Type of Report: Semi-annual, January - June1999.
University of Arizona
NAS5-31364

TASK OBJECTIVES

During the first half of 1999, we continued to work on algorithm testing, code testing and code deliveries, error analysis, QA , pre-launch validation and SCF development. Specific objectives and tasks included:

- delivery of the 1km monthly vegetation index product (MOD13A3)
- revise and debug 250 m and 1km MOD13A1, MOD13A2 and MOD13A3 vegetation index products and add the latest QA ECS and MODLAND metadata requirements based on the X-and N-day tests at MODAPS;
- prototype vegetation index and test VI compositing algorithms with the daily, SeaWiFS data streams;
- preparations for at launch QA and MODIS data analysis, including software, QA tools, security, network and hardware issues and the development of a data management plan
- end-to-end error analysis of the vegetation indices;
- MODIS Quick Airborne Looks (MQUALs) testing and development;
- validation activities including LBA, community core sites, Mongolia, etc.
- ATBD update on April 30, 1999.

WORK ACCOMPLISHED

1. Level 3 Vegetation Index Compositing Algorithms and Aggregation software

Currently all pre-launch code is baselined and being reviewed and adjusted for one last delivery. Most of the work is focused on adjusting metadata to comply with the ECS and MODLAND requirements. Focus was placed on the following algorithms:

- 1km Monthly (MOD13A3)
- 1km 16 day (MOD13A2)
- 250m 16 day (MOD13A1)
- Aggregation code (MODPRAGG)

Achievements:

- 1km Monthly algorithm finished and submitted
- Code is operational in-house (TBRS-SCF-AZ)
- Test data is also available at our SCF
- Enhancement to the algorithms were implemented
- Metadata fields added

Science requirements and code adjustments that were incorporated:

A. BRDF and CVMVC algorithms are able to run independently from and in conjunction with each other.

B. BRDF approach has built in flexibility:
   - Run with 5 or more observations (the number of observations should be made adjustable i.e. 4 or 6 or 7 observations)
   - Outlier thresholds for $NDVI_{BRDF}$ output should be adjustable. Currently: $NDVI_{MVC}$ -0.3 • $NDVI_{BRDF}$ • $NDVI_{MVC}$ + 0.1 (against incorporation of cloud affected pixels)
   - Potentially ingest a BRDF data base (post launch implementation) and derive standardized reflectance data with a limited number of observations
   - Outlier thresholds could be built in for reflectance observations; e.g. 1: all observations must fall within 2 times the standard deviation of the mean; e.g. 2: Compute BRDF and RMSE for each observation to test for outliers (post launch implementation).

C. CVMVC approach has built in flexibility:
   - Outlier thresholds for $NDVI_{CVMVC}$ output should be implemented and made adjustable; $NDVI_{MVC}$ -0.3 • $NDVI_{CVMVC}$ • $NDVI_{MVC}$ + 0.1 (against incorporation of cloud affected pixels
   - The number of observations closest to nadir (CVMVC) needs to be adjustable 2,3,4,5,…16

D. PCF, Process control file can control the following options:
   - Run BRDF and CVMVC at the same time in conjunction with each other
   - Run CVMVC by itself
   - Run BRDF by itself with BRDF data base (post launch)
   - Number of observations in BRDF
   - Number of observations in CVMVC

Current overall status:

– All software packages for four products (MOD13A1, MOD13A2, MOD13A3 and MODPRAGG) are being prepared for delivery as version 2.1

– The other PGEs will be delivered in the fall, 1999 with help from Montana, including:
   - ✓ PGE 27 (MOD13C1 - NDVI and EVI at climate modeling grid (CMG - 25km) and 16 day resolutions);
   - ✓ PGE 28 (MOD13C2 - NDVI and EVI at CMG and monthly resolutions).

2. Research and Prototyping Efforts

- **Sun angle standardization and uncertainty using SeaWiFS data:**

Sun angle standardization of the NDVI was investigated for ground data (PARABOLA and Exotech). Based on the ground data, an empirical relationship was developed for the NDVI and solar zenith angle to potentially correct the NDVI values observed at different sun angles. Although a first order solar zenith angle correction can be made as function of the magnitude of the NDVI, the solar zenith angle correction was related to the vegetation type and its phenology. The empirical solar zenith angle - NDVI relationship was applied to a composited SeaWiFS-NDVI image to evaluate the effect of solar zenith angle on the NDVI on a global scale.

