MODIS SEMI-ANNUAL REPORT: JUL/01/02 - DEC/31/02

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

(Contract: NAS5-96061)

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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 second half of 2002 (July through December):

- Adjustment of LAI/FPAR algorithm (PGE33/34) for Collection 4:
  a) new LUTs for main and back-up algorithm to improve consistency with field measurements reported by BigFoot,
  b) new compositing scheme for 8-days composits;
  c) incorporation of new biome landcover map (MOD12, layer 3);
  d) new qc scheme;
  e) miscellaneous bug fixes (fixes for fill value for SDS, fixes Dead detector problem, fixes to handle new MODAGG AggrQC, added FPAR_PCF_PROCESS_ENV variable as new metadata field)
- Analysis of Collection 3 Global LAI/FPAR data
- Field campaign in Flakaliden, Sweeden, June 24-July 10, 2002.
- Talk at the MODIS STM, 'MODIS LAI and FPAR Products: an Update on Status and Validation', Greenbelt MD, July 22-24, 2002.
- Talk at the IDU workshop 'A Benchmark Dataset of Multidimensional Earth Science Satellite Data for Testing of Learning Algorithms', Monterey, CA, September 4-6, 2002.
- Talk at NIST workshop, 'Long-term Monitoring of Global Vegetation from Space', College park, MD, November 12-14, 2002.
- Poster presentation at the EOS-IWG meeting, 'MOD15A2: MODIS Global LAI and FPAR', Ellicot City, MD, November 18-20, 2002.
- Poster presentation at the Fall AGU meeting, 'MOD15A2: MODIS Global LAI and FPAR', San Francisco, CA, December 6-10, 2002.

- Talk at the MISR STM, 'LAI/FPAR Algorithm: Status and Results', Los Angeles, CA, December 10-12, 2002.

Publications during reviewed period

- Wang, Y, Buermann, W., Stenberg, P., Voipio, P., Smolander, H., Häme, T., Tian, Y., Hu, J., Knyazikhin, Y., and Myneni, R.B., "A New Parameterization of Canopy Spectral Response to Incident Solar Radiation: Case Study with Hyperspectral Data from Pine Dominant Forest", Remote Sens. Environ., (accepted, Jan 2003)
- Shabanov, N., Wang, Y., Buermann, W., Dong, J., Hoffman, S., Smith, G., Tian, Y., Knyazikhin, Y., Myneni, R.B., "Effect of Foliage Spatial Heterogeneity on the MODIS LAI and FPAR Algorithm over Broadleaf Forests", *Remote Sens. Environ*., (accepted, Jan 2003).
- Buermann, W., Anderson, B., Tucker, J., Dickinson, R., Lucht, W., Potter, C., and Myneni, R.B., "Circulation anomalies explain interannual covariability in northern hemisphere temperatures and greenness", J. Geophys. Res. (accepted Dec 2002).
- Buermann, W., Wang, Y., Dong, J., Zhou, L., Zeng, X., Dickinson, R., Potter, C., Myneni, R.B., (2002), Analysis of a multi-year global vegetation leaf area index data set. J. Geophys. Res., 107(D22)
- Zhou, L., Kaufmann, R.K., Tian, Y., Myneni, R.B., Tucker, C.J., (2003), "Relation between interannual variations in satellite measures of vegetation greenness and climate between 1982 and 1999", J. Geophys. Res. 108(D1).

Adjustment of LAI/FPAR algorithm (PGE33/34) for Collection 4

Changes in Collection 4

- *Improved LUTs for the main and back-up algorithms for biomes 1 and 3 (PGE33)*

Benefits:
a) High quality retrievals have been increased by 10%
b) Non-physical peaks in the global LAI distribution have been removed
c) Improved agreement with field measurements (BigFoot data over ARGO and KONZ sites)

- *Improved QA scheme*

Benefits
a) Consistency between MODLAND and SCF_QC quality flags has been achieved
b) Interpretation of QA has been substantially simplified

- *At-launch static IGBP land cover, used as input to the LAI/FPAR algorithm, was replaced with the MODIS land cover map (MOD12Q1, layer 3)*

Benefits
a) Crosswalking of 17 classes IGBP scheme to 6-biome LC has been eliminated
b) Uncertainties in the MODIS LAI/FPAR product due to uncertainties in land cover map have been substantially reduced

- *Projection change from ISIN to SIN*

Benefits: Complies with Land team reprojection strategy

- *Fixed problem in daily product where 0's instead of Fill values were showing in between scans (pointed to by LDOPE)*

Benefits: Correctness of MOD15A1

- *New 8-day compositing scheme (PGE34/MOD15A2)*

Benefits:

a) Compositing over best quality retrievals, instead of all retrievals
b) Lowers LAI values, decreases saturation and number of pixels generated by the back-up

Remaining Issues

- *New compositing scheme and updated LUTs result in lower LAI values and increased retrieval quality of LAIs over biomes 1-3. Further analysis of MODAGG data to improve retrievals over biomes 4-6 is needed.*

- *What are the scientific issues at this point?*

a) Improve consistency with field data (more field sampling is needed)
b) Work on seasonality problems for needle leaf forests.

