Semi-annual Report, January to July 2003
University of Arizona/ NAS5-31364
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1. TASK OBJECTIVES

During the first half of 2003, work revolved around the following tasks:

1) Evaluation of collection 4 reprocessed data and the new aerosol correction
2) Evaluation of combined Terra/Aqua production
3) In-house global MODIS VI data production
4) EOS Algorithm Refinement and Science Proposals
5) Continue the validation and evaluation effort of the MODIS VI products
6) New MODIS VI User Guide (version 2.0)
7) Prepare for MODIS Land Meeting at Baltimore (July 15-16, 2003) Speedup and parallelizing some of the in-house applications
8) Developing tools for analysis and evaluation of a possible combined Aqua/Terra product.
9) Development of a tool for spatial filtering and averaging when producing lower resolution output products from a higher resolution input.

Collection 4 deliveries were made in September/October 2002. These new versions went into production, both forwards and reprocessing, starting December 2002. We performed an evaluation of Collection 4 in order to understand the achieved improvements. Another change in the surface reflectance aerosol correction (MOD09) required an assessment of its impact on the MODIS VI product. We evaluated this change using our reference tile (h08v05) in Southwest U.S.

Given the similarities between the two MODIS sensors (Terra and Aqua) the MODIS land team made the recommendation that all SCF teams look into the possibility of combining both sensors into one product, to do so, we evaluated various combined production scenarios.

Our global MODIS VI reproduction continues with the aim of achieving a 3 year global MODIS VI data record. We also produced a new version (V2.0) of our MODIS VI user guide to be available on line on our web site. In coordination with the rest of the MODIS Land Science team we updated our web page to reflect the newest information and to provide more information to users. We're also evaluating the MODIS VI product in studying vegetation dynamics and drought in Arizona using both the Terra and Aqua VI product for the last three years.

We also submitted two proposals in response to NASA's newest EOS research announcements, for both science algorithms and new science using EOS data.

The specific accomplishments for the last six months were:

- Collection 4.0 MODIS VI 1km, 500m, and 250m product were evaluated on a regional to global scale and for a long time series.
- Evaluation of a combined Terra/Aqua production scheme
- Evaluated the effect of the new aerosol correction on our VI product
- Continue the production of simplified global MODIS VI data set to be made public
- Submitted two proposals
- Updated our MODIS Web page and the User guide
- Submitted material for the 2003 MODIS Land Meeting and the MODIS Workshop in Brazil.

2. WORK ACCOMPLISHED

Based on the above objectives our work was divided into 5 categories

- Algorithm development, maintenance:
    a. Combined production evaluation
    b. Aerosol correction change impact on MODIS VI
    c. Addressing spatial problem with the product
- SCF maintenance and in-house code development
- Science and application research
- Meetings in Baltimore and Brazil
- Production of MODIS VI global data set

Algorithm and Code development

In order to evaluate the effects and benefits of a combined production, we developed a specialized version of the 250m MODIS VI Algorithm. This version is able to ingest both Terra and Aqua and produce combined products as follows:

- 16 days Terra only
- 16 days Aqua only
- 16 days Terra and Aqua combined
- 8 days Terra and Aqua combined

We planned to compare how the increased temporal frequency and/or shorter compositing period will affect the long term data record. Combining the two sensors will have many benefits and problems of which we list:

- Increased temporal frequency (for example every eight days)
- Better time series (~46 cycles per year)
- Increased quality and cloud reduction
- Complicated staging/processing
- Chance of no production due to short composite period
- Issues with the different radiometric characteristics?

Assuming the benefits from combined production will mostly be cloud elimination we tested the algorithm over the following areas (Figure 1).

- Minimal cloud cover (Tile h08v05)
- Persistent cloud cover (Tile h12v09)
- Near perpetual cloud cover (Tile h11v09)