Software was developed to standardize the SeaWiFS reflectance data to globally constant solar zenith and view angles. A series of 27 days of SeaWIFS data were composited with the Ross-Thick /Li-Sparse BRDF model and the data normalized at fixed sun angles of 0,10,20,30,40,50 60 and 70 degrees and 20 ° view zenith angle was processed. The empirical results are currently compared to the results derived from sun angle standardized data sets generated by the application of a BRDF model.

- **Further Optimization of the Enhanced Vegetation Index**

Hiroki Yoshioka is working on ways to establish and develop a quantitative basis for optimizing vegetation index (VI) continuity across different sensors, particularly across the MODIS, AVHRR, and Landsat series of sensors. Vegetation indices are one of the more important products in monitoring temporal and spatial variations of vegetation canopy biophysical parameters. Long term observations require much effort to ensure continuity, particularly across new sensors, drifts in calibration, filter degradation, and variations in band location and/or bandwidths. With the presence of new sensor systems and future formation flying, the issue of cross-sensor VI continuity, and VI equivalencies, becomes a critical issue and requirement that needs to be addressed.

We approach this problem by optimizing the VI's to theoretically guarantee the same value for the same target under identical conditions based on simulation models and field measurement data. The resulting VI products by this method will become time and sensor independent. We will first establish and quantify NDVI continuity as well as its limitations in terms of change detection; e.g., atmospheric-related limitations may preclude a full continuity solution in Landsat data. However, this potential restriction in the accuracy of VI's for change detection can be overcome through formulations of the atmospheric resistance concept into the VI. Optimized VI's minimize such environmental restrictions and offer numerous adjustment factors, which provide flexibility in optimization of the vegetation index for continuity purposes. Thus, the Landsat VI time data series can be made atmosphere resistant, whether the variations in atmosphere are image to image variations, cross-sensor variations in atmosphere influence (MODIS to TM), or variations resulting from filter degradation over time.

3. QA Documents:

- **MODIS Aggregation QA Plan**
  Kamel Didan and Wim van Leeuwen drafted a QA plan for the MODIS aggregation product and submitted it for review to the other SCF's . This document will function as an information source and as a guideline for the QA tasks and scenarios that need to be performed on the MODAGG product. Since AZ has been maintaining the MODAGG code for the last year, they will continue to implement routine changes where needed, based on the requirements and priorities set in mutual agreement among the three SCF's (Boston, Montana, AZ). If large changes need to be

implemented, some help from the other SCF's is expected. LDOPE has agreed to help with routine QA evaluations.

- **Vegetation Index Product, Quality Assurance (QA) Plan, Version 2**
  A previously drafted QA document was updated in June to anticipate QA needs, including accuracy assessment and validation activities for MOD13 products, and direct the SCF development. IDL routines were augmented to do Quality Assurance analysis on MODIS VI products and related science issues (multiple vegetation indices issues, quality flag visualization), including inputs of the MOD09 reflectance product. The QA tools are being packaged for distribution among the Land SCF's.

- **Golden tile selections**
  Fifteen "golden tiles" were selected where QA will be undertaken operationally by the LDOPE and in detail by the MODAGG SCF's. The list of 15 Golden tiles is not intended to exclude other miscellaneous sites for operational QA evaluations. The Golden tile selection for the MODPRAGG and MOD13A1 and MOD13A2 products are based on the following criteria:
  - Exercise all parts of the MODAGG and MOD13 algorithm (land /water mask, cloud mask, multiple orbit/ observation selection, atmospheric criteria, etc).
  - Representation of all biomes, including urban areas.
  - Have a globally representative sample (each continent is represented)
  - Include the core validation sites.
  - Include sites that will be produced with 50% production (Mongolia needs to be added).
  - Have adjacent tiles to check spatial continuity.
  - Have tiles where AZ, Boston, Montana SCF's have more than average expertise (their backyards).
  - The distribution of ground control points, hence geo-registration, was not considered.

