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TASK OBJECTIVES

Most of this period was focused on validation activities in support of the Level 2 and Level 3 Vegetation Index (VI) products. We participated in the SCAR-B experiment in Brazil and successfully collected ground data within primary and secondary forest canopies. A global set of Landsat TM images were processed into simulated MODIS vegetation index images for an assessment of VI performance in all major biomes. This work was submitted to the journal, Remote Sensing of Environment. We are using the Myneni canopy radiative transfer code to simulate six, structurally variant, biome types and begin coupling of the VI results with biophysical parameters (leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (fAPAR)). The AMBRALS code is also being used to aid in the development of the level 3, compositing algorithm. A proposal to the Global Imager (GLI) NASDA sensor was submitted for joint MODLAND-GLI cooperation in algorithm development and testing. Another proposal to support activities within some of the South American test sites was also submitted. Finally, a test site data plan and a validation plan were completed at the end of the year. Current efforts now involve validation of the VI products and establishing linkages of the VI with leaf vegetation biophysical parameters, namely leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (fAPAR).

WORK ACCOMPLISHED

1. SCAR-B Campaign (Field + AVIRIS)

We participated in the SCAR-B experiment in Brazil. We spent 3 weeks in the field mostly in the Porto Velho, Jamari, and Ji-Parana areas, where there was extensive fire activity and smoke laden atmospheres. Our activities were restricted to radiometric measurements of incoming solar radiation over clear and smoke-filled skies within and outside of the forests, including ÔcontrolledÕ burns. Overall, much was gained in understanding the vegetation signal in the forest and in burned forests and how this signal is affected by the atmosphere. Irradiance measurements were made with ExotechÕs mounted over reference Spectralon panels. Canopy irradiance measurements within primary, secondary, and burned canopies were made at each of the study sites, which were located in close proximity to Brent HolbenÕs sun photometer network. Some canopy floor reflectance measurements were also made as well as leaf area index (LAI), absorbed photosynthetically active radiation (APAR), and spectral canopy transmittance measurements. The objectives of this experiment included:

1. Influence of smoke particles, water vapor, trace gases, and clouds on the spectral signatures and vegetation signals from forested, savanna, geologic, and agriculture sites.

2. Measurements of radiative transfer within rainforest vegetation communities, including canopy spectral transmittance; canopy extinction coefficients; canopy reflectance; intercepted and absorbed PAR; soil, litter, and understory reflectance; and ÔpureÕ leaf, soil, litter, and wood spectral signatures.

3. Vegetation index (VI) algorithm development in Ôhigh biomassÕ conditions.

4. Atmospheric resistance VI modelling under complex and variable atmospheric conditions which include smoke and other spatially varying aerosols.

5. The effects of land use conversion and biomass burning on: (1) canopy radiative transfer; (2) canopy and soil biogeochemistry; (3) soil, vegetation, and litter parameters and dynamics; (4) canopy structure and morphology.

We now have 18 AVIRIS scenes over Porto Velho sites. In addition we have another 20 scenes over Ji-Parana, which were sent to Dr. Dar Roberts for pre-processing into reflectances using an atmospheric radiative transfer code that is being developed by Dr. Robert Green. We plan on processing these images into MODIS bands in order to produce the vegetation index images, which will be coupled to the ground measurements.

2. Global TM Data Set

A manuscript was prepared detailing the processing and analysis of the global set of TM imagery acquired from the Global Land Cover Test Site (GLCTS) initiative. This study was a good prelude to a much more comprehensive validation effort which will include field and satellite components. The paper is entitled: ÒA Comparison of Vegetation Indices over a Global Set of TM ImagesÓ, by A.R. Huete, H.Q. Liu, K. Batchily, and W. van Leeuwen. One of the most important findings was the extent to which the NDVI saturates over forested canopies (broadleaf and evergreen). The abstract is:

