MODIS SEMI-ANNUAL REPORT: JAN/01/01 - JUN/30/01

Radiative Transfer Based Synergistic MODIS/MISR Algorithm for the Estimation of Global LAI & FPAR

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Summary of the algorithm. The objective of the contract is to develop a radiative transfer based synergistic algorithm for estimation of global leaf area index (LAI) and fraction of photosynthetically active radiation absorbed by vegetation (FPAR). The algorithm consists of a main procedure that exploits the spectral information content of MODIS measurements and the angular information content of MISR measurements to derive accurate estimation of LAI and FPAR. Should this main algorithm fail, a backup algorithm is triggered to estimate LAI and FPAR using vegetation indices. Both algorithms are capable of executing in MODIS-only or MISR-only mode, should cloud contamination, data frequency and spatial or temporal resolution requirements hinder a joint MODIS/MISR mode of operation. The MODIS-only mode of the algorithm requires a land cover classification that is compatible with the radiative transfer model used in the derivation. Such a classification based on vegetation structure was proposed and it is expected to be derived from the MODIS Land Cover Product. Therefore, our algorithm has interfaces with the MODIS/MISR surface reflectance product and the MODIS Land Cover Product. Validation of the LAI/FPAR product is an important part of algorithm development. Multiple validation techniques will be used to develop uncertainty information on Terra LAI/FPAR products. Successful validation will be accomplished if timely and accurate product uncertainty information becomes routinely available to the product users within two years after Terra's launch.

Summary of work performed during the first half of 2001 (January through June):

- Evaluation of global MODIS LAI/FPAR product: temporal variation in MODIS LAI/FPAR product was investigated.
- Paper describing quality of LAI/FPAR product from year one of MODIS data has been submitted for publication in RSE.
- Paper describing results on validation of the LAI/FPAR product using SAFARI 2K field data has been submitted for publication in RSE. Results suggest the algorithm correctly accommodates structural and phenological variability in semi-arid woodlands and savannas, and is numerically accurate to within the field measurement uncertainty.
- Participation in the MODLAND-VALERI field campaign, France, June 10-17, 2001. Data needed for validation of the LAI/FPAR product were collected and archived.
- Preparation has been made for the Harvard Forest field campaign, 2001.
- In total, six papers describing our MODIS scientific activities have been submitted for publication in various journals.
- Invited talk at the 8th International Symposium Physical Measurements & Signatures in Remote Sensing, Aussois, France, January 8-12, 2001.
- Talk at the MODIS Science Team Meeting, January 22-26, 2001.
- Participation in NASA CCI workshop, May 1-4, 2001.
- Talk at the AGU meeting, Boston, May 29 – June 2, 2001.
- Talk at the MISR Science Meeting, Pasadena, June 4-6, 2001.
- Talk at the Land Product Validation Meeting, ESA, Frascati, Italy, June 7-8, 2001.

Field Campaign

The Boston University team participated in the MODLAND-VALERI field campaign, France, June 10-15, 2001. Our objective was to collect data needed for validation of the LAI/FPAR product; validate the MODIS LAI/FPAR algorithm; to describe the spatial variability of LAI/FPAR and to investigate the scale effect on LAI/FPAR retrievals. Ground measurements of LAI, FPAR, canopy hemispherical reflectance and transmittance were made using the LAI-2000 plant canopy analyzer, AccuPAR ceptometer, LI-1800 portable spectroradiometer and LI-1800-12 (external integrating sphere), and ASD handheld spectroradiometer. Optical property measurements of leaves from the dominant overstory species were made at the Puechabon VALERI site, on June 12th, 13th and 14th with the LI-1800 portable spectroradiometer. A detailed report on this campaign is under preparation.

The site, Puechabon is located in the South East of France, near Montpellier and is a 3km by 3km Mediterranean forest mainly composed of oak, box trees, and thyme. The data was collected during the week of June 10-15, 2001.

