Maintaining and Refining NASA's Land Product Validation Infrastructure

A proposal in response to NRA-03-OES-02 (EOS Algorithm Refinement)

PRINCIPAL INVESTIGATOR: Dr. Jeffrey T. Morisette
Code 923 Biospheric Sciences Branch
NASA's Goddard Space Flight Center
Greenbelt, MD 20771
Tel. 301-614-6676 Fax. 301-614-6695
Jeff.Morisette@nasa.gov

CO- INVESTIGATOR: Dr. Jeffrey L. Privette NASA's GSFC

Abstract:

Over the past six years, the MODIS Land Science Team has developed a validation infrastructure that supports key activities needed to determine the accuracy of its global land products. These include resource support of the "EOS Land Validation Core Sites", coordination of EOS, MODIS and other NASA-funded land validation activities, and international leadership of efforts to establish standardized validation protocols and global land product inter-comparisons associated with NASA's priority land products. The proposed work will continue and enhance this infrastructure to maintain validation support for current and future EOS land products (including those from MODIS, MISR, CERES and ASTER)as well as forthcoming land products from NPOESS Preparatory Project (NPP, launch ~2006)and National Polar Orbiting Environmental Sensing System (NPOESS; launches starting ~2010). One of the ultimate objectives of the proposed work is to understand the variability of the products with respect to their role in continuing long-term Climate Data Records.

PROJECT DESCRIPTION

1. Introduction

In December 1999, NASA launched Terra, the first of the major Earth Observing System (EOS) platforms. Despite its technological improvements, Terra may be most noteworthy for ushering in the age of multidisciplinary operational products. Terra includes five sensors, including the MODerate Resolution Imaging Spectroradiometer (MODIS; Justice. and Townshend, 2002). MODIS is a wide field-of-view (2330 km) sensor that provides daily coverage of most locations, and complete global coverage every two days. Since 1990, MODIS science teams, stratified by land, atmosphere and ocean disciplines, have been formulating, and now operating, computer algorithms capable of generating global change research parameters in near real-time.

In 1997, the MODIS Land Discipline Team (MODLAND) began developing an infrastructure to support validation of its operational products. The effort was novel since the MODIS high-level products are global and diverse (e.g., Albedo, Leaf Area Index, Burn Scars, and Net Primary Production; Justice et al., 1998b). In cooperation with existing science networks, MODLAND established a set of Earth Observing System (EOS) Land Validation Core Sites for which an aggressive image collection program was initiated (Morisette et al., 1999). The resulting Core Site data archives were also developed in cooperation with EOS Distributed Active Archive Centers (DAACs), which facilitate easy data access through web-based interfaces and provide an ongoing focus for validation of global land products.

To help contain costs and expand available resources, MODLAND also helped initiate the Land Product Validation (LPV) subgroup of the Committee on Earth Observing Satellites (CEOS) Working Group on Calibration and Validation (WGCV) in year 2000. Through a series of LPV workshops, international scientists have collaboratively defined several “Product Site” networks – or networks catered to just one satellite product – that increase the global sample beyond the Core Sites. The LPV workshops have also begun working toward the development of consensus strategies for validation data collection, formatting, analysis and exchange. In sum, these various activities have helped to coalesce a multitude of uncoordinated activities (some associated with validation, some not) into an organized resource to help achieve accuracy information for EOS products.

MODLAND product developers, as other EOS sensor product development teams, have used this resource in part to refine and strengthen their operational products in a "cost-sharing" fashion. Likewise, the validation results have allowed EOS product users develop reasonable error budgets for their final results.

The implementation of the EOS Land Validation Core Sites, land product validation coordination, and LPV activities resulted from the combined efforts of many, including several NASA science teams and multiple US and international agencies. However, the primary manpower support for this work has come through validation funding from the MODIS land team at approximately $250K per year. The primary source of funding for the data has been approximately $333K per year from the Scientific Data Purchase for IKONOS, and $83.3 per year from the Office of Earth Science (OES) data programs for ETM+ data. This sizable investment has provided a very strong foundation for the validation of global land products. We now propose to continue development of this community resource as an independent EOS support activity. Consistent with NRA directions, budgeting for "core" validation support will not be carried by the MODIS land team beyond September 2003. Moreover, funds are no longer available through the Scientific Data Purchase, and because the OES budget for Landsat orders is not secure, we have thus been encouraged to use this NRA to request continued funding for Landsat data (personal communication with Martha Maiden, Program Executive for Data Programs, OES). Therefore, to maintain and enhance the land product validation infrastructure that has been established and is poised to expand, a new funding source is required.

It is important to note that the proposed activities enable a system that serves validation as well as other science communities and activities.

The solicitation (NRA-03-OES-02) states:

> The goal of the algorithm refinement activity in this NRA is to provide the scientific community with an archived long-term data set of each relevant measurement parameter with ***the measurement uncertainties indicated as a function of time and location for all the data.***

Emphasis has been added to that portion of the statement that is particularly relevant to this proposal, which is programmatic in nature, and critical for the continuation and refinement of NASA's current infrastructure for global land product validation. Here we

consider "validation" to be the quantitative assessment of a product's uncertainty by comparison with independent sources (Justice et al., 2000). Validation of current and future EOS land products can be done more rigorously and most cost-effectively if:

1. A set of "Core" validation sites are maintained in the long term
2. MODIS-, EOS-, and other NASA-funded land validation activities are coordinated
3. Consensus validation protocols are adopted within the international community, thus allowing for international data collection, processing and sharing and collaboration on validation activities

Together, validation activities need to focus on quantitatively assessing the variability of those products contributing to long-term Climate Data Records (CDRs). Any trend in a parameter's time series must be evaluated against the unexplained variability in that parameter. Similar parameters from multiple sensors and multiple platforms can only be compared with an understanding of the variability of each parameter. Validation activities focused on determining the signal to noise ratio in climate trends and allowing statistical comparison of products from multiple sensors and platforms provide a critical component to NASA's Earth Science Enterprise (ESE). If a satellite-derived product is a significant component of NASA's long term climate modeling efforts, then the uncertainty in that product needs to be established. Indeed, all CDRs must be validated.

