MODIS Land Validation Plan

MODIS Land Discipline Team

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Abstract / Executive Summary

MODLAND will use several validation techniques to develop uncertainty information on its products. The methods include comparisons with in situ data collected over a distributed set of validation test sites, comparisons with data and products from other airborne and spaceborne sensors, analysis of trends in MODLAND products, and analysis of process model results (including EOS IDS models) which are driven or constrained by MODLAND products.

Primary validation techniques include collection of, and comparison with field and aircraft data, and comparison with data and products from other satellites. To accomplish this goal, MODLAND will establish a semi-permanent array of test sites, usually including a flux tower, for extended temporal measurement of terrestrial biophysical dynamics over a range of land cover types. The image and field data will be archived in cooperation with the EDC and Oak Ridge DAACs, respectively. Results of MODLAND validation activities will be conveyed to the end-user through both published literature and quality assessment metadata accompanying the product data sets.

MODLAND validation work will involve

- *commitment to the EOS Land Validation Core Sites*
- *product-specific activities and validation protocols (primarily by MODLAND PIs),*
- *close cooperation with EOS Validation Investigators to meet specific product validation needs,*
- *interaction with established data networks (e.g. FLUXNET, AERONET),*
- *participation in community field campaigns (LBA, SAFARI 2000, GCIP),*
- *developing novel validation instrumentation and approaches (e.g. MQUALs, sunphotometers with BRDF capability),*
- *collaboration with other AM-1 instruments teams (CERES, ASTER, MISR and Landsat 7),*
- *and collaboration with the data providers (PI's, DAACs, ESIPS).*

Together these essential activities provide the foundation for operational product validation. Successful validation will have been accomplished if timely and accurate product uncertainty information becomes routinely available to the product users within two years after launch.

Most internet sources referenced in the MODLAND Validation plan are provided through the MODLAND validation home page:

http://pratmos.gsfc.nasa.gov/~justice/modland/valid/

1.0 Introduction

This document describes the activities the MODLAND team will use to evaluate and validate its operational products and algorithms. It reviews recent activities and describes those planned through approximately two years after launch. Up-to-date information on MODLAND validation efforts and links to most internet sites referred to in this plan are available at: *http://pratmos.gsfc.nasa.gov/~justice/modland/valid/*.

1.1 Scientific Objectives

In the first six months after launch, MODLAND will assist in the initial sensor calibration as it pertains to the MODLAND products, although primary calibration responsibility lies with the MODIS calibration support team. After this period, a primary objective for MODLAND is to validate the level 2-4 products of MODLAND, including *radiometric* products such as Vegetation Indices (VIs), Bi-directional Reflection Distribution function (BRDF), Land Surface Temperature (LST), and Fraction of Photosynthetically Active Radiation (FPAR), and *biophysical* products such as Land Cover, Fire Scars, Leaf Area Index (LAI) and Net Primary Production (NPP). Because each of these is a global product, MODLAND plans to develop uncertainty information over each of the significant surface-atmosphere systems that exist.

1.2 Missions

MODIS will be carried onboard the first major EOS spacecraft, designated AM-1. In spring of 1998, EOS program management announced postponement of the June 30, 1998 launch of AM-1 until sometime after mid 1999. This launch delay has caused those validation activities requiring MODIS data to be either delayed or limited to comparisons with MODIS-like data (e.g. MODIS airborne simulator, SeaWiFS, AVHRR). Also several ER-2 deployments have been postponed from 1998 to 1999. However, protocol development, instrumentation of validation sites, and other measurement strategies have proceeded as planned. In addition to AM-1, MODIS will fly aboard PM-1 in December 2000. These two spacecraft will likely be repeated in the morning and afternoon orbits with advanced versions of MODIS, providing a consistent data set from 1999-2018.

1.3 Science Data Products

The MODIS Land Instrument team will produce the following products upon launch: Surface Radiance and Reflectance (atmospheric correction), VIs, LAI, FPAR, Albedo, BRDF, Fire, Burn Scar, Land Cover, Land Cover Change, Snow Cover and Sea-ice, LST, and NPP (Justice *et al.*, 1998; Running *et al.*, 1994).

2.0 Validation Overview

2.1 Overall Approach

In order to validate the MODIS land products, it will be necessary to validate specific biophysical parameters under a wide variety of combined surface cover and atmospheric conditions, from northern forests to arid deserts to moist, tropical systems. MODLAND will use several validation techniques to develop uncertainty information on its products. The methods include comparisons with *in situ* data collected over a distributed set of validation test sites, comparisons with data and products from other airborne and spaceborne sensors (e.g., AVHRR, MISR), analysis of trends (e.g., spatial, temporal) in MODLAND products, and analysis of process model results (including EOS IDS models) which are driven or constrained by MODLAND products.

Our *primary* validation activities will be collection of and comparison with field and aircraft data, and comparison with data and products from other satellites. Field data collection will include instantaneous measures of spectral reflectances and TIR radiance at various test sites, first as a calibration activity, and second, as validation of our radiometric variables. Secondary will be establishment of a semi-permanent array of test sites, usually including a flux tower, for extended temporal measurement of terrestrial biophysical dynamics over a range of land cover types. These *in situ* and image data will be archived in cooperation with the Oak Ridge and EDC DAACs, respectively. Results of all validation activities will be conveyed to the end-user through both published literature and quality assessment “metadata” accompanying the product data sets.

2.2 EOS AM-1 Validation Investigations

The EOS validation program funded 21 Type I (R&A) and 44 Type II (EOS Validation) Investigations (*ftp://eospso.gsfc.nasa.gov/sterling/Validation/nra_selections.pdf*) as a result of NRA: MTPE-97-03 (see *http://eospso.gsfc.nasa.gov/validation/frame.html*). Fifteen of the investigations funded by the EOS Validation Program Office are highly relevant to MODLAND activities (listed in Table 1). Although these projects have just begun, MODLAND has sought to interact with these investigators through collaborative activities and organizational meetings. An initial meeting was held near Goddard Space Flight Center (GSFC) in December 1997(Justice *et al*., 1998b) and an LAI/FPAR validation protocol development meeting is planned for October 1998. We anticipate further development of these collaborations in the future. More information on these studies can be found at the EOS Investigations web site: *http://eospso.gsfc.nasa.gov/validation/frame.html* .

The validation activities directly relevant to land products are summarized at: *http://pratmos.gsfc.nasa.gov/~justice/modland/valid/am1/abstract.html*

The summary of EOS validation program can be found at: *http://eospso.gsfc.nasa.gov/validation/valpage.html*

Table 1: EOS Validation Investigations

EOS Validation Activities	***Investigator; MODIS counterpart***	***Remotely sensed data***	***Primary Products***
EOS-1	Baldocchi ; Running	none	All MODLAMD products except Sea-ice
EOS-2	Fowler ; Hall	AVHRR, MODIS	Snow cover & Sea-ice
EOS-3	Gower ; Running/Myneni	MODIS, ASTER	LST, LAI/FPAR, Land cover
EOS-4	Hook ; Wan	none	Surface reflectance/emission
EOS-5	Li ; Hall	MODIS	Snow cover
EOS-6	Liang ; Vermote	MODIS, MISR, ETM+, ASTER, Aircraft	Surface reflectance, BRDF/Albedo
EOS-7	Meyer ; Vermote/Running	MODIS, ETM+	LAI/FPAR
EOS-8	Nolin ; Hall	MODIS, MISR	BRDF/Albedo
EOS-9	Olson ; Justice	none	All MODLAMD products except Sea-ice
EOS-10	Privette ; Justice	AVHRR, TM/ETM+ ASTER, MODIS	All MODLAND products except Sea-ice
EOS-11	Schowengerdt ; Vermote	MODIS	Level 1A product
EOS-12	Shi ; Hall	TM/ETM+, SPOT AVHRR, MODIS ASTER, AVIRIS, MAS	Snow cover
EOS-13	Teillet ; Vermote	SPOT	Level 1A product
EOS-14	Thome ; Vermote	MODIS, ASTER	Level 1A product
EOS-15	Ward ; Justice	AVHRR, MODIS, MISR, MOPITT	Land Aerosol product

(Note: numbering in Table is specific to MODLAND and not part any EOS numbering convention.)