> A set of TM images representing a wide range of vegetation conditions from the global land cover test site (GLCTS) initiative were processed to simulate the Moderate Resolution Imaging Spectroradiometer (MODIS), global vegetation index imagery at 250 m pixel size resolution. The sites included boreal forest, temperate coniferous forest, temperate deciduous forest, tropical rainforest, grassland, savanna, and desert biomes. Differences and similarities in sensitivity to vegetation conditions were compared among various spectral vegetation indices (VIs). All VIs showed a qualitative relationship to variations in vegetation. However, there were significant differences among the VIs over desert, grassland, and forested biomes. The normalized difference vegetation index (NDVI) was sensitive to and responded primarily to the highly absorbing red reflectance band, while other indices such as the modified vegetation index (MVI) were more responsive to variations in the near-infrared (NIR) band. As a result, we found the NDVI to mimic red reflectances and saturate over the forested sites. The MVI, by contrast, did not saturate and followed variations in NIR reflectances. In the arid and semiarid biomes, the NDVI was much more sensitive to canopy background variations than the MVI. Maximum differences among vegetation index behavior occurred over the evergreen needleleaf forest sites relative to the deciduous broadleaf forests and drier, grassland and shrub sites. These differences appear to be useful in complimenting the NDVI for improved monitoring of vegetation, with the NDVI sensitive to fraction of absorbed photosynthetic active radiation (fAPAR) and the MVI more sensitive to structural canopy parameters such as leaf area index and leaf morphology.

We plan on continuing the TM validation effort with more global scenes and with an implementation of a Ôdark object subtractionÕ routine, with the aim of further simulating the MODIS processing chain.

3. Level 3, Product Development

AMBRALS-BRDF integration

Shuping Jia, Ph.D. student, has been testing AMBRALS utility for the level 3 compositing VI work. Thus far, we are getting inconsistent results regarding the utility of AMBRALS in VI compositing. We are not always getting an improvement in normalization of angular data to nadir. Within a certain range of view angles, BRDF adjustment tends to increase the error. These preliminary results indicate that a mixed ÔoptimizationÕ and BRDF code may be needed, whereby only in the case of angles exceeding (e.g., 30 degrees) do we implement AMBRALS. The main limitation of AMBRALS occurs when there are only 7 or fewer points available over a compositing cycle. This is less than the numbered required by AMBRALS for proper modeling, however, it is a reasonable limitation of the number of points that will routinely to be available for compositing over 16-day intervals.

The Walthall BRDF model and the Roujean BRDF model were coded separately from AMBRALS-BRDF code, to do more in depth research on the incorporation of BRDF models in vegetation index composite scenarios. The effect of pixel resolution differences between the MODIS BRDF product (1 km) and the MODIS vegetation index composite product (250 m and 500 m pixel resolution) are being investigated using ASAS data.

MODIS compositing research:

Ongoing research topics: a) parameterization of empirical and semi- empirical BRDF models for different land cover types and MODIS spectral bands, b) utilization of the BRDF models to correct off-nadir measurements to nadir-equivalent values for vegetation index (VI) compositing and biophysical interpretation, and c) comparison of different vegetation index compositing scenarios.

High spectral resolution bidirectional reflectance factor (BRF) measurements, made with the Advanced Solid State Array Spectroradiometer (ASAS) flown by the C-130 aircraft (spatial resolution: 3 m at nadir), were processed to apparent and at-surface reflectances. Major land cover types included are: deciduous and coniferous forest (Oregon Transect Ecosystem Research Project - OTTER); Boreal Ecosystem Atmosphere Study - (BOREAS); grassland (First ISLSCP Field Experiment - FIFE) and shrub savanna sites (Hydrologic, Atmospheric pilot Experiment in the Sahel - HAPEX-Sahel). The ASAS reflectance data were convolved into the first four MODIS bands and corrected for atmosphere effects with Ò6SÓ. Aerosol optical depth data from the airplane and field sunphotometers and variable aerosol distributions and atmosphere profiles were used to correct for atmospheric effects. All scenes for each target (14 targets) were co-registered after which average apparent and surface reflectances were extracted at different spatial resolutions (~1.5 km) and for each MODIS band. The view zenith angles ranged between 0 and 60 in both the forward- and backscatter- direction.

The normalized difference vegetation index (NDVI) and modified VI (MVI) were selected as classifiers in five different vegetation index composite scenarios:

-a maximum VI based on apparent reflectance data.
-a maximum VI based on at-surface reflectance.
-a BRDF standardized VI, based on surface reflectances at nadir view angle and mean solar zenith angle.
-a BRDF normalized VI, based on surface reflectances at nadir view/sun angles.
-a normalized bidirectional VI distribution function.

