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## TASK OBJECTIVES

During the second half of 1998, we continued to work on algorithm testing, code testing and code deliveries, QA and SCF development. In addition, we continued error and uncertainty analysis, theoretical basis, and validation work. Specific objectives and tasks included:

- revise and debug 250 m and 1km MOD13A1 and MOD13A2 vegetation index products;
- develop 1km monthly vegetation index product (MOD13A3)
- level 3 algorithm testing and BRDF integration into the level 3 compositing algorithms;
- prototype vegetation index and test VI compositing algorithms with the daily, 1km AVHRR data stream and SeaWiFS data streams;
- prepare for at launch QA and MODIS data analysis, including software, QA tools, security, network and hardware issues;
- end-to-end error analysis of the vegetation indices;
- MODIS Quick Airborne Looks (MQUALs) development;
- Validation activities including LBA, core sites, Mongolia, etc.

## WORK ACCOMPLISHED

### 1. Level 3 Vegetation Index Compositing Algorithms and Aggregation Software

Kamel Didan, working on MODIS coding tasks, has become familiar with use of the SDP toolkit and HDF-EOS in order to take over the full the MODIS programming effort (input and output) involving production and maintenance of the vegetation index products.

♦ Version 2.1 PGE 25 (MOD13A1 - NDVI at 250 m and 16 day resolutions) was delivered by Kamel Didan to SDST in collaboration with GSFC in December 1998 with code optimizations and metadata adjustments. Memory problems were worked out and the MCF file was adjusted. Version 2.1 will possibly become 2.2 after testing with new data.

♦ Version 2.1 of PGE 35 (MOD13A2 - NDVI and EVI at 1km and 16 day resolutions) was also delivered in December 1998 with code optimizations and metadata adjustments. The code was further optimized to reduce CPU load and accommodate our allocated CPU time. The MCF file was adjusted to overcome a memory bug in the ODL libraries and various looping parts of the code were adjusted. Minor adjustments were made to the overall packaging of the code. Version 2.1 will possibly be 2.2 after testing with new data.

- **Aggregation Code (**MOD_PRAGG):

The Aggregation code was optimized by making a reduction in User time of approximately ~15%. With the new Version 2.1 of L2G and MOD09, a set of bugs materialized in the AGG Code and needed immediate attention given its value to all the L3 (downstream) code. All bugs are currently fixed, except for some science issues that will need some addressing in the future. This will depend heavily on the MOD09 and L2G status. We are currently wrapping up the code for delivery.

**Current overall status:** All software packages for the three products (MOD13A1, MOD13A2, and MODPRAGG) are being prepared for delivery as version 2.1 (or possibly 2.2)

- The other PGEs will be delivered in the spring, 1999, including:

1. PGE 26 (MOD13A3 - NDVI and EVI at 1km and monthly resolutions): The code has been designed from the ground up taking advantage of its similarity in I/O to the 1km 16-day composite. The code has been polished for inherited redundancies. Thorough testing has yet to be accomplished and we are in the process of acquiring the necessary LUN (seed file, MCF files, and PCF files) for the code (with the assistance of Gang Ye).

2. PGE 27 (MOD13C1 - NDVI and EVI at climate modeling grid (CMG - 25km) and 16 day resolutions).

3. PGE 28 (MOD13C2 - NDVI and EVI at CMG and monthly resolutions).

## 2. Research and Prototyping Efforts

- **1 km AVHRR Prototyping effort:**

NDVI and QA imagery were successfully prototyped with an HDF-EOS formatted 1-km AVHRR data set provided by Boston University. Software to process these data (HDF files) had to be adjusted since the AVHRR data does not have the same QA flags and spectral bands as the MODIS product will have. Based on this prototyping with 1 km AVHRR data, some 'outliers' (mostly cloud-affected pixels) were identified in the data. Some minor adjustments will be incorporated to the MODIS code that will decrease the appearance of the 'outliers'.

- **SeaWiFS Prototyping with GAC Data:**

The MODIS Vegetation Index Compositing Algorithm (VICA) was successfully prototyped with 27 days of SeaWiFS data to increase the proportion of BRDF- corrected, nadir equivalent reflectance data. Even with 27 days of data, the BRDF could not be applied globally due to cloud effects. Some efforts were made to start setting up a BRDF parameter database to aid in the standardization of off-nadir data to nadir. However, it is currently unclear if the tilt angle of SeaWiFS (20°) will be an obstacle since there is a total lack of nadir reflectance data.