The primary goal of the proposed effort is to provide the infrastructure support required to efficiently validate global land products – with the ultimate objective of understanding the variability in land-related CDRs. It leverages a system that has been developed and improved incrementally over the past seven years, and currently serves a large user community that extends well beyond the EOS validation scientists.

2. Maintaining and enhancing the EOS Land Validation Core Sites

2.1. Background

The EOS Land Validation Core Site system was initiated in a 1998 meeting of the Science Working Group for the AM (Terra) Platform (SWAMP) and the newly-selected EOS Validation Team (Justice, Starr, Wickland et al., 1998). The system was developed to facilitate cost-effective, multi-product and multi-sensor validation activities by consolidating resources (data acquisition, instrumentation, field campaigns) around a consensus set of sites. The sites were selected based on their ecological and

climatological distribution, heritage and future land use, accessibility, and overlap with existing science networks (e.g., Long Term Ecological Research [LTER] program, FLUXNET network (http://daacl.esd.ornl.gov/FLUXNET/), AERosol Robotic Network (AERONET, (http://aeronet.gsfc.nasa.gov:8080/), and the Global Land Cover Test Sites (GLCTS). The latter leads to complimentary data sets, but more importantly, allows validation to be conducted within a scientific context – an aspect that allows significant leveraging of validation resources (Morisette, Privette, and Justice, 2002).

In our efforts to coordinate MODIS product validation, we commenced an aggressive data acquisition plan for the Core Sites at the onset. Our goal was to develop extensive data archives for each of the Core Sites. This resource would allow scientists to easily conduct inter-sensor data and product comparisons, parameterize algorithms and process models (e.g., Interdisciplinary Science projects), and access fine and intermediate resolution (1m to 30 m) products. As the value of these archives became evident, other projects and teams volunteered additional data resources.

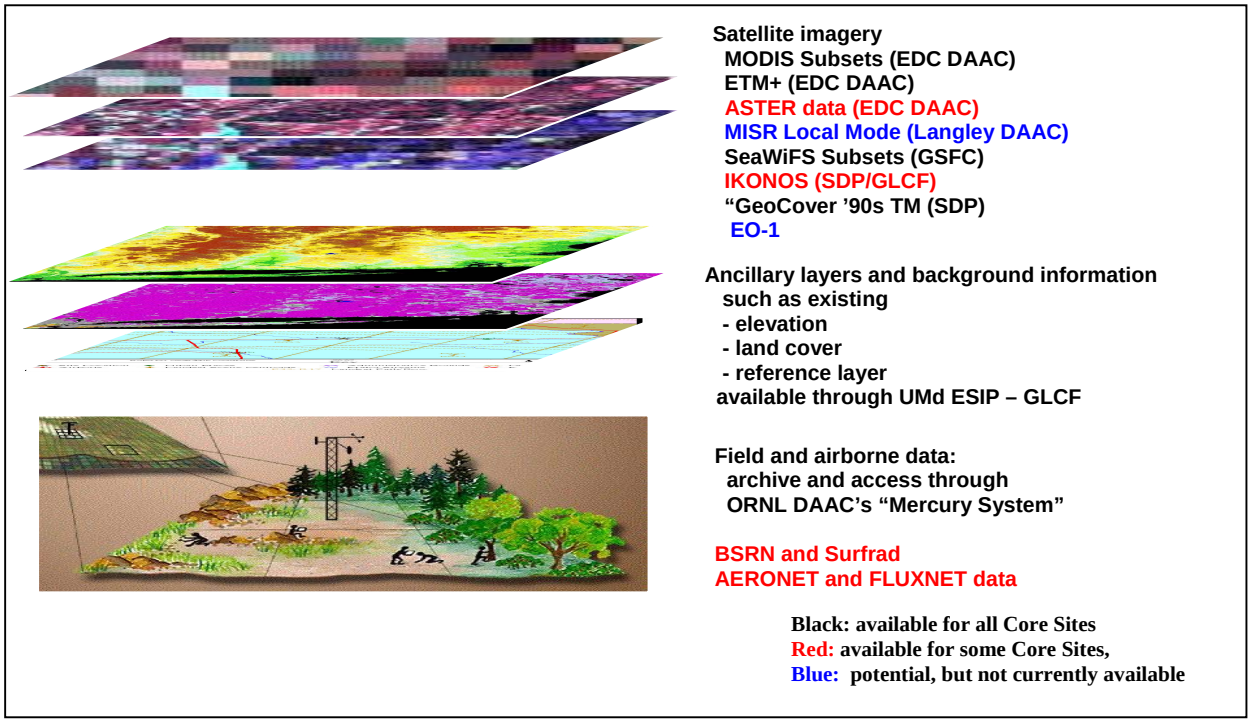
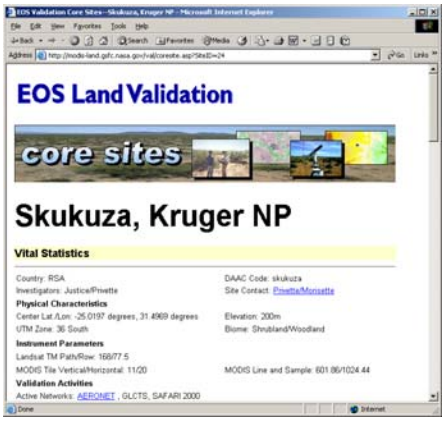


Figure 1: EOS Land Validation Core Site data suite

Concurrently, we initiated efforts with the Land Processes (LP) and Oak Ridge National Laboratory (ORNL) DAACs to facilitate data storage and internet access. Further, we developed our own web-based interface; which provides direct, web-based access to the