4. QA tools

Trevor Laing developed a software package/toolkit for the MODIS VI products that will allow for easy interpretation of the QA flags at the bit and tile level. This software was developed in an ENVI/IDL environment. The software has four components. The first component was developed for a generalized file format to contain text descriptions of QA fields and conditions and has the means of parsing the file for the other components of the toolkit. The second component was developed as a per-pixel QA browsing tool, which provides a text description of QA conditions of corresponding pixels in a displayed image. The third component was the developed as a QA image filtering tool, which allows the user to select a subset of QA criteria and create a filtered QA plane containing only the selected QA fields. The fourth component was developed to do QA dependent masking, which allows the user to select a subset of QA conditions for a single QA criterion, and create a version of an image containing only pixels which were produced under the specified conditions. This software package has successfully fulfilled its objectives in providing a viable solution to many of the common MODIS QA image visualization problems. The toolkit provides the user with the ability to quickly display a meaningful description of per-pixel QA information while viewing MODIS science products, and the ability to quickly create new images based on QA plane data.

There are several places where the QA toolkit could be improved. The QA-plane filtering tool could be improved by allowing users to interactively specify a color scheme assigned to the filtered QA image. Also, the QA-dependent masking tool could be extended to include more than one bit-field. Plans are being made to distribute these tools among the land SCF's with the appropriate documentation.

To evaluate the products, software was written (Kamel Didan) to extract all the relevant input data and the associated MODIS VI output data for a certain number of pixel locations. These are basically algorithms that run at the SCF only, in parallel to the ones running at the MODAPS. These special runs will aid in detailed QA and scientific analysis. The generated output was run (Wim van Leeuwen) through some other in-house developed BRDF modeling software to verify that the algorithms perform correctly.

The LDOPE QA database was used to ascertain that the MOD13 input data products were made. The LDOPE QA database was also used to consider which granules/tiles to order. The products produced by the MODAPS were ordered from the MEBDOS, after which they were downloaded through ftp (network testing) MODAPS production summaries. The MODLAND known problems page was checked out indicating some problems in the AGG code which were resolved. The MOD13 products are not made as of yet. Therefor, no opportunity to set the Science Quality Flag and Science Quality Explanation metadata using the LDOPE QA database has been provided.

5. Science Computing Facility:

A DLT7000 tape drive and DLT stacker (DLT7000 7 cartridge autoloader) as well as data management software were purchased for data archiving and data back-up. This was set up and integrated by our application system analyst, Farideh Farahnak. She continues to work on archiving/retrieving and scheduling tasks with the Irix Networker Network edition using archive and autochanger option software. A complete and incremental system backup (incremental each Friday) on DLT tapes was implemented. The purchase of another 108 GB data vault is being considered to deal with anticipated data volumes.

We also upgraded the operating system, IRIX 6.5.3, on all machines where possible, installed the PGS toolkits, and provided system support/maintenance for both software and hardware issues, and installed patches on the servers/workstations to provide a better and more secure networking system. The directory file and disk systems are being reorganized. A second server has been set up as a mirror of the main MODIS processing server to reduce downtimes. All licensed software packages on the servers are being updated.

Network throughput is still being tested/tracked, but is currently insufficient to perform all the MODIS QA and validation needs. The SCF will be in close communication with the NASA Goddard and EDC sites for the network throughput to the

AZ-SCF. The proposed solution was to install a Vbns switch in Chicago and reroute the communications. The throughput is still not satisfactory.

A preliminary data management plan was drafted by Kamel Didan and Wim van Leeuwen to prepare for MODIS QA and validation activities after launch.

6. GLI - MODIS Collaboration:

Several exchanges and visits fostering GLI- and MODIS collaboration have taken place this year:

- January 14 - February 3, we were visited by Ms. Asako Konda and Dr. Koji Kajiwara of Chiba University near Tokyo, Japan. The purpose of their visit was to discuss joint validation activities and to initiate planning for the Mongolia field experiment this August, 1999. They participated in fieldwork at the Audobon Research Ranch within the SALSA experiment.

- February 23 - 26, Kamel Didan and Alfredo Huete attended the GLI Algorithm Peer Review Meeting at NASDA, Tokyo, Japan. At this meeting we discussed MODIS and GLI algorithms, code structures, and ways to process and integrate various algorithms. We also covered some potential MODIS - GLI validation activities.

- May 27 - June 1, Dr. Yoshioki Honda visited us from Chiba University, Japan, to discuss the Mongolia field experiment and to initiate further validation activities in the U.S. Dr. Honda is the project scientist leader for the Mongolia experiment, a 5 year field campaign. We agreed to send two people from our group to participate this August for 1 month.

- June 8 - June 12, Dr. Vu Saito, GLI project manager and three other scientists; Mr. Tsuneo Okuda, Mr. Junichi Inoue, Mr. Masahiro Hori, visited us to further discuss algorithm development, coding and processing issues and ways to process and mosaic joint land and cryosphere bands.

