NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences – 2012
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A.41 Making Earth System data records for Use in Research Environments

The National Aeronautics and Space Administration (NASA), through its Earth Science Data Systems, supports the NASA Earth Science research community in providing Earth science data products and services driven by NASA's Earth Science goals. NASA's Earth Science Program is dedicated to advancing Earth remote sensing and pioneering the scientific use of satellite measurements to improve human understanding of our home planet in order to inform economic and policy decisions and improve operational services of benefit to the Nation. Through MEaSUREs, NASA is continuing its commitment to expand understanding the Earth system using consistent records. NASA has begun to deploy new types of sensors to provide three-dimensional profiles of Earth's atmosphere and surface. Emphasis is placed into linking together multiple satellites into a constellation, developing the means of utilizing a multitude of data sources to form coherent time series, and facilitating the use of extensive data in the development of comprehensive Earth system models. Under the title program element of the ROSES-2012 announcement, proposals were solicited to focus on the creation of Earth System Data Records (ESDRs), including Climate Data Records. An ESDR is defined as a unified and coherent set of observations of a given parameter of the Earth system, which is optimized to meet specific requirements in addressing science questions. These records are critical to understanding Earth System processes, to assessing variability, long-term trends, and change in the Earth System, and to provide input and validation means to modeling efforts.

NASA received a total of 81 proposals in response to the Cooperative Agreement Notice element and selected 27 for funding.

Yehuda Bock/Scripps Institution of Oceanography
Solid Earth Science ESDR System

Building on NASA's investments in the measurement of crustal deformation from continuous GPS, the Solid Earth Science ESDR System (SESES) we will provide mature, long term ESDRs that support NASA's Earth Surface and Interiors (ESI) focus area, and meet the ESI science goals for understanding earthquakes and the processes that drive tectonic motion and crustal deformation. This project is responsive and directly relevant to the Group on Earth Observation s Global Earth Observation System of Systems (GEOSS) strategic targets for building an integrated system of systems, specifically in the areas of Data Management,Science and Technology, and User Engagement, with the focus in the Disasters and Weather GEOSS Societal Benefits Area,

By leveraging work under several earlier and ongoing NASA projects, SESES will:
(1) Continue to provide multi-decade calibrated and validated GPS-derived deformation time series and deformation vectors, based on daily GPS data that include GPS networks in western North America. The time series are a unique product in terms of number of

stations and duration (20 years), and have been modeled and catalogued for coseismic, postseismic and transient deformation, as well as instrumental offsets.
(2) Provide the following new multi-decade GPS-derived ESDRs:
(a) Expand current ESDR generation from the Western US to include global GPS sites.
(b) Troposphere delay time series for calibrating atmospheric delay errors in Interferometric Synthetic Aperture Radar (InSAR) that are one of the limiting InSAR error sources.
(c) Precipitable Water Vapor (PWV) time series for use in Probable Maximum Precipitation studies, historical weather event analysis, and studies of long-term water vapor trends.
(d) Fusion of GPS and seismic measurements at collocated stations to estimate three-dimensional high-rate displacement time series with mm precision, during significant historic seismic events (e.g., 2003 Mw 8.3 Tokachi-oki earthquake in Japan; 2010 Mw 7.2 El Mayor-Cucapah earthquake in northern Baja California; 2011 Mw 9.0 Tohoku-oki earthquake in Japan) and new events during the project duration.

Datasets to be used in constructing the ESDR include Global Positioning System data from multiple regional and global networks; seismic data (from broadband seismometer and accelerometers) collected at or near (1-2 km) of a GPS station; surface pressure and temperature data from onsite sensors, nearby weather stations, and weather models.

All ESDR s will be accessible through NASA's Crustal Dynamics Data and Information System (CDDIS), and will also be archived at the project s database at UCSD's Scripps Orbit and Permanent Array Center (SOPAC), where they would be accessible through the project s GPS Explorer web portal. SESES IT system has been designed using modern IT tools and principles in order to be extensible to any geographic location, scale, natural hazard, and combination of geophysical sensor and related data.

The team will continue to provide value and support to ongoing NASA Earth data system evolution by participating in Data System Working Group on Technology Infusion. The project s product quality and accessibility will continue to be scrutinized by a community-based advisory committee.

No new algorithm development is required. All algorithms used in this project will represent NASA technology investments through the AIST, ESI and ACCESS programs. Calibration and validation of the GPS measured deformation time series is done through a combined solution of two independently derived GPS position time series. In addition quality control tools based on Principal Component Analysis, developed under an AIST-08 project will be applied to the time series. Calibration and validation of the GPS troposphere and precipitable water series will be likewise done by comparing the independently derived parameters.

Mary Brodzik/National Snow and Ice Data Center

An Improved, Enhanced-Resolution, Gridded Passive Microwave ESDR for Monitoring Cryospheric and Hydrologic Time Series

One of the goals of the NASA Earth Science Enterprise Research Strategy is to develop data sets that advance our understanding of the cryosphere and its relationship with the rest of the Earth System on time scales of seasons to a few years (NASA, 2000). Variations in sea ice extent, terrestrial snow and vegetation cover, upper ocean circulation, and atmospheric circulation are mutually interactive and generate significant variations of climate on seasonal to interannual time scales, both globally and in specific regions. Our proposal addresses climate variability by continued production and enhancement of Level 3 gridded passive microwave data sets valuable in understanding the dynamics of the cryosphere and terrestrial ecosystems, together with interactions with the global climate and the hydrologic cycle, over a variety of seasonal, interannual and multi-decadal time scales.

Polar snow and ice-covered ocean and land surfaces are especially sensitive to climate change and are observed to fluctuate on interannual to decadal timescales. Due to limited sunlight and meteorological sensitivity, microwave data is particularly useful for measuring this variability and to address the specific role that snow and ice play in both influencing and responding to the long-term state of the oceans and atmosphere. Passive microwave radiometers have been a mainstay of remote sensing of the cryosphere, despite being available at relatively low resolutions (~25 km) compared to optical techniques (less than 1 km). They provide short-timescale, large-area spatial coverage, and high temporal repeat observations, for monitoring hemispheric-wide changes.

Most users of radiometer data prefer to use gridded Level 3 data for cryosphere studies. Currently available global gridded passive microwave data sets serve a diverse community of hundreds of data users, but do not meet many requirements of modern ESDRs or CDRs, most notably in the areas of intersensor calibration and consistent processing methods. The original gridding techniques were relatively primitive and were produced on grids that are not easily accommodated in modern software packages. Further, since the time that the first Level 3 data sets were developed, the Level 2 passive microwave data on which they are based have been reprocessed as Fundamental CDRs (FCDRs) with improved calibration statistics. There is now a great need to regenerate gridded Level 3 products using improved techniques from these modern Level 2 FCDRs.

Using validated, state-of-the-art interpolation methods, we propose a complete reprocessing using the most mature available Level 2 satellite passive microwave records from 1978 to the present. We will reprocess the complete data record from SMMR, SSM/I-SSMIS and AMSR-E in a single, enhanced-resolution gridded passive microwave ESDR. The ESDR will make use of the latest improvements to the Level 2 SSM/I-SSMIS and AMSR-E data record that are newly available this year. The new, gridded ESDR will satisfy the needs of current and future users who require a reliable, consistent, gridded time series of microwave radiometer data

Sean Buckley/Jet Propulsion Laboratory

NASADEM: Creating a New NASA Digital Elevation Model and Associated Products

Our objective is to provide the scientific and civil communities with a state-of-the-art global digital elevation model (DEM) derived from a combination of Shuttle Radar Topography Mission (SRTM) processing improvements, elevation control, void-filling and merging with data unavailable at the time of the original SRTM production:

• NASA SRTM DEMs created with processing improvements at full resolution
• NASA ICESat/Geoscience Laser Altimeter (GLAS) surface elevation measurements
• DEM cells derived from stereo optical methods using Advanced Spaceborne Thermal Emission & Reflection Radiometer (ASTER)
data from the NASA Terra satellite
• Global DEM (GDEM) ASTER products developed for NASA and the Ministry of Economy, Trade & Industry of Japan by Sensor
Information Laboratory Corp
• National Elevation Data for US & Mexico produced by the US Geological Survey (USGS)
• Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) developed by the USGS & the National Geospatial-Intelligence
Agency (NGA)
• Canadian Digital Elevation Data produced by Natural Resources Canada

We propose a significant modernization of the publicly- and freely-available DEM data. Accurate surface elevation information is a critical component in scientific research and commercial and military applications. The current SRTM DEM product is the most intensely downloaded dataset in NASA history. However, the original Memorandum of Understanding (MOU) between NASA and NGA has a number of restrictions and limitations; the original full resolution, 1-arcsecond data are currently only available over the US and the error, backscatter and coherence layers were not released to the public. With the recent expiration of the MOU, we propose to reprocess the original SRTM raw radar data using improved algorithms and incorporating ancillary data that were unavailable during the original SRTM processing, and to produce and publicly release a void-free global 1-arcsecond (~30m) DEM &error map, with the spacing supported by the full-resolution SRTM data.