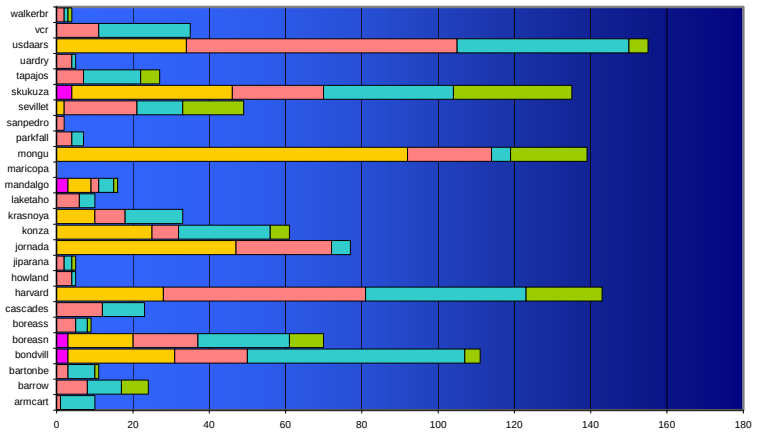
Core Site Data suite. The web-based system is populated by an extensive database that was established in 1999 and continues to grow. It contains pointers to all of the Core Site image, field, and airborne data sets as well as browse imagery and metadata for many of the data sets. This relational database contains links to several hundred validation-related data sets. Shown below is an example web page for the Kruger National Park, South Africa. The information shown on the page is dynamically generated from information in the database. The page contains links to IKONOS, Enhanced Thematic Mapper Plus (ETM+), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery; subsets from MODIS and Sea-viewing Wide Field-of-view Sensor (SeaWiFS); AERONET data, a link to ORNL's Mercury System, photos and figures, and other links and background information for the site. All but the IKONOS data are freely and directly available for on-line file transfer protocol (ftp) access. (IKONOS data can be ordered by NASA-funded investigators through the Scientific Data purchase – instructions are provided on the Core Site web page.) Currently there are 26 Core Sites: which all have similar links provided through the main EOS Land Validation Core Site Web page (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/).



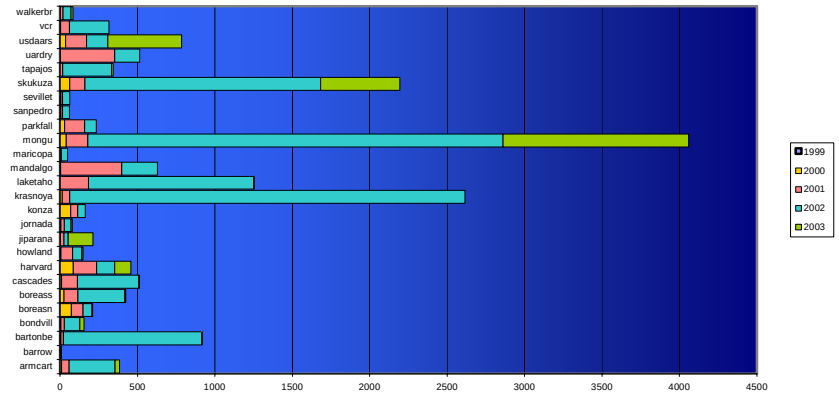
The multi-resolution image suite, and links to field data networks, are a useful resource for global land product validation. Of all reported MODLAND validation activities in the year following launch, half of those occurred at or near an EOS Land Validation Core Site (Morisette et al, 2002). Close coordination with the BigFoot group (see http://www.fsl.orst.edu/larse/bigfoot/index.html and support letter from Cohen) has led to the inclusion of all BigFoot Sites in the EOS Land Validation Core Sites. Many of the sites selected as CEOS "LAI-Intercomparison" sites (discussed below) are also EOS Land Validation Core Sites (http://modis.gsfc.nasa.gov/MODIS/LAND/VAL/CEOS_WGCV/lai_intercomp.html).

The EOS Core Sites provide Earth scientists with readily accessible *in-situ* and EOS instrument data. The ORNL-DAAC consistently reports that all or most of their top ten data referrals are for data collected at EOS Core Sites (ORNL User Working Group bi-annual reports). Figure 2 shows the number of MODIS subsets and ETM+ files retrieved from the EOS Land Validation Core Site on-line directories hosted at the LP DAAC.

These statistics suggest that data at the Core Sites are well utilized. It is interesting to note the trend of more ETM+ files being pulled in 2000 and 2001, and more MODIS filed extracted in 2002 and 2003. We believe this reflects the progression of first coupling field data with Landsat to create high-resolution products, then retrieving the MODIS files for comparison.



Number of **ETM+** scenes ftp-downloaded from the EOS Land Validation Core Sites



Number of **MODIS** scenes ftp-downloaded from the EOS Land Validation Core Sites

Figure 2: ftp statistics for the ETM+ and MODIS data from the EOS Land Validation Core Sites

The EOS Land Validation Core Sites now serve as a focus for global land product validation. These sites have served MODIS/Terra product validation and are the primary validation locations for all of the MODIS land products except for the snow and fire products (see table 1, Morisette, Privette, and Justice, 2002). The Core Sites will continue to be used for MODIS/Aqua land product validation efforts by multiple teams (see support letters from Justice, Running, Baldocchi, Myneni, and Townshend). Further,

they are providing a major contribution to international land product validation (Baret et al., in review), and are an important component of the validation plans for upcoming satellite missions (Section 6.3, NPP/NPOESS, 2001). As such, it is imperative that the support of these sites be continued throughout this decade.