Expected Changes

- *Will adjust LUTs to decrease saturation and back-up retrievals for biomes 4-6 to improve agreement with field data*

- *Combined Terra/Aqua product (late Collection 4 or Collection 5)*

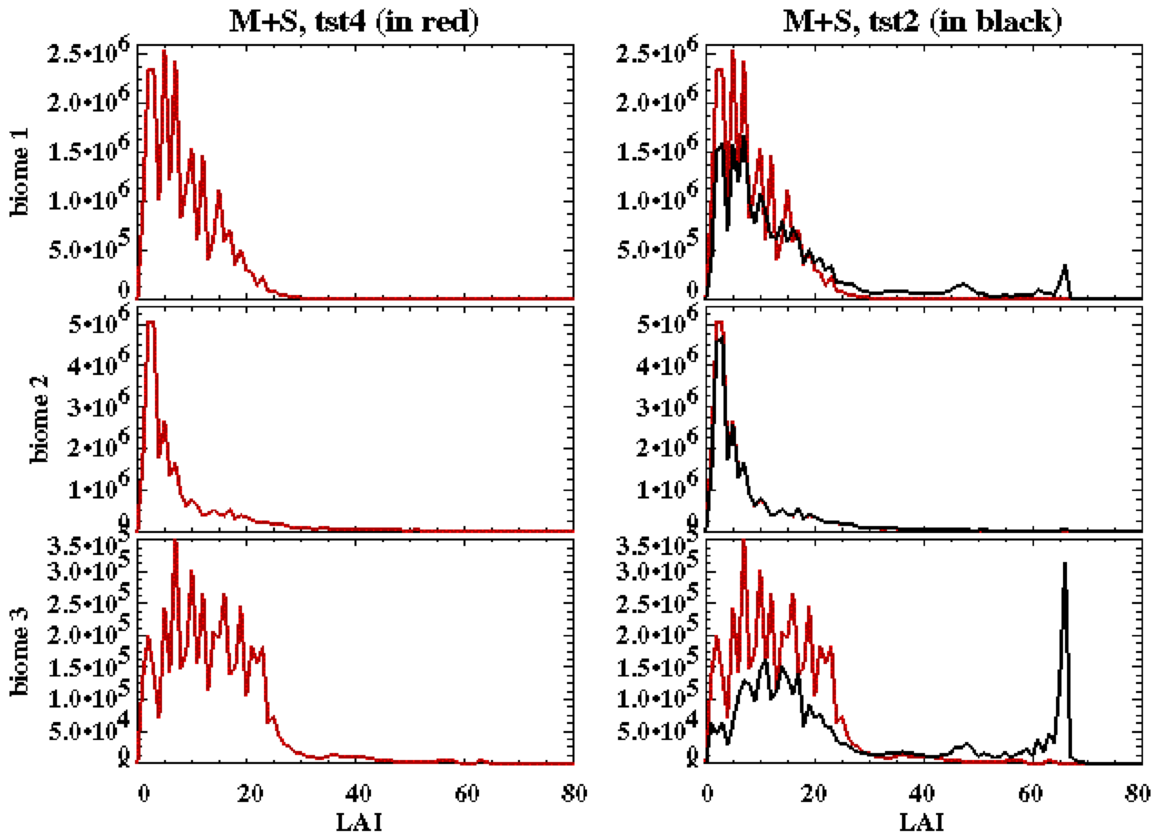

Figure 1: By tuning LUTs for main algorithm we decreased in collection 4 amount of pixels generated by main algorithm under condition of saturation for biome 1 and 3 (peaks with high LAI are eliminated).

