Local Analysis of MISR Surface BRF and Albedo Over GSFC and Mongu AERONET Sites

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***Abstract*—We have developed an atmospheric correction algorithm to retrieve the surface bidirectional reflectance factor (BRF) and albedo from Multiangle Imaging SpectroRadiometer (MISR) measurements for small areas around Aerosol Robotic Network (AERONET) sunphotometer sites, using AERONET aerosol and column water vapor information. Our goal is to develop an indirect validation method for MISR surface reflectance products over heterogeneous land. Our algorithm makes independent retrievals with both the Li Sparse–Ross Thick kernel BRF model and the modified Rahman–Pinty–Verstraete BRF model used in the Moderate Resolution Imaging Spectroradiometer and MISR land algorithms, respectively. In this study, we report the first results of processing MISR Collection 4 data for 2003–2004 for two sites, Mongu, Zambia, and Greenbelt, MD. We found that MISR generally provides accurate retrievals of BRF and albedo in both clear and hazy atmospheric conditions, correctly reproducing the parameter time series and spatial distribution. We found that the MISR BRF, on average, is less anisotropic in the visible bands. The difference is greatest in the blue band, but decreases with increasing wavelength such that it is negligible in the near-IR band. This discrepancy originates in part in the MISR aerosol retrieval algorithm over heterogeneous land, which tends to select an aerosol model that favors spectrally invariant shapes of surface BRF. The other part of the discrepancy comes from the surface hemispherical-directional reflectance factor retrieval algorithm where the iteration loop that removes the diffuse atmospheric transmittance is currently turned off. Our initial results suggest that the MISR surface albedo is on average lower than our retrievals by about 0.005 in the green and red bands. In the near-IR, it agreed with our retrievals with the modified Rahman–Pinty–Verstraete model for the Mongu site, but was systematically lower over the Greenbelt site by about 0.016. When significant aerosol absorption is present (Mongu), the albedo discrepancy is additionally biased by the difference between the MISR and AERONET retrievals of aerosol absorption.**

***Index Terms*—Aerosol Robotic Network (AERONET), albedo, atmospheric correction, bidirectional reflectance, Multiangle Imaging SpectroRadiometer (MISR), validation**

I. INTRODUCTION

VALIDATION is a critical component of the Earth Observing System (EOS) [1] aimed at establishing the accuracy of satellite-derived products on the regional and global scales, under different atmospheric and surface conditions. Due to spatial heterogeneity of the land surface, validation of surface reflectance is a difficult and challenging task. Measurements of albedo from the ground or towers [2] can be used as validation data at a moderate resolution (≈1 km) only for relatively homogeneous surfaces. Field measurements are sparse globally, and each represents only local conditions. We are not aware of any detailed ground-based measurements of surface bidirectional reflectance factor (BRF) and albedo to characterize heterogeneous land. A comprehensively planned validation experiment would have to cover the area of at least several satellite footprints with a statistically representative grid of points and a sampling interval comparable to the scale of surface variability (e.g., several tens of meters). Such an approach, which would amount to several thousand measurements concurrent with the satellite overpass, does not seem feasible. Moreover, the ground-based measurements of surface directional reflectance made under natural solar illumination conditions need to be atmospherically corrected to derive the BRF [3]. This implies more complex measurements with concurrent characterization of aerosol and water vapor.

In this paper, we present an alternative approach of indirect validation of Multiangle Imaging SpectroRadiometer (MISR) surface reflectance products over Aerosol Robotic Network (AERONET) sunphotometer [4] sites. The idea is to collect the best ancillary information on atmospheric aerosol and water vapor, and perform an independent atