NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences (ROSES) - 2006
NNH06ZDA001N
A.20 Making Earth System data records for Use in Research Environments (MEaSUREs/06) (formerly REASoN)

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-2006 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 86 proposals in response to the CAN element and selected 29 for funding.

Robert Atlas/NOAA
A Cross-Calibrated Multi-Platform Ocean Surface Wind Velocity Data Set for Meteorological and Oceanographic Applications

This proposal is in response to the NASA Earth Science Enterprise (ESE) Cooperative Agreement Notice, Making Earth System Data Records for Use in a Research Environment (formerly REASoN). Under the REASoN solicitation, a cross-calibrated multi-platform ocean surface wind data set was created using a variational analysis to combine wind measurements derived from Quikscat, Seawinds, AMSRE, TRMM TMI and SSM/I. By combining these measurements, a consistent data record of high resolution (25km) ocean surface winds will be available from 1987 to 2007 with far reaching applications in meteorology and oceanography. Under MEaSURE, we propose to continue this record through 2012 incorporating data from current and future missions such as Windsat, ASCAT, DMSP SSM/I (F16-F20), GMI and GCOM-W (AMSR-2). Upon completion, a consistent 25-year (1987-2012) climate record of ocean surface

winds that includes all NASA and NOAA assets will be available for atmospheric and oceanic research and for improved weather and short-term climate prediction. This will be the culmination of extensive research and development under the Pathfinder and REASoN programs.

Gao Chen/NASA Langley Research Center
Creating a Unified Airborne Database for Assessment and Validation of Global Models of Atmospheric Composition

In response to NASA's MEaSUREs announcement, we propose to provide Earth System Data records critical to the validation and assessment of global models. While these records are expected to be of use to the modeling community at large, they are already of interest to a broad group of global chemistry and climate modeling groups participating in recent Atmospheric Chemistry and Climate (AC&C) initiatives endorsed by the WCRP-SOARC/IGBP-IGAC, which aim to address uncertainties in atmospheric chemistry-climate interactions. The proposed 4-year effort is endorsed by AC&C and partners (e.g. AeroCom) and will directly address the critical needs related to the top two activities recently selected by AC&C, i.e., 1) a 20-25 year hindcast of tropospheric ozone and aerosols, and 2) a definition of processes that control the distribution of the tropospheric trace gases/aerosols between mid and upper troposphere. The proposed effort will enable model verification and comparison exercises associated with these activities by providing observational data in appropriate format and temporal and spatial scales along with objectively assessed uncertainties. We proposed to create airborne ESDR (Earth System Data Record) products which will be derived from a wealth of publicly available airborne data sets accumulated primarily from NASA airborne field studies as well as from studies sponsored by NOAA and NSF over the past two decades. The proposed project will be focused in 3 areas:

1) To compile publicly available data sets from NASA airborne campaigns as well as from other campaigns sponsored by NOAA and NSF.
2) To assemble a measurement evaluation panel, including both measurement experts and modelers from a broad spectrum of institutions and agencies, to provide objective assessment of measurement uncertainties and biases and to determine how to best integrate these observations into forms useful for model comparison.
3) To generate a standardized in-situ observational database with the best possible matching of temporal and spatial scales to model output, representing snap-shot spatial distributions of trace gas species and aerosol properties of interest.

Previous studies have shown the importance of model comparisons to revealing inadequate understanding or representation of critical processes. However, AC&C recently identified several barriers to useful comparisons of models and observations, including a general lack of understanding between the modeling and measurement communities, a lack of a centralized and standardized observational database, insufficient information on data quality and uncertainties, and difficulties posed by mismatches in the temporal and spatial scales of model output and measurements. The proposed activities will make efforts to bridge the gaps between the modeling and measurement

communities, address the measurement uncertainty issues, and provide standardized data with best possible matching with model temporal and spatial scales. We believe that our airborne ESDR products will be useful to AC&C recommended modeling activities as well as the satellite community in terms of validation and potential retrieval algorithm improvement. The results of the proposed project will maximize the value of observations collected by NASA's suborbital program and will make a significant contribution towards improving current understanding of atmospheric chemistry and its interactions with climate as well as the ability to predict climate change.

Toshio Chin/Jet Propulsion Laboratory
Multi-sensor Ultra-high Resolution (MUR) global SST field

The role of high-resolution sea surface temperature data in modeling and forecast of coastal weather including cyclones/hurricanes is increasingly critical as the spatial resolution of atmospheric models improves. Satellite-based, high-resolution mapping of the sea surface temperature (SST) must involve integration of several data sets (including MODIS and AMSR-E SST data), due to differences in sampling patterns and weather dependency (data drop-off due to clouds) among the sensors. We will employ proven dynamically-corrected (motion-compensated) and multi-resolution numerical techniques for the data integration task. Several satellite data will be fused to produce a consistent, decade-long, global SST record. The record will also be appended over the proposal period via our near real-time production capability.

At present, the international GODAE High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP) defines "ultra-high" resolution to be horizontal scale of finer than 2 km. Either an infrared (IR) or microwave (MW) instrument is used to measure SST from a number of satellites. The IR measurements offer a high resolution (1 km) capability but suffer from contamination (data-void) by clouds. On the other hand, the MW measurements are reliable due to cloud-penetrating coverage but are much coarser (25 km) in resolution. We will leverage off work done through the GHRSST project to apply diurnal models for calculating SSTs at a consistent depth (skin versus bulk). Also, cloud contamination affects differently among the IR data sets due to the significant differences in sampling patterns between the geostationary and polar-orbiting satellites. Through the proposed project, we will employ methods which have been developed by the PI/co-PIs and applied successfully to satellite data, to fuse the SST data from both types of the instruments, by retaining the advantage of each type, to produce a global SST product with an unprecedented resolution and coverage.

Kamel Didan/University of Arizona
Vegetation Phenology and Enhanced Vegetation Index Products from Multiple Long Term Satellite Data Records

Vegetation indices from remote sensing are by far the most widely used remote sensing tools for studying vegetation and large-scale ecosystem processes. In this context, knowledge of phenologic variability and the environmental conditions controlling their

activity are further prerequisite to inter-annual studies and predictive modeling of land surface responses to climate change. Satellite phenology encompasses the analysis of the timing and rates of vegetation growth, senescence, and dormancy at seasonal and interannual time scales. Vegetation indices, which capture the aggregate functioning of a canopy, are the most robust and widely used measurement for extracting phenology information. Time series measures of MODIS enhanced vegetation index (EVI) have been shown highly correlated with flux tower photosynthesis in both tropical and temperate ecosystems at seasonal scales.

In this investigation, we propose to extend the advanced capabilities of the 7+ year Terra and Aqua MODIS Phenology and EVI algorithms to create a consistent and seamless ESDR VI and phenology records covering the AVHRR, MODIS and NPOESS eras. This effort will make available a multi- sensor data record spanning the period 1981 to 2012 and provide a sensor independent measurement of these parameters. This effort will primarily focus on producing coarse (0.05^{o} degree) resolution phenology from AVHRR-MODIS- VIIRS, and will be extended to limited, medium resolution (1km) AVHRR-MODIS-VIIRS for the conterminous USA, to take advantage of the new National Phenology Network.

Our proposal brings together expertise in multiple instrument characterization, calibration, validation, data processing, science-based product generation, distribution, and user community support. Our products will be evaluated to establish their accuracies and uncertainties and their suitability to climate related studies and in advancing NASA Earth System 'missions to measurements' concept. We plan to evaluate our Phenology product to a global list of published in-situ phenology observations, LTER's, NEON sites, and from phenology and flux tower networks (e.g., Fluxnet). We will also collaborate with the newly established National Phenology Network to achieve an independent evaluation of this product. To demonstrate the value of these products we plan to offer an interactive data mining and change 'hot spot' identification system, where the Phenology metrics and EVI record could be interactively queried in both temporal and spatial domains. Both data records will be archived and distributed from the USGS for EROS DAAC facility, benefiting from their expertise and exposure to the user community.