A. *Sampling Strategy*

The measurements were taken within the 9km^2 site. The measurements began by walking 50 meters south of the road (arrow points to road) and then 40 meters into the vegetation, where the first measurement was taken. From this first point, AccuPAR and LAI-200 measurements were taken every four meters for the next 20 meters in the same direction.

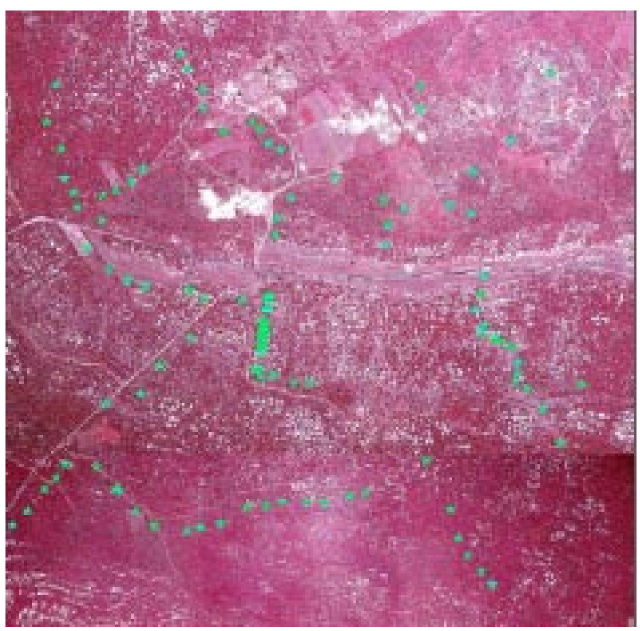


Figure 1. Puechabon site sampling. Each green star corresponds to the path of within the 20 meter transects where the measurements were taken (Aerial picture IFN, 07/15/1992)

Figure 2. Sampling strategy for local measurements. The transect is 20m long with four acquisitions at each point, which are four meters apart.

B. *Radiation measurements*

<u>Incoming Radiation Fluxes</u>

From June 11th to 15th, 2001, the LI-1400 Data Logger was programmed to record downward PAR (in µmol $m^{-2}sec^{-1}$) and SWR (in Wm^{-2}) fluxes every second from 5am to 10am at the house located in St. Martin de Londres, France. At the same time, a BF2 device acquired downward diffuse PAR (µmol $m^{-2}s^{-1}$). This instrument was located at the same place as the LI-1400 Data Logger.

Table1. Measurement Types and Location

	Plot number												
	1	2	3	4	5	6	7	8	9	10	11	12	MELODY
LAI	+	+	+	+	+	+	+	+	+	+	+	+	
FPAR	+	+	+	+	+	+	+	+	+	+	+	+	+
Leaf Spectral Transmittance								+		+			+
Leaf Spectral Reflectance								+		+			+
Canopy spectral Transmittance								+		+			+
Canopy Spectral Reflectance													
Soil Spectral Reflectance								+		+			+

C. *Leaf and Canopy Spectra*

Using the LI-1800 and ASD, measurements were collected on June 12th, 2001, in the morning and evening and on June 13th, 2001, in the morning, on the top of the MELODY[1] project tower to measure incident radiation and radiation reflected by vegetation canopy. These measurements were also taken on the canopy ground to measure canopy spectral transmittance. Ten leaves were cut during the June 12th, 2001 evening measurements and the spectral transmittance and reflectance of adaxial and abaxial leaf sides were measured in laboratory conditions, approximately two hours later with the LI-1800 and the LI-1800-12 external integrating sphere. The leaves were divided into five groups with respect to their location in the canopy space (sun leaves and shaded leaves) as well as with respect to their age (current year, 1 year, older than one year) and the following 5 groups were created:

SC – Sun leaves of current year;
S1 - 1-year-old sun leaves;
DC- Shade leaves of current year;
D1 –1-year-old shade leaves;
DO – Shade leaves, older than 1 year

