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TASK OBJECTIVES

During the first half of 2000, we concentrated our efforts on fin preparations for code delivery, QA, and SCF development for MODIS data ingest. Much effort was also placed on validation activities which included the joint GLI-MODIS, Japanese radio-controlled helicopter experiment at four EOS core validation sites as well as Brazil-LBA validation activities at Brasilia and Tapajos core sites. We also are currently preparing a MODIS Vegetation Index Users Guide for the EDC DAAC.

- New code submissions of MOD13A1, MOD13A2 and MOD13A3 vegetation index products.
- Creation of a new, 500m Vegetation Index product.
- New submission of a revides aggregation code.
- Continued development of QA tools and data management plan.
- Validation activities at EOS core sites, including Konza Prairie, La Jornada, Walnut Gulch, AZ, and Oregon
- Brazil-LBA validation activities at Brasilia and Tapajos sites
- AVHRR comparisons with MODIS composited data
- Homepage modification and early images and results preparedness
- Vegetation Index User's Manual for the EDC-DAAC
- Investigation of artifacts and anomalies in the VI image products.

WORK ACCOMPLISHED

1. Algorithm Development:

1.1 MODPR13A2, 1km VI product:

This code was almost completely rewritten in order to accommodate the following adjustments and changes:

- Production under cloudy conditions,
- Accommodate new upstream files specifications,
- Address all QA issues in accordance with current LDOPE strategy,
- New science improvements based on real MODIS data,
- Code performance improvements in order to reduce memory and CPU load requirements.

1.2 New 500m Vegetation Index Product:

As a result of the processing restrictions imposed on the 250m data production, MODLAND adopted the production of a reduced, but global 500m resolution VI. This, however, required the development of a new, versatile algorithm to handle the multiple resolution and production scenarios in the 500m VI. This code has also been written as with the 1km product such that it can be produced under cloudy conditions and accommodates the latest upstream file specifications.

1.3 MODPR13A1, 250m Production Plan:

The 250m algorithm was modified to become more versatile in its production capability. The algorithm is currently designed to handle 250m production and allow for the following VI production scenarios:

- 250m only production with only the NDVI produced,
- 500m only production (new product) with both the NDVI and EVI produced,
- A mixed 250m and 500m production with both NDVI and EVI at 250m.

The current devised algorithm can be produced under all production plans and is only dependent on availability of produced data. This helps reduce the MODAPS task in devising production scripts and rules. Other modifications made to this algorithm include science improvements in terms of handling the different data quality inputs and devising better compositing techniques. CPU and memory requirements were reduced, however disk requirements increased due to the addition of the EVI.

1.4 Aggregation code:

This algorithm was also rewritten to handle the different production plans. Currently the code will handle the different data resolutions without recourse to external interventions and solely dependent on the input data. All QA issues were solved as per LDOPE strategy. We also worked on dead detector handling, production under cloudy conditions, and improvements on science aggregation rules based on testing with real MODIS data.

2. - Product preparation for public release

2.1 Quality Assurance, Quality control

As part of our commitment to our product and as agreed upon by the different science teams, our group performed

- in house quality evaluation to prepare the VI product for public release
- all issues pertinent to metadata, QA, QC and file standardization were solved, and issues with DAAC ingest were solved.

Using real MODIS data and through visits with the LDOPE facility at GSFC for a combined 6 week period we performed all

- necessary science quality check-ups and algorithm performance evaluation. We noticed considerable improvement in the data quality which led us to commit to a public release date earlier than anticipated initially.
- We continue to evaluate our product on a daily basis and improve the algorithm with a target of reaching the public release date with the most up to date algorithm, that both addresses science issues we've discovered and MODIS data quality shortcomings.
- We've identified upstream product problems that were affecting our products and worked closely with the proper SCFs and LDOPE to sort them out leading to improvement in data integrity.

2.2 User guide and internet presence for public release

As required by DAAC (EDC) a comprehensive user guide describing the different aspects of the algorithm, data structure, data quality, product problems will be available to the public by the release date, currently set at early August. We also developed an internet presence to further assist public users of the VI and to the efficiency of use of the MODIS VI product. The current home page provides the proper links to all MODIS SCFs, production links and general MODIS information as agreed upon by the MODLAND team.

2.3 Early products

We achieved an acceptable network throughput when downloading data from MODAPS which helped us acquire all our products. In doing so we created different global scale high resolution VI maps for almost all MODIS data collected thus far. Those early products were presented at the IWG meeting in Tucson, April, 2000; at the MODIS Science Team meeting, June 2000; the LBA Ecology Science Conference, June 2000; and for the upcoming IGARSS meeting in July 2000. We have also sent VI early images to various MODIS team members to be used for the early product showcase and be displayed on the various MODIS internet pages. They were also included in the MODIS data handbook.

We also developed the capabilities to download and archive all our MODIS products in- house and generate VI maps on a constant basis. We anticipate our efforts to increase in this direction so that we may ultimately produce global VI maps for the different resolutions (1km, 500m, and 250m).