Well calibrated, long term time series of vegetation indices and land surface phenology have wide social, cultural and economic significance to the well being of our planet, i.e., food supply, human health, invasive species, droughts, etc.. This proposal addresses a number of challenging, cross-discipline topics integrating multi-tiered phenology user communities, remote sensing, and modeling communities to advance our understanding of the Earth's terrestrial surface and biomes and their sustainability in the face of increasing human and environmental pressures. Our participants encompass a diverse geographically-distributed group of young and senior scientists across several Universities and government research units to enhance partnerships and collaborative opportunities.

Eric Fetzer/Jet Propulsion Laboratory
A Multi-Sensor Water Vapor Climate Data Record Using Cloud Classification

The state-of-the-art humidity and temperature observations from space are made by AIRS/AMSU/HSB, AMSR-E, MLS, and MODIS in the A-Train satellite constellation. We are currently assembling a multi-year record of A-Train water vapor and temperature observations. We will use the multi-sensor A-Train observations to classify individual water vapor scenes by cloud type using well-established cloud classification methods. Similar cloud classes will be generated for the historical satellite sensor record. The complete data set will contain simultaneous information about water vapor and cloud state over the multi-decadal satellite record.

Lucien Froidevaux/Jet Propulsion Laboratory
GOZCARDS: Global OZone Chemistry And Related trace gas Data records for the Stratosphere

This proposal will provide a commonly-formatted Earth system data record (ESDR) for stratospheric composition, of high relevance to the issue of ozone decline and recovery. These ozone and related trace gas data records are needed to evaluate the representation of atmospheric composition in models ranging from classic 2-D stratospheric dynamical-chemical models that have formed the basis of previous ozone depletion assessments to a newly emerging class of 3-D chemistry climate models.

The data records will be drawn from satellite-derived global stratospheric composition measurements from 1979 to the present, along with on-going data, as well as from GMAO GEOS-4 and GEOS-5 meteorological analyses. The data records will be time series of averaged profiles as a function of latitude and equivalent latitude for ozone (O_3), hydrogen chloride (HCl), chlorine monoxide (ClO), nitric acid (HNO_3), water vapor (H_2O), nitrous oxide (N_2O), nitrogen dioxide (NO_2), nitrogen oxide (NO), methane (CH_4), and hydrogen fluoride (HF).
Additional "derived data records", using a constrained photochemical model, will be provided for active chlorine (ClO_x) and odd nitrogen (NO_x).

Along with this stratospheric trace gases ESDR, we will provide a temperature record using existing long-term meteorological analyses (GEOS-4 and GEOS-5). The GMAO daily data will also lead to a consistent set of stratospheric O_3 columns; we will also produce derived quantities relating to O_3 loss in polar regions, where polar stratospheric clouds (PSCs) can form and heterogeneous chemistry leads to O_3 depletion and the Antarctic ozone hole phenomenon. These quantities will include the volume (V_PSC) and area (A_PSC) of air with temperatures below PSC formation thresholds, as well as estimates of PSC "lifetimes".

The satellite-based profiles come, in part, from high quality data that are now discontinued, namely solar occultation data from SAGE I (for O_3 and NO_2), SAGE II, SAGE III, POAM II, and POAM III (for O_3, H_2O, and NO_2), HALOE (for O_3, HCl, H_2O, NO, NO_2, CH_4, and HF), and UARS MLS (for O_3, ClO, and H_2O). The records going forward in time will depend on Aura MLS (for O_3, HCl, ClO, HNO_3, H_2O, N_2O) and SciSat-1 ACE-FTS profiles (for O_3, HCl, ClO, HNO_3, H_2O, N_2O, NO, NO_2, CH_4 and HF).

Data records will be zonal means on a common vertical (pressure and/or height) grid, with time resolution of 1 month (1 day when possible). Records binned in equivalent latitude and potential temperature will also be provided, as this is best for evaluating polar processes.

The establishment of such data records involves the evaluation of offsets and assessments of time consistency using ground-based data. We will strive to provide both the original records and merged data records.

Web-based data access to commonly-formatted files and various related plots will be provided. We also plan to actively participate in Data Systems Working Group meetings.

Robert Frouin/Scripps Institution of Oceanography, UCSD

A Time Series of Photosynthetically Available Radiation at the Ocean Surface from SeaWiFS and MODIS Data

The solar energy available for photosynthesis, known as PAR, controls the growth of phytoplankton and, therefore, regulates the composition and evolution of marine ecosystems. Knowing the spatial and temporal distribution of PAR over the oceans is critical to understanding 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 project objective is to produce a 12-year time series of PAR at the ocean surface from SeaWiFS, MODIS-Terra, and MODIS-Aqua data. The product will cover the global oceans, with a spatial resolution of about 9.3x9.3 km (equal area grid) and a temporal resolution of one day. The time series will start in September 1997, i.e., at the beginning of the SeaWiFS operational phase.

Daily PAR will be computed using a mature algorithm, tested and evaluated, which has been applied operationally by NASA's Ocean Biology Processing Group (OBPG) to generate the SeaWiFS PAR product. The algorithm will be adapted/modified to include data from multiple ocean-color sensors. Combining data from satellite sensors with different equatorial crossing times will account for the diurnal variability of clouds. The advantage of using ocean-color sensors to estimate PAR is that they provide chlorophyll concentration, another key parameter in ocean primary productivity modeling. Furthermore, the same data pre-processing is required, i.e., PAR can be produced with little extra effort. In this way, studies of ecosystem dynamics are facilitated.

Consistency across time will be achieved by comparing estimates obtained using data from one or two sensors with those from the three sensors when they are all operating, determining adjustment factors, and applying those factors to reduce biases during the periods with only one or two sensors. Accuracy will be quantified on daily, weekly, and monthly time scales against existing in-situ measurements, and it will be monitored during the last years of the time series using long-term PAR sensors installed at selected sites. Eventually, the algorithm will be refined, and the time series re-processed.

Large-scale data production will be accomplished by the OBPG, who will make the time series and related documents available to the public from their web site. The processing

system, including routine check of accuracy and control of quality, will be designed to operate during the entire lifetime of SeaWiFS and MODIS, and to accommodate future sensors with ocean-color capabilities. The project will provide an invaluable PAR dataset, with possibility of extension in the future, for studying the evolution of marine ecosystems and the role of the oceans in carbon cycling and climate change.

Jay Herman/ NASA Goddard Space Flight Center
Earth Surface and Atmospheric Reflectivity Since 1979 from Multiple Satellites (TOMS, SBUV, SBUV-2, OMI, SeaWiFS, NPP, and NPOESS)

This proposal concerns the production of a continuous ultraviolet reflectivity data record for the surface of the Earth and its atmosphere using multiple satellite data records since 1979. The scene reflectivities of the Earth at blue and ultraviolet (UV) wavelengths (320 nm to 415 nm) are low over most surfaces (except ice and snow), and are almost independent of the seasonal changes in vegetation on land and in the oceans. This makes it ideal for examining changes in radiation reflected back to space from changes in cloud and aerosol amounts, especially as affected by the start of climate change. The ultraviolet reflectivity of the Earth's surface and atmosphere (clouds, aerosols, and Rayleigh scattering) has been accurately measured since the launch of Nimbus-7/TOMS and Nimbus-7/SBUV in October 1978. Gaps in the TOMS data record, most notably the period from 1993 to 1997, and the degrading calibration of Earth-Probe/TOMS (1997 - 2006) after 1999, have made it necessary to join the data record from multiple satellites to produce a continuous climate quality Earth System Data Record (ESDR) quality data set.. The current reflectivity data record will be extended during the life of this proposal to produce a 35-year (1979 to 2013) continuous ESDR, which can be further extended using the developed software from the proposed work and data from the ongoing GOME-2 satellite series, NPP (proposed launch in 2010-2011), and followed by NPOESS. The resulting data, documentation, and software will be made freely available on NASA data servers via ftp bulk download and, for various subsets and images, on the existing TOMS website http://toms.gsfc.nasa.gov. This proposal contains no algorithm development or cal-val activities other than what is needed to join data sets from several independent satellites with the necessary precision.