2.2. Proposed work plan / specific tasks

We propose to build on the existing Core Site infrastructure by adding data sets, expanding the number of sites, and combining data and results from multiple sites to better estimate global uncertainty in the MODIS land products. In addition to the data sets listed in Figure 1 continued efforts will add a 20-year record of AVHRR-NDVI, SPOT-VEGETATION data from 1999 to present, subsets of Shuttle RADAR Topography Mission (SRTM) elevation data, and precipitation data from the Tropical Rainforest Measuring Mission (TRMM). The Advanced Very High Resolution Radiometer (AVHRR) and SPOT data sets will be processed by the GIMMS lab at Goddard Space Flight Center (personal communication with Dr. Tucker, Global Inventory Mapping and Modeling [GIMMS] director). Pilot work with GIMMS has supplied subsets of SPOT VEGETATION data for 1999 for all of the Core Sites, and a 20-year record of AVHRR data for the Skukuza, South Africa Core Site. SRTM data is due to become available in 2003 and we will use the personnel and computing resources requested in the proposal to process and provide access to SRTM subsets over the Core Sites. For the TRMM-derived products we will use the experience learned from the SAFARI 2000 data CD-ROM production (Privette et al., 2001; Nickeson et al., 2002); which includes TRMM-derived products, to supply precipitation data for the Core Sites.

We propose to expand the number of sites by adding two sites a year for the next three years. Candidate sites will be those that build on existing science networks and/or fill gaps in our current global distribution. For science networks we will consider both national, such as LTERs (Hobbie et al., 2003) and AERONET (Holben et al., 1998), and international, such as CEOS/Global Terrestrial Observation System (GTOS). Candidate sites are those where 1) field data that can serve validation needs are being collected, and 2) there is a strong interest in the use of MODIS land products. Currently 7 of the 26 Core Sites are part of the LTER network. The MODIS land team maintains communication with the LTER network and considers additional LTER sites to be strong candidates for new Core Sites (primary contact: John Vande Castle, LTER network office, letter of support attached). The LTER program's Twenty-Year Review states the

program should continue its partnership with federal agencies to explore new technologies, including remote sensing (LTER, 2002). There are two LTER sites currently using MODIS data that are interested in further collaboration, these are the Kellogg Biological Station, MI (personal communication: Phil Robertson) and Bonanza Creek, AK (personal communication: Dave Verbyla). The AERONET program, coordinated by Dr. Brent Holben of Goddard Space Flight Center, will continue to provide sun photometer data for key validation sites, at least during aircraft and/or intensive field campaigns. To increase the number of international sites, we will look to the Terrestrial Ecosystems Monitoring Sites (TEMS, www.fao.org/gtos/tems; Cihlar et al., 2002) database as the primary directory of international sites and networks that carry out long-term terrestrial monitoring and research activities (Cihlar, 2002). From this large list of sites (1,723 sites at the time of this proposal), we will focus on the "regional networks" of the Global Observation of Forest Cover and Land Dynamics (GOFC/GOLD) program (see support letter from Dr. Townshend, GOFC/GOLD Chair; more on international efforts is given in Section 4). Whether in the US or internationally, Core Sites will be added to help us achieve a more "globally representative" set of sites; which implies enough sites within each continent to cover the major biomes (Stilings, 1992; Odum, 1971) within that continent (Morisette, Privette, and Justice, 2002). Figure 3 shows the Core Sites on the globe as well as their distribution in precipitation, temperature and productivity (shown as LAI, Leaf Area Index). Any new core site will be considered with respect to its location in both geographic and meteorological/productivity space.

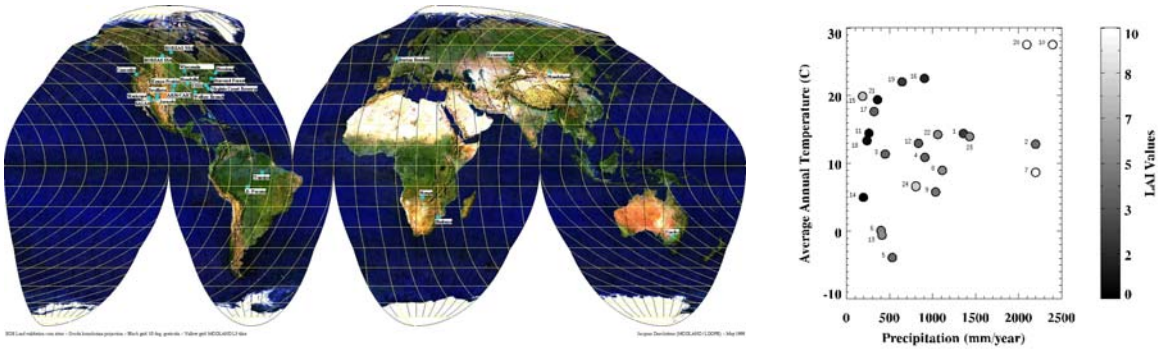
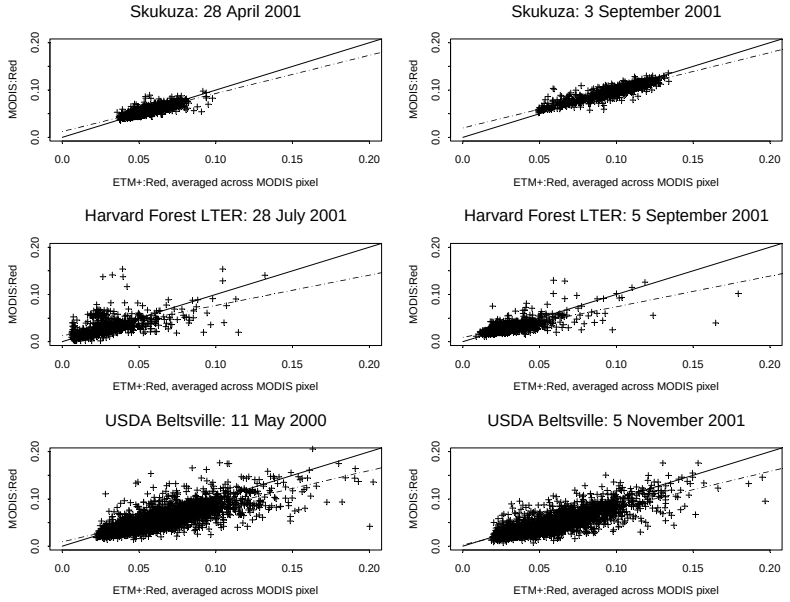