3. QC/QA Activities for the MODIS VI Products:

QC/QA activities during this period were conducted by Tomoaki Miura and focused on assessments and evaluations of early product quality (data consistency) and algorithm performance. Tomoaki Miura visited the LDOPE facility (May 29 - June 21) for the quality assessment of the MODIS VI products. Specific tasks accomplished are listed below:

- Visual inspections and documentation of the quality of early products (data consistency) over the golden tiles (GTs) and evaluation of the science issues associated with the algorithm.
- The QA combinatorial analysis (one of the VI science QA analysis plans) was being prototyped and the up-to-date analysis results were translated into a color lookup table to generate a QA map from the VI quality SDSs.
- As a continuation of the work originally performed by Wim van Leeuwen, Tomoaki developed additional, command line-based QA tools for science QA analyses of the VI products. On-line help of these tools are being prepared in HTML format.
- The performance of the BRDF-based compositing and the backup, constrained view zenith angle MVC (CV-MVC) algorithms were assessed and compared with the MVC algorithm over the Golden Tiles. Our assessment focused specifically on: 1) view zenith angle distributions of the composite images, 2) success rates of the BRDF-based compositing algorithm and their spatial and temporal patterns, and 3) relationships of these properties with composite VI values. The results of these assessments will be presented at the IGARSS 2000 conference.
- For the MOD13A1 and MOD13A2 public release, the QA part of the VI product user's guide has been written (1st draft).
- As part of the QC/QA activities, Tomoaki also summarized the statistical quality control methods to document field-observation data quality.

4. Error/Uncertainty Analysis of Vegetation Indices

Tomoaki Miura completed further error analysis of atmospherically-corrected reflectances and vegetation indices induced by the assumptions in the dark target approach to estimate and correct for aerosol effects. The assumptions concerned in this study included: 1) errors in the dark target reflectance estimates and 2) selections of incorrect aerosol models. The results of this study were summarized into a paper and the manuscript was submitted to the Remote Sensing of Environment journal.

5. AVHRR- MODIS Data Comparisons

Patricia Rodriguez, a graduate Ph.D. student has been working on this task. The general objective of this task is to compare and evaluate the MODIS vegetation indices (NDVI-EVI) with that derived by the AVHRR (NDVI) at both global and local scales. Color tables were created for visual inspection of NDVI and EVI data at all scales. The analysis included inspection of composites of MODIS and AVHRR data (1-km and 500m), generation of global and regional histograms, and line transects across a gradient range of vegetated areas. As part of this effort we download weekly AVHRR NDVI composites for in-house analysis. Current results show the NDVI values from the AVHRR to have a much smaller dynamic range in values. The slope of a MODIS-AVHRR crossplot typically range from 0.67 to 0.77, a consequence of the variable bandwidths between the two sensors as well as the influence of the atmosphere, particularly in the NIR where the AVHRR is prone to water vapor influences.

We are also extracting MODIS and AVHRR data over 21x21 window sizes, centered on several Earth Observing System (EOS) validation core-sites in the southwestern USA and the Amazon Basin LBA, for statistical and 'time series analysis'. We have made the following analysis over such extracted areas:

- Statistical analysis over data on smaller windows (1x1,3x3,5x5), is part of the quality analysis and quality control of the VI's,
- Cross-plots of AVHRR and MODIS NDVI were generated over local sites, including a varied range of vegetation, to asses the performance of the sensors,
- Cross-plots of MODIS NDVI and EVI were generated to analyze the sensitivity of the VI's over a gradient of vegetated areas.

6. Validation Activities:

6.1 Jornada Experimental Ranch, New Mexico, May 7 - 10 and June 5 - 9, 2000

Karim Batchily, Hiroki Yoshioka, Fricky Keita, and Tomoaki Miura participated in the May (dry season) La Jornada Experimental Range (New Mexico) field campaign in order to collect ground and airplane data for MODIS sensor validation. The survey flights took place May 9th and May 10th at La Jornada and Sevilleta sites (short grassland). The MQUALS package was mounted onto the USDA-ARS plane out of Weslaco, Texas. On May 10th, there was an ETM+ overpass with MODIS nadir looking. This provided an opportunity to validate the MODIS surface reflectances and vegetation indices with ground and airborne radiometric data.

The main objectives of this experiment were to collect both *in situ* (field) radiometric and biophysical data with 250m ~ 1km pixel sizes at various solar zenith angles over (1) grassland, (2) transitional, and (3) mesquite sites in the Jornada experimental range as part of the MODIS validation activities. We also attempted to collect *in situ* , high spectral resolution radiometric data for many “pure” targets in the Jornada experimental range (e.g., plant canopies and soils) in order to develop NDVI continuity relationships among disparate sensor systems. We collected the following:

- airborne-observational surface reflectance data together with aerial digital imagery (over the grass, transition, and mesquite sites),
- ground-observation surface reflectance data (over the transition site),
- percent cover estimates (over the grass, transition, and mesquite sites),
- LAI estimates derived from LAI-2000 measurements and digital imagery (over the grass and transition sites),
- bare soil surface reflectance data.