7. MQUALS and Validation Activities:

Various tests and developments were made to the MQUALS package thus far including:

- An Audobon Research Ranch experiment and flight, January 28-30 (bad weather)
- A flight through La Jornada Experimental Range and Sevilleta (both LTER sites in New Mexico) on May 29-31. In this case, various component parts of MQUALs were installed on an USDA-ARS aircraft, flying out of Weslaco. We were able to fly our Exotech along with theirs and we attached the Dycam 3-band digital camera. The weather was fair for this experiment with clouds present nearly 90% of the time. This left us with approximately 30 minutes of worth of

data. The dycam is still the weak link to the package with continued software development problems.

- Another flight just took place at Konza Prairie community validation site from July 11 through July 18. This was a large interdisciplinary experiment involving MODLAND, Dave Meyer's validation project, and Warren Cohen's BigFoot validation project. The weather was exceptionally clear and a lot of useful data collected.
- Cross-calibration trials: we have run several cross-calibration experiments with the two Exotechs with MODIS-like filters as well as with TM-based Exotechs and various Spectralon reference panel surfaces.
- We have an upcoming calibration experiment planned with Kurt Thome and his crew involving the MQUALS instruments and theirs at Railroad Playa and Ivanpah during the week of July 26.
    - July 26 TM5 overpass
    - July 27, ETM+ L7 overpass
    - July 28, TM5 overpass
- Lessons learned:
    - It is essential to supply all flight lines and GPS coordinates before the experiment begins. This is needed by the pilot, avoids confusion, and facilitates ground-biophysical sampling coordination.
    - It is difficult to cover multiple sites that are quite distant to each other. Thus, the ARM/CART site was 3-4 hours away from Konza making it difficult to cover both unless a ground crew could be deployed to make measurements of incoming irradiance onto a reference plate.
    - Thus, we could have flown to a nearby (ARM/CART) landing strip, dropped off someone to measure the constant plate, flown the site, return to the strip to pick up the extra person and fly back to Konza. Local crews and experts to the area best handle such logistical considerations, not by the Arizona group.
    - The purpose of MQUALS was to be able to ship the 'mobile' package to other sites and let the EXPERTS at these sites, who are familiar with the area, handle all the logistics.
    - A more serious logistical problem was that we contracted with a young, inexperienced and actually misleading pilot. We asked for a plane with GPS and it turned out he didn't have a functioning one - so we lost 1 day of flying. We asked for a hole in the plane - and this guy actually did not have this either!! He thought we could work around this. So we wound up tying the package with rope onto the bottom of the plane (a day's effort here). In the future we recommend shipping the aluminum mount (or a spare one) to a local person to ensure that the plane and pilot we are contracting meet our requirements.

An article summarizing the MODIS Quick Airborne Look (MQUAL) approach to land product validation was published in the **Earth Observer:** http://eospso.gsfc.nasa.gov/eos_observ/1_2_99/jan_feb_99.html

The abstract is attached below:

The proposed ‘MODLAND Quick Airborne Looks’ (MQUALS) is an airborne radiometric system (instrument and protocol) for rapid and low cost product validation over a diverse and complex range of global biome types. The light airborne package can be flown ‘below the atmosphere’ at low altitudes of 150m to 300m AGL for accurate characterization of top-of-canopy reflectances. We propose to characterize a wide range of canopy types and conditions in a consistent manner with the same radiometric package. The same package has the flexibility of flying at higher altitudes (500 - 1000m AGL) for a range of scaling studies. The basic package consists of well calibrated and traceable “transfer radiometers”, digital spectral cameras, and an albedometer, all attached to a laptop computer for synchronized and timed measurements. Typical spatial coverage would be in the range of ten kilometers or less at a ‘pixel’ resolution between 1 and 2 meters. Pixel size could be increased to 100 m or more at higher flying altitudes. A key feature of MQUALS is the rapid processing, “turn-around” of the airborne measured results to within 7 - 10 days.

8. Meetings and conferences:

- A. Huete and K. Didan attended the GLI Algorithm Peer Review Meeting at NASDA, Tokyo, Japan, Feb. 23 - 26.

- Willem van Leeuwen and Kamel Didan attended the MODLAND SDST meeting held in Greenbelt, Maryland from 29 - 31 March, 1999.