We will reprocess the entire SRTM dataset from raw sensor measurements with validated improvements to the original processing algorithms. We will incorporate GLAS data to remove artifacts at the optimal step in the SRTM processing chain. We will merge the improved SRTM strip DEMs, refined ASTER and GDEM V2 DEMs, and GLAS data using the SRTM mosaic software to create a seamless, void-filled NASADEM. In addition, we will provide several new data layers not publicly available from the original SRTM processing: interferometric coherence, radar backscatter, radar incidence angle to

enable radiometric correction, and a radar backscatter image mosaic to be used as a layer for global classification of land cover and land use.

This work leverages an FY12 $1M investment from NASA to make several improvements to the original algorithms. We validated our results with the original SRTM products and ancillary elevation information at a few study sites. Our approach will merge the reprocessed SRTM data with the DEM void-filling strategy developed during the MEaSUREs 2006 project of Co-I Kobrick.

NASADEM is a significant improvement over the available 3-arcsecond SRTM DEM primarily because it will provide a global DEM and associated products at 1-arcsecond spacing. ASTER GDEM is available at 1-arcsecond spacing but has true spatial resolution generally inferior to SRTM 1-arcsecond data and has much greater noise problems that are particularly severe in tropical (cloudy) areas. At 1-arcsecond, NASADEM will be superior to GDEM across almost all SRTM coverage areas, but will integrate GDEM and other data to extend the coverage. Meanwhile, DEMs from the German Tandem-X mission are being developed as part of a public-private partnership. However, these data must be purchased and are not redistributable. NASADEM will be the finest resolution, global, freely-available DEM products for the foreseeable future.

Eric Fetzer/Jet Propulsion Laboratory
A Multi-Sensor Water Vapor, Temperature and Cloud Climate Data Record

We will create a combined data record of clouds, water vapor and atmospheric temperature incorporating all water vapor measurements by A-Train sensors. Under a currently funded MEaSUREs proposal we are combining AIRS/AMSU water vapor and CloudSat cloud observations. However, these represent only about 1% of the total available water vapor observations in the A-Train swath, and CloudSat includes less than half the temporal coverage of AIRS and AMSR-E (2006-2010 versus 2002-2012). This new effort will incorporate cloud information from MODIS, AIRS/AMSU, MLS, and AMSR-E in addition to CloudSat and CALIPSO. We will generalize cloud insights gained from our current experience with CloudSat to the other A-Train sensors, and build on other cloud analysis capability being developed with funding by the NASA SCIS program. The new record will include every water vapor and temperature observation from AIRS/AMSU, MLS and AMSR-E over the 10 year A-Train lifetime. Our objective is to fully characterize cloud information obtained by A-Train instruments, and relate those cloud characteristics to observed water vapor. Our approach will use MODIS and AIRS/AMSU cloud information to characterize the cloud state for all A-Train water vapor observations. We will generalize our current experience for those water vapor observations along the CloudSat/CALIPSO track. The novelty of the proposed work is the incorporation of all A-Train water vapor scenes. This will include roughly two orders of magnitude more observations from several sensors, and extend over the entire A-Train record of about a decade. We will also examine the cloud state of water vapor observations taken by NOAA and METOP A AMSU-B instruments when they are

collocated and contemporaneous with the A-Train. The methodologies developed will be applicable to sounder/imager combinations on other spacecraft.

Bryan Franz/Goddard Space Flight Center
Production and Distribution of MERIS Data Products in Support of the Ocean Color Climate Data Record

The European Space Agency (ESA) MEdium Resolution Imaging Spectrometer (MERIS) has been operating from the ESA/ENVISAT satellite since it was launched in 2002, producing global radiometric observations of the Earth in the visible to near-infrared spectral regime at a resolution of 1.2-km, with regional data collection at 300-meter resolution. MERIS is capable of producing data products similar to those of MODIS and SeaWiFS, to study land, ocean, and atmospheric processes and global change. Recently, ESA agreed to provide the full MERIS dataset of calibrated top-of-atmosphere radiances to NASA in exchange for the MODIS and SeaWiFS datasets. This proposal seeks to develop full processing and distribution support for global ocean color products derived from the recently acquired MERIS Level-1B archive. Processing will be done using standard NASA software and algorithms identical to those employed for MODIS and SeaWiFS, and output products will be generated in standard NASA Level-2 and Level-3 formats. The resulting products will be used to support sensor time-series intercomparison and cross-calibration studies within the NASA Ocean Biology Processing Group, thus providing a valuable tool for assessing error in the multi-mission ocean color time-series that is now challenged by the ending of SeaWiFS operations in 2010 and significant degradation in the performance of the aging MODIS sensors. The data products produced from MERIS will be made available to the public through the same distribution mechanisms currently available for all other NASA Ocean Color missions, with full user support and analysis tools, thus readily enhancing a host of on-going research and applications in Ocean Biology and Biogeochemistry and enabling new investigations that exploit the expanded coverage and unique features that MERIS contributes.

Joaquim Goes/Lamont Doherty Earth Observatory
A Time Series of Sea Surface Nitrate and Nitrate Based New Production in the Global Oceans

The sinking of organic material produced by photosynthesis from the upper euphotic layers into the ocean's interior represents a potential long-term sink for atmospheric CO2. Its magnitude is regulated primarily by the supply of inorganic nitrogen, primarily nitrate (N), to the euphotic layer (Eppley and Peterson, 1979; Lewis et al., 1986, Platt et al., 1989, Flynn and Fasham, 1997). For this reason, understanding the space and time variations of N availability in the euphotic layer is a highly essential aspect of research concerning ocean carbon cycling processes and climate change. Despite its importance, N data obtainable by traditional shipboard techniques fall far short of the spatial and temporal scales required for global climate research. Although N

in seawater lacks a distinct electromagnetic signature that can be utilized for its estimation from space, remote sensing data has been suggested as a promising alternative to in situ measurements because N correlates well with seawater temperature. Empirical algorithms for sea surface nitrate (SSN) based on its relationship with sea surface temperature (SST) have been in existence for quite a while, but their application over large temporal and spatial domains has been limited, due to the time and space varying nature of SSN-SST relationships. We have shown however, that it is possible to obtain robust estimates of SSN over local, regional and basin scales at daily, weekly monthly and interannual time scales using remotely sensed Chlorophyll (Chl) and SST (Goes et al., 1999, 2000, 2004). We have also shown the immense potential of this method for mapping N-based new production (NnP) in order to measure of carbon export into the world's oceans (Goes et al, 2000, 2004a, b). Here we propose to create two innovative Earth Science Data Records (ESDRs), one SSN and the other NnP, using mature ESDRs of Chl available from NASAs SeaWiFS and MODIS-Aqua and of SST available from the US National Oceanographic Data Center s (NODC) Long-Term Stewardship and Reanalysis Facility (LTSRF). By aiding in assessments of carbon drawdown into the world's oceans and by providing an innovative means for validating and improving coupled ecosystem models that currently rely on global maps of N generated from multi-year data sets, our proposed ESDRs offer the potential to greatly improve our understanding of the role of the oceans in global carbon cycling, earth system processes and climate change especially in regions and seasons which are inaccessible to traditional shipboard studies. Large-scale data production will be accomplished in collaboration with NASA s Ocean Biology Processing Group (OPBG), which will make the time series evaluation products and related documents available to the public from their web site. The processing system, including routine check for accuracy and quality control, will be designed to accommodate future sensors with ocean-color capabilities. We also plan to disseminate data locally through Columbia University s International Research Institute (IRI), Climate Data Library portal. We envision that our products will be utilized by two communities working on Ocean Carbon Cycling and Global Climate Change studies. This proposal responds to the objectives of the MEaSUREs program that will 1) provide and add mature data records for NASA Earth System research and produce scientific analysis tools and service capabilities; 2) provide a calibrated product with described uncertainties; 3) employ community involvement in ESDR development and apply standards and interfaces for exchange of data and information through a collaboration with OBPG at GSFC; and 4) support ongoing data system evolution.

Matthew Hansen/University of Maryland

Vegetation Continuous Fields ESDR for the AVHRR and MODIS Records: 1981 - Present

Vegetation continuous fields (VCFs) depict the sub-pixel fraction of three land cover types: tree cover, bare ground and non-tree vegetation. The tree cover type is further partitioned into fractions of needleleaf, broadleaf, evergreen and deciduous tree cover. VCF depictions improve upon traditional land cover characterizations in which each pixel is assigned a single land cover class. Earth Science Data Records (ESDRs) are a

consistent time series of observations over decades, developed by NASA to answer critical Earth science questions. It has been recognized by the science community that VCFs are an important and basic measurement of the land surface that should be included in the ESDR compilation. VCF products have been adopted by a significant and growing number of Earth science researchers, including use in global and regional climate models, global terrestrial carbon cycle models, hydrology, fire ecology, habitat studies and agricultural monitoring. Researchers frequently express the need for a longer, consistent time series suitable for identifying land cover change and for validating models.