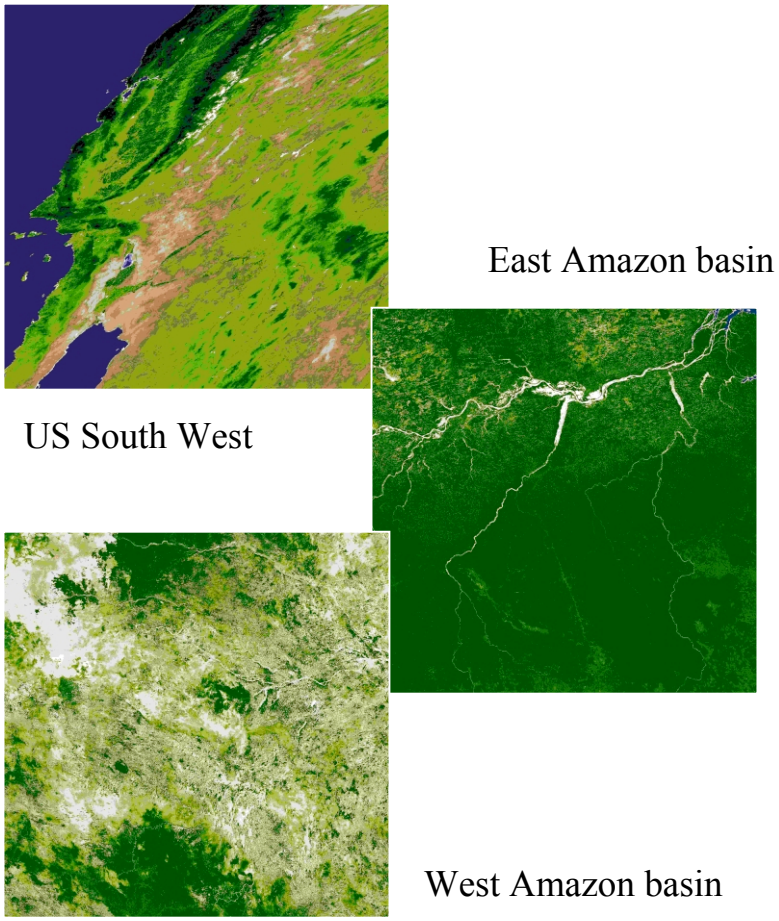


Figure 1: test performed on areas with various cloud cover persistency

The initial results support the following conclusions:

- Persistent and perpetual cloud covered areas benefited the most from combined production (Figure 2)
- Data collected with Aqua MODIS sensor, due to its PM overpass, has less cloud cover,
- Areas with minimal cloud cover will not benefit from a combined production
- An Eight day composite period seems to be a more reasonable goal, since it will increase the temporal frequency of the VI production, which will benefit time series studies

- Overall the benefits from combined production do not seem to justify the complication stemming from combining both sensors and the staging and added cost.
- A better solution would have been to produce Terra and Aqua eight days apart but at the regular sixteen days compositing cycle. This scenario is currently being investigated.

	Terra only (8 days)	Aqua only (8 days)	Terra + Aqua (8 days)
Quality stats	% Cloud 74.34 % Climatology 59.55 % Low Aero 16.56 % Avg. Aero 9.58 % High Aero 14.31 % Mixed Cloud 74.34 % Snow/Ice 0.00 % Shadow 10.49	% Cloud 51.82 % Climatology 47.78 % Low Aero 26.99 % Avg. Aero 19.58 % High Aero 5.64 % Mixed Cloud 51.82 % Snow/Ice 0.00 % Shadow 21.78	% Cloud 39.65 % Climatology 32.86 % Low Aero 36.79 % Avg. Aero 20.45 % High Aero 9.90 % Mixed Cloud 39.65 % Snow/Ice 0.00 % Shadow 21.50

Figure 2: Comparison of various Terra/Aqua production scenarios and their Quality statistics

Our future plan is to perform a global test for two seasons (cloudy versus non cloudy) and make a recommendation on what is the best approach for combining both sensors.

Global data set production

We started this task 6 months ago, and our aim was to produce a global geographic projection MODIS NDVI and EVI product at 2km spatial resolution. This internal reproduction exercise is progressing well, and we decided to extend it to 1km global in both the geographic and Interrupted Goode Homolosine projection. The goal is to make this data set available to climate modelers and for global vegetation dynamic studies. So far both collections 3 and 4 are used, and we aim at replacing all collection 3 with collection 4 data for consistency. We're also performing research on global vegetation dynamics using this data set and the MODIS Land cover product plus the 1km DEM GTOPO data set, in order to understand vegetation change and dynamics with respect to land cover type and elevation gradient. Figure 3 illustrates some of these global geographic Surface Reflectance data sets. We're only archiving the global surface reflectance data to reduce disk requirements, since producing VI is very simple and could be done on demand.

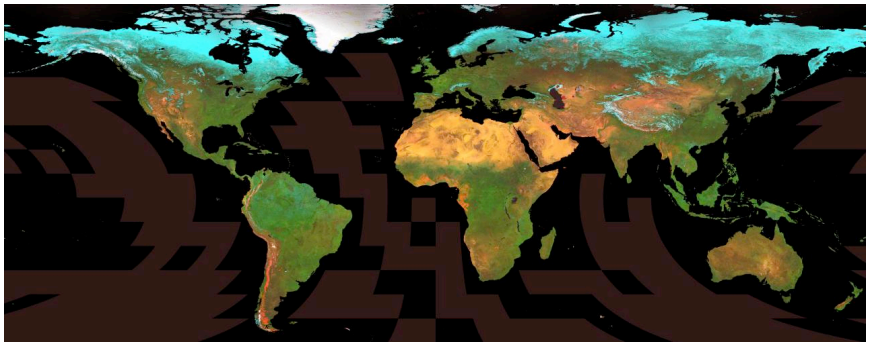


Figure 3: MODIS composited Surface Reflectance (MNR) False Color composite (08/13/02 to 08/29/02)

