASA for the SIPS is approximately $30 million over four years and 4 months. The other 113 proposals were for ST member research, and 40 were selected. Five Discipline Leads were selected, but not a Team Leader. The total funding to be provided by NASA for the ST member investigations is approximately $29 million over three years. The investigations recommended by NASA are listed below. The Principal Investigator, institution, investigation title, and a project summary are provided. The selected Discipline Leads are identified following the institution name below.

Science Investigator-led Processing Systems:

Gene Feldman/Goddard Space Flight Center
Ocean Biology Processing Group (OBPG) Proposal for the
NASA Suomi NPP Ocean Science Investigat-Led Processing System (SIPS)

This proposal will seek the selection of the Ocean Biology Processing Group (OBPG) at NASA Goddard Space Flight Center (GSFC) to develop and operate the Suomi NPP Ocean Science Investigator-led Processing System (SIPS). We will demonstrate our outstanding capabilities for algorithm integration, software development and testing, product quality assessment, and data system operation, including data production, transfer, reprocessing and near-real-time products. Our technical and management approach will be based on over three decades of highly successful support for past and current NASA missions and international programs. The proposing team are all members of the OBPG, which is currently responsible for production, archiving and distribution of ocean data products from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate-resolution Imaging Spectroradiometer (MODIS) on both the Aqua and Terra Spacecraft,, the Ocean Salinity Products from Aquarius/SAC-D and several other past and current satellite sensors.

The core activities to be performed under the proposed effort will be supported on the existing Ocean Data Processing System (ODPS). The ODPS was originally developed for SeaWiFS, and has since been expanded and augmented to support numerous ocean remote sensing satellite projects including MODIS on the Terra and Aqua satellites beginning in 2004. It is currently supporting the Visible and Infrared Imaging Radiometer Suite (VIIRS) as the Suomi NPP Ocean Product Evaluation and Analysis Tool Element (PEATE). The ODPS provides fully automated capabilities for: data acquisition and ingest, including both satellite sensor and ancillary data; processing of sensor data from Level 0 to generate Level 1, Level 2 and global Level 3 data products; cataloging and management of all acquired and processed data; substantial reprocessing capacity; and browse, order and distribution of data products. The Level 2 and Level 3 processing is performed using science algorithms and software provided by Ocean Team science investigators, including current members of the Suomi NPP Science Teams.

Our proposed approach for the Suomi NPP Ocean SIPS will build upon the capabilities and design philosophies of the OBPG and the ODPS as they have evolved to support SeaWiFS, MODIS, VIIRS and many other sensors. This evolution has been facilitated by three characteristics of our team and system: 1) the organizational and physical co-location of science software and algorithm development and data processing system development and operation; 2) the decoupled nature of the overall ODPS design, which allows both ongoing development of data processing system components and rapid integration of new and modified science software without disruption of ongoing data processing operations; and 3) the distributed system hardware architecture, which has facilitated regular expansion and technology refresh of system processing, storage and network capacity to keep pace with the continually increasing requirements of the NASA ocean satellite programs. Our philosophy has always been and will always be that is that the science drives the system rather than the system driving the science.

Steven Friedman/Jet Propulsion Laboratory
Development, Operation and Management of the Sounder SIPS for Processing Suomi NPP Sounder Data

We will develop, deliver and operate the Sounder Science Investigator Led Processing System (SIPS), an advanced and mature system for integrating scientific software and processing Suomi NPP (SNPP) sounder data. Based on a heritage spanning nearly fourteen years of developing systems for processing NASA A-Train and SNPP sounder data, the Sounder SIPS team includes experienced system engineers, algorithm developers, scientists, and operations personnel capable of delivering the software and technical infrastructure for operational processing of SNPP sounder data products from both the Advanced Technology Microwave Sounder (ATMS) and the Cross-Track Infrared Sounder (CrIS) instruments. The Sounder SIPS team will work hand-in-hand with the Sounder Science team to develop and refine science software to produce Levels 1, 2 and 3 products from ATMS and CrIS instrument data. The Sounder SIPS will be a complete system capable of supporting both routine processing of SNPP sounder data and the Science Team in science algorithm refinement, verification and validation.

The Jet Propulsion Laboratory (JPL) will team with the Goddard Earth Sciences Data and Information Services Center (GES DISC) to build and operate the Sounder SIPS, building upon our joint-expertise and our excellent working relationship that we have established during implementation of the AIRS Project. Our roles for the development and operation of the Sounder SIPS will extend this synergy to SNPP. JPL will provide overall project management, science software development, test and validation support. The GES DISC will perform all data processing activities for the Sounder SIPS, producing Levels 1, 2 and 3 products.

The Sounder SIPS will leverage expertise gained while developing the Sounder Product Evaluation and Analysis Tool Element (PEATE) and in managing the Atmospheric Infrared Sounder (AIRS) Project at JPL. The Sounder PEATE, which began in 2007 to support the Sounder Science Team in evaluating SNPP data, has developed many products and tools to facilitate the Science Team's analysis of how well SNPP data meets

NASA science needs. Additionally, the Sounder PEATE has tested many algorithms for the Science Team, and they have started to make experimental products available to the public via a working arrangement with the GES DISC. In addition to experience gained by working with SNPP data through the Sounder PEATE, the Sounder SIPS will benefit from its physical colocation and shared staffing with the AIRS Project. The AIRS Project has extensive experience collaborating with a science team to produce initial product releases followed by planned product revision cycles. Four revision cycles have been completed to date, demonstrating the end-to-end synthesis of concept-to-products. Each build involved integration of code from multiple AIRS Science Team members, development of production code, data product verification and validation, documentation and delivery of code and documentation to a NASA DAAC. The expertise we have gained through our PEATE and AIRS experience will enable us to develop a highly efficient and successful Sounder SIPS.

Liam Gumley/University of Wisconsin-Madison
Suomi NPP Atmosphere Science Investigator-Led Processing System (SIPS)

In this proposal the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison offers to become the Atmosphere Science Investigator-Led Processing System (SIPS) for Earth System Data Records from the NASA Suomi National Polar-Orbiting Partnership (SNPP). The Atmosphere SIPS will be responsible for processing and reprocessing SNPP VIIRS aerosol and cloud products, providing assessment capabilities for these products, assisting the SNPP Science Team in developing and testing the product generation software, and delivering the products, software, browse imagery, and associated ancillary data and metadata to NASA for distribution. This project will leverage and extend the resources and capabilities of the NASA SNPP Atmosphere Product Evaluation and Analysis Tool Elements (PEATE) project in operation at SSEC since 2007. The Atmosphere PEATE has provided vital support to the SNPP Science Team VIIRS aerosol and cloud investigators, and transitioning to an Atmosphere SIPS at SSEC will provide the new SNPP Science Team with the best environment for developing, evaluating, and producing high quality calibrated sensor observations and derived aerosol and cloud products for NASA and the research community. SSEC offers a unique combination of atmospheric science expertise in algorithm development and product calibration/validation; computational science expertise in data processing, ingest, storage, and distribution; and operational expertise in real-time satellite product generation that will, in conjunction with the SNPP Science Team, enable the rapid and efficient creation of high quality NASA climate data records from SNPP. The Atmosphere PEATE has developed extensive capabilities that will assist the Atmosphere SIPS, including compute and storage facilities enabling rapid reprocessing of the SNPP mission record, satellite collocation algorithms enabling rapid identification of matchup datasets, flexible and efficient algorithms and software for creating Level 3 gridded products, a versatile public data search, discovery, and distribution system, a common data format to facilitate consistent science algorithms for multiple sensors, an algorithm test and development environment matching the production environment. The Atmosphere PEATE has also used its resources to assist with several efforts related to the SNPP mission, including providing crucial assistance

for the early checkout and evaluation of the CrIS sensor, including the creation of the first valid CrIS calibrated radiances, and the first reprocessing of the entire CrIS mission record to create a consistent radiance dataset; supplying products to the broad research community including NRL Monterey and the National Weather Service to facilitate the rapid adoption of SNPP data into existing operational forecast and decision making systems; assisting the MODIS Science Team with verifying results from MODIS Collection 6 algorithms to ensure long-term climate data record quality and continuity. The Atmosphere PEATE has demonstrated the ability to provide science expertise, software and reprocessing resources, product evaluation workflows, and supporting datasets to assist the NASA SNPP Science Team and the research community, and this record of achievement speaks directly to the ability of SSEC to successfully carry out the tasks required for the NASA SNPP Atmosphere SIPS.

Edward Masuoka/Goddard Space Flight Center
Development and Operation of a Science Investigator-led Processing System for VIIRS Land products

The primary objective of this proposal is the development and operation of a Science Investigator-led Processing System (SIPS) to produce global land products from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on Suomi NPP to meet the needs of NASA Earth System Science and Applied Sciences. The products produced by the SIPS will include both standard and experimental products developed by the VIIRS Science Team and near real-time data products to meet the needs of NASA's near real-time community. The VIIRS products will be produced in formats compatible with the corresponding swath-based and gridded products from MODIS instruments on EOS-Terra and EOS-Aqua. This will enable science and applications users to take advantage of the mature analysis tools already developed for MODIS.

In implementing the VIIRS SIPS, we will utilize existing software and computer systems from the VIIRS Land PEATE that are currently used to produce global land products from VIIRS and to apply software integration and quality assessment processes that we have successfully applied to MODIS and VIIRS products. VIIRS products from Suomi NPP are being reprocessed in the VIIRS Land PEATE utilizing the latest calibration look-up-tables from the VIIRS calibration support team (VCST) and improved science algorithms from the VIIRS science team. This reprocessing will be completed by May 2014 and the VIIRS data products and browse images will be available from the LAADS DAAC for evaluation by the community. After the first reprocessing results are evaluated, we anticipate that there will be several Type 1 products, e.g. land surface reflectance, that can move quickly through an Algorithm Theoretical Basis Document (ATBD) review and form the basis for subsequent reprocessing campaigns.

For both MODIS and VIIRS products we follow a rigorous process of software integration and testing for both standard and experimental products. Working closely with each science team member's software developer we have been able to baseline changes in their software within one to two days. Depending on the magnitude of the testing required, i.e. how many days, weeks or months of a product are needed to

evaluate a change, large-scale science testing may a week or more to run after which our quality assessment team and the principal investigator's team examine the results of the testing.

The VIIRS Land PEATE provides the CERES team with sub-sampled VIIRS products to be used in the generation of a CERES climate data record and near real-time processing. Our SIPS will continue to provide these products using our Product Data Record (PDR) server at GSFC and the SIPS protocol to deliver these products to the processing system at NASA's Langley Research Center.

Edward Masuoka/Goddard Space Flight Center
Development and Operation of a Science Investigator-led Processing System (SIPS) for producing products from the OMPS Nadir instrument on Suomi NPP

The primary objective of this proposal is the development and operation of a Science Investigator-led Processing System (SIPS) to produce ozone and other atmospheric products from the Ozone Mapping Profiler Suite (OMPS) Nadir instrument on Suomi NPP to meet the needs of NASA Earth System Science and Applied Sciences. The products produced by the SIPS will include both standard and experimental products developed by the OMPS Nadir Science Team and near real-time data products to meet the needs of NASA's near real-time community.

In implementing the OMPS SIPS, we will utilize existing software and computer systems from the Atmospheric Composition Processing System (ACPS) that are used to produce global products from OMPS Nadir and apply software integration and testing processes that we have successfully applied to OMPS and the Ozone Monitoring Instrument (OMI) on EOS Aura. In our role as the Ozone PEATE, we have produced the Nadir Total Column and Profile sensor data records (SDRs) as well as producing and evaluating new products, e.g. SO2 retrievals. We are also responsible for producing data products from the OMPS Limb instrument on Suomi NPP and our proposed activities in the OMPS SIPS heavily leverages our investment in this activity.

<u>Suomi NPP ST Members:</u>

Hartmut Aumann/Jet Propulsion Laboratory
Analysis of the AIRS and CrIS radiometric calibration under cloudy conditions and error propagation into environmental variables.

AIRS on EOS Aqua and CrIS on NPP and NPOES are both hyperspectral infrared sounders with similar frequency coverage, noise characteristics, and spatial coverage. AIRS Level-1, Level-2, and Level-3 products are widely used for both weather and climate applications and CrIS products will be used to extend this record after the end of the AIRS mission.

AIRS and CrIS, however, differ in many key aspects including instrument type (grating-array spectrometer vs. Fourier spectrometer), scan pattern, and detailed spectral and noise characteristics. So AIRS and CrIS Level-1, 2, and 3 products with the same name cannot be treated as a single continuous data set.

We propose to produce an AIRS/AMSU and CrIS/AMTS data subset, which will be designed by our team, produced and hosted for the public by the Sounder SIPS, and used by us, by the NASA NPP science team, and by other data users to quantify the differences between the AIRS and CrIS products as they pertain to each specific use. The proposed product is an enhanced versions of the existing Simultaneous Nadir Observations (SNOs), currently produced by the Sounder PEATE. We will use the characteristics of instrument differences derived from SNO to:

1) Refine the analysis of the recently identified zonal bias between AIRS and CrIS calibrated radiances under clear and cloudy conditions, and work with the CrIS calibration team to eliminate or to minimize the problem.
2) Evaluate how this and other differences propagate through the Level-2 algorithms currently available and/or under development by the science team.

The proposed effort will facilitate the quantitative comparison of different retrieval algorithms and a seamless transition in the climate data record from AIRS to CrIS data products.

