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

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

(Contract: NAS5-96061)

N. Shabanov, Y. Wang, G. Smith, Y. Knyazikhin, 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 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 second half of 2001 (July through December):

- Participation in the Harvard Forest Field Campaign, August 1-8, 2001. Data needed for validation of the LAI/FPAR product were collected and archived. Preliminary analysis of data has been performed.
- Paper describing results on validation of the LAI/FPAR product using the Harvard Forest 2000 field data has been submitted for publication in RSE.
- Second paper describing results on validation of the LAI/FPAR product using SAFARI 2K field data has been submitted for publication in RSE.
- Data collected during the VALERI 2001 field campaign, Alpilles, France, February 26-March 15, 2001, has been analyzed. A paper describing results on validation of the LAI/FPAR product using VALERI 2001 field data is under preparation.
- Comparison of LAI and FPAR fields over Africa derived from MODIS and MISR data has been performed.
- Evaluation of the utility of satellite based vegetation leaf area index data for climate simulations has been performed.
- Talk at the 4th International GEWEX meeting, Paris, France, September 10-14, 2001.
- Talk at the Phenology Conference, Wageningen, The Netherlands, December 5-7, 2001.
- Talk at the MISR Science Meeting, Pasadena, December 5-7, 2001.
- Poster at the AGU meeting, San-Francisco, December 10-14, 2001.
- Talk at the MODIS Science Meeting, Baltimore, December 17-19, 2001.
- NASA LAI/FPAR Press Release, December 20, 2001 (Release NO 01-126).

Field Campaign

The Boston University MODIS/MISRLAI/FPAR Team hosted a field validation campaign 1-8 August, 2001, at the Harvard Forest LTER in Petersham, Massachusetts. Researchers from the BU MODIS BRDF/Albedo, BU MODIS Land Cover, the JPL MISR Parabola, and the University of Arizona MQUALS teams are participated in this field campaign. The Harvard Forest is a 3,000-acre site, located 42.5382^0 North and 72.1714^0 West, in Petersham, Massachusetts, USA. The site has a transition land cover dominated by mixed hardwood and conifer forests, ponds, extensive spruce and maple swamps. Harvard Forest is well known for its long history of scientific research focused on monitoring natural disturbances, environmental change and human impacts. This site was selected for several recent major field campaigns: BigFoot, Flux Network (FLUXNET), Global Landcover Test Site Initiative (GLCTS), Long-Term Ecological Research (LTER); it is also an EOS core validation site. Objectives of the Harvard Forest 2001 Field campaign were to collect data needed for validation of the MODIS LAI/FPAR, BRDF/Abedo, Land Cover and EVI products; 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 transmittance were made using the LAI-2000 plant canopy analyzer, AccuPAR ceptometer, LI-1800 ASD handheld spectroradiometer. Optical property measurements of leaves from the dominant overstory species were also made on August 7-8 with the LI-1800-12 (external integrating sphere). MQUALS Aircraft overflights on August 6, 2001 acquired hyperspectral reflectance of the Harvard Forest. A 30 m crane was used to collect data on canopy reflectances over selected patches using the ASD, LI-1800 and Parabola instruments.

Sampling Strategy

Based on an analysis of ETM+ images of the Harvard Forest, 20 patches of 120 by 120 m were selected to collect data on LAI, FPAR, canopy hemispherical transmittance, and leaf spectra. 15 patches were delimited by a matrix of 3 rows labeled “1-3” and 3 columns, labeled “A-C”, for a total of 9 points. Thus, each grid-centered point was located 30 m from its neighbors. The columns were oriented north to south, with rows running perpendicularly. Five patches were laid out at a finer resolution, containing 6 rows labeled “1-6” and 6 columns, labeled “A-F”, for a total of 36 points. Data were acquired with ASD, LAI-2000, LI-1800 and AccuPAR ceptometers at each grid cell.

Preliminary Results: *Hierarchical Analysis of Multiscale Variation in LAI andNDVI Data*

A key to scaling process in remote sensing is to understand the magnitude of the effects resulting from processes acting at different scales in the landscape. Nested-hierarchical models can be used to partition variance in an image at different levels. Each level in the hierarchy corresponds to a different scale. In a forested landscape, for example, the most fundamental element might be individual trees. The next level might be patches or stands of trees. All patches of the same kind would combine to form forest classes, which would be a third level in the hierarchy. These different forest types might then combine to form a general class of forest, which exists with other classes at this level, such as grassland, water, savannas. Therefore, each successive level in the hierarchy is more general and is formed by combining elements from the level below.