The proposal team has successfully created global VCF products, first single products from AVHRR and MODIS data, and recently, annual products from MODIS Collection 5 at 250m resolution. The regression tree methods developed for these efforts are robust across temporal and spatial resolutions, and satellite instruments. In addition, we have developed reusable, flexible code, built upon open source libraries, which automates model building and data processing.

Building on the heritage of previous MEaSURES projects, we will use the Land Long Term Data Records (LTDRs) of daily surface reflectance and normalized difference vegetation index (NDVI) to provide a coherent input data set. These new long-term data sets will provide the core products needed to create consistent multi-instrument VCF LTDRs from 1981 to the present.

We propose to create Earth Science Data Records (ESDRs) of global vegetation continuous fields from AVHRR and MODIS LTDRs for 1981 through the most current data available. Annual data products of percent tree cover, percent non-tree vegetation cover and percent bare ground at 0.05 degree resolution will be produced for all time periods. We will also create five-year products that further partition tree cover into needleleaf, broadleaf, deciduous and evergreen classes. A supervised regression-tree method will be used with phenological and physiological metrics derived from the LTDRs and with training derived from Landsat supplemented by high-resolution data from Ikonos, RapidEye and QuickBird. A reference data layer of fractional water cover will be included in the product, and error estimates and quality flags will be provided for each data product pixel and for the product as a whole. Software and data developed for this project will be freely available to the scientific community.

Because of the extensive use of VCF representations by the carbon modeling community, we propose to evaluate the implications of using the VCF ESDRs in the CASA-GFED3 carbon cycle model. We will use the extended VCF time series to prescribe biomass allocation patterns in CASA-GFED3 and determine the sensitivity of modeled carbon fluxes and carbon flux uncertainties to the new VCF data.

George Huffman/Science Systems and Applications, Incorporated

Next-Generation Global Precipitation Climatology Project (GPCP) Data Products

The suite of current GPCP precipitation products (Version 2) based on global observational data has become a science community standard, having been used in over 2500 journal articles. The current monthly (1979-present), pentad (1979-present), and daily products (1997-present) have been developed by research groups over the last 15 years and are produced by a consortium of those groups, supported and sometimes funded by various agencies. The GPCP is the precipitation component of an internationally coordinated set of (mainly) satellite-based global products dealing with the Earth s water and energy cycles, under the auspices of the Global Water and Energy Experiment (GEWEX) Data and Assessment Panel (GDAP) of the World Climate Research Program. The GDAP (Chair: C. Kummerow) is coordinating the development and production of the next generation of products covering the water and energy cycles to enhance the community s ability to analyze the Earth s climate processes for the satellite era (~30 years).

We propose to produce the next generation (Version 3) of GPCP merged precipitation products, which will involve a significant shift to new data streams, modern Level 2 algorithms, advanced merger techniques, and finer time and space resolutions. We will complete the development of the techniques, implement the techniques to merge the relevant data sets into a consistent, globally complete observationally based precipitation analysis at various time scales from monthly to 3-hourly, and provide quality control, validation, and uncertainty estimation for the products. In parallel, precipitation estimates from numerical reanalyses will be merged with the observations to provide additional joint observation-model products with improved quality where model use is acceptable. Throughout, the CDR standards of consistency and homogeneity will be emphasized. The final result will be on-going production of an improved suite of inter-consistent products over the time span 1979-present with resolutions matching the other GEWEX-related water/energy cycle products. Specifically, the products will cover the period 1979-present at the monthly and pentad time scales, the period 1982-present for daily, and the period 1998-present for 3-hourly. One important difference from other data sets is that all these products will be inter-consistent for all overlapping time spans.

Leveraging NASA-funded products and research is a key part of the work. The analyses will utilize a number of NASA and NASA-supported data sets, algorithms and products, including those based on SSMI and SSMIS (using GPROF), AIRS, TRMM, and the forthcoming GPM. This proposal will also be linked to the current MEaSUREs effort to provide error estimates for precipitation products at monthly to 3-hr time scales, so that the new GPCP Version 3 products will have attached bias and random error estimates.

We expect these data sets to provide key input to the climate community in the broad sense, namely users who require long, global records of precipitation that emphasize CDR characteristics ahead of instantaneous precision. The various time resolutions are intended to support modern requirements for distributions of precipitation rate at a variety of time scales. This consistent set of products over a range of time resolutions will allow the critical study of climate-scale fluctuations and their connection to weather-scale variations and extremes.

Ian Joughin/University of Washington
Greenland Ice Mapping Project Two: Measuring Rapid Changes in Ice Flow

Numerous recent studies have revealed rapid change in ice discharge from, as many of the ice sheet s outlet glaciers have accelerated dramatically over the last decade. These observations are significant in that they show Greenland s mass balance can fluctuate rapidly and unpredictably. Despite the large magnitudes of these changes, we do not yet understand the underlying processes controlling fast flow well enough to determine their long-term impact on sea level. As a consequence, outlet glacier dynamics were a wild card in the sea-level projections included in the Fourth Assessment by Intergovernmental Panel on Climate Change (IPCC), and will remain so in the upcoming Fifth Assessment. Improving such predictions and gaining a firm understanding of the dynamics that drive mass balance requires annual to sub-annual observations of outlet glacier variability (velocity and ice front position) to avoid aliasing of this rapidly varying signal. The technology for measuring velocity in Greenland is mature and, under the ongoing Greenland Ice Mapping Project (GIMP-1), we are regularly measuring the velocity of the Greenland Ice Sheet, establishing a record from 2000 to 2012. Here we propose to continue this effort so that we continue to measure Greenland ice flow velocity until 2017, a period when Greenland should continue to evolve rapidly with the current warming. In addition to providing products of utmost priority to the community currently trying to assess ice sheet stability, this project will provide important baseline data for future generations. In particular, GIMP-2 will provide an important precursor data set to NASA‘s DESDynI L-band SAR mission scheduled to launch near the end of the decade. In addition, GIMP-2 velocity measurements will provide a strong complement to the thinning measurements made by NASA s ICESAT-2 and IceBridge missions.

Seiji Kato/Langley Research Center
A Long-Term TOA and Constrained Surface Radiation Budget Dataset Using Merged CERES, ERBE and ISCCP/SRB Products from the Past 30 Years

The CERES TOA and surface radiative flux records have recently eclipsed the 10-year time series threshold. Similar broadband instruments (scanner) also made measurements from November 1984 through February 1990 (ERBS), from February 1985 through January 1987 (NOAA9), and from November 1986 through May 1989 (NOAA10) under Earth Radiation Budget Experiment. In addition, an ERBE/ERBS nonscanner record spanned nearly 20 years, bridges ERBE scanner and CERES measurements. Two other ERBE nonscanner made measurements from February 1985 through December 1992 (NOAA9) and from October 1986 through November 1994 (NOAA10). We propose to recalibrate the ERBE nonscanners and produce radiometrically consistent top-of-atmosphere (TOA) shortwave and longwave irradiance level 3 products. In addition, using nonscanner- and scanner-derived TOA irradiances as a constraint and based on ERBE and GEWEX-SRB modeled surface irradiance products, we propose to produce level 3 surface irradiance products that are consistent with observed TOA irradiances in a

framework of 1D radiative transfer theory. Furthermore, based on these TOA and surface irradiance products, we will develop a data product contains the contribution of atmospheric and cloud property variability to TOA and surface irradiance variability. All algorithms used in the process are based on existing CERES algorithms. The proposed project utilizes knowledge gained in the last 10 years through CERES data analyses and apply the knowledge to existing data to develop long-term (nearly 30 years) consistent and calibrated data product (TOA irradiances at the same radiometric scale) from multiple missions (ERBS and CERES). All data sets produced by this proposed work will be available from Langley Atmospheric Science Data Center.

John Kimball/The University of Montana
Continuity and Enhancement of the Global Earth System Data Record for Landscape Freeze/Thaw State Dynamics

We propose to extend and enhance the Earth System Data Record (ESDR) quantifying daily landscape freeze/thaw (FT) state dynamics over all global vegetated land areas where seasonal frozen temperatures are a significant constraint to ecosystem processes, including land-atmosphere carbon, water, and energy fluxes. The freeze/thaw ESDR (FT-ESDR) captures dynamic seasonal to annual variability, and large regional and global trends in frozen temperature constraints to landscape water mobility and ecosystem processes in response to recent climate change. The proposed FT-ESDR continuity and enhancements will provide a continuous global data record encompassing almost four decades and representing one of the longest satellite environmental data records in existence, while providing an extended domain, finer spatial resolution FT retrievals for the northern latitudes and increased product science utility over the existing global baseline.

