Global BRDF and Albedo from the EOS MODIS and MISR Sensors

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Abstract A 16-day standard BRDF and albedo product will be produced from combined MODIS and MISR data at a spatial resolution of 1km. This paper demonstrates that BRDF and albedo retrieval accuracies from simulated MODIS/MISR angular sampling are within 5 to 10 percent in the majority of sampling situations.

Key words Bidirectional reflectance, Albedo, MODIS, EOS

1 BACKGROUND

With the launch of the EOS-AM-1 satellite platform in 1998, two key sensors of NASA's Earth Observing System will begin global optical observations of the earth's surface. These are the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Multi-Angle Imaging Spectroradiometer (MISR).

Among the data products to be derived from these sensors is a land surface Bidirectional Reflectance Distribution Function (BRDF) and Albedo Product that will be produced by the MODIS team but will make use of both MODIS and MISR data. It will be generated with a spatial resolution of 1km over land globally, in seven spectral bands and once every 16 days. The atmospherically corrected multiangular observations acquired over this time period will be inverted using the Ambrals BRDF model and, additionally, the modified Walthall model. The BRDF parameters found and direct-diffuse ("black-sky") and isotropic-diffuse ("white sky") spectral and broadband albedos will be produced along with detailed quality assessment information.

In the MODIS processing stream, a coupling between atmospheric and surface scattering will be achieved by taking into account BRDF effects in atmospheric correction; an iterative coupling has been shown to converge rapidly[1,2]. Spectral-to-broadband conversion will be carried out for a standard clean-sky case (molecular scatttering only) using standard splines. This has been shown to produce broadband albedos with an accuracy of a few percent relative[3].

The MODIS BRDF/Albedo Product will be generated from code called the "Algorithm for MODIS Bidirectional Reflectance Anisotropy of the Land Surface (Ambrals)"[4]. The Ambrals BRDF model[5] is a kernel-driven semiempirical BRDF model following the approach of Roujean *et al.*[6]. The reflectance of a possibly mixed pixel is modeled as a sum of volume scattering, surface scattering and an isotropic term, where each of these terms is given by kernel functions dependent on viewing and illumination geometry only, which are derived from theories of light scattering in vegetation. The Ambrals model provides a choice of two kernels for volume scattering and surface scattering each (Ross-thin, Ross-thick and Li-sparse, Li-dense), representing different types of surfaces.

The model parameters retrieved in inversion are the respective contributions of each type of scattering to the overall BRDF, allowing for a wide range of BRDF shapes. Besides being able to model mixed pixels, the advantages of this approach are rapid analytical inversion, linear spatial scaling properties, and rapid albedo calculation. Also it does not require prior knowledge of scene properties[3]. It produces good fits with field-measured data sets[3,7].

2 REFLECTANCE AND ALBEDO RETRIEVAL ACCURACIES FROM MODIS/MISR SAMPLING

An important aspect of BRDF/albedo modeling from space-based multiangular reflectance observations is whether the angular sampling provided by a given sensor or sensor combination is sufficient to allow retrieval of the full bidirectional reflectance distribution function at all angles. If the BRDF is to be predicted at angles that are between angles where observations were made, the retrieval of that reflectance is an exercise of interpolation. In cases where the reflectance is to be predicted in angle ranges where no observations were made, for example when sampling was done only in a small range of solar zenith angles and the prediction is to be for some different solar zenith angle, predicting the reflectance is an exercise in extrapolation. Whether the extrapolation succeeds depends on whether the physical basis of the model used is correct and predicts the correct shape of the BRDF away from the observed angles, and whether the parameters governing the BRDF can be discriminated reliably and accurately from the angular sampling that is available.

These questions were addressed in two studies conducted for the MODIS BRDF/Albedo Product, where MODIS and MISR angular sampling was simulated as a function of latitude and time of year to investigate the noise sensitivity and retrieval accuracy of Ambrals inversions. The noise sensitivity study has been reported in part elsewhere[3,8] and will soon be published in full. We here will concentrate on examples of the second study, aimed at demonstrating Ambrals BRDF retrievals under conditions of limited angular sampling.

BRDFs of six different land cover types (grassland, brush, broadleaf crops, savanna, broadleaf and needleleaf forest) were simulated using the discrete ordinates method radiative transfer code (DOM/RTCODE) by Myneni[9]. These BRDFs were sampled as MODIS and MISR would using approximate geometries calculated with the Xsatview software (by Barnsley and Morris). We here show examples for the first day of the year, where the sun is in the southern hemisphere. Only observations with sun zenith angles smaller than 75 degrees were considered, which corresponds to the cutoff of MODIS atmospheric correction. The bidirectional reflectance samples thus constructed were inverted using the Ambrals model and the results compared to the known original BRDFs. Fig. 1 shows two examples of typical MODIS and MISR sampling geometries across the viewing hemisphere for a 16-day period in March.