- Alfredo Huete and Yosio Shimabokuro (INPE), both could not attend the third LBA Science Team Meeting held in Belem, Brazil, April 19 - 21. This was not a good sign for MODIS participation in LBA and as Diane Wickland noted, next time difficulties arise we should get in contact with her.

- Alfredo Huete, Wim van Leeuwen and Kamel Didan attended the MODIS Science Team Meeting held in Greenbelt, Maryland from May 3 - 6, 1999.

- Two abstracts were submitted and accepted for presentation at the EOS/SPIE Symposium on Remote Sensing, 20-24 September, 1999, University of Florence, Italy. Two manuscripts are being prepared for publication in the proceedings:

1) Global-scale analysis of vegetation indices for moderate resolution monitoring of terrestrial vegetation with SeaWiFS sensor. Alfredo Huete, Kamel Didan, Willem J.D. van Leeuwen, Hiroki Yoshioka, and E. Vermote

ABSTRACT: Vegetation indices (VI's) have emerged as an important tool in the monitoring, mapping, and resource management of the Earth's terrestrial vegetation. They are radiometric measures of the amount, structure, and condition of vegetation which serve as useful_ indicators of seasonal and inter-annual variations in vegetation and resultant_ climatic and anthropogenic influences on the environment.__ In this study, the Sea-viewing Wide Field-of-View sensor (SeaWiFS) is used to prototype and analyze coarse resolution monitoring of the Earth's surface with vegetation indices. A 16-day series of SeaWiFS GAC (4-km resolution) data for the period, September 15 to October 1, 1997, was collected over the entire globe and composited to cloud-free, single channel reflectance images. The images were degraded to 8km and corrected for Rayleigh scattering, ozone absorption, and water absorption.
Histograms and transects were extracted over four ‘continental’ regions, North America, South America, Africa, and Asia, representing a wide range of land cover types. The histograms of the individual bands and

two vegetation indices were analyzed along with some transect plots crossing major transitional areas within each continent. Unique distributions of NDVI and EVI values were displayed in the histograms. The EVI had a more normal distribution of values over the global set of biomes while the NDVI was skewed toward higher values approaching saturation over forested regions. The NDVI mimicked the skewed distributions found in the red band while the EVI resembled the normal distributions found in the NIR band. The EVI was also found to greatly minimize smoke contamination over extensive portions of the tropics. Smoke was found to degrade histogram peaks in the NDVI and red channel but had minimal effects in the NIR and EVI histograms. As a result, major biome types within continental regions were discriminable in both the imagery and histograms. The results how that multiple indices are useful for effective monitoring of the diverse set of global biomes with the EVI being particularly useful in high biomass, forested regions.

2) Vegetation change monitoring with spectral indices: the importance of view and sun angle standardized data.Willem J.D. van Leeuwen, Alfredo R. Huete, Trevor Laing, Kamel Didan

ABSTRACT: Remotely sensed reflectance data is often acquired at variable view and solar geometric configurations. Although vegetation change detection and monitoring with NDVI (Normalized Difference Vegetation Index) or other spectral indices are very sensitive to the effects of solar and view angle geometry, tools and methods to correct for these effects have not yet been fully developed to monitor vegetation dynamics more accurately. Since the NDVI tends to increase with both larger view and larger solar zenith angles, the resulting variability in both view and solar zenith angles are important for inter-comparison of vegetation covers at different latitudes and seasons. The main objectives of this research were to: 1) demonstrate the importance of view and sun angle standardization of reflectance and spectral vegetation index data for vegetation change monitoring, 2) determine the use and limitations of BRDF models to standardize reflectance and spectral vegetation index data, and 3) present a vegetation density dependent sun angle correction of the NDVI.
BRDF (Bi-directional Reflectance Distribution Function) model parameters can be used to normalize and interpolate the surface reflectance to nadir view angles, using multi-angle cloud-free reflectance data (van Leeuwen et al., 1999. MODIS Vegetation Index Compositing Approach: A Prototype with AVHRR data, Remote Sens. Environ., in press). The sun angle variability can be standardized by using a BRDF model, although the data necessary to standardize to a certain sun angle for a composite time interval is very limited, and thus would be less accurate outside of the observed sun angle range. If multi-angle data are not available, a second method allows us to extrapolate (nadir) satellite observations (e.g. Landsat) to a standard sun angle throughout the year by using predetermined linear regression relationships between sun angle and nadir NDVI values for a range of vegetation types. An empirical relationship between NDVI and solar zenith angle was determined based on nadir ground reflectance data collected with the Parabola and Exotech radiometers for a wide range of land cover types. Both methods were applied to one month of daily, atmospherically corrected, multi-angle SeaWiFS (Sea viewing Wide Field-of-view Spectroradiometer) land reflectance data, with promising results. The difference in NDVI due to a sun angle change form 20° to 70° can be up to 50 %, and is generally higher for forested regions then for grassland regions. The NDVI values for very dense vegetated and bare soil surface areas are less affected by solar zenith angle effects. The magnitude of the effect of sun-angle is also demonstrated on a continental scale by using view angle standardized reflectance data and a vegetation density dependent relationship between sun-angle and NDVI. This research showed that the sun and view angle effects on the widely used spectral indices need to be standardized to improve the accuracy of vegetation change detection and vegetation and crop monitoring during the growing season and for the comparison of vegetation growth at a range of latitudes. It is intended to demonstrate the sun and view angle phenomena with actual MODIS (Moderate Resolution Imaging Spectroradiometer) data as soon as the MODIS land-products are becoming available after the July (1999) launch.