N. Christina Hsu/NASA Goddard Space Flight Center
Long-Term Aerosol Data Records: Using Deep Blue to Synergize SeaWiFS, MODIS, AVHRR, and TOMS Observations

One of the key components of NASA's Earth Science Research Strategy to better understand the complex nature of Earth's climate is the determination of the global radiation balance. Comprehensive regional-to-global climate models (R/GCM) 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 parameters to the R/GCMs. Many EOS-era instruments (e.g., SeaWiFS, MODIS, and MISR) are designed to provide such information with a high degree of fidelity.

With the advent of this new generation of satellite sensors in the 1990s, a well-calibrated, accurate long-term aerosol dataset from satellite measurements is now becoming possible. Such a dataset is a critical component in performing the quantitative evaluations of aerosol variability on a global basis that are needed to form a consensus among the scientific community and policy makers regarding the role of aerosols in modifying the global radiative budget due to anthropogenic activities. However, the creation of such a dataset has been a difficult task because of the limited lifetime of satellite sensors as well as the calibration issues between different satellite platforms. Furthermore, different sensors take different algorithmic approaches to retrieve aerosol properties. As a result, separating the changes due to algorithm differences and calibration effects from those due to actual climate trends can be challenging as one tries to stitch together the various satellite measurements acquired to date.

To alleviate this problem, we propose to produce long-term global aerosol records over both land and ocean by applying a consistent algorithm called "Deep Blue" to measurements from SeaWiFS and the MODIS sensors onboard both Terra and Aqua. This new Deep Blue algorithm has recently been successfully integrated into the MODIS operational stream as part of PGE04. The resulting products include aerosol optical thickness, Ångström exponent, and dust absorption over land and ocean. MODIS operational retrieval algorithms previously were not able to provide aerosol properties over bright-reflecting surfaces. Our Deep Blue algorithm utilizes blue-wavelength measurements from instruments such as SeaWiFS and MODIS to infer the properties of aerosols, where the surface reflectance over land in the blue part of the spectrum is much lower than for longer wavelength channels. Deep Blue therefore eliminates the resulting gaps in MODIS aerosol products by performing retrievals over such bright-reflecting surfaces.

We further propose to extend the above records by exploiting the synergy between the data from SeaWiFS and the MODIS sensors and data taken from AVHRR and TOMS. By characterizing the agreements and differences between SeaWiFS/MODIS with the historic TOMS/AVHRR retrievals using data from the overlapping years, knowledge can be transferred backward to retrievals acquired in the years before the overlap to obtain a better estimate of the long-term trend using TOMS and AVHRR data. Finally, we plan to extend the application of the Deep Blue algorithm from MODIS and SeaWiFS to the future sensors VIIRS to be flown on NPP and NPOESS. As a result, this proposed work will produce well-calibrated coherent long-term aerosol data records for the first time using measurements from the state-of-the-art satellite sensors for use in climate related studies.

Ian Joughin/Applied Physics Lab, University of Washington
Greenland Ice Mapping Project: Measuring rapid changes in ice flow

Numerous recent studies have revealed rapid change in ice discharge from Greenland's outlet glaciers. A near doubling in flow speed of many of Greenland's glaciers substantially increased the rate at which the ice sheet calved icebergs to the ocean over

the last five years. These results 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 them well enough to predict their long-term impact on sea level. As a consequence, outlet glacier dynamics remain a "wild card" in the sea-level predictions included in the just-released IPCC Fourth 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 has matured to the point where we are well positioned to make such measurements. We have demonstrated this capability through earlier projects where we have mapped ice-sheet wide velocity and extent for 2000 and 2006. Here we proposed a comprehensive set of observations that will extend this time-series through the next five years, a period when Greenland is likely to 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 also will provide important baseline data for future generations.

John Kimball/Flathead Lake Biological Station
An Earth System Data Record for Land Surface Freeze-Thaw State: Quantifying Terrestrial Water Mobility Constraints to Global Ecosystem Processes.

We propose to develop an Earth System Data Record (ESDR) quantifying land surface freeze/thaw state dynamics of the global biosphere over a long-term data record of more than 25 years. The freeze/thaw ESDR (F/T-ESDR) is based on an extensive foundation of previous NASA funded research, and will be developed using multi-frequency satellite microwave remote sensing time series spanning multiple missions and sensors, including passive microwave radiometery from the Scanning Multichannel Microwave Radiometer (SMMR), Special Sensor Microwave Imager (SSM/I) and Advanced Microwave Scanning Radiometer for EOS (AMSR-E), and radar scatterometer data from SeaWinds-on-QuikSCAT. The combined information content from these sensor records will enable a global F/T record extending from 1979 onward, which is longer than the total observation length of virtually all other global satellite remote sensing records, including NOAA AVHRR.

The transition of the land surface between predominantly frozen and non-frozen conditions occurs each year over more than 50 million km2 of the global biosphere, affecting surface hydrological activity, meteorological conditions, and ecological trace gas dynamics profoundly. Abrupt near 0ºC, this state transition represents the closest analog to a biospheric on/off switch existing in nature. Satellite microwave remote sensing is uniquely capable of detecting and monitoring a range of related biophysical processes associated with the measurement of landscape F/T status, while the science justification and remote sensing algorithms and approaches for the F/T-ESDR are well developed from an extensive heritage of past NASA Earth Science research. Major landscape hydrological and ecological processes embracing the remotely-sensed F/T signal include the timing and spatial dynamics of seasonal snowmelt and associated soil thaw, runoff generation and flooding, ice breakup in large rivers and lakes, vegetation

growing seasons and net primary production, and the seasonal switch of the land surface between a net source of atmospheric CO2 in winter and a terrestrial carbon sink following thawing in spring. Thus the F/T state variable provides a surrogate measure of water mobility in the landscape and the interactions between terrestrial water, carbon and energy cycles. The proposed activities will produce a consistent and well calibrated global record of terrestrial freeze/thaw state dynamics that will improve measurement and diagnosis of climate change trajectories and impacts to the global biosphere. Anticipated applications of the F/T-ESDR include global change assessment and monitoring, numerical weather forecasting, hydrological and biospheric assessment and forecasting.

The F/T-ESDR specifically addresses several NASA Earth Science Research Strategy focus areas, and current gaps in the NASA Earth Science Research Plan created by recent cancellation of the Hydros ESSP mission, which was to measure surface soil moisture and its freeze-thaw state. The Freeze/Thaw state variable was selected with soil moisture as one of 4 recommended high priority observations/missions for the next decade to be implemented by NASA within the 2010-2013 timeframe, as defined by the National Research Councils recent Decadal Survey. The proposed F/T-ESDR will provide valuable baseline information for assessing the global change significance of future F/T state changes, and designing sensor orbit, resolution and accuracy requirements to meet future NASA F/T mission objectives.

Michael Kobrick/ Jet Propulsion Laboratory
The Definitive Merged Global Digital Topographic Data Set

Measurements of the Earth's topography are one of the most fundamental data sources in Earth science. A major advance for topographic mapping was taken with the flight of the Shuttle Radar Topography Mission (SRTM), a joint project of NASA, the German and Italian space agencies, and the National Geospatial-Intelligence Agency (NGA), to use radar interferometry to map all the planet’s topography between ±60 latitude. The data have been transformed into DEMs, which are now available to the public through the Land Processes Distributed Active Archive Center (LPDAAC) at the U. S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center (EDC).

SRTM topography has become the most popular data set distributed by EDC, with the number of data downloads far exceeding any other remotely sensed data. Since no subsequent global mapping projects are currently planned the SRTM data will remain as the 'definitive' topographic data set for decades to come. Its improvement and augmentation by incorporating and combining with other existing NASA topographic data sources would represent a significant enhancement and upgrade in a very cost-effective way.