· **Sun angle standardization and uncertainty:**

Sun angle standardization of the NDVI was investigated with ground data (Parabola and Exotech). Based on the ground data, an empirical relationship was developed for the NDVI with 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 a 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. The preliminary results were presented at the IFB meeting in San Francisco, December 1998. Currently, software is being developed to standardize the SeaWiFS reflectance data to globally constant solar zenith and view angles.

## 3. Quality Assurance (QA) Document:

A previously drafted QA document was updated in September (Vegetation Index Product Quality Assurance (QA) Plan; Version 1.2) to anticipate QA needs including accuracy assessment and validation activities for MOD13 products and direct the SCF development. IDL routines are being augmented to do Quality Assurance analysis on MODIS VI products and related science issues (Multiple Vegetation Index issues, Quality flag visualization) including inputs from the MOD09 reflectance product. The QA document can be found at: http://gaia.fcr.arizona.edu/~wim/pdf_files/mod13qaplan.pdf

## 4. Science Computing Facility:

Farideh Farahnak (application system analyst) integrated an Origin data vault 6 (18 GB) and 4 (18 GB) disks into the SCF (5 workstations and two servers) to cope with data and processing demands. Wim van Leeuwen identified a DLT7000 tape drive and DLT stacker (DLT7000 7 cartridge autoloader) as well as data management software for data archiving and data back up which are scheduled to be integrated by the spring of 1999. Farideh Farahnak positively evaluated the Irix Networker Network edition with archive and autochanger option software. Network throughput is currently being tested, but is currently insufficient to perform all the MODIS QA and validation.

We had an encounter with a computer hacker who deleted our files and operating system. This required a lot of work in re-installing the data, operating system, and COTS. Farideh Farahnak 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 is being set up as a mirror of the main MODIS processing server to reduce downtimes. All licensed software packages on the servers are being updated.

## 5. Error and Uncertainty Analysis

Tomoaki Miura, Ph.D. student has been working on establishing the “end-to-end” uncertainty analysis approach for the MODIS Vegetation Index (VI) products. He has completed an instrument dependent signal to noise analysis involving the sensitivity of the vegetation indices to the noise-equivalent radiances of each band (red, NIR, and blue). These analyses were described in terms of noise-equivalent delta NDVI and EVI

(NEδ*NDVI* and NEδ*EVI*, respectively). He also investigated the impact of the near-infrared (NIR) and red band noise on the NEδ*NDVI* and NEδ*EVI*.

Both additive and multiplicative (as well as a mixed case) noise were incorporated into the computations as well as the measured radiometric performance data of the MODIS reflective bands. Field and aircraft observational, high resolution reflectance spectra (10 nm sampling intervals) were used in this study, representing five categories: a) bare soils, b) trees, c) shrub/grasses, d) agriculture, and e) clouds/snow. These spectra were convolved to the sensor bandpasses and converted to top-of-atmosphere (TOA) radiances using the "6S" radiative transfer code, using a mid-latitude summer and continental aerosol atmosphere with a 23 km visibility, and a 75 degrees solar zenith angle with a nadir view, used as the baseline. In addition, we examined solar zenith angles ($\theta_s$) of 15, 30, 45, and 60 degrees, and 100, 10, and 5km visibilities (corresponding aerosol optical thickness, AOT, at 550 nm of 0.11, 0.42, and 0.78). Sensor noise was then associated with the simulated TOA radiances for each target. We examined various NIR and red band noise levels, including SNR of 200, 50, 30, and 20, holding one band constant while varying the other. The TOA radiances were processed back to the surface reflectances and into vegetation indices (VIs) while the noise (NEδ*L*) was simultaneously propagated using uncertainty propagation equations developed by Tomoaki Miura, in order to estimate the NEδ*NDVI* and NEδ*EVI*.