2.3 Measures of Success

Successful validation will have been accomplished if timely and accurate product uncertainty information becomes routinely available to the product users within two years after launch. During this period, MODLAND will adjust algorithms as necessary to provide better performance and consistency with validation data. Previously derived products will be reprocessed in a timely manner following changes to the operational algorithms.

3.0 Validation Sites

In order to validate global biophysical variables, a reasonable sampling of the global variability of each variable must be tested. Each MODLAND product varies through space and time; so much of the difficulty of validation is in adequate sampling of the range of the variable. A second major problem is measuring each variable with precision over areas representative of MODIS pixels, i.e. 250m-1km or larger. These two issues necessitate a combination of approaches which will include a global distribution of sites in different land cover types and phenological regimes, with measurements taken at least periodically throughout the year, comparison with other global and regional scale data sets or sample data sets and comparison with high resolution data from airborne and spaceborne sensors.

To provide the *in situ* and other reference data, we will utilize a five-tiered categorization of field site measurement capabilities and intensity developed in part during the EOS Validation Test Site Planning Meeting (Suttles *et al.*, 1996). Table 2 describes the tiers and provides examples. This categorization yields an inverse degree of measurement intensity per site with number of sites in the tier. Thus, MODLAND will rely on few intensive field campaigns (e.g., BOREAS, LBA) but a large number of sites for which only satellite scenes are regularly available. One deviation in this scheme is the MODLAND Tier 5 (instrument calibration sites) which is primarily for radiometric calibration.

Table 2: MODLAND Hierarchical Test Site Scheme

Tier		Approx. Number of Sites	Sample Area (km^2)	Description of Instrumentation and Sampling	Example Sites/ Networks
1	Intensive Field Campaign Sites; International Field Campaign Programs	5	1,000	Intensive sampling of *all* relevant land and atmospheric parameters, including boundary layer gas exchange; often over land cover gradients	FIFE, BOREAS, HAPEX-Sahel, TRACE-A, SAFARI, LBA
2	Fully Instrumented Sites	5	100	*Full suite* of radiation and flux measurements; ground, tower and aircraft measurements	ARM/CART sites
3	Biome Tower Sites	20-30	100	Long term, select instrument packages for *process* studies; ground and tower measurements; all major ecosystems and climatic regions	Harvard Forest - Temperate Deciduous Forest Site
4	Globally Distributed Test Sites	60	25	Limited surface and atmosphere *characterization*; select instrument suites at different sites; widely distributed variable sampling frequencies (intermittent to continuous) capture seasonal or interannual variability, climatology; permanent sites	LTERS, NOAA CMDL, BSRN and SURFRAD networks
5	Instrument Calibration Sites *	<5	10	Well-instrumented for vicarious *calibration*; unique reflectance and emittance properties of uniform, typically non-vegetated surfaces; ground and aircraft measurements may include geometric calibration site(s)	White Sands, Railroad Playa

**** EOS instrument vicarious calibration test-sites needs will be coordinated by the EOS Calibration Working Group (http://modarch.gsfc.nasa.gov/MODIS/CAL/) and is not the responsibility of MODLAND.***

3.1 AM-1 Land Validation Core Sites

MODLAND will conduct its primary validation activities at the EOS Land Validation Core Sites (presented in Figure 1 and Table 3). The core test sites are intended as a focus for land product validation over a range of biome types; however, they will also be useful for validation of some atmospheric products. The initial site list was developed at the EOS Validation Scientist Meeting, December, 1997, and represented a consensus amongst the instrument teams and validation investigators. Although these sites are intended for long-term use, the list will inevitably undergo some changes through the EOS era. Each site has a point of contact responsible for overall validation coordination at the sites. Although these sites are not intended to meet all EOS test sites needs, they will provide a focus for satellite, aircraft, and ground data collection of land product validation, and will provide sites at which scientists can readily access *in situ* and EOS instrument data. Up-to-date

information on the Core Sites is located at
http://pratmos.gsfc.nasa.gov/~justice/MODLand/valid/core_sites.html

Core sites are either currently used by independent investigators or are actively under development. In most cases, each site includes a fixed tower on which above-canopy instrumentation will be mounted to provide near-continuous sampling of canopy-scale radiometric and meteorological variables. A conceptual model for a core site instrument package is shown in Fig. 2 and includes a CIMEL™ ground and sky-scanning sunphotometer (surface reflectance, vegetation index, BRDF), albedometers (albedo), and a CO_2 flux system (NPP). These data are augmented by surface measurements of LAI and FPAR at less frequent time intervals. Core Sites will receive priority deployment of validation instrumentation and cover each major biome type delineated in MODLAND operational algorithms.

Current work has focused on, developing site contacts, instrumenting the Core Sites, and coordinating the acquisition and archiving of existing and future data for the sites. For example, for each site ASTER data have been requested for the "Initial check out" (ICO) period (the first 105 days after launch) for both day and night coverage. The Landsat 7 team has included the core sites in their long term acquisition plans.