William Balch/Bigelow Laboratory for Ocean Sciences
Use of Suomi NPP for deriving science data records of ocean particulate inorganic carbon concentration: algorithm improvements, product validation and achieving continuity with the EOS product

The goal of this work is to support the particulate inorganic carbon (PIC) algorithm within the Suomi National Polar-orbiting Partnership (Suomi NPP). This algorithm is critical for understanding the global distribution of coccolithophores (calcifying phytoplankton) and understanding the impacts of climate change on these organisms, which are essential for the functioning of the ocean biological pump. This work has three central objectives: A) PIC ALGORITHM IMPROVEMENTS: There are several sources of error within the PIC algorithm that need improvement: derivation of the diffuse attenuation coefficient used in the model, determination of the coccolith backscattering cross-section and derivation of the backscattering attributable to phytoplankton chlorophyll. This proposed work will investigate all three aspects which will allow for an improved VIIRS PIC algorithm. This work also will result in an updated PIC algorithm theoretical basis document (ATBD). B) PIC ALGORITHM EVALUATION: The major challenge to the maintenance of the PIC algorithm in the Suomi NPP era is the still-limited sea-truth PIC data taken since the launch of NPP in October, 2011, available for product evaluation. The PIC algorithm has been based on an ever-increasing, but still relatively small, set of field measurements (small as compared to the chlorophyll validation data set, which contains ~350X more data simply because

more investigators have sampled it for several more decades). To date, there are 74 validated ship PIC match-ups with VIIRS PIC estimates. The work proposed here will involve a modest field validation effort (240 stations within the north and south Atlantic) to augment the field PIC data available for evaluation of the VIIRS PIC product. We propose to participate in three Atlantic Meridional Transect cruises from vastly under-sampled regions of the North and South Atlantic, specifically in support of the Suomi NPP mission. This work will provide collection/analysis of other variables, too: chlorophyll concentration and particulate organic carbon (POC), inherent optical properties (IOPs; e.g. particle absorption and scattering) and apparent optical properties (AOPs; for validating VIIRS normalized water-leaving radiance measurements), all in support of their evaluation as VIIRS EDRs and CDRs. NASA will incur no ship time expenses for the field work; all three cruises are part of the Atlantic Meridional Transect program, long supported by the National Environmental Research Council of the U.K.
C) CONTINUITY OF THE PIC SCIENCE DATA PRODUCT: The overarching goal of this work is to seamlessly transition the PIC science data product from the EOS era to the Suomi NPP era (and ultimately to the JPSS and PACE eras). Critical in this goal is defining the error budgets of the VIIRS PIC algorithm for comparison to the same product derived from MODIS and traceable to the ATBD. This work will be well-coordinated with the Ocean Science Investigator-led Processing Systems (Ocean SIPS). This proposal includes a request for a post-doc in order to begin training the next generation of scientists for coccolithophore bio-optical and biogeochemical work in support of the NASA PIC ocean color product. ***SIGNIFICANCE*** This proposal addresses 2 of the 6 Earth science focus areas: 1) Carbon Cycle and Ecosystems plus 2) Climate Variability and Change. It supports 3 objectives identified for NASA Carbon Cycle and Ecosystems research: (1) document and understand how the global carbon cycle, terrestrial and marine ecosystems are changing, (2) quantify global productivity, biomass and carbon fluxes; and (3) provide useful projections of future changes in global carbon cycling and marine ecosystems for use in ecological forecasting, and as inputs for improved climate change predictions. Ultimately, it will allow better evaluation of the future global carbon cycle as it is influenced by climate change.

Christopher Barnet/Science and Technology Corporation
SOUNDER DISCIPLINE LEAD
Development and Validation of a Community Hyper-Spectral Infrared Microwave Earth Retrieval Algorithm:CHIMERA

Understanding climate change and the cascade of societal impacts is a key NASA strategic goal. Modern microwave and hyper-spectral infrared sounders are measuring the top of atmosphere radiance with unprecedented precision. The radiances can be inverted to retrieve high vertical resolution temperature, moisture profiles along with cloud, surface, and atmospheric trace gas composition.

We are proposing a type-2 development of science quality standard products for both AIRS/AMSU and CrIS/ATMS. We have named the algorithm the Community Hyper-Spectral Infrared Microwave Retrieval Algorithm or CHIMERA.

The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is now the operational retrieval code for the CrIS and ATMS temperature and moisture requirements. NUCAPS uses the same algorithm as the NASA Aqua/AIRS/AMSU Science Team and the NOAA operational Metop IASI/AMSU/MHS processing system, thus enabling consistency of products from all three sounding platforms. This algorithm also provides retrievals of many trace gases (e.g., ozone, carbon monoxide, methane, carbon dioxide, sulfur dioxide, nitric acid, and nitrous oxide), necessary for long-term stability in the core products and many research products (e.g., OLR, cloud products, and surface products).

As the primary scientific developer of NUCAPS and the NOAA IASI system, the PI of this proposal is intimately aware of the flexibility that went into the NUCAPS design and its capability. The NUCAPS algorithm was developed for climate applications; however, many implementation choices were necessary for real time weather applications. Also, NOAA makes improvements to the operational algorithm as the understanding of the instruments and algorithm improves. Therefore, the real-time NOAA product error improves over time but it is not suitable for long-term Earth system science studies.

This proposal will use the science version of NUCAPS as the basis for CHIMERA. CHIMERA will enhance the utility of these products by providing a better error estimates and quality control (QC) of the existing product, and to provide a level-3 (i.e., gridded product) capability.

We are proposing to use the Sounding SIPS to re-process the entire Aqua/AIRS/AMSU and Suomi-NPP datasets, focusing initially on the overlap period (May 2012 to present). We are proposing to perform a hierarchy of climate validation studies to ensure that the CHIMERA products from both satellites are characterized in absolute performance (i.e., with respect to independent in-situ observations), consistent with short term climate indices, and produce similar climate sensitivity. The sensitivity study extends previous work with AIRS done by this proposal team (Gambacorta et al. 2008).

The CHIMERA code, reprocessed soundings and associated level-3 products will be made available to the community via the Sounding SIPS.

Bryan Baum/Space Science and Engineering Center
ATMOSPHERE DISCIPLINE LEAD
Continuity of Cloud Top Pressure and Cloud Infrared Thermodynamic Phase by Combining CrIS and VIIRS Measurements

The goal of this effort is to provide cloud properties from merged CrIS and VIIRS data. While MODIS has four channels within the broad 15-Â CO2 band, VIIRS has no infrared (IR) absorption channels. The lack of at least one IR absorption channel on VIIRS degrades the accuracy of the cloud top pressure/height and thermodynamic phase products. Fortunately, we have adopted a method to synthesize a high spatial resolution 13.3-Â CO2 channel for VIIRS. The approach involves using the high spatial resolution

VIIRS IR window channels in combination with a lower spatial resolution 13.3-Â channel derived using CrIS high spectral resolution measurements convolved with the MODIS 13.3-Â spectral response function. In the first year, we will transition to the SIPS (Science Investigator-led Processing System) existing software that builds a high spatial resolution 13.3-Â pseudo-channel for VIIRS that is similar to MODIS band 33. This pseudo-channel will be at the VIIRS pixel spatial resolution of 750 m, but will be limited to the portion of the VIIRS swath for which the CrIS data are available. Based on the availability of the 13.3-Â pseudo-channel, cloud top pressure/height/temperature will be derived using an optimal estimation method. Additionally, the MODIS IR cloud thermodynamic phase algorithm will be modified for use with the VIIRS. The software for deriving the pseudo-channel and both cloud algorithms will be transitioned into operations in the first year of this work, and the associated ATBDs will be prepared concurrently. The second part of our effort is to place the VIIRS/CrIS cloud properties into context with those from MODIS and other sensors. For this, the cloud products will be analyzed using the Space-Time Gridding (STG) method, which maps the data onto a common spatial grid using a specified list of filters. The benefit of the STG method is that each data set is filtered exactly the same way, which is important for comparing cloud climate data records coherently. Subsequently, weekly and monthly maps (the time element is flexible) will be built from the daily VIIRS gridded products and compared with those derived from MODIS. The proposal will use additional support from existing personnel and infrastructure at UW-Madison. The proposal will provide a business plan and timeline for the anticipated work.

Pawan Bhartia/Goddard Space Flight Center
Development of Vertical Ozone Profile Dataset from the OMPS Limb Profiler Instrument on Suomi NPP

We propose to evaluate, maintain, and improve the ozone profile algorithm for the OMPS Limb Profiler (LP) sensor, and to provide error and uncertainty estimates by formal error analysis, internal validation, and comparison with external datasets. Two versions of the ozone algorithm have been developed under our guidance since the launch of Suomi NPP. The OMPS PEATE has released one day a month sample dataset processed using the most recent version. The full dataset is planned to be released by the end of March. Our evaluation of the sample dataset indicates that the OMPS LP ozone profiles are of high quality. They compare well with MLS and ozonesondes; in some cases better than other recent satellite sensors. This is despite the fact that the aerosol retrieval module built into the pre-launch code to correct the ozone profiles for aerosol contamination is not working well. We have turned it off and have replaced it with a simpler scheme. Though this simple scheme appears to handle the current low level of aerosol loading in the stratosphere reasonably well, it may not do so if a major volcanic eruption were to occur. We plan to make improvements to the aerosol correction scheme as part of our investigation. Other improvements include more precise altitude registration, correction for ozone inhomogeneity along the line-of-sight of the instrument, and evaluation/correction of geopotential height and temperature data in the upper stratosphere and mesosphere provided by the Global Modeling and Assimilation Office

(GMAO) at NASA GSFC. We use GMAO data to convert the ozone density vs. altitude profiles produced by OMPS LP to mixing ratio vs. pressure profiles, as well as for altitude registration.

Eva Borbas/University of Wisconsin
Continuation of EOS Clear Sky Infrared Total Precipitable Water Vapor Product Using a Combination of VIIRS and CrIMSS Measurements

We propose to provide total column water vapor properties from merged VIIRS infrared measurements and CrIMSS (CrIS plus ATMS) water vapor soundings to continue the depiction of global moisture at high spatial resolution started with MODIS. While MODIS has two channels within the 6.5-Â H2O band and four channels within the 15-Â CO2 band, VIIRS has no infrared (IR) absorption channels. However, the VIIRS IR windows at 8.6, 10.8 and 12 Â give some indication of low level moisture (which constitutes much of the total column amount) and we propose to complement this with CrIMSS column moisture determinations. This VIIRS/CrIMSS algorithm will follow the approach used for MODIS. A clear sky regression relationship will be established between total precipitable water vapor (TPW) and VIIRS IR window brightness temperatures (BTs) and CrIMSS water vapor soundings calculated from a global training radiosonde based profile data set. A high spatial resolution surface emissivity database will be used to help differentiate surface emission and atmospheric moisture absorption. CrIMSS is added in clear and partly cloudy regions to enhance the TPW depiction and to extend the coverage.

The goal of this effort is to provide TPW from merged VIIRS and CrIMSS water vapor data at 780 meter resolution, enhancing the capability to track atmospheric moisture gradients at spatial resolutions commensurate with moisture variability (documented structure function analysis by Moeller et al. (1993) notes 500 meter variability). The operational MODIS algorithm for retrieving temperature and moisture profiles along with TPW and Total Ozone from IR MODIS measurements is a clear sky synthetic regression retrieval method, called MOD07. In this method, a dataset of global radiosonde determined atmospheric temperature and moisture profiles are used to establish a regression relationship with radiative transfer forward model calculated synthetic MODIS clear sky BTs with assigned accuracy and surface properties; the calculated regression coefficients are then applied to real MODIS BT measurements. We propose to develop a VIIRS TPW algorithm which is similar to the MOD07 synthetic regression algorithm in terms of BT and viewing angle classifications, but because of the absence of water vapor absorption channels on VIIRS we will compensate by adding the CrIMSS water vapor sounding EDR products to the regression relation. The resulting relationship for TPW will then be applied to actual VIIRS IR channel measurements and CrIMSS sounding EDRs to produce a TPW product at full VIIRS spatial resolution.

In the first year, we will develop the software that builds the relationship between VIIRS measurements, CrIMSS profile products, and TPW, compare the results with heritage MODIS, AIRS/AMSU, SSMI, GPS, and CART site MWR TPW determinations, and prepare concurrently the associated ATBD. In the second year, we will transition the

software to the SIPS (Science Investigator-led Processing System) and evaluate global VIIRS plus CrIMSS water vapor determinations against those from heritage sources. To do this, daily and monthly level 3 maps (the time element is flexible) will be built using the Space Time Gridding (STG) software established at CIMSS from the VIIRS level 2 products and compared with STG level 3 compilations from heritage sources. In the last year we will refine and maintain the delivered software, if necessary, finish the product evaluation, submit the final project report, and disseminate research findings via peer-reviewed publications.

Karen Cady-Pereira/AER, Incorporated
Developing Retrieval Algorithms for NH3 and CO from NPP CrIS Measurements

Ammonia (NH3) and carbon monoxide (CO) play key roles in atmospheric chemistry: NH3 as part of the nitrogen cycle and CO as a precursor for ozone and carbon dioxide. Continuing industrialization across the globe is altering the source intensity and distribution of these gases both directly and through temperature and moisture adjustments due to climate change. In turn these species also affect the climate: NH3 is an important source of PM2.5 aerosols that have a small but highly uncertain radiative effect. CO is estimated to have an indirect forcing of 0.2 W/m2. Feedbacks associated with climate change will modulate the effect NH3 and CO have on atmospheric chemistry, air quality and the climate itself.