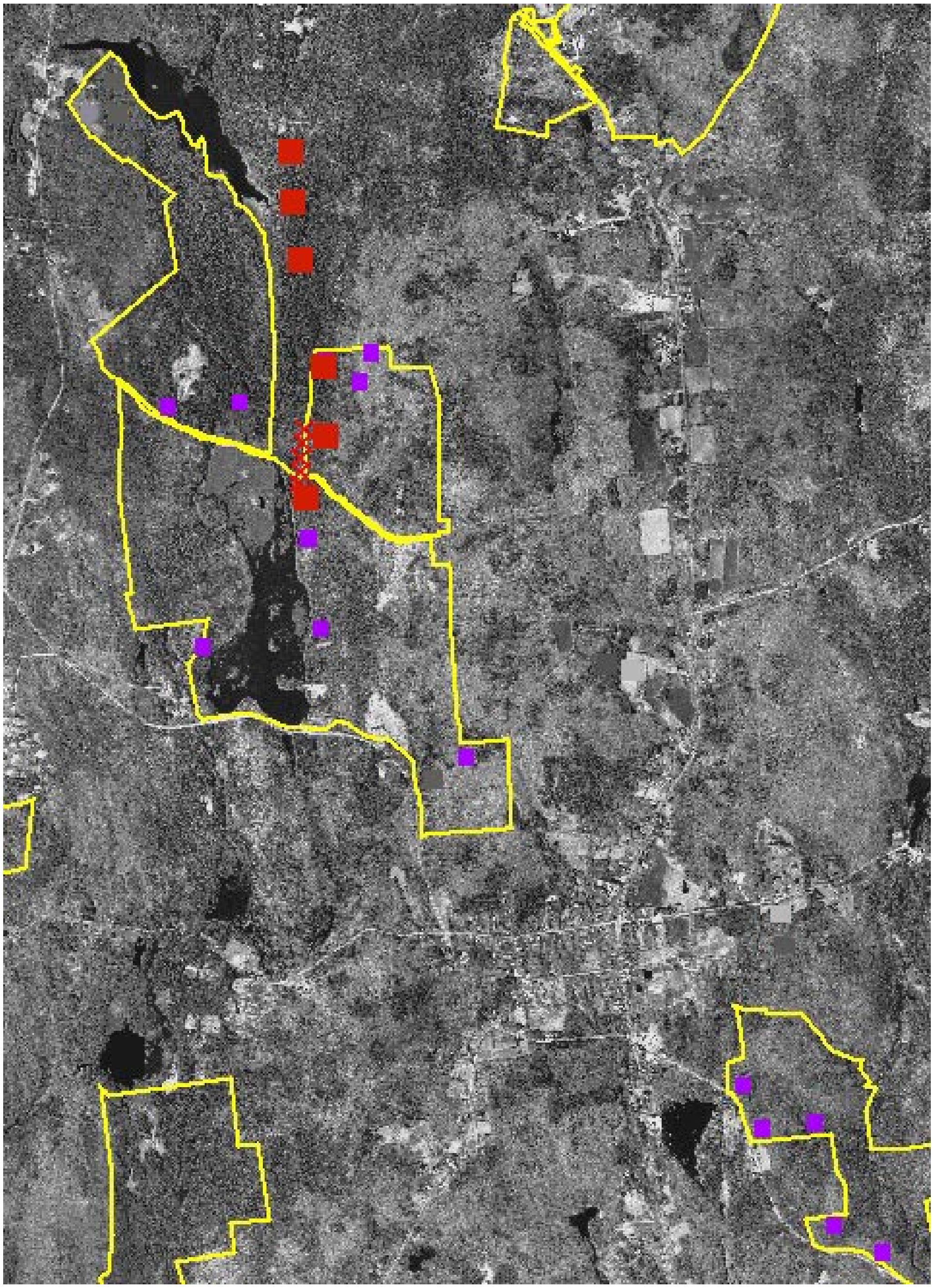

Figure 1. Distribution of patches in the Harvard Forest. The pathway of a 30m crane with ASD, LI-1800 and Parabola instruments is shown as red cross symbols. Fine and coarse resolution patches are depicted as red and pink squares, respectively.