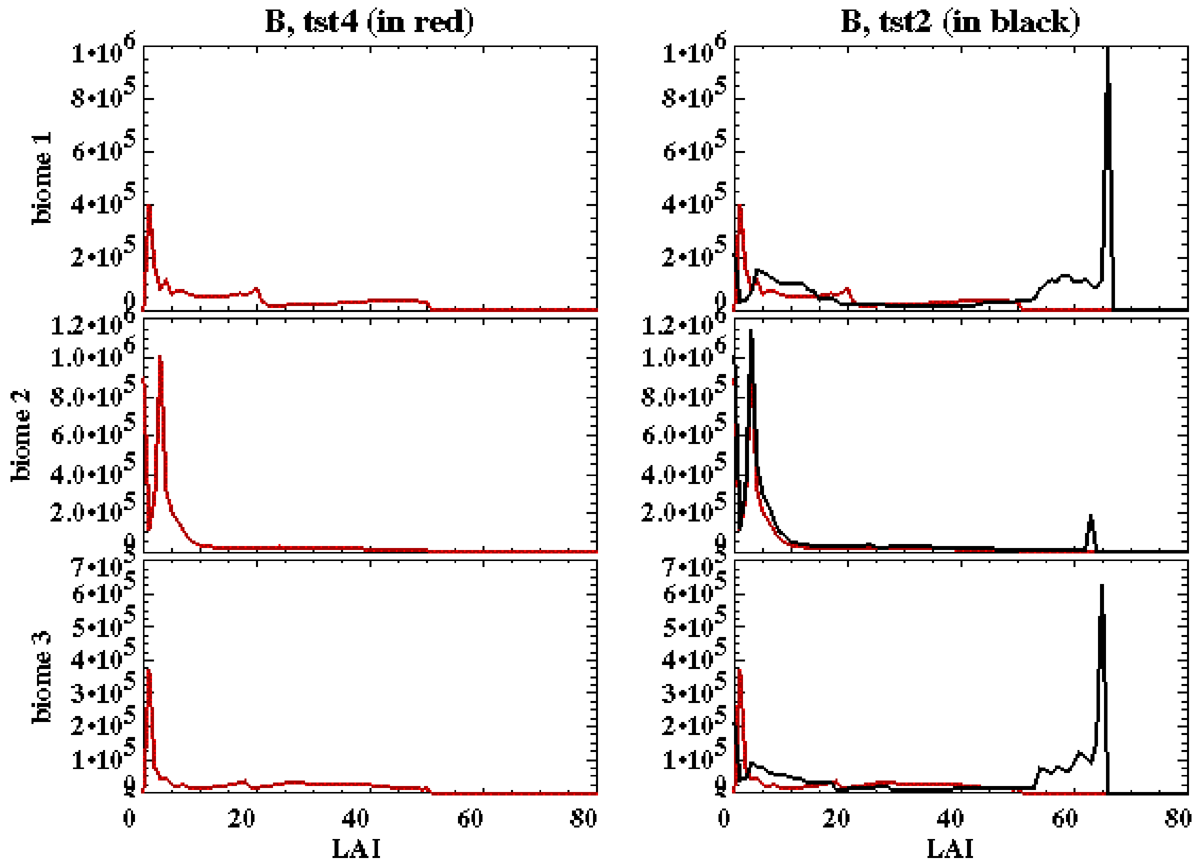

Figure 2: Back-up algorithm LUTs were also adjusted to match main algorithm LUTs. This resulted in eliminating peaks with high LAI, similarly to main algorithm case. This improves fit to field measurements.