Both species are highly variable in space and time “NH3 more so than CO” and it is difficult to predict future emissions based on the current databases, which are sparse over much of the Earth. NASA EOS instruments like TES, MOPITT, and AIRS have provided a wealth of information on the distribution of these gases, and shown that CO levels are is decreasing significantly. However, they are well past their design life and so the future of these critical NASA EOS records is endangered. The CrIS instruments on the Suomi NPP satellite and on the future JPSS platforms have the potential to monitor these species across the globe over many years accurately and consistently. Our proposed project will develop the algorithms and software to retrieve NH3 and CO based on the optimal estimation approach and constraints that we adopted for TES NH3 and MOPITT CO. This will enable NASA to create consistent extended NH3 and CO data records that will provide modelers with the information needed for a better understanding of the processes in which each are involved. This in turn will inform the policy decisions that ultimately affect human health and the health of our natural environment.

Jeffrey Czapla-Myers/University of Arizona
Support for the Calibration and Validation of Suomi NPP VIIRS

NASA’s Earth Science program conducts research using airborne and spaceborne platforms to collect data that are used to help understand the complex interaction of the various Earth systems such as the atmosphere, land, ice, and oceans. One of the key requirements is the provision of well-calibrated, multiyear and multisatellite time series data and data products. The primary objective of this work is to calibrate and validate the at-sensor radiance and the surface reflectance intermediate product (IP) from the Visible

Infrared Imaging Radiometer Suite (VIIRS), which is onboard the Suomi National Polar-orbiting Partnership (S-NPP) spacecraft. An additional primary objective of this work is to cross calibrate VIIRS with current sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS), which is onboard the Aqua and Terra spacecraft. A secondary, yet equally important objective of this work, is the creation of a web distribution system for the radiometric calibration data that are generated using the Radiometric Calibration Test Site (RadCaTS), which is an instrumented and automated calibration site at Railroad Valley, Nevada.

RadCaTS is an automated test site that is located at Railroad Valley, Nevada, which is recognized as an instrumented radiometric calibration site by the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV). It has all of the necessary instruments to perform the absolute radiometric calibration of satellite and airborne sensors. The measurements include the surface reflectance, optical properties of the atmosphere, temperature, pressure, wind speed and direction, humidity, and precipitation. RadCaTS is currently being used to provide supplementary data to the in situ measurements that are performed for Landsat 8 OLI. Upgrades to the system in 2014 include a wireless uplink, which will allow data to be processed near real time, which can then be distributed to the user community via a web-based portal.

This proposal seeks to support the S-NPP Science Team and the NASA Land Product Evaluation and Analysis Tools Element (PEATE) in the calibration and validation of the VIIRS at-sensor radiance and surface reflectance IP using RadCaTS. The RadCaTS facility is well-suited for the absolute radiometric calibration of an individual sensor, and the cross calibration of multiple sensors, and as a transfer standard in case of a data gap. Specifically, RadCaTS will also be used to cross calibrate S-NPP VIIRS with MODIS, and also the Joint Polar Satellite System (JPSS) VIIRS when it launches in 2017.

Kamel Didan/University of Arizona
Vegetation Indices from the Suomi NPP VIIRS Sensor: Extending the EOS-MODIS VI Science Algorithm and Experience

Vegetation indices are now a standard tool of Earth system science. They continue to play a central role in global change research, in terrestrial ecology, land cover and land use change, carbon cycle, and a host of other areas where simple to complex questions and applications are addressed. Vegetation indices (VI) also support ecosystem and climate models by providing a proxy and an easy tool for the spatial scaling of a list of parameters about the land surface and primary production in particular. Their pervasive use is due to the simple, robust, and intrinsic characteristics of their formulation that makes no assumptions about the observations or the data used to derive them.

The goal of this proposal is to reuse the EOS-MODIS suite of VI Science and Production Algorithms to generate continuity with the VIIRS VI data record in the post EOS era. Doing so will insure the continuity of these products. We note there are two VIIRS data streams, an operational data stream lead by NOAA geared towards applications and with a quick product turnaround (< one hour) with limited reprocessing capability, and the

data resulting from this solicitation, which is geared towards the production of standard and high fidelity science products, will be used for long-term terrestrial ecosystem and climate change studies starting from the AVHRR-NDVI while using EOS-MODIS traditions. Our proposed VIIRS products will be generated with the same rigor and attention to quality as the EOS-MODIS suite of products. The EOS-MODIS heritage is key to meeting this requirement as specified in the call.
Our overarching objective is to insure continuity of the VI data record. This is of particular value considering this time series is not only stable but has reached a critical capability of supporting the detection of climate trends. We are proposing an integrated approach based on a reliable science foundation, data generation algorithms, and full characterization of product quality assurance and error quantification for this VIIRS VI time series. Our objectives are:

Implement the NDVI and EVI algorithms to the VIIRS record. This includes the assessment and optimization of their spectral, spatial, and temporal characteristics to quantify land vegetation responses to climate variability.

Extend the EOS MODIS VI production algorithms for generating high fidelity VIIRS VI products into the post-EOS era.

Implement lessons learned from the EOS MODIS era and extend these to the VIIRS VI user community. In particular exploring shorter compositing periods for phenology studies, while we maintain the VI algorithms for long term continuity.
Fully characterize the VI product suite and estimate errors and uncertainty to support land surface vegetation monitoring and change detection.

Implement a product user support model for the dissemination of information about the product suite and value addition that builds on the current EOS-MODIS VI model.

Christopher Elvidge/NOAA-NESDIS National Geophysical Data Center
VIIRS Nighttime Lights

The VIIRS instrument day/night band (DNB) collects global low light imaging data that have significant improvements over comparable data collected for 40 years by the DMSP Operational Linescan System. One of the prominent features of DNB data are detections of electric lighting present on the earth's surface. Most of these lights are from human settlements. VIIRS collects source data that could be used to generate monthly and annual science grade global radiance maps of human settlements with electric lighting. There are a substantial number of steps involved in producing a product that has been cleaned to exclude background noise, solar and lunar contamination, data degraded by cloud cover and features unrelated to electric lighting (e.g. fires, flares, volcanoes). NGDC proposes to develop the algorithms for the production of high quality global VIIRS nighttime lights. Products will be generated on monthly and annual increments and made available via an open access web site. There is a broad base of science users for VIIRS nighttime lights products, ranging from land use scientists, urban geographers,

ecologists, carbon modelers, astronomers, demographers, economists, and social scientists.

Bryan Franz/Goddard Space Flight Center
Co-Investigator Carlos Del Castillo, OCEAN DISCIPLINE LEAD
Extension of the MODIS Ocean Color Time-Series to S-NPP/VIIRS: Marine Remote Sensing Reflectance and Derived Products

This proposal will seek to develop, validate, and maintain a time-series of ocean color products from NPP/VIIRS that is consistent with the current NASA global time-series established with SeaWiFS and MODIS. The product suite will include water-leaving remote sensing reflectance (Rrs) at each VIIRS visible spectral band, chlorophyll concentration (Chl), marine diffuse attenuation at 490nm (Kd490), the inherent optical properties (IOPs) of total and component absorption and scattering. The proposing team are all members of the NASA Ocean Biology Processing Group (OBPG), which is currently responsible for maintaining the quality and consistency of the SeaWiFS and MODIS ocean color products and developing many of the algorithms employed.

Rrs is the fundamental product derived from ocean color sensors, from which most bio-optical or bio-geochemical products are derived. Development and maintenance of a consistent Rrs product at the highest possible quality is thus paramount to continuation of meaningful ocean color science into the VIIRS era. The retrieval of Rrs from spaceborne sensors, however, is highly sensitive to instrument calibration and the retrieval algorithms. The establishment of Rrs time-series of sufficient quality for ocean color science has historically required significant efforts to quantify and correct for sensor degradation issues that change radiometric performance over time, across scan, and between detectors and mirror sides. The OBPG has augmented the calibration of MODIS using vicarious techniques to achieve a level of accuracy and stability that far exceeds what can be achieved through the on-board (solar, lunar) calibration alone, and we propose to extend this level of effort to VIIRS. We also seek to maintain the Rrs algorithm for VIIRS consistent with the algorithm currently employed for MODIS. This algorithm has many components, collectively referred to as atmospheric correction, that account for the radiative transfer of light from the sun through the atmosphere, into the euphotic zone of the upper ocean and back to the sensor. A consistent atmospheric correction algorithm for VIIRS has already been developed by the OBPG, and extensive radiative transfer simulations have been performed to produce the atmospheric models specific to the VIIRS bandpasses. Here we propose to maintain VIIRS compatibility as NASA's multi-sensor atmospheric correction algorithm evolves and advances.

The standard MODIS Chl and Kd490 algorithms are empirical band ratio algorithms derived by relating field measurements of spectral Rrs to field measurements of Chl and Kd490 using the NASA bio-Optical Marine Algorithm Dataset (NOMAD) in situ archive. These MODIS algorithms and the NOMAD dataset are currently maintained by the OBPG. We propose to establish these same empirical algorithms for VIIRS, accounting for the VIIRS-specific band centers and updating as necessary to maintain currency with NOMAD and consistency with MODIS and SeaWiFS. Similarly, the

current MODIS IOP and other derived-product algorithms require only minor refinements for applicability to VIIRS band centers. We will establish the full suite of VIIRS ocean color algorithms consistent with those currently employed for MODIS standard ocean color products, and maintain those algorithms to incorporate any advancements developed by the MODIS science team, the OBPG, or the broader research community.

Robert Frouin/Scripps Institution of Oceanography, UCSD
Development of a Science Quality Ocean Surface PAR Product from NPP VIIRS Data

Photo-synthetically available radiation (PAR) at the ocean surface is an important parameter for biological and ecological studies. It controls phytoplankton growth and ultimately regulates the composition and evolution of marine ecosystems. There is a need for a global, long-term, consistent PAR time series to understand biogeochemical cycles of carbon, nutrients, and oxygen and to address important climate and global change issues such as the fate of anthropogenic atmospheric carbon dioxide.

In view of this, the proposal overall objective is to develop a science quality standard ocean surface PAR product from VIIRS data. Specific objectives are: (1) to improve the current algorithm used by the Ocean PEATE to generate the VIIRS PAR experimental product, (2) to correct the resulting estimates for differences/biases due to limitations in the modeling and diurnal variability of clouds, and (3) to quantify product accuracy. The algorithm improvements will deal with spectral integration of atmospheric functions, ocean albedo parameterization, specification of aerosol optical properties, extension to observations at large solar zenith angles, and they will take into account, using climatology, diurnal changes in cloudiness, i.e., fractional cloud coverage and optical thickness. Biases between sensors will be determined by comparing PAR estimates obtained from VIIRS with those from MODIS after adjusting the MODIS values for differences with combined estimates from SeawiFS, MODIS-Terra, and MODIS-Aqua. This will require also applying algorithms modifications to SeaWiFS and MODIS. Accuracy of the PAR estimates will be quantified theoretically and in comparisons with in-situ measurements and other radiation products. A PAR ATBD will be developed that accounts for algorithm improvements and specifies accuracy.

Implementation of the improved PAR algorithm and routine production and distribution of bias-corrected PAR estimates from VIIRS data and will be accomplished by the NASA-designated SIPS, as currently performed by the NASA OBPG for SeaWiFS and MODIS. Similar procedures and interactions are anticipated. The PAR products from the SIPS and OBPG will be consistent and compatible. The SIPS will allow for multiple data re-processing as the PAR algorithm improves and include routine check of accuracy and control of quality.

The project will result in a 4.6 km resolution (equal-area grid) global ocean surface PAR product using NPP VIIRS data. The product will extend into the future the daily, weekly, and monthly PAR record started in 1997 with SeaWiFS and continued with MODIS. A

wide range of research applications will benefit from the long term PAR record, such as primary production and carbon export modeling, ecosystem dynamics and mixed-layer physics, photochemical transformations of dissolved organic matter, and control of stable soluble iron in marine waters. The contribution of the project to understanding the role of the oceans in carbon cycling and climate change, one of NASA objectives in Earth science research, is expected to be very significant.
The project is highly responsive to Program Element A.29 in the ROSES-2013 Announcement, which addresses the development of science quality standard data products using Suomi NPP measurements that will enable continuity of key standard Earth system data records from NASA's EOS Terra, Aqua, and/or Aura satellites, and which lists PAR as one of the key EOS products.

Bo-Cai Gao/Naval Research Laboratory
Continuation of Standard Cirrus Reflectance Product from the EOS Terra and Aqua MODIS to Suomi NPP VIIRS

The MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on the Terra and Aqua spacecraft have a channel centered at 1.375 micron (Ch. 26) with a width of 30 nm for remote sensing of cirrus clouds from space. The cirrus reflectance data product has been generated for approximately 14 years from the Terra MODIS data and 12 years from the Aqua MODIS data at a NASA computing facility. This product has already been used in a variety of climate research and applications, such as for the study of tropical thin cirrus cloud effects on radiative forcing at the top of the atmosphere and the assessment of thin cirrus contamination effects in operational aerosol data products. The cirrus reflectance product is contained within a suite of EOS/MODIS standard cloud products. The VIIRS (Visible Infrared Imaging Radiometer Suite) instrument currently on board the Suomi NPP (National Polar-orbiting Partnership) satellite has a similar channel centered at 1.378 micron (M9) with a width of 15 nm specifically designed for detecting thin cirrus clouds. The VIIRS M9 channel is narrower and significantly more sensitive for remote sensing of cirrus clouds than the MODIS channel 26. At present, there is no VIIRS cirrus reflectance data product produced at any of the NASA and NOAA sponsored computing facilities. We propose to build on our experience in developing the operational MODIS cirrus reflectance algorithm to produce a standard cirrus reflectance product from VIIRS data, and then to transfer the VIIRS version of the cirrus reflectance algorithm to the NASA Suomi NPP Atmosphere SIPS (Science Investigator-led Processing Systems) for routine processing. Because the VIIRS M9 channel has a higher signal to noise ratio and is nearly free of the out of band response effects found in the MODIS Channel 26, we expect that the quality of the proposed VIIRS cirrus reflectance data product would be superior to the current MODIS product. We will validate the VIIRS cirrus reflectance data product with co-located Lidar data collected with CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) on board the CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) satellite platform. This is a type 1 proposal, i.e., products ready for SIPS production in less than one year.

