MODIS SEMI-ANNUAL REPORT: JUL/01/98 - DEC/31/98

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

Contract: NAS5-96061

J. Knjazihhin, Y. Zhang, Y. Tian, N. Shabanov, and R. B. Myneni

Geography Department, Boston University, 675 Commonwealth Avenue, Boston, MA 02215

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 their 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.

Summary of work performed during the second half of 1997 (July through December)

- Prototyping of the MODIS version of the algorithm with three months of atmosphere corrected SeaWiFS data (Oct trough Nov 97), two years of weekly composite of atmosphere corrected AVHRR data from 1989 and 1990 (the LASUR data set) and 6 scenes of atmosphere corrected LANDSAT data has been finalized. Articles summarizing this activity are currently in preparation. The prototyping results were delivered to S. W. Running and included in his presentation at the MODIS Science Team Meeting, Dec 15-16, 1998.
- Prototyping of the MISR version of the algorithm with POLDER (Polarization and Directionality of the Earth's Reflectance) data. An article devoted to the analysis of how the use of multi-angle information can improve LAI and FPAR products is currently in preparation. Some preliminary results were presented at the MISR Science Team Meeting, Dec 14-16, 1998.
- The MISR version of the algorithm was modified and delivered to JPL.
- MOD15 Product Accuracy/Uncertainty document has been finalized and added to the MODIS Standard Data Product Catalog.
- A strategy to validate the LAI/FPAR product based on the information theory was developed and presented at the MODIS LAI/FPAR Validation Meeting in Boston, Oct 12-13, 1998.
- Theoretical aspects of the retrieval techniques for geophysical parameters were presented at the International Forum on BRDF in San Francisco, Dec 11-12, 1998.
- A special Look-up-Table for modeling the BRDF effect in atmospheric correction of MODIS data was created and delivered to co-MODIS PI E. Vermote.
- Several methods to adjust configurable parameters in the algorithm to improve the performance of the algorithm with real MODIS and MISR data were developed.

Electronic versions of the presentations at the Oct 12-13 MODIS LAI/FPAR Validation Meeting, Dec11-12 International Forum on BRDF and Dec 14-16 MISR Science Team Meeting as well as two papers describing theoretical basis of the LAI/FPAR algorithm are available at http://cybele.bu.edu/download/download/download.html.

The prototyping activities are a valuable means of testing the physics of the algorithm, and also constitute the first step towards establishing the validity of the algorithm. The goal of these activities is to understand the behavior of the algorithm as a function of spatial scale and uncertainties in input data, optimal combination of wavebands, and to develop guidelines for validation of the algorithm. Based on our prototyping results, a strategy to validate LAI and FPAR products was developed. It involves a set of activities directed at validating important aspects of the algorithm. This report contains results on prototyping the MISR version of the algorithm. Also, some illustrations demonstrate various aspects of our validation strategy.

Data used

POLDER (Polarization and Directionality of the Earth's Reflectance Instrument) data set at 6.17 km resolution includes atmospherically corrected canopy reflectances in twelve view direction at blue (443nm), red (670nm) and near-infrared (865nm) wavelengths. Data acquired mainly over Africa from November 1 to November 16, 1996 were used in our prototyping activities. Figure 1 demonstrates the distribution of numbers of BRDF (bidirectional reflectance distribution function) observations during this period. To minimize uncertainties in surface reflectances, a composited POLDER data set based on maximum NDVI was created. The composited data set was used as input to the algorithm.

Hot Spot

Figure 2 demonstrates mean angular distributions of canopy reflectances about principal plane for different biome types, sun angles and spectral bands. Averaging were performed over all available pixels from each biome type. A number of pixels for which the accumulated angular reflectances were about the principal plane made up 12% of the total number of available pixels. One can see that the hot spot effect was not available for a per pixel processing.

Data Density Plot

In our data analysis we evaluate the data density distribution function. Its definition is very simply: specify a fine cell in the spectral space; count number of canopy reflectances in this cell; divide this value by the total amount of points. The data density distribution function was evaluated for each biome type and for different seasons. Figure 3 shows location of points of high density for different biomes and in different spectral spaces. An area bounded by the contour contains 25% of pixels from a given biome type. One can see that they tend to occupy certain well localized spaces in the spectral space. Each data cluster separates the most probable canopy realizations. This obvious fact was used to test the algorithm. For example: derive 25% data cluster for biome 5 (Broadleaf Forests) which corresponds to the most green season; run the algorithm using canopy reflectances from this data cluster; compare the most probable value of LAI derived from the LAI/FPAR algorithm with ones reported in literature. An analysis of the data density distribution functions derived from MODIS data and field measurements is included