Figure 3: EOS Land Validation Core Sites in geographic (left) and meteorological (right) space

In addition to expanding the number of sites and adding to the Core Site data suite, we propose to fund a full-time, post-doctoral level researcher to combine the current single-site validation work into a more comprehensive global validation approach. The

application of validation techniques and principles learned in the first two years of MODIS validation can be applied to the data sets available at the Core Sites. For example, the validation procedure for the MODIS surface reflectance product, discussed in Vermote (2002), can be applied systematically to all EOS Land Validation Core Sites that have coupled MODIS, ETM+ and AERONET sun photometer data. As a pilot study for this type of work, an automated procedure has been developed to use AERONET, ETM+, and 6S modeling (Vermote, 1997) to produce high-resolution atmospherically corrected images that can be aggregated and compared to the MODIS surface reflectance product. Figure 4 shows the results of this activity for the near-infrared band at three Core Sites on two dates for each site. The Core Site infrastructure provides easy access to the data required to conduct such analysis across the globe and through time.



Matching Correlation coefficients:

0.85	0.93
0.38	0.76
0.79	0.83

Figure 4: ETM+ averaged over 500 m vs the corresponding MODIS value for three scene, two dates each, the "red" band; the solid line is a reference 1-to-1 line and the dashed line is best-fit linear regression line

The analysis shown in Figure 4 provides an example of how the data suite available at the Core Sites can be used to assess accuracy over a distributed set of locations and time periods. The MODIS team has termed this "Stage-2" validation (http://eosdatainfo.gsfc.nasa.gov/eosdata/ssinc/modland_dataprod.shtml?). The full-time research position proposed here will develop methods to best utilize the Core Site data suite to advance MODIS land products to stage-2 validation. The core sites have developed into a data-rich archive of field and image data. The proposed research position will work toward synthesizing these valuable data sets to quantify the global accuracy of several MODIS products. During the first year, this researcher will produce similar validation analysis for all paired ETM+ and AERONET data sets (currently the

Core sites contain 57 such data sets); with a thorough investigation of how the relationship between the MODIS data and the atmospherically corrected ETM+ data changes across sites and through time. Other multi-temporal, multi-site product validation analyses will be conducted by the full-time research position, as described in section 4

DELIVERABLES FOR
MAINTAINING & ENHANCING THE EOS LAND VALIDATION CORE SITES:

- **Maintain the web-based infrastructure and on-line access of the EOS Land Validation Core Sites**
- **Addition of the AVHRR, SPOT VEGETATION, TRMM-derived products, and SRTM data to the Core Site data suite**
- **Expansion of the number of sites to somewhere between 30 and 40 in number**
- **Research on combining data and results from other sites to advance MODIS land product to "stage 2" validation.**

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3. Coordination of land product validation activities

3.1. Background

Coordinating validation activities ensures efficiencies by facilitating the validation of several products, sometimes from different instrument teams, from a given field and/or airborne effort. This coordination emphasizes the reuse of instrumentation, facilities and data resources, thereby making these efforts more cost-effective. There will likely be land product validation components to several proposals funded under this NRA. In addition, the current NASA CAN (CAN-02-OES-01), and other NRAs (NPP Science Team, NRA-03-OES-01; Interdisciplinary Science Teams, NRA-03-OES-03) will also include studies with land validation components. To maximize both the value and impact of these validation efforts, it is vital to maintain a level of coordination for these otherwise disparate activities.

There are a number of major field investigations that have benefited significantly from their association with the Land Validation Core Sites. Several of the Core Validation Sites are a result of major field campaigns that took place at these sites. The Boreal Ecosystem-Atmosphere Study (BOREAS, http://www.eosdis.ornl.gov/BOREAS/boreas_home_page.html) provided the BOREAS-NSA and BOREAS/BERMS SSA sites, the Prototype Validation Exercise (PROVE, http://jornada-www.nmsu.edu/gis-rs/intr/intr.htm), yielded Jornada, two LBA (Large Scale Biosphere Atmosphere Experiment in Amazonia) sites, Santarém and Ji-Parana, are

Core Sites, and two sites from the SAFARI 2000 (Southern African Regional Science Initiative 2000), Skukuza and Mongu also are Core Sites. BOREAS was an extensive remote sensing and field experiment conducted the mid-1990's in central Canada. Many tower sites from this experiment are now maintained by the Boreal Ecosystem Research and Monitoring Sites (BERMS, http://berms.ccrp.ec.gc.ca/e-links.htm), and are still being monitored by the BERMS group. A Harvard Atmospheric and Environmental Chemistry group, led by Dr. Steve Wofsy (http://www-as.harvard.edu/people/faculty/scw/), and the BigFoot group still monitor the BOREAS northern old black spruce site near Thompson, Manitoba. All of these investigations benefit from their association with the Core Sites, and Land Validation scientists benefit from the activities on-going at these sites. The Core Site infrastructure provides an added incentive for the continuation of these types of activities.

The support we provide to the large field efforts assures that NASA-provided data are made available if at all possible. This includes coordinating with Terra operations to avoid spacecraft maneuvers during field activities, working with Landsat-7 mission operations to adjust the seasonality file that directs the freqency of acquisitions during field activities, and in some cases influencing the MODIS reprocessing schedule to accommodate the needs of a particular project.

Land Validation support has also extended beyond the set of 26 Core Sites. The acquisition and online placement of Landsat ETM+ data acquired for MODIS land validation activities have been coordinated for other groups with validation components, such as the GOFC/GOLD and SAFNet (Souther African Fire Network, Roy et al., 2002) projects. These projects utilize the current Core Site infrastructure and other non-Core Site support that has been provided. High-resolution satellite data have been provided to these projects in support of their validation activities at non-core study areas or regions of interest. Online directories at the LP-DAAC have been established for these regional data where scenes containing land cover targets of opportunity have been identified.