Louis Giglio/University of Maryland

Development of a Suomi NPP VIIRS Global Burned Area Earth System Data Record

Earth System Science studies recognize and include fire as an important process in the terrestrial carbon cycle, and there is an established need for long term, spatially- and temporally-explicit global burned area data. The advent of the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites enabled the first systematic production of high quality, 500-m global burned area maps. These data are now used by both the global modeling and fire applications communities. Increasing interest in quantifying changing fire regimes as a result of anthropogenic change and a warming climate make the development of a long-term observation record a priority. The Global Climate Observing System has identified a set of Essential Climate Variables (ECVs) needed in support of the United Nations Framework Convention on Climate Change including active fire and burned area. Unfortunately, neither the original NPOESS Integrated Operational Requirements nor the latest JPSS Level 1 Requirements mandate that a burned area data record be produced for Suomi NPP. We propose to develop a VIIRS Burned Area product that will continue in a consistent manner the 14-year MODIS record into the Suomi NPP and JPSS era and form the basis for a burned area Earth System data record. The mapping approach will be based on the existing MODIS Direct Broadcast and MCD45 burned-area mapping algorithms, with an emphasis on data consistency and continuity. The proposal will include porting the existing MODIS production code, algorithm tuning, product generation within the NASA Land PEATE, quality assessment, product intercomparison with the equivalent MODIS product, and product distribution. Given the limited duration of the proposal, a CEOS Stage 2 Validation of the VIIRS global burned area data record will be undertaken using pre- and post-burn Landsat 8 image pairs following the CEOS Land Product Validation protocol for burned area validation. As part of this effort we will contribute to the international efforts in fire product standardization, intercomparison, and validation through the GOFC/GOLD fire implementation team and the CEOS/CalVal fire validation subgroup.

This proposal is responsive to Section 2.1.1 (NASA Suomi NPP Data Products for EOS Continuity) and 2.1.2 (Innovative and Practical Applications of Suomi NPP Data) of the ROSES Suomi NPP Science Team and Science Investigator-Led Processing Systems for Earth System Data Records from Suomi NPP call.

Watson Gregg/Goddard Space Flight Center
Combining Data Assimilation with an Algorithm to Improve the Consistency of VIIRS Chlorophyll: Toward a Multidecadal, Multisensor Global Record

Observing long term trends in ocean color data requires consistency among successive missions, since the lifetime of each is finite. S-NPP/VIIRS is the newest global ocean color mission, following the highly successful SeaWiFS and MODIS-Aqua sensors. Like all preceding ocean color sensors (except perhaps MODIS-Terra, which should be discounted because of inadequate capability), VIIRS has a different design and orbit than

any other global sensor. Rectifying the differences among different sensors and producing consistent ocean color observations is crucial to our understanding of global ocean biology variability and trends.

We propose to investigate the ability of an established approach to improve the consistency of VIIRS ocean color data. Our approach has been applied to the data sets of SeaWiFS and MODIS-Aqua and has increased the consistency of these sensor data sets globally and in all major oceanographic basins. In addition to improving consistency, the approach also forces satellite data to conform more closely to in situ data, producing a unified description of ocean biology from satellites and in situ platforms.

We now have 2 full years of VIIRS chlorophyll data and have evaluated the data quality extensively. Although there are issues with VIIRS, it appears to have potential to continue the ocean color time series. Our data assimilation approach can enhance the sensor data quality and consistency with MODIS-Aqua, but our in situ data bias correction has not been productive due to lack of in situ data so far.

In this proposal we hope to obtain sufficient in situ data to apply the bias correction and formalize the use of data assimilation of data product enhancement and consistency with MODIS-Aqua. We intend to proceed toward making our methodology available for routine processing, cognizant that this Level-4 algorithm will likely involve substantial obstacles. However, we believe that in situ bias correction and data assimilation for sampling bias reduction are approaches whose time has come and confronting the challenges of implementing them in a data processing scheme are worthwhile.

Dorothy Hall/Goddard Space Flight Center
Development of S-NPP Cryospheric EDRs to Extend the EOS Data Record for Earth System Science

Major changes have been documented in recent decades in the Earth's cryosphere. Snow cover is declining in the Northern Hemisphere in springtime, Arctic sea ice extent and thickness has been decreasing and surface temperatures of the Arctic as a whole, and in particular of the Greenland ice sheet, have been increasing. Thus it is critical to provide the means to document changes in snow and ice features in the cryosphere with a high degree of accuracy. Continuation of the high-quality Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) records into the Suomi-National Polar-orbiting Partnership (S-NPP) era with Visible Infrared Imaging Radiometer Suite (VIIRS) data is of the utmost importance for development of Environmental Data Records (EDRs) for Earth system science studies.

The current Joint Polar Satellite System (JPSS) S-NPP cryosphere S-NPP EDRs are: binary snow-cover extent; snow-cover fraction; sea ice characterization; and ice surface temperature (IST). We propose to develop improved or alternative S-NPP products to ensure high-quality cryosphere EDRs for Earth system science and applications, and to achieve continuity with EOS standard MODIS data products.

To achieve our goal of producing S-NPP EDRs that are compatible with MODIS standard products, we will produce S-NPP snow cover, sea ice cover and IST EDRs, along with uncertainty analysis and demonstration of continuity between MODIS and S-NPP cryosphere products. We will also write the associated algorithm theoretical basis documents (ATBDs). Because we can leverage our EOS experience we will be able to deliver algorithms and products on a Type 1 development schedule for NPP which means that products will be ready for production in less than one year.

Our team is knowledgeable about the similarities and differences between the MODIS and VIIRS instruments, algorithms and data products as well as the systems used to produce them. We have a great deal of experience in development and evaluation of the MODIS and S-NPP algorithms and data products. We are thus uniquely qualified to undertake this work.

Our team members will request membership on the Cryosphere Sciences Measurement Team and will plan for at least two members: Co-I Tschudi, with primary expertise in sea ice, and PI Hall or/and Co-I Riggs, with primary expertise in snow cover, to participate in measurement team meetings.

Andy Harris/University of Maryland
New Physically Based Sea Surface Temperature Retrievals for NPP VIIRS

VIIRS is the flagship imaging radiometer of the next-generation US polar-orbiting meteorological satellite program. It has 16 high-accuracy channels (5 in the thermal IR) and represents a substantial increase in information over the previous generation instrument. However, the primary sea surface temperature (SST) algorithm still using a 2-channel technique (NLSST) . A second algorithm uses channels at 3.7, 11 & 12 microns but, since it is subject to solar contamination, this algorithm is only used at night. Both of these algorithm forms are identical to those developed for the now 30-year-old AVHRR instrument. The NLSST algorithm itself is subject to regional and seasonal biases, which we show are intrinsic limitations of the algorithm methodology. The current algorithms are also affected by atmospheric aerosols and have no inherent skill in compensating for them. Additionally, no explicit error calculation is attempted (or even possible) for the retrievals. We note in passing that a modern physical retrieval (Optimal Estimation) is already being applied to the venerable AVHRR instrument, thus, in terms of retrieval technology, VIIRS is now lagging behind the instrument that it is supposed to supersede.

The time has come to exploit the sophistication of the VIIRS instrument and apply modern retrieval techniques to realize maximum return on the investment. We propose adapt and evaluate a physical retrieval methodology that we have recently applied to geostationary imagers. VIIRS offers the advantage of more channels that can help to resolve ambiguities in the retrieval and produce a more stable solution. Our new method also permits a direct estimate of goodness-of-fit which translates directly to uncertainty (error) information in the retrieval. Furthermore, the method is not biased towards the first guess and has a sensitivity to true SST close to 1:1. These retrieval characteristics are important for producing a climate-quality record of SST. Capabilities to determine

impacts due to aerosol, water vapor distribution and air temperature variations will be assessed during this project. The dual 4 micron window channels will be employed to permit estimation of any solar contribution. This, in turn, will facilitate improved SST retrieval accuracy in the daytime.

All the above should lead to a truly independent SST retrieval (not tied to in situ data-rich regions). This is critically important because the value of remotely-sensed SSTs is greatest where other measurements are sparse one irony of the current matchup-based algorithm methodology is that confidence is least where the need is greatest. With a physically-based retrieval methodology, in situ data can serve as a properly random sample to validate both the product and the accompanying uncertainty estimates, leading to greater confidence in the VIIRS SST product. This is of critical importance since SST is designated an Essential Climate Variable (ECV) by WMO GCOS, who have placed stringent requirements on satellite-based observations of this key climate parameter.

Simon Hook/Jet Propulsion Laboratory
In Flight Validation of VIIRS Mid and Thermal Infrared Data and Products for Earth Science

The stated goal of NASA's Earth Science Research Program is to utilize global measurements to understand the Earth system and its interactions as steps toward the prediction of Earth system behavior. NASA has identified the provision of well-calibrated, multiyear and multi-satellite data and product series as a key requirement for meeting this goal. The main objectives of this study are to validate the mid and thermal infrared data and products from the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership and cross validate them with equivalent data and products from the Moderate Resolution Imaging Spectroradiometer (MODIS).

In order to validate these data and product series we have developed a set of automated validation sites that make all the necessary validation measurements on a near continuous basis (every 2 minutes) and have made these measurements since 1999. Measurements include skin (radiometric) temperature and bulk (contact) temperature together with the standard meteorological variables: wind speed, wind direction, net radiation, air temperature and relative humidity. These same data are being used to validate the mid and thermal infrared data and products from other instruments including the Moderate Resolution Imaging Spectroradiometer (MODIS) on both the Terra and Aqua spacecraft. VIIRS is the follow-on instrument for MODIS. This work will provide a continuous and consistent validation record for MODIS and VIIRS from the launch of Terra in 1999 through the launch of VIIRS on NPP in late 2011 continuing until 2017 (the end of this project).

The existing data have been used to validate the accuracy of the mid and thermal infrared at-sensor radiance measured by VIIRS as well as the Land Surface Temperature (LST) product derived from the measured radiance The data have also been used to cross-compare VIIRS and MODIS. Various artifacts have been identified and corrected in the VIIRS data and products thereby ensuring the data can potentially be used as Earth

System Data Records (ESDRs) defined by NASA as a unified and coherent set of observations of a given parameter of the Earth system. For example these data have been used to show that problems observed in the VIIRS LST product were a consequence of the data product algorithm rather than the Level 1 radiance at sensor data. These problems include the the accuracy of the LST retrieval being dependent on the atmospheric water vapor content, with LST retrievals over moist atmospheres being less accurate than those over dry atmospheres. We will continue our validation activities to ensure the VIIRS mid and thermal infrared data and products are calibrated and validated, and any difference between them and the MODIS data are fully understood to ensure that VIIRS data can be used in addition to and ultimately in place of MODIS data in ESDRs.

N. Christina Hsu/Goddard Space Flight Center
Extending Long-Term Aerosol Data Records from MODIS to VIIRS: Data Continuity and Enhancements to the E-Deep Blue Algorithm

One of the key components of the Earth Science Research Program's goal to better under-stand the complex nature of Earth's climate is to constrain the global radiation balance. Comprehensive regional-to-global climate models (R/GCMs) are playing an ever-greater role in addressing this issue. Because of their important role in modifying the radiative energy balance, the characteristics of aerosols, especially near their sources and sinks, are essential components of these R/GCMs. Several EOS-era and later instruments (e.g., SeaWiFS, MODIS, MISR, and VIIRS) are able to provide such information with a high degree of fidelity.

Many globally-important aerosol sources, notably of mineral dust and smoke aerosols, are found in semi-arid and arid regions. Thus, the ability to determine aerosol optical depth as well as particle type over these areas is particularly important. While the original MODIS operational retrieval algorithms were not able to provide aerosol properties over bright surfaces such as deserts, our previously-developed Deep Blue algorithm narrowed these gaps in MODIS aerosol products by performing retrievals over such surfaces. Deep Blue utilizes blue-wavelength measurements to infer the properties of aerosols, since the surface reflectance over land in the blue part of the spectrum is much lower than for longer wavelengths. We recently successfully implemented (for both the MODIS and SeaWiFS sensors) an enhanced Deep Blue algorithm, extending spatial data coverage to most land areas, including both deserts and vegetated surfaces, to provide information on aerosol optical depth (AOD), Ã exponent, and dust absorption. Together with over-ocean aerosol retrievals developed by us and other groups, this closes some of the major remaining gaps in spatial coverage in aerosol datasets from MODIS-like sensors.