The most notable improvement will be the elimination of data voids, where radar shadowing or extremely low radar echo strength prevented the determination of an elevation measurement. Although rare, these can greatly affect use of the DEMs in applications like hydrology and volcanic hazard mapping.

Secondly, although the SRTM data exceed their specifications for vertical accuracy by a factor of three, there are detectable meso-scale trends in the data at the meter level that can affect determination of crucial geophysical parameters like glacier volume and ice sheet changes, important measurements in quantifying global climate change.

Finally, we propose to document and distribute other potentially valuable SRTM data sets, namely the global radar image data and a sample set of raw radar echo data with supporting ancillary data.

Therefore we propose to undertake four principle tasks:

Undertake a systematic program to combine SRTM data with those from other sensors, principally ASTER, to fill voids in the DEMs according to a prioritized plan, as well as extend the coverage north of the current 60 latitude limit.

Work with the ICESat project team at the Goddard Space Flight Center to combine laser altimeter topographic profiles with SRTM DEMs to produce and distribute enhanced resolution data sets.

Produce documentation, users guides and other supporting information for the existing SRTM image and ancillary data cells, as well as generate image mosaics at multiple scales and distribute them via the world wide web.

Generate, document and distribute a standard and representative set of SRTM raw radar echo data, along with the appropriate ancillary tracking and pointing data necessary for users to process the echoes into DEMS using improved algorithms or techniques.

Christian Kummerow/Colorado State University
A Long-Term Precipitation Dataset with Uncertainty Information

The broad social and economic relevance of rainfall combined with the development of new satellite sensors/techniques for global monitoring has led to multiple long-term global products that rarely agree despite significant efforts towards calibration and validation. These discrepancies are particularly problematic for climate studies because uncertainties in spatially and temporally averaged values are the result of a number of factors including differences between meteorological regimes, sensor calibration, and satellite orbit characteristics. As a result, these uncertainties cannot be computed from errors in the instantaneous rainfall estimates, but require further insights into the sources of bias errors.

Building on algorithm development work funded through NASA's Precipitation Measurement Program, we propose to create a new rainfall and cloud water dataset using the latest version of the Goddard Profiling (GPROF) algorithm and based on a multi-decadal constellation of satellite radiometer data including SSM/I, TMI, AMSR-E, WINDSAT and SSMIS. The algorithm will be run on the Level 1C brightness temperature dataset, which is part of a currently funded REASoN effort to produce a

consistent calibrated brightness temperature dataset from this diverse set of radiometers. While this proposal aims to fold in prior data beginning with SSM/I F8 launched in 1987, and has a radiometer intercalibration component that goes beyond the algorithm development work, the bulk of this proposal is not the generation of a new long-term homogeneous data set, but the characterization of the intrinsic uncertainties, including those related to the partitioning between cloud water and rainfall, the sensitivity of rainfall products to meteorological regimes and the relation between this product and previously established ones. By evaluating and interpreting differences in light of the intrinsic uncertainties, algorithm formulations and input brightness temperatures, we hope to add information about the product that is as essential as the product itself for use in studying climate variability and trends related to the global water and energy processes.

Ronald Kwok/Jet Propulsion Laboratory
ESDR of small-scale kinematics of Arctic Ocean sea ice

To date, RADARSAT-1 has provided over eleven years of near-uninterrupted 3-day snapshots of the Arctic Ocean ice cover. This has more than doubled the record of SAR (Synthetic Aperture Radar) imagery acquired from an initial expected mission life of five years. The high-resolution data set of small-scale kinematics and deformation derived from these SAR observations has contributed significantly to sea ice science in: the development of new approaches for modeling the mechanical behavior of sea ice and the validation of these models; the characterization of the sub-daily ice motion; a description of the seasonal and regional variability of sea ice deformation; the validation of ICESat freeboard algorithms; and, the estimates of sea ice exchange between the Arctic Ocean and the peripheral seas. Existing funding supports the processing of only seven years of RADARSAT-1 acquisitions into small-scale ice motion estimates. For the remaining years of RADARSAT-1 data, we propose: 1) to continue the processing of the data stream to construct a near decadal record of small-scale ice motion of the of the Arctic Ocean; 2) to produce a record of ice motion of the northern Bering Sea; and, 3) to assemble bi-weekly high-resolution image mosaics of the Arctic Ocean. The Bering Sea ice motion will contribute to our understanding of the rapidly changing local climate and ecosystem. 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 Envisat. These datasets will add to the publicly available archive of RADARSAT-1 image and ice motion products. The proposed work will be a joint project of the Jet Propulsion Laboratory and the Alaska Satellite Facility.

Stephane Maritorena/University of California at Santa Barbara
Beyond Chlorophyll: Implementation and Distribution of Innovative Ocean Color Earth Science Data Records.

Satellite ocean color data products are all too frequently relegated to a single, unique product, the chlorophyll concentration. However, ocean color signals (the normalized water-leaving radiance spectra, LwN) contain information describing the concentrations

and type of suspended particulate and dissolved materials, the composition of the phytoplankton community and the productivity of the water column. Over the past decade many new satellite ocean color science data products have been introduced which are transforming our understanding of ocean biological and biogeochemical processes. The implementation, distribution and management of these innovative ocean color data records are fraught with difficulties - at least by existing structures. First, there is a large suite of products that qualify as ocean color Earth Science Data Records (OC-ESDR's). Existing data centers, such as the NASA Ocean Biology Processing Group (OBPG), need to be focused on the primary objective of providing the highest quality LwN and chlorophyll determinations from the suite of available satellite sensors. Second, existing data centers are not well suited to quickly handle the rapid rate of new innovative algorithms and products as is occurring today. The plethora of possibilities along with the large volume of data and the complex algorithms to implement is a huge load for a single group to handle (no matter how capable). Further, it is also necessary to constantly characterize the generated products and rapidly assess changes that may result from either versions of the input data stream (here LwN) or from updated OC-ESDR algorithms. These difficulties all act to limit the wide use of innovative OC-ESDR's. Last, a decentralization of ocean color data product creation and dissemination is healthy as individual groups with different background and vision can make their unique contribution to the OC-ESDR's available.

Here, we propose to implement a small scale ocean color data center (micro-DAAC) capable of processing and distributing a broad suite of OC-ESDR's, some of them from merging of multiple sensors, while nimble enough to successfully manage scientific innovation.

1. Create and distribute a variety of established OC-ESDR's ranging from ocean optical properties and phytoplankton functional groups to phytoplankton growth rates and carbon-based productivity,
2. Implement and distribute quality indices for these OC-ESDR's so users know what they are getting and how it relates to previous versions of the products, similar satellite data products and in situ data sets,
3. Update the suite of OC-ESDR's distributed in consultation with our advisory board and data users, and
4. Track and manage algorithm and data lineage throughout the process and implement methods for automatically informing users of updated products or analyses.

Our proposed implementation of an OC-ESDR micro-DAAC builds on our experience in satellite data system research (ReASON; Frew, Siegel & Maritorena), in the development and implementation of novel satellite ocean color algorithms (Maritorena, Siegel & Behrenfeld) and in the acquisition and application of field-based calibration/validation data (Nelson, Maritorena, Siegel & Behrenfeld). The OC-ESDR micro-DAAC will be implemented in collaboration with the GSFC Ocean Biology Processing Group-providing added value to their efforts and to ours. It is our hope that the true value of scientific innovation possible with NASA Earth science data can be realized through the development of small, focused data centers cooperating with existing NASA data centers.