The proposed activities are the logical extension of an expiring MEaSUREs activity (Kimball, PI; McDonald, Co-I), and build on a successful FT-ESDR developed by merging overlapping satellite passive microwave daily brightness temperature (Tb) records from the Scanning Multichannel Microwave Radiometer (SMMR) and Special Sensor Microwave Imager (SSM/I). The FT-ESDR includes a consistent and relatively precise (>80% mean spatial classification accuracy) daily (AM and PM) classification of the predominant frozen and non-frozen status of the landscape at moderate (25-km) resolution, with detailed metadata. We propose to continue the global FT-ESDR baseline by incorporating additional calibrated Tb records from the continuing SSM/I series, while documenting product accuracy in relation to global WMO station observations and similar FT retrievals from other satellite microwave records.

The proposed activities will utilize lessons learned from our initial FT-ESDR development and ongoing validation and product quality assessment activities. We will also evaluate potential enhancements to the FT-ESDR baseline, including an expanded product domain encompassing the larger cryosphere, production of regionally enhanced FT records for northern (>/=45N) land areas using similar overlapping Tb records from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) and WindSat, with

potential two- to four-fold spatial resolution enhancement over the existing FT-ESDR baseline.

The proposed FT-ESDR serves several Earth Science focus areas and associated user communities, including Water & Energy Cycle, Carbon Cycle & Ecosystems, and Climate Variability & Change. The initial FT-ESDR (version 01) is publicly available through the NSIDC DAAC; current (Feb-012) user metrics for these data indicate more than 2083 hits and 138 GB of data downloaded to the community, with more than 20 known scientific publications involving these data, while the number of users, science applications and publications from these data continue to grow. The proposed FT-ESDR continuity and enhancements will enable precise detection and diagnosis of both climate variability and long-term trends extending over almost 40 years. The proposed activities will directly benefit the NASA SMAP mission, which has a planned mid-2014 launch and will provide an operational FT product similar to the FT-ESDR; the proposed data records will inform mission science and product development and validation, and provide baseline information for assessing the global change significance of future FT measurements from SMAP and associated accuracy requirements, validation and uncertainty measurements for meeting mission objectives.

Nickolay Krotkov/Goddard Space Flight Center
Multi-Decadal Sulfur Dioxide Climatology from Satellite Instruments

Sulfur Dioxide (SO2) is a short-lived gas primarily produced by volcanoes, power plants, refineries, metal smelting and burning of fossil fuels. Where SO2 remains near the Earth s surface, it is toxic, causes acid rain, and degrades air quality. Where SO2 is lofted into the free troposphere, it forms aerosols that can alter cloud reflectivity and precipitation. In the stratosphere, volcanic SO2 forms sulfate aerosols that can result in climate change. The SO2 Group has a unique multiyear experience in detecting, tracking and measuring volcanic eruptions and degassing and anthropogenic pollution from space. Our group primarily uses UV satellite data from the Ozone Monitoring Instrument (OMI) on NASA's EOS-Aura satellite and the Total Ozone Mapping Spectrometer (TOMS) on multiple satellites. However, our TOMS volcanic SO2 data as well as the most accurate off-line OMI SO2 retrievals are not yet publicly available.

We propose to create and archive a long-term consistent SO2 ESDR combining measurements from backscatter Ultraviolet (BUV), thermal infrared (IR) and microwave (MLS) instruments on multiple satellites. Our approach is applying our unique in-flight calibration techniques and our mature validated SO2 algorithm to obtain the best measurement based ESDR of volcanic and anthropogenic SO2 masses and emissions, including SO2 height information. The UV data will be complemented with IR and MLS data to extend coverage at night and high-latitude winter months. The ESDR will contain quality assessments that would enable users to judge the reliability and precision of the data. The ESDR will be available on our product oriented public web site: http://so2.gsfc.nasa.gov

Proposed combined SO2 record will produce the best estimates of the volcanic and anthropogenic contribution to global atmospheric SO2 concentrations. Such measurements are essential given the growing concern over the response of the Earth to anthropogenically-forced climate change, effectiveness of air quality regulations and intercontinental transport of air pollution. Since SO2 is the major precursor of sulfate aerosol, which has climate and air quality impact, SO2 measurements will contribute to better understanding of the sulfate aerosol distributions and its atmospheric impact.

Ronald Kwok/Jet Propulsion Laboratory

ESDR of Small-Scale Kinematics of Sea Ice of the Arctic and Southern Oceans: A New Data Set Based on Envisat

We propose to continue the production of ESDRs of Arctic sea ice motion with acquisitions from ESA s Envisat Synthetic Aperture Radar (SAR). In addition, we will provide, for first time, data sets of sea ice motion of the Southern Ocean: the coverage of the Envisat SAR of the Southern Ocean allows routine ice motion products of the Weddell and Ross Seas to be derived and distributed to the general science community for understanding climate and the changes in the Southern Ocean ice cover. The available Envisat data set spans the period from April 2007 to April 2012 and provides denser spatial and temporal sampling of the sea ice cover compared to RADARSAT-1 (RS-1), which helps fill the gap in small-scale ice motion observations between the termination of the RS-1 data stream in mid-2008 through the potential Sentinel-1 (launch date in 2013) data stream.

We propose to construct more refined products based on the denser temporal Envisat coverage for the science community. This proposal is offered as a direct successor to the current MEaSUREs work, which builds upon and extends earlier work supported by NASA. This ESDR will form a unified and coherent set of observations of sea ice motion of the Arctic and Southern Oceans. The ice motion ESDR will be optimized for characterizing sea ice kinematics at the small scale, which will be useful for constructing climatologies, understanding mass balance and observed trends, model validation and model improvements.
We propose: 1) to process the Envisat data stream to construct a record of small-scale ice motion of the Arctic and Southern Oceans; 2) to develop products that take advantage of the temporal and spatial sampling scheme of the Envisat mission; 3) to produce mosaics of the Envisat images of the Arctic Ocean; 4) to create a multi-year time series of Fram Strait and Nares Strait sea ice export; and, 5) to address the use of Sentinel-1 data sets for producing ESDR of the Arctic and Antarctic ice cover . The image mosaics are new products that will support a wide variety of research topics and comparison with historical SAR datasets from ERS-1, ERS-2, and RS-1. These datasets will add to the publicly available archive of RADARSAT image and ice motion products.

Felix Landerer/Jet Propulsion Laboratory

An Earth System Data Record of Earth's Surface Mass Variations from GRACE and Geodetic Satellites

We propose to continue our current MEaSUREs activities by providing a high-quality, consistent Earth System Data Record (ESDR) of Earth s surface mass changes, derived from temporal gravity field variations as observed with the twin GRACE-satellites (Gravity Recovery and Climate Experiment) and with geodetic satellites (e.g., Lageos, Starlette, Ajisai, Stella) tracked by satellite laser ranging (SLR). The GRACE satellites, launched in 2002, resolve monthly time changes of gravity between spherical harmonic degrees 2 and 60 (resolving length scales from roughly 9000 to 300 km, respectively). The GRACE mission has proven to be the single-best technology available for comprehensive, global, near real-time monitoring of surface mass changes. GRACE has observed climate-relevant phenomena such as ice mass loss (from Greenland, Antarctica, glaciers and ice caps), groundwater depletion (e.g., over India or California), and ocean mass changes (e.g., global sea level rise from ocean mass changes as well as regional variability associated with ocean currents). While offering less spatial resolution (only up to approximately 5000 km), surface mass changes from satellite laser ranging techniques provide a much longer data record, since 1976. In addition, SLR methods are highly complementary to GRACE in that SLR is particularly sensitive to low-degree harmonics, and can help to constrain these components during the GRACE period. Thus, we propose to combine GRACE and SLR data, augmented by geocenter estimates. To derive a consistent record, SLR data needs to be processed with the same geophysical background models as GRACE. Upon improving and homogenizing the SLR and GRACE records, we propose to use established EOF-reconstruction methods to establish a long-term data record with more information content than SLR alone. This activity will help bridge the likely data gap between the current GRACE and the GRACE Follow-On mission, scheduled for launch in 2017.