The decomposition of variance for the Harvard Forest site is listed in Table 1, and the variograms of the three-level hierarchy are shown in Figure 2. The majority of variation, 59.66% in the NDVI data and 76.55% in the LAI data, is at the scale of classes. Both the region and pixel effect are relatively small. For both the NDVI and LAI data, the pixel variograms reach their sill at about 60 m and remain flat for all larger lags. The range for the class effect is about 500 m, which is roughly twice that of the region scale.

The class effect contributes more variance (76.55%) in the LAI data than the NDVI data (59.66%). The variance of the region effect decreases to 11% in the LAI data, compared with 26.17% in the NDVI data. The relatively higher variance of the class effect indicates that there are large differences between the means of different land cover types. For example, broadleaf forests have mean LAI values as large as 5, compared to zero LAI values for water or bare land. Thus, the LAI values at this site depend heavily on the land cover types to which the pixels belong. Within a vegetation type, the LAI variation among pixels is only about 23.45%. Hence LAI at the Harvard Forest site is relatively homogeneous within classes, but varies strongly among classes.

Table 1. Hierarchical Model Results for the Harvard Forest Scenes

Scene	Image	Variance	Percentage of Variance (%)
NDVI	Original image	0.008365	100
	Class effect	0.004991	59.66
	Region effect	0.002189	26.17
	Pixel effect	0.001185	14.17
LAI	Original image	2.7476	100
	Class effect	2.1032	76.55
	Region effect	0.3147	11.45
	Pixel effect	0.3296	11.99

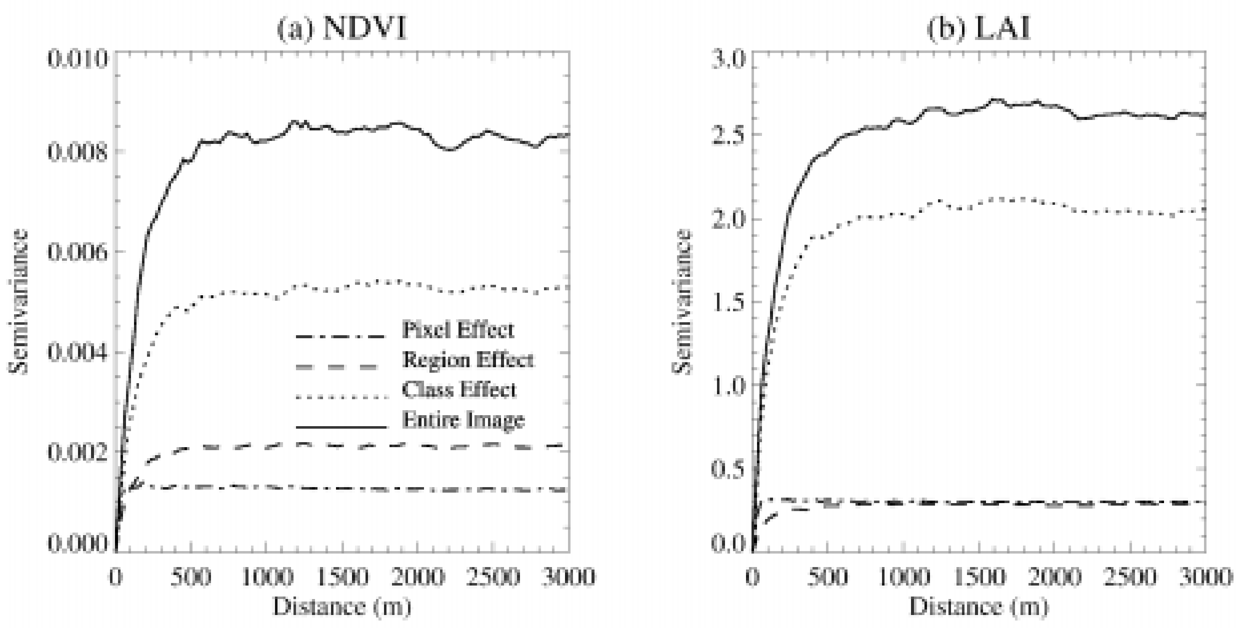

Figure 2. Hierarchical decomposition of variograms for (a) NDVI and (b) LAI of the Harvard Forest site.