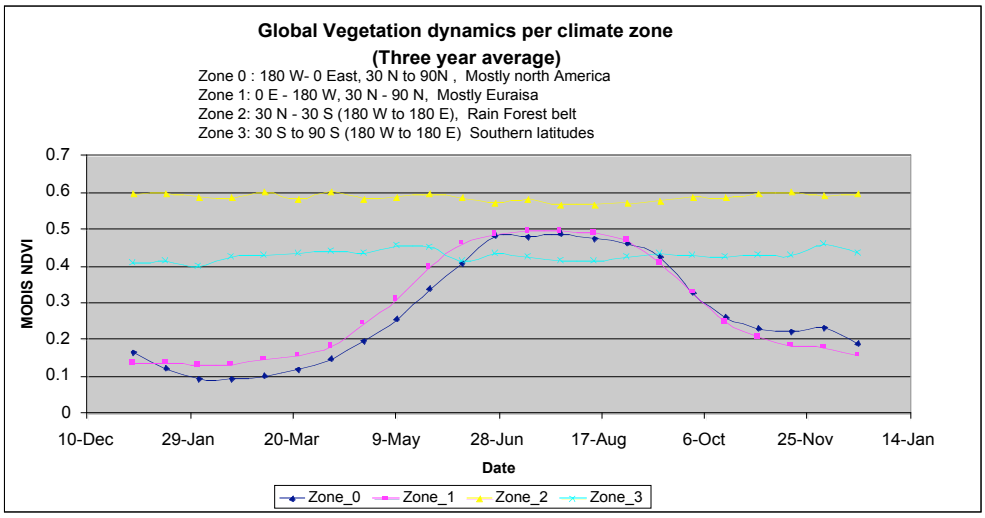


Figure 4: Annual Global Vegetation Dynamics, using MODIS NDVI (2km), three year average. Per climate zone

This research is progressing very well and we should finish this data record in the upcoming few months. Once completed this data will be made public to various science teams and climate research groups.

Collection 4 evaluation

Collection 4 has been in production for almost a year and should be finished by the end of 2003. By then collection 4 will replace and supercede collection 3. In order to make these changes and improvement transparent to users we devised a series of web pages (Figure 5), that are hosted by the USGS DAAC (at http://edcdaac.usgs.gov/modis/mod13a2v4.html)

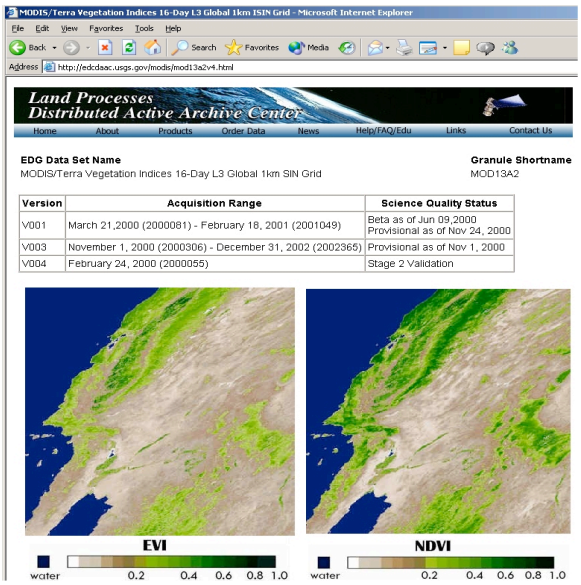
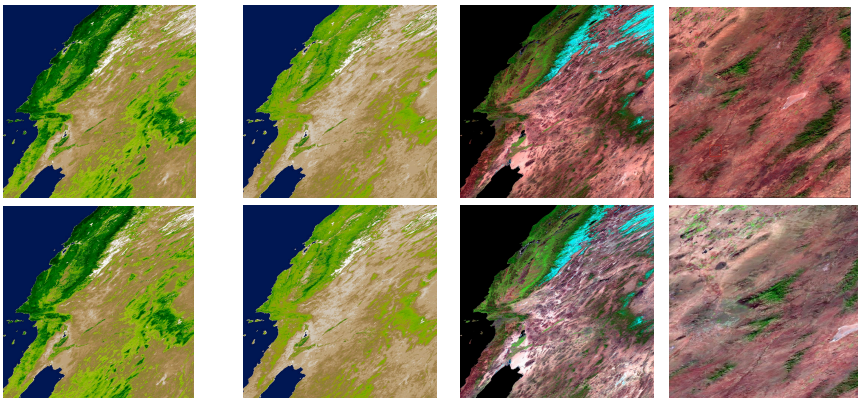


Figure 5: Newest web page for the MODIS VI products

We're also in the process of evaluating various aspects of the MODIS VI products:

- Spatial continuity
- Aerosol correction effects (Figure 6)
- Time series differences
- Cloud elimination

Figure 6 illustrates an example of improvement related to changes in aerosol correction at the surface reflectance level (MOD09)



Collection 4, Aerosol affect

Collection 3, Aerosol affects

Figure 6: Aerosol correction impact on MODIS VI (Collection 4). The image from collection 4 (Test 5.4) are sharper due to better aerosol correction.

