Retrieving canopy structure from MISR

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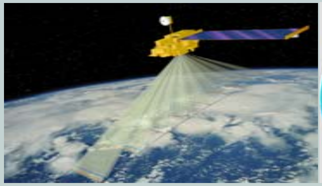
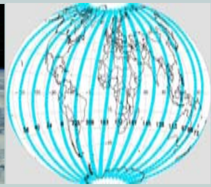
Abstract. The Multi-angle Imaging SpectroRadiometer (MISR) on NASA's Terra satellite provides global imagery at nine discrete viewing angles and four visible/near-infrared spectral bands. An algorithm for the estimation of the Leaf Area Index (LAI) and the Fraction of absorbed Photosynthetically Active Radiation (FPAR) has been developed and implemented for operational use with the MISR instrument, and LAI and FPAR products with known accuracy, precision and uncertainty are being generated for data starting in October 2002. The algorithm performs an accurate separation of the background reflectance from the canopy-surface system and estimates the fraction of ground shaded area, fractional ground cover, and recollision/escape probabilities, but only LAI and FPAR are being archived. This poster discusses the feasibility of reliably retrieving the full set of canopy parameters generated by the operational MISR LAI/FPAR algorithm, which in turn can further be used to obtain new information about the 3D canopy structure for use in the Community Land Model (CLM), e.g., sunlit/shaded leaf area indices, and ecological models, e.g., the aspect ratio. This poster also discusses a physical interpretation of empirically demonstrated relationships between MISR data and lidar canopy heights and how the physics behind this relationship can be used to develop synergistic approaches to interpretation of multi-angle, hyperspectral and lidar data.

MULTI-ANGLE IMAGING SPECTRORADIOMETER



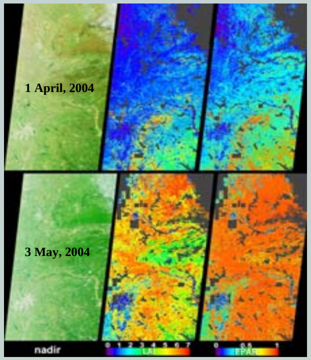


The MISR instrument on the Earth Observing System (EOS) Terra platform orbits the Earth about 15 times each day. There are 233 distinct orbits, called paths, which are repeated every 16 days, and since the paths overlap, near global coverage is obtained in 9 days. The MISR instrument views symmetrically about the nadir in forward and aftward directions along the spacecraft flight track. Image data are acquired with nominal view zenith angles relative to the surface reference ellipsoid of 0.0°, 26.1°, 45.6°, 60.0° and 70.5° in four spectral bands (446, 558, 672, and 866 nm). The MISR data are distributed from the NASA Langley Atmospheric Sciences Data Center (http://eosweb.larc.nasa.gov/).

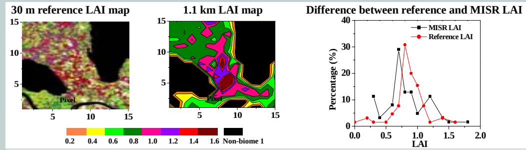
Right-hand Panel: MISR vertical-viewing (nadir) camera image of Massachusetts acquired on April 13, 2000.

MISR LAI AND FPAR PRODUCTS ARE AVAILABLE AT "STAGE 1 VALIDATED QUALITY"

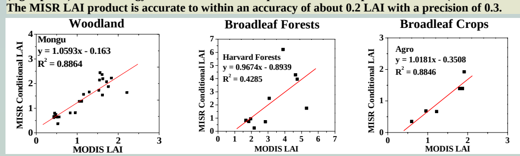
Spring greening of the southern US (Texas, Oklahoma)

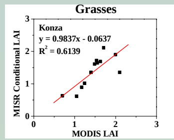


Vigorous vegetation growth in the Southern United States after heavy rains fell during April and early May, 2004, is quantified in these images and LAI&FPAR product from MISR. The left-hand images are natural-color views from MISR's nadir camera acquired on April 1 (top set) and May 3 (bottom set). The middle and right-hand panels show two MISR standard products – LAI and FPAR.