The gravity field solutions delivered by the GRACE-Science Data System (SDS) are still improving through better background models as well as from improved knowledge of internal satellite alignments and orbit determination. While the GRACE-SDS does not provide gridded surface mass fields, these types of products are what most geoscientists require for their research & applications projects. Going from spherical harmonics to a gridded surface mass product requires several GRACE-specific complex filter and correction steps, which need to be carefully implemented and adjusted for a variety of processing parameter choices. A central goal of our project is to broaden the user community of data products derived from GRACE and geodetic satellites beyond the traditional users, dominated by geodesists. We will provide a long-term, climate-quality ESDR of global surface mass variations that is consistent over time, optimized for relevant applications, with uncertainty estimates, and well documented for user-ready applications. Based on our past successful ESDR projects, we are confident that the outlined strategies to improve and add value to the existing time-variable gravity observations can achieve this goal.

The proposed ESDR products fulfill a critical need for the precise understanding of Earth s climate system dynamics, providing data records for land, ocean and cryospheric applications. We will distribute all data via our GRACE tellus website in CF-compliant formats, and partner with JPL s PO.DAAC to use several of their data services. The demonstrated utility and broad uses of GRACE data are behind NASA's decision to approve GRACE-FO rather than wait until the 2020s for a GRACE-II mission as recommended in the Decadal Survey in 2007. GRACE and GRACE-FO also figure prominently in the 2010 NASA SMD Science Plan.

Dennis Lettenmaier/University of Washington
Development of Pre-SWOT ESDRs for Global Surface Water Storage Dynamics

The scarcity of global-scale water use data limits the ability of the land surface schemes used in earth system models to represent the effects of water management impacts on the land surface water and energy balances. As a result, many such models ignore human impacts on the water cycle altogether. In addition, river flows are poorly monitored in many regions of the world. Furthermore, the amount of water stored in liquid phase at the land surface and its space-time variability, which have implications for sea level rise, are poorly known. Satellite altimeters provide one source of data that has the potential to these effects. Although the current generation of nadir-pointing track altimeters was intended primarily for ocean problems, impressive progress has been made in estimation of the relative variations in height of large lakes and reservoirs globally, and the heights of some rivers. The constraints imposed by track altimeters on the availability of altimeter-derived surface water data will be resolved with the launch of the Surface Water and Ocean Topography (SWOT) mission, expected in 2019. While current altimeters are constrained for the reasons noted above, there nonetheless will be great value in producing quality controlled records of those elements of the surface water cycle that SWOT will measure, and for which records can be established back to the beginning of the satellite era, preparatory to the SWOT mission. We propose here to extend the existing inland water altimetry-derived data sets (mostly of surface heights) in several ways. First, we will utilize all available altimetry data (especially including Jason-1 and 2 during the post-TOPEX era). Second, we will extend recent work by the PIs group to estimate storage change in large natural lakes and river channels as well as reservoirs using altimetry-based heights and surface extent from visible sensors (primarily MODIS). Third, we will develop altimetry-based records of surface slope, width, and elevation for a set of large global rivers, based on multiple track altimeter crossings and from MODIS-based (and possibly other visible band) surface width estimates. We will also extend the coverage of river information by retracking altimetry measurements to maximize accuracy of river heights for rivers of moderate width. In addition, we intend to produce model-based estimates of surface water storage (in lakes, reservoirs, and river channels) and fluxes (runoff and streamflow) from the mid-20th century to present. Our work will draw from three current inland water altimetry data sets (USDA/GRLM, CNES, and ESA). For this, reason, we have direct links to all three on the project team. This proposal is directly relevant to the call s request for projects that & provide precursor products [to planned missions, specifically SWOT] that begin to baseline geophysical

parameters that will be produced from these satellites ... and & develop long-term, consistent, and calibrated data and products that are valid across multiple missions and satellite sensors. The project supports the Group on Earth Observations (GEO) Integrated Global Water Cycle Observations (IGWCO) theme objectives 1 and 2, and the needs of the GEO Global Climate Observing System (GCOS) and the Global Terrestrial Network (GTN) which list lake level and river discharge as Essential Climate Variables. The project team consists of PI Dennis Lettenmaier and Co-I Bart Nijssen (University of Washington), Co-Is Charon Birkett (University of Maryland), Eric Wood (Princeton University), and C.K. Shum and Mike Durand (Ohio State University), and unfunded collaborators Sylvain Biancamaria (CNES/LEGOS) and Jerome Benveniste (ESA), all of whom have extensive previous experience with the processing and development and/or application of satellite altimetry products to inland waters.

Nathaniel Livesey/Jet Propulsion Laboratory
A Long-Term Record of Upper Stratospheric and Mesospheric Temperature Profiles

Long-term data records of temperature profiles spanning the upper stratosphere and mesosphere (US/M hereafter) are sparse and intermittent. This region is, however, far more sensitive to climate change than is the lower atmosphere: US/M temperature trends of ~2-3 K/decade have been reported, compared to ~0.2 K/decade at lower altitudes. We will produce a long-term observational dataset of daily, near-global US/M temperature profiles from roughly 25-80 km altitude covering 1991 to the present. This unique and valuable new record spanning over 20 years will facilitate studies that advance our understanding of US/M processes, how those processes are affected by climate change, and coupling of the US/M to the lower atmosphere.

The record will include observations from the Microwave Limb Sounder (MLS) on the Aura satellite (launched in 2004) and the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on the Thermosphere, Ionosphere, Mesosphere, Energetics, Dynamics (TIMED, launched in 2002). Data for 1991 to 1998 will be taken from the earlier MLS instrument on the Upper Atmosphere Research Satellite (UARS, launched in 1991). The record will be augmented with more-coarsely-sampled (approximately monthly global coverage) solar occultation observations from the Halogen Occultation Experiment (HALOE) on UARS, the Fourier Transform Spectrometer (FTS) instrument on the Canadian Atmospheric Chemistry Experiment (ACE, launched in 2004) mission, and the Solar Occultation for Ice (SOFIE) instrument on the Aeronomy of Ice in the Mesosphere (AIM, launched in 2007) mission. The UARS HALOE record will be used, in conjunction with long-term ground-based records from lidar, to bridge the gap between the UARS and TIMED/Aura periods. Biases between all the datasets will be quantified and 'bias-corrected' datasets will be generated and validated.

To accomplish these objectives, we will:

* Produce a 'definitive' record of US/M temperature from UARS MLS: The operational use in retrievals of a model with polarized radiative transfer calculations, required for accurate temperature retrievals in the mesosphere, was not computationally feasible during the UARS era. Advances in computing power make possible the application of the algorithms and software developed and proven for the later Aura MLS instrument to UARS data.

* Produce an 'independent' record of US/M temperature from Aura MLS: Current Aura MLS retrievals are focused on providing the most accurate record of atmospheric composition, at the expense of some simplifications and approximations in processing the temperature observations. They use daily meteorological analysis fields as a priori constraints, which could result in biases in long-term trends. The Aura MLS record will be reprocessed to remove these issues.

* Produce daily global gridded data for UARS/Aura MLS and TIMED SABER, using a well-established Fourier synoptic mapping approach.

* Quantify and ameliorate of biases between instrument and with respect to ground-based data to provide a consistent, bias-corrected, long-term US/M temperature record.

* Generate derived products including winds, potential vorticity and static stability to facilitate studies of dynamical processes in the US/M, using existing well-established software.
All the products described above will be validated with respect to the available correlative data and made available to the scientific community.

David Long/Brigham Young University

Improved, Enhanced-Resolution, Gridded Passive Microwave ESDR for Monitoring Cryospheric and Hydrologic Time Series

One of the goals of the NASA Earth Science Enterprise Research Strategy is to develop data sets that advance our understanding of the cryosphere and its relationship with the rest of the Earth System on time scales of seasons to a few years (NASA, 2000). Variations in sea ice extent, terrestrial snow and vegetation cover, upper ocean circulation, and atmospheric circulation are mutually interactive and generate significant variations of climate on seasonal to interannual time scales, both globally and in specific regions. Our proposal addresses climate variability by continued production and enhancement of Level 3 gridded passive microwave data sets valuable in understanding the dynamics of the cryosphere and terrestrial ecosystems, together with interactions with the global climate and the hydrologic cycle, over a variety of seasonal, interannual and multi-decadal time scales.

Polar snow and ice-covered ocean and land surfaces are especially sensitive to climate change and are observed to fluctuate on interannual to decadal timescales. Due to limited sunlight and meteorological sensitivity, microwave data is particularly useful for

measuring this variability and to address the specific role that snow and ice play in both influencing and responding to the long-term state of the oceans and atmosphere. Passive microwave radiometers have been a mainstay of remote sensing of the cryosphere, despite being available at relatively low resolutions (~25 km) compared to optical techniques (less than 1 km). They provide short-timescale, large-area spatial coverage, and high temporal repeat observations, for monitoring hemispheric-wide changes.