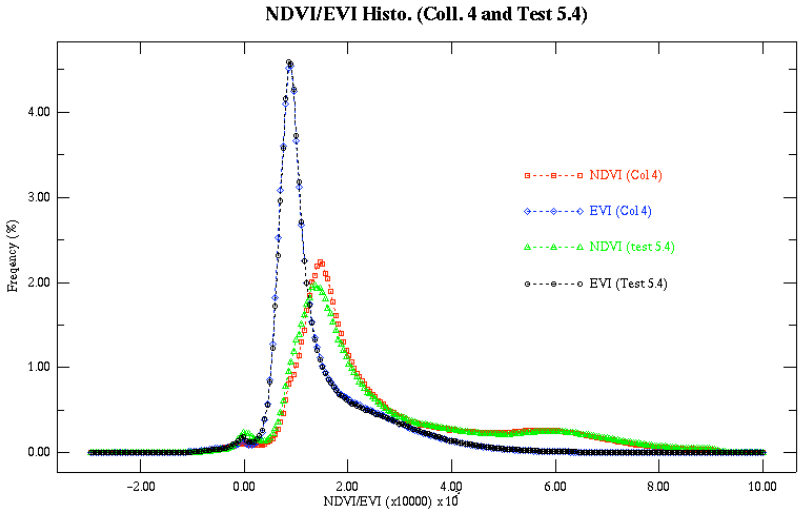
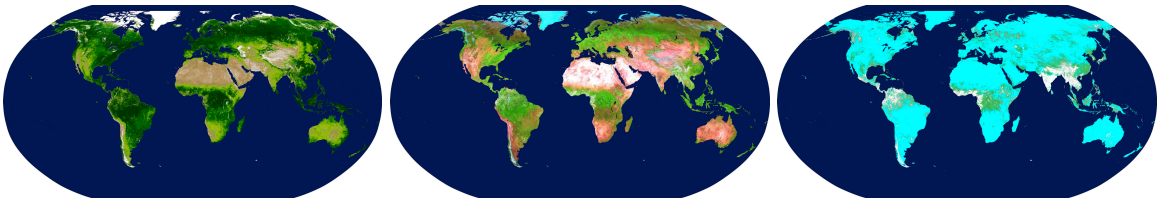


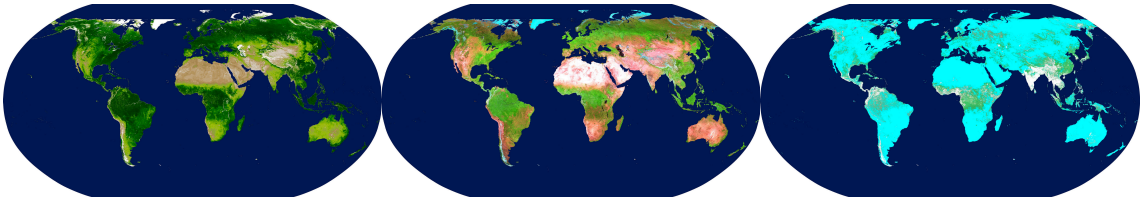
Figure 7: Aerosol correction impact on MODIS VI. NDVI shows a slight difference between the two version, as opposed to EVI, which by design should be internally, handles residual aerosol contamination.

Terra Aqua comparisons

Since both Terra and Aqua MODIS have the same radiometric characteristics, same processing, production, and science software one would expect the land products from these two sensors to be highly correlated. To evaluate the correlation between MODIS Terra and Aqua we performed a comparison of the VI products from both sensors.