Kyle McDonald/Jet Propulsion Laboratory

An Inundated Wetlands Earth System Data Record: Global Monitoring of Wetland Extent and Dynamics

Wetlands exert major impacts on global biogeochemistry, hydrology, and biological diversity. The extent and seasonal, interannual, and decadal variation of inundated wetland area play key roles in ecosystem dynamics. Wetlands contribute approximately one fourth of the total methane annually emitted to the atmosphere and are identified as the primary contributor to interannual variations in the growth rate of atmospheric methane concentrations. Climate change is projected to have a pronounced effect on global wetlands through alterations in hydrologic regimes, with some changes already evident. In turn, climate-driven and anthropogenic changes to tropical and boreal peatlands have the potential to create significant feedbacks through release of large pools of soil carbon and effects on methanogenesis. Despite the importance of these environments in the global cycling of carbon and water and to current and future climate, the extent and dynamics of global wetlands remain poorly characterized and modeled, primarily because of the scarcity of suitable regional-to-global remote-sensing data for characterizing their distribution and dynamics.

We will construct an Earth System Data Record of Inundated Wetlands (IW-ESDR) to facilitate investigations on the role of inundated wetlands in climate, biogeochemistry, hydrology, and biodiversity. The IW-ESDR will enable advances in understanding the role of wetlands in 1) global cycling of methane, carbon dioxide and water, 2) interactions among climate, greenhouse-gas emissions, and water exchange, 3) climate change effects and feedbacks, 4) maintaining ecological health and biodiversity of critical habitats, and 5) management of water resources for long-term sustainability. We will employ mature algorithms to produce two complementary ESDR components:

1) Fine-resolution (100m) maps of wetland extent, vegetation type, and seasonal inundation dynamics, derived from Synthetic Aperture Radar (SAR), for continental-scale areas covering crucial wetland regions.

2) Global monthly mapping of inundation extent at ~25 km resolution for the period 1992-2009, derived from multiple satellite observations.

Comparison and validation of these data sets will ensure self-consistency within the ESDR. Accuracy assessment of the fine-scale regional wetlands data sets will take advantage of high-resolution wetlands maps to be made available through collaborators.

The IW-ESDR will provide the first accurate, consistent and comprehensive global-scale data set of wetland inundation and vegetation, including continental-scale multitemporal and multi-year monthly inundation dynamics at multiple scales. Each component of the ESDR has been designed to facilitate a range of studies by addressing critical gaps in data and understanding of the role of inundated wetlands in important cycles and processes. The regional high-resolution component derived from the SAR observations provide key information needed for regional- to continental-scale studies focusing on

biogeochemistry, hydrology, plant and animal biodiversity, water resource management, and long-term sustainability of wetland ecosystems. The global, monthly ~25 km inundation data set, spanning almost two decades, represents a unique, comprehensive source of quantitative information to support analyses and modeling of wetlands in global cycling of methane, carbon dioxide and water, and in simulating interactions among climate, greenhouse-gas emissions, and water exchange for past, current and future time periods.

The IW-ESDR data set will be maintained, archived and available to the science community through integrated web sites at JPL, the University of Montana NTSG ESIP, and the Japan Aerospace Exploration Agency. Web-based tools will be provided to support user access to ESDR components. Distribution of thematic mosaics and assembly of user-defined mosaics will be supported.

Richard McPeters/ NASA Goddard Space Flight Center
Creating a Long Term Multi-Sensor Ozone Data Record

The proposed research is for a five year effort to produce long term ozone data records by merging data from multiple instruments. The ultimate goal is an ozone Earth Science Data Record (ESDR) - a consistent, calibrated ozone time series that can used for trend analyses and other studies. Both total column ozone and ozone vertical profile data sets will be produced, and we expect records at various spatial/temporal resolutions will be necessary to meet different research requirements. As one of the first groups to implement "missions to measurements" the TOMS team at Goddard Space Flight Center has created the total ozone merged ozone data record (MOD) by consistently combining total column ozone data from TOMS/OMI and SBUV instruments. We will expand this product, adding data from three additional instruments. Data from GOME (1995-2003) on ERS-2 will provide coverage in periods when there are gaps or data quality issues in the TOMS and SBUV data records. Data from the recently launched GOME-2 instrument will be added, and data from OMPS will be included after the launch of NPP. We propose to concentrate most of our efforts on producing an ozone vertical distribution data set. We will merge profile data from various instruments, including SBUV(/2), UARS and AURA MLS, Sciamachy, GOME-1 and GOME-2. This proposal will support preparation of data from the different instruments for inclusion in the merged ozone data time series. We will also consider processing the GOME and OMPS spectral data with the same algorithm used for TOMS and SBUV in order to ensure consistency.

Richard Ray/NASA Goddard Space Flight Center
Integrated Multi-Mission Ocean Altimeter Data for Climate Research

Satellite radar altimetry plays a crucial role in monitoring the topography and sea state of the world's oceans. The TOPEX/Poseidon (T/P) and Jason-1 missions have delivered nearly a half-million global sea level measurements every ten days, with either or both T/P and Jason operating continuously since 1992. NASA's Earth Sciences Senior Review

(2005) recognized the criticality of ocean radar altimetry by rating Jason as the mission with the highest scientific value and highest relevancy to NASA Earth Science Strategic objectives of the 12 missions which had entered into their extended mission phase. The Review noted that: "Extending observations of sea surface topography to decadal scales is essential to implementation of NASA's 10-year goals in addressing the fundamental questions: 'How is the Earth changing and what are the consequences for life on Earth?' and 'How can predictions of climate variability be improved?'"

A continuous record of global sea surface height requires an exacting effort to provide these data free from instrument-dependent biases and from algorithm and model inconsistencies. Many altimeters in assemblage, with different characteristics and processing histories, are required to provide this multi-decadal record. Today there are 3 active radar altimeter missions (Jason, GFO, ENVISat). Extending the observations to latitudes greater than 66 requires incorporation of radar altimeter data obtained from other missions (ERS-1, ERS-2, ENVISat) which have less inherent accuracy than that of T/P and Jason. Extending the series backward in time requires evaluating data from many earlier missions that have temporal gaps in coverage.

For this proposed work we will start by improving the quality of the Climate Data Records produced from T/P and Jason based on concurrent progress made in a wide variety of areas including the GRACE gravity field modeling and resulting improvements in orbits and the geoid, the ocean response to atmospheric pressure loading, the sea-state bias, and in the definition of the International Terrestrial Reference Frame. We will leverage these improvements by suitably applying them to increase the value of historical altimeter holdings for climate research. Our proposal is based on work started in the mid-1990s under the auspices of the NASA Pathfinder program. Our team undertook the reprocessing of data from both older and then-current radar altimeter missions to increase their accuracy and consistency. Despite having over 300 regular users and providing a key data base for monitoring ocean circulation, sea-level rise, and other ocean variability, this Ocean Altimeter Pathfinder Project was discontinued in 2002.

Herein we propose building on our previous work with the Ocean Altimeter Pathfinder Project -- by availing ourselves of the recent remarkable progress made in improving (a) gravity fields for geoid and orbit applications, (b) ocean tide models, (c) calibrations of radiometers needed to remove long-period trends in the wet troposphere corrections, (d) sea-state algorithms, and (e) in the International Terrestrial Reference Frame. All of these improvements are well documented in the literature, are within the capabilities of our proposed team, and will be well coordinated within the physical oceanography community through our continued participation within NASA's Ocean Surface Topography Science Team. These data will be made available to the outside community through the nearly total reuse of the robust ICESat Science Information Processing System.

Eric Rignot/Jet Propulsion Laboratory
Ice Velocity Mapping of the Great Ice Sheets: Antarctica.