Support of land validation activities has evolved since the initial establishment of the first set of 24 Core Sites. Since that time, we have seen an increase in the number of core sites supported, the validation networks involved, the number of available data sets, the web content, and leveraging with data partners where mutually beneficial. This expansion has fortunately coincided with the increase in availability and use of MODIS and validation data.

3.2. Proposed work plan / specific task

After determining which of the awarded proposals contain land product validation activities, we will communicate with the PIs to verify the locations of their validation work, and encourage them to utilize the established EOS Core Sites. If they choose not to work at a Core Site, we can evaluate the long-term potential their site would have for land product validation, taking into account the location and climatology of the site with respect to the current set of Core Sites (see Figure 3).

When new sites are added, we will coordinate with the MODIS Adaptive Processing System (MODAPS) to incorporate the new sites into the current list of extracted sites, assuring their archival and online availability at the LP-DAAC. Likewise, any alterations or removal of existing sites are coordinated with MODAPS. The addition of new sites also involves the coordination of ancillary data and addition of links to any active networks. Automated extraction of SeaWiFS data will also be coordinated with the SeaWiFS team, and historical and/or complimentary satellite data sets can be acquired. The coordination effort includes support of major validation field campaigns. An interface to MODIS Operations will be provided by working with the Terra and Aqua mission control to enter dates and locations of field efforts on the Terra/Aqua "white board," thereby avoiding any spacecraft maneuvers during these campaigns that might result in a loss of data. Interface with Landsat-7 mission operations is also provided for new core sites and major validation campaigns to assure data are acquired at every opportunity for international sites (where the default is to acquire on cloud-free scene per season, and not necessarily every overpass). The availability of other coincident satellite data for these campaigns will be explored or planned for where possible. The coordination of fine resolution satellite data tasking has been provided in the past with the IKONOS satellite and will be provided in the future by either IKONOS or QuickBird (or other fine resolution sensor data) that can be accessed through the Science Data Purchase at NASA's Stennis Space Center.

The Core Sites serve as a central focus of validation activity. By interfacing with validation teams and groups that have validation components, we are in a unique position to be informed about the activities of many groups and individuals. By fostering and maintaining this communication, and tracking validation activities and status, we can thus best facilitate the sharing of the data sets, instrumentation, information, and other resources.

We plan to maintain our current schedule of monthly MODIS land validation support team teleconferences with the land-related DAACs, the ORNL and the LP DAAC. We will keep both DAACs apprised of new investigations related to land validation and will work with them to assure that data services and tools meet the needs of investigations and users.

DELIVERABLES FOR COORDINATION OF LAND PRODUCT VALIDATION ACTIVITIES

- **Validation support will continue to foster the exchanges of information and expertise between validation scientists.**
- **The validation web-server database, already containing hundreds of links to data sets and information for the Core Sites, will continue to be updated as new data are acquired and new products are made available.**
- **Email notifications to validation investigators of new validation data acquisitions when they become available will continue.**
- **The validation web pages will be enhanced, new design features will simplify the navigation to desired data.**

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4. International collaboration via the CEOS WGCV Subgroup on Land Product Validation

4.1. Background

The great effort and cost of collecting and producing accurate "truth" data (including ground-, aircraft- and satellite-based observations) around the world, together with the relative infancy of field spatio-temporal sampling and scaling techniques, makes global product validation a major challenge for any Earth observation program. Recognizing that operational land products will become increasingly common in future missions, we have worked with community experts to establish the Land Product Validation (LPV) subgroup of the CEOSWGCV in year 2000. J. Privette (Co-I of this proposal) served as the founding Chair of the LPV Subgroup; in February, 2002, J. Morisette (PI) became Chair.

The LPV's mission is to foster quantitative validation of high-level global land products derived from remote sensing data. The specific objectives are:

- To increase the quality and economy of land product validation by developing standards and protocols for field sampling, error budgeting, data exchange and product evaluation,
- To facilitate international cooperation and coordination in validation activities by sharing information on instruments, analyses and field activities, and
- To provide a forum for discussion of current issues and for exchange of technical information on efficient approaches to global validation.

The LPV implementation approach is to sponsor *topical meetings* (e.g., albedo), which bring together world experts on the measurement, production, and use of a given product to discuss validation procedures and develop data collection standards. The initial topical priorities came from the GOFC/GOLD. These are consistent with those of the Integrated Global Observing System (IGOS) "Terrestrial Carbon Observation" group, which noted the need to "endorse and promote initiatives aimed at testing and validating satellite-derived products, such as those carried out under CEOS LPV" (Cihlar, Heimann, and Olson, 2002).

Table 1:Topical Workshops of the Land Product Validation Subgroup to date

Year	Workshop Topical Focus	Location	Reference
2000	Biophysical Products/ Initial Coordination	Ispra, Italy	Privette et al., 2000
2001	LAI/FPAR	Frascati, Italy	Privette et al., 2001, Privette et al. 1998
	Land Cover	Ispra; Toulouse	Strahler et al., 2001
	Fire Products	Lisbon, Portugal	Morisette et al., 2001
2002	Albedo	Boston, Mass.	Privette et al., 2002
2003	Land Cover	Ispra, Italy	forthcoming

The primary goals of the workshops are to define a community research agenda, coordinate international activities (e.g., field activities, product intercomparisons and data sharing), and to begin taking steps towards establishing a consensus on the "best practice" approach documentation for validation of the respective products. In the interim, we solicit and post online select "Case Study" presentations from successful projects, such that new validation researchers can quickly begin producing high quality results consistent with standards used internationally. Two examples below highlight new activities stemming from recent workshops.