Validation of the MODIS LAI/FPAR Algorithm with Data from the Harvard Forest 2000 Field Campaign

The MOD15A2 product in Integerized Sinusoidal Grid projection at 1 km resolution was used for validation purposes. The Harvard Forest is located in the tile h12v04, line 895 and sample 818 (WWW 1). We selected a 5x5 pixel area centered on the Harvard Forest for comparison purposes. We used all available clear-sky composites from June to September of 2000, as the leaf area at the site did not change appreciably after maximum leafing in June. The LAI/FPAR retrievals are from one of the three algorithmic flows: (1) values produced by the main algorithm, and not saturated, (2) values produced by the main algorithm but under a condition of saturation, (3) main algorithm failed; the reported values are from the NDVI-based back-up algorithm. Saturation denotes the situation when surface reflectances are insensitive to LAI. For validation purposes, we used values produced by the main algorithm only and maximized the number of unsaturated pixels. According to these criteria, the composite for days 241-248 (August 28-September 4, 2000) was selected, where 5 of the 25 pixels were unsaturated.

A significant portion of the LAI retrievals utilized in this validation exercise is comprised of retrievals obtained under condition of saturation, that is, the surface reflectances were insensitive to LAI. Therefore, LAI cannot be retrieved with high accuracy, unless the algorithm is given more information, typically in the form of multi-directional reflectance data. As a result, saturation was frequently encountered at LAI values greater than 3.5. In this case, the algorithm reports saturation in the QC flags and estimates the lower boundary of possible LAI variation, LAI_{min}, but reports the most probable value, that is, the average of LAI_{min} and the maximum LAI of the LUT which is 7.

The distribution of LAI values collected in the field and retrieved from ETM+ and MODIS reflectance data are shown in Fig. 3a. The corresponding mean values are 5.09+/-0.76; 4.49+/-0.85; 5.64+/-0.34, respectively. In this plot, note that the set of retrieved values contains unsaturated as well as saturated values, resulting in bimodal histograms; the peak with higher LAI represents saturated values. The MODIS LAI distribution has a strong peak of saturated values. Thus, the algorithm had insufficient information for accurate retrievals. Nevertheless, it was possible to identify the saturation domain correctly, as can be determined from the QC flags. The correspondence between the mean values may be deemed satisfactory. The disagreement between field and MODIS retrievals is 11%, which is well below the specification (20%).

Our previous analysis indicates that the solar zenith angle (SZA) dependency of FPAR can be ignored in dense heterogeneous canopies. The FPAR retrievals from the algorithm were validated in a manner similar to LAI. The FPAR distributions from BigFoot, ETM+ and MODIS are shown in Fig. 3b. The corresponding mean values are 0.962+/-0.03; 0.836+/-0.06; 0.918+/-0.01, respectively. The largest discrepancy is between ETM+ and BigFoot data (~0.1), possibly because the field measurements were based on a good sampling of canopy transmittances and poor sampling of canopy reflectance. Consequently, FPAR is likely to be overestimated. The disagreement in the case of MODIS fields is less than 4.5%, which is satisfactory, and below the specification (10%).