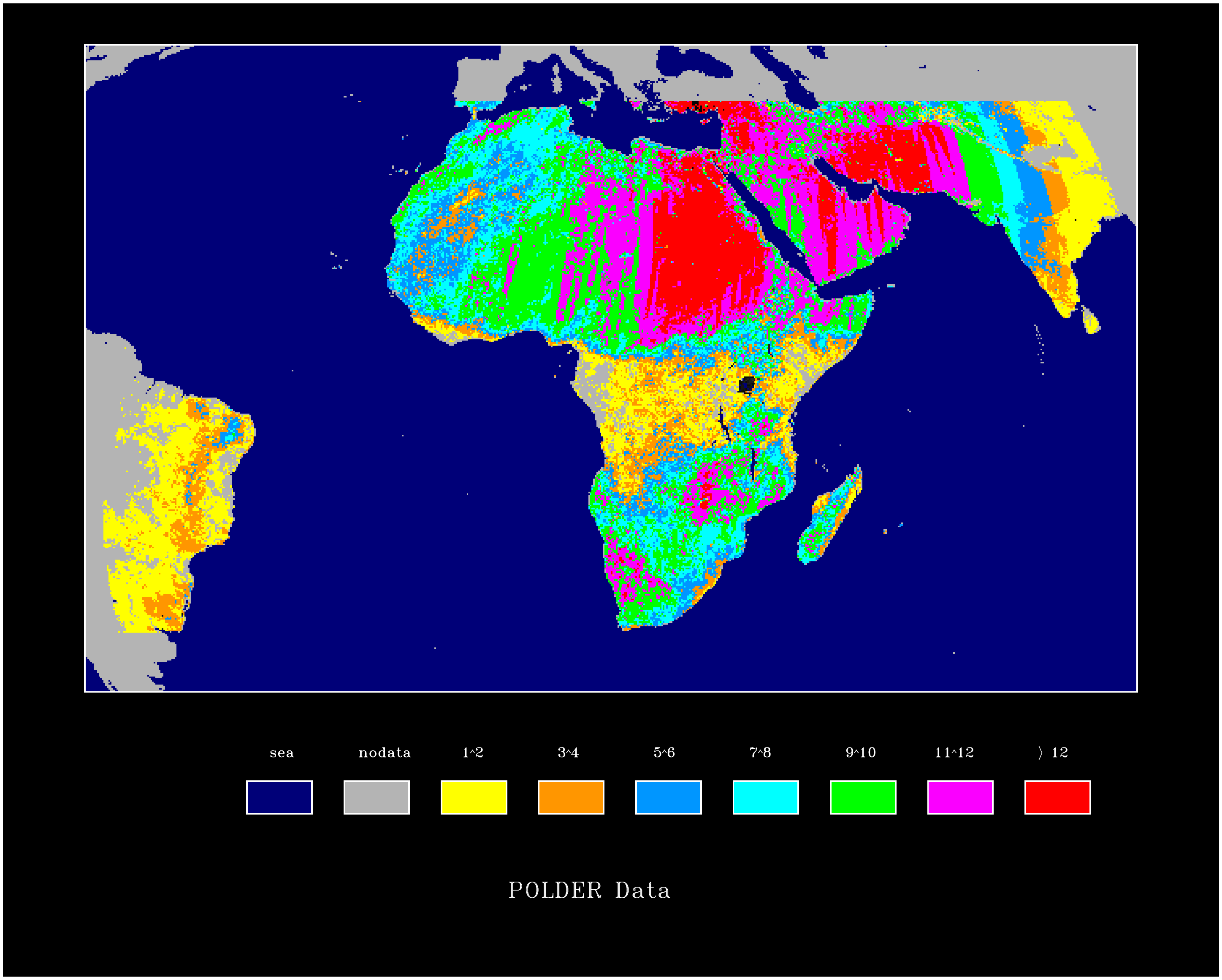

Figure 1. Distribution of numbers of BRDF observations during the period from November 1 to November 16, 1996.