Leaf Area Index (LAI) Validation Network

Participants in the 2001 Frascati LAI/Fpar Workshop (Privette et al., 2001) initiated an

LAI Intercomparison activity in which investigators from field sites around the world evaluate satellite LAI products against their field measurements. The merging of the various sites and national networks produced a global sample set of 36 LPV sites, many of which are also EOS Land Validation Core Sites.

We have supported this network through the operational creation and archiving of 200 km x 200 km MODLAND product subsets (vs. the standard 10°x10° MODLAND product "tiles"). The subsets are placed in online ftp directories at the LP-DAAC for rapid user access (links from http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL). We have also purchased Landsat ETM+ imagery over the sites for use in scaling and land cover studies. These images are made available online at no cost. Because the costs of conducting field campaigns and scaling field data are considerable, the partnerships developed through this program have significantly improved the degree to which the MODLAND LAI product can be validated (see Letter of Support from R. B. Myneni).

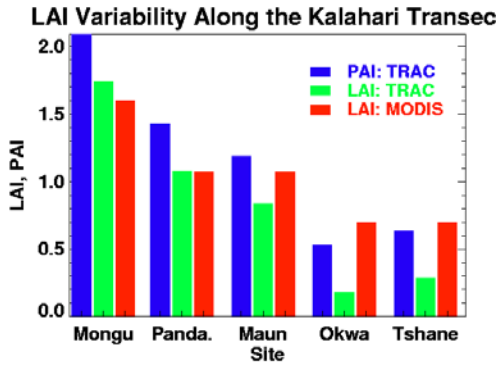

Figure 5. The LPV LAI Intercomparison will characterize MODIS LAI accuracy over 36 different land covers, structural forms and soil conditions globally using "volunteered" field data sets. An example (left) of a multisite evaluation along the IGBP Kalahari Transect shows the initial MODIS product responded correctly to decreasing vegetation due to decreasing annual precipitation. The bars show field-measured (TRAC) Plant Area Index (PAI), TRAC-derived LAI, and MODIS LAI (Privette et al., 2002).

Albedo Validation Network

In October 2002, MODLAND and LPV co-sponsored an International Albedo Validation Workshop. Participants assembled a list of 274 sites where albedo measurement are or soon will be available (Privette et al., 2002). The network of sites includes the FLUXNET eddy covariance tower network and the Baseline Surface Radiation Network (BSRN; dedicated to the measurement of radiative fluxes). For each site, we recently coordinated with MODAPS and the ORNL-DAAC for the operational extraction of 7 km x 7 km multi-product subsets, which the DAAC is making available online in ASCII format. Because the MODLAND albedo product describes two theoretical conditions (a non-scattering sky and a completely overcast sky, respectively), we also developed a

table of skylight climatology for each site based on data from the nearest AERONET station. In addition, we began collaborating with the MODIS Atmosphere Team to produce MODIS aerosol optical depth data over many of the sites. Together, these resources allow simple, near-real time determination of MODIS visible, near-infrared and shortwave albedos as would be measured by field instrumentation. The eventual goal is to likewise host near-real-time field albedo measurements such that it is trivial to access the data needed for statistically significant comparisons.

Figure 6: A subset of the Albedo Product Site Network distribution. Most sites are members of the FLUXNET and BSRN networks, although not all host field albedo instruments. Each 16 days, subsets (7 km x 7 km) of the MODIS albedo product subsets are created and posted online at the ORNL DAAC. Figure courtesy of R.J.Olson. (http://public.ornl.gov/fluxnet/modis.cfm).

Finally, under the auspices of LPV, we are working with the CEOS WGCV Working Group on Information Systems and Services (WGISS) on the development of an online data interface designed to facilitate cross-archive searching, reformatting, and downloading of data. The interface is a prototype technology to download data from multiple sensors in a single format and projection, without visiting multiple data centers or archives. J. Morisette (PI) currently serves as Co-Chair of this activity, and coordinates the LPV responsibilities of providing science priorities, testing prototype systems and providing satellite data (e.g., Landsat imagery) to WGISS.

4.2. Proposed work plan / specific task

We propose to continue in our leadership role in LPV, coordinate two topical workshops per year, and expand the current data and web-based infrastructure currently in place for the LPV subgroup and its related activities.

Further, we have budgeted for one postdoctoral researcher to synthesis results from the LAI Intercomparison effort noted above. Because nearly all of the requisite data sets (including field, Landsat and MODLAND subsets) are already in-house, the initial task is largely one of data reduction, scaling, comparison and analysis. This effort will be done in cooperation with both the field data collectors, and Dr. Ranga B. Myneni, the

MODLAND LAI product developer. This effort will begin in year one and should be completed by year two. In year two and three, the researcher will embark on developing a method for albedo intercomparison, including operational generation of "blue sky" albedo from the MODIS black and white sky components.

Building on results from existing and planned workshops, we will work with a group of experts for each product to develop a validation protocol for the land products. These will be initiated as CEOS documents and/or developed into peer reviewed papers.

DELIVERABLES FOR: INTERNATIONAL COLLABORATION VIA THE CEOS WGCV SUBGROUP ON LAND PRODUCT VALIDATION

- **Complete the LAI Intercomparison Project**
- **Publish "consensus best practice" documents for validation of**
  1) LAI/FPAR
  2) Albedo and
  3) Land Cover in peer-reviewed literature
- **Sponsor topical workshops on the following moderate resolution satellite products at a rate of two/year: LandCover, Fires/Burn Scar, LAI/FPAR, Albedo, Land Surface Temperature and Snow Cover.**
- **Support continued validation of the EOS program, and the developing NPP/NPOESS validation programs, through continued acquisition and online posting of tasked scenes (e.g., Landsat ETM+) and operational subsets (e.g., MODLAND products).**

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5. Supporting NPP/NPOESS and Climate Data Records

One of the most useful applications of satellite data is the analysis of long-term data series, or Climate Data Records (CDR). These data can help answer key questions on variability, forcing and consequences in NASA ESE's Carbon, Water Cycle, and Climate Change themes. Past studies (e.g., Myneni et al., 1997) with AVHRR series have, e.g., demonstrated a lengthening of the northern hemisphere growing season. In the EOS era, an expanded set of CDRs have already led to important scientific discoveries (Tsvetsinskaya et al., 2002). To assure CDR longevity, NASA's ESE program will soon transition from the research-grade Earth Observing System (EOS; 1999 - ~2007) to the operational National Polar-orbiting Environmental Satellite System (NPOESS) operational systems (~2010-2018). The NPOESS Preparatory Project (NPP) will bridge the data gap, and therefore represents a critical stage in CDR continuity.