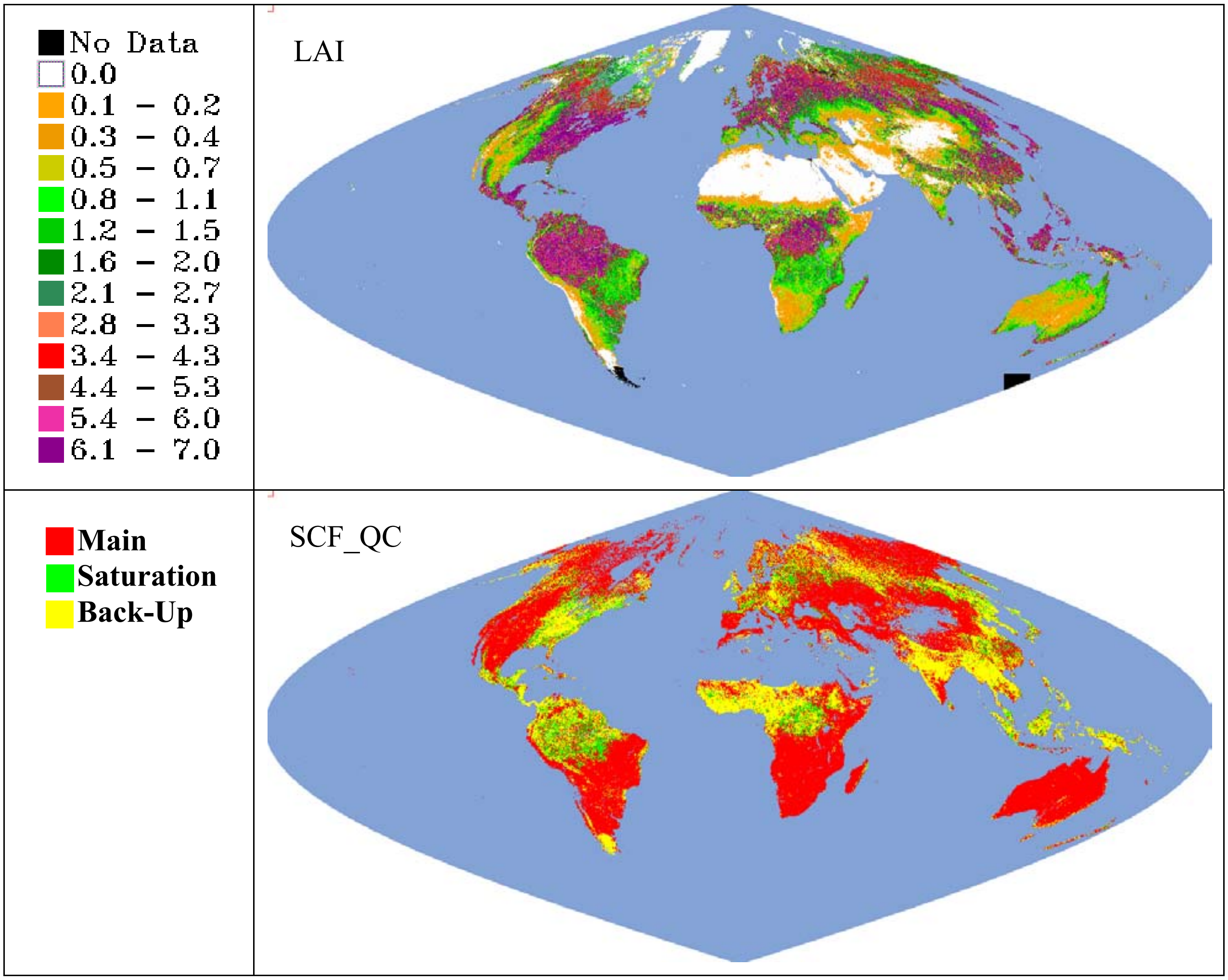

Figure 3a: Composite 201-208, 2001, collection 3 LAI and corresponding quality data. Pixel distribution along processing branches: Main algorithm, no saturation 63%; Main algorithm with saturation 8%; Back-up algorithm 29%.