As Greenland glaciers accelerate threefold in response to climate warming and large parts of West Antarctica and the Peninsula slide faster to sea than they should to maintain a state of mass equilibrium, a better understanding the evolution of ice sheets and impact on future sea level rise have become top priority Earth System science questions. These ice sheets hold enough ice to raise global sea level by 70 m. A real potential exists for them to raise sea level by 1 to 10 feet by year 2100. Predictions are difficult because numerical models are too primitive and polar scientists need better observations to understand key physical processes. Here, we propose to generate and distribute a new Earth Science Data Record (ESDR) critical to ice sheet and climate change research: digital maps of ice velocity of the Antarctic continent. A companion project by the Applied Physics Laboratory (APL) at the University of Washington in Seattle covers Greenland. Ice velocity is a fundamental characteristic of ice sheet dynamics. It provides direct information on the rate of mass discharge into the ocean, its contribution to sea level change, and its sensitivity to climate forcing. It is the most powerful observational constraint to apply on a new generation of numerical ice sheet models capable of realistic predictions. The project will use data from a suite of international synthetic-aperture radar satellites, with processing tools developed over the past 10 years of research, and representing the state of the art for mapping ice sheet velocity, independent of cloud cover and solar illumination, with a uniform, high-resolution, sampling of entire continents. We know how to generate this type of product. We published results in high profile journals that have led to major advances in determination of the mass balance of ice sheets and contribution to sea level and have been discussed by the press, medias and politics throughout the World. These were research products. We want to make community products, of higher quality and standard, to benefit glaciologists, ice sheet modelers, climate modelers, physical oceanographers, solid earth scientists, atmospheric scientists, geologists, i.e. the scientific community at large. Our institute has pioneered the use of the radar technique and kept a leading edge on science applications. Our partner is the National Snow and Ice Data Center, 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. These products will establish a legacy for the International Polar Year, for science, and to inform the general public and educational entities on the evolution of polar region. This project will serve the highest science objectives of NASA' Science Mission Directorate in climage change research and study of the Earth's ice cover and sea level rise.

David Robinson/Rutgers University
Development of Northern Hemisphere Snow and Ice Climate Data Records

The proposed project intends to: 1. assess compliance of current Northern Hemisphere (NH) terrestrial snow and sea ice data records with National Research Council Climate Data Record (CDR) characteristics; 2. blend NH terrestrial snow and sea ice data products into CDRs; and 3. provide state-of-the-art NH terrestrial snow and sea ice CDRs

in multiple formats and on multiple time steps for the research community, decision-makers, and stakeholders.

To accomplish our project objectives, we propose the following: 1. for each current NH terrestrial snow and sea ice data record, we plan to assess how many of the NRC CDR characteristics the data record meets; 2. the current data records will be blended using statistical measures to develop enhanced, CDR-compliant records of NH terrestrial snow and ice conditions; 3. the CDRs and associated products will then be provided via an existing Web site (http://climate.rutgers.edu/snowcover/) for access by the community. The CDRs will also be distributed to relevant national data centers.
The key elements of this project include our previous experience in working with the relevant data set; our proven success in creating data records and transitioning them to data centers; and our understanding of the NRC report on CDRs.
This project will provide important information for answering questions related to the following NASA Earth science questions:
1. How is the global Earth system changing?
2. What are the primary causes of the earth system variability?
3. How does the Earth system respond to natural and human-induced changes?
4. What are the consequences of change in the Earth system for human civilization?
5. How well can we predict future changes in the Earth system?

William Rossow/The City University of New York/The City College
Global Cloud Process Studies in the Context of Decadal Climate Variability: Enhancement and Continuation of Data Analysis for the International Satellite Cloud Climatalogy Project (ISCCP)

The proposed work is to enhance the use of observations from the available constellation of satellites for studying the role of clouds in causing weather and climate variations and to extend the data record to the end of the GEWEX project in 2012 as called for in the Global Earth Observing System of Systems plan. The ISCCP datasets currently provide a description of cloud variations covering the largest range of scales from mesoscale to planetary and from diurnal to interannual (more than 1300 papers have been published based on the ISCCP datasets). Simply extending the ISCCP record, now the longest, truly global cloud dataset, from 24 to 29 years has a straightforward value for climate studies in expanding the time scales that can be studied to inter-decadal scale. Another crucial reason to extend the ISCCP record is to overlap the observation period of the CloudSat and Calipso missions: this was planned for the last funding period but the launch of these missions was delayed by about two years so that this could not be done. In fact, there will be an unprecedented complement of cloud-observing instruments in orbit during the next few years that cover the electromagnetic spectrum in great detail and provide, for the first time, a global view of the atmosphere's vertical structure: the combination of the "A-train" set of satellites, TERRA and TRMM creates rich possibilities for advancing understanding of clouds. This combination of measurements may not be duplicated anytime in the near future. However, the major limitation of all of these satellite missions is that their time sampling is much too sparse for direct observations of the evolution of cloud systems, precluding straightforward cloud process studies. Hence, the ISCCP

datasets, which have much more frequent time sampling (3 hr), provide the essential "glue" for analysis of all these observations by providing the capability to re-arrange the sparsely sampled measurements into an "evolutionary" order for different types of cloud systems. The major limitation of the current ISCCP datasets used for this purpose is their relatively sparse spatial sampling (30 km). However, work done at the NOAA National Climatic Data Center, with help from the PI's group, is well on the way to refurbishing an alternate collection of the radiance data with 10 km spatial sampling (only a factor of two less dense than the original datasets). Moreover, older radiance data have been found that may allow extension of the ISCCP record back to at least 1981, possibly even to 1979. Thus, the rationale for extending the ISCCP project is to take advantage of the availability of a more densely sampled radiance dataset to produce a much more effective merger of ISCCP products with newer cloud observations, particularly the profiling information from TRMM, AIRS, MLS, CloudSat and Calipso. The proposed work includes modifying the ISCCP analysis code for application to the 10 km-sampled radiances with some re-tuning of the algorithm tests, which should produce modest improvements. Then, the whole record will be completely re-processed using the refined calibrations and analysis methods developed under the current funding. Processing the 10km-sampled radiances has additional consequences: (1) the Global Precipitation Climatology Project can use the denser infrared radiance data to interpolate microwave precipitation measurements to obtain higher space-time sampling (possibly 3 hr, 25 km), (2) the Global Aerosol Climatology Project uses the pixel-level (Level 2) ISCCP product, so the denser sampling would allow resolving smaller time intervals than monthly and (3) the GEWEX Surface Radiation Budget project would have much reduced sampling noise in its radiative flux products using the denser ISCCP products.

David Roy/South Dakota State University
Web-enabled Consistent Large Area Landsat Data Streams and Derived Surface Characterizations - A MODIS-Landsat Data Fusion for the Terrestrial User Community

The overall objective of MEaSUREs solicitations is to select projects providing Earth science data products and services driven by NASA's Earth science goals and contributing to advancing NASA's missions to measurements concept. This proposal contributes to the Land measurement theme; working at high spatial resolution and using state of the art and validated MODIS land products to systematically generate seamless consistent mosaiced Landsat ETM+ data sets with per-pixel quality assessment information and derived land cover characterization at monthly and longer time periods. This proposal will improve the consistency and quality of ETM+ SLC-off data through a fusion with MODIS land products. The resulting high spatial resolution mosaic products will be generated for the conterminous USA and Alaska for a 7 year period, from October 2006 to September 2013, and made freely available to the user community.

This proposal is a formal collaboration between the United States Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) and its academic partner, the recently inaugurated South Dakota State University Geographic Information Science Center of Excellence (GIScE). Through this partnership, the USGS Landsat

project will commit to making all ETM+ SLC-off data acquired over the conterminous USA and Alaska, and later for select regions globally, available at no cost and regardless of cloud cover. The processing, based on heritage techniques and contemporaneous fusion of MODIS data, will be prototyped at the GIScE with systematic processing undertaken at EROS. Data products will be updated in near real time and made available to the user community through a modified EROS internet distribution interface. This is a 5 year proposal with an annual mean budget of approximately $720K and significant USGS cost sharing.