Most users of radiometer data prefer to use gridded Level 3 data for cryosphere studies. Currently available global gridded passive microwave data sets serve a diverse community of hundreds of data users, but do not meet many requirements of modern ESDRs or CDRs, most notably in the areas of intersensor calibration and consistent processing methods. The original gridding techniques were relatively primitive and were produced on grids that are not easily accommodated in modern software packages. Further, since the time that the first Level 3 data sets were developed, the Level 2 passive microwave data on which they are based have been reprocessed as Fundamental CDRs (FCDRs) with improved calibration statistics. There is now a great need to regenerate gridded Level 3 products using improved techniques from these modern Level 2 FCDRs.

Using validated, state-of-the-art interpolation methods, we propose a complete reprocessing using the most mature available Level 2 satellite passive microwave records from 1978 to the present. We will reprocess the complete data record from SMMR, SSM/I-SSMIS and AMSR-E in a single, enhanced-resolution gridded passive microwave ESDR. The ESDR will make use of the latest improvements to the Level 2 SSM/I-SSMIS and AMSR-E data record that are newly available this year. The new, gridded ESDR will satisfy the needs of current and future users who require a reliable, consistent, gridded time series of microwave radiometer data

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Stephane Maritorena/University of California at Santa Barbara
Creating Unified Ocean Color Data Records with Uncertainties

The generation of unified satellite data records through the merging of ocean color data from multiple sensors has proven beneficial to the science users community at various levels. First, merged products offer improved coverage of the ocean at daily to monthly time scales, which reduces the uncertainties in estimates derived from those products for both local and global studies. Second, merged data products often have lower uncertainties than the same product from any single sensor. Last, data merging has also proven a powerful tool to identify inconsistencies among the different data sources or issues with the sensors radiometry. In all, data merging benefits both the ocean color and biogeochemistry science that uses its data and the inter-sensors calibration/validation activities.
Here, we propose to continue the development of unified and coherent ocean color time series through the merging of data from multiple sensors. We will continue the development of merged ocean color products from the GSM semi-analytical model. This model merges data at the Remote sensing reflectance level and derives several biogeochemically relevant data products simultaneously along with uncertainty estimates

at each pixel. In addition, we will also generate merged products from higher level data (e.g. chlorophyll-a concentration) as such products are no longer available to the science community. We will also develop new merged ocean color products. In particular, we will develop a merged remote sensing reflectance product that will allow users to work with a data set with improved spectral resolution and lower uncertainties. Last, uncertainty estimates for all merged products will be generated on a pixel-by-pixel basis. All products and uncertainty estimates will be validated through matchup analyses. The merged records will cover the time span over which multiple ocean color sensors are or will be available (SeaWiFS, MODIS, MERIS, VIIRS, OLCI,&). Both global (9-4 km resolution from level-3 data) and regional (1-4 km resolution from level-2 data) merged products will be developed.

Eric Rignot/University of California Irvine
Ice Velocity Mapping of the Antarctic Ice Sheet

Ice sheets hold the largest potential for sea level rise in the coming decades to centuries and represent the largest source of uncertainty in projected sea level rise (IPCC AR4, 2007; Willis and Church, 2012). At present, the ice sheets in Greenland and Antarctica are already contributing significantly to sea level change (Rignot et al., 2011). Ice sheet surface velocity is a fundamental observable of their dynamics, that has only been available recently from space and that is central to assessments of past, current and future contributions to sea level (USCCRP, 2012). Here, we will generate and distribute continental-scale, multi-year, digital ice velocity vector products of the Antarctic continent as Earth Science Data Records (ESDR) to the research community. We have developed experience in a prior MEaSUREs project to generate these ESDRs, overcome major technical and scientific hurdles, quantify errors for the first time, and distribute the ESDRs to the broad research community (Rignot et al., 2011a). The new ESDRs and ancillary products such as grounding line positions and image mosaics from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and international Interferometric Synthetic-Aperture Radars (InSAR)) will help document the rate of change in ice sheet dynamics and boundaries, the rates of ice mass flow to the ocean and contribution to sea level rise, and the sensitivity of ice dynamics to climate forcing on multi-decadal time scales for the first time. These ESDRs will in turn play a central role in the development of more realistic numerical ice sheet models coupled with atmospheric and oceanic numerical models to produce more reliable hindcasts and forecasts of ice sheet evolution. Data required for this project will be provided by a suite of satellites operated by international agencies that cooperated with NASA in a highly successful pole-to-cost InSAR coverage of Antarctica for the International Polar Year (IPY) 2008-2009 that is unique in the history of remote sensing and collaboration between space agencies. These agencies have expressed the desire to continue this collaboration beyond the 2008-2009 International Polar Year. The project will therefore employ data from the Canadian Space Agency RADARSAT-2, the Japanese ALOS PALSAR-2, the European Sentinel-1, as well as historical data from RADARSAT-1, ALOS PALSAR, Envisat ASAR and ERS-1/2 going back to 1996. The project will also provide a pathway for NASA's DESDynI-R mission to be flown around 2017. The

ESDRs will be generated using well-proven, documented and peer-reviewed algorithms and numerical tools developed over the past twenty years that represent the state of the art in mapping ice sheet velocity from space, independent of cloud cover and solar illumination, at a uniform, high-resolution sampling of entire continent. For data distribution, customer support and feedback, we will continue to partner with the National Snow and Ice Data Center, in Boulder, CO, a national data depository for cryospheric science products, with international reputation and unmatched experience archiving, documenting and distributing cryospheric data and querying its scientific impact on the research community, educational entities and the public at large. Glaciologists, ice sheet modelers, climate scientists, geophysicists, physical oceanographers, solid earth scientists, atmospheric scientists, biologists and geologists, scientist interested in the Antarctic continent at large but also educational professional, organizers of field logistics, journalists and the public will use these ESDRs. These science products will establish a long-term legacy for Antarctic science and the evolution of Polar Regions in a warming climate. The project will serve the highest science objectives of NASA's Earth Science Mission Directorate in climate change research, in particular its science objectives in the study of the Earth's ice cover and sea level rise.

William Rossow/The City College of The City University of New York
Globally Merged, Reconciled and Gridded Observations of Near-Surface Atmospheric and Land Surface Properties and Their Diurnal-to-Decadal Variations

Investigations of land-atmosphere interactions have usually tended to rely, in part, on a variety of models to describe either atmospheric conditions near the land surface (global or regional weather analyses or forecast models) or the variations of land surface properties with changing weather conditions (land surface models) because some aspects of the near-surface meteorology or land properties were not readily available from observations. However, the detailed behavior of these models, usually run with the atmosphere and surface uncoupled, has not been verified. Earlier projects to pull together global, combined data products, namely the International Satellite Land Surface Climatology Project (ISLSCP) and the Global Soil Wetness Project (GSWP, which used some of the ISLSCP product), were focused primarily on assembling a comprehensive set of the atmospheric forcing for land surface models (LSMs). There are three reasons to revisit this activity. The first reason is that there are a number of conventional and satellite products that were available at the time of the previous studies but not used: in particular, diurnally resolved surface observations of air temperature, humidity and winds, boundary layer cloud properties and the diurnal variations of land surface skin temperatures. Although there were problems with these data products, including sparse spatial coverage and accuracy, the second reason is that there are now available new versions or new data products from new sensors that improve the quality of information available for land surface albedo, skin temperatures, higher-time-resolution precipitation, new soil moisture products, high-vertical-resolution profiles of temperature, humidity and clouds (also land surface properties from MEASURES products). The third reason is that in the previous products, many of the key quantities specific to the interaction of the atmosphere and land, namely fluxes of energy and water (even carbon) between them,

were represented only by model outputs, not observation-based analyses, because the latter were not available. Now there are new observation-based products quantifying the diurnal variations of all aspects of the surface radiative, sensible heat and latent heat fluxes soon to be available from GEWEX. However, the variety of data products and observations now available still represents a wide range of space-time sampling intervals and space-time coverage; moreover, there are often many alternate products available but without knowledge of their relative merits. To assemble this collection of information into a coherent and physically consistent set that accurately quantifies the global variations of the near-surface atmospheric and the surface properties from diurnal to decadal scales requires a lot of work to reconcile the resolution and coverage differences, to evaluate quality of the multiple products and to project these products into a common space-time framework. To support and foster investigations of the interaction of the atmosphere and land surface, we propose to construct a multi-variate data product that reconciles the variation scales of these measurements, merges and maps them into a comprehensive description of the near-surface atmospheric properties together with the land surface property variations on diurnal-to-decadal time scales. The atmosphere would be represented by near-surface windspeeds, temperature, humidity, downwelling radiation, boundary layer cloudiness and type. The land surface would be represented by its albedo, infrared and microwave emissivities, skin temperature, upwelling radiation, soil moisture, topography, land type, roughness length and other relevant vegetation properties. We will also explore how much more information about the atmospheric boundary layer can be obtained from available observations to augment the surface meteorology and boundary layer cloudiness information.