Fig. 2 shows the results of a rather severe test showing the retrieved reflectances on the principal plane for grassland and broadleaf forest in the red and near-infrared bands. The BRDF is shown for three different solar zenith angles, 0°, 30°, and 60°. The solid line represents the true BRDF given by the DOM/RTCODE model, all other lines represent the retrievals from Ambrals under MODIS/MISR sampling at different latitudes from 80 degrees south to 40 degrees north (at 60 degrees or more north the sensor, having a morning equatorial crossing time and considering the solar zenith angle cut-off, has no observations on January 1). This test is severe because the predictions are made irrespective of the sun angle of the observations, which is about 60 degrees at the extreme latitudes and shows a minimum of 20 degrees at about 20 degrees south. As Fig. 2 shows, the principal plane BRDF is nonetheless correctly recoveredfor all latitudes, both bands, and all solar zenith angles. The only exception is one retrieval in the red band for the broadleaf forest, which is too high; these latter simulated observations correspond to 40 degrees northern latitude at a sun zenith angle

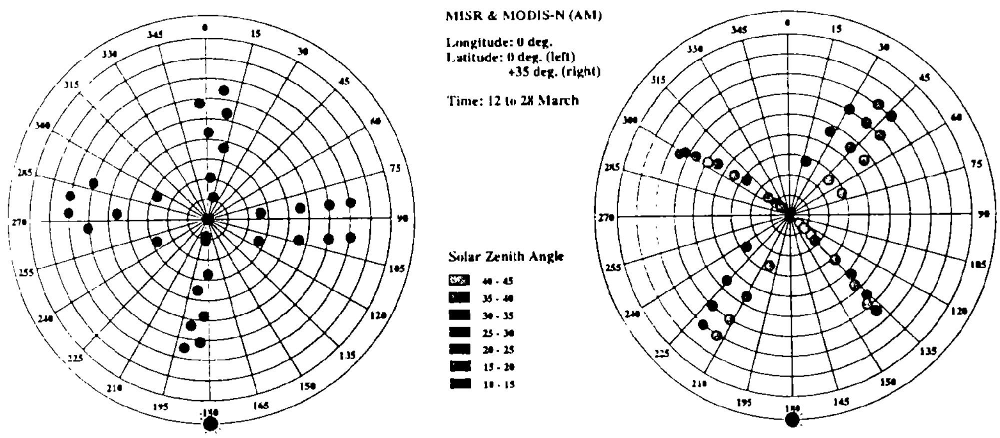

Fig. 1 Examples for MODIS and MISR angular sampling in the viewing hemisphere, March 12 to 16, at the equator and at $+35°$ latitude. The solar zenith angle range in both cases is about 15 degrees. Data and plots produced by Xsatview software (Barnsley and Morris)

of about 60 degrees. Clearly, the extrapolation to sun at nadir is not working well under this sampling. In all other cases, both interpolation and extrapolation of the BRDF work well. The change of shape of the BRDF with sun angle and with view angle is correctly modeled. The hotspot is a little weak at times. Perhaps it needs to be strengthened in the kernels used. In summary, Fig. 2 shows that in principle retrievals of full BRDFs are indeed feasible under MODIS and MISR sampling. Results for the other land cover types tested were similar. We will investigate the impact of varying degrees of cloud cover on the retrievals in upcoming work.

Fig. 3 shows, as a function of latitude for the first day of the year, the error made in black-sky albedo retrieval at the mean sun angle of the observations (requiring interpolation of the observations by the BRDF model) and at a fixed solar zenith angle of $30°$ (requiring varying degrees of extrapolation at the different latitudes). Results are shown for all six land cover types and both bands. The shaded area shows 10 percent relative error in either direction. As can be seen, most results are within that band. Errors are within a few percent in the majority of cases, with only small errors occuring especially in the near-infrared band. The smaller albedo values in the red band more easily lead to retrieval errors of 10 percent, in the worst cases where large sun zenith angles are involved of 20 percent. There is an anomaly of the retrieved BRDF and albedo for the broadleaf forest in the near-infrared that we have not been able to fully explain yet. Generally, however, albedo retrieval for land cover types is accurate to within a few percent over large parts of the latitude range.

Summarizing our findings, we believe that we can retrieve interpolated reflectance and black-sky albedo to within a few percent relative in the median, whereas extrapolated values will have median accuracies between 5 and 10 percent relative, with larger errors occuring at times for solar zenith angles larger than 45 degrees. Even though these studies are based on comparisons of one model against another, similar accuracies may reasonably be expected from the MODIS BRDF/albedo product.