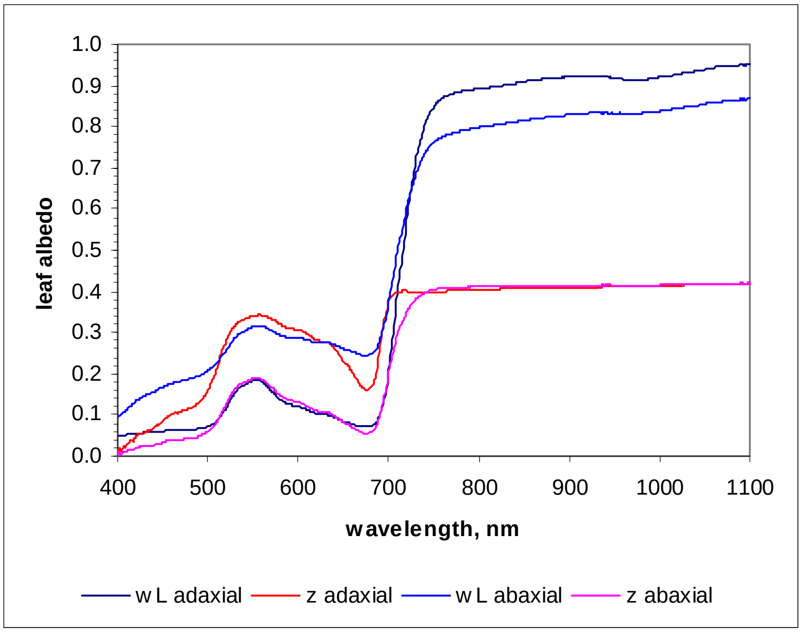


Figure 3. Mean spectral leaf albedo wL and ratio *z* of leaf reflectance to leaf albedo of 1-year-old shade leaf.

On June 14th, spectral upward and downward radiation fluxes were measured at an 40m x 40m area near the plot 8 and plot 10 where AccuPAR measurements were taken. Several leaves from these sites were cut and their optical properties were measured in laboratory conditions, approximately two hours later with the LI-1800 and the LI-1800-12 external integrating sphere.

[1] MEditerranean Landscape in a changing wOrld: coupling DYnamic and functional analyses (http://melody.cefe.cnrs-mop.fr/)

Performance of the MODIS LAI/FPAR algorithm:

A. *Temporal inconsistency in MODIS data*:

Day-to-day differences in LAI can be large in MOD15A1. For example, in the images of the southeastern U.S. (Fig. 4) several pixels have absolute LAI differences of approximately 6.0 between days 307 and 308. These differences tend to be prevalent where the algorithm pathway changes from one day to the next (e.g, note upper-right quadrant in the images below). However, large differences also occur where the algorithm pathway is consistent, usually where the empirical backup rather than the radiative transfer algorithm is used.

B. *Explanations*:

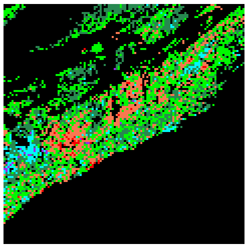
There are several factors causing day-to-day variations in LAI:

Uncertainties in surface reflectance product. This refers to the main algorithm which is sensitive to uncertainties in BRF. Ideally, atmospherically corrected canopy reflectance of a given pixel should not vary over several days. Day-to-day variations in LAI produced by the primary algorithm are proportional to the uncertainty in the MODIS surface reflectance product (MOD09). The main algorithm fails if uncertainties in surface reflectances exceed 20%.

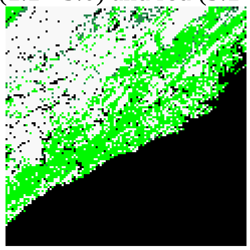
Differences in LAIs caused by the use of different algorithms (RT vs. empirical backup). This is the case when the algorithm attempts to retrieve LAI using cloud-contaminated data. The main algorithm mainly fails in this case, while the backup algorithm produces low values of LAI.