However, accurate estimates of long-term aerosol trends cannot be achieved without high-fidelity long-term aerosol Earth System Data Records (ESDRs), which rely on high-quality and consistent sensor calibration and retrieval algorithms applied across different satellite platforms. With the aging of the MODIS Terra and Aqua sensors, extending such long-term continuous ESDRs from the EOS-era MODIS to VIIRS is imperative. The intent of this proposal is to request funding for providing data continuity

of aerosol data records by using a consistent aerosol retrieval algorithm from MODIS to VIIRS, to meet requirements for both short- and long-term aerosol applications such as air quality and climate studies. Specifically, the proposed objectives are:

1) To develop and maintain the MODIS-like Deep Blue aerosol products using VIIRS radiance data, and provide an EOS-heritage type of algorithm over ocean;
2) To advance the Deep Blue algorithm by adding new aerosol products into the VIIRS data suite, such as the identification of aerosol types including volcanic ash, which are not currently available in the MODIS dataset;
3) To characterize error budgets over various atmospheric and surface conditions, through validation of the VIIRS Deep Blue aerosol products against ground-based measurements and retrievals from AERONET and field campaigns;
4) To compare the Deep Blue aerosol products between MODIS/Aqua and VIIRS to examine the effects of sensor calibration on the retrieved aerosol properties, particularly with regard to any AOD offset and long-term trends.

Chuanmin Hu/University of South Florida
Refine and Improve Suomi NPP Chlorophyll a and Other Ocean Color Data Products Using a Novel Algorithm Concept

NPP Ocean Data Products to work on: chlorophyll a concentration (Chl, primary), and remote sensing reflectance (Rrs, secondary).

Ultimate goals: Increase valid Chl data coverage by at least 50% (possibly 100%); Reduce Chl and Rrs data product uncertainty; Improve cross-sensor consistency for Chl. Problem statement and background: Despite significant progress, two problems still exist in the current global ocean color data products for all ocean color missions and especially for the most recent NPP VIIRS: 1) data coverage (quantity), and 2) data accuracy (quality). These problems not only create data gaps and potential spatial/temporal aliasing, but also lead to large inconsistencies between sensors. For example, monthly mean chlorophyll-a derived from the default algorithms (ChlOCx) can differ by 10-20% between VIIRS and MODIS/Aqua in some major ocean basins. Such differences can overwhelm realistic changes of the ocean (often < 10%) in response to climate variability.

A novel algorithm concept, namely the Ocean Color Index (OCI) algorithm, has shown great potentials in achieving multi-sensor consistency and recovering low-quality (i.e., flagged) data to increase coverage. This is because that the OCI algorithm is nearly immune to most errors in the input remote-sensing reflectance (Rrs) data for clear waters (Chl < 0.25 mg m-3, representing ~80% of the global ocean). The ATBD of this algorithm has been published in 2012, and the algorithm has been implemented by the NASA OBPG for all ocean color missions where the products have been generated and distributed for community evaluations. The algorithm has also been recommended by the Ocean Team Leader of the MODIS Science Team (Franz) to replace the current standard MODIS Chl algorithm.

Specific objectives: The project is designed to fully realize the potentials of the OCI algorithm concept to improve both data quantity and data quality, to refine VIIRS data products to continue the MODIS EOS observations, and to bridge to future ocean color missions such as PACE. Specifically, the project has the following objectives:

1) Increase valid data coverage by at least >50% for most ocean areas by recovering some of the low-quality data. These low-quality data are currently discarded in the global data composites;
2) Refine the OCI algorithm to minimize the impact of colored dissolved organic matter (CDOM) on Chl retrievals, with cross-sensor differences reduced from >10% to <5% and cross-basin biases reduced by more than 50%;
3) Extend the same algorithm concept to higher-Chl waters;
4) Reduce uncertainties in the spectral Rrs data product;
5) Make recommendations to future sensor design and data processing.

Approach: The project relies entirely on optical modeling and analyses of both satellite data (through NASA data archive) and in situ data (NASA's SeaBASS archive). Specifically,

1) Quality control flags will be examined against Chl_OCI data quality to determine which flags can be relaxed (and to what degree) in order to increase data quantity without compromising quality. Validation will be performed using both in situ data and spatial/temporal consistency checks, with uncertainty estimated;
2) Algorithm coefficients will be fine-tuned using ratios of Rrs(412)/Rrs(443) (or other combinations of the blue bands) and SeaBASS data will be partitioned to major ocean basins in order to minimize the influence of CDOM on Chl retrieval accuracy and to minimize cross-basin biases;
3) The new algorithm concept is applicable to ~80% of the ocean (clear waters). To extend to higher-Chl waters, Rrs spectral slope (or other spectral combinations) will be incorporated;
4) The OCI algorithm also provides a constraint on the Rrs spectral curvature, thus will be used to refine Rrs data products to reduce uncertainties;
5) Based on the results above, recommendations on future sensor design (e.g., signal-to-noise) and data processing (e.g., flag settings) will be made.

Glynn Hulley/Jet Propulsion Laboratory
A Unified VIIRS Land Surface Temperature and Emissivity (LST&E) Product for Earth Science Research and MODIS Continuity

A key Earth System Data Record (ESDR) identified by the NASA Earth Science Division is land surface temperature and emissivity (LST&E). LST&E data are critical variables for studying a variety of Earth surface processes and surface-atmosphere interactions such as evapotranspiration, surface energy balance and in atmospheric retrieval schemes.

The current VIIRS Land Surface Temperature (LST) EDR provides radiometric LST values over land and larger inland waters in swath format, equivalent to the standard MODIS Level 2 product (MOD11_L2). The VIIRS EDR deviates from its MODIS counterpart in three major areas: (1) It employs a split-window algorithm that has a

different functional form than the heritage MODIS MOD11_L2 algorithm; (2) it has a functional dependency on previously-generated emissivity dependent coefficients and (3) it does not provide dynamic land emissivity for the three VIIRS thermal infrared bands (M14-16) per the current MODIS Day-Night (MOD11B1) or MODIS-TES (MOD21) LST&E products.

Initial evaluation of the operational VIIRS LST EDR product against the MODIS LST products (MYD11 and MYD21) and ground-based measurements have shown that the current VIIRS algorithm significantly underestimates the LST over deserts and arid regions. Additionally, the algorithm performance is further degraded for high atmospheric water vapor content conditions, where differences up to 15 K have been observed with MODIS-retrieved LST products. A further shortcoming in the current VIIRS LST algorithm is that the emissivity is fixed and embedded in the surface coefficients, and is no longer treated as an independent variable as in the MOD11 split-window formulation. The drawback of this is that the VIIRS algorithm is unable to accommodate spatial and temporally-adjusted emissivity values. Consequently the VIIRS operational product will not produce a dynamically retrieved land surface emissivity product similar to the current MODIS MOD11B1 and MOD21 products. The land surface emissivity is critical for a host of Earth surface related studies including the surface radiation budget, land use/land cover change, hydrology and drought monitoring, and needed to ensure continuity with EOS products. Recent studies have shown that the MODIS-TES physical-based approach (MOD21 product), which retrieves LST and emissivity for MODIS bands 29, 31, and 32 is highly complementary to the current MOD11 split-window approach since it allows for more accurate retrievals over semi-arid and arid areas and slightly less accurate retrievals over heavily vegetated areas and water bodies where the existing MOD11 algorithm has optimum performance.

We will develop a unified, science quality VIIRS LST&E ESDR product by using a combination of the well established and complementary TES and split-window algorithms (MOD11/MOD21 approaches). A full uncertainty analysis will be provided with the product, including a dynamically varying emissivity for the VIIRS TIR bands (M14-16). The PI and Co-I's have established a methodology for merging the MODIS-TES (MOD21) and MODIS split-window (MOD11) products in a currently funded NASA MEaSUREs project to generate a long-term, unified MODIS LST&E ESDR. The new unified VIIRS LST&E ESDR will be suitable for incorporation in this unified product and provide a continuous, well-characterized, high quality time series of measurements starting with MODIS-EOS in 2000 and spanning the S-NPP and JPSS-1 and JPSS-2 satellites through 2022.

Chris Justice/University of Maryland
LAND DISCIPLINE LEAD
Agricultural Monitoring Applications of VIIRS Data and the Land Discipline Lead

The proposal will make a significant contribution to the NASA Applied Science Program and further its mission providing an innovative use of NASA Earth Science Data in support of policy making (AMIS) and management decisions (FAS and the global

agricultural monitoring community). The goal of this applied sciences proposal is to replicate and extend the current MODIS capabilities for crop condition monitoring with data from Suomi-NPP VIIRS, developing compatibility with the MODIS data archive necessary to establish crop condition anomalies and entraining the resulting VIIRS products into two operational systems currently used for agricultural monitoring decision support: the GLAM System and the G-20 GEOGLAM Crop Monitor. Ensuring continuity of products from MODIS to VIIRS is of critical concern for those utilizing NASA data products for operational agricultural monitoring. Given the importance of timely data for agricultural monitoring, the proposal will establish a VIIRS LANCE (near real time) capability for VIIRS Surface Reflectance and Vegetation Index products for agricultural monitoring, as was developed for MODIS, building on products developed by the VIIRS Science Team. The proposal will enhance the current GLAM user interface by adding VIIRS data and additional related tools. We will partner with established end-users from the agricultural monitoring community to evaluate, refine and utilize the resulting VIIRS products in their DSSs. This proposal will continue a long-standing relationship of transitioning the results of NASA Science Team research into USDA (FAS IPAD) operations and will make the NASA VIIRS capability available to the broader GEO Agricultural Monitoring Community of Practice, as has been the case for MODIS. VIIRS data will be added to the highly visible Crop Monitor(DSS)established in the framework of the G20 GEOGLAM program. The proposal includes a separate section for the PI to be the VIIRS Land Discipline Leader.

Bjorn Lambrigtsen/Jet Propulsion Laboratory
Microwave sounder Earth System Data Records

While both ATMS on S-NPP and AMSU-A/HSB on Aqua are primarily used to support joint microwave-infrared retrievals (with CrIS and AIRS, respectively), microwave-only retrievals are also important for atmospheric and climate research. Key weather and climate states, primarily associated with clouds, convection and precipitation, are poorly sampled by infrared systems. Products derived from infrared observations therefore suffer from various types of sampling bias. The work proposed here will largely eliminate these sampling biases by developing a set of microwave-only geophysical products that are equivalent to corresponding microwave-plus-infrared ones, but at the cost of reduced vertical resolution. In the current (IDPS) CrIMSS system, products derived from ATMS are counted as Intermediate Products (IP) and are both incomplete and do not undergo the same quality processing as the CrIMSS products do. In the AIRS system, a full set of microwave-only products are generated and distributed, but they also suffer from only limited quality control and have received limited scientific attention

We will develop a microwave sounder retrieval system that generates ESDR quality data on a par with CrIMSS and AIRS. Our approach will be to develop an initial retrieval system based on the AIRS microwave retrieval system. Later we will evaluate other existing retrieval components and systems and build on the best of them with only modest new code development. We will focus on physical retrieval systems and largely avoid empirical ones, such as neural networks and other regression methods, since the

latter are likely to have a particular weather/climate state embedded through their training set, limiting their suitability for climate research. We will work closely with groups who have candidate retrieval components or systems that meet ESDR requirements.

AMSU on Aqua was the first microwave sounder flown by NASA in the EOS era, but it was preceded and now accompanied by a number of NOAA AMSU instruments. We will treat the series of NOAA --> Aqua --> S-NPP microwave sounders as a single series for the purpose of developing an EOS era time series. We will develop a retrieval system to be applied uniformly across the combined AMSU ATMS record.This will enable a subsequent task of generating a merged data set spanning the entire EOS era, and continuing into the JPSS era. We will produce sample data sets to demonstrate the feasibility of such a reprocessing and data fusion project.

Our team is thoroughly familiar with the Aqua and NPP sounder retrieval systems, and we have strong connections with external groups with additional expertise.

ZhongPing Lee/University of Massachusetts Boston
Upgrade the Kd(490) Product to the Normalized Diffuse Attenuation Coefficient at 490 nm (nKd(490)) for Suomi NPP

The diffuse attenuation coefficient at 490 nm, Kd(490), is one of the standard ocean data products of the Earth Observing System (EOS), which represents an important component of the Earth Data Records (EDR). Traditionally, and even today, its derivation from satellite ocean color measurements takes the same approach as that for producing chlorophyll-a concentration ([Chl]), i.e. using the blue-green ratios of remote-sensing reflectance (Rrs) as the sole input to empirically generate the desired product. Such an approach is generally appropriate for deriving [Chl] in oceanic (or Case-1) waters, but is subject to inherent ambiguity and errors for Kd(490) for both oceanic and coastal waters. This is because that the diffuse attenuation coefficient is an apparent optical property, i.e. it varies with sun angle, while [Chl] does not. We propose to upgrade this attenuation product from two aspects: 1) remove the sun-angle related ambiguity, and 2) improve data quality through a retrieval system based on the radiative transfer theory. To achieve this upgrade, we propose to generate the normalized diffuse attenuation coefficient at 490 nm, nKd(490), from the Rrs products provided by Suomi NPP VIIRS. nKd(490) is defined as the diffuse attenuation coefficient for the Sun at zenith with a black sky, which matches the definition of the normalized water-leaving radiance (nLw) for satellite ocean color missions. This nKd(490) product is thus not only clear in its representation, but also facilitates its evaluation with field measurements. In addition, because nKd(490) will be produced through a mechanistic system rooted in the radiative transfer theory, this product will have higher science quality for the global oceans, in particular for turbid coastal waters. Furthermore, because the semi-analytical system takes a step-wise approach for the calculation of nKd(490), an uncertainty map of the nKd(490) product will also be generated via the error-propagation theory. The results from this effort will provide data products important not only to support the decadal continuity of the EDR, but also to study Earth from space to advance scientific understanding and meet societal needs.