SDST product development

Level 2 and level 3 beta code were written for the VI and submitted to Eric Vermote for integration with the surface reflectance product. The beta code has been approved. Several composite scenarios have been coded:

a) The traditional maximum NDVI composite scenario.
b) A vegetation index compositing scheme based on the MODIS cloud product and data quality and the selection of the vegetation index for the day with a view angle closest to nadir (this would avoid large BRDF effects).
c) A vegetation index composite scenario based on the MODIS cloudmask product and data quality flags and the incorporation of a BRDF model (WalthallÕs and RoujeanÕs) to extrapolate to nadir-equivalent reflectances after which the vegetation indices are computed based on a 10-day period.

Larger and more realistic test data sets are being assembled (daily continental pathfinder GAC data and the ASAS bidirectional reflectance data sets) and tested to determine the success and limitations of these algorithms. We are working on integration of HDF into the compositing code. Different compositing scenarios are being tested with and without the BRDF adjustment and sensitivity analyses are being incorporated to determine the feasibility of a BRDF correction. To evaluate the compositing scenarios, tools are being developed and integrated in the coded algorithms.

4. Myneni code

As part of the pre-launch validation effort, vegetation canopy radiant transfer models are being utilized to provide a theoretical and physical basis to the VI equations. This is to ensure the performance and behavior of the VI agrees with that of radiant transfer theory. Radiant transfer modeling is used to vary sensor specifications, vegetation structure and amounts, canopy backgrounds, atmosphere conditions, and sun-target-view geometries. The Myneni, 3-d canopy radiative transfer model is particularly valuable in that it is now designed to distinctly model ÔsixÕ structurally variant, ÒbiomeÓ types. Thus, we are generating bidirectional reflectances over an array of vegetation biomes and LAI, ground cover, and soil conditions. From this, we are generating nadir- and directional VIs for testing the level 2 and 3 vegetation index algorithms. In addition, since these models are being used in the LAI/fPAR algorithms, we are able to couple the VIs to the same biophysical parameters to provide empirical biophysical measures of LAI and fPAR and to further validate the performance of the VIs in depicting differences in vegetation.

5. Test Site Data Plan

An EOS-Test site plan in support of vegetation indices was submitted to Dr. Tim Suttles at the end of December. The objectives for this plan were to outline our (1) ground-based, correlative observations for EOS; and (2) our data product validation/algorithm development.

For VI analysis, we have three objectives in a test site program: (1) spatial and temporal discrimination of vegetation differences; (2) seasonal bidirectional reflectance properties of different biomes; and (3) coupling and translation of VIs to biophysical parameters. The first two objectives are mostly radiometric and require a broad range of ÔglobalÕ test sites while the third objective is more rigorous and constrained to a limited number of intensive field campaigns involving biophysical sampling of vegetation. Our goal is to test the VIs over as wide a range of biomes as possible, representing the full range of biomass and structural conditions.

Through the test site program, we also wish to establish empirical relationships to vegetation biophysical parameters, primarily fPAR and LAI, but also % green cover and biomass. In the post-launch phase, we also wish to intercompare VIs derived from different satellite sensor systems with the goal of establishing scale- and bandwidth-dependent translation and continuity among the sensors including: AVHRR, Landsat TM, MODIS, GLI, SPOT, and MISR.

A summary of some of the key Òtest siteÓ areas for validation activities include:

1. BOREAS, 1996. Boreal forest in Canada. Biophysical measurements are planned (LAI, fPAR).

2. U.S. LTER sites (1996-1998) including: La Jornada (desert) Konza Prairie tallgrass prairie), Central Plains Experimental Research Station (short grass), H.J. Andrews (coniferous forest), Harvard Forest (deciduous forest), Hubbard Brook (deciduous forest), North Temperate Lakes (mixed deciduous/evergreen forest). Included on this list are the OTTER experiment sites (Oregon Transect, incl. H.J. Andrews) and the FIFE sites (Konza Prairie).

3. San Pedro Basin (Arizona and Mexico), semiarid grass/shrub.

4. South American sites, 1996-2000, including:

(i) Brazil sites from the SCAR-B experiment in the Amazon, 1995 (Ji-Parana, Maraba, Pt. Velho, Alta Floresta, Pantanal, Cerrado).