To verify this hypothesis a data set consisting of 29 pairs of consecutively dated A1 tiles were used. A difference $\Delta LAI = LAI_{main} - LAI_{backup}$ was calculated for every pixel where the two days were marked cloud-free, one day was produced with the main LUT algorithm and the other produced through the back-up NDVI based algorithm. Plotting these differences against the value of the main algorithm shows that as they increase, the back-up values increasingly lag behind (Fig. 5). For all these curves, $\Delta LAI \approx LAI_{main}$ (i.e. $LAI_{backup} \approx 0$). Little variation in physical condition of land cover can be expected on a 1 x 1 km scale over a 24-hour period. Therefore, the causes of variations in LAI values will be due to changes in the atmosphere. The main algorithm fails when the pixel's reflectance data are corrupted due to clouds or atmospheric effects. NDVI, in these cases, is close to zero, therefore, the backup algorithm outputs low LAI values. Further evidence of the sensitivity of the main LUT algorithm to cloud contamination can be seen in the distribution of QA values by latitude (Fig. 6). The main algorithm fails more often over tropical latitudes where there is frequent cloud cover.

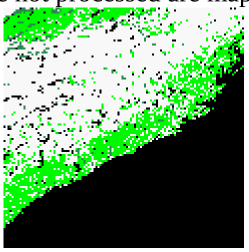
Thus, cloud mask affect the LAI/FPAR retrievals. However, QA values can help user to discriminate between reliable and unreliable retrievals.



(MOD15A1.A2000307.h11v05.002.2000345134046.hdf -
MOD15A1.A2000308.h11v05.002.2000349233453.hdf)
SDS: Lai_1km
(Differences of zero and unprocessed pixels are mapped in black. Increases in LAI are mapped in sea-green (0.1 - 1.0), cyan (1.1 - 3.0) and purple (3.1 - 5.8), and decreases are mapped in green (0.1 - 1.0), coral (1.1 - 3.0) and red (3.1 - 4.8))



(MOD15A1.A2000307.h11v05.002.2000345134046.hdf)
SDS: FparLai_QC
(Pixels for which the empirical backup has been used (ok quality) are mappped in white, pixels for which the radiative transfer algorithm has been used are mapped in sea green and green (quality ok and best, respectively),and pixels that are not processed are mapped in black, including water.)



(MOD15A1.A2000308.h11v05.002.2000349233453.hdf)
SDS: FparLai_QC
(Pixels for which the empirical backup has been used (ok quality) are mappped in white, pixels for which the radiative transfer algorithm has been used are mapped in sea green and green (quality ok and best, respectively),and pixels that are not processed are mapped in black, including water.)