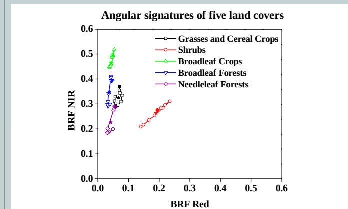
Validation of moderate resolution satellite products includes (*i*) ground sampling of LAI, (*ii*) generation of a fine resolution LAI map (left panel) using field data and high resolution satellite images and (*iii*) comparison of the aggregated fine resolution map (middle panel) with the product (right panel). This strategy is illustrated for a cropland site near Alpilles in France (43.81N, 4.75E). The MISR LAI product is accurate to within an accuracy of about 0.2 LAI with a precision of 0.3.



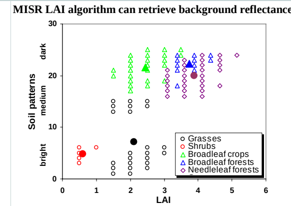


The MISR LAI product (version 3) show structural and phenological variability in agreement with field data. The product is accurate to within 0.5 units in herbaceous vegetation and savannas and overestimates LAI by about 1 unit in broadleaf forests. LAI retrievals over needle leaf forests remain at provisional quality level (*Hu et al., 2006*).

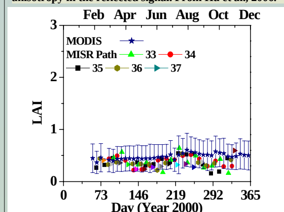
INFORMATION CONTENT OF MISR DATA



BRF at red and NIR wavelengths as a function of the view zenith angle form a curve on the RED vs. NIR plane - an angular signature in spectral space. The signature is characterized by (*i*) its location, which is mainly determined by the biome type; (*ii*) inclination (slope and intercept), which is determined by soil type and the vegetation ground cover; and (*iii*) the length, which measures the degree of anisotropy in the reflected signal. From Hu et al., 2006.



Separation of the background reflectance from canopy-surface system. Shown are the distribution of all LAIs and soil patterns for which simulated and observed reflectances differ by the combined uncertainty in model and measurements (hollow symbols) and their mean values (solid symbols). Signatures shown in Left Panel were input to the MISR LAI algorithm. From Zhang et al., 2002ab.



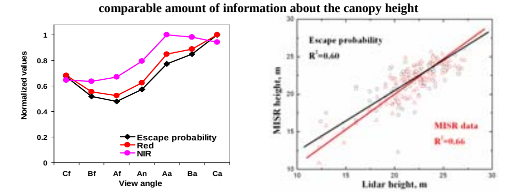
The analyses performed to date have just begun to capitalize on the information provided by the MISR measurement approach. With several years of Terra data now in hand, advances in the use of multiangle data for retrieval of canopy structure can be expected with continuing research.

Multiangle data can distinguish the exposed, bright background from the canopy, making it possible to capture seasonal LAI variations that are not seen in single-angle views. Shown are the annual temporal signatures of LAI, for year 2000, from MODIS and MISR for a 2° by 2° degree area centered on the Walnut Gulch (San Pedro) shrubland site in Arizona, (31.74N, 109.94W). From Hu et al., 2006.

POTENIAL OF MISR DATA TO PREDICT FOREST VERTICAL STRUCTURE

Empirically demonstrated relationships between MISR data and canopy heights suggest the ability of MISR data to predict the vertical structure of forest canopies (Kimes et al., 2006, Heiskanen, 2006). What is the physics behind the observed correlation?

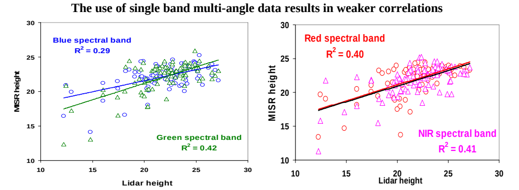
The wavelength independent escape probability and multi-angle spectral data convey comparable amount of information about the canopy height



The probability that a scattered photon will escape the vegetation canopy in a given direction (legend "Escape probability") is derived from AirMISR data acquired over the Harvard Forests EOS Core Validation site. AirMISR radiances at red (legend "Red") and near-infrared (legend "NIR") spectral bands are added for comparison.