(ii) the Chilean sites incorporated into the Global Land Cover Test Site (GLCTS) initiative, with its steep latitudinal and elevational gradients, accompanied by corresponding variations in vegetation types. Sites include: Site 1, Coquimbo (30S lat./71.2W long.); site 2. Santiago (33.5S lat./70.7W long); site 3, Talca (35.5S lat./71.5W long.); site 4, Osorno (40.5S lat./73W long.); site 5, Copiapo (27.5S lat./70.6W long.). All of these sites are active research areas for faculty and students at the Universidad de Chile;

(iii) Argentina sites; there are two Òlong-termÓ ecological sites in Argentina; Las Chilcas (tallgrass site in the Pampas) - similar to Konza Prairie and Rio Mayo (shrubsteppe site) in Patagonia. In collaboration with the Inter-American Institute for Global Change (IAI), we propose to include three Argentina sites, Dry and Humid Pampas and the Patagonia site.

5. Asian test sites

(I) CERN sites in China. The Chinese Ecological Research Network is a potential source for test sites surrounded by intensive land-use changes occurring with ChinaÕs current economic expansion. The U.S. LTER network is active with CERN and has more information;

(ii) The Japanese Global Imager (GLI) is a MODIS-like sensor to be launched in 1998. As part of the terrestrial science program they have identified four primary test sites over which they hope to work with MODIS in instrument cross-calibration and validation of vegetation biophysical parameters. These test sites include: Mongolia grasslands, Thailand tropical rainforests, rice paddy fields, agricultural intensification, and Siberian forests (Boreal).

6. Validation plan

A draft validation plan of the VI algorithm was prepared and included both pre-launch and post-launch validation activities. Validation of the VI involves testing and confirmation that it is performing as designed in meeting the primary science objectives, or intended uses, of the VI. Pre-launch validation of VI performance in discriminating spatial and temporal vegetation differences is accomplished through independent means which include surface biophysical measurements, theoretical canopy modeling, and precursor airborne and satellite data sets. Post-launch validation with the MODIS sensor include correlative measurements and emphasize the long term performance and quality of the VI product. The primary science objectives of the VIs, which will require validation, include:

i. Spatial and temporal discrimination of vegetation differences.
ii. Seasonal vegetation profiles of the growing season (phenological).
iii. Coupling and translation of VIs to biophysical parameters.

There are five components to the validation of the VI algorithms:

i. Vegetation canopy radiant transfer models.
ii. Field-based correlative measurements.
iii. Experimental aircraft image data.
iv. Existing satellite data sets: (Landsat Thematic Mapper (TM) and the NOAA- Advanced Very High Resolution Radiometer (AVHRR)).
v. Future satellite data sets.

Pre-launch algorithm test/ development activities:

In pre-launch phase, a combination of sensors and data sets will be used to simulate MODIS data for the anticipated range of terrestrial surfaces with atmospheric, topographic, and angular variations. Initial validation of the VI equations themselves is accomplished with canopy radiative transfer models such as the Myneni 6 biome canopy code, the SAIL model, and two-stream canopy model. Experimental data sets are also widely used from both ground radiometric measures (e.g., PARABOLA) to aircraft sensor data. Field measured BRDF data sets are very valuable in simulating MODIS view, angular relationships. Atmospheric radiative transfer codes are also utilized to superimpose varying degrees of atmospheric contamination onto the experimental and canopy model data sets. In this manner, the sensitivity of the VI equations to the atmosphere can be assessed. Finally, precursor satellite data from the Landsat TM and AVHRR are extremely important in VI validation on a global basis.

A suite of satellite sensor systems are needed to effectively match the MODIS instrument. The AVHRR data sets can be used to simulate some of the spatial and temporal capabilities of MODIS. Landsat TM and SPOT data can be used to simulate some of the spectral and spatial MODIS properties. The satellite data sets offer actual viewing conditions (clouds, angles, atmospheres, etc.) and surface conditions. We plan on primarily utilizing Landsat TM and NOAA-AVHRR satellite data sets in the pre-launch validation activities for the VI. The primary source of this data is from the global land cover test site (GLCTS) program, which cover nearly all of the field experimental sites discussed above and provide both Landsat TM and daily AVHRR data over each test site.

The true measure of success of the VI product will be its performance in discriminating spatial/temporal vegetation patterns. This will mean coupling the VI values with ground biophysical measures that can be independently confirmed (measured) to have changed. We will periodically check on the translation coefficients to go from VI to biophysical parameters, over specific land cover types.

Post-launch activities:

In the post-launch period, we will focus on the validation of the global VI data product and address how the product will be evaluated through the operational life of the sensor. Planned field activities and studies in support of validation include:

i. The LBA experiment in the Amazon, 1999.
ii. The Chilean and GLCTS test sites.
iii. LTER sites
iv. Continue with the GLI Asian test sites.