As part of the Japanese helicopter experiment, we revisited the Jornada site in June (5 – 9th) and obtained another validation set accompanied by an ETM+ overpass and a MODIS nadir look. Xiang Gao, a Ph.D. student is conducting a correlation analysis of these data sets with the MODIS surface reflectance and VI products using both single day and composited MODIS data as well as ETM+ and ground and aircraft data. The June 9th MODIS data was not available and we are attempting to recover this data.

6.2 The Japanese RC-Helicopter Experiment, May-June, 2000

Dr. Yoshiaki Honda of the Center for Environmental Remote Sensing (CEReS), Chiba University, Japan has developed a radio controlled (RC) helicopter sensor package for use in field validation of satellite data for remote sensing applications. As part of joint ADEOS-2-GLI and Terra-MODIS joint validation activities, the The U.S. campaign encompassed several Earth Observing System (EOS) Land Validation Core Sites. Last year, Honda’s group prototyped and successfully tested their RC helicopter package in the Mongolian Grasslands. The Global Imager (GLI) is NASDA’s Japanese equivalent to the MODIS sensor and will be launched onboard ADEOS 2 in early 2001.

The U.S. summer campaign was coordinated by our TBRS lab in Arizona and involved validation sites in Arizona, New Mexico, Kansas, Montana, British Colombia, and Oregon. Validation scientists at each site coordinated their field measurements and satellite acquisitions with the planned helicopter overflights. The on-site measurements provide a ‘ground truth’ of actual vegetation, soil, and land cover conditions providing independent performance estimates of how well satellites can measure the land surface and its seasonal- and long-term changes.

The RC helicopter “ground truth” measurement system was very useful in characterizing the optical properties of the validation sites. Measurements included top of canopy, bidirectional reflectances and BRDF. The RC helicopter can be manually operated and guided by GPS. An onboard computer enables the entire system to be programmed to hover over GPS-defined locations. The unit can fly up to altitudes of 100 m and 200 m horizontal distances from the operator. The helicopter carries an onboard spectroradiometer enabling the measurement of reflected energy from the ground surface. At 100 m altitude it is below the atmosphere and acquires data with no atmosphere contamination. This is useful in establishing optical relationships between spectral reflectance data and ground biophysical properties such as green vegetation biomass, leaf area index, percent green vegetation cover, and soil and litter properties.

The helicopter unit is considered ideal to measure the bidirectional reflectance properties of the surface or BRDF. The unit, with GPS, is able to hover at various sensor view angles, providing a 3-dimensional profile of reflected radiances, useful in analyzing information on the size and shape of the vegetation canopy (i.e., shrub-like, trees, grass, etc..). There are 34 measurement points in one routine of BRDF measurements, which consume approximately 15 minutes. Specifications:

- Sensor Mount Unit: two stepping motors are used to allow movement of -180 degrees to 180 degrees at horizontal level, and from -60 degrees to 60 degrees at vertical level.
- Spectrometer: this is a dual port multispectral spectrometer with sensor field-of-view from 20 degrees to 1 degrees. The spectrometer can acquire data of the surface and that of a mounted, white reference panel.
- Digital Camera: the camera has interchangeable lenses. The images are recorded onto a PC card and one HD card which can hold 1 GB data. Each image captures 6 million pixels or 160 images. Images are saved in lossless TIFF format.
- Laser range profiler: the profiler can measure distances of up to 200 m at 50 cm accuracy.
- Laptop computer: the PC has a CPU AMD586 133MHz 48MB. It has the card for the stepping motor and records measurement data also.
- Measurement condition monitoring system: this enables one to monitor the ground surface via CCD camera and BS system.

Summary Schedule of Helicopter experiment

USA Observation Schedule		**Event**
Date	Place	
May 31	Tucson (Arizona)	Japanese arrival
June 1	Tucson (Arizona)	Preparation & Planning @ ERL
June 2	Tucson (Arizona)	Observation
June 3	Tucson (Arizona)	Observation
June 4	Tucson (Arizona)	Observation
June 5	Travel Arizona to Jornada, New Mexico	
June 6	Jornada (New Mexico)	Preparation & Planning
June 7	Jornada (New Mexico)	Observation
June 8	Jornada (New Mexico)	Observation
June 9	Jornada (New Mexico)	Observation
June 10	Jornada (New Mexico)	Observation