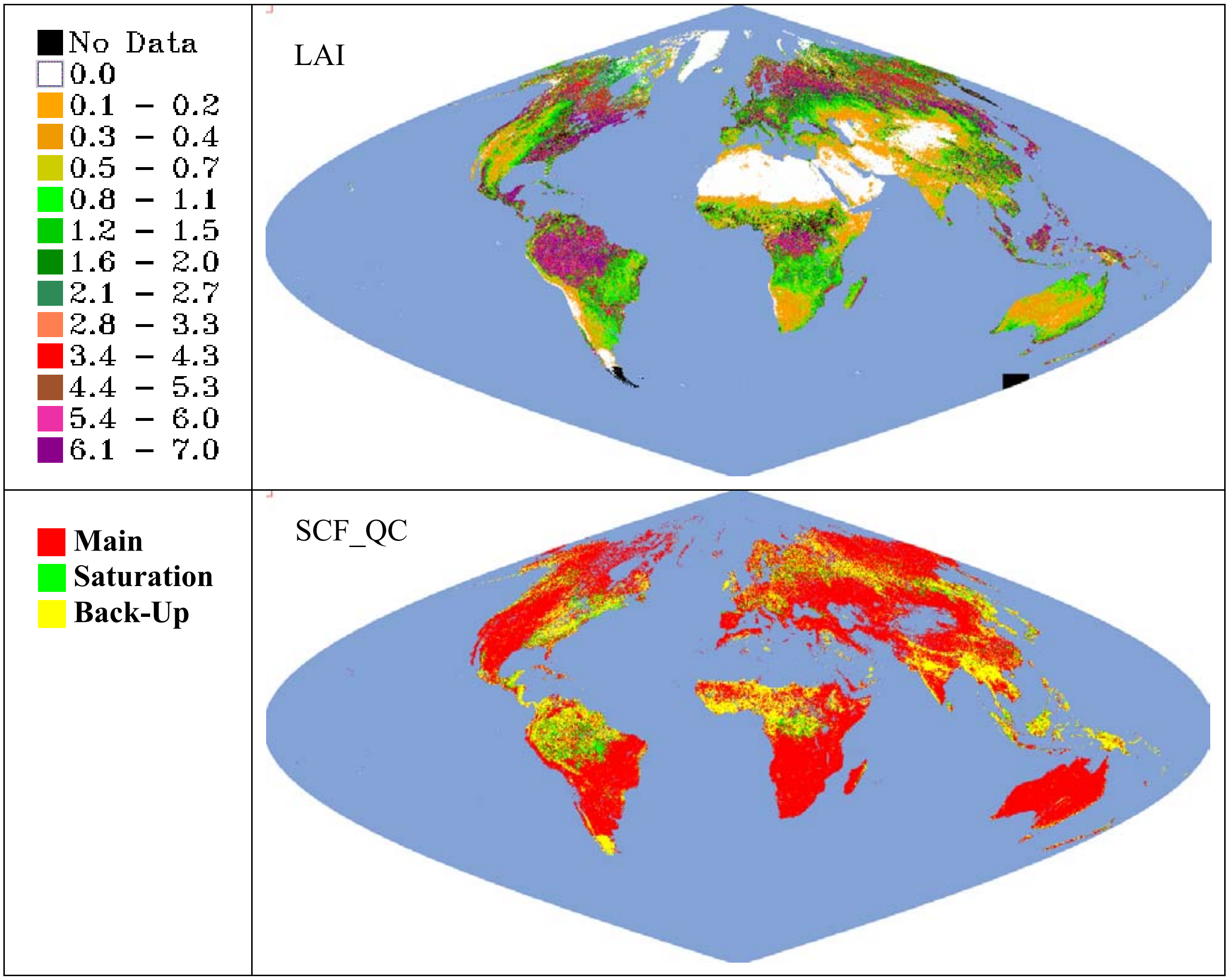

Figure 3b: Composite 201-208, 2001, collection 4 LAI and corresponding quality data. Pixel distribution along processing branches: Main algorithm, no saturation 71%; Main algorithm with saturation 6%; Back-up algorithm 23%.