Terra NDVI False Color MNR VI QA



Aqua NDVI False Color MNR VI QA

Figure 8: Global VI, Surface Reflectance, and QA maps for Terra and Aqua

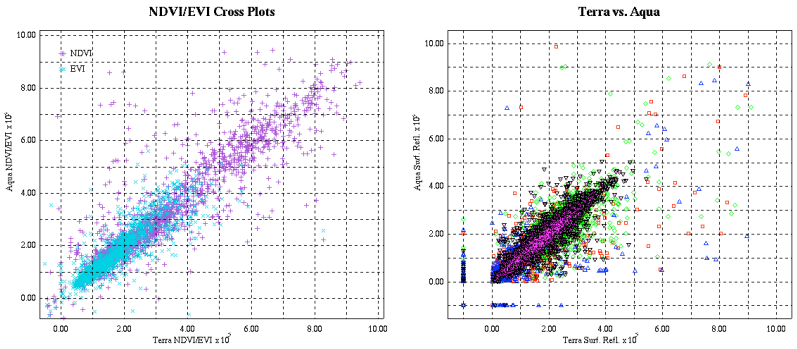


Figure 9: Terra vs. Aqua NDVI/EVI and Surface Reflectances (Linearity 1:1)

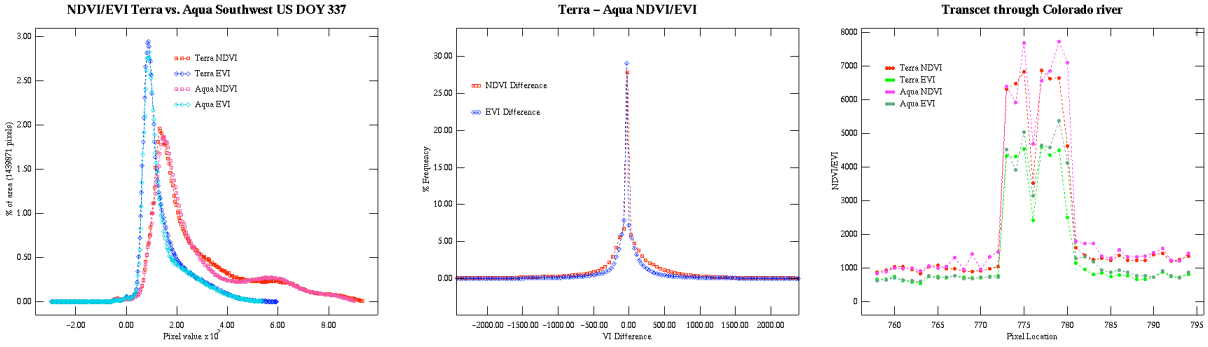


Figure 10: Terra and Aqua NDVI/EVI histograms, difference histograms, and transect

All analysis indicate that MODIS VI products from Terra and Aqua are identical except for few differences that could easily be attributed to cloud cover difference between the two overpasses and/or sun and viewing angle differences. Overall both product are linearly correlated and could be interchanged. This results further reinforces the idea of finding a way to combine both sensors into one product, or to improve their temporal frequency by changing their production dates.

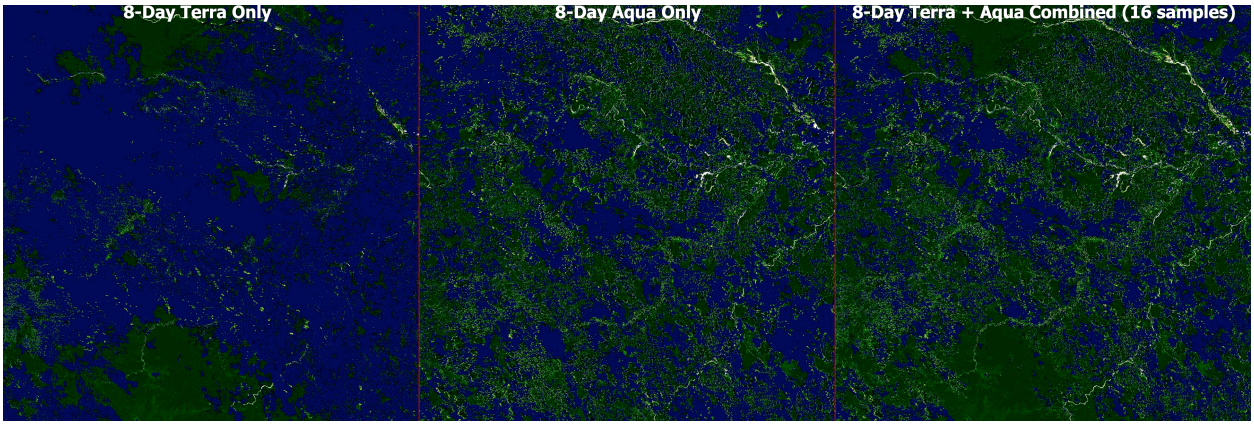


Figure 11: Illustrate the combination of 8-day data from both aqua and terra satellites. Blue areas are cloudy pixels that have been filtered out. The benefits are obvious in cloudy regions such as this (tile h11v09).

The red histograms show that the combined product produces more accurate NDVI/EVI values.