- I am scheduled to give a presentation at a DOE/ DoD workshop on "Developing New Technologies to Assess Vegetation changes and to Reclaim Arid Lands for Mitigating Impacts of DoD and DOE Activities" The workshop will be in Las Vegas on Aug. 2,3 at the Hq of Bechtel Nevada, the Test Site contractor. The title of my presentation is "The use of low resolution satellite imagery in arid areas, its uses and limitations".

9. Publications:

- Leeuwen van, Wim J.D., Alfredo R. Huete and Trevor W. Laing , 1999, "MODIS Vegetation Index Compositing Approach: A Prototype with AVHRR Data.", Remote Sensing of Environment (in press, 1999).

- "A Light Aircraft Radiometric Package for MODLAND Quick Airborne Looks (MQUALS)" by Alfredo Huete, Fricky Keita, Kurtis Thomé, Jeff Privette, Wim van Leeuwen, Chris Justice, Jeff Morisette, *Earth Observer*, v.11, n.1, p.22.

- A.R. Huete, C. Justice, W.J.D. van Leeuwen, 1999. MODIS vegetation index algorithm theoretical basis document (MOD13; v3.0). http://modarch.gsfc.nasa.gov/MODIS/ATBD/#LAND

- Miura, T., Huete, A.R., and Yoshioka, H., 1999, Evaluation of sensor calibration uncertainties on vegetation indices for MODIS, IEEE Trans. Geosci. Remote Sensing (provisionally accepted).

- Gao, X., Huete, A., Ni, W., and Miura, T., 1999, Investigation of spectral vegetation index relationships with biophysical plant parameters for a zero soil background case, Remote Sens. Environ. (to be submitted).

10. UPCOMING TASKS:

The tasks for the coming half year will include further development and evaluation of the vegetation index compositing algorithms and QA tools, error and uncertainty analysis, validation activities, and related science issues . Testing of the at launch and post launch products and software and SCF development continues.

- **Research plans and tasks :**

  - Prototype and analyze MODIS vegetation index composite results with SeaWiFS data using alternative composite scenarios (e.g. minimum blue channel) and more temporal data (3 months),
  - Continue to set up and document QA analysis procedures and QA tools for automated QA and in depth analysis of MODIS algorithms and their products,
  - Sun and view angle standardization of vegetation indices with BRDF models and empirical equations. The incorporation of the Ross-thick_Li-sparse BRDF model in the compositing algorithm will allow for this, but needs further evaluation.
  - Further update of the ATBD as needed.

- **Product software testing and development tasks:**

  – Deliver latest version with metadata updates PGE 25 26, 35 in July.
  – As the X-Day testing is continuing, all code should be ready and be tested at the MODAPS. A major part of the coding effort will concentrate on working bugs out as they materialize during these test phases.
  – Fix expected bugs in the 1km/250m 16 day composite that will result from the new versions of MOD09 and L2G
  – Synthetic data will need to be generated for us to test our code with the new version output (During the X-Day test exercises).
  – CMG grid vegetation index product software will follow in the fall as all the previous product. These efforts will start in August.
  – Document all aspects of the VI production software

- **SCF reorganization and development tasks:**

  – Further develop data management protocols for on-line, near-line and off-line storage to facilitate QA and validation tasks at the time of MODIS launch.
  - Improving the network throughput from NASA to TBRS-SCF (Tucson AZ) with the help of Andy Germain with NASA and CCIT at UofA.
  - Stay on top of security patches and set up monitoring system of the network for security reasons.
  - Prepare and participate in PI processing (production environment) tests.