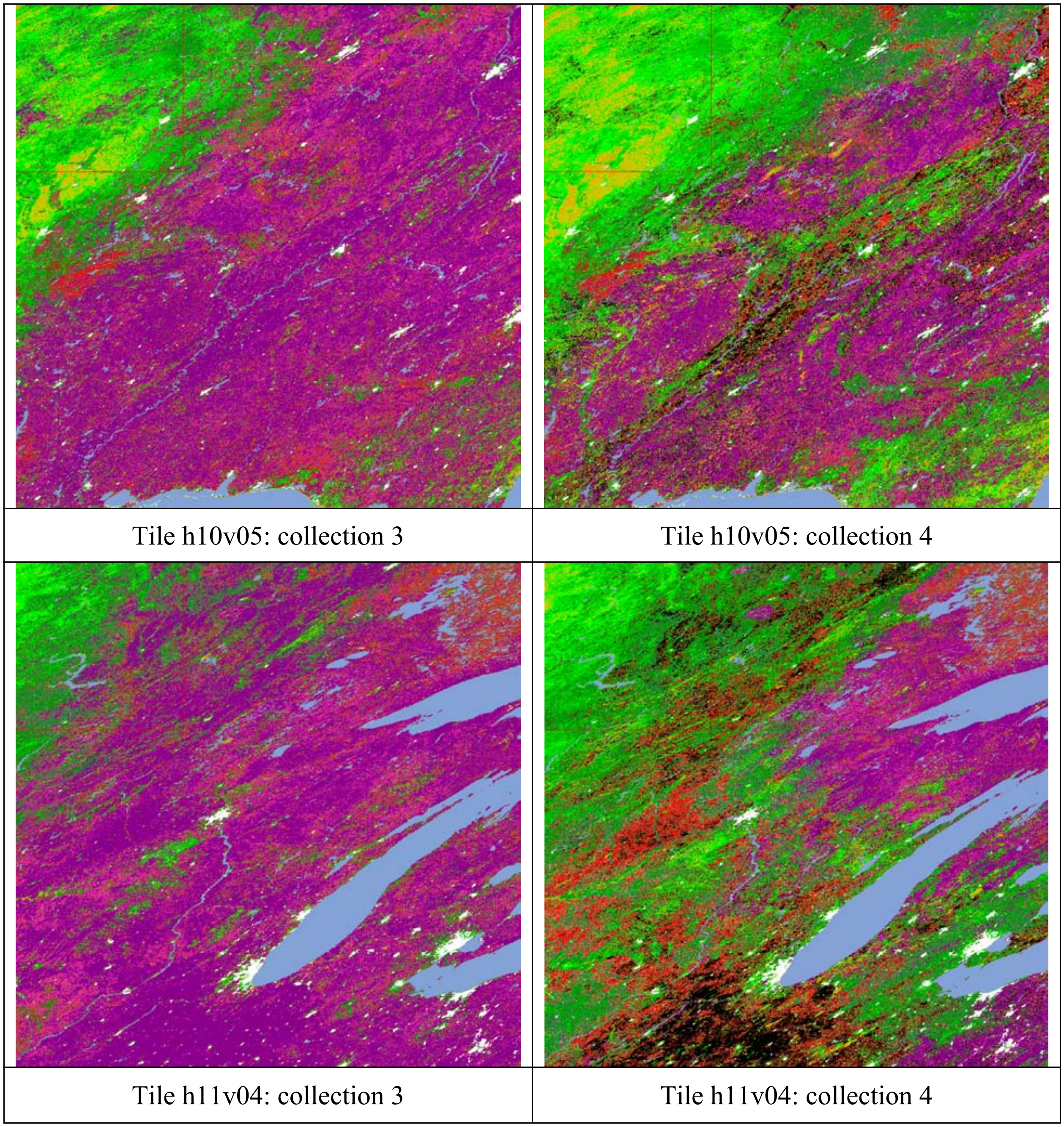

Figure 4: Example of impact of changes in LUTs and compositing scheme on MOD15A2 LAI values for tiles h10v05 and h11v04.

Analysis of Collection 3 Global LAI/FPAR data

We performed analysis of 8-day 1 km MODIS LAI and FPAR values (MOD15A2), collection 3, obtained with the main algorithm under conditions of no saturation. The global LAI time series from July 2000 to October 2002 is shown in Figure 5, panel (a). The LAI profiles averaged over year 2000 through 2002 are shown in panel (b) for different biomes and in panel (c) for broad latitude bands. Similar plots for FPAR are shown in panels (d), (e) and (f). Also shown time series of retrieval index, defined as the fraction of the main algorithm retrievals: global in panel (g), for different biomes in panel (h) and for broad latitude bands in panel (i). The discontinuity in time series is due MODIS being down for 24 days (June 10 to July 3rd) in year 2001. Panels (b) and (e): The biome LAI and FPAR profiles are reasonable. However, the strong seasonality in needle forests requires further investigation. Note that the needle forests have an LAI of about 2 during the winter months. Is the seasonality in needle forests true? Note that the winter retrievals in needle forests, especially in the North, are from fewer pixels (based on the retrieval index plot). The broadleaf forests plot should be interpreted with caution, as it includes both evergreen broadleafs from the tropics and the decidous broadleaf forests from the temperate regions. Which explains why the winter values in this biome are high (LAI of about 4). Panels (c) and (f): All the time profiles look reasonable. The Southern Hemisphere profile clearly shows the inverted seasonality (from a northern perspective). However, the LAI seasonality in >50N latitude band requires further attention. It looks like there are too few main algorithm retrievals and in some cases zero retrievals. Panel (g): Retrievals from the main algorithm are generally 70% and stable. There is one problematic 8-day period in collection processing in year 2002. This is due to low global coverage: only 53 of a total of 286 tiles are available for this 8-day period (March 22 to 29th). Panel (h): The retrieval indices for shrubs and savannas are consistently high (~80%), but low for broadleaf forests (~50%). Also, we do not see a seasonal cycle in these cases. For the other three biomes, grasses, broadleaf crops and needle forests, we note a seasonality in retrieval indices, especially in the case of needle forests, where the main algorithm retrievals are as low as 20-30% during the winter period. Panel (i): The retrieval indices decrease in boreal summer period in all latitudes between 23N and 50N, probably because of increased clouds. Again, there is a clearly seasonality in the main algorithm retrievals in the northern latitudes, 50N and above; in some periods the main algorithm retrievals are virtually non-existent.