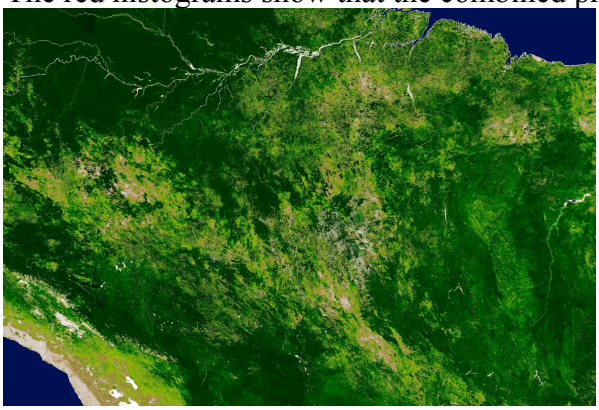


Figure 12: 250m Original Input Data

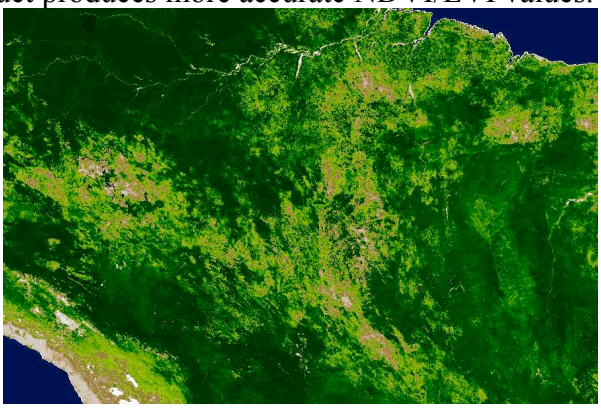


Figure13: 4km Filtered and Spatially Averaged Data

Although it is hard to tell at this resolution in this document, the quality of the filtered image is much "cleaner" since about 10% of all pixels were filtered out due to bad data quality. The filtering is based on the EVI QA layer as provided in the input files and is mainly designed to improve the data in coarser resolutions.

New MODIS VI User Guide (version 2.0)

The newest version of the MODIS VI User guide (V2.0) is completed and should go online very soon. This new version addresses problems with the previous one and adds more information about versioning and the various collections. Users should find this document valuable and a guide towards a better understanding of the various MODIS VI products., (http://tbrs.arizona.edu/project/MODIS/UserGuide_doc.php)

MODIS Land Meeting at Baltimore (July 15-16, 2003)

This meeting focused and discussed the future plans for a new collection (5.0) and possibly 6.0. Recommendation were also made to improve the visibility of MODIS land products and to reach larger science user bases. Dr.. Huete (PI) provided an overview of our combined Terra/Aqua production research performed by Dr. Didan (associate team member).

EOS Algorithm refinement and Science Proposals

We submitted two proposals:

- Validation and Performance Assessments of the MODIS Vegetation Index Product Series from the Terra and Aqua Platforms: EOS Algorithm Refinement Proposal. A Proposal to NASA NRA-03-OES-02.
- Arid Ecosystem Response Variability to Shifts in Climate and Vegetation with Coherent ASTER/ MODIS Seasonal Data. A Proposal to NASA NRA-03-OES-02

Both proposals focus on MODIS Terra and Aqua VI products. The algorithm refinement proposal details our future (3 years) plans for improving, validating, and making use of the MODIS VI products. Currently our product are Stage 2 validated, subsequently one of our aims is to bring the validation level to Stage 3. In the science proposal we plan to take advantage of various EOS data sources including MODIS to study climate changes and their impact on arid ecosystem vegetation.

Continued validation and evaluation effort of the MODIS VI products

<u>US Southwest</u>

We're generating time series of both NDVI and EVI to study the vegetation dynamics of semi-arid region (US Southwest) and the related climate changes..

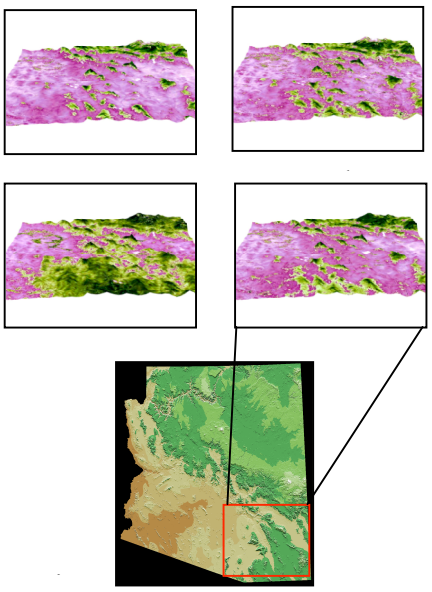


Figure 14: MODIS NDVI overlaid on South Eastern Arizona DEM. This series of images depict seasonality and response to monsoon precipitation.

Amazon basin

In coordination with our LBA project, we are evaluating the MODIS VI product usefulness in studying the vegetation dynamics and gradients across the rain forest to Cerrado vegetation gradient (Brazil).