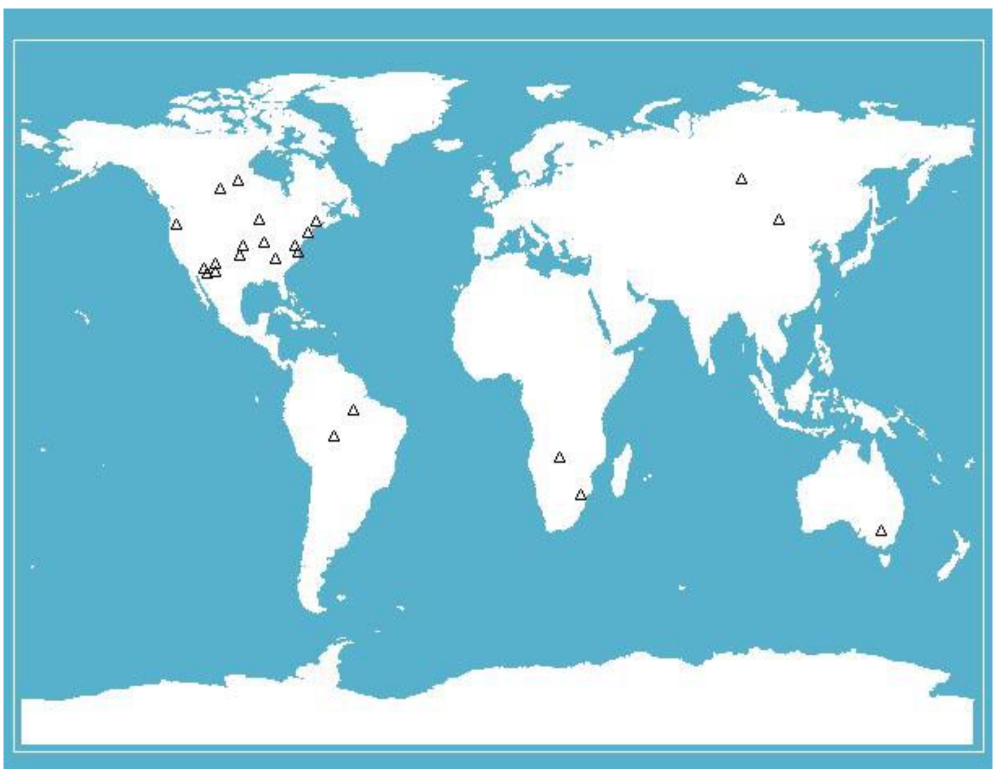

Figure 1: EOS Land Validation Core Site Locations

Table 3: Core Validation Test Sites

Site Name	***Biome***	***Coordinator***	***Latitude***	***Longitude***	***Tower (Network) ****
ARM/CART	Agriculture	Meyer	36.64	-97.5	YES(B, F, G)
Bondville,IL	Agriculture	Meyers	40.01	-88.29	YES(A, B)
BOREAS, NSA	BorealForest	Baldocchi	55.88	-98.48	YES(A, B, F)
BOREAS, SSA	BorealForest	Baldocchi	53.98	-105.12	YES(A, F)
Cascades LTER	Evergrn. Forest	Running	44.5	-121.62	YES(A, B, F, G)
Harvard Forest	Decid. Forest	Baldocchi	42.37	-72.25	YES(B, F, G)
Howland	Decid.Forest	Baldocchi	45.3	-68.8	YES (A, F, G)
Ji-Parana	Trop.Forest	Huete	-10.22	-61.89	Planned
Jornada LTER	Shrubland	Huete	32.5	-106.75	YES (G)
Konza Prarie	Grassland	Baldocchi	39.08	-96.62	YES (F, G)
Krasnoyarsk	Forest	Murphy	56.5	92.5	YES
Maricopa Ag.	Agriculture	Huete	33.04	-111.58	None
Mongu	Woodland	Privette	-15.45	23.25	Planned (A, G)
SALSA	Desert shrub/grassland montane forest	Huete	31.74	-109.85	None
Sevilleta LTER	Desert/grassland	Holben	34.32	-106.8	None (A)
Skukuza	Savanna	Privette	-25	31.67	YES (A, G)
Tapajos	Trop.Forest	Huete	-3.23	-54.75	Planned
Uardry	Grassland	Hook	-34.39	145.3	None
Ulan Bator	Grassland	Huete/Honda	45.7511	106.2644	None
USDA ARS	Agriculture	Liang	39.03	-76.85	YES(A, F)
Virginia Coast	CoastalArea	Justice/Vermote	37.5	-75.67	None (A)
WalkerBranch	Decid.Forest	Baldocchi	35.9	-84.3	YES(F, G)
Wisc.LTER	Forest	Norman	46	89.6	YES(F)
/Park Falls			/45.95	/-90.27	

***A= AERONET(1998), B = Bigfoot, F=FLUXNET, G = Global Land Cover Test Sites**

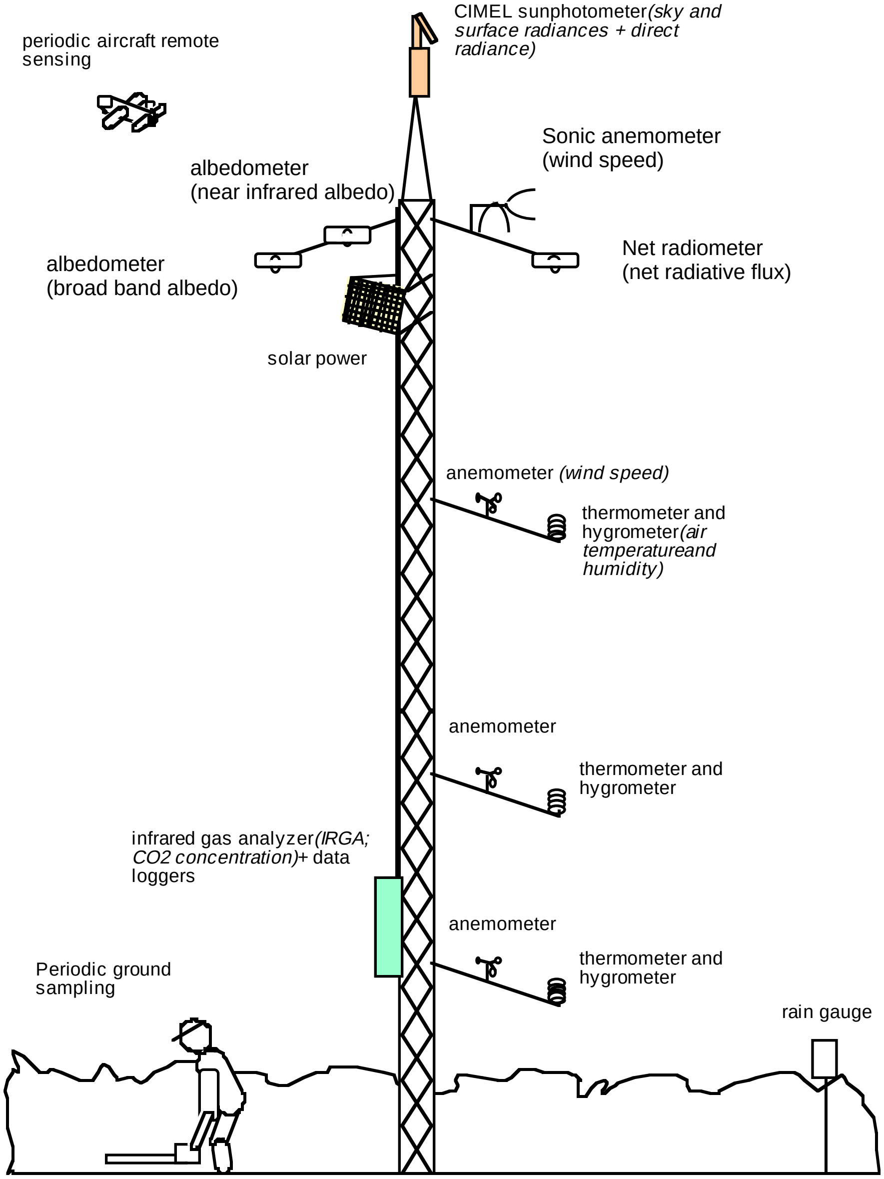

Figure 2: Tower schematic

This schematic depicts a typical continuous flux tower instrumentation that will be deployed at most of the Core Validation Test Sites, as well as the periodic but less frequent transect sampling (requiring airborne and/or ground-based personnel).

3.2 Land Product sites

In addition to the EOS Land Validation Core Sites, MODLAND PIs will conduct validation activities at sites not in the Core list. These are referred to as "Product" sites. These sites will provide both diversity and redundancy to the biomes represented by the Core Sites. In contrast to the core sites, they are not expected to provide sufficient data for validation of the majority of MODLAND products but will be used to address product specific validation needs. The Land Cover Change, Land Surface Temperature, and Snow/Sea-ice sites, which have the potential to provide validation data to the wider EOS community, are detailed here.

3.2.1 Land Cover sites

Pre-launch verification of the Boston University Land Cover product is based on testing the classification procedure using operational algorithms and code on 1-km AVHRR data and on simulated MODIS data. The validation data cover a network of sites which are described by their primary structural, physiognomic, physical and morphological attributes. Development of this Validation and Test Sites (VATS) database allows for quantified, statistical measure of classification accuracy based on contingency Table analysis and measures of agreement. Boston University has developed site data for supervised classification and accuracy of Central America, and will complete a comprehensive testing and validation site database for North America by mid-October 1998. The Land Cover VATS are located within the System for Terrestrial Ecosystem Parameterization (STEP) database: for documentation see *http://crs-www.bu.edu/~jcfh/gform30.txt* and for the actual database see http://crs-www.bu.edu/~jcfh/step.html.

Boston University conducted a New England field campaign during June-July 1998 to develop a comprehensive validation test site database for Land Cover and Land-Cover Change. Boston University has developed a test site database for Land Cover algorithm training, testing and validation for North America comprising over 900 sites. These site will be augmented and additionally validated as part of Boston University's development of the IGBP Confidence Site validation dataset, and expanded to a global test site dataset by early 1999.