Robert Levy/Goddard Space Flight Center
A Consistent Dark-Target Aerosol Data Record, Created from MODIS, VIIRS and Beyond

To answer fundamental questions about our changing climate, we must quantify the role of aerosols and how those aerosols are changing over time. This is a global question that requires regional characterization, because in some places aerosols are increasing and in others they are decreasing. For the last dozen years, NASA's EOS sensors have provided geophysical products, including the MODIS dark-target aerosol products used for research and routine applications. However, a dozen years is not long enough for determining climate change. Therefore, as we transition from EOS into successor programs such as NPP/JPSS, aerosol data continuity will be required to answer the question, are aerosols increasing or decreasing?

NPP-VIIRS has been orbiting on S-NPP since late 2011, and NOAA (through IDPS) is delivering an operational aerosol optical depth (AOD) product. Even though the IDPS VIIRS product is modeled on the traditional MODIS product there are many unavoidable differences introduced by differences in the sensors themselves and choices made during algorithm development. These differences result in subtle differences in the AOD products. When separately compared to sunphotometer (AERONET) data, globally, both datasets show similar accuracies. However, there are significant regional differences and the current IDPS VIIRS product cannot be used to extend MODIS's regional aerosol data record. By modifying the MODIS dark-target algorithm for use with VIIRS radiances, we can produce a VIIRS dataset more statistically similar MODIS historical one. Use of a common algorithm leads to a more consistent data set, and the potential for stitching together a MODIS VIIRS climate data record.

We are in an excellent position to systematically process VIIRS using this MODIS-heritage retrieval algorithm. Our proposal team has developed the successful MODIS aerosol product, and can repeat this success for VIIRS. There are issues, including calibration, Level 1 (Sensor Data Record) availability, and having access to an environment (e.g. SIPS) where the VIIRS data can be processed robustly. However, many of these problems can be mitigated, and the remainder can be characterized through validation procedures.

We intend to produce a MODIS-like product both in content and in structure to satisfy users who have invested infrastructure in accessing the MODIS aerosol product and need to continue their own products. For example, the CERES surface flux retrieval requires knowledge about the aerosol properties, which are in turn provided by retrievals from imager data in the field of view. MODIS provides constraints on Terra and Aqua, and VIIRS is used for S-NPP. Changes in aerosol retrieval approach will have a direct impact on surface radiation budget, which is important for understanding changes on surface energy budget, hydrology, etc. A consistent aerosol retrieval applied to VIIRS would

limit discontinuities related to the CERES flux records. Likewise, a consistent MODIS â VIIRS product is necessary for such applications as assimilation within forecast models and interpretation with regard to climate assessments.

During the MODIS era, we have become accustomed to a consistent time series of aerosol properties, and as we transition to VIIRS that consistency must continue. We propose to lead the community forward by producing a multi-sensor, multi-decadal, continuous time-series of aerosol properties adequate to answer global and regional climate questions, and compatible with the community's existing infrastructure built over the past 14 years.

Alexei Lyapustin/Goddard Space Flight Center
Generation of Advanced VIIRS Land-Atmosphere Product Suite with Algorithm MAIAC

This NOI addresses the ROSES-2013 A.29 call for the Suomi National Polar-orbiting Partnership (NPP) Science Team. This proposal capitalizes on our progress in the MODIS data processing algorithms developed at NASA under EOS science funding. A new Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm uses a novel approach based on a time series analysis and processing of groups of pixels. MAIAC product suite includes parameters for atmosphere (cloud mask, aerosol optical depth, particle size parameter and aerosol type (background, smoke, dust)), land (surface reflectance, BRDF, albedo, dynamic land-water-snow mask, seasonal/rapid surface change mask), and cryosphere (sub-pixel snow fraction and snow grain size/albedo for snow-covered surfaces). This product suite is "radiatively" united by the energy conservation principle. Because of uniquely high 1km resolution, ability to resolve fine aerosol sources and gradients, and good accuracy both over dark and bright/urban surfaces, MAIAC aerosol product generates an unparalleled interest in the air quality community. Recent land group analysis of MODIS Aqua data found a dramatic (a factor of 3-10) increase in accuracy of MAIAC NDVI over tropics compared to the standard MODIS NDVI. About 80% of this improvement comes from cloud mask, which is also less conservative and provides a factor 2-5 more clear-sky data for land analysis. As a consequence, a strong correspondence is now observed between MAIAC-based greening and browning anomalies over Amazonia with Multivariate ENSO Index, which does not exist with standard MODIS (or AVHRR) data.

The MAIAC/MODIS ATBD was written and passed the NASA ATBD Review. The operational version of code is presently tested on MODIS Adaptive Operational Processing System (MODAPS). Our own multi-disciplinary evaluation based on MAIAC processing of the entire MODIS Terra/Aqua records at continental scales (e.g., North and South America) has been ongoing for several years with public data release and broad science community involvement.

Because of higher observation frequency and constrained footprint growth with scan angle, VIIRS offers a particular advantage for MAIAC application. We have converted MAIAC for VIIRS. A limited testing showed a good consistency between MAIAC

datasets from VIIRS and MODIS Aqua, and a significant improvement over standard IDPS VIIRS products. We propose the following activities:
1) Update MAIAC VIIRS code to account for latest MAIAC-MODIS developments;
2) Optimize MAIAC for VIIRS to account for a different bandset, resolutions, and science capabilities (e.g., lack of NIR bands for precipitable water retrievals);
3) Produce and defend MAIAC ATBD at NASA Review panel;
4) Perform systematic comparison between MAIAC VIIRS and MODIS Aqua products, as well as document improvements from standard VIIRS IPs and EDRs.
5) Work with SIPS for operational implementation of MAIAC.
A very large volume of work already conducted for MODIS and VIIRS leads us to qualify MAIAC as Type 1 products, e.g., ready for operational production in less than 1 year.

Richard McPeters/Goddard Space Flight Center
OZONE DISCIPLINE LEAD
Improved Ozone Products from the OMPS Ozone Mapper and Nadir Profiler

We propose a three-year research program to improve the accuracy of the ozone products from OMPS. The proposal concentrates on the two nadir instruments, the Nadir Mapper and the Nadir Profiler, and is closely linked to a complementary proposal that concentrates on the OMPS Limb Profiler sensor. Under a previous proposal we evaluated the ozone EDR products produced by the NOAA operational system under the JPSS program. We found that the standard ozone EDR products produced by IDPS algorithms had implementation problems, but that the instrument produced high accuracy results when the algorithms developed by our group at NASA for the TOMS and SBUV instruments were used. For the nadir mapper we propose to implement our recently created version 9 algorithm, a Rodgers optimum retrieval algorithm that can use arbitrary sets of wavelengths. A significant advantage of this algorithm is that it produces error estimates for each retrieval. For the nadir profiler we propose to use the newest version of our SBUV/2 algorithm, the v8.6. We expect to improve retrievals in the troposphere by adding information from wavelengths below 312 nm to the nadir mapper algorithm. We plan to take full advantage of the Suomi-NPP instrument suite by ingesting data from other instruments such as the profile ozone from the limb profiler, snow maps from VIIRS and temperature profile from CrIS in an effort to improve our total and profile ozone products. For example, by using profile information from the OMPS limb instrument as the Ã priori for the nadir profiler, we hope to improve the accuracy of the retrieved profiles at altitudes below 25 km.

Peter Minnett/University of Miami, RSMAS
Sea-Surface Temperature from VIIRS - Extending the MODIS Time Series for Climate Data Records

The proposed activity will build on extensive experience of the PI and his group on deriving accurate Sea-Surface Temperatures (SSTs) from the two MODIS's, thereby ensuring continuity of the SST time series into the VIIRS era. It also builds on the experience and software used in the precursor study to assess the suitability of VIIRS

SST EDRs for scientific applications, and on the positive conclusions of that study. Our approach will be to use a combination of atmospheric radiative transfer modelling to simulate brightness temperate measurements and of matchups between VIIRS on-orbit data and sub-surface measurements from quality-controlled drifters to refine the algorithms for cloud screening and atmospheric correction to derive skin SSTs, and to assess their uncertainty characteristics. SI-traceable skin temperature measurements from a cluster of well-calibrated ship-board radiometers will provide independent determinations of the uncertainties and a mechanism for the rigorous generation of Climate Data Records of SST. The calibration and deployment of the suite of radiometers used by the PI's group will be part of this proposed activity. In our current VIIRS project, we have found that comparisons with the global SSTs derived from the WindSat microwave radiometer are a very useful tool in identifying spatial and temporal domains where the VIIRS SSTs are likely to have greater uncertainties, as the sources of uncertainties in infrared and microwave retrievals are mostly different. However, the orbit and scan geometry of WindSat result in global fields that are less than optimum for these comparisons; as soon as they are validated we intend to use SSTs from the Japanese AMSR-2 on GCOM-W1, which is in an A-train orbit and therefore much better suited for comparisons with VIIRS. A major focus will be on understanding the causes of the limitations on the accuracies for the VIIRS SSTs and how to overcome them, and in addition to the study of the brightness temperatures and retrieved SSTs, it will be necessary to understand the performance of the instrument on-orbit. Throughout earlier VIIRS study, the PI established a good working relationship with the VIIRS Characterization Support Team, led by Dr. X. Xiong, with a two-way flow of information; we anticipate this will continue throughout the period of performance of this proposed project. Also, throughout the previous VIIRS study, the PI interacted closely with the group at NOAA/STAR whose focus is on refining algorithms and processing streams for near-real time delivery to forecasting centers. This will continue throughout the proposed study to ensure a profitable dialog related to the on-orbit performance of VIIRS, even though the priorities and solutions to deriving SST for operational and for research applications are different. The model developed for the processing and reprocessing of MODIS SSTs will be adopted and developed for VIIRS. In the current MODIS scheme, the RSMAS team develops and revises the algorithms for deriving skin SST and delivers the code to the OBPG at GSFC; working with the OBPG, we test their implementation of the code to ensure the output fields are correct; the PO.DAAC at JPL takes the L2 skin SST fields from the OBPG and using uncertainty estimates we provide, and with additional data from ancillary sources generates the GHRSST L2P files for distribution to the community. The MODIS SSTs from Terra and Aqua are amongst the most-requested SST fields from the PO.DAAC. The L2P files are then delivered to the NOAA National Oceanographic Data Center for archiving and further distribution. In addition, the OBPG generates extractions of the MODIS brightness temperatures in the vicinity of the buoys and ship-board radiometers, as input to the Match-up Data Bases built at RSMAS. We will adopt this model for VIIRS, interacting with the VIIRS Ocean SIP, wherever it is situated, to ensure the continuation of the EOS SST data stream.

Jean-Luc MONCET/AER Incorporated
Refined Atmosphere Data Products from CrIS and ATMS

The atmospheric sounding algorithm developed by the Atmospheric Infrared Sounder (AIRS) Science Team (AST) resulted from a large development effort and has provided valuable science products. In parallel, there was a substantial development investment in an algorithm that has been installed in the Interface Data Processing Segment (IDPS) and is processing data from the sounding instruments on the Suomi National Polar-orbiting Partnership (S-NPP) platform. The AST and IDPS have each been demonstrated to perform well and have well-developed components, but neither is fully suitable for Earth science applications of data from AIRS, CrIMSS, and beyond. The NPP Sounding Group report provides recommendations, some of which requiring significant changes to the algorithm approaches, to address shortfalls in the suitability of these algorithms. Building on these existing capabilities and recommendations, we propose to:

Establish a modular, flexible algorithm software infrastructure, based on our current algorithm, allowing easy comparisons of the various key elements of the algorithms

Incorporate features from the AST and IDPS algorithms and additional enhancements, drawing on findings of NPP Sounding Group report to improve treatments of:

- clouds
- radiative transfer
- surface emissivity and refectivity
- background data
- profile representation methods
- Validate the algorithm
- Compile and update error and uncertainty analysis

The proposed algorithm will make optimal use of the S-NPP sounding measurements, exploiting current state-of-the art features and new advances, and will have error properties that make error characterization straightforward and reliable. The flexibility of the algorithm is such that it can be applied with virtually no revisions (other than data inputs) to AIRS data, to support a consistent data record spanning AIRS and S-NPP. The products of this algorithm will provide the basis for applications that address Earth science questions and lead to findings for which prior datasets were insufficient.

Ranga Myneni/Boston University
Global LAI-FPAR Earth System Data Records from Suomi VIIRS to Extend the EOS MODIS Time Series

One of the goals of the Suomi VIIRS instrument is to provide a continuation of the EOS record of climate-quality observations in the post-EOS sensor era. However, not all of the science data products being produced by the EOS instruments were included in the original Suomi program. NASA has decided to include several such omitted EOS data products, including LAI and FPAR, as part of the suite of data products to be generated from the VIIRS instrumental data. In response to the first call in 2010, the PI’s proposal to provide the algorithm, quality control and validate the LAI/FPAR products was selected for investigation. The primary objective of this successor proposal is to provide

and maintain the algorithm for operational production of global LAI/FPAR science data records by the NASA Suomi NPP Land SIPS from Suomi VIIRS data and to evaluate these products to assure continuity with the EOS MODIS product time series. This objective is realized through three sets of research activities (a) VIIRS LAI/FPAR algorithm refinement and implementation, (b) Evaluation of VIIRS LAI/FPAR ESDRs for accuracy, precision, uncertainty, spatial coverage and continuity, and (c) VIIRS project activities. The tangible end product of this proposal will be a continuous, well-characterized, long time series of global LAI and FPAR products, spanning the EOS and NPP era, suitable for research in Earth system science, global change and application studies.