SCF Maintenance

a. In house code development to serves various MODIS project needs and research purposes:
b. Creating a repository for all MODIS VI related tools developed at our facility. These tools will be made public to all MODI VI users and to the MODIS Land team.
c. Installed the newest version of MODIS Reprojection Tool, which is now able to project and stitch multiple MODFIS tiles.
d. Upgraded our storage system to about 3.5 TB.

3. Validation

During the Arizona AVIRIS campaign, we performed various field measurements that will both benefit MODIS, our LBA project, and GLI. This campaign focused on northern and southern Arizona and covered various land cover types, from Ponderosa pine forest to riparian areas. The data will be used for validation, continuity, and various vegetation dynamic studies. The data collected on the ground and by AVIRIS, MODIS, GLI, and TM will be analyzed and further used to validate the various products. The AVIRIS campaign is still ongoing and should finish by the end of July.

4. SCF Tools Developed

- Cloud Mask Tool
  Created tools for masking out clouds from the input products for aqua and Terra VI products in order to perform some of the analysis needed for performing the Aqua/Terra combined analysis. The results of this work were presented at the MODLAND meeting in July.

- Masking geographic regions

- An application for creating masks of geographic regions spanning over multiple tiles. Given a set of lat/long coordinates, using the coordinate to tile mapper, a mask of the polygon as it is represented in each tile can be created, regardless of the output resolution desired. This is useful when there is a specific area of concern. For example, we used it to mask out the state

of Arizona from the h08v05 tile. The mask created holds values indicating whether a particular pixel should be included or not.

- Spatial Down sampling and Filtering. A tool for performing spatial averaging of our MOD13 product in order to decrease the amount of less accurate data as we move to a coarser resolution product by filtering out pixels that are considered to contain degrading data. Such pixels are either cloudy, have a view zenith angle greater 45 degrees, or has a high value for aerosol contamination. However, there are more things to do with this tool as we need to decide on a proper averaging method to best suit the needs of the final resulting product. In the end, the final product will be used to filter and down sample a global 1km dataset to 4km, 8km, and possibly 25km while discarding scientifically weak data.

All of the above applications have been written in C using HDF and pthreads to achieve better performance. pthreads is a C library that is used for writing parallel programs. This means that our tools can take advantage of more than one processor on the target computer system; which greatly improves performance over applications written to run on only one processor. However, known limitations in the HDF library (Version 4.1r5), prevents reading and writing files in parallel. Since many of our applications are I/O intensive, this sometimes impacts the performance increase experienced.

Other SCG related tasks:

- Arranging to install new 3T and 0.5T fibre channel hard drives to Irix server.

- Re-construction of whole file structure for all Irix servers and workstations, for the need of MODIS and other projects in TBRS.

- Working as web server administrator and webmaster of TBRS lab, administrating
- ftp, samba server, etc.

- Administrating the Windows 2000 server for the Matlab, Arcinfo, etc, software.

Ordering, processing, backup MODIS VI data including 1km, 500m, 250m, and input data of core sites. For both Terra and Aqua, the data flow is around 180G bi-week,

5. GLI – MODIS Activities

The GLI MODIS coordination is still on going with an aim at completing a comparison of both sensors VI products. Although GLI is not yet producing any Level 3 products, we relying on our in-house algorithm to produce special VI products from both sensors to be compared and analyzed for continuity.

We started evaluation of the products from the Japanese GLI (GLobal Imager) satellite. The current project status is that only some intermittent data has been produced. It is not publicly available, but has only been distributed to PIs for evaluation. The project is at least four (4) months away from normal operation. According to schedule, data production and publication

will commence in December 2003. The sensors are currently being calibrated and the test data that was made available consisted of a few particular Level-1B scenes.

Our goal is to provide a qualitative analysis, comparing the GLI data with corresponding MODIS data in order to provide a measurement on how the two systems compare; especially regarding the production of VI products. With this in mind, the comparisons that can be performed as of now will have to be based on the L1B data until higher level products become available. Based on this, any preliminary comparisons and conclusions that we can make must be further validated once normal production data can be obtained.

The investigation of the current GLI Land team project status came to a quick halt. It was discovered that the public web pages for the project were hardly updated in the past year and many of the newer documents were only available in Japanese. It seems as if some of the other GLI teams were making some progress, since their web pages contained more (and more recently updated) information. However, the land team's page seems to have stagnated some time ago. Our second try was through the PI's door. There were some more general documents available, but for the land team, the PI's door area contains nothing but empty bullets. So the only information available is through the common discipline group.

Except for the data that was distributed to the PIs on the "First Look" cds, there is no publicly available data. The project master plan talks about data being available starting in Phase 4, which is supposed to commence in December 2003. I currently do not have any idea on if this time frame is expected to hold, or if there will be further delays since few news updates have been made in recent months.