Fig. 4 Temporal inconsistency in MODIS data

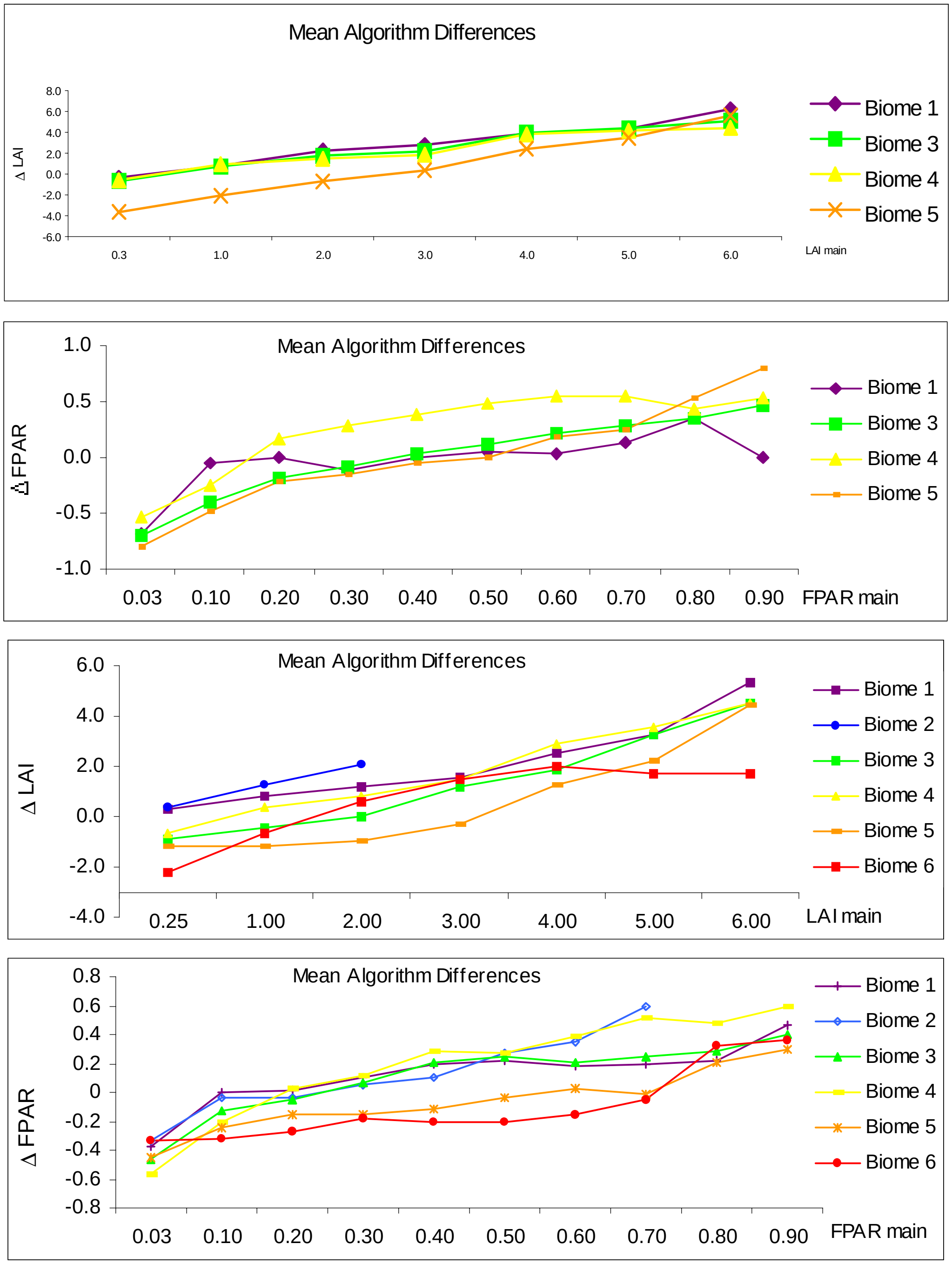


Figure 5. Differences between values produced by the main and by the back-up algorithm as a function of values from the main algorithm. Data derived from MOD15A1 tiles (top 2) for 6 pairs of days for 2 tiles from central Africa and (bottom 2) a pair of days using 17 tiles over the North and South American continent.