3.2.2 Land Cover Change sites

Validation activities for the MODIS land cover change products from the University of Maryland will be based on comparison of the Vegetation Cover Conversion (VCC) and

Vegetation Continuous Fields (VCF) products with high-resolution data from Landsat, ASTER and commercial sensors. In the case of both VCC and VCF validation, field observations will be collected for comparison with both the high- resolution validation images and the MODIS products. Additional details are listed in the full VCC and VCF Validation Plan, which can be retrieved from the University of Maryland MODIS web site at *http://www.geog.umd.edu/landcover/modis.html*

Some of the EOS Core Sites will serve the purpose of validation for the MODIS VCC products in terms of the availability of high-resolution satellite data and ground observation data. In addition to these sites, Table 4 list others to be used specifically for validating the VCC product. For these product-specific sites, either high-resolution data or ground observation data or both will be requested and utilized.

Table 4: Land Cover Change product validation sites

Site Name	Landsat WRS2	Land Cover Conditions
Bassilicata, Italy	188/032	Urbanization
Brussels, Belgium	198/025	Urbanization
Caracas, Venezuela	004/053	Urbanization
CERN, China *	(multiple)	Agriculture/Forest/Grass
Charlotte, NC *	017/036	Urbanization
Chongqing, China	127/039	Urbanization/Flooding
Eindhoven, Holland	198/024	Urbanization
Ilebo, Zaire	179/063	Burning/Mosaic
Manaus, Brazil	231/062	Deforestation/Flooding
Muchinga, Zambia	170/069	Agriculture/Burning
Santa Cruz, Bolivia	230/072	Deforestation/Agriculture
Shanghai, China	119/038	Urbanization/Flooding
Washington, DC *	015/033	Urbanization
Xingu, Brazil	224/068	Deforestation/Mosaic

* = sites with associated field work

3.2.3 Land Surface Temperature sites

Land Surface Temperature has been validated by comparing results from the existing LST algorithms against TIR spectral BRDF measurement data, MODIS Airborne Simulator (MAS) data, and field measurements using a multi-method strategy (Justice *et al.*, 1998). Post-launch validation will utilize a similar strategy, including comparison of LSTs obtained from ASTER and AVHRR data over a range of land cover types in different seasons (Justice *et al.*, 1998). Sites specific to LST validation are listed in Table 5.

Table 5: Land Surface Temperature validation sites

Primary Validation Sites for EOS Validation of Land Surface Temperature Products	
Amburla/Alice Springs, NT, Austrialia	Park Falls, WI, USA *
Broome, Australia	Qinghai Lake, Qinghai, China
Death Valley, NV, USA	Railroad Valley, NV, USA
Dunhuang Gansu, China	Safawi, Jordan
Gobi Desert, China	Salton Sea, CA, USA
La Crau, France	San Luis Obispo, CA, USA
Lake Tahoe, CA, USA	Tsukuba, Japan
Mammoth Lakes, CA, USA	Uardry Sheep Farm, Australia *
Mauna Loa, HA, USA	Uyuni Salt Flats, Bolivia
Nam Co (Lake), Tibet	

* EOS Land Validation Core sites

3.2.4 Snow and Sea-Ice sites

The Snow and Sea-ice products will be validated with ground observations from aircraft and field campaigns. Post-launch the Snow and Sea-Ice products will also utilize ETM+, ASTER and NOAA Operational Hydrologic Remote Sensing Center (NOHRSC) snow and Sea-ice maps and the Advanced Microwave Scanner Radiometer (AMSR) derived snow and ice maps (available following EOS-PM1 Launch). The Snow and Sea-ice sites are listed in Table 6.

Table 6: Snow and Sea-Ice validation sites

Primary Validation Sites for EOS Validation of Snow and Sea-ice Products	
ARM/Barrow, AK, USA	Lake Mendota, WI, USA
Central Alaska, USA	Malaspina Glacier
Cordillera Blanca, S. America	Mammoth Mt, CA, USA
Cordillera Real, Bolivia	N.W. Minnesota, USA
Glacier National Park, MT, USA	Nevado Sajama, S. America
Greenland AWS: Various Sites	Niwot Ridge, CO, USA
Juneau Icefields, USA	Ross Sea, Antarctica
Keene, NH, USA	Vatnojokull and Hofsjokull, Iceland

3.3 Operational Surface Networks

Data from several surface networks will also be used in MODLAND validation. Primarily, these include the AERONET sunphotometer network (surface reflectance, vegetation indices, BRDF), FLUXNET CO_2/H_20 flux network (NPP) and the Global Land Cover Test Sites (GLTCS). In most cases, the EOS Core Validation Test Sites are members of at least one of these networks. In addition, MODLAND will investigate the usefulness of the BSRN and SurfRad networks for albedo validation.

AERONET (AErosol RObotic NETwork) is an optical ground based aerosol monitoring network and data archive supported by EOS. AERONET provides hourly transmission of CIMEL sunphotometer data to the GOES (or METEOSAT) geosynchronous satellites, which in turn relay the data to GSFC for daily processing and archiving. By teaming with AERONET, MODLAND scientists should have access to validation data from a global network of CIMELs in near real-time. This existing network will help in pre-launch validation of the spectral reflectance product. Details on additional validation activity with AERONET are discussed under MODLAND Prototype Field Experiments (section 4.1.2.2) and Instrument development (section 4.3). AERONET data are on-line at *http://spamer.gsfc.nasa.gov* .

With the recent funding of the FLUXNET validation proposal, MODLAND seeks to have a global array of test sites available for comprehensive terrestrial surface measurements. FLUXNET is the global organization of many regional networks of CO_2/H_20 flux towers, including AMERIFLUX for North America, EUROFLUX for Europe, OZFLUX for Australia, New Zealand, additional stations in South America developed by LBA, and stations being organized in Japan and China. There are now about 60 stations planning to be in operation by December 1998 of which over half are currently operating, funded by a variety of national sources. FLUXNET will be the point of global organization, developing instrument calibration procedures, sampling protocols, variable unit standards, archival and metadata standards, and distribution procedures. During the first year after launch several FLUXNET sites will be closely examined for integration into MODLAND validation activities. Lessons learned will then be used to ramp up this validation resource to use additional FLUXNET sites in later years. Core sites that are also part of FLUXNET are noted in table 3.

The Oak Ridge DAAC will be the point of FLUXNET data archive and distribution. The GCOS/GTOS terrestrial observing systems are also adopting the flux tower plan for a component of land surface monitoring. Details on FLUXNET can be found at *http://cdiac.esd.ornl.gov/programs/NIGEC/fluxnet/polson.html* and *http://cdiac.esd.ornl.gov/programs/NIGEC/fluxnet/*.

Through the new BIGFOOT initiative, the NASA Terrestrial Ecology program will be funding coordinated NPP modeling work at up to five FLUXNET sites. This initiative represents a scaled-down version of the MODLERS program, with emphasis shifting from LTER sites to FLUXNET sites, and with greater emphasis on MODLAND validation. BIGFOOT will compare NPP, Land Cover, and LAI values that were sampled, derived, or modeled with equivalent MODLAND products over a 10 x 10 km area. Modeled NPP values will also be adjusted for comparison with FLUXNET NEP (net CO_2 exchange) data. BIGFOOT will extend MODLER's work on sampling and scaling techniques, and prototype activities leading to the integration of a significantly larger number of FLUXNET sites in MODLAND validation. Background information on the MODLERS program can be found at: *http://atlantic.evsc.virginia.edu/~jhp7e/modlers/*

The Global Land Cover Test Sites (GLTCS) project has produced multi-temporal datasets of satellite imagery for a globally distributed set of test sites. These data sets consist of a standard set of Landsat, AVHRR, Land Cover, and elevation data. Nine of the 23 Core sites have or will have the suite of GLCTS available (see Table 3). These data establish a base-line record of TM and AVHRR imagery for these sites, which can be used to summarize the sites with respect to heterogeneity and land cover distribution. Details on GLCTS can be found at: *http://glcts.maxey.dri.edu/glcts/*

4.0 Pre Launch Activities

In addition to establishing validation site locations, working with EOS investigators, and developing infrastructure within existing networks, MODLAND is working in the pre-launch time frame to: collect field and imagery data useful for validation, develop and deploy validation instruments, develop validation protocols, test algorithms, and coordinate validation activities. These pre-launch activities serve as examples of what will be undertaken post-launch.