NPP is managed by NASA, however the algorithms and processing system are being developed will be operated by the NPOESS Shared System Performance Responsibility (SSPR) contractor (Northrop Grumman Space Technology (NGST). The SSPR has subcontracted the development of the VIIRS sensor to Raytheon Corp. (the "sensor vendor"). The algorithms and production systems for NPP/NPOESS have thus far lacked the extensive peer-review of their EOS counterparts. Predictably then, one of the major community concerns for the NPP/NPOESS program is the absence of clear definitions for Environmental Data Record (EDR) "validation," or in the context of the government EDR contract, "performance verification." Indeed, realistic plans for field data provision do not exist.

It is clear, however, that the NPP/NPOESS validation program will strongly leverage the MODIS validation program. Indeed, the two NPOESS Calibration and Validation Plans (respectively issued by the SSPR contractor and the Integrated Program Office, a joint Air Force, NOAA and NASA-staffed office managing NPP/NPOESS), explicitly state that knowledge and resources (including Core Sites) developed under the EOS validation program are directly applicable to NPP/NPOESS. In some cases, the NPOESS program specifically assumes further development and refinement of EOS validation methods and resources,e.g.,

> The capabilities of VIIRS are also leading to many new operational EDRs that are not currently addressed in today's validation resources. Use of new methods and resources increases the risk to validation, yet it is anticipated that the MODIS experience will provide much information directly applicable to the VIIRS validation effort. … The MODIS Land team has developed a plan to address the validation of the similar fire product, and these methods, if proven successful as is anticipated, will serve as a model for VIIRS validation and drastically reduce the risk to the validation of this EDR… *In situ* and ground data is currently available from the existing test sites established for the validation of EOS and other research and operational satellite programs. The NPOESS plan will build on existing sites … and will leverage the EOS experience in planning the NPOESS validation program. (TRW Inc., 2002; p. 138).

The frequent references to MODLAND validation in these documents are are testimony to the value of the team's past efforts. The expected use of MODLAND resources, at least through the end of the NPOESS program (tentatively 2018), underscores the logic in using a consistent set of well-characterized sites, resources, and protocols over multiple missions and sensors.

We propose to meet with the to-be-selected NPP Science Team upon its selection (late summer 2003) to review the current MODLAND validation program and the outstanding challenges. Further, we will seek a position as associate member of the NPP Calibration and Validation Integrated Project Team (IPT) such that we can begin incorporating that program's needs into our evolving system of resources. In general, we will support with the IPO, SSPR and NASA NPP Project Office in whatever capacity is most effective.

6. Personnel and Project Management

This NASA land validation project will be led by Dr. Jeffrey Morisette. Morisette has served as the MODLAND validation coordinator for the past five years, and is the current Chair of the CEOS WGCV Land Product Validation Subgroup. Morisette will manage Ms. Nickeson and Ms. Su and continue to serve as the primary point-of-contact with the EOS instrument and science communities. Morisette will also liaise with other missions (e.g., SeaWiFS, Landsat) that provide data to the project.

Dr. Privette (Co-I) will manage the post-doctoral researcher conducting the synthesis and inter-comparison activities as well as the SSAI technician conducting field data reduction for select Core Site data sets. He will also be the primary link with the NPOESS program, particularly the NPOESS Preparatory Project (NPP; launch 2006) for which he is Deputy Project Scientist. The NPP mission will produce 26 "Environmental Data Records" which are similar to the MODIS products, and has similar calibration and validation requirements. As the NPP algorithms were designed by private industry, it is particularly important that an enhanced, peer-reviewed EOS validation infrastructure (including 'best practice' field data collection and application) be available for NPP contract performance verification. Privette will work with the NPP Science Team, the Integrated Program Office (IPO) and the NPP contractors (primarily Northrop-Grumman Space Technology and Raytheon Company) to assure that the EOS system is sufficiently leveraged, and also that the unique NPP needs are fed back into the evolving EOS validation system.

Ms. Jaime Nickeson will serve as the science liaison. Her activities will include general coordination of the field, aircraft and satellite data sets, support of validation campaigns and general communications (telecons, e-mail listserv, data availability notification). She will work full time on this project (1 FTE).

Ms. Ming Su will serve as the Database Administrator for the Validation System. Her activities will include development of an expandable data base system which includes metadata entries for all aircraft and satellite scenes over the Core Sites and Intercomparison Sites. She will upgrade, enhance and generally maintain the web-based server as time permits (0.4 FTE).

A postdoctoral researcher will be hired to conduct the multi-site/multi-sensor intercomparison activities. This activity will commence with the LAI intercomparison activity for which all ETM+ scenes and most field data have already been collected and procured. Once complete, the postdoc will commence intercomparison work on other EOS products, starting with albedo in response to the new ORNL DAACs staging of MODLAND albedo subsets at 274 FLUXNET and BSRN sites globally.

7. Facilities and Equipment

Available for the project, through existing infrastructure are two Dell "Power Edge" 1650 Pentium III-T servers with over 300 GB storage. The machine will maintain the web-server databases and "php" pages supporting the web-based infrastructure of the proposed work. We also intend to continue leveraging off the ORNL and LP DAAC and their commitment to land product validation. This involves on-line ftp directories for ETM+, ASTER, MODIS, SPOT, and AVHRR product thought the LP DAAC and ORNL's Mercury system for field data metadata registration and searching.