The NEδ*NDVI* were the smallest over trees and the largest over bare soils, while the NEδ*EVI* were the smallest over bare soils and the largest over trees among the four categories (excluding the clouds/snow category). In most cases examined, the mean NEδ*NDVI* and NEδ*EVI* were both below ±0.007 VI units. Noise variations in the NIR were fairly insignificant, relative to the impact of noise in the red band on the vegetation indices. It was felt that improving the $SNR_{NIR}$ would not improve the resultant NEδ*VI* once it reaches above 75. On the other hand, improving the SNR of the red and blue bands may more effectively improve the NEδ*VI*.

- ***Red Band Sensitivity Analysis***

As a way to reduce sensor costs, we explored the possibility of land and oceans communities sharing a common red band. This came up in light of the fact that some excellent NDVI images were being generated from the SeaWiFS sensor, which has an oceans-like red band configuration. The red band configurations for land and oceans differ both in band center location and in bandwidth. Typically, for land applications, the red band is centered near 650nm with bandwidths wider than or equal to 50 nm (e.g., Landsat MSS and TM, SPOT, AVHRR, MODIS), while those for oceans applications are centered at 670 nm and are much narrower (< 20 nm) (e.g., CZCS, SeaWiFS). The red spectral region is a chlorophyll absorption zone and red band sensitivity is a function of the relative location of the red band to the absorption feature. We analyzed two cases with respect to vegetation index optimization with the red band:

- Bandwidth analysis (from 10nm to 100 nm)
- Band-center analysis (from 640 nm to 700 nm)

Using high-resolution vegetation spectral reflectance curves (from the Kuusk canopy model) as a standard; we analyzed the effect of band configuration on the resulting reflectance signals for pure vegetation targets and no atmosphere. We then looked at the range of vegetation canopy reflectances from low LAI's to high LAI's to establish the dynamic range of reflectances. This was repeated for dark, medium, and bright soil background conditions to encompass an environmental range of canopy conditions. Finally, we translated the reflectance output results into the NDVI (and other VI's) to establish the effect of band configuration on both the NDVI values as well as on the dynamic range of NDVI values over a range of LAI and canopy background conditions.

The resulting NDVI dynamic range was found to be optimal at 685 nm and to be best with a 10nm bandwidth. As we went to coarser bandwidths, the band-center is shifted to shorter wavelengths to maintain optimal NDVI values. The coarsest, 100 nm, band tested would be centered at 650 nm, while the 50 nm bandwidth (characteristic of MODIS) is best centered at 670 nm (rather than the current 645 nm). Thus, with finer bandwidths, one can center the band within the absorption peak of chlorophyll. With wider bandwidths, one would have to shift to shorter band-centers to avoid the sharp rise in reflectance resulting from the 'red edge'. However, one must qualify the results thus far obtained here since these results are strongly dependent on the original shape and structure of the Kuusk model - generated reflectance curve. Other vegetation types may have absorption peaks in a different location.

### · *Band positions, bandwidths, and spatial resolution tradeoff's*

From an overall Signal-to-Noise Ratio (SNR) assessment we can state that a change in bandwidth from 50nm (MODIS-land) to 20nm (oceans, e.g., SeaWiFS) reduces the signal by a factor of 0.4 (assuming no improvements in sensor, electrical noise). The change of center band location from 645nm (MODIS-land) to 670nm (oceans/ SeaWiFS) only changes SNR by a factor of 0.96, and is essentially irrelevant to this analysis. Finally, we can now analyze how a change in spatial resolution impacts on the overall SNR:

- If we go from a MODIS land configuration (645nm, 50nm) to a narrower 20nm band, centered at 670nm and for a constant 250 m pixel resolution, the SNR is reduced to 0.38 of the original SNR;
- If we simulate the same as above but go from a 250 m pixel to a 400 m pixel, then the SNR is maintained at 0.98 the original;
- If we go to a 500 m pixel resolution, the SNR is increased by 1.54; and
- If we go to a 1km pixel resolution (16x the original MODIS red band pixel), then the SNR increases by 6.14.
- In conclusion, the land and oceans communities can share a narrower red band (20nm), but only if the spatial resolution is 400 m or coarser.