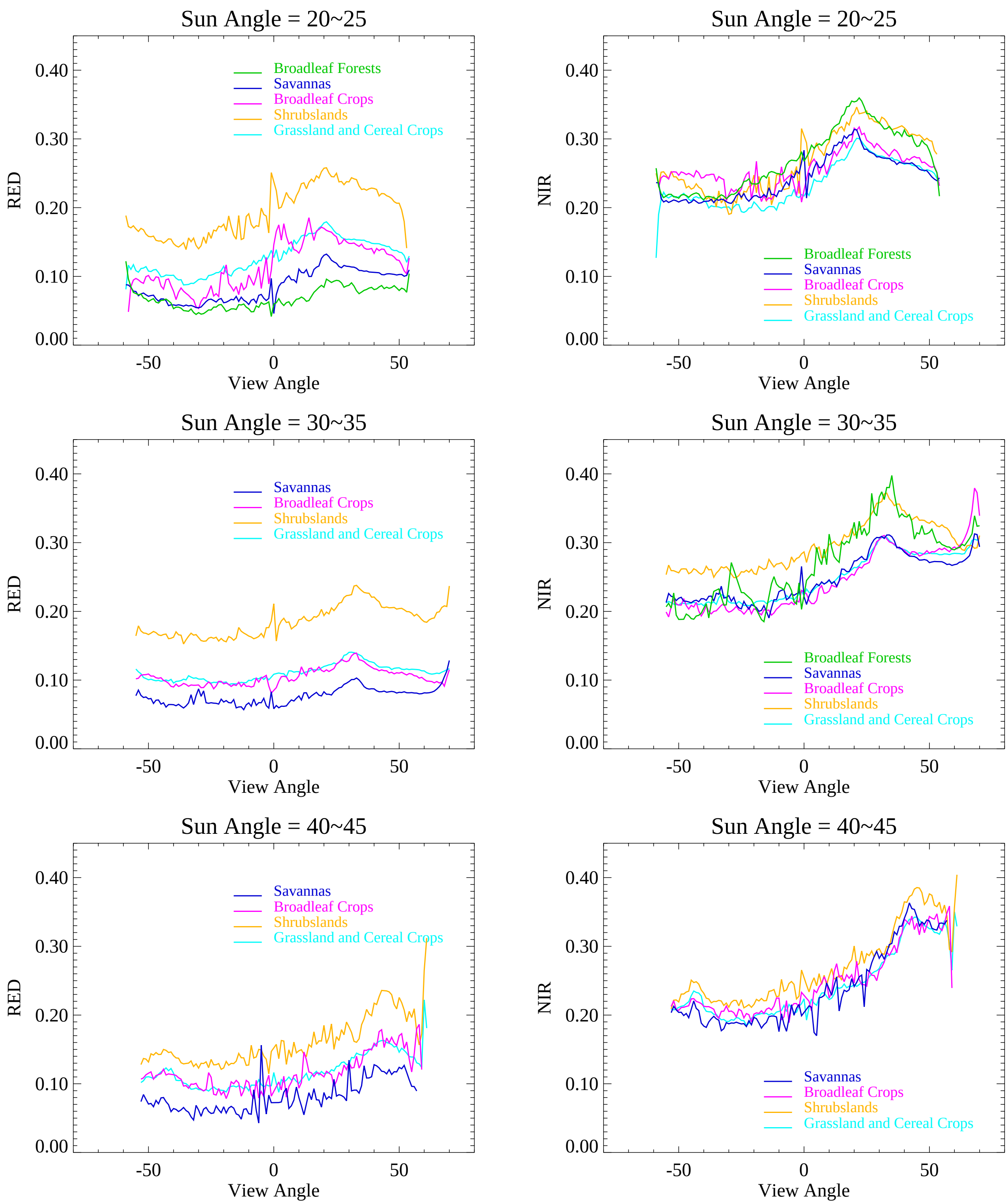

Figure 2. Mean angular distribution of canopy reflectances about principal plane for different biome types, sun angles and spectral bands.

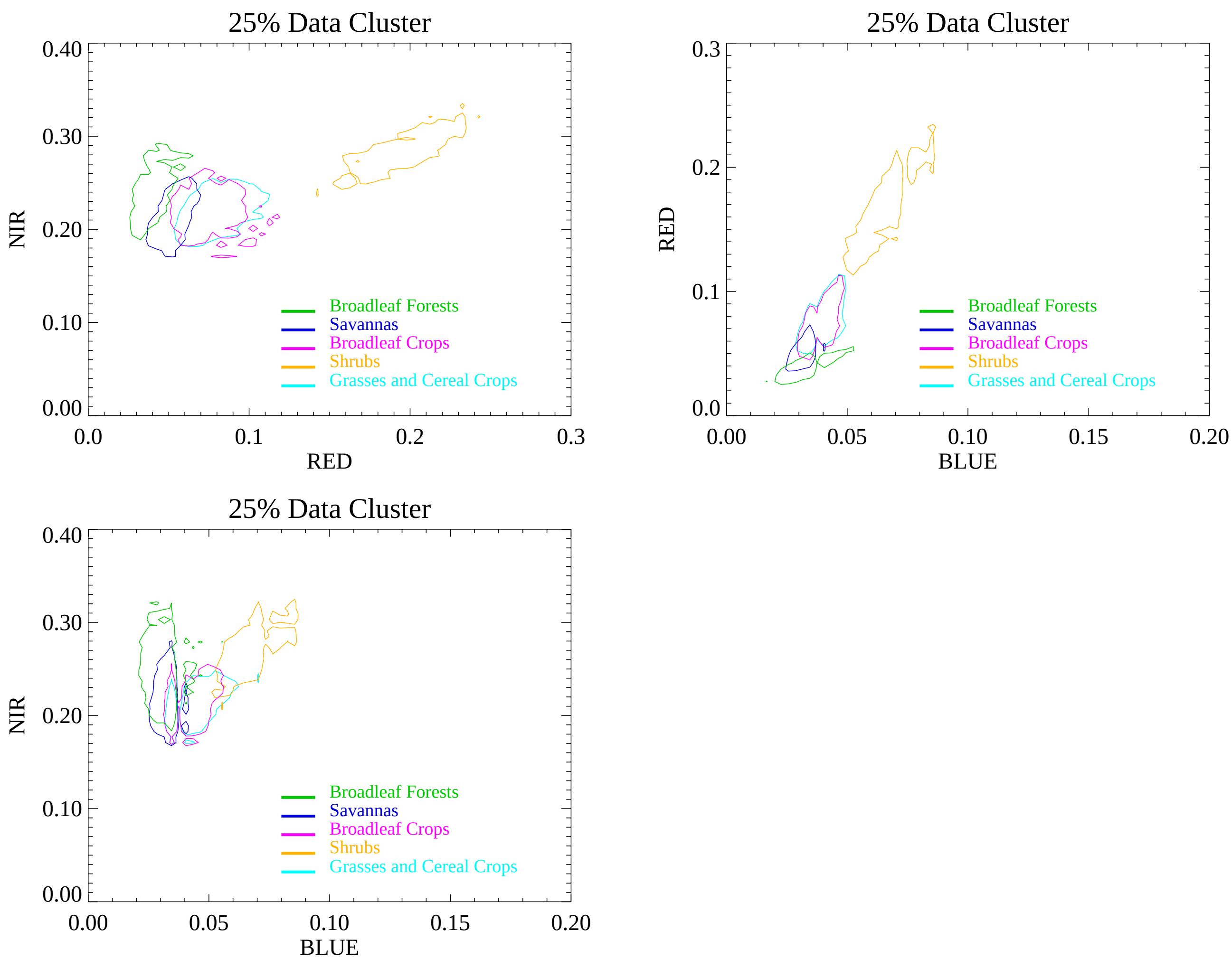

Figure 3. The POLDER data density distribution function. Areas bounded by the contour contains 25% of pixels from given biome type.

in our validation program (see our presentation at the Oct 12-13 MODIS LAI/FPAR Validation Meeting, test #3).