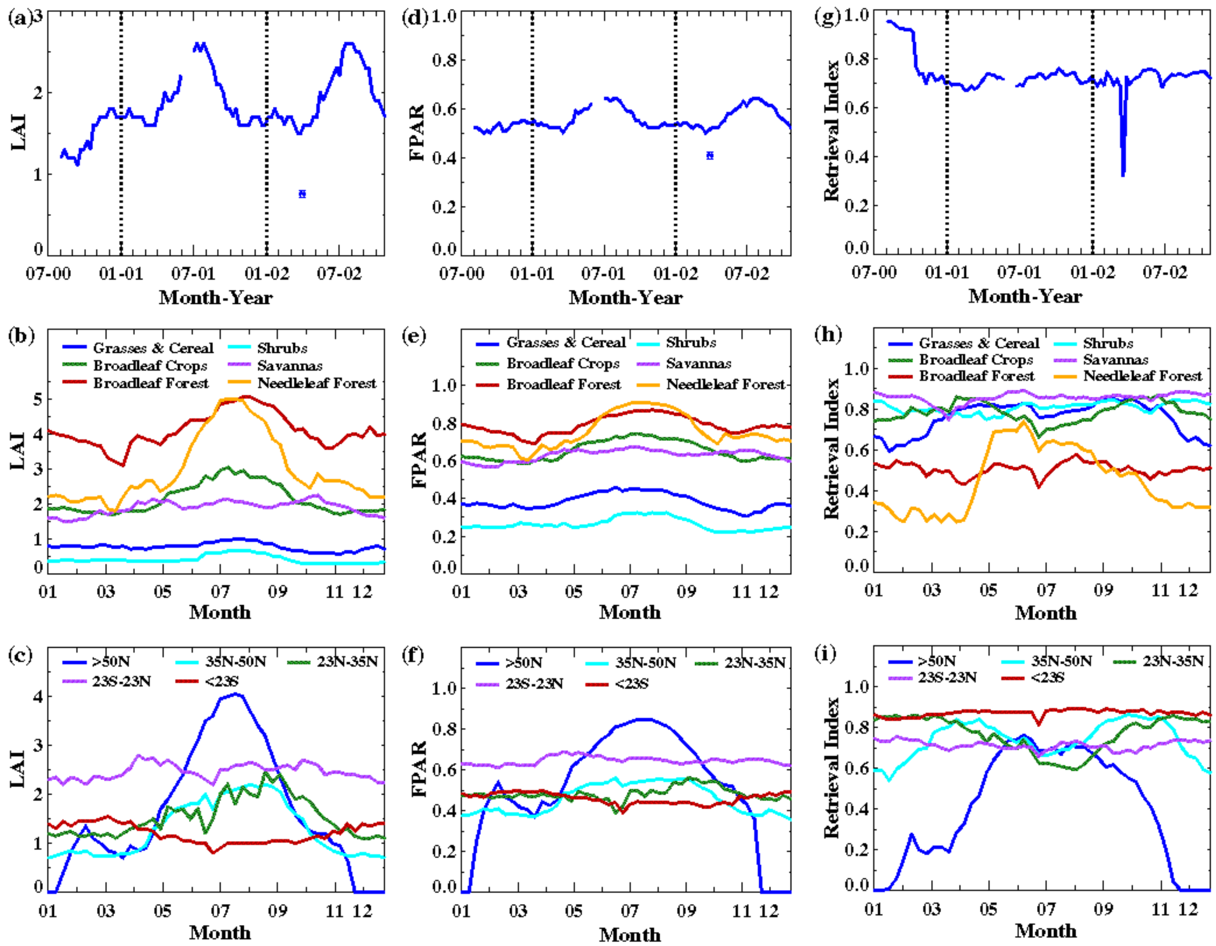

Figure 5: Diagnostics of MOD15A2 product, collection 3. Data used spans period July 2000 through October 2002.

Flakaliden field campaign (Sweden, June 24- July 10, 2002)

Introduction

The Flakaliden field campaign was conducted between June 25 and July 4, 2002 with the objective of collecting data needed for validation of the Moderate Resolution Imaging Spectroradiometer (MODIS). Participants in the campaign numbered 39 from seven countries including: Sweden, Finland, United States, Italy, Germany, Estonia, and Iceland. Flakaliden is located in northern Sweden, a region dominated by boreal forests, and was selected as a MODIS validation test site. Field measurements such as LAI, FPAR, canopy spectral transmittance, and above canopy PAR and SWR, in combination with high resolution satellite imagery of the study area (ETM+) will be used to validate LAI and FPAR products for needle leaf forest acquired from MODIS data. In addition, canopy spectral transmittance, soil/understory spectra, leaf optical properties, and shoot structure were collected to study within canopy radiation regime. Data were collected at five different forest sites located near the town of Vindeln, Sweden, with operations based at Flakaliden, a research area operated by the Swedish University of Agricultural Science (SLU). Sites were chosen to represent different types of needle leaf boreal forest, both uniform spruce and pine stands and mixed coniferous forest.

Site Description

Measurements were collected at five field sites, including Flakaliden research area, Svartberget, located within the Vindeln Experimental Forest, a uniform pine stand, Granskog, and a mixed