During the next 6 months, Tomoaki will complete the noise sensitivity analysis. He also intends to formulate a more thorough global analysis strategy for residual atmospheric effects on vegetation indices (VIs), of which results may be used for investigating effects of atmospheric mis-corrections on VI uncertainties. He will also investigate “measurement error models” that treat independent variables as random variables in regression analyses.

## 6. Canopy Simulation Models and Theoretical Analysis

Hiroki Yoshiako continues to work on the theoretical basis for vegetation indices through the use of canopy radiative transfer theory. Investigations of vegetation isolines have been conducted to characterize patterns of reflectance variations for a canopy-soil system of layers. Using the transmittance and reflectance of the canopy layer and de-coupling the canopy layer from the soil layer underneath the canopy, we have been able to derive the slope of the vegetation isoline and its NIR-intercept as functions of LAI and fraction of green cover. A technique to numerically obtain the slope and the NIR-intercept of vegetation isolines has also been proposed by using the SAIL model. The technique, however, is general so that it has potential to be used with any other turbid-medium radiative transfer models for vegetation canopies. The derived vegetation isoline equations have been analyzed in detail for deeper understanding of reflectance variation patterns as a function of both canopy optical properties and the background brightness. We also indicated the usefulness of the derived equations by performing simple demonstrations of NDVI and SAVI characteristic behaviors using the derived equations.

In the next 6-months, the characteristic behavior of the common two-band vegetation indices will be investigated using the vegetation isoline equations. We derive vegetation isoline equations for the atmosphere-canopy-soil system of layers (a three-layer system) to investigate the behavior of existing vegetation isolines. The concept of vegetation isolines will then be applied to the relationship between the blue and red bands (in addition to NIR-red) to expand the investigation for three-band vegetation indices such as EVI. The behavior of the three-band vegetation indices will be investigated to understand its variation patterns against surface optical parameters.

Two papers have been prepared on this topic:

1. "Derivation of Vegetation Isoline Equations in Red-NIR Reflectance Space"
   H.Yoshioka, A. R. Huete, and T. Miura, University of Arizona, Tucson Arizona

   ***Abstract-*** A technique to derive vegetation isoline equations in red-NIR reflectance space for homogeneous canopies is proposed and demonstrated. A canopy radiative transfer model, known as the Cooper-Smith-Pitts model,is utilized with truncation of the higher order interaction term between the canopy and soil layers. The technique consists of two model simulations, one with a perfect absorber as canopy background and the other with an arbitrary background to estimate the canopy optical properties necessary for the determination of the isoline parameters. These cases are independent of the soil optical properties of any specific site, hence, the results can be used for any type or series of soils to construct the vegetation isoline equation. A set of simulations was also conducted using the SAIL model to demonstrate the vegetation isoline derivation by the proposed technique. Reflectances and vegetation indices (VI) estimated from the vegetation isoline, generally showed good agreement with those simulated by the SAIL model, especially for relatively darker soil. The isoline equation and derivation were found to be useful for further study of two-band VIs and their variation with canopy background.

2. "Analysis of Vegetation Isoline in Red-NIR Reflectance Space"
   H. Yoshioka, A. R. Huete, and T. Miura , University of Arizona, Tucson Arizona

   ***Abstract***: Characteristic behaviors of the vegetation isoline were analyzed by focusing on its three properties: the slope, NIR-intercept and the intersection between the isoline and the soil line. These properties are the key factors of understanding variations of vegetation index value against change of background brightness, known as background noise. The analyses were conducted based on the vegetation isoline equation recently derived by using representation of canopy reflectance of the adding method. The isoline parameters, slopes and NIR-intercepts of vegetation isolines were numerically obtained by the SAIL canopy model. Some of the known behaviors of the vegetation isoline were simulated and analyzed in detail.

## 7. MODIS Quick Airborne Looks (MQUALS):

This is a light aircraft-based radiometric package for rapid 'ground truth' characterization of MODLAND test sites in a consistent manner with an identical and 'traceable' radiometric package. The airborne radiometric system (instrument and protocol) is 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 100m to 300m AGL for accurate characterization of top-of-canopy reflectances. 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.