Steven Platnick/Goddard Space Flight Center
Development of VIIRS L2 Cloud and L3 Gridded Atmosphere Team Products for NASA Research and EOS Data Record Continuity

Continuity of Level-2 (L2) cloud data records between MODIS and VIIRS is problematic because of the absence of key spectral channels on VIIRS (CO2-slicing, water vapor) and a significant change in the spectral location for a key shortwave infrared band used for cloud microphysical retrievals. We propose to further develop a suite of L2 algorithms, designed and tested by our team with previous NPP funding, which is applied to the spectral channels common to the two instruments. The code is based on the MODIS Collection 6 algorithms for cloud mask (MOD35) and cloud optical/microphysical properties (MOD06), and the GOES-R Algorithm Working Group (AWG) algorithm for cloud-top properties. Since the algorithms can be run with similar spectral observations from both MODIS and VIIRS, they provide the basis for establishing a continuous cloud data record across the two instruments. We also propose to develop cloud-top property retrievals from an Atmosphere PEATE algorithm that uses CrIS to generate MODIS-like CO2 and water vapor channels that, when combined with VIIRS channels, creates an observational data record closer to that available from MODIS alone. Alternatively, it can serve as the basis for continuing a combined Aqua MODIS/AIRS data record. The MODIS Atmosphere Team experience is that Level-3 (L3) retrieval statistics can be extremely sensitive to aggregation choices. We propose to develop a L3 VIIRS product, that at a minimum, includes aggregation choices and statistical datasets that provide compatibility with MODIS Atmosphere Team products (MOD08). In support of broader NPP Atmosphere Team needs, the effort will include MOD08-consistent aerosol and cloud datasets. We will also develop a merged VIIRS aerosol and cloud sampled L2 product (similar to the MODATML2 product) that can be used as a basis for users to develop research-specific gridded products. The proposed product development is responsive to solicitation section 2.2.1, Data Products for EOS Continuity. Based on solicitation definitions, development schedules are nominally Type 2 (VIIRS-only L2 product) and Type 3 (VIIRS/CrIS product, joint aerosol and cloud L3 and merged L2 product).

Crystal Schaaf/University of Massachusetts Boston
Suomi NPP VIIRS BRDF/Albedo/NBAR Products to Extend the Long Term Consistent MODIS Standard Data Record

Land surface albedo and the related surface reflectance anisotropy (as described by the bidirectional reflectance distribution function or BRDF) is an essential climate variable (ECV) required by global and regional climate and biogeochemical models. Thus albedo/BRDF has been recognized as a key land product for both the MODIS EOS record and the Suomi-NPP VIIRS record. Unfortunately the NOAA derived VIIRS albedo product only provides a single daily broadband albedo value with no accompanying BRDF information. It also does not offer any per band values to capture the surface radiation effects of the photosynthetically active shortwave, the near-infrared, or the shortwave infrared, all widely used for the canopy structure studies. This NOAA albedo product is extremely rudimentary representing little more than an average surface reflectance for time of overpass with virtually no quality or uncertainty information. In contrast the MODIS Albedo/BRDF products are rigorous per pixel characterizations of the intrinsic surface quantities with extensive quality and uncertainty information. The EOS-MODIS products have been extremely popular with the scientific and applications communities with the albedo data being used to initialize and tune climate models and monitor land, snow, and ice contributions to surface radiative forcing. The view angle corrected Nadir BRDF-Adjusted Reflectance (NBAR) values are particularly valued by the Direct Broadcast community and in general are being used to drive land cover and vegetation phenology studies and monitor range lands, agricultural fields, and impact of various disturbances. The intrinsic BRDF information is being used for studies of surface structure and variation and is also used to provide a priori surface anisotropy information for other satellite sensors with limited angular range such as MERIS, Landsat, and AWiFs and for satellite products such as cloud optical properties, surface temperature and emissivity, aerosol information, and low light imagery. The algorithms for daily BRDF/Albedo/NBAR products rely on cloud-free, multidate, multiangle surface reflectance data to capture appropriate BRDFs with particular emphasis on the day of interest to capture more the rapid daily variations. These daily values have been shown to provide improved monitoring of extreme environments and rapidly changing situations such as ephemeral snow, snow melt, coastal variations, and natural and anthropogenic disturbances. This proposal aims to transition the MODIS era daily algorithms for use with the VIIRS sensor with special emphasis on the different VIIRS channels, pixel resolutions, and upstream processes, and on the production of appropriate narrow to broadband conversions. Evaluations will utilize available aircraft and field data, particularly of challenging high latitude and coastal environments, and intercomparisons with MODIS and other multi-angle satellite products (e.g. SEVIRI, MISR) will be undertaken under the protocols of the CEOS/Working Group on CalVal (WGCV)/ Land Product Validation (LPV). Robust measures of uncertainty and extensive quality flags will also be produced to provide consistent long term Suomi-NPP VIIRS BRDF/Albedo/NBAR products to augment and extend the EOS/MODIS era record.

Wilfrid Schroeder/University of Maryland
S-NPP/VIIRS Active Fire Algorithm and Data Record Development and Refinement

The S-NPP/VIIRS active fire algorithm builds on the heritage EOS/MODIS Fire and Thermal Anomalies product, using a hybrid thresholding-contextual method to detect daytime and nighttime sub-pixel biomass burning activity, as well as other high temperature sources such as gas-flares, volcanic lava flow, etc. The new S-NPP/VIIRS active fire product will bridge the current EOS fire data record with the upcoming JPSS, providing continuity to the MODIS time series into the next decade. Compared to the MODIS active fire product, the current VIIRS operational product in the IDPS lacks a full 2D image classification array (fire mask) and essential sub-pixel fire characterization (fire radiative power) required by the user community. Here we propose to continue the development and refinement of the VIIRS active fire algorithm, including the design and implementation of new EOS-equivalent Level 3 (tiled) and 4 (gridded) derived products. Tuning of the algorithm to the specific spectral and spatial characteristics of the instrument will address large omission errors observed with the current version of the algorithms running in the IDPS (EOS Collection 4 equivalent) and the Land PEATE (EOS Collection 6 equivalent). We will build on the team's expertise working with pre- and post-launch S-NPP/VIIRS Level 1 data to develop a science quality active fire EDR, supporting the re-processing of the S-NPP/VIIRS data record once algorithm tuning and documentation (Algorithm Theoretical Basis Document) are completed. Provisions for Level 3 and 4 product generation will be included in the Level 2 active fire data set, incorporating all required metadata to enable efficient handling of the data. Data validation will be performed using available reference data, supporting algorithm development and refinement by building on similar protocols and accuracy metrics developed for the EOS active fire data record.

Thomas Stone/US Geological Survey
Enabling Quantitative Assessment of Suomi NPP VIIRS Radiometric Response Over Time by Calibration Against the Moon

The Suomi National Polar-Orbiting Partnership (NPP) satellite has extended NASA's collection of Earth environmental measurement data that are global in coverage and decadal in extent. As a pre-operational satellite, NPP has been purposed to acquire measurements for e.g. studies of long-term climate variability. The efforts of the NPP Science Team are directed toward securing high quality, long time series data records that enable continuity with NASA's Earth Observing System (EOS) missions, and forward into the Joint Polar Satellite System (JPSS) era. To assimilate observational datasets collected by radiometer instruments on multiple satellite platforms into a unified collection, consistent calibration among the different instruments and stability of the individual calibrations over the mission lifetimes is an essential requirement. The technique for using the reflected light from the Moon as a radiometric reference for Reflective Solar Band (RSB) imagers has a proven capability to meet both inter-calibration and stability requirements, and can provide a consistent reference to mitigate a gap in Earth observation coverage if needed. The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on NPP regularly views the Moon, and lunar calibration is an integral part of ongoing radiometric calibration efforts for the VIIRS RSBs. The radiometric reference standard for the Moon is provided by the Lunar Calibration program at the U.S. Geological Survey (USGS) in Flagstaff, AZ. Support for NPP VIIRS

calibration efforts using the Moon is provided by USGS through the NPP Science Team. This proposal seeks to continue the USGS presence on the NPP Science Team, to maintain lunar calibration support for VIIRS through established protocols and ongoing cooperation with the VIIRS calibration and validation teams. Additionally, lunar calibration is an indispensable component of the NPP Science Team Ocean Discipline's independent development of on-orbit calibration for VIIRS that is necessary to produce high-quality ocean color measurements. This proposal will maintain USGS support for these efforts, and will affirm association with the Ocean Biology and Biogeochemistry Measurements Team under the renewed NPP Science Team. Use of the Moon as a stable, consistent reference is an important part of the data quality assurance efforts to secure continuous calibration and enable continuity with EOS and eventually JPSS data products. The proposed activity will provide a necessary component to meet these goals.

Joel Susskind/Goddard Space Flight Center
Analysis of CrIS/ATMS Using an AIRS Version 6-Like Retrieval Algorithm

The objective of this proposal is to develop, test, and implement a CrIS/ATMS retrieval algorithm for the purpose of generating of long term climate data records which are consistent with those currently being produced operationally using AIRS. The status of the research is consistent with the Type-1 schedule.

The Suomi-NPP mission was launched in 2011 as part of a sequence of Low Earth Orbiting satellite missions under JPSS. NPP carries CrIS and ATMS, which are advanced infra-red and microwave atmospheric sounders that were designed as follow-ons to the AIRS and AMSU instruments on Aqua. One objective of AIRS/AMSU was to provide accurate unbiased sounding products with good spatial coverage that are used to generate stable multi-year climate data sets to study the earth’s interannual variability, climate processes and changes with time. To achieve the objective of this proposal, it is critical to process CrIS/ATMS using an algorithm similar to the currently operational AIRS Version-6 algorithm. We have been conducting research to optimize products derived from CrIS/ATMS observations using a preliminary version of the CrIS/ATMS retrieval algorithm, which is otherwise analogous to AIRS Version-6, but does not yet contain the benefit of a Neural-Net first guess start-up system which significantly improves results derived from AIRS. Our CrIS/ATMS algorithm produces most of the products generated by AIRS including temperature, moisture, trace gases, cloud products, and OLR. Our CrIS/ATMS temperature profile and surface skin temperature retrievals of very good quality, and are better than AIRS Version-5 retrievals, but are still significantly poorer than those of AIRS Version-6. The CrIS/ATMS retrievals will improve when a CrIS/ATMS Neural-Net start-up system is ready for use.

We recently received CrIS/ATMS Neural-Net coefficients and associated code from Bill Blackwell, the developer of the Neural-Net algorithm. We are currently in the process of implementing the CrIS/ATMS Neural-Net code into our CrIS/ATMS retrieval algorithm. When this implementation is completed, it will form the basis for our proposed CrIS/ATMS Version-6 retrieval algorithm. We will conduct further optimization studies and then port that code to the Sounder PEATE for implementation and long-term testing

with the goal of comparing CrIS/ATMS monthly mean level-3 products with analogous AIRS products. In this comparison, possible biases between level-3 results produced by the different instruments are less important than agreement between inter-month and interannual differences. In the event we see shortcomings in the CrIS/ATMS level-3 products, we will conduct further research to diagnose and alleviate them. In the meantime, we ported our current preliminary CrIS/ATMS processing system to the Sounder PEATE so that they can begin to generate many months of CrIS/ATMS monthly mean level-3 products which we will compare with AIRS Version-6. Our research should allow us to be ready for SIPS production in less than one year after award.

We are also examining CrIS/ATMS retrievals generated by NOAA using their NUCAPS retrieval algorithm. NOAA has no requirement or plans to generate level-3 NUCAPS products, but we have done so using NOAA's NUCAPS level-2 products and NOAA's suggested Quality Control procedures. The current NUCAPS algorithm appears to have limitations in spatial coverage which could hamper its utility for climate monitoring purposes. The Sounder PEATE will generate NUCAPS level-3 monthly mean products and we will evaluate them, together with those from our algorithm, as to their compatibility with those of AIRS Version-6.

Eric Vermote/Goddard Space Flight Center
Development of the VIIRS Climate Quality Surface Reflectance Product Suite

The primary objective of this proposal is the development of a well-calibrated, high quality, daily, multispectral-land surface reflectance product from the VIIRS sensor, providing global land observations to meet the needs of NASA Earth System Science and Applied Sciences and continuity with the EOS-MODIS surface reflectance product. Such a high quality, global, multi-year dataset is fundamental for interdisciplinary studies of the earth system and can be used to study a wide range of land and climate related questions, quantify land use and land cover change, providing the basis for time-series analysis to characterize processes and examine functions within the earth's land surface. A science quality surface reflectance product compatible with MODIS, will be a fundamental data record and a necessary input to several other VIIRS Land CDR's. It is recognized that the IDPS system is producing an intermediate surface reflectance product (SR-IP), however there is no plan of producing a consistent and reprocessed highly accurate surface reflectance from the beginning of the mission that will ensure the continuity with EOS-MODIS. It is recognized that the IDPS system is producing an intermediate surface reflectance product (SR-IP) and will make incremental improvements to known problems, however there is no plan for the IDPS to produce a consistent, reprocessed and highly accurate surface reflectance from the beginning of the mission that will ensure the continuity with EOS-MODIS and allow higher order CDR's to be developed.

This proposal covers the VIIRS surface reflectance product suite to continue the MODIS record: level 2 surface reflectance, gridded daily product, gridded 8-day composite product.

The focus areas will be:

a) The close monitoring of the calibration and instrument characteristics and their impact on the surface reflectance product as well as upstream product (VIIRS Cloud Mask (VCM) and Aerosol), we will act as the land liaison with the calibration, VCM and atmosphere group. We will also provide those critical inputs to downstream products (e.g. Vegetation indices, Albedo).

b) The continuous and systematic near real time Validation of the surface reflectance CDR product over the AERONET sites through the use of rigorous performance metrics (Accuracy, Precision and Uncertainties).

c) The in-house quality assessment of the global performance of the product as well as the quality flags (cloud mask, exception conditions) mainly by using the global daily product and cross-comparison with others dataset of opportunity (consistency with Aqua MODIS, CALIPSO data for clouds).

d) MODIS algorithm refinements from Collection 6 will be integrated into the VIIRS algorithm and shared with the NOAA JPSS project for possible inclusion in future versions of the operational product.