A field-based monitoring program at each of the sites is envisaged, covering at least six of the major biome types. We would measure spatial and temporal changes in vegetation at a higher resolution than the MODIS satellite to keep track of the sensitivity of the MODIS-based algorithms to detect the known changes. Other satellite data sensors to be used in validation are Landsat 7, SPOT-VEGETATION, GLI, MISR and ASTER will be used to Ôzoom inÕ onto the intensively measured field sites and provide linkage of field results to the MODIS sensor. Some of the important measurement needs (in situ) at the calibration/validation sites include both radiometric and biophysical.

7. HAPEX-SAHEL REPORT

The final report on the HAPEX-Sahel West Central Supersite was submitted by Wim van Leeuwen, Alfredo Huete and Michael Guilbault and included methods, measurements and selected results of the 1992 field work and research in Niger. The report included the seasonal development of each subsite (vegetation type) which were monitored by means of nadir radiometric reflectance and temperature measurements in the field. Bidirectional reflectance factors (BRF) were measured in the field to characterize the anisotropy of representative soil and vegetation types. The final results of the soil CO_2 efflux measurements made by Mike Guilbault were also submitted.

8. GLI proposal

A proposal entitled ÒInvestigation of Cooperative GLI - MODIS Activities for Algorithm Development for Enhanced Global Terrestrial ScienceÓ was submitted to NASDA in Japan. In this proposal the MODLAND team seeks joint, cooperative algorithm development and research activities between the Global Imager (GLI) and MODIS sensors. Dr. Alfredo Huete is the principal investigator of this GLI-MODLAND proposal with the MODLAND team as co-investigators. In this proposal we describe the current status of remote sensing products planned by the MODLAND team and outline potential areas for cooperation with the GLI instrument project.

We propose to work jointly with GLI scientists to develop optimal, standard algorithms for global terrestrial science. This includes joint efforts in testing and evaluation of standard products; calibration and correlation of the GLI and MODIS sensors; development of joint synergistic activities, common test sites, field experiments, and validation exercises to compliment global-scale terrestrial science. We would like to explore how the two sensors can be integrated to aid in creating an integrated, comprehensive long-term (monitoring) program in documenting the Earth system on a global scale. Table 1 compares some of the characteristics of the AVHRR sensor with MODIS, GLI, and the Landsat TM sensors.

The primary objectives of this proposal are to:

(1) Evaluate and compare standard algorithms for the different sensors (commonality).

(2) Determine and evaluate potential and advanced synergistic, GLI-MODIS sensor applications for standard algorithms, including mutual quality assurance monitoring.

(3) Establish translation and extension between the 2 sensors, with respect to land products, with consideration to bandpass and filter function differences.

(4) Plan and conduct joint validation and calibration exercises.

(5) Integrate Asian ecological test sites into a joint MODIS-GLI test site program.

(6) Conduct cooperative research activities, such as joint field data collection and analysis.

Table 1. Comparison of GLI bands with MODIS and Landsat TM

	GLI #	GLI Bands	MODIS Bands	TM Bands	AVHRR Bands
Blue	20	425 - 495	459 - 479	450 - 520	
Green	21	520 - 570	545 - 565	520 -600	550 -
Red	22	640 - 700	620 - 670*	630 - 690	680
NIR	23	770 - 880	841 - 876*	760 - 900	725 - 1100
NIR			1230-1250		
MIR	28	1540-1740	1628-1652	1550-1750	
MIR	28	2100-2320	2105-2155	2080-2350	
Pixel size		250 m	250 m* & 500 m	30 m	1 km
Temporal		daily	1-2 day	16 day	daily
Swath		1600 km (±43¡)	2330 km (±55¡)	185 km	2700 km (±65¡)

9. ASPEN Global Change Institute

Participant in sixth annual Aspen Global Change Institute Summer Science Session, Aspen, Colorado, July 9 -22, 1995. The session theme of the two-week workshop was entitled ÒChanges in Global Vegetation Patterns and Their Relationships to Human ActivityÓ, with Jim Tucker and Bill Emory as co-chairs. I presented and submitted a paper entitled ÒSoil radiative influences in satellite monitoring of vegetationÓ.

10. Future Activities

Preparations are being made for field-related validation activities in Chile and Argentina (March - April, 1996) and BOREAS later in the summer months, 1996. Two papers will also be presented at the IGARSSÕ96 conference, May 27 - 31, 1996.

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