David Roy/South Dakota State University
Global Long-Term Multi-Sensor Web-Enabled Landsat Data Record

The previous 2006 NASA MEaSUREs solicitation funded the Web Enabled Landsat Data (WELD) project. The WELD project has demonstrated the capability to generate and distribute Landsat 7 ETM+ 30m composited and mosaicked Earth System Data Records with a weekly, monthly, seasonal, and annual reporting frequency for the conterminous United States (CONUS) and Alaska. This proposal seeks to (1) extend the CONUS and Alaska WELD Earth System Data Record back to 1982 when the first Landsat 30m data started to be acquired and (2) to expand the WELD processing to global scale to provide Landsat 30m information for any terrestrial non-Antarctic location for six 3-year epochs spaced every 5 years from 1985 to 2010. Specifically, in collaboration with researchers at NASA AMES and the University of Maryland, we propose to generate the following combined multi-sensor (Landsat 4, 5 TM and 7 ETM+) 30m products:

1. Weekly, monthly, seasonal and annual products, CONUS and Alaska, 1982 to 2012, defined in the current WELD product Albers projection, generated at the PI s institution;

2. Annual percent land cover and 5-year land cover change products, CONUS, 1985 to 2010, Albers projection, generated at the PI s institution;

3. Monthly global products, for six epochs (1985, 1990, 1995, 2000, 2005, 2010), 36 months per epoch, defined in the MODIS Sinusoidal projection, generated on the NASA Earth Exchange (NEX) supercomputer at NASA AMES; and

4. Global percent land cover and change for each 36 month epoch (1985, 1990, 1995, 2000, 2005, 2010), MODIS Sinusoidal projection, generated on USGS global 30m land cover initiative hardware at the USGS EROS.

This MEaSUREs proposal directly supports the moderate global spatial resolution data needs of the climate and global change science communities and the needs of the applications community.

The WELD products will be archived and distributed from USGS EROS, and the cost borne by the USGS EROS. Including the NASA AMES request, the annual mean budget is approximately $968,000 and totals for the 5 years to $4,842,228.

Justin Sheffield/Princeton University
Development of Consistent Global Long-Term Records of Atmospheric Evaporative Demand

Evapotranspiration (ET) can be considered as the linchpin climate variable because it forms the link between the water, energy and carbon cycles at the Earth s surface. Understanding the evolution of ET is a key factor in climate change, playing a central role in the potential acceleration of the water cycle, providing land-atmosphere feedbacks, and modulating extreme events such as droughts and heatwaves. Controls on terrestrial ET are particularly complicated and are constrained by surface radiation, the atmospheric boundary layer, and the state of the vegetation-soil system. Accurately modeling terrestrial evapotranspiration processes is fundamental to understanding past changes in climate, and climate predictions and projections. ET is driven by atmospheric demand (radiative and aerodynamic controls) and surface limitations (environmental and ecophysical controls). Much of the uncertainty in ET derives from uncertainties in atmospheric evaporative demand, often referred to as potential evapotranspiration (PET). This quantifies the combined effects of available radiation for evaporation and the ability of the atmosphere to accept evaporated water. Multiple studies have documented regional changes in the components of PET, and have shown that changes in pan evaporation, a measurement proxy for PET, have been driven by changes in solar radiation, vapor pressure deficit and wind speed. However, global, long-term estimates of PET and its trends are very uncertain because of the lack of observations. Yet this is crucial for understanding the potential for acceleration of the hydrological cycle and its extremes, the role of temperature as a presumed forcing of change, and the robustness of projected future changes from climate models.

The goal of this proposal is to develop an ESDR for PET, including the supporting surface meteorological and radiation data. It may appear that an ESDR for PET is rather limited, given that an ESDR for actual ET is more directly relevant to a range of science problems, but this proposal shows the importance of providing a consistent, long-term, global dataset for PET as a necessary first step towards a consistent global ET dataset and the challenges of doing this. The project will provide a 1982-2008 (and potentially longer) dataset of land atmospheric evaporative demand at 3-hour, 0.25-degree resolution. Additionally, the project will develop long-term and consistent estimates of the ancillary data sets of near surface meteorology and radiation, needed to calculate the global variation in PET, including its uncertainties. We will use a suite of existing and newly reprocessed observational and remote sensing datasets of radiation and meteorology to determine the uncertainties in long-term trends in forcing variables of PET. Uncertainties will be derived from detailed analysis of the consistency of remote sensing products and how they replicate in-situ data trends. These will be merged with empirical estimates and reanalysis data to form consistent records of forcing variables. The proposed PET ESDR addresses NASA's goal of developing long-term, consistent Earth System Data Records that can drive advancements in understanding the climate system by taking a prerequisite step towards improved understanding of the role of ET in a changing climate and thus making progress towards better prediction of climate change and particularly extreme events. The work contributes exactly to the MEaSURES call by developing a PET ESDR that integrates across satellite products and merges with available in-situ observations. The work is well aligned with the recommended GCOS Essential Climate Variables for the near surface atmosphere and is essential for subsequent derivation of ET, closure of the terrestrial water and energy budgets, and improved land surface ECVs. Furthermore, the ESDR will contribute to evaluation of impacts related to humidity, radiation and wind and for design of renewable energy systems.

Martin Snow/University of Colorado
Multi-Satellite Ultraviolet Solar Spectral Irradiance Composite (MUSSIC)

Solar spectral irradiance (SSI) in the ultraviolet wavelength range (0-400 nm) provides the primary direct energy input to the Earth's atmosphere. This irradiance has been measured by a variety of space-based instruments for the past 30 years. However, the datasets from these individual instruments have different levels of uncertainty in their absolute calibration and corrections for instrumental drifts. The atmospheric and global climate change communities need a single, consistent, long-term dataset that combines the individual instrumental records.

In this proposal, we will compare the ultraviolet SSI measurements from NASA's Solar Radiation and Climate Experiment (SORCE) to the observations from NOAA's Solar Backscatter Ultraviolet (SBUV/2). The SBUV/2 instrument has been included on both current and prior NOAA missions. Additionally, we will compare the SORCE measurements to ESA s Global Ozone Monitoring Experiment (GOME) and SCanning Imaging Absorption SpectroMeter for Atmospheric CartograpHY (SCIAMACHY). The SORCE instruments were carefully calibrated before launch and their uncertainties are

well understood. The other SSI instruments on other satellites in this study do not have strong preflight calibrations or methods for maintaining their inflight accuracy. Our analysis will transfer the SORCE calibration to these other datasets which overlap SORCE in both wavelength and time.
Previous composite ultraviolet SSI datasets (e.g. DeLand & Cebula, 2008) only use data through 2004. Our work will extend these datasets to the current epoch including the recent solar minimum and the rise of cycle 24. We also propose to extend the multi-satellite composite to include the Extreme Ultraviolet (EUV) wavelength range (0-120 nm). Previous work used only the 120-400 nm range. Since there are long periods without observational coverage in the EUV, we propose to use the Flare Irradiance Spectral Model (FISM) published by Chamberlin et al. (2007) to fill these gaps. This model is an empirical model based on solar activity proxies.

In addition to the SSI composite, we will produce a composite Mg II index from 1978 to the present. The Mg II index is used as a proxy for ultraviolet solar activity in many climate models, and the currently available composites end before the last solar minimum.

Joao Teixeira/Jet Propulsion Laboratory
A Data Record of the Cloudy Boundary Layer

Objective: To create a science-driven multi-sensor multi-parameter earth system data record of duration 10+ years of observations and uncertainty characteristics of the subtropical cloudy boundary layer. In addition to aggregating existing level-3 products, unique elements of the record will include: (1) a long term (25+ year) climate data record of liquid water path based on an existing data-fusion algorithm for all available conically scanning microwave radiometers (SSM/I, TMI, AMSR-E, SSMIS, AMSR2, GMI); (2) a climatology of planetary boundary layer height from the global positioning system; (3) a multi-sensor approach to derive boundary layer water vapor content from established passive microwave (AMSR-E) and near-infrared (MODIS) algorithms; (4) A unique climatology of warm rain from the CloudSat cloud profiling radar.

Motivation and Methodology: In 2007 the IPCC reiterated that clouds remain the largest source of uncertainty in climate projections. In this context, boundary layer clouds are thought to be the main reason for this uncertainty and to play a central role in cloud-climate feedbacks and interactions. These clouds are also important to the surface energy balance and Sea Surface Temperature (SST) distribution, and are key elements in biases in seasonal coupled model forecasts and simulated mean climate. Current climate and weather models are still far from realistically representing boundary layer clouds. A key problem is the lack of a coherent data record of cloudy boundary layer properties as measured from space. Motivated by this scientific focus, this project will address this key problem by creating the first data record uniquely focused on the cloudy boundary layer as seen from space. The goal is to produce a simple and easily used repository of diagnostic tools relevant to interpreting the key physical processes governing the cloudy boundary layer.