Execution of the algorithm

It may be the case that the main algorithm produces no solutions. The following characteristics of the main algorithm are introduced. A pixel for which the algorithm retrieves values of LAI and FPAR is termed a successful pixel. A pixel for which the main algorithm does not produce LAI value is termed an unsuccessful pixel. The ratio of the number of successful pixels to the total number of pixels is the success index. The success index increases with the increase of uncertainties in surface reflectances. However the quality of LAI/FPAR product decreases in this case (MODIS Quarterly Report, # 6; JAN/01/98 – MAR/31/98).

In order to investigate the synergy of the LAI/FPAR retrieval technique, we run the algorithm for each vegetated pixel three times, using surface reflectances in one (near-nadir), six and twelve view directions, respectively. This scheme prototypes the execution of the algorithm in MODIS-only and joint MODIS/MISR modes of operation. Figure 4 demonstrates the dependence of the success index on the uncertainties in the surface reflectances for various biome types and numbers of view directions used. Uncertainties in canopy reflectances viewed in the nadir directions were minimal for the composited POLDER data. Inclusion additional angular information, however, results in the increase of uncertainties in measured data that, in its turn, tends to decrease the quality of the LAI/FPAR product. A question then arises of weather or not the LAI/FPAR algorithm is capable to account for this tendency and take advantage of multi-spectral and multi-angle instruments. The affirmative answer to this question is demonstrated in the next sections of this report.

LAI values under condition of saturation

It may be the case that the LAI/FPAR algorithm admits a number of solutions, covering a wide range of LAI values. When this happens, the canopy reflectances are said to belong to the saturation domain, being insensitive to the various parameter values characterizing the canopy. The algorithm produces a LAI value in this case. However its reliability is low. The algorithm can recognize this situation and reports its occurrence by assigning a special value to the QA parameter. Figure 5 demonstrates the frequency of LAI values retrieved under condition of saturation as a function of uncertainties for various biome types and numbers of view directions used. One can see that the use of multi-angle information results in decreasing the LAI values under condition of saturation. This is the evidence that the synergistic MODIS/MISR LAI/FPAR algorithm can take advantage of multi-spectral and multi-angle instruments. The saturation domain can be specified from field measurements. Therefore, a validation of this aspect of the algorithm is included in our validation program (see our presentation at the Oct 12-13 MODIS LAI/FPAR Validation Meeting, test #5).

LAI-NDVI relationship

Figure 6 demonstrates the NDVI-LAI regression curves (MODIS Semi-Annular Report, #7; JAN/01/98 – JUN/30/98) for various biome types and numbers of view angles used. The use of single-angle information results in poor retrieval of the biome 2 (Shrubs) regression curve.