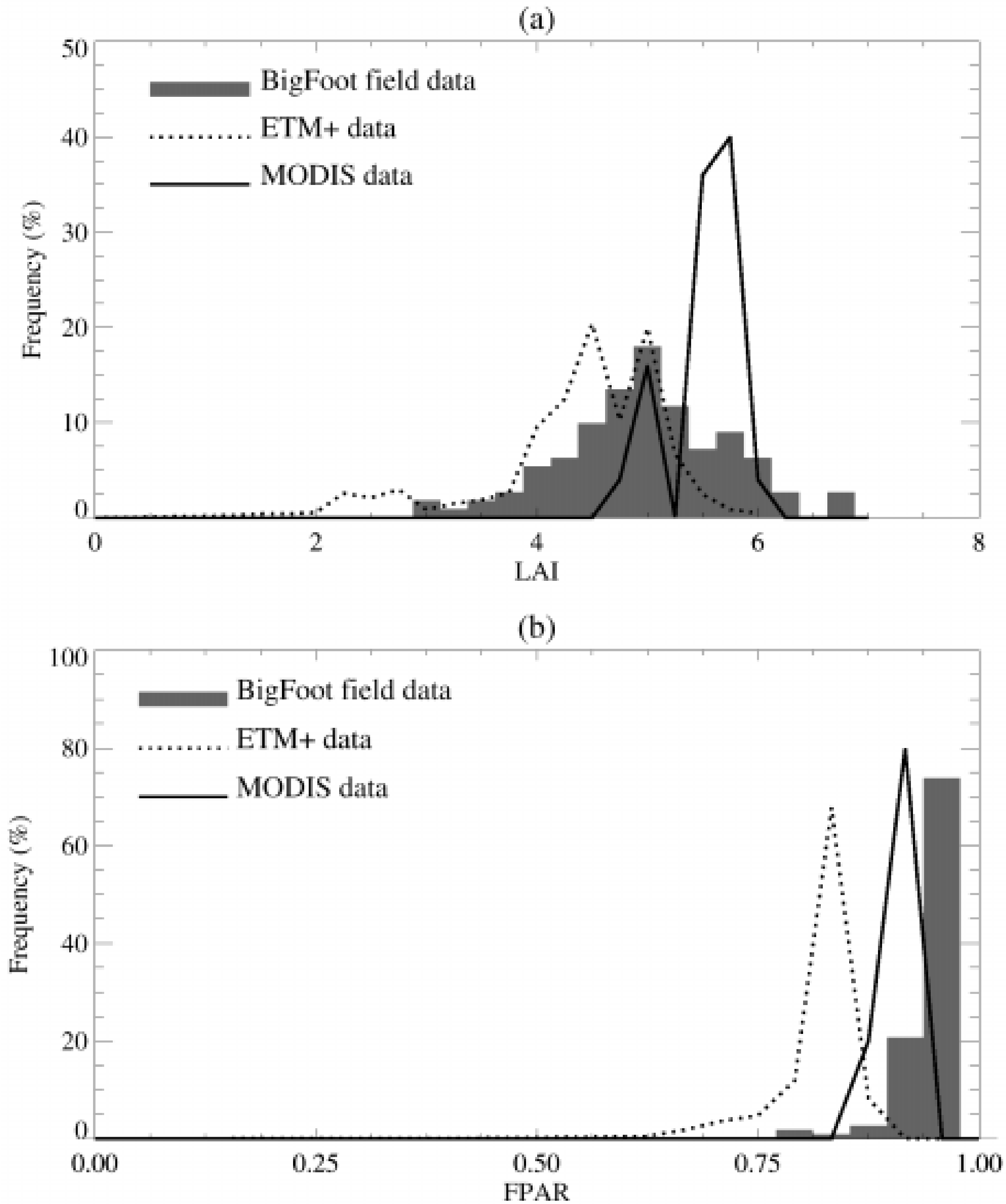

Figure 3. Panel (a) shows LAI histograms derived from the BigFoot data (shaded contour), ETM+ data (dotted line) and MODIS data (solid line). Panel (b) shows the same, but for FPAR.

Publications:

- MODIS instrument on NASA's Terra satellite improves global vegetation mapping, makes new observations possible, Earth Observatory, NASA News Archive, http://earthobservatory.nasa.gov/Newsroom/NasaNews/2001/200112206806.html.
- Shabanov, N.V., Y. Wang, W. Buerman, J. Dong, S. Hoffman, G.R. Smith, Y. Tian, **Y.** Knyazikhin, and R.B. Myneni, Validation of the radiative transfer principles of the MODIS LAI/FPAR algorithm with field data from the Harvard Forest, *Remote Sens. Environ*., 2001 (submitted for publication).
- Martonchik, J., J. Hu, Y. Knyazikhin, and R.B. Myneni, Surface reflectances and LAI/FPAR retrieval resilts from MISR, *IEEE Trans. Geosci. Remote Sens*., 2001 (submitted for publication).
- Tian, Y., C. E. Woodcock, Y. Wang, J. L. Privette, N. V. Shabanov, L. Zhou, W. Buermann, J. Dong, B. Veikkanen, T. Hame, M. Ozdogan, Y. Knyazikhin, and R. B. Myneni, Multiscale Analysis and Validation of MODIS LAI Product over Maun, Botswana, *Remote Sens. Environ*., 2001 (submitted for publication).