Chung-Lin Shie/UMBC
Reprocessing of Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) Data Set for Global Water and Energy Cycle Research

We propose to resume processing of, and to reprocess, the Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) data set. This data set has been widely used by scientific communities for global energy and water cycle research and regional and short period data analysis since its official release in 2000/2001. Accurate sea surface fluxes measurements are crucial to understanding the global water and energy cycles. The oceanic evaporation that is a major component of the global oceanic fresh water flux is particularly useful to predicting oceanic circulation and transport. Remote sensing is a valuable tool for global monitoring of these flux measurements. The GSSTF algorithm has been developed and applied to remote sensing research and applications. The latest version (version 2) of GSSTF covered the data period starting in 1987 and ended in 2000. Objective: The objective of this project is to continually produce a uniform data set of sea surface turbulent fluxes derived from remote sensing data and analysis that have been and continue to be useful for global energy and water flux research and applications. Method/Technique: Our approach is first to update the algorithm codes with bug fixes discovered and reported by users and developers of GSSTF version 2. The data set will then be reprocessed and brought up-to-date using improved input data sets. The input data sets include a recently released NCEP sea surface temperature analysis, a uniform (across satellites) surface wind and microwave brightness temperature data set from the Special Sensor Microwave Imagers on board the DMSP satellites produced by the Wentz of RSS. To gauge the improvement of the data set over the previous version and provide error/confidence estimates, the surface fluxes will be compared with historical field experimental data and buoy observations. Error estimates of the flux products will be included in the documentation.
Significance of the Project: This product is useful for diagnosing the global water and energy cycle and hence can contribute to the WCRP/GEWEX and NASA/NEWS goals. Model climate simulations show an enhanced hydrologic cycle, which must be corroborated with observations. The daily temporal and one degree spatial resolution of the product can be used to examining climate variability at these scales. Oceanic evaporation contributes to the net fresh water input to the oceans and drives the upper ocean density structure and consequently the circulation of the oceans. Fully tested, this product can serve as a crucial input for data assimilation of oceanic GCMs for forecasting.

John Townshend/University of Maryland
Earth Science Data Records of Global Forest Cover Change

We propose to produce the following Earth Science Data Records (ESDR) at fine and moderate spatial resolutions and provide the algorithms and services for producing such products:

1. Global fine resolution surface reflectance ESDR for four epochs centered around 1975, 1990, 2000, and 2005;
2. Fine resolution forest cover and change ESDR between the four epochs;
3. Global 250-m vegetation continuous field (VCF) of tree cover and annual change ESDR from 2000 to 2006.

The fine resolution ESDR will be produced primarily using the three GeoCover data sets created by NASA and the follow-on Mid-Decadal Global Land Survey (MDGLS) data set being jointly developed by NASA and USGS. The surface reflectance ESDR will be created using an atmospheric correction algorithm implemented in the LEDAPS system, which has a demonstrated capability of producing consistent surface reflectance products for the entire North America continent using the GeoCover 1990 and 2000 data sets within two to three weeks.

The surface reflectance ESDR will be used to create forest cover and change products using an automated change detection method called training data automation (TDA)-support vector machines (SVM). The TDA-SVM method has been tested in study areas representing major forest biomes across the globe and produced highly accurate results. This method is being integrated into the LEDAPS system to allow mass data processing capability. We will also produce fragmentation and change products based on the land cover change products.

The 250-m ESDR will be produced using the MODIS vegetation continuous fields (VCF) algorithm and MODIS data acquired since 2000. High levels of consistency will be maintained between the 250-m ESDR and the 2000-2005 fine resolution forest cover change ESDR. We will use the 250-m ESDR and the fine resolution ESDR to calculate net annual forest cover changes

Comprehensive validation will be conducted for all ESDR products to be developed through this study. To facilitate use of the developed ESDR products by the conservation community, a special subset of these products will be produced for protected land areas and their surrounding areas. According to the World Database on Protected Areas (WDPA), protected areas account for about 10% of the worlds' land area. All products produced through this study will be made available to the science community and the general public through GLCF's internet distribution system.

Thomas Vonder Haar/Science and Technology Corp.
Improvement of the NVAP Global Water Vapor Data Set for Climate, Hydrological, and Weather Studies

This proposal utilizes the Aqua retrievals of total column and layered precipitable water to extend the global water vapor data record, and to improve and refine the historical NASA Water Vapor Project (NVAP) global products. From 1992 - 2003 in three separate efforts, the principal investigator and his team at STC-METSAT have developed this unique 14-year climate data set (1988 - 2001) for NASA's Pathfinder Science program. The existing NVAP dataset has been cited in over 150 scientific papers, but a reanalysis is needed to make the dataset consistent for detection and understanding of long-term trends which are hypothesized to occur as Earth warms. By continuing to expand the temporal coverage of water vapor measurements from satellites and improving the analysis, we create a record of variability of Earth's water vapor on various scales. The use of Aqua water vapor retrievals will greatly improve the error characteristics of the historical NVAP data, and also allow for much improved studies on long-term variability and climate trends.
Key features of this dataset for researchers are the daily, vertical-layer water vapor fields over BOTH land and ocean. This enables advanced climate and weather research as well as studies of interest to hydrologists.

In our approach, years 2003 and 2004 will be "bridge" years, where the heritage NVAP approach will be compared to the powerful Aqua measurements from MODIS and AIRS. This will extend the influence of the Aqua instruments back in time by comparing the pre-Aqua data set approach to the Aqua record. The final result will be a 24-year global water vapor dataset spanning 1987 - 2010 called NVAP-MEaSUREs (NVAP-M).

The proposed effort will support the research aims of the new IPCC-FAR and will lay the groundwork for additional NPP and NPOESS contributions to the global water vapor record.

Frank Webb/ Jet Propulsion Laboratory
SOLID EARTH SCIENCE ESDR SYSTEM

Building on NASA's investment in the measurement of crustal deformation from continuous GPS, we will build and deploy a Science Data System (SDS), which will provide mature, long-term ESDRs that support NASA's Earth Surface and Interiors (ESI) focus area and provide NASA's component to the EarthScope PBO. Our project will be the only system providing such ESDRs that meet the ESI science goals for understanding earthquakes and the processes that drive tectonic motion and crustal deformation, and using this knowledge for societal benefits from mitigation of natural hazards to K-12 science education. It will integrate the generation of ESI ESDRs with data analysis and exploration, product generation and modeling tools based on daily, high-rate, and real-time GPS data, that include GPS networks in western North America and a component of NASA's Global GPS Network (GGN) for terrestrial reference frame definition. The system is expandable to multiple regional and global networks. The SDS will build upon mature data production, exploration, and analysis algorithms developed under NASA's

REASoN, ACCESS, and SENH programs. This project is responsive and directly relevant to goals 3A-6 and 3A-7of Table 1 of the NRA.

The community will be engaged in the development of these records though the team's existing involvement in community driven science strategic planning, organization, and support for the broader EarthScope efforts. Additionally, the team will continue to provide value and support to ongoing NASA Earth data system evolution by participating on DSWG in Technology Infusion. The proposed SDS will be NASA's primary geodetic contribution to EarthScope. The coordination with the broader community will be through the continued and expanded active participation of team members with UNAVCO.

In addition to GPS surface deformation data products, we will also provide GPS-based tropospheric data products for calibration for deformation studies based on InSAR techniques from past, current, and planned space sensors from ESA and NASA. The products will include over a decade of tropospheric time series for use in calibrating water vapor errors that are one of the limiting InSAR error sources. Ready access to such a long term record of tropospheric data products will assist in the formulation of requirements for the next InSAR mission by providing InSAR researchers calibration maps with which to develop and test atmospheric error mitigation strategies. These records will cover the lengthy archive of InSAR data sets from the last decade as well as from future data sets collected during the lifetime of this project. The tropospheric products will be based on algorithms from the open literature some of which were developed by team members. The products will be in the form of GPS-derived in situ ground based calibrations for remotely sensed tropospheric data and for tropospheric calibration maps over tectonically active regions with dense GPS networks.

Finally, the SDS will further ESI's goals in GGOS by providing access to L1-L4 GPS data products from tracking stations in both the PBO and global GPS networks.