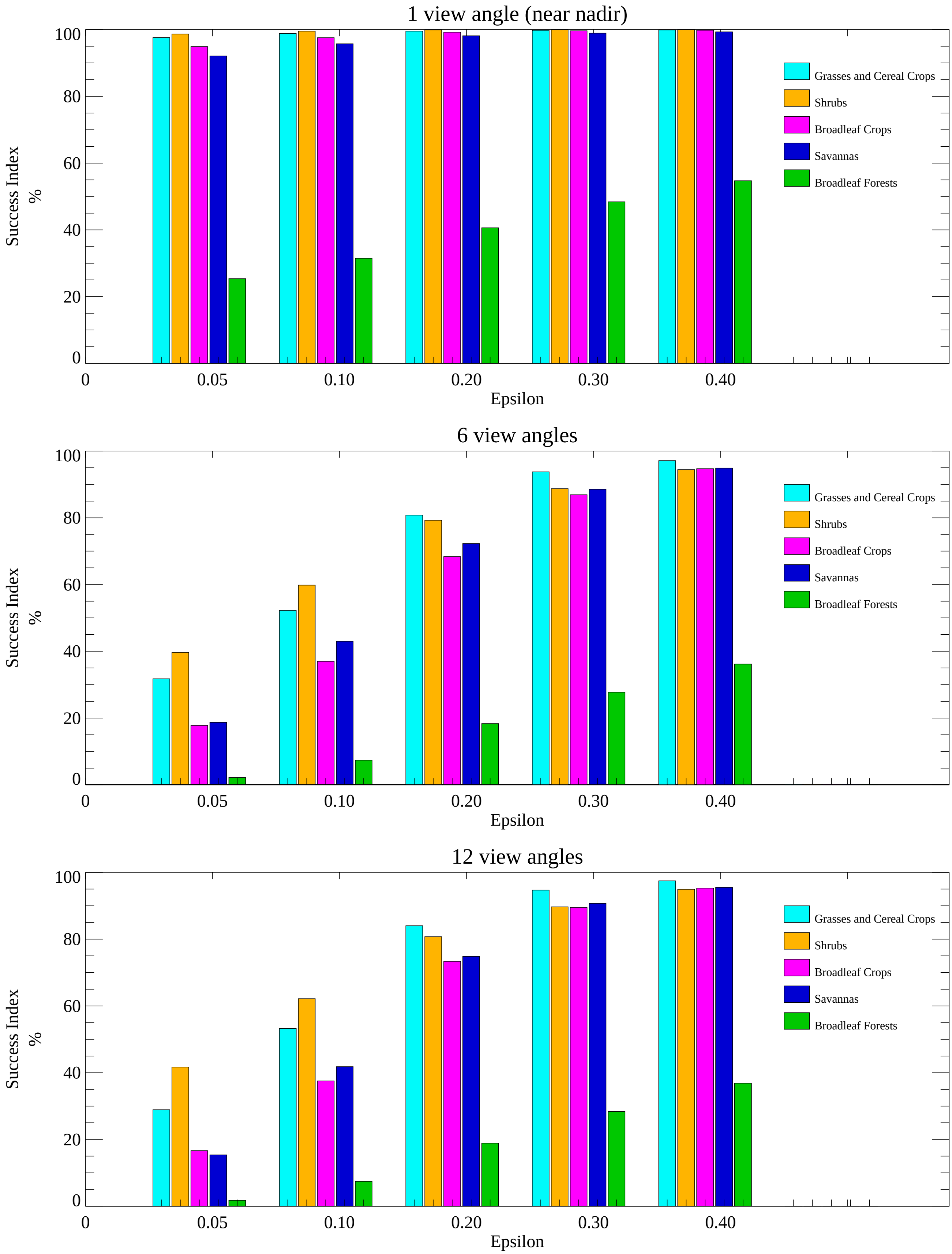

Figure 4. Dependence of the success index on the uncertainty for various biome types and numbers of view directions.

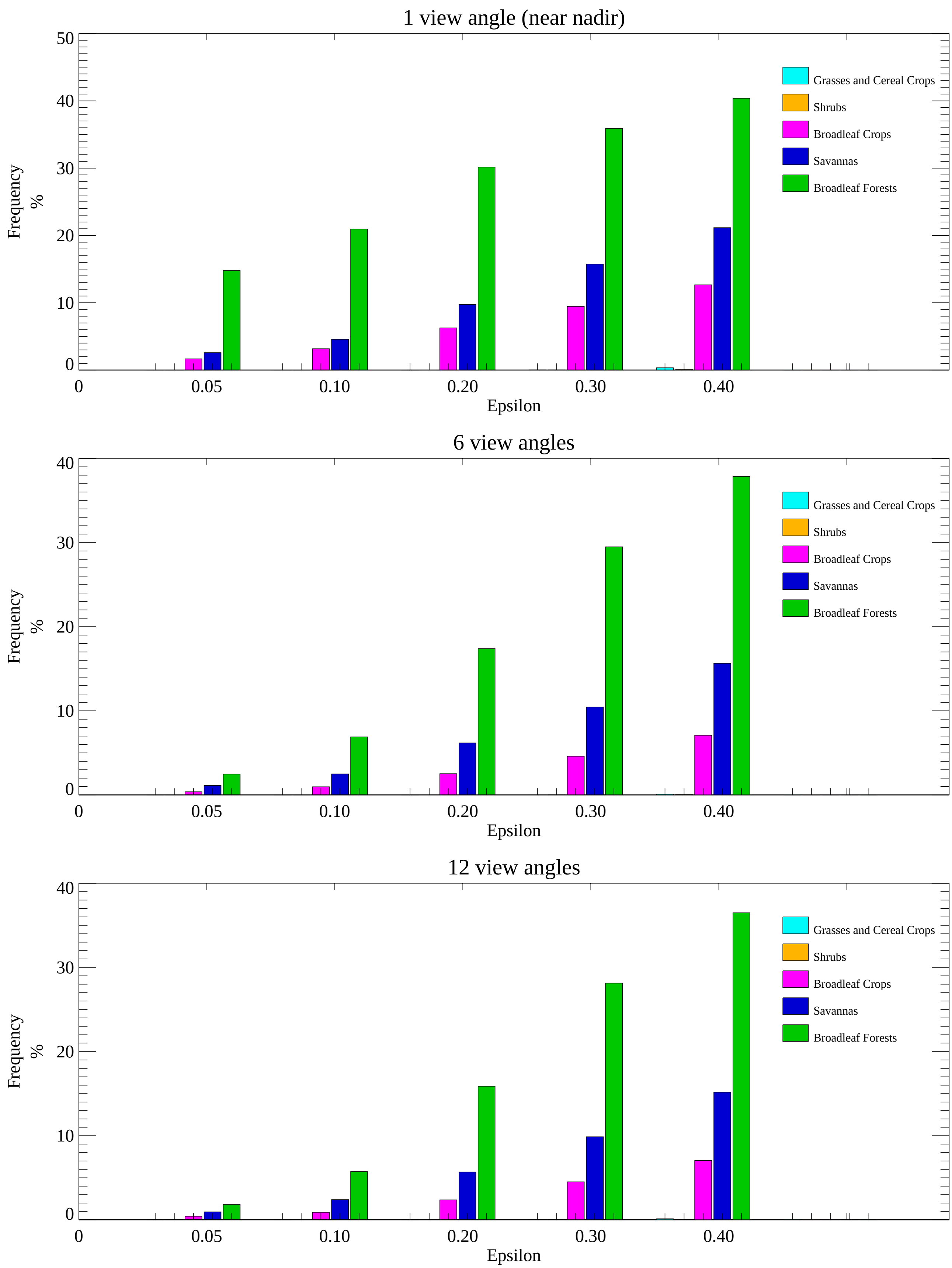

Figure 5. Frequency of LAI values retrieved under condition of saturation as a function of uncertainty and number of view directions.