4.1 Field Data

Field data have been or are being collected through independently organized efforts (e.g., BOREAS, SCAR-A) and through MODLAND-(co-)led campaigns such as WINCE (snow cover), PROVE, and CALWEST (LST). Recent MODLAND activity has included a significant investment into field instrumentation, and development of new instruments, for active PI involvement.

4.1.1 Independently-led Campaigns

Data from independent campaigns have been used extensively by MODLAND. Table 7 lists those campaigns that have produced data sets used for pre-launch algorithm validation. In many cases, MODLAND scientists took active roles in data collection.

Table 7: Independent Field Campaigns

Independent Pre-Launch Activities	Partic-ipating Team Members	Principal Sensors	Reference	Primary Purpose
1 - BOREAS	All	MAS, AVIRIS, TM, ASAS	http: //boreas/BOREAS/BOREAS_Home.html	Biophysical validation, LST, snow, BRDF, VI, Fire,...
3 - HAPEX-Sahel	Huete, Strahler	ASAS, TM	http: //www.orstom.fr/hapex/	VI-biophysical, BRDF/albedo
4 - MONSOON - 90	Huete, Strahler	ASAS, TM, AVIRIS	Kustas *et al.*, 1994	Land Cover, BRDF/albedo, VI-seasonal study
5 - OTTER	Running, Huete, Strahler, Myneni	ASAS, TM	http: //www-eosdis.ornl.gov/daacpages/otter.html	Land Cover, BRDF/albedo, VI-biophysical coupling, LAI/FPAR
6 - SAFARI '92	Justice	AVHRR, TM	Tompson *et al.*, 1996	Fire validation
7 - SCAR-A, C	Vermote	MAS	http: //ltpsun.gsfc.nasa.gov/MAS/scarahome.html, http: //ltpsun.gsfc.nasa.gov/MAS/scarchome.html	Surface reflectance
8 - SCAR-B	Huete, Justice	MAS, AVIRIS	http: //ltpsun.gsfc.nasa.gov/MAS/scarbhome.html	VI in smoke, VI saturation analysis, Fire

4.1.2 MODLAND-led Campaigns

In some cases, complementary data needed for comprehensive satellite product and algorithm validation are absent in campaigns not coordinated in part by MODLAND. Thus, to better define workable field sampling protocols and provide the needed data, MODLAND has taken an active role in leading or co-leading field campaigns. These are outlined in Table 8 and described thereafter. MODLAND has actively sought and obtained participation of outside scientists (both EOS and non-EOS) in these efforts. Details on these are given below.

Table 8: MODLAND Pre-Launch Field Campaigns

MODLAND Pre-Launch Activities	Investigator	Date	Principal Sensors	Primary Purpose
1-Alaska	Hall	1995	MAS	Snow cover detection
2-CALWEST	Wan	Aug.-1995 & Jun.-1996	MAS, TIMS	TIR cal./val. (Railroad Valley Playa, NV)
3-CALWEST	Wan	Mar.-1997	MAS	LST and LSE cal./val. (Death Valley)
4-PROVE-Grassland	Huete, Justice, Running, Strahler	May-97	CIMEL (BRDF)	Short canopy structure and optics, product scaling in heterogeneous cover
5-CALWEST	Wan	Jun.-1997	MAS, TIMS, AVIRIS	LST and LSE cal./val. (Railroad Valley, NV)
6-PROVE-Forest	Huete, Justice, Running	Aug.-1997	CIMEL (BRDF), GOES	Tall canopy structure, scaling of FPAR, LAI, albedo and cover type, topography effects
7-WINCE	Hall	Winter, 1997	MAS, MIR	Snow cover detection
8-CALWEST	Wan	Mar.-1998	MAS	LST and LSE (Mono Lake and Death Valley)
9-Maricopa	Huete	Aug.-1998	ATLAS	[Multi-product algorithm]
10-East Anglia, UK	Muller, Strahler	1998 +	Field and low-level airborne	BRDF, albedo, landcover

4.1.2.1 Winter Cloud Experiment (WINCE)

Hall helped lead the Winter Cloud Experiment (WINCE), a 1997 campaign designed in part to improve the detection and separability of clouds, snow and ice in remote sensing imagery. The cooperative effort between researchers at the Univ. of Wisconsin-Madison and NASA included several flights of the NASA ER-2 high altitude research aircraft equipped with the MAS sensor, among others. The aircraft overflew ground instrumented sites in New Hampshire, Wisconsin and New York. Using data from WINCE and a 1995 Alaska campaign, Hall *et al.* are assessing the accuracy of the MODLAND snow-mapping algorithm: ”SNOWMAP”. An enhanced SNOWMAP algorithm has been compared with several existing snowcover algorithms, which employ Landsat Thematic Mapper (TM) and MODIS Airborne Simulator (MAS) scenes. Results consistently show that the enhanced SNOWMAP algorithm performs very well at mapping snow in both non-forested and forested areas.. The results are being extrapolated to the hemispheric scale using 1-km land-cover data of North America and Eurasia from EDC. This will help provide an expected global accuracy of the MODIS snow-mapping algorithm in the pre-launch time frame. Details on WINCE are given at *http://cimss.ssec.wisc.edu/wince/wince.html*

4.1.2.2 Prototype Validation Exercises (PROVE)

MODLAND organized two campaigns designed to evaluate the instrumentation, sampling strategies and interdisciplinary coordination required to collect validation data sets at the EOS Land Validation Core Sites. The Grassland PROVE was held between 20-30 May 1997 at the USDA’s Jornada Experimental Range (JORNEX), a desert grassland north of Las Cruces, NM. The Forest PROVE was held between 11-15 August 1997 at a NOAA-operated CO_2 flux tower site in the Walker Branch Watershed, Oak Ridge, TN. In each campaign, most of the requisite data were collected such that the full MODLAND product chain can be validated (excepting land surface temperature, snow, fire and fire scar). Remote sensing data were acquired from aircraft, AVHRR, GOES, POLDER, and TM. By teaming with EOS IDS and non-EOS field scientists, the PROVE campaigns typify MODLAND’s plans to leverage validation efforts off existing activity and infrastructure.

In addition to routine data collection, several new methods for data collection were prototyped, most notably a CIMEL sunphotometer modified to sample surface-reflected radiances from a tower top position (see Section 4.4, Needs for Instrument Development). Other experimental data collection methods, including digital photography for vegetation structure and FPAR, and collection of off-nadir radiometry data via light aircraft (Cessna 185), were also prototyped. Ground albedo data and hemispherical photography were acquired at various locations. These data were aggregated with new mixture models to scales of satellite pixels. Data from PROVEs continues to be processed and used for validation of atmospheric correction, VIs, BRDF, Albedo, LAI, FPAR and NPP. Significant emphasis is being placed on parameter scaling. Initial conclusions were delivered at the PROVE follow-on meeting in November, 1997. A special PROVE issue of Remote Sensing of Environment is under development with a submission deadline of 30 October 1998. Additional information on the Grassland PROVE is available at *http://pratmos.gsfc.nasa.gov/~justice/modland/valid/prove/grass/prove.html* and

information on the Forest PROVE is available at
http://pratmos.gsfc.nasa.gov/~justice/modland/valid/prove/forest/prove.html

4.1.2.3 CALWEST Campaigns

Wan conducted several field campaigns in California and Western states (CALWEST) to validate the LST algorithm with day and evening MAS and field data. Three field campaigns were conducted in Railroad Valley playa, NV with the ASTER team, while three others were conducted as a series of EOS calibration/validation activities. Another field campaign was conducted in Death Valley, CA, in March, 1997, for validating the LST & LSE retrieved from MAS data with the new day/night LST algorithm. The highly diverse land covers and local basing of the ER-2 aircraft (carrying the MAS) in California have greatly facilitated these effective campaigns. CALWEST data sets are also being considered for validation of other MODLAND algorithms and products. CALWEST related activity is posted at: *http://www.icess.ucsb.edu/~wan/modislstgp.html*.