June 11	Travel Jornada to Carlsbad, New Mexico	
June 12	Carlsbad, New Mexico	Demonstration
June 13	Travel Carlsbad to Konza Prairie, Kansas	
June 14	Konza Prairie (Kansas)	Meeting with David Meyer, PI
June 15	Konza Prairie (Kansas)	Observation
June 16	Konza Prairie (Kansas)	Observation
June 17	Konza Prairie (Kansas)	Observation
June 18	Travel Kansas to Missoula, Montana	
June 19	Travel Kansas to Missoula, Montana	
June 20	Missoula (Montana)	Meeting with Steve Running
June 21	Missoula (Montana)	Observation
June 22	Missoula (Montana)	Observation
June 23	Missoula (Montana)	Observation
June 24	Travel Montana to Victoria, Canada	
June 25	Travel Montana to Victoria, Canada	
June 26	Victoria (Canada)	Meeting with.Dr. Iizuka
June 27	Victoria (Canada)	Observation
June 28	Victoria (Canada)	Observation
June 29	Victoria (Canada)	Observation
June 30	Travel Victoria to Oregon	
July 1	Otter (Oregon)	Meeting with Warren Cohen/ Bev Law
July 2	Otter (Oregon)	Observation
July 3	Otter (Oregon)	Observation
July 4	Travel Oregon to Los Angeles	movement
July 5	Travel Oregon to Los Angeles	movement
July 6	Travel Oregon to Los Angeles	movement
July 7	LosAngeles (California)	Shipping
July 8	LosAngeles (California)	Final Coordination
July 9	Travel to Japan	

6.3 Validation/ LBA-activities

In May and in July of this year we plan validation activities at two LBA core sites, Tapajos (forest) and Brasilia (cerrado). The objectives of these field activities are to obtain spectral reflectance signatures of major forest and cerrado canopy types, including:

- Primary, undisturbed forest (upland)
- Primary, undisturbed forest (lowland)
- Disturbed forest at different levels of secondary succession (how old are the regenerating forests?)

- ❖ Pasture
- ❖ Settlements (Sao Jorges area)
- ❖ The 4 major cerrado types ranging from grassland to woodland and mixtures of the two.
- ❖ Radiometric validation of MODIS reflectances and VI's.

We will derive the top of the canopy reflectance values from the INPE plane over the major land cover types in both areas. An ASD spectroradiometer will be used for reflectances. Hiroki Yoshioka, Laerte Ferreira, and Alfredo Huete participated along with our Brazilian counterparts, led by Yosio Shimabokuru and Edson Sano. Irradiances will be measured on the ground either at the airport site or on top of a canopy access tower. An Exotech will be used to derive the irradiance values while the ASD is being flown. The ASD and Exotech sensors will require cross-calibration and spectral extrapolations to achieve the reflectance calculations. The results of this analyses will be direct comparisons between MODIS VI's that were composited over a 16-day interval with the derived VI's (nadir) from the radiometers.

7. Meetings, Conferences, and Workshops:

Yoshioka, H., T. Miura and A. Huete, "Development of Biophysical Parameter-Specific Spectral Vegetation Indices: Applications to Agriculture", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Miura, T., Yoshioka, H., and Huete, A.R., "On the Statistical Nature of NDVI and SAVI Variations Induced by Canopy Background Brightness", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Huete, A., K. Didan, T. Miura, H. Yoshioka, "Application of Enhanced Vegetation Indices for Tropical Forest Monitoring", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Dematte, J. A. M., A. R. Huete, Ferreira Jr., L.G., M. C. Alves, M.R. Nanni, Cerri, C.E., "Evaluation of Tropical Soils Through Ground and Orbital Sensors", poster presentation at the Second International Conference on Geospatial Information in Agriculture and Forestry, ERIM, Lake Buena Vista, Florida, 10-12 January 2000.

Huete, A.R., "Global Rangeland Assessment and Monitoring with Spectral Vegetation Indices", ***Invited Speaker***, Society for Range Management Symposium on Remote Sensing Research and Applications to Range Management, Annual Meeting of the Society for Range Management, Boise, Idaho, Feb. 14 –18, 2000.

Huete, A.R., "Advanced Vegetation Indices from MODIS", presented at the EOS-IWG Meeting Morning Plenary Session on Land Processes and Terrestrial Carbon Cycle Science, Tucson, Arizona, April 12, 2000.

Huete, A.R., K. Didan, T. Miura, and W. van Leeuwen, "MODIS Vegetation Indices", presented at the MODIS Science Team Plenary Session, Land Discipline Group, College Park, Maryland, June 7-9, 2000.

Huete, A., "MQUALS Validation 2000 and the Honda Helicopter Experiment", presented at the MODIS Discipline Group Meeting, College Park, Maryland, June 9, 2000.

Huete, A.R., K. Didan, Y. Shimabokuro, L. Ferreira, and E. Sano, "Regional Amazon Basin Analyses with MODIS Vegetation Indices: Early Results and Comparisons", Poster presentation at the 'First Scientific Conference of the Large Scale Biosphere-Atmosphere Experiment in Amazonia', Belem, Para, Brazil, June 26-30, 2000.

Ferreira, L., H. Yoshioka, A. Huete, and E. Sano, "Assessing the Use of the MODIS Vegetation Indices for Vegetation Mapping in the Brazilian Cerrado", Poster presentation at the 'First Scientific Conference of the Large Scale Biosphere-Atmosphere Experiment in Amazonia', Belem, Para, Brazil, June 26-30, 2000.