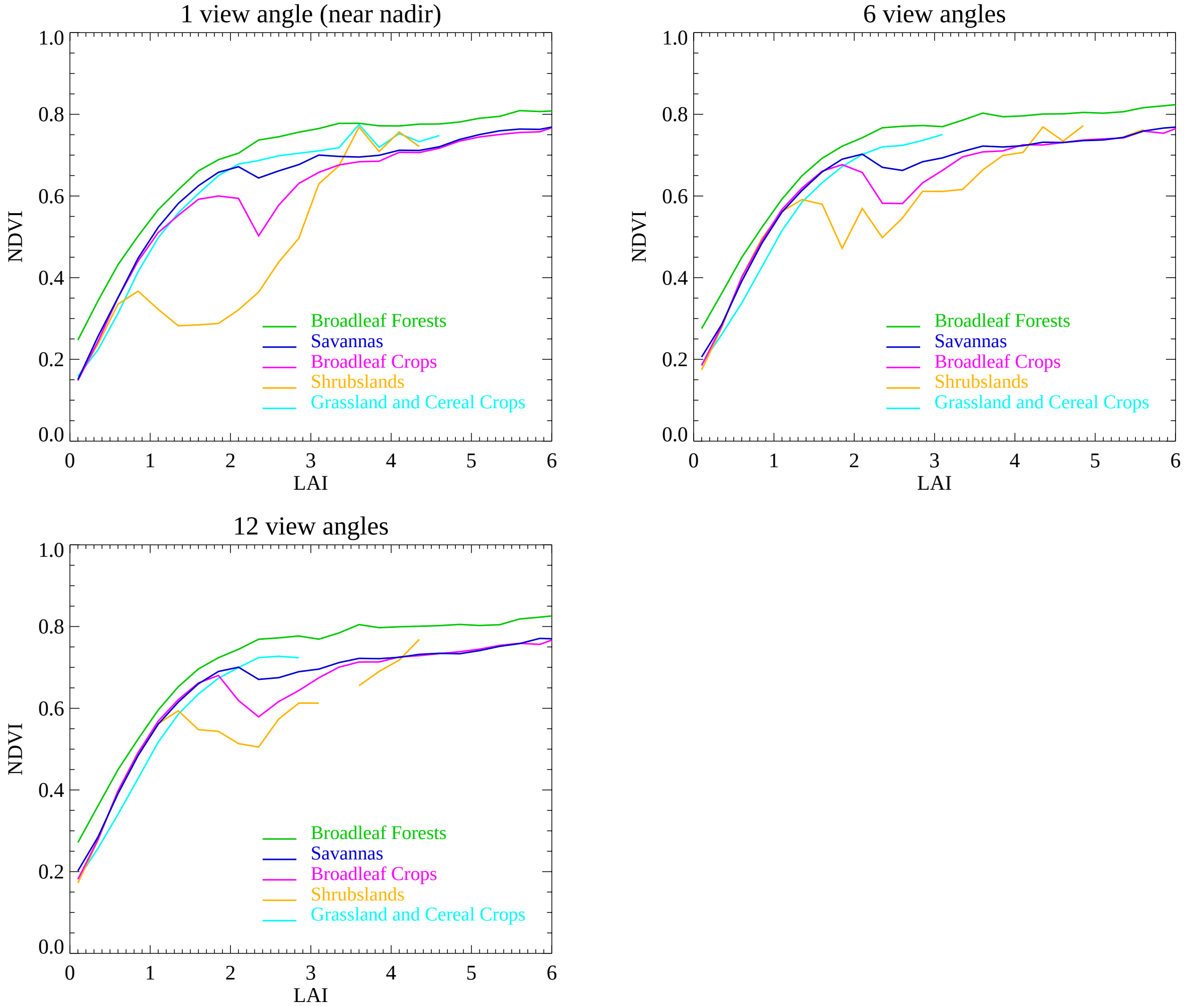

Figure 6. The NDVI-LAI regression curves for various biome types and numbers of view directions.

This biome type exhibit lateral heterogeneity, low to intermediate vegetation ground cover and bright background. Therefore, the information conveyed about canopy structure by surface reflectances at low resolution is small (definition of “information conveyed about LAI by canopy reflectances” is presented at the Oct 12-13 MODIS LAI/FPAR Validation Meeting, test #5; evaluation of this characteristic is included in our validation program). However the use of multi-angle information tends to improve the accuracy of LAI retrievals. This can be taken as the evidence that the synergistic MODIS/MISR LAI/FPAR algorithm takes advantage of multi-spectral and multi-angle instruments.

LAI-NDVI relationships derived from various data sets

Figure 7 demonstrates the NDVI-LAI regression curves derived from two years weekly composite of atmosphere corrected AVHRR data from 1989 and 1989 (the LASUR data set), the composited POLDER data and from Myneni’s analysis of 14 year AVHRR NDVI data set. These curves show similar trends. The data density distribution functions of POLDER and LASUR data sets are added here for better illustration of the correlation between LAI values and location of points of high density; that is, the closer their location to the NIR axis the higher are the most probable values of LAI.