11. Miscellaneous

- **PM Data Products Handbook: MODIS Vegetation Indices**

Product Description

The MODIS vegetation index (VI) products will provide consistent, spatial and temporal comparisons of global vegetation conditions which will be used to monitor the Earth's terrestrial photosynthetic vegetation activity in support of change detection, phenologic, and biophysical interpretations. Gridded vegetation index maps depicting spatial and temporal variations in vegetation activity are derived at 8-day, 16-day and monthly intervals for precise seasonal and interannual monitoring of the Earth’s vegetation. The MODIS VI products will improve upon currently available indices and will more accurately monitor and detect changes in the state and condition of the Earth’s vegetative cover. The vegetation index products are made globally robust with enhanced vegetation sensitivity and minimal variations associated with external influences (atmosphere, view and sun angles, clouds) and inherent, non-vegetation influences (canopy background, litter), in order to more effectively serve as a ‘precise’ measure of spatial and temporal vegetation ‘change’.

Two vegetation index (VI) algorithms are to be produced globally for land, at launch. One is the standard normalized difference vegetation index (NDVI), which is referred to as the “continuity index” to the existing NOAA-AVHRR derived NDVI. The other is an ‘enhanced’ vegetation index with improved sensitivity into high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. The two VIs compliment each other in global vegetation studies and improve upon the extraction of canopy biophysical parameters. A new compositing scheme that reduces angular, sun-target-sensor variations is also utilized. The gridded vegetation index maps will use as input, MODIS AM and PM surface reflectances, corrected for molecular scattering, ozone absorption, and aerosols, and adjusted to nadir and standard sun angles with use of BRDF models. The gridded vegetation indices will include quality assurance (QA) flags with statistical data, that indicate the quality of the VI product and input data.

- 250 m NDVI and QA at 8-,16-day and monthly (high resolution)
- 1 km NDVI, EVI, and QA at 8-, 16-day and monthly (standard resolution)
- 25 km NDV, EVI, and QA at 8-, 16-day and monthly (coarse resolution)

Research and Applications

Due to their simplicity, ease of application, and widespread familiarity, vegetation indices are widely used by the broader user community from global circulation climate modelers; EOS instrument teams and interdisciplinary projects in hydrology, ecology, and biogeochemistry; to regional- and global-based applications involving natural resource inventories, land-use planning, agricultural monitoring and forecasting, and drought forecasting. Some of the more common applications of the vegetation index include:

- Global warming/ climate
- Global biogeochemical and hydrologic modeling
- Agriculture; precision agriculture; crop stress, crop mapping
- Rangelands; water supply forecasting; grazing capacities; fuel supply
- Forestry, deforestation, and net primary production studies
- Pollution/ Health issues (rift valley fever, mosquito-producing rice fields)
- Desertification
- Anthropogenic change detection and landscape disturbances.

Data Set Evolution & Applications

At the time of launch, there will be a 20-year NDVI global data set (1981 - 2000) from the NOAA- AVHRR series, which could be extended by MODIS AM and PM data to provide a long term data record for use in operational monitoring studies. The MODIS AM or PM data set can readily be composited to provide 16-day, cloud-free time series maps of vegetation activity. When both AM and PM data are combined, higher frequency, 8-day, cloud-free time series data is readily made available.

Suggested Reading

Cihlar, J.C., H. Ly, Z. Li, J. Chen, H. Pokrant, and F. Huang, 1997. Multi temporal, Multichannel AVHRR data sets for Land Biosphere Studies— Artifacts and Corrections. Remote Sens. Environ. 60:35-57.

Huete, A.R., Liu, H.Q., Batchily, K., and van Leeuwen, W., 1997, A comparison of vegetation indices over a global set of TM images for EOS-MODIS, Remote Sens. Environ., 59:440-451.

Leeuwen van W.J.D., A. R. Huete and T. W. Laing, 1999. MODIS Vegetation Index Compositing Approach: A Prototype with AVHRR data. Remote Sensing of Environment, Accepted.