During the last 6 months, we acquired the instrumentation and began work on configuring the system with a laptop computer and labview software. We conducted a few tests of the MQUALS package over the Appleton – Whittel Research Ranch of the Audubon Society. This site is mostly uniform grassland situated fairly close to the Tucson International Airport. It is an 8, 000 acre, well-preserved ranch that is located in northern foothills of the Huachuca Mountains and has not been grazed by cattle for the last thirty years. Activities at this site are also associated with the SALSA experiment.

The goal of these test runs was to test the airborne validation scheme and its coupling to field radiometric and biophysical data at MODIS scales. We were also trying to assess the quality and potential of the 3-band digital camera. Two flights were conducted on October 28 and November 15, 1998. The flights were complimented with ground-based radiometer measurements along a 50-m grid, fAPAR measurements along the same grid, percent cover, biomass, and soil sampling. A 5 km transect was delineated with GPS coordinates and a 50 m sampling grid was marked with poles over a 500 m by 500 m area. The light aircraft flew at 3 different altitudes; 150 m, 1000 m, and 3000 m across the 5-km transect line with 1-degree field of view lenses on the radiometer. The ground-based Exotechs (one over a reference plate and the other on a yoke for ground samples) were fitted with 15-degree field of view lenses. The albedometers and digital cameras were also flown. Ground and airplane reflectance factors were computed as the ratio of radiance measurements over each target to the radiance inferred from observation of the horizontally positioned Spectralon plate.

In conclusion, all the data collected during this campaign were processed within seven days after the measurements, with exception of the aircraft digital images that were not downloaded due to software problems. The 3-band digital camera had to be sent back to the manufacturer for upgrade to a parallel interface, which would allow images to be downloaded to laptop in real time, and in a much more rapid fashion. Both of the flight s we made was plagued by digital camera software related problems.

Plans are currently being devised for MQUALs activities in the next 6 months. A few more 'local' tests will be conducted in the San Pedro Riparian zone as well as over

Maricopa Agriculture Center, both in Arizona. Shortly after the April 15th launch of Landsat 7, we will participate in some vicarious calibration field experiments in Nevada. By summer, current plans are to fly over some of the Bigfoot Forested sites.

## 8. LBA Activities:

This no-cost, MODland proposal to LBA is titled “Validation and Evaluation of MODIS Data Products in the Large Scale Biosphere-Atmosphere Experiment in Amazonia". The basic idea behind this proposal was to contribute and provide our 'early' Land products to LBA and its P.I.'s across the Amazon Region (including the Cerrado portions of Brasilia). In exchange we would be participants in a large International field campaign and have access to the data collection/ measurements as well as an extensive satellite database, which includes high-resolution imagery and photos and historical records.

MODIS land products are of particular interest to the "Carbon Dynamics" and "Land-Use and Land-Cover Change" ecological themes within LBA. The carbon dynamics group is interested in the NPP and net photosynthesis products across the Amazon Basin while the "Land-Use and Land-Cover Change" group is interested in the surface reflectance - VI, LST, Fire, land cover and land cover change, albedo, BRDF, and LAI/fPAR products.

The dominant land cover sites include the Santarem Primary Forest Site (with 65 meter free-standing tower); the Santarem Logged Forest Site (with 65 meter free standing tower); Santarem Pasture Site (with 20 meter Rohn tower). The Europeans are also planning to install permanent towers and Brazil-LBA is interested in deploying mobile towers in the cerrado region. There are an additional set of less-intensely measured sites in Acre, Altamira, Belem, Brasilia, Manaus, and Rondonia. Brent Holben will instrument Santarem, Cuiaba, Manaus, Brasilia, and other sites with sun photometers.

The main difficulty concerns the disparate scales in which many of the P.I's are working (<1-m scale) with limited 'point' measurements. There are several issues concerning MODLAND validation at LBA:

- there is a big gap between the limited size and number of point-based measurements made by the LBA-P.I.'s and 250m to 1km MODIS land products;
- there is a lack of consistency in ground parameter measurement methods;
- there is an absence of surface related radiometric measurements;
- although MODLAND is interested in validation, most P.I.-led measurement methods are not designed for validation.

Although the flux tower and the point-based surface parameter measures will be useful to MODIS, it seems that a complete MODLAND validation and product performance analysis will have to be conducted by us or our Brazilian collaborators (co-investigators). Our evaluation of the performance of MODIS products in the Amazon region cannot be carried out by simply exchanging data sets (satellite images for point-measures) as it looks like we may need to supplement field activities.