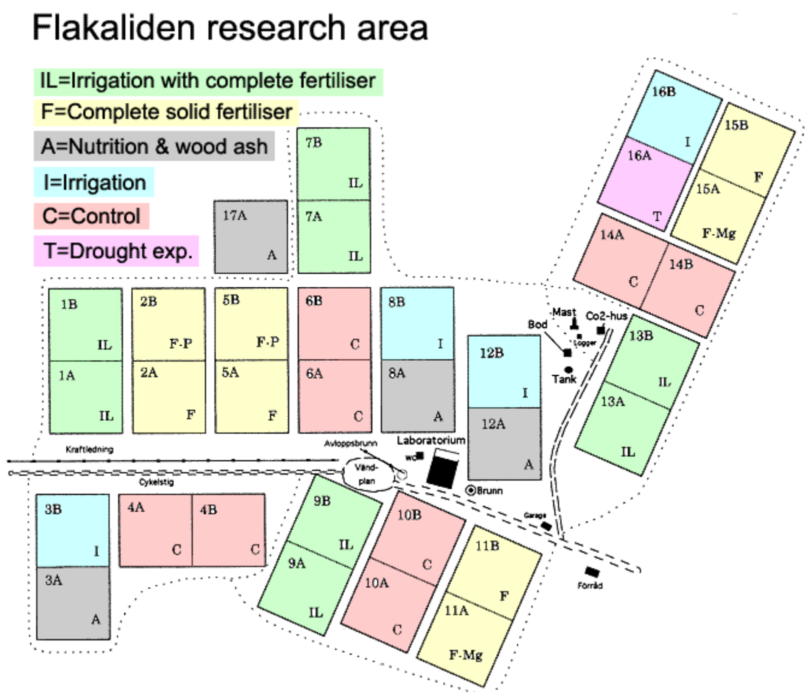

Figure 4. Experimental layout of Flakaliden.

needle leaf forest, “Blue1” site (Figure 3). Flakaliden and Svartberget were both selected for collection of *in situ* measurements, for they have operated as forest research stations for a long time with historical data expanding back many decades.

Data Collected

GROUND MEASUREMENTS- FLAKALIDEN

Spectral up- and downward radiation flux densities were collected at Flakaliden at eight 50 m x 50 m plots, including: 9A, 9B, 10A, 11B, 14A, 15A, 16A, and 16B (Figure 4). Reference measurements for all plots were made using a LI 1800 from Boston University (BU), which had been calibrated with the BU ASD used in the field. Calibration measurements were carried out on the roof of the field station in order to avoid interference from the canopy. When field measurements were taken in plot 11B, two ASD instruments, one from Italy and one from NASA, were mounted alongside the LI 1800 on the roof. However, the Italian ASD on the roof was not calibrated with the BU ASD used in the field.

LAI measurements were collected in four of the Flakaliden plots: 9A, 9B, 11B, and 16B. Readings were planned for more plots, but measurements were limited by poor weather conditions. All four plots were sampled using the lying down technique previously described; however, plots 9B and 11B were sampled twice, the second time applying the technique of using a 45-degree restrictor. For the lying down technique, the grids present in the plots were expanded so that more sample points were included within each plot.

The LI 1400 data logger recorded downward PAR and SWR fluxes from the field station roof for long periods of time over a span of four days. Measurements of incident PAR were taken under the canopy in plots 9B, 11B, 12B, and 14A. Again more plots were planned, but measurements were restricted by weather conditions.

Leaves of various forest species were sampled in Flakaliden and their leaf optical properties were measured under laboratory conditions using an LI 1800 spectroradiometer with External Integrating Sphere.

Similar measurements were performed at the other sites: “Blue1 pixel”, “Pine1 stand”, “Svartberget”, and “Granskog”,

HELICOPTER EXPERIMENT

On the final day of the campaign, July 4, a helicopter was used to measure spectral upward radiation flux density above each of the validation sites. Two ASD were mounted below the helicopter, programmed to record measurements on command, and a LI 1800 spectroradiometer was positioned at every validation site in an open area to acquire reference data. A flight plan was developed to include all five validation sites in this order: Blue1, Pine1, Flakaliden, Granskog, and Svartberget.

For Blue1, the helicopter flew along 4 transects, the first from west to east, the next from east to west, and so on until all transects were complete. Measurements were taken every 100 m along the 1 km transects at a height of about 30 m above the canopy. A total of 88 ASD readings were acquired over the Blue1 pixel.

Four transects were followed by the helicopter in the Pine1 100-m plot. Readings were taken every 20 meters along transects, acquiring a total of 20 ASD measurements above the plot. The same flight pattern and sampling technique was followed over the Granskog plot as was flown over the Pine1 plot.

At Flakaliden ASD measurements were collected over plots 16B, 15A, 16A, 14A, 11B, 9B, and 9A. It had been planned to also measure plots 12B and 11A, however, the helicopter had difficulty in location and was not able to complete the plots due to time constraints. Helicopter measurements were taken above the center of each plot at heights of 15, 30, and 45 meters. ASD ground measurements of spectral upward and downward radiation fluxes were also taken at each plot at approximately the same time as the helicopter readings. Ground measurements were taken within all plots corresponding with helicopter readings and followed the grid located in the centers of the plots. For plots 16B, 15A, 14A, 11B, and 9B 6 points were sampled, while for plots 16A and 9A, only 4 and 3 points were collected respectively.

After Granskog was measured, the final helicopter destination was Svartberget. The helicopter flew and took measurements over five 300-meter transects, including the transects used for previous ground measurements. Seven ASD readings were recorded from the helicopter along each transect. Ground measurements were taken of spectral upward and downward radiation fluxes using an ASD from Lund, but only covered 2 out of the 3 ground transects.