8. Upcoming Presentations

Ferreira, L., A. Huete, H. Yoshioka, and E. Sano, "Preliminary Analysis of MODIS Vegetation Indices over the LBA Sites in the Cerrado Region, Brazil", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Gao, X., and A. R. Huete, "Validation of MODIS Land Surface Reflectance and Vegetation Indices with Multi-scale High Spatial Resolution Data", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Miura, T., A. R. Huete, K. Didan, W. J. D. van Leeuwen, and H. Yoshioka, "An Assessment of the MODIS Vegetation Index Compositing Algorithm Using the Quality Assurance Flags and Sun/View Angles", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Huete, A., K. Didan, Y. Shimabokuro, and L. Ferreira, "Regional Amazon Basin and Global Analyses of MODIS Vegetation Indices: Early Results and Comparisons with AVHRR", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Descloitres, J., N. E. Saleous, A. R. Huete, and E. F. Vermote, "MODIS land surface reflectance and vegetation index products compared to SeaWiFS and AVHRR", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Justice C., Hall D., Huete A., Muller J. P., Myneni R., Running S., Strahler, A., Townshend J., Vermote E., Wan X., Roy D., Decloitre J., "A preliminary evaluation of land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS)", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Huete, A., Didan, K.,,Miura, T., and Rodriguez, P., "Validation of the MODIS vegetation indices over a global set of test sites: preliminary results", EOS/SPIE Conference on Remote Sensing for Earth Science Applications, Barcelona, SPAIN, Sept 25-29, 2000.

9. Publications:

Qi, J., Kerr, Y.H., Moran, M.S., Weltz, M., Huete, A.R., Sorooshian, S., and Bryant, R., 2000, Leaf area index estimates using remotely sensed data and BRDF models in a semi-arid region, Remote Sens. Environ., 73:18-30.

Yoshioka, H., Huete, A.R., and Miura, T., 1999, Derivation of vegetation isoline equations in red - NIR reflectance space, IEEE Trans. Geosci. Remote Sensing, (in press).

Miura, T., Huete, A.R., and Yoshioka, H., 1999, Evaluation of calibration uncertainties on vegetation indices for MODIS, IEEE Trans. Geosci. Remote Sensing, 38(3):1399-1409.

Yoshioka, H., Miura, T., Huete, A.R., and Ganapol, B.D., 2000, "Analysis of Vegetation Isolines in Red-NIR Reflectance Space" Remote Sens. Environ. (in press).

Gao, X, Huete, A., Ni, W., Miura, T., 2000, Optical - biophysical relationships of vegetation spectra without background contamination, Remote Sens. Environ. (in press).

Nagler, P.N., Rodriquez, H.B., Glenn, E.P., and Huete, A., 2000, Relationships among vegetation ground cover, leaf area index and vegetation indices using ground- and aerial based methods in the Colorado River delta, Mexico, Remote Sens. Environ. (submitted May 2000).

Miura, T., Huete, A.R., Yoshioka, H., and Holben, B., 2000, An error and sensitivity analyis of atmospheric resistant vegetation indices derived from dark traget-based atmosphereic correction, Remote Sens. Environ. (submitted June 2000).

10. Limitations:

We are attempting to build up our SCF with enough storage and processing capability to handle the MODIS VI products. We are somewhat resource limited but are purchasing additional memory, which should hold us for another few months.

11. UPCOMING TASKS:

- Preparation for the Public Release of MODIS Vegetation Indices to the EDC-DAAC. This is currently scheduled for August 4, 2000. As part of this release, a User's Guide is also being prepared.
- Blue band EVI problem in which ice and snow can yield false "green signals". Also, the blue band produces much un-processed data not corrected for atmosphere. This produces a 'speckling effect' in the EVI image.
- Prepare talk and paper for the upcoming SPIE meetings in Barcelona, Spain, September 25 – 29.
- Participate in the GLI science team meeting (November 7-9) and develop vegetation index code as well as joint MODIS-GLI validation plans.
- Continued development of our TBRS group homepage to handle a general description of our work, our data management plan, and create a mechanism for the display of early images and results. The address of the homepage is: http://gaea.fcr.arizona.edu/MODIS/MODIS_Research.html

APPENDIX 1. (Abstracts)

A. Presentations

Yoshioka, T., Miura, T., and Huete, A.R., “Development of Biophysical Parameter-Specific Spectral Vegetation Indices: Applications to Agriculture” , ERIM 2nd International Conference on Geospatial Information in Agriculture and Forestry, January 10 – 12, 2000 in Orlando, FL

Abstract: Spectral vegetation indices (VI) are one remote sensing-based method utilized to estimate plant biophysical and structural parameters, such as leaf area index and fraction of absorbed photosynthetically active radiation. For effective local and regional applications of VI products, precise knowledge of the theoretical and empirical relationships between the VI and the target canopy parameters are indispensable. Although there are many studies which show empirical relationships between VIs and plant biophysical parameters, a more active approach is to design an index that can be customized to specific applications and/ or areas. In this paper, the theoretical basis of a customizable vegetation index is introduced. The index is a weighted average of the soil-adjusted vegetation index (WASAVI) with different adjustment factors. The design concept of WASAVI is to match the vegetation index isolines to the true vegetation isolines by optimizing these adjustment factors, allowing customization to each target field in , e.g., applications to precision farming.