The set of sun photometers will provide local-based atmosphere correction from which 'true' surface reflectances and vegetation indices could be derived. Since land cover change/ transformations are central to LBA, the data collected will provide an excellent opportunity to analyze the sensitivity of MODLAND products to slight, moderate, and drastic changes in land cover.

We have a set of Brazilian collaborators, including Yoshio Shimabukuro and Getulio Batista, who have experience in conducting field measurement campaigns and would be willing to implement our validation protocols. The main limitation in this respect is funding since LBA P.I.'s are expected to cover as many of the costs of their Brazilian collaborators as possible, however ours is a no-cost project. There is thus a shortage of funds available to conduct fieldwork in Brazil. This will be of concern in FY 2000, after the MODIS launch, in which we may want to use the LBA sites for validation related activities.

· **Cerrado test sites:**

The Brazilian Cerrado is the second largest biome in South America (~2,000,000 $km^2$) and consists of evergreen woodland, grassland and seasonal savanna with a layer of herbaceous species with scattered trees and bushes that can sometimes form continuous canopy. The cerrado is a very complex and fragile biome. A Ph.D. student from Brazil, Laerte Guimaraes, is working on site selection for field validation work in conjunction with LBA activities and objectives. He is working on a study titled “Assessing the temporal and spatial patterns of the Brazilian Cerrado vegetation through the use of use of spectral vegetation indices”.

In order to understand the seasonal patterns of the vegetation and to evaluate the vegetation indices responses to such temporal changes as well as their ability to discriminate among the major vegetation types encountered in the cerrado biome, a full hydrologic year, 1995 AVHRR LAC data, from the 1 km AVHRR Global Land Data project (USGS-EDC) was examined. The selection of the study sites was primarily focused on the ability to encompass the major vegetation types and land use forms encountered in the cerrado biome. The dominant "true" savanna formations are represented by the Emas National Park (ENP), the Brasilia National Park (BNP), and the Veadeiros National Park (VNP). Together, these 3 sites depict the transitions from the dominant herbaceous stratum (ENP) to the more complex, wooded dominated stratum (BNP and VNP).

The response of the vegetation indices to the seasonal variations observed for the different vegetation types was assessed through the VI temporal profiles. The patterns as well as the distinctions among these profiles were closely related to those patterns observed in the red-NIR concept space. Clear temporal discrimination was observed between the deciduous broadleaf forested formations and the savanna formations and converted sites. However, the clear separation between the cerrado forested formation (ANP site) from these two categories (savanna formations & converted sites) as well as between the savanna formations and converted sites depends on the time of the year. The similar vegetation amounts found at the VNP and pasture sites during the wet season, for example, restricts the distinction among these sites to the dry season. In the next 6 months we hope to extend this analysis using the SeaWifs data on the cerrado vegetation.

## 9. Maricopa 98' Validation Test Site:

The main objective of the 1998 Maricopa experiment (MAC) in Arizona (32.9N, 112W) was to collect a seasonal data set of airborne and field radiometric measurements and biophysical measurements of various crops at different phenological stages. The fields included alfalfa, lesquerella, cotton, and sorghum, as well as bare soil.

Ground-based measurements were taken from gridded plots and transects and were measured at three or more sun angles, spaced at approximately 60°, 40°, and 20°. The grids were to be used with the airborne ATLAS sensor for image calibration. The ATLAS sensor has six bands in VIS/NIR, three bands in SWIR, and six in TIR, with a sensor FOV of 72°; all six shortwave TM bands were represented, along with a 0.60-0.63 µm and a 0.69-0.76 µm band, and ground resolution was 2.5m. The NASA Stennis Space Center arranged for the ATLAS sensor to fly MAC on the following five dates throughout the growing season: May 5 (DOY=125), June 9 (DOY=160), June 24 (DOY=175), July 12 (DOY=193), and Aug. 19 (DOY=231). Ground-based measurements were simultaneously taken during the ATLAS overflights on all but the last date. Instead, additional ground-based radiometric and biophysical data were collected on a multi-day period over Aug. 4-7 (DOY= 216-219) and again on Sept.16 (DOY=259).