4.1.2.4 Maricopa Campaign

The major objective of the 1998 Experiment at the Maricopa Agricultural Center, Arizona (Core Site, see Table 3) was to prototype a validation campaign through different levels and intensities of radiometric and biophysical sampling. A seasonal data set of airborne and field radiometric measurements were collected along with biophysical measurements of various crops at different phenological stages. The NASA Stennis Space Center arranged for the ATLAS sensor to fly over Maricopa at six different dates throughout the growing season. Field-based biophysical and radiometric sampling were conducted over different grid sizes in order to examine surface heterogeneity, aggregation techniques, and coupling to the ATLAS sensor for scaling purposes. Measurements were also made at various sun angles for standardization of the data sets to desired sensor and aircraft overpass times. Current work is focused on integrating the light aircraft MQUALS package and 1 km SeaWiFS data to complete an end-to-end, MODIS-like validation protocol. Weaknesses encountered thus far include (1) the difficulty in standardizing sun angle behavior; and (2) difficulty in replicating biophysical measures among different methodologies. However, a great deal has been learned regarding sampling grid configurations with respect to both sample intensities and size. Additional information is available at:
http://gaia.fcr.arizona.edu/MARICOP.html

4.2 Interaction with other Sensor Data and Teams

MODLAND is also using data from existing satellites (e.g., SeaWiFS, AVHRR, TM

POLDER) for the analysis of large time and spatial scale trends, heterogeneity issues, and algorithm behavior at large view angles. Major efforts include vegetation index compositing using the AVHRR PATHFINDER and Landsat 5 data, land cover type mapping with a series of Landsat TM from Shenandoah National Park, and atmospheric correction and fire product validation with AVHRR GAC imagery.

Many of the validation interests of MODLAND overlap with those of the MISR team. MODLAND will participate in the ground segment accompanying those AirMISR flights that are over vegetated areas. Flights in 1999 are currently planned for the ARM-CART site and the USDA the Beltsville Agricultural Research Center (BARC) site. Validation of albedo over a region of several square kilometers, including issues of spatial scaling, will be a focus of these multi-angular campaigns. CERES is undertaking a BRDF validation effort using a radiometer mounted to a helicopter, which was successfully prototyped at the ARM-CART site in the summer of 1998. MODLAND will obtain the data acquired in this and subsequent campaigns by the CERES team for validation of the BRDF/albedo product through spatial modeling of heterogeneous and homogeneous surfaces.

4.3 Instrument Development

Three instrument development activities are underway by MODLAND investigators. First, an 8-band CIMEL sunphotometer has been reconfigured to measure surface-reflected radiance from tower-top positions. This modification should allow automated collection of directional surface reflected radiances as required for validation of atmospheric correction, vegetation indices, and BRDF. This development activity was conducted in coordination with GSFC’s AERONET program (Brent Holben, PI, and see section 3.3). MODLAND deployed the reconfigured CIMEL during both PROVEs (Grassland and Forest), on a 50 m CO2 flux tower at the Smithsonian Environmental Research Center (SERC), an eastern deciduous forest site near Annapolis, Maryland and BARC. Currently there is a BRDF Modified CIMEL at the Howland Forest Site and a deployment planned in late 1998 for the Harvard Forest Site. Analysis of the modified CIMEL data is currently underway. AERONET will provide four BRDF equipped instruments through 1999 and maintain the software and equipment for these instruments. These will be deployed as much as possible to cover a range of biomes. Anne Vermeulen , with MODLAND at GSFC, will coordinate with AERONET and the PIs at the site of deployment to arrange monitoring of the BRDF measurements. Uncalibrated real-time data are available at *http://spamer.gsfc.nasa.gov*.

The second development involved new methods for validation LST product. Previously, Wan's LST group conducted all field campaigns over flat homogeneous sites without vegetation or fully covered with short vegetation (e.g., lake surfaces, large flat playas and bare lands). The ground-based instrumentation and methodology developed for these measurements were not adequate for heterogeneous areas. Presently, LST validation methods are being extended to cover more general sites using a low-level aircraft or a tethered balloon (300-1500 m above the surface) as a platform for a TIR camera. This TIR camera system will provide coverage for the analysis of LST's spatial and temporal variations in a MODIS pixel.

The third development is the instrument package for the MODIS Quick Airborne Looks (MQUALS). This is an aircraft mount that will house an array of 3 digital cameras, a calibrated Exotech 4-channel radiometer, and an albedometer. The aircraft will fly over 10 x 10 km areas within key EOS Land Validation Core Sites. The Exotech will use custom filters to match the first four bands from the MODIS. Also, the spectral digital camera array will include MODIS bands 1, 2, and 3 for 1998 with an optional purchase of a 4th camera (MODIS #4) in 1999. Off-nadir and thermal sensing capability may be added if it can be readily implemented with one or two fixed-mount radiometers. The package will be housed on a versatile mount usable by most aerial photo-based light aircraft with port holes. MQUALS pre-launch testing will begin in October over the Maricopa and SALSA Core sites. There is a NASA ATLAS set of overflights planned in December. Accuracies and uncertainties of MQUALS will be tested at that time. If resources remain, priority will go to an overfly of Jornada LTER in the Spring of 1999, following the winter rains. The remaining MQUALS overflights before MODIS launch will take place in accordance with (1) a level 1b vicarious calibration site by MCST - possibly Lunar Lake; and (2) by the key sites selected from the LAI/FPAR/NPP validation protocol development meeting at Boston University, October 1998. Information on MQUALS can be found at *http://gaia.fcr.arizona.edu/MQUALS.html*

5.0 Post-launch Activities

The validation strategies and results from the pre-launch time period will guide the activity after launch. The instruments and networks developed before launch will provide enhanced and specific field data within an established infrastructure. The pre-launch field activities will provide lessons for future data collection and establish analysis procedures used to check product algorithms. Post-launch validation will apply these lessons to future field work and the actual MODLAND products will be evaluated with the established analysis procedures.

MODLAND's strategy in the post-launch time frame will be to separate validation emphases before and after six months after launch. During the first six months in orbit, the MODIS Level 1B data will be experimental and several 1B processing chains will be tested. Moreover, geolocation errors will be significant. Thus, serious downstream product validation cannot be accomplished. Given this situation, MODLAND is proposing to conduct a series of rapid light aircraft deployments aimed at providing first order assessment of L1B data and radiometric products high in the MODLAND product stream (atmospheric correction and vegetation indices). In addition to these deployments, MODLAND will continue its pre-launch validation activities including further development of the Land Validation Core sites, the product sites, and algorithm assessment with data from other satellites.

MODIS L1B data is expected to become stable after six months of MODIS operation. At this time, MODLAND will begin extensive evaluation of its products using MODIS data. This will involve continuous collection of some field parameters at validation test sites, augmented with short "snapshot" field and light aircraft campaigns aimed at providing complimentary data. In addition, several large scale field campaigns involving MAS, MASTER and other EOS airborne sensors will be conducted. Finally, MODIS products will be compared to simultaneously acquired products of other satellite sensors. MODIS has specific requirements for higher spatial resolution data from Landsat 7 and ASTER. The MODIS requirements have been built into the acquisition strategies for these instruments for the core sites. Future work will ramp this effort up to additional sites as needed.