Myneni,R.B , Keeling, C.D., Tucker, C.J., Asrar, G., Nemani, R.R., 1997, Increased plant growth in the northern high latitudes from 1981 to 1991, Nature Vol 386,pp 698-702

MOD 13
PRODUCT SUMMARY

Coverage:
Global land surface (level 3)
Spatial/ Temporal Characteristics:
8-, 16-day and monthly at 250m,
1km, and 0.25• resolutions
Key Science Applications:
Global vegetation monitoring
Biogeochemical and hydrologic modeling
Health and Food security
Range & Forestry monitoring
Agriculture management
Key Geophysical Parameters:
Vegetation index (NDVI & EVI)
Processing Level:
Level 3, gridded
Product Type:
Standard, at-launch
Science Team Contact:
A. Huete

- **MODIS Bio- page**

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MODIS Research Area

"Determination of Dynamic Soil-Vegetation-Detritus Interactions with MODIS Instrument Observations"

My research has mostly focussed on the development of Vegetation Indices for seasonal and inter-annual vegetation monitoring; climatic - and anthropogenic- induced change detection; land cover assessment; and the coupling of Vegetation Indices to vegetation biophysical parameters. There are two important issues to consider in the extraction of vegetation information from satellite imagery. The first concerns standardization of all extraneous variables in the remotely sensed signal, namely atmospheric variability, presence of clouds and sub-pixel clouds, sun angle and sensor view angle variations, and instrument calibration drift and filter degradation. The MODIS Vegetation Index products consist of cloud-free and atmospherically corrected, 16 day and monthly gridded maps, composited to a nadir view angle and standard sun angle at 250 m, 1 km, and 0.25° pixel resolutions. We have designed the vegetation index products to take full advantage of the MODIS atmosphere correction, cloud mask, and BRDF products. The second issue to consider for quantitative information extraction concerns the inherent mixing of the vegetation signal with that of the canopy background and non-photosynthetic components within a canopy such as woody material, senesced vegetation , and litter. These influences are considered within the vegetation index equations themselves, mainly through the application of basic vegetation canopy radiant transfer theory and empirical observations. As a result, the Vegetation Index products have been developed for both continuity purposes with the AVHRR- normalized difference vegetation index (NDVI) as well as for improved, enhanced capabilities with the enhanced vegetation index (EVI). Examples of the vegetation index products can be found at http://gaea.fcr.arizona.edu.

Data Products

MOD12 - Land Cover/Land Cover Change
MOD13 - Gridded Vegetation Indices
13A1 - 250 m NDVI every 16 days
13A2 - 1 km EVI and NDVI every 16 days
13A3 - 1 km EVI and NDVI every month
13C1 - 0.25° EVI and NDVI every 16 days (climate modeling grid)
13C2 - 0.25° EVI and NDVI every month (climate modeling grid)

ATBDs

Vegetation Index

Field Work and Data Availability

We have accumulated extensive ground- and airborne radiometry observations as well as satellite data over a diverse set of land cover conditions. Data include SeaWiFS, Landsat TM, AVHRR, ASAS, AVIRIS, and biophysical sampling of vegetation and soils.

- Monsoon'90 Hydrology experiment at Walnut Gulch, Arizona (TM, AVIRIS, ASAS, SPOT, AVHRR,…)
- Hydrologic Atmospheric Pilot Experiment in the Sahel (HAPEX-Sahel) experiment, 1992
- Smoke, Clouds, and Radiation Experiment (SCAR-B) in Brazil, 1995
- Chile transect from hyperarid, arid, semi-arid, subhumid, humid rainforest (1996).
- U.S. - Mexico Border Region (1992 seasonal TM data set)
- SALSA experiment in Arizona (1995 - 2000)
- Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), 1999 - 2003
- Maricopa Agriculture Center in Arizona (TM, AVIRIS, ATLAS, SPOT,..), 1985-
- La Jornada Experimental Range (1997, 1999)
- Konza Prairie (1999)
- Mongolia field campaign in Mandolgovi (1997 - 2002)
- Railroad Playa, Ivanpah calibration sites (1999)

Related World Wide Web Sites:

The MODIS Home Page
The MODIS Land Discipline Group Home Page
International Arid Lands Consortium: http://ag.arizona.edu/OALS/IALC/Home.html
Arizona Regional Image Archive: http://aria.arizona.edu/
Aeronet: http://aeronet.gsfc.nasa.gov:8080/
USGS Vegetation Mapping Program: http://biology.usgs.gov/npsveg/index.html