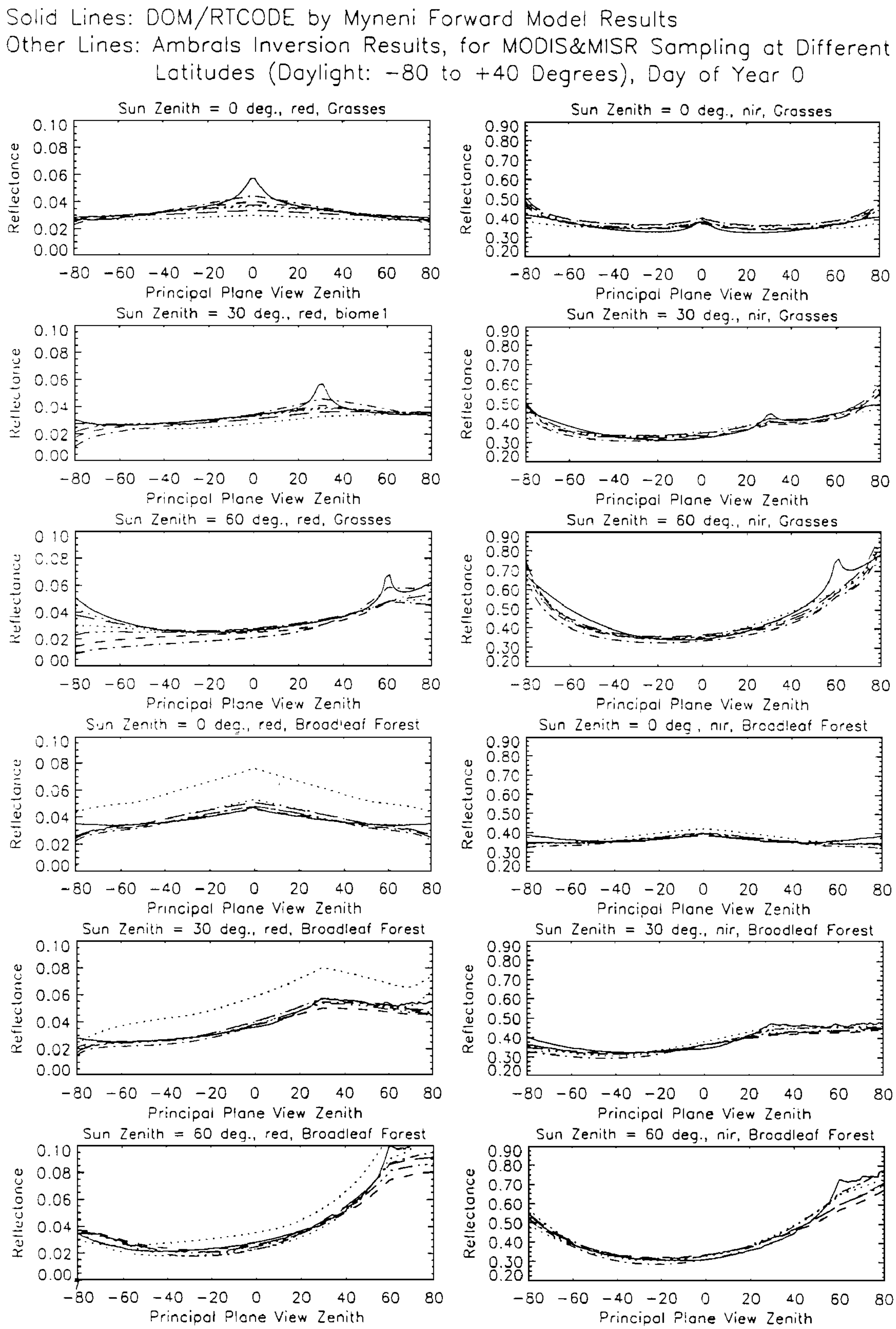

Fig. 2 Sample retrievals of the complete BRDF from limited angular sampling

Fig. 3 Black-sky albedo relative retrieval error from limited angular sampling

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Wolfgang Wanner, born May 30, 1964, obtained his Master's and Ph.D. degrees in physics from the University of Kiel, Germany, in 1990 and 1993, respectively. He is now Assistant Research Professor at the Center for Remote Sensing and the Department of Geography of Boston University, USA. Interested in the physics of transport and scattering, he has worked on galactic dynamics, the propagation of charged particles in the solar magnetic field, and the scattering of light in vegetation canopies. He is currently preparing theory and algorithms for deriving a global BRDF/albedo product from the MODIS and MISR sensors of NASA's Earth Observing System. Wolfgang Wanner is the author or co-author of 10 journal articles, 20 conference papers, and 3 software systems.

用EOS MODIS和MISR数据计算全球BRDF和反照率

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摘　要　用空间分辨率为1km的MODIS和MISR数据可计算16天BRDF和反照率产品，该文证明了在多数采样条件下，用MODIS/MISR角度采样的BRDF和反照率反演精度在5到10个百分点以内。

关键词　双向反射率，反照率，MODIS，EOS