Miura, T., Yoshioka, H., and Huete, A.R., “On the Statistical Nature of NDVI and SAVI Variations Induced by Canopy Background Brightness”, ERIM 2nd International Conference on Geospatial Information in Agriculture and Forestry, January 10 – 12, 2000 in Orlando, FL

Abstract: One of the most common approaches in remote sensing for measuring or monitoring crop growth is the empirical correlation of spectral vegetation indices (VIs) with such crop biophysical parameters as leaf area index (LAI), percent green cover, and fraction of absorbed photosynthetically active radiation (fAPAR). These empirical relationships are developed by a least-squares fitting criterion aimed to statistically minimize variations observed in data sets, in which VIs respond to factors not associated with green vegetation and the biophysical measurements are contaminated with measurement errors. As most of these techniques are based on normality assumptions, it is of interest to understand the statistical nature of these variations. In this study, we investigated the statistical nature of variations of two commonly used VIs, the normalized difference vegetation index (NDVI) and soil adjusted vegetation index (SAVI), as induced by canopy background brightness. A set of equations were developed to transform density functions (variations) of canopy background reflectances to that of the NDVI and SAVI. The uniform and normal densities were examined as hypothetical distributions of the canopy background reflectances. The resultant NDVI densities were totally skewed to the larger values for both the uniform and normal densities, exhibiting strong non-normality for the latter density case. The degree of skewness was largest over a bare soil and decreased with increasing LAI values. The SAVI densities also resulted in an asymmetrical distribution although its variations were much smaller than the NDVI. These results show the importance of statistical nature of VIs in order to develop a more accurate and precise estimator of biophysical parameters.

Huete, A.R., “Global Rangeland Assessment and Monitoring with Spectral Vegetation Indices”, ***Invited Speaker***, Society for Range Management Symposium on Remote Sensing Research and Applications to Range Management, Annual Meeting of the Society for Range Management, Boise, Idaho, Feb. 14 –18, 2000.

Abstract: A consistent set of satellite, aircraft, and ground-measured reflectances were collected over grass-shrub conditions in Arizona, New Mexico, Kansas, and Mongolia. This effort was part of a validation campaign to assess the usefulness and performance of spectral vegetation indices from low-resolution satellite sensors such as the AVHRR, VEGETATION, SeaWiFS, and soon to be launch MODIS and GLI. Calibrated Exotech radiometers were used to conduct yoke-based transects and low altitude aircraft transects at all the locations. The experiments were conducted at numerous sun angles in order to adjust all data sets to a common sun angle irradiance condition. The standardized reflectances were then utilized to compute a few spectral vegetation indices, including the normalized difference vegetation index (NDVI), the soil-adjusted vegetation index (SAVI), and the enhanced vegetation index (EVI).   The grasslands consisted of shortgrass and tallgrass prairies with annual and perennial species, and various levels of shrub cover. Vegetation parameters measured included biomass, leaf area index, percent cover, and canopy height. Satellite data analyzed included SeaWiFS and Landsat Thematic Mapper. The results showed that we were able to couple the ground- and aircraft-based VI's with those from the satellite. Furthermore, we found that all of the grassland sites fell onto a common VI - biophysical parameter regression line with most deviations attributed to the proportion of senesced or dead plant material as well as shrub contents. With proper standardization of satellite data with atmosphere correction and sun angle adjustment, remote sensing offers great potential in monitoring rangeland biophysical parameters.

Huete, A.R., K. Didan, Y. Shimabokuro, L. Ferreira, and E. Sano, “Regional Amazon Basin Analyses with MODIS Vegetation Indices: Early Results and Comparisons”, Poster presentation at the ‘First Scientific Conference of the Large Scale Biosphere-Atmosphere Experiment in Amazonia’, Belem, Para, Brazil, June 26-30, 2000.

Abstract: Vegetation indices have emerged as important tools 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 and serve as useful indicators of seasonal and inter-annual variations in vegetation. In this study, early images from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to evaluate the normalized difference and enhanced vegetation indices (NDVI, EVI) for regional vegetation monitoring of the Amazon Basin. We analyzed the MODIS vegetation indices over the primary and secondary forests as well as cerrado biomes and investigated the use of the MODIS vegetation indices in discriminating different types of land use conversions in both biomes. Comparisons of the MODIS products were made with Landsat, SeaWiFS, and AVHRR images. The histograms of the individual bands and the vegetation indices were analyzed and compared with the different sensor NDVI products. Chlorophyll saturation over the dense vegetated areas are investigated and the aerosol resistance properties of the EVI and its extended sensitivity over dense vegetation are evaluated. We found the MODIS vegetation indices to significantly improve upon the detection and discrimination of land conversions within densely vegetated environments.