Distribution of LAI and FPAR over Africa

The MISR LAI/FPAR algorithm was applied to the composited POLDER data. Figures 8 and 9 show the color-coded images of distribution of LAI and FPAR over Africa.

Conclusions

- Results from prototyping of the LAI/FPAR algorithm with POLDER data demonstrate that spectral and angular information are synergistically used in the extraction of LAI and FPAR.

- The quality of the retrievals can not be better than the quality of the worst spectral BRDF, if uncertainties in spectral canopy reflectances are not available.

- The use of multi-angle information results in decreasing the frequency of LAI values retrieved under a condition of saturation.

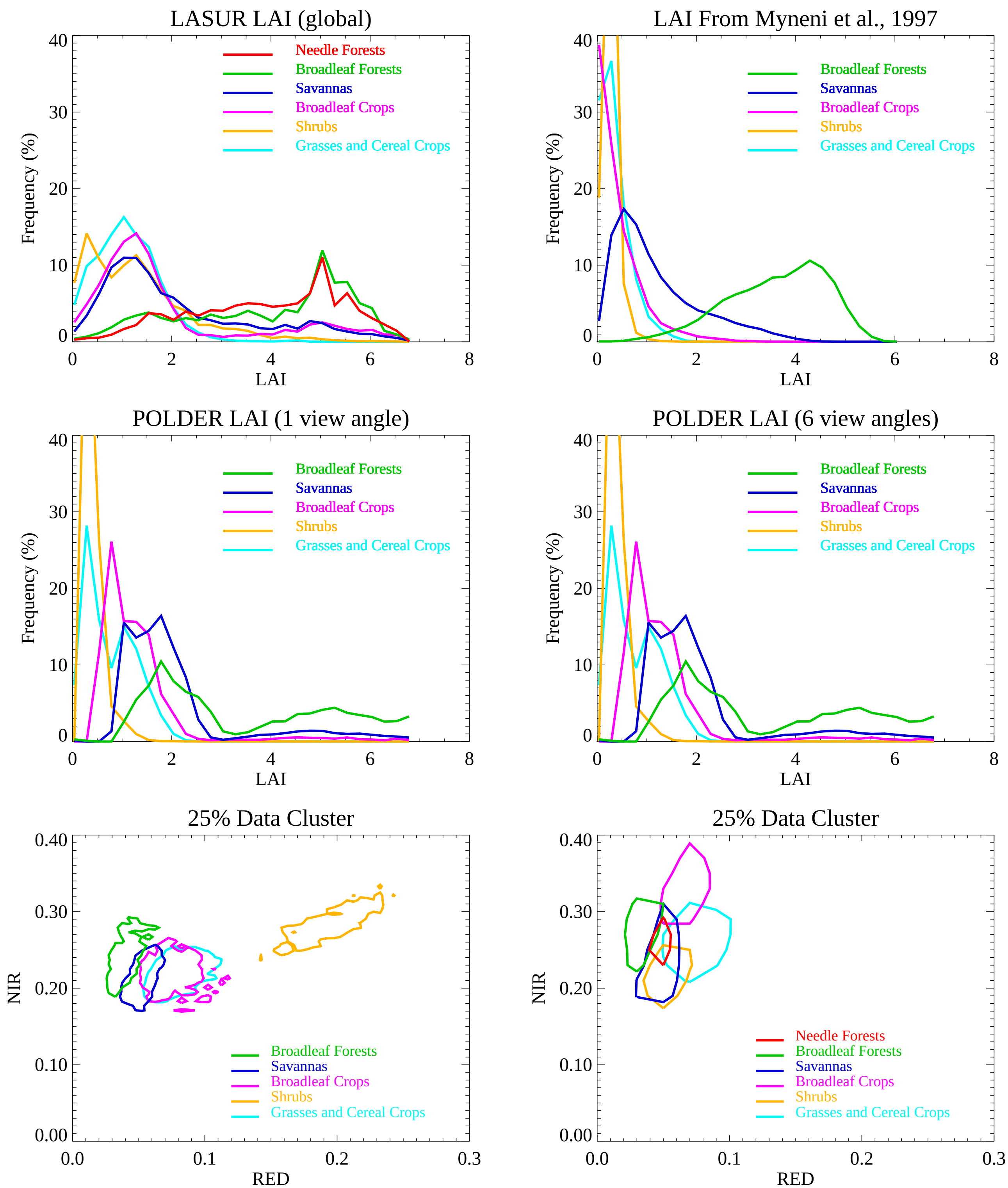

Figure 7. NDVI-LAI relationships derived from LASUR, POLDER and AVHRR NDVI data sets.