The instruments used to collect the ground data at each grid point or along the transect included the Exotech-Yoke to record reflectance data in four bands, four AccuPAR ceptometer readings to give fAPAR, LAI estimates via the LAI2000 and/or destructive sampling, and dry-weight biomass from infrequent destructive sampling. The deliverables from this campaign included a season-long record of the following: (i) crop growth and development to include a database of (a) four stages of cotton percent cover at different row orientations, and (b) cotton plots, intensively measured at three scales, and (c) transects in four crop types (primarily cotton, but also three other crops), (ii) the crops' percent cover (provided by digital photographs), height, and biomass (g/1m2 quadrat, oven-dried weight), as well as spectral reflectance in the Blue, Green, Red, and NIR bands, and vegetation indices, NDVI and SAVI, (iii) the crops' reflectance, vegetation indices, and fAPAR data for several sun angles, (iv) the crops' leaf area index (LAI) provided by images and an LAI-2000 meter, and (v) the biophysical and radiometric relationships derived using both ground and airborne sensors.

Results and analysis are being processed. We basically learned how difficult it is to sample the vegetation amidst the row structures and heterogeneity encountered in agricultural settings. The variance in the biophysical data more than offset the detection of reliable sun angle trends, resulting in very noisy data. In the future, biophysical sampling must be more localized and registered with radiometric information to establish initial relationships.

## 10. GLI- MODland activities

The Vegetation Index Algorithm that we presented to the GLI instrument team was accepted for phase 2 activities or execution and validation phase. The algorithm includes an NDVI based compositing component followed by atmosphere correction of the composited product for Rayleigh scattering and ozone absorption, followed by computation of the vegetation indices. The atmosphere correction scheme involves the Gauss-Seidel methodology and includes polarization influences. The process of atmospherically correcting the composited product was a decision passed onto us by NASDA in their desire to keep CPU budgets to a minimum.

We are currently reviewing the Mongolia experiment 1998 CD-Rom for Dr. Yoshiako Honda. The results of the field campaign are expected to be released in January 1999.

Future plans include discussion as to our participation in the 1999 Mongolia field experiment and how to combine MODIS-GLI validation methodologies. At the moment we have two Japanese, Dr. Koji Kajiwara and Ms. Asako Konda, from Chiba University participating in some of our MQUALs testing.

## 11. Meetings and conferences:

- Wim van Leeuwen presented a paper and a poster at the IEEE IGARSS Conference, Seattle, WA, July 1998:
  - W.J.D. van Leeuwen, Alfredo Huete, Trevor Laing, “Evaluation of the MODIS vegetation index compositing algorithm using SeaWiFS data”
  - A.R. Huete, Dana Kerola, Kamel Didan, Wim J.D. van Leeuwen, Laerte Ferreira, “Terrestrial Biosphere Analysis of SeaWiFS data over the Amazon Region with MODIS and GLI Prototype Vegetation Indices”.

- Alfredo Huete attended and gave two presentations at the SeaSTART Regional Conference meeting, Joint IGBP-DIS/LUUC/SEA STAT-LUCC/DIS Workshop, August 13-18, 1998 in Chulalongkorn University, Bangkok, Thailand. The talks were titled: "Introduction to vegetation indices", and "The MODIS instrument and land products".

- Wim van Leeuwen and Kamel Didan attended the MODLAND SDST meeting at GSFC (Sept 9-10, 1998).

- Alfredo Huete attended and gave a VI-algorithm presentation at the ADEOS-2 GLI Science Team Meeting in Tokyo, Japan, September 9-11, 1998. The talk was entitled ",Mosaicking, atmospheric correction and vegetation index algorithms".

- Alfredo Huete attended and gave a presentation on "MQUALS" and "Summary of Biophysical/Vegetation validation breakout session from the December, 1997, SWAMP meeting", at the LAI/FPAR/NPP Global Validation Development Workshop at Boston University, October 12-13 1998.

- Alfredo Huete was an invited speaker at the International Workshop on Global Change in East Asia, held at Chiba University, Japan on December 10-11, 1998. His paper was entitled: "The use of vegetation indices for coarse resolution monitoring of terrestrial vegetation with SeaWiFS sensor".