The proposed project leverages the IT and Web Services developments of SCIGN-REASoN and ACCESS projects. These projects have streamlined the access to data products for researchers and modelers, and leveraged the real-time components of the SENH applications project to create an on-the-fly interactive research environment through our modern data portal, GPS Explorer. Our 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. We have built upon open GIS standards, particularly those of the OGC, and have used the principles of Web Service-based Service Oriented Architectures to provide scalability and extensibility to new services and capabilities.

Frank Wentz/Remote Sensing Systems
Distributed Information Services: Climate/Ocean Products and Visualizations for Earth Research (DISCOVER) - Continuation of Project

We are proposing to continue the DISCOVER (Distributed Information Services for Climate and Ocean Products and Visualizations for Earth Research) project for another five years. DISCOVER is a NASA funded collaboration between Remote Sensing Systems (RSS) and the Global Hydrology Resource Center (GHRC). The major focus of DISCOVER is to provide highly accurate, long-term geophysical products derived from satellite microwave sensors. These products are suitable for some of the most demanding Earth research applications and are available via easy-to-use display and data access tools. Most of the products are generated in near real-time (3-12 hours) on a 24x7 basis, so they also are suitable for some weather applications. DISCOVER's basic products include sea surface temperature (SST) and wind, atmospheric water vapor, cloud water, and rain rate. From these basic retrievals, an array of higher-level products are derived (1) by merging retrievals from different satellites on different platforms and (2) by combining different types of retrievals. An example of the first type of derived product is the optimally interpolated SST fields created from two different microwave sensor observations: TMI and AMSR-E. An example of the second type is evaporation fields derived by combining SST, wind, and water vapor. DISCOVER currently has an extensive user base. These users have a high level of confidence in our microwave products, some of which (water vapor time series for example) have become a standard in the climate community. DISCOVER is highly relevant to current climate research, particularly with respect to the water and energy cycle. At the completion of this proposed work, we will have nearly 30 years of consistently processed wind speed, water vapor, cloud water, and rain rate products. It would be hard to overstate how important these Earth Science Data Records will be to climate research.

Eric Wood/Princeton University
Developing Consistent Earth System Data Records for the Global Terrestrial Water Cycle.

We propose to develop consistent, long-term Earth System Data Records (ESDRs) for the major components (storages and fluxes) of the terrestrial water cycle at a spatial resolution of 0.5 degrees (lat-long) and for the period 1950 to near-present. The resulting ESDRs are intended to provide a consistent basis for estimating the mean state and variability of the land surface water cycle at the spatial scale of the major global river basins. The ESDRs we propose to include are a) surface meteorology (precipitation, air temperature, humidity and wind), b) surface downward radiation (solar and longwave) and c) derived and/or assimilated fluxes and storages such as surface soil moisture storage, total basin water storage, snow water equivalent, storage in large lakes, reservoirs, and wetlands, evapotranspiration, and surface runoff. We intend to construct data records for all variables back to 1950, recognizing that the post-satellite data will be of higher quality than pre-satellite (a reasonable compromise given the need for long-term records to define interannual and interdecadal variability of key water cycle variables). A distinguishing feature will be inclusion of two variables that reflect the

massive effects of anthropogenic manipulation of the terresrtial water cycle, specifically reservoir storage, and irrigation water use.
The overall goal of the proposed project is to develop long term, consistent ESDRs for terrestrial water cycle states and variables by updating and extending previously funded Pathfinder data set activities to the investigators, and by making available the data set to the scientific community and data users via a state-of-the-art internet web-portal. The ESDRs will utilize algorithms and methods that are well documented in the peer reviewed literature. The proposed ESDRs will merge satellite-derived products with predictions of the same variables by LSMs driven by merged satellite and in situ forcing data sets (most notably precipitation), with the constraint that the merged products will close the surface water budget. The primary land surface forcing variable, precipitation, will be formed by merging model (reanalysis) and in situ data with satellite-based precipitation products such as TRMM, GPCP, and CMORPH. Derived products will include surface soil moisture (from TRMM, AMSR-E, SMMR, SSM/I passive microwave and ERS microwave scatterometers), snow extent (from MODIS and AVHRR), evapotranspiration (model- derived using ISCCP radiation forcings from geostationary and LEO satellites), and runoff (from LSM predictions and in-situ measurements).
There currently exists no comprehensive effort to integrate data sets from remote-sensing, in-situ and models on global scales, and a major focus of our proposal will be to do so. Such a data set is needed to address the NASA strategic goal 3A, which is to study Earth from space to advance scientific understanding and meet societal needs. In particular, the developed ESDRs will help NASA meet its research outcomes in three areas related to this strategic goal; namely Outcome 3A.2, Weather and extreme weather events, by providing more accurate land states (surface soil moisture and snow extent) from which to initialize weather and seasonal climate prediction models; Outcome 3A.4 Progress in quantifying reservoirs and fluxes in the global water cycle, though improved understanding of water cycle variability obtained from the long-term consistent ESDRs; and Outcome 3A.7 Societal benefits from Earth system science, by providing ESDRs that support determination of drought and flood risks globally and advances the understanding of freshwater sustainability. Furthermore,the project will participate in the Data Systems Working Groups, in the areas of managing distributed data (Standards and Interfaces WG), collaborating for the optimal use of existing tools (Reuse WG), and integrating methods for merging heterogeneous datasets (Technology Infusion WG).

Victor Zlotnicki/California Institute of Technology
An Earth System Data Record of changes in Earth masses from GRACE, CHAMP and other satellites.

Researchers have utilized data from the GRACE mission for many new research applications in hydrologic, cryospheric, and ocean studies, made uniquely possible by GRACE, for example, determining the mass losses of Greenland and Antarctica. GRACE measures time changes in the gravity field, from which we derive time changes in surface mass distributions. Because this is a totally new data type, we continue to find ways to make major improvements on the accuracy of the derived mass distributions. The GRACE time series started in mid 2002, and resolves monthly time changes in gravity

between spherical harmonic (SH) degrees 2 and about 60 (roughly, wavelengths 180o to 6o, in degrees of latitude or longitude); longer time averages can resolve shorter wavelengths). About 2 years earlier, the German mission CHAMP started to measure the Earth's gravity field, and it continues to do so today, albeit with lower accuracy for comparable time-space scales since it uses a different technology to measure gravity. Researchers have retrieved CHAMP gravity coefficients for SH degrees 2-10 (roughly, wavelengths longer than 36o in degrees of latitude or longitude) averaged over 3 months with accuracy comparable to GRACE's one month averages, at the same wavelengths. A long time series (3 decades at monthly spacing) of the Earth's gravity field's SH degree 1,2, and 3 coefficients (roughly, wavelengths longer than 120o) exists from satellite laser ranging (SLR) to Starlette, Ajisai, Stella, LAGEOS 1 and 2, Etalon 1 and 2, Beacon-C. The degree 1 coefficients pose a special problem. GRACE and CHAMP tracking alone provide weak constraints on them. Combinations of GPS data from ground network stations and low Earth orbiters, with ocean bottom pressure estimates, allow retrieval of their seasonal and some interannual variability but not yet trends, while SLR provides the strongest constraint on degree 1. GRACE intersatellite ranging data do not improve the degree 1 coefficient beyond the value provided by the GPS tracking. Thus an adjustment to all the known data is necessary better to constrain these degree 1 terms, a task we also propose here. This proposal focuses on reprocessing as needed by the various missions in order to obtain a consistent time series of global mass distributions, for use in estimates of mass change in the hydrologic, cryospheric and oceanic components of the Earth System, for the time period 2000-present, extended into earlier decades at much lower resolution. We understand that different length scale and frequency bands, and different accuracies, can be expected from the different missions. We aim to eliminate systematic differences in processing as a source of discrepancy, to generate different sets of time series of mapped mass variability, with the same wavenumber and frequency content. We will generate science-enabling, consistent gridded mass distributions, (expressed as cm of equivalent water thickness), with improved spatiotemporal coverage, resolution and accuracy for Earth mass studies, and with error estimates. We will provide the data through a public Web and ftp interface, using standard formats for data and metadata, together with such other web services as may become standard.