5.1 MODLAND Quick Airborne Looks

We plan to conduct six MQUALS (described above under "Instrument Development", Section 4.3) over the six representative biome types (desert, grasses/cereal crops, broadleaf crops, shrubland/savanna, needleleaf forests, broadleaf forests) in the period between AM-1 launch and Launch + 6 months (likely location are given in Table 9). MODIS Level 1B data available during this period is expected to be experimental and eventually replaced with reprocessed data. The flights will be conducted on days in which MODIS will scan the targets at a near-nadir position. Except for an AERONET sunphotometer (to assess atmospheric aerosols) and a stable reference plate (irradiance), no ground instrumentation is currently planned for the MQUALS. These rapid but low cost assessments will satisfy three MODLAND goals: 1) They will provide feedback on different Level 1B processing chains and their potential effects on land products, 2) they will provide early quantitative checks on two critical “upstream” land products (atmospheric correction, surface reflectance, vegetation index, and albedo), and 3) they will provide high spatial resolution surface heterogeneity data for more accurate scaling at validation test sites. The spatial variability of reflectance and albedo observed by MQUALS at the Core Sites will allow the construction of a spatial model of reflectance and albedo based on TM-derived spatial patterns. This will link the data stream generated at the core site with the coarser spatial resolution of MODIS land products. Longer transects to be flown by MQUALS across landscape gradients will allow investigation of transitions in land cover type and the properties of NDVI, reflectance, albedo and LAI products across a string of 50 to 100 MODIS pixels. Initial results are anticipated within 1-2 weeks of MODIS data delivery to the Science Computing Facility (SCF).

Table 9: MODLAND Quick Airborne Looks (Candidate post-launch sites).

EOS Validation Test Site	Principal Sensors	Responsible Team Members	Primary Purpose
Maricopa Ag. Center, AZ (agriculture)	Airborne Exotech, digital cameras, albedometer CIMEL sunphotometer	Huete, Strahler, and Vermote	MODIS L1B feedback; surface reflectance, albedo, and VI trend checks; spatial heterogeneity
Walker Branch Watershed, TN (decid. forest)	same	Huete, Strahler, and Vermote	same
Missoula, MT or HJ Andrews LTER, OR (needle forest)	same	Huete and Vermote	same
Konza, KA (grassland)	same	Huete and Vermote	same
Jornada LTER, NM (shrubland)	same	Huete, Strahler, and Vermote	same
Hog’s Island LTER, VA (agriculture)	same	Huete and Vermote	same
Lunar Lake	same	Huete *et al.*	calibration

5.2 Field Campaigns

MODLAND will lead or co-lead several large scale field campaigns (see Table 10) to augment ongoing activities at the Validation Test Sites. These campaigns will provide information on products not routinely validated at the test sites (e.g., snow cover, fires, and surface temperature) or additional information on products that are measured at test sites. The field campaigns may involve an ER-2 or high flying aircraft with one or more of the EOS instrument airborne sensors (e.g., MAS, AirMISR, MASTER). Use of smaller radiometric instrument packages on light aircraft is also planned (e.g. MQUALS) . In some cases, validation personnel from other AM-1 instrument teams, particularly MISR and ASTER, as well as outside investigators, will participate. Normally, a land cover gradient will be targeted.

Table 10: MODLAND-led Planned Field Campaigns

MODLAND Post-Launch Activities	Investigator	Date	Principal Sensors	Primary Purpose
1-East Anglia, UK	Muller, Strahler	1998-2001	Field and low-lever airborne	BRDF, albedo, landcover
2-WINCE-2	Hall	Feb.-1999	MAS	Snow cover in New England and mid-western states
3-REP/WEST	Justice	Summer 1999	MAS	Fire detection coordinated with prescribed burns
4-Uyuni Salt Flats, Bolivia	Wan	Jun./Jul.1999	Airborne and field sensors	TIR cal./val. campaign
5-CALWEST	Wan	Sept. 1999	MAS, MASTER, AVIRIS, field sensors	LST and LSE, TIR cal/val
6-Tibet	Wan	Oct. 1999 or March 2000	in-situ only	TIR band vicarious calibration jointly with Chinese pIs
7-CALWEST	Wan	Summer 2000	MAS, MASTER, AVIRIS, field sensors	LST and LSE Validation jointly with GCIP MRBEX
8-VATS	Strahler	Ongoing	TM, ETM+, ASTER	Land cover and land cover change
8-VATS	Strahler	Ongoing	TM, ETM+, ASTER	Land cover and land cover change

As in the pre-launch case (Table 4), MODLAND will also participate in independently-led field campaigns in the post-launch time frame as shown in Table 11. MODLAND successfully submitted a no-cost proposal (PI: A. Huete) to the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) program. The exact nature of MODLAND's involvement is currently under discussion, however the location of two Core Validation

Sites within the LBA region will help ensure early EOS remote sensing capability to the primarily ecology-based NASA involvement.

In addition, MODLAND has worked extensively to help shape and launch the SAFARI 2000 campaign. This international federated activity will investigate the land-atmosphere interactions in southern Africa over three years (1999-2001). MODLAND is helping coordinate the SAFARI 2000 Land Core Sites but will also rely on various other sites in the region (e.g., for biomass burning). In particular, MODLAND is collaborating with two EOS Validation Investigators and two Land Use Land Cover Change Investigators in that region. The SAFARI 2000 Land Core Sites are given at *http://pratmos.gsfc.nasa.gov/~justice/modland/valid/s2k_sites.html*.

Table 11: Independent Post Launch Field Campaigns

Independent Post-Launch Activities	Investigator	Date	Principal Sensors	Reference	Primary Purpose
1-BIBEX	Justice		tbd	Through IGBP http: //www.igbp.kva.se/element.html	Fire, scar assoc. with IGBP
3-LBA, Brazil	All	1999	MAS, AVIRIS	http: //www.cptec.inpe.br/lba/	Dry season tropical forest & cerrado, fire, biophysical and surface radiation, LST, VI
4-SAFARI 2000	Justice	2000	MAS, AVIRIS Simulated VCL	http: //safari.gecp.virginia.edu/	biogenic, pyrogenic and anthropogenic aerosol and trace gas sources and sinks

5.3 Other Satellite Data

MODLAND will continue to utilize data from other sensors throughout the post-launch time frame. As indicated above, a number of data sets (e.g., AVHRR PATHFINDER data) are currently being used to help validate algorithms, particularly the characteristics associated with large spatial or temporal scales. Valuable information on view and solar angle effects, as well as multiple orbit compilation, continues to result from these efforts. Post-launch, the primary focus of these efforts will shift to comparison of MODIS and non-MODIS data and products. Primary activities will include of sub-pixel heterogeneity using higher resolution sensors including Landsat TM (ETM+), ASTER and MISR.

It is important here to note that all of MODLAND validation activity involves issues of scaling: from ground measurements, to tower, to airborne, to high resolution spaceborne, to actual MODIS data. Different products will emphasis different observations along this spectrum but ETM+ and ASTER data will provide a spatial scaling link for post-launch calibration. These data are needed for linking field measurements to MODIS data as well as extrapolating from the relatively small number of field and tower sites to larger areas and additional locations, thus providing the number and extent of validation sites needed to complete a *global* validation. With this, acquisition of Landsat 7 and ASTER over the validation sites is extremely critical.

In addition to the higher resolution satellite data, post-launch comparison will also include products (e.g., vegetation index, land cover type, fires, snow cover) from sensors including AVHRR, DMSP OLS, SeaWiFS, ATSR, GOES and Meteosat. Other data resources, such as the Forest Service Fire Reports, will support these analyses. The MODLAND team is also in contact with the National Space Development Agency of Japan (NASDA) to work with them on coordinating validation activities between MODIS and the Global Imager (GLI). Validation activities for GLI are anticipated to start around the year 2000. Information on GLI can be found at:
http://hdsn.eoc.nasda.go.jp/guide/guide/satellite/sendata/gli_e.html

5.4 Geometric Registration Sites

Georegistration will be accomplished through a network of 300 ground control points to be used by all AM-1 ground sensors. The points include coastal positions, lakes, rivers, and other obvious but stable geological or geographical features. In addition, 6000 ocean control points will be used. These are also being used by SeaWiFS scientists. However, the positions of these points are known only to 1 km, and hence are less accurate than the ground control points. Our goal is to characterize the pointing errors of MODIS within six months after launch.