Ferreira, L., H. Yoshioka, A. Huete, and E. Sano, “Assessing the Use of the MODIS Vegetation Indices for Vegetation Mapping in the Brazilian Cerrado”, Poster presentation at the ‘First Scientific Conference of the Large Scale Biosphere-Atmosphere Experiment in Amazonia’, Belem, Para, Brazil, June 26-30, 2000.

Abstract: The Brazilian Cerrado, the second largest biome in South America, is marked by a distinct seasonal contrast and comprises an intricate mosaic of land cover types, vertically structured as grassland, shrubland, and woodland. This is a very complex biome to characterize due to the high degree of spatial heterogeneity and extensive land use alterations. We conducted a preliminary evaluation on the ability of the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices (VI’s) to differentiate among the major Cerrado physiognomies.   A field campaign was conducted from April 16th through May 5^{th,} 2000, at the Brasilia National Park (BNP), a 30,000 ha area of preserved Cerrado near Brasilia, recently incorporated into the LBA science plan. Data collected at the BNP included distinct ground biophysical measurements (e.g., LAI and fAPAR) and radiometric measurements, acquired at both the ground and airborne levels. This was used to evaluate the response of the MODIS VI’s to the cerrado biophysical and structural parameters. A preliminary analysis of the airborne spectroradiometric data, convoluted to the MODIS and AVHRR bandpasses and converted to the normalized difference vegetation index (NDVI) and

the enhanced vegetation index (EVI), indicates the ability of the MODIS EVI to discriminate the four major cerrado types encountered at BNP (i.e., cerrado grassland, shrub cerrado, wooded cerrado, and cerrado woodland). On the other hand, both the MODIS NDVI as well as the AVHRR NDVI fail to differentiate the shrub cerrado from the cerrado grassland. Although not fully conclusive, our results demonstrate a higher performance of the MODIS sensor and the EVI algorithm for mapping and monitoring the vegetative cover in the Cerrado Region, Brazil.

Ferreira, L., A. Huete, H. Yoshioka, and E. Sano, "Preliminary Analysis of MODIS Vegetation Indices over the LBA Sites in the Cerrado Region, Brazil", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: The Brazilian Cerrado, the second largest biome in South America, comprises an intricate mosaic of land cover types, vertically structured as grassland, shrubland, and woodland. Due to intensive agricultural and grazing occupation, the Cerrado is today the most severely threatened biome in Brazil. Previous investigations, mainly based on temporal AVHRR data sets converted to the normalized difference vegetation index (NDVI), indicate that the dominant land cover types may be grouped into three spatial domains, encompassing the savanna formations and pasture sites, the forested areas, and the agricultural crops. In this study, we analyze the performance of the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices (NDVI and the enhanced vegetation index – EVI) over the major cerrado vegetation communities. In particular, early MODIS VI images over the cerrado region will be validated over the Brasilia National Park, a 30,000 ha area of preserved cerrado near Brasilia. MODIS vegetation indices at 250m and 500m resolution will be compared with biophysical vegetation measurements and simultaneously acquired aircraft and ground optical measurements in a field campaign to be conducted this coming April, 2000.

Gao, X., and A. R. Huete, "Validation of MODIS Land Surface Reflectance and Vegetation Indices with Multi-scale High Spatial Resolution Data", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Surface reflectance is a key component for many level 3 and level 4 MODIS products, such as land cover, snow cover, vegetation indices, leaf area index, and fraction of absorbed photo-synthetically active radiation. In this study, we attempt to validate the MODIS land surface reflectance and derived vegetation index (VI) products. Our validation will be implemented by scaling fine-grained surface measurements to several levels of MODIS pixel size (250m, 500m, and 1000m), then assessing the differences between these surfaces and the MODIS products. The fine-grained surfaces will be obtained by two independent methods: 1) a light-aircraft package flying at low altitudes to provide "ground truth" radiometric data free of atmosphere influences and; 2) high resolution satellite images (ETM+). The confidence and accuracy of using ETM+ imagery, combined with fine-grained surface/aerial measurements, to validate MODIS products will be assessed at a number of validation sites, including; 1) jointly with level 1b calibration sites over uniform areas devoid of vegetation; 2) at Walnut Gulch in the arid/semiarid watershed of southeastern Arizona and; (3) agricultural crop areas in Maricopa Agriculture Center (MAC) of Arizona. These validation activities over a variety of test sites will help to better understand the performance of the algorithm and accuracy of the products during the first 6 months after launch.