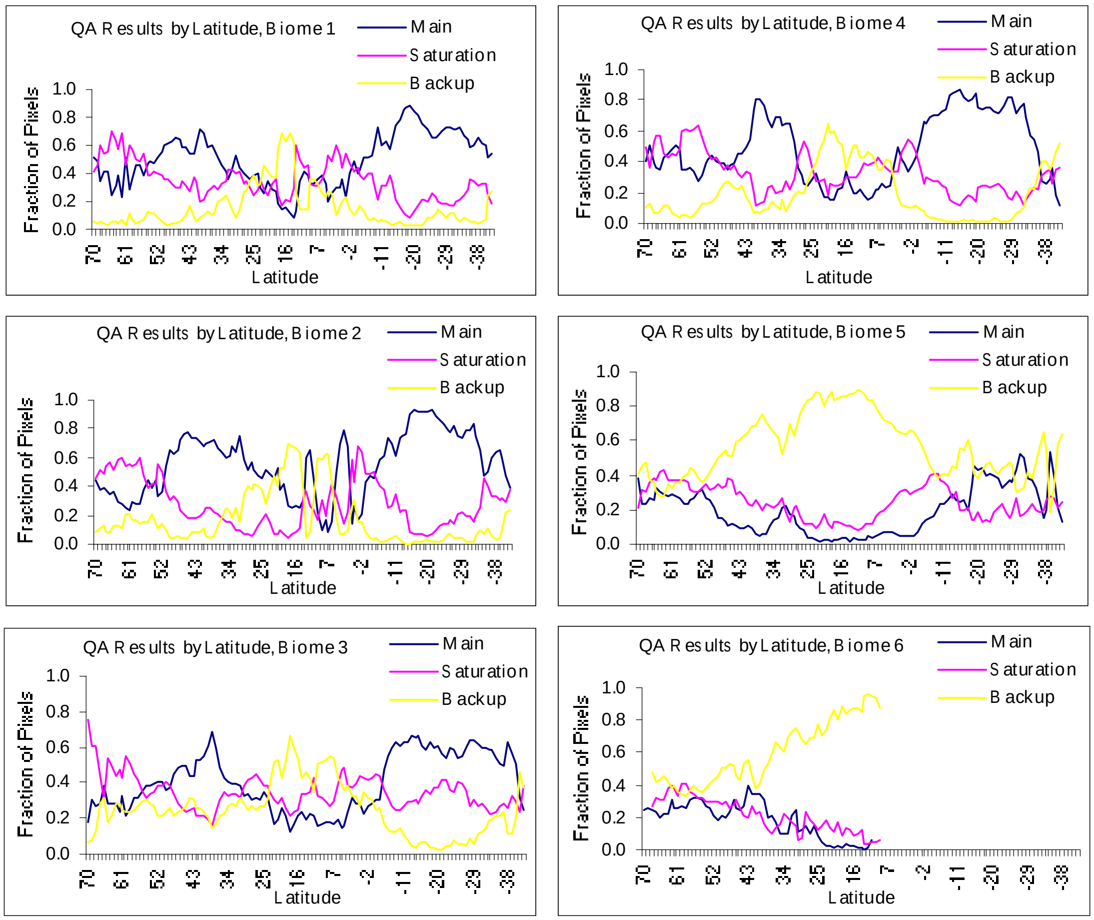


Figure 6. Average QA value of pixels as a function of latitude. Each chart is an average of the values from four A2 global coverage periods, whose initial dates are 6/25, 7/19, 8/20 and 8/28. For each degree of latitude all pixels in each QA condition, that were marked as 'not cloudy, are divided by the total number of non-cloudy pixels for that biome at that latitude.

<u>Publications:</u>

- Yuhong Tian, Yujie Wang, Yu Zhang, Yuri Knyazikhin, Jan Bogaert and Ranga B. Myneni, Radiative transfer based scaling of LAI/FPAR retrievals from reflectance data of different resolutions. *Remote Sens. Environ*. (submitted Apr. 2001).
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- B. Combal, F. Baret, M. Weiss, A. Trubuill, D. Mace, A. Pragnere, R. Myneni, Y. Knyazikhin and L. Wang, Retrieval of canopy biophysical variables from bi-directional reflectance: Using prior information to solve the ill-posed inverse problem, *IEEE Trans. Geosci. Remote Sens*. (submitted Jan 2001).
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- Lyapustin, A. and Knyazikhin, Y., Method of Green Function in the Radiative Transfer Problem. Part I: Homogeneous non-Lambertian Surface. *Applied Optics* (accepted Mar 2001)