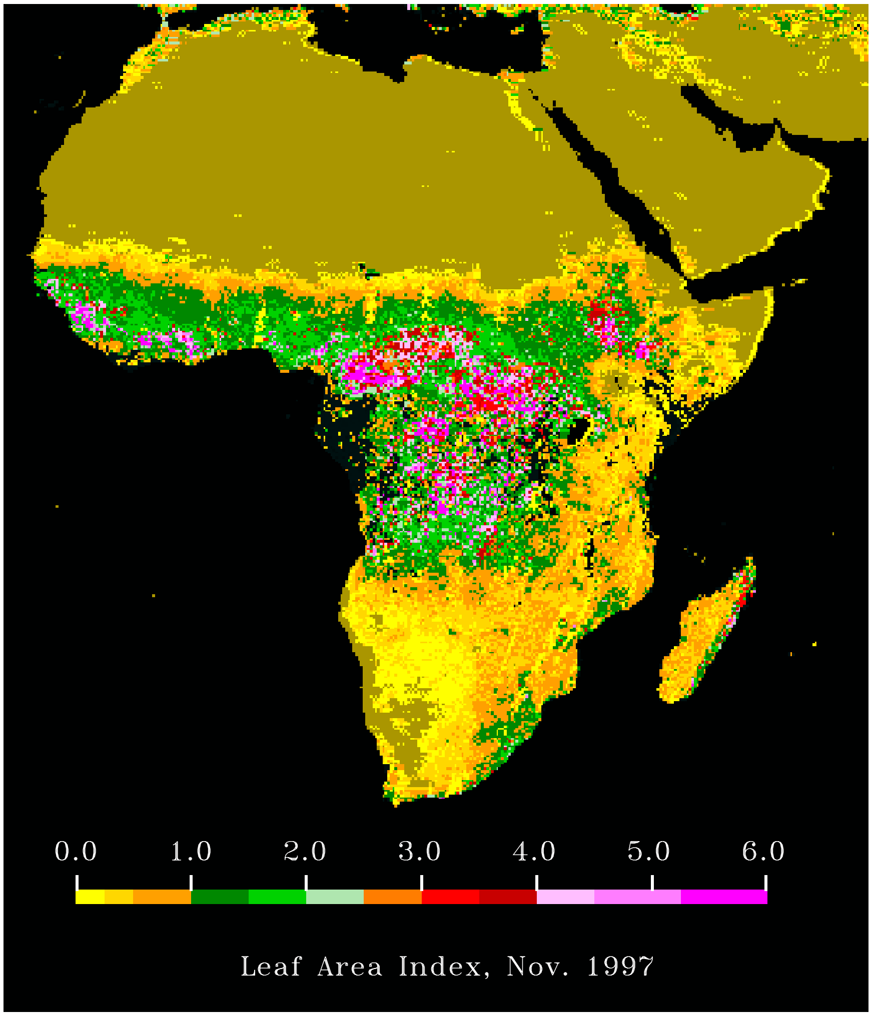

Figure 8. Distribution of LAI values over Africa.

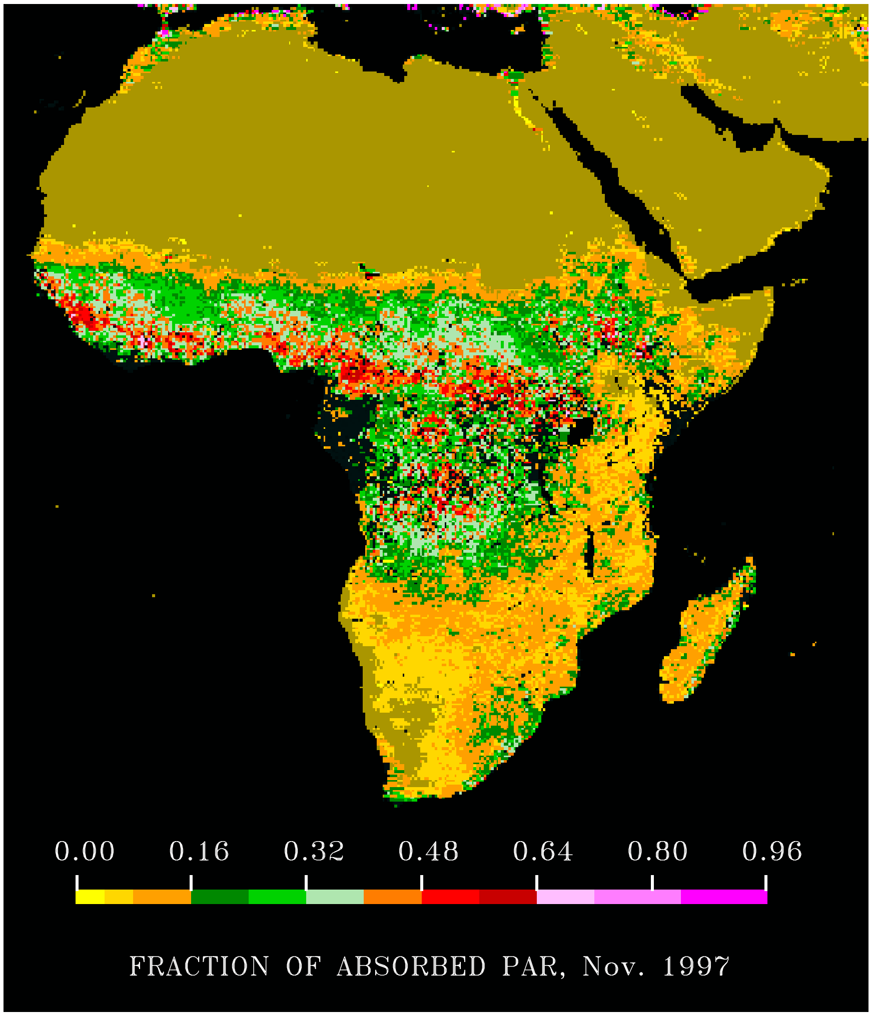

Figure 9. Distribution of FPAR values over Africa.