Recent state of the art satellite observations, particularly those from the A-Train sensors, allow for a more complete characterization of the cloudy boundary layer than ever before. Relevant observations include the cloud Liquid Water Path (LWP) from optical and microwave sensors, cloud height distributions from various sources including Calipso, MISR and MODIS, Radiative fluxes from CERES, cloud microphysics from MODIS, boundary layer height from the Global Positioning System, light precipitation estimates from CloudSat, key moisture and temperature variables from various sensors, and vertically resolved cloud occurrence from active sensors.
All of these parameters are of first order relevance to understanding the distribution and variability of boundary layer clouds. Furthermore the observations are considered to be of high quality in subtropical ocean regions, where many of the essential interactions are thought to occur. Therefore, we propose to create an earth system data record composed of observations relevant to the cloudy boundary layer that will provide the context to understand and model clouds in the boundary layer regimes known to be particularly sensitive to climate perturbations.

Prasad Thenkabail/United States Geological Survey
Global Cropland Area Database (GCAD30) Through Landsat and MODIS Data Fusion for the Years 2010 and 1990 and Its Dynamics over Four Decades Using AVHRR and MODIS

Monitoring global croplands (GCs) is imperative for ensuring sustainable water and food security to the people of the world in the Twenty-first Century. However, the currently available cropland products suffer from major limitations such as: (1) Absence of precise spatial location of the cropped areas; (b) Coarse resolution nature of the map products with significant uncertainties in areas, locations, and detail; (b) Uncertainties in differentiating irrigated areas from rainfed areas; (c) Absence of crop types and cropping intensities; and (e) Absence of a dedicated web\data portal for the dissemination of cropland products.

Therefore, our project aims to close these gaps through a Global Cropland Area Database at nominal 30m (GCAD30) with 4 distinct products:
1. Cropland extent\area,
2. Crop types with focus on 8 crops that occupy 70% of the global cropland areas,
3. Irrigated versus rainfed, and
4. Cropping intensities: single, double, triple, and continuous cropping.
The project will disseminate these data and products through the USGS Powell Center Global Croplands Working Group web portal (https://my-beta.usgs.gov/wggc/) which will also include web mapping for user interaction, feedback, and improvements.

First, the above 4 products will be generated for GCAD for nominal year 2010 (GCAD2010) based on Landsat 30m Global Land Survey 2010 (GLS2010) fused with Moderate Resolution Imaging Spectroradiometer (MODIS) 250m NDVI monthly maximum value composites (MVC) of 2009-2011 data, and suite of secondary data (e.g., long-term precipitation, temperature, GDEM elevation).

GCAD30 will be produced using three mature cropland mapping algorithms (CMAs):
1. Spectral matching techniques (SMT; http://www.iwmigiam.org; Thenkabail et al., 2009a, b, 2007);
2. A cropland classification algorithm (ACCA) that is rule-based: (Thenkabail et al., 2012; e.g., http://www.sciencebase.gov/catalog/folder/4f79f1b7e4b0009bd827f548); and
3. Hierarchical segmentation (HSeg) algorithm: (Tilton et al., 2012; http://science.gsfc.nasa.gov/606.3/TILTON/).
The SMTs will be preferred for parts of the world with large volumes of field-plot and other geo-specific map data (section 12.1). ACCA will be applied in regions with sparse or unreliable field-plot data, but where numerous other sources of data (see section 7.1) and large volume of training data generated from HSeg (Tilton et al., 2012) exist. Further, HSeg will be used in conjunction with SMTs and ACCAs to help improve classification accuracies and generate training data over highly fragmented croplands.

Second, the same 4 products will be generated for GCAD1990 which will combine GLS1990, AVHRR 1989-1991, secondary climate and topographic data and national statistical data. Third, GCAD four decades will characterize the global cropland dynamics from the 1980s to present based on AVHRR 8 km (1982-2000) and MODIS 250m (2001-2017) continuous monthly time-series. All the products will be extensively evaluated for accuracies, errors, and uncertainties using data such as: (i) 25% of 20,000+ in-situ data, (ii) several thousand globally well distributed very high resolution (sub-meter to 5 meter) Commercial Imagery Derived Requirement (CIDR) Database of USGS, available free of cost to the project through the National Geospatial Intelligence Agency (https://warp.nga.mil/), (iii) our ongoing collaborative work over large areas (e.g., rice map of Asia; Figure 7), and (iv) maps from national systems (e.g., USDA CDL; see global letters of support).

GCAD30 will make significant contributions to Earth System Data Records (ESDRs), Group on Earth Observations (GEO) Agriculture and Water Societal Beneficial Areas (GEO Ag. SBAs), GEO Global Agricultural Monitoring Initiative (GEO GLAM), and the recent “Big Data” initiative by the White House. The project has the support of USGS Working Group on Global Croplands (http://powellcenter.usgs.gov/current_projects.php#GlobalCroplandsAbstract).

Omar Torres/Goddard Space Flight Center
A 30-Year Record of Aerosol Properties over Land from TOMS and OMI Observations

We propose the production of a global record of aerosol properties over land derived from 33 years of near-UV observations by five sensors. The derived products include the UV aerosol Index, aerosol extinction optical depth and aerosol absorption optical depth. The combined 33 year-record of aerosol information derived from the TOMS family of sensor (Nimbus-7, 1979-1992; Meteor-3, 1992-1994; Earth-Probe, 1996-2005) constitutes the only global data set on aerosol properties over-land before the deployment

of the MODIS and MiSR sensors on the Terra platform. The 1978-2005 TOMS record of Aerosol Index and aerosol optical depth provided the first global depiction of the global aerosol load. With the launch of the OMI instrument in 2004, the near UV record continues to be extended to the present and the foreseeable future using a mature retrieval algorithm. The proposed data set will provide a useful set of observations covering a period when no other data sets over land are available. In addition to the above described products we will also generate an Aerosol Index simulator that will facilitate the comparison of transport model results to satellite observations.

Josh Willis/Jet Propulsion Laboratory
A Climate Data Record of Altimetric Sea Level Change and Its Mass and Steric Components

The trend in global mean sea level is one of the most important observations of human-caused climate change. It is simultaneously an indicator and an impact of anthropogenic global warming. And, it is poorly predicted. Estimates of global mean sea level rise range from 20 cm to 2 meters by the end of the 21st Century (Willis and Church, 2012). The stakes are high. The cost of adapting to a 2 m rise over the next century would be an order of magnitude greater than adapting to a 50 cm rise (Nicholls et al., 2011). With such high uncertainty in future projections, the need for continuous monitoring, and the establishment of a highly accurate Earth Science data record (ESDR) of global sea level is all the more essential. If the rate of sea level rise were to suddenly accelerate, satellite altimeters would be the first to detect it. In this way, they can function as an early warning system for sea level rise, provided the data are sufficiently accurate.
We propose to develop an ESDR of sea level change based on observations from satellite altimeter missions. Sea level has been measured from space by precise radar altimeter missions since 1992. However, corrections to such observations undergo frequent improvements, and our team is at the forefront of those efforts. These include using of precision orbit determination (POD) and terrestrial reference frames, radiometer calibrations for the wet path delay correction, the dry path delay correction, sea state bias, tides (which also affect the POD and are not a correction but a well understood signal that is removed), instrument correcxtions, etc. All of these corrections will be improved and made consistent across the missions. Both alongtrack, gridded (in space and time), and globally-averaged data products will be generated in widely used formats with metadata conforming to widely used standards. We will apply these improvements to existing and future altimetric satellites (e.g., the upcoming AltiKa/SARAL data). We will also provide globally-averaged estimates of the steric and mass components of sea level rise derived from Argo floats and the GRACE satellites from 2005 to date. The sea level data and their uncertainty estimates will be carefully validated against a network of tide gauges and a dedicated calibration site (the Harvest Platform).
Satellite altimeters provide the most accurate estimates of global sea level rise, and well over 150 scientific publications per year make use of these data. Global sea level change, however, is not uniform and multi-decadal trends in sea level change reveal complex spatial patterns that are likely to be a mixture of natural and anthropogenic variability (Han et al., 2010; Gille, 2008). A highly accurate climate data record of sea level change

will be critically important if such changes are to be explained and attributed to either anthropogenic or natural drivers. Indeed, such an understanding is urgently needed in order to make improved projections of regional sea level rise, which are still poorly constrained by state-of-the-art climate model projections.

An ESDR of sea level change will also help to fulfill NASA s strategic mission of advancing Earth system science to meet the challenges of climate and environmental change, and to serve the strategic goals of the US Global Climate Change Program to advance science and inform decisions . Due to the nature of sea level rise as both indicator and impact of climate change, the scientific community, policy makers and the public at large will all benefit from improved knowledge of the record of sea level change, both locally and globally.