6.0 Implementation of Validation Results

6.1 Approach and Role of EOSDIS

Successful validation will in part depend on ready access to high quality and fully documented validation and calibration measurements collected by a variety of sources. Below we outline a plan, under active development by ORNL and EDC DAACs and MODLAND scientists, for processing and archiving *in situ* validation data and satellite imagery related to the validation sites. Note this model assumes a diverse program in which MODLAND scientists, EOS Validation Investigators, and independent investigators are all conducting validation activities. The MODLAND approach is congruent with EOS validation data archiving policy, see *http://eospso.gsfc.nasa.gov/validation/policy.html*.

6.2 **In situ** *Validation Data Processing, Distribution, and Archiving*

Much validation data is expected to be submitted to the Oak Ridge National Laboratory (ORNL) Data Active Archive Center (DAAC) for Biogeochemical Dynamics for distributing and long-term archiving. The ORNL DAAC has experience in processing data through its ongoing work with previous campaigns (e.g., FIFE, OTTER, BOREAS). The ORNL DAAC participated in both of the PROVE campaigns and assisted with collecting, coordinating, cataloging, and archiving data.

The proposed data access system, MERCURY, is a Metadata Search and Data Retrieval System being developed at ORNL. It is Web based, highly automated, rapid to deploy, and easy to maintain. Basically, data and their metadata can be contained in files at any on-line machine connected to the internet. The documentation file contains some meta tags that define searchable fields in the document. A harvester crawls the web periodically and harvests these fields and automatically builds a searchable index. This index is searchable via the MERCURY interface. When a data set is identified as wanted, a clickable link in the documentation allows the user to download the file. In FY1999 the DAAC proposes to implement the Mercury system to provide initial and timely access to distributed data. A demonstration version of Mercury is available at *http://daacnt1.esd.ornl.gov/servlet/demo*

ORNL will work on developing prototype datasets for several sites; develop guidelines for validation data, metadata, coordinated web sites; and maintain the Mercury Web site. Much of the Jornada PROVE data has been submitted to the ORNL. This will soon be posted for public use. These data include albedometer transects, hemispherical photography, and GPS ground control points. ORNL will also jointly work on designing an approach to link field data with EOS AM-1 satellite products to be stored at the EDC DAAC.

6.3 Image Validation Data Processing, Distribution and Archiving

MODLAND is working with EDC DAAC to derive a system for extracting and processing EOS image data associated with the validation sites. The proposed EDC responsibilities include:

1. Extraction of EOS ASTER, MISR and ETM+ satellite scenes for the Core Sites (with possible subsetting features) at a rate of 4 to 12 scenes a year,
2. Storing these scenes in an FTP directory structure based on the Core Sites
3. Receiving MODIS Land products subset over the Core Sites for storage in the ftp directories
4. Coregistering the imagery.

The level of effort required for these three tasks will depend on availability of funds and will require interaction with the MODLAND validation and PI teams. For efficiency, the subsetting and compiling tasks will be targeted as a DAAC function, however, the coregistration might need to be done outside the ECS. EDC currently plans to use as many ECS/V0 IMS tools and capabilities as possible, leverage off of the "DAAC-unique extensions" when funding for this is available, and to handle EOS Validation Investigators as higher priority customers. Within this context, for the pre- and launch plus one year, the MODLAND team will work with EDC to make available as much AM-1 and ETM+ imagery data for as many Core Sites as possible. Priority within the Core Sites will be given to those with active *in situ* data collection and related ORNL Mercury links. These issues are currently being considered by MODLAND validation coordinators and EDC Science Advisory Panel.

7.0 Summary

This document describes the validation activities underway or planned by the MODIS Land Science Team. To adequately cover the broad range of surface-atmosphere systems that will be encountered around the world, multiple validation methods—applicable to different temporal and spatial scales—will be implemented. Nevertheless, the highly discretized nature of land systems, in contrast to most atmospheric and ocean systems, makes *in situ* measurement of coarse resolution parameters extremely difficult. Essentially, this increases the uncertainty of the validation data itself. These concerns further necessitate a validation approach that is comprehensive and at times redundant. The work will involve

- commitment to the EOS Land Validation Core Sites,
- product-specific activity and validation protocols (primarily by MODLAND PIs),
- close cooperation with EOS Validation Investigators to meet specific product validation needs,
- interaction with established data networks (e.g. FLUXNET, AERONET),
- participation in community field campaigns (LBA, SAFARI 2000, GCIP),
- developing novel validation instrumentation and approaches (e.g. MQUALS, sunphotometers with BRDF capability),
- collaboration with other AM-1 instrument teams (CERES, ASTER, MISR) and Landsat-7
- and collaboration with the data providers (PIs, DAACs, ESIPS).

Together, these essential activities provide the foundation for operational product validation.

8.0 References

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9.0 Acronyms

ADEOS	Advanced Earth Observing Satellite (Japan)
AERONET	Aerosol Robotic Network
AirMISR	Airborne MISR
AMSR	Advanced Microwave Scanning Radiometer
ARM	Atmospheric Radiation Measurement Program
ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer
ATBD	Algorithm Theoretical Basis Document
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
BARC	Beltsville Agricultural Research Center
BRDF	Bidirectional Reflectance Distribution Function
BRSN	Baseline Surface Radiation Network
CART	Clouds and Radiation Testbed
CERES	Clouds and the Earth’s Radiant Energy System
DAAC	Distributed Active Archive Center
DMSP OLS	Defense Meteorological Satellite Program - Operational Linescan System
ECS	EOSDIS Core System
EDC	Environmental Data Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ESIP	Earth Science Implementation Partners
ETM+	Enhanced Thematic Mapper Plus
FPAR	Fraction of Photosynthetically Active Radiation
FTP	File Transfer Protocol
GAC	Global area coverage
GCIP	GEWEX Continental-Scale International Project
GCOS/GTOS	Global Climate Observing System
GEWEX	Global Energy and Water Cycle Experiment
GLCTS	Global Land Cover Test Sites
GLI	Global Imager
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
ICO	Initial Check Out
IDS	Interdisciplinary Science Teams
IGBP	International Geosphere-Biosphere Program
IMS	Information Management System
ISCCP	International Satellite Cloud Climatology Project
JORNEX	Jornada Experimental Range
LAI	Leaf Area Index
LBA	Large Scale Biosphere-Atmosphere Experiment in Amazonia
LDOPE	
LSE	Land-Surface Emissivity\
LST	Land-Surface Temperature
LTER	Long Term Ecological Research
MAS	MODIS Airborne Simulator
MASTER	MODIS/ASTER Airborne Simulator)
MISR	Multi-angle Imaging Spectro-Radiometer
MODIS	Moderate Resolution Imaging Spectroradiometer

MODLERS	MODis land science team & Long-term Ecological Research network Synthesis
MQUALS	MODIS Quick Airborne Looks
MRBEX	Mississippi River Basin Experiment
MTPE	Mission to Planet Earth
NPP	Net Primary Production
NRA	NASA Research Announcement
NEP	net CO_2 exchange between terrestrial ecosystems and the atmosphere
NOAA	National Oceanic and Atmospherice Administration
NOHRSC	NOAA Operational Hydrologic Remote Sensing Center
ORNL	Oak Ridge National Lab
POLDER	Polarization and Directionality of Earth's Reflectances
PROVE	Prototype Validation Exercise
SCAR-A	Sulfate, Clouds and Radiation–Atlantic (Delmarva Peninsula and near-by Atlantic Ocean, July 1993)
SCAR-B	Smoke, Clouds and Radiation–Brazil (Brazil, August-September 1995)
SCAR-C	Smoke, Clouds and Radiation–California (Pacific Northwest, September 1994)
SCF	Science Computing Facility
SERC	Smithsonian Environmental Research Center
SGP	Southern Great Plains
TIR	Thermal Infrared
TLCF	Team Leader Computing Facility
TM	Thematic Mapper
VCL	Vegetation Canopy LIDAR
VI	Vegetation Index
WINCE	Winter Cloud Experiment