As far as current documentation can tell, the project is still in its calibration phase. This means that no results in terms of validations have yet been posted either. However, the calibration team seems to be busy. The data samples on the first look cds contain L1B (level 1 B) data and has mainly calibration purposes.

One suggestion on what could be done in order to prepare for the GLI/MODIS validation, is to gather MODIS data (at L1B) and perform some initial atmospheric correction on both data sets (MODIS and GLI), then compute VIs from the corrected data for comparison. Such a comparison is likely to be prone to error propagation and possibly misleading, especially if the data we have from GLI is from a not properly calibrated sensor. However, if it is desired to have some initial, preliminary results, this is one possible solution.

6. Symposia and Conferences

MODIS Outreach workshop, Brazil, May 2003. A MODIS Land workshop was organized in Goias, Brazil:

Atenciosamente, A Comissao Organizadora

It is with great pleasure that we announce the "I MODIS WORKSHOP:

POSSIBILITIES AND APPLICATIONS FOR THE ENVIRONMENTAL MONITORING";
This workshop, sponsored by the Institute of Social and Environmental Studies (IESA - UFG), the Federal Center for Technological Education (CEFET - GO), and EMBRAPA CERRADOS, and in collaboration with Brazilian Space Research Institute (INPE), IBAMA, and the Government of Goias State, will take place in Goiania, from May 23 through 25;
For the first day we plan a hands on training on MODIS data and products (e.g. data availability and acquisition, pre-processing, reprojection, etc); The second and third days will be devoted to general presentations and invited talks, among them we highlight those to be given by Dr. Alfredo Huete from the University of Arizona:

- "Status of MODIS Biophysical and Land Cover Products for Long-Term Time Series Analysis";
- "Use of MODIS VI's for Ecosystem Variability Studies"

Further information can be accessed at http://www.ufg.br, under the MODIS logo (this homepage will be continuously updated);
Attached to this e-mail is the first MODIS Land Cover mosaic for Brazil, an initiative of our research group ("Environmental Monitoring of the Cerrado Biome through Advanced Imaging Sensors);

MODIS Land Science Terra meeting at Baltimore, July 2003.

7. Papers, etc..

Huete, A.R., Miura, T., and Gao, X., 2003, Land cover conversion and degradation analyses through coupled soil-plant biophysical parameters derived from hyperspectral EO-1 Hyperion, IEEE Trans. Geosci. & Remote Sensing (in press).

Ferreira, L.G., Yoshioka, H., Huete, A., and Sano, E., 2003, Optical characterization of the Brazilian savanna physiognomies for improved land cover monitoring of the cerrado biome: Preliminary assessments from an airborne campaign over an LBA core site, *J. Arid Environ.* (in press).

Wang Zheng-Xing, Liu Chuang, Huete Alfredo, 2003, “From AVHRR-NDVI to MODIS-EVI: advances in vegetation index research”, *Acta Ecologica Sinica*, (in press).

Ferreira, L.G. and Huete, A.R., 2002, Assessing the seasonal dynamics of the Brazilian Cerrado vegetation through the use of spectral vegetation indices, *Int. J. Remote Sensing* (in press).

Gao, X., Huete, A.R., and Didan, K, 2003, Multisensor comparisons and validation of MODIS vegetation indices at the semiarid Jornada Experimental Range, *IEEE Trans. Geosci. & Remote Sensing* (in press).

Ferreira, L.G., Yoshioka, H., Huete, A., and Sano, E., 2002, The seasonal response of spectral vegetation indices in the Brazilian Cerrado: an analysis within the large scale biopshere-atmosphere experiment in Amazonia, *Remote Sens. Environ.* (in press).

Zhang, X., Friedl, M.A., Schaaf, C.B., Strahler, A.H., Hodges, J.C.F., Gao, F., Reed, B.C., Huete, A., 2003, Monitoring vegetation phenology using MODIS, *Remote Sens. Environ.*, 84:471-475.

8 Future Activities for the next 6 months (July – Dec. 2003)

The following tasks are in order of importance:

- Complete evaluation on a global basis of combined Terra and Aqua production
- Start planning for Collection 5.0
- Study of global vegetation dynamics using MODIS VI products
- In our research group we have developed a multitude of tools for performing various computations for our needs. Most of them are related to the MODIS project in some way. Over the next few months we are planning on a general refining of these tools, making them more readily available and well documented for the users of our system. If applicable we might make some of them publicly available on our website.
- As soon as more GLI data becomes available, there will be an effort to evaluate the quality of VIs produced from the GLI satellite.
- The following ideas for paper manuscripts
    - MODIS Compositing Algorithm
    - Metrics for Global vegetation dynamics
    - Combining Terra and Aqua MODIS sensors