This proposal will develop a science quality standard product for NPP VIIRS Surface Reflectance. This proposal is a Type 1 proposal.

Jun Wang/University of Nebraska - Lincoln
Evaluate and Enhance Suomi NPP Products for Air Quality and Public Health Applications

We propose to evaluate and enrich the utility of SNPP data for applied science research. Following the SNPP's science strategy to continue the NASA's EOS data record, and to avoid future possible discontinuity of using NASA's data in air quality and public health applications, our proposed work has the following two components.

(1) PM2.5 air quality applications. We will (a) evaluate and improve the application of the (MODIS-type if possible) VIIRS aerosol product for the operational monitoring of PM2.5 air quality in Remote Sensing Information Gateway (RSIG) at the U.S. Environmental Protection Agency (EPA), (b) subsequently transfer RSIG's PM2.5 estimates to the Environmental Public Health Tracking Network (EPHTN) at the Centers for Disease Control and Prevention (CDC), and (c) evaluate and improve VIIRS-RSIG PM2.5 estimates for enhanced spatial predictions in on-going EPA-CDC EPHTN efforts, currently using CMAQ model output and filter-based PM2.5 observations from EPA-AQS. The PM2.5 derivation will build upon the team's expertise in this area and associated published methods by extending the use of aerosol vertical profiles from chemistry transport models from GEOS-Chem to regional models, WRF-Chem and WRF-CMAQ. We will also compare and contrast the differences among the use of AODs from MODIS Collection-6 algorithm, MODIS-type VIIRS algorithm, and existing VIIRS algorithm (maintained by NOAA) for air quality applications and surface PM2.5 estimates, and evaluate the feasibility of multi-sensor multi-product and multi-model ensemble approach (including the use of Bayesian downscaler model) for estimating surface PM2.5. To assess uncertainty and validate the PM2.5 estimate, we will use the

existing ground-based PM2.5 data and other EOS (such as CALIOP) data in addition to well suited validation data sets from the NASA DISCOVER-AQ Earth Venture-1 Mission along with two new Satellite-to-Air Quality VALidations (SAQ-VAL) sites located in the mid-atlantics region.

(2) Public heath (skin-cancer-related) applications. We will incorporate OMPS-based estimates of surface UVB irradiance and erythemal doses into the CDC's EPHTN, and apply them in both public heath advisory and skin cancer research. By integrating ground observations (AERONET), atmospheric chemical transport model (GEOS-Chem) simulations, VIIRS AOD, OMPS-based estimate of O3, and aerosol index, we will estimate surface UV irradiance and erythemal doses from OMPS, and thereby continue the TOMS and OMI surface UV product since 1970s. The surface UV irradiance and erythemal doses data are highly needed in the skin-cancer-related research that often relies on the model-based data. After evaluating the accuracy of the our UVB product with ground measurements, we will spatially match UVB exposure doses to 3,100 U.S. counties, and their association with county-level melanoma incidences reported by CDC and National Cancer Institute (NCI) will be studied (through the leverage of existing projects).

This applied science proposal fits the solicitation in section 2.1 of this NRA: incorporate Suomi NPP data products into decision support systems currently managed or used by one or more end-user organizations, and applications-related proposals can include the development of data products. Our interdisciplinary team includes experienced remote sensing experts, environmental exposure modelers, software engineer, and atmospheric modelers. The investigators collaborations with partners from EPA, CDC, NASA GSFC, and University of Wisconsin will further strengthen this proposed work and broaden the SNPP's applied science. The proposed tasks will be leveraged from (a) PI and Co-I existing projects that heavily use the MODIS and MISR aerosol products and OMI trace gas and UV product for air quality and public health applications; and (b) EPA and CDC's in-kind supports.

Frank Wentz/Remote Sensing Systems
Analysis and Mitigation of Atmospheric CrossTalk in VIIRS SST Retrievals

Sea-surface temperature (SST) is a key variable in depicting climate change, and the Committee on Earth Observation Satellites and the World Climate Research Program have designated SST as an essential climate variable. There currently exists a 33-year climate record of SST inferred from satellite infrared (IR) radiometers. The Suomi NPP Visible Infrared Imager Radiometer Suite (VIIRS) continues this timeseries of IR SST retrievals.

The thermal IR radiation seen by satellite radiometers is a product of both the ocean's skin temperature and the temperature of the intervening atmosphere. Water vapor, aerosols, and clouds all contribute to the atmospheric part of the temperature measurement. It is not uncommon for 80% of the received radiation to come from water vapor. Cold aerosols in the upper atmosphere can significantly depress temperature seen

by the satellite, and undetected clouds, which are completely opaque in the thermal infrared, will produce a cloud top temperature measurement rather than a measurement of SST.

SST retrieval algorithms are designed to remove the atmospheric part of the measurement by using the spectral information in the thermal IR measurements along with cloud clearing algorithms. However, some of the atmospheric temperature signal undoubtedly leaks through the retrieval algorithm, and the reported SST is a combination of the true SST and a temperature associated with the atmosphere. We call this algorithm deficiency atmospheric crosstalk, and it is by far the largest source of error for IR SST retrievals. Atmospheric crosstalk is a very serious concern for climate research. Possibly the most important aspect of climate variability, either anthropogenic or natural, is the complex interaction between the oceans and the atmosphere. One example is the Pacific Decadal Oscillation. It is essential for satellite climate measurements to uniquely distinguish sea surface temperature variability from atmospheric temperature variability.
Atmospheric crosstalk is a well-known phenomenon and has been discussed in the literature. Our investigation will build on the past research and provide a much more comprehensive and quantitative analysis of atmospheric crosstalk, particularly as it relates to sensing climate variability. The investigation will be based on the sensor combination of the S-NPP VIIRS and the Japanese space agency microwave (MW) radiometer AMSR2. The AMSR2 MW SST retrievals are not affected by the atmosphere (except for rain which is easily excluded). Also AMSR2 provides accurate retrievals of water vapor V and liquid cloud water L. Hence AMSR2 provides an ideal reference for studying the atmospheric crosstalk in the VIIRS retrievals.
Using the information we obtained from the atmospheric crosstalk analysis, we will develop and implement new, physically based SST retrieval algorithms for VIIRS. Two algorithms are proposed: VIIRS standalone and combined VIIRS and AMSR2. The VIIRS standalone algorithm is a physically parameterized statistical algorithm (PPSA). The PPSA+AMSR2 algorithm is an extension of the PPSA that requires the AMSR2 retrievals of SST, V, and L. Both algorithms will be designed to mitigate the atmospheric crosstalk on spatial and temporal timescales associated with climate change.
The analyses and algorithms developed under this VIIRS/AMSR2 investigation will be directly applicable to the MODIS/AMSR-E sensor combination on the NASA Aqua spacecraft. As an additional-cost option, we propose to include MODIS/AMSR-E as part of the investigation.

Kai Yang/University of Maryland College Park
Extending NASA's Long-Term Satellite Data Records: Advanced SO2 and NO2 Measurements from Suomi NPP OMPS

We propose to continue membership on Suomi NPP (SNPP) science team, with active participation in its focus group, Atmospheric Science Measurement Team, and to produce two key EOS standard Earth System Data Records (ESDRs), atmospheric SO2 and NO2 columns, using the measurements from SNPP OMPS Nadir Mapper (NM). Our main goals are to:

1. Continue and improve NASA's EOS Aura/OMI Level-2 SO2 and NO2 data records by producing high-quality (Type 1) products of vertical SO2 and NO2 columns from the hyper-spectral radiance measurements of SNPP OMPS NM;

2. Develop Level-3 SO2 and NO2 data (Type 2) products to serve the interests of a broader atmospheric composition and air quality user community;

3. Continue and improve our long-term explosive volcanic SO2 climate data record (CDR) that started with the TOMS missions in 1978 and continued to date with OMI, with improved explosive volcanic SO2 emission height estimates; Continue and improve the OMI public data record of volcanic degassing SO2 sources;

4. Continue and improve near-real-time (NRT) volcanic SO2 and ash detection for aviation decision support.

Motivation/Method/Results:

The mission essential SO2 and NO2 ESDRs, produced by Aura/OMI since 2004, have been used for a wide range of studies, from air pollution emission to climate forcing. As Aura/OMI is about to enter its 10th year in orbit and the unexpected instrument anomaly has degraded its spatial coverage, the continuation of the EOS global SO2 and NO2 ESDRs can only to be accomplished with new satellite sensors. SNPP OMPS, with its NM covering the wavelength range of 300 380 nm in a single spectral band (as opposed to OMI's division of this spectral range into two bands at 310 nm), is not only uniquely suitable for improved SO2 quantifications, but also highly capable of NO2 measurements. As members of the current NPP Science Team, we are tasked to evaluate the sensor data records of OMPS NM and have concluded that this instrument provides very stable and highly precise hyper-spectral Earthshine measurements, which can be exploited to create SO2 ESDR with quality that meet and exceed that achieved with Aura/OMI. Our recent research has further demonstrated that NO2 products, with quality sufficient to continue the Aura/OMI records, can also be created using longer wavelength measurements from SNPP OMPS NM. Both OMPS SO2 and NO2 results have been obtained using the same iterative spectral fitting (ISF) algorithm that we have developed and improved with previous and current NASA funding for simultaneous and consistent retrieval of O3, SO2, other trace gases (including NO2, BrO, HCHO), and aerosol index. In short, we can achieve the goals of this proposal by applying this matured algorithm to the full spectral measurements of SNPP OMPS NM for high quality SO2 and NO2 retrieval.

Our proposal responds to NASA solicitation of NPP Science Team in accordance to the requested investigations to develop science quality standard data products using Suomi NPP measurements that will enable continuity of key standard Earth system data records from NASA's EOS Terra, Aqua, and/or Aura satellites [A29, 2.1], and specifically, NASA is interested to develop science-quality Suomi NPP data products from OMPS to enable extension of the records of the following EOS data products: NO2 Total Column,

SO2 Total Column [A.29, 4.3.3]. Note that NOAA currently does not produce NO2 and SO2 standard products from SNPP OMPS.

The proposed research builds on the achievements of our proposal team in satellite remote sensing of atmospheric constituents and their validations, our expertise in instrument characterization, soft calibration, and artifact corrections, and our experiences in developing, implementing, and maintaining both the standard and NRT SO2 processing software for OMI and OMPS.

Xiaoyang Zhang/South Dakota State University
Development and Validation of a Global Land Surface Phenology Product from NPP VIIRS for EOS-MODIS Continuity

This proposal responds to ROSES2013 A.29 (NPP Science Team And Science Investigator-Led Processing Systems for Earth System Data Records from Suomi NPP), focusing on the development of science quality standard data products using NPP VIIRS that will enable continuity of a key standard Earth System Data Record (ESDR) from EOS data. Specifically, we propose to develop and implement an operational ESDR from VIIRS data focused on land surface phenology (land cover dynamics). This product is part of the MODIS land data product suite, but is not currently produced as a NOAA JPSS Environmental Data Record (EDR). Growing evidence has recently emerged that climate change-induced shifts and extremes in phenology have substantial impacts on agriculture, ecosystem function, biodiversity, and terrestrial carbon budgets at multiple scales. Timing of leaf-on and leaf-off periods also affects land surface albedo, exerting strong control on surface radiation budgets and the partitioning of net radiation between latent and sensible heat fluxes, impacting atmospheric boundary layer processes and affecting weather prediction. At multiple levels, there is critical need to produce accurate and timely global land surface phenology data sets from VIIRS.

The activity described in this proposal builds off more than a decade of previous work in this area by the PI and his co-investigators. Over the past twelve years, we developed and refined the only operational global land surface phenology product (MODIS MCD12Q2; a.k.a. land cover dynamics), which provides metrics characterizing seasonal dynamics in global vegetated land surfaces during the MODIS era. In addition, the PI has worked extensively with AVHRR data to produce land surface phenology data sets spanning the 30-year AVHRR record. Together, these products characterize the nature, magnitude, and timing of changes in phenology over past three decades. The work described in this proposal addresses two urgent needs: (1) to provide continuity with these data sets using VIIRS; and (2) to provide operational data streams for use in numerical weather prediction, carbon monitoring, agricultural planning, and disaster management.

The primary objective of this proposal is, therefore, to develop and implement an algorithm to produce continuous and well-calibrated time series of global land surface phenology metrics from VIIRS that provides continuity with the MCD12Q2 product from MODIS. The resulting datasets will be suitable for characterizing and understanding

interannual-to-decadal scale changes in ecosystem responses to a variable and changing climate. Specific tasks we propose include: (1) to develop and implement a land surface phenology product with a spatial resolution of 375-m from NPP VIIRS that provides continuity with MODIS phenology products; (2) to develop a phenology product with a spatial resolution of 0.05 degree from the VIIRS surface reflectance CMG (Climate Modeling Grid) that extends phenology measurements begun by AVHRR; (3) to conduct inter-comparisons between the VIIRS and MODIS phenology products to ensure continuity of the VIIRS product with the MODIS data record; (4) to evaluate and validate the stability, precision, uncertainty, accuracy, and spatial and temporal continuity of the proposed VIIRS phenology product; and (5) to deliver scientific code, and an associated Algorithm Theoretical Basis Document to the NASA-designed Science Investigator-led Processing Systems (SIPS).