- Wim van Leeuwen and Fricky Keita attended the (IFB) International Forum on BRDF (Bidirectional reflectance distribution functions) in San Francisco, December 11 and 12. Dr. van Leeuwen gave a presentation and was theme chair for "Remote Sensing Data Standardization using BRDF Models: Vegetation Indices, Leaf Area Index, and Land Cover Classification."

- Alfredo Huete and Wim van Leeuwen attended the MODIS Science team meeting at GSFC (December 15-17, 1998).

## 12. UPCOMING TASKS:

The tasks for the next 6 months will include further development of the vegetation index compositing algorithms, error and uncertainty analysis, validation activities, and related science issues as well as the testing of the 'at launch' and 'post launch' products and software SCF development.

- **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,
  - Evaluate the use of a historical BRDF data base in combination with vegetation index composite scenario; to be tested on 8 km and 1 km AVHRR (test robustness of the MODIS and alternative compositing algorithms) data,
  - 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.
  - Update of ATBD to final version,
  - Finalize MQUAL protocol and put out a manual,
  - Complete and update error and uncertainty charts.

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

  - Deliver PGE 26, 27, 28 (CMG's) in Spring, 1999,
  - As the WILT (Week In a Life Time) is approaching all code should be ready to be tested. A major part of the coding effort will concentrate on working bugs out as they materialize during the WILT phase,
  - Prepare to implement multiple processing routes through the use of PCF file flags. This would only concern the 1km and 250m 16 day compositing software.
  - Finish the 1km monthly NDVI and EVI (MOD13A3) and deliver it,
  - 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 WILT exercise),
  - CMG grid vegetation index product software will follow in the Spring as all the previous products. These efforts will start after the WILT exercise,
  - Document all aspects of the VI production software.

- **SCF reorganization and development tasks:**

  - Purchase of DLT7000 tape drive, DLT7000 7 cartridge stacker, IRIX networker archiving software, RAM memory,
  - Organize the MODIS file-systems and upgrade the operating system on servers/workstations to 6.5.2. to set up the at launch processing environment,

- Install the TOOLKIT release 5.2.3 with HDF-EOS2.3, EOSview, MAPI,
- Integrate the DLT7000 tape drive and DLT700 stacker in the SCF,
- Set up the Networker software for archiving/retrieving data. Improve system performance on the servers,
- Develop data management protocols for on-line, near-line and off-line storage,
- Improving the network throughput from NASA to TBRS-SCF (Tucson AZ) with the help of Andy Germain with NASA and CCIT at University of Arizona,
- Stay on top of security patches and set up monitoring system of the network for security reasons,
- Prepare for PI processing (production environment).

## 13. Publications:


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- Leeuwen van, Wim J.D., Alfredo R. Huete and Trevor W. Laing , 1998, "MODIS Vegetation Index Compositing Approach: A Prototype with AVHRR Data", Remote Sensing of Environment, (Accepted with minor revisions, December 1998).

- Miura, T., Huete, A. R., van Leeuwen, W. J. D. ; Didan, K. 1998. Vegetation detection through smoke-filled AVIRIS images: An assessment using MODIS band passes. J. Geophys. Res. Vol. 103 , No. D24 , p. 32,001

- Huete, A.R., Didan, K., van Leeuwen, W.J.D., and Vermote, E., 1998, The use of vegetation indices for coarse resolution monitoring of terrestrial vegetation with SeaWiFS sensor, Proc. Global Change in East Asia Conference, Tokyo, Japan, Dec. 10-11, 1998.

- Huete, A.R., Kerola, D., and Didan, K., 1998, Mosaicking, atmospheric correction and vegetation index algorithms, IN Proc. Of the 3rd GLI Workshop, September 1998, ADEOS-II/GLI Sensor Team, National Space Development Agency of Japan, NASDA Report 98POA1-D003, pp. 114-120.

- Huete, A.R., 1998, "Introduction to vegetation indices" and ",The MODIS instrument and land products", Abstracts in Proceedings, SeaSTART Regional Conference meeting, Joint IGBP-DIS/LUUC/SEA STAT-LUCC/DIS Workshop, August 13-18, 1998 in Chulalongkorn University, Bangkok, Thailand.