Miura, T., A. R. Huete, K. Didan, W. J. D. van Leeuwen, and H. Yoshioka, "An Assessment of the MODIS Vegetation Index Compositing Algorithm Using the Quality Assurance Flags and Sun/View Angles", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Spectral vegetation index (VI) products, as derived from satellite sensors with low spatial and high temporal resolutions, have been utilized for operational monitoring of terrestrial vegetation. These satellite products are both spatially and temporally composited in order to remove clouds, minimize atmospheric contaminations, and standardize sun/view angles. The compositing algorithm of the Moderate Resolution Imaging Spectroradiometer (MODIS) VI products emphasizes a global, operational view angle standardization. It utilizes a bi-directional reflectance distribution function (BRDF) model to produce nadir looking equivalent reflectance values if enough cloud free observations are available during a 16-day compositing period. Otherwise, a backup, maximum value composite (MVC) criterion that includes a view angle constraint is utilized to composite. In this study, we assess and characterize this new compositing algorithm using MODIS data and compare it with the conventional MVC algorithm. Our assessment specifically focuses on: 1) view angle distributions of the composited images, 2) relative frequencies of two compositing scenarios documented in quality assurance (QA) flags and their spatial distribution patterns, and 3) relationships of these properties with VI values.

Huete, A., K. Didan, Y. Shimabokuro, and L. Ferreira, "Regional Amazon Basin and Global Analyses of MODIS Vegetation Indices: Early Results and Comparisons with AVHRR", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Vegetation indices have emerged as important tools 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. In this study, early images from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to evaluate the normalized difference and enhanced vegetation indices (NDVI, EVI) for global and regional vegetation monitoring. The histograms of the individual bands and the two vegetation indices are analyzed from hyperarid to moist tropical vegetation biomes and compared with the AVHRR-NDVI product. At the regional level, tropical forest monitoring and discrimination of land use conversions over the Amazon Basin are analyzed and compared with LBA field results at the Tapajos validation core site. The aerosol resistance properties of the EVI and extendedOsensitivity over dense vegetation are evaluated. The NDVI histograms are compared with the EVI as well as the AVHRR-NDVI.

Descloitres, J., N. E. Saleous, A. R. Huete, and E. F. Vermote, "MODIS land surface reflectance and vegetation index products compared to SeaWiFS and AVHRR", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: Improved spatial resolution and radiometric performance provide new capabilities to recent instruments such as MODIS. In particular, more accurate algorithms have been implemented to derive operational products from MODIS data for land applications. However, long-term time series analyses are essential to understand the inter-annual variability of land properties and in particular to monitor the vegetation. Therefore the recent MODIS land products have to be linked to existing comparable long-term data sets derived from older sensors such as AVHRR and SeaWiFS. This paper presents some early MODIS land surface reflectance and vegetation index products and compares them to similar products derived from SeaWiFS and AVHRR. The results of this comparison are discussed with respect to the characteristics of each of these instruments. The strengths of MODIS land products and their importance for land applications are highlighted.

Justice C., Hall D., Huete A., Muller J. P., Myneni R., Running S., Strahler, A., Townshend J., Vermote E., Wan X., Roy D., Decloitre J., "A preliminary evaluation of land surface products from the NASA Moderate Resolution Imaging Spectroradiometer (MODIS)", IEEE, IGARSS 2000, Honolulu, Hawaii, July 24 – 28, 2000.

Abstract: The MODIS instrument is designed for improved observation of the land surface and investigators have been selected to provide the next generation of land surface data products. New capabilities in spatial and radiometric resolution have allowed for improved algorithms. A suite of MODIS land products have been designed to contribute to the study of terrestrial ecosystems, radiation budget and land use and land cover change. Products include surface reflectance and temperature, vegetation indices, fire, snow and ice cover, leaf area index, albedo, land cover and land cover change. Data quality assessment and product validation activities have been developed associated with these products. This paper presents a preliminary assessment of MODIS data quality and early results from the MODIS land product development.

Huete, A., Didan, K.,,Miura, T., and Rodriguez, P., "Validation of the MODIS vegetation indices over a global set of test sites: preliminary results", EOS/SPIE Conference on Remote Sensing for Earth Science Applications, Barcelona, SPAIN, Sept 25-29, 2000.

Abstract:Vegetation indices have emerged as important tools 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. In this study, early vegetation index images from the Moderate Resolution Imaging Spectroradiometer (MODIS) are evaluated over a global set of biomes from hyperarid deserts and semiarid grasslands to humid grasslands and forests. Field validation experiments were conducted over such a range of sites to assess the performance of the normalized difference and enhanced vegetation indices (NDVI, EVI) for global and regional vegetation monitoring. Both 1 km and 250 m resolution vegetation index products were processed, corrected for atmosphere, and composited to 16-days for the areas of interest. The histograms of the individual bands and the two vegetation indices are analyzed and compared with the AVHRR-NDVI product. Experimental data collected in the Brazilian cerrado and forests were also used to assess the capability of the MODIS VI products for land conversion discrimination and change detection. Preliminary results show the MODIS VI products to offer enhanced sensitivity for land use discrimination and monitoring at both regional and global scales. The EVI was fairly well resistant to residual aerosol contamination and had a good range of sensitivity over the high biomass, forested areas.