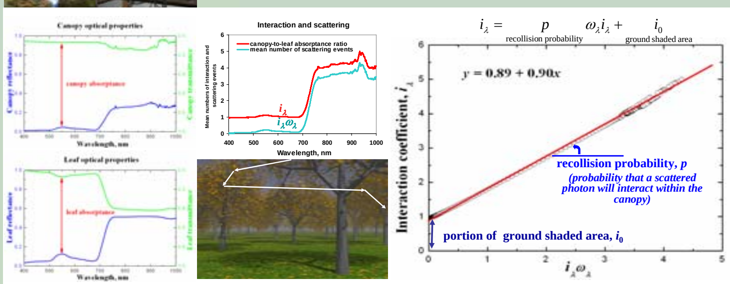
Multivariate linear regression models were used to predict the LVIS height from AirMISR data (red dots) and from the directional escape probabilities (black dots). Shown are predicted versus measured LVIS heights over the Harvard Forest EOS Core validation site, a temperate mixed forest in Massachusetts (Lat: 42.33N to 42.77N; Lon: 71.81W to 72.43 W).

The use of single band multi-angle data results in weaker correlations



CANOPY SPECTRAL INVARIANTS EXPLAIN THE PHYSICS BEHIND THE OBSERVED CORRELATION

Canopy spectral invariants allow the separation of structurally variant and spectrally invariant components from hyperspectral data and provides a strong physical basis for synergy of multi-angle, hyperspectral and lidar data.

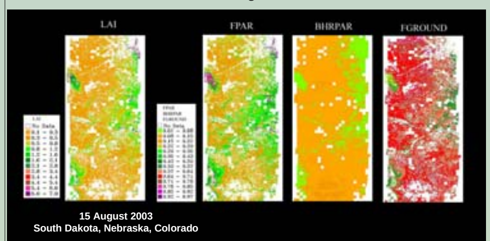


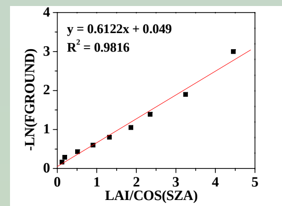
The Flakaliden field campaign was conducted from June 25 to July 2, 2002 with the objective of collecting data needed for validation of satellite land surface products. Canopy spectral transmittance and reflectance, soil/understory reflectance spectra, needle optical properties, shoot structure and LAI were collected for six plots composed of Norway spruce (Huang et al., 2006).

OBTAINING NEW INFORMATION ON CANOPY STRUCTURE FROM MISR PRODUCTS

FGROUND at PAR wavelengths = 1 – BHRPAR - FPAR

FGROUND ∝ Gap fraction at solar zenith angle θ_{sun} $=\exp(-\,G(\theta_{sun})\,LAI/\cos\theta_{sun})$





The MISR Land Surface Product includes LAI, FPAR and BiHemispherical Reflectance integrated over the Photosynthetically Active spectral Region (BHRPAR). From these products, the fraction of PAR absorbed by the ground can be estimated as 1–BHRPAR–FPAR (Hu et al., 2006).

FGROUND with independent estimates of LAI can be used to derive at least three measures of canopy structure – (1) extinction coefficient for use in ecological models (2) estimates of mean leaf inclination and (3) the gap fraction. Sunlit and shaded leaf area indices can be directly obtained from the extinction coefficient, LAI and portion of ground shaded area.

LAI–FGROUND regression curve derived from the MISR Land Surface Product. The relationship follows Beer's law, $\exp(-\,G(\theta_{sun})LAI/\cos\theta_{sun})$, as expected. Here $G(\theta_{sun})$ is a geometric leaf orientation factor. Since LAI/FPAR and BHRPAR products are derived from two independent algorithms using different input information, this result suggests the consistency and complementarity of the MISR surface product suite that includes LAI, FPAR and BHRPAR (Diner et al., 2005; *Hu et al., 2006*).

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ACKNOWLEDGEMENTS

The research is performed at Boston University under contract # 1259071 with Jet Propulsion Laboratory, California Institute of Technology, as part of the EOS-MISR project and by the NASA Earth Science Enterprise under grant G35C14G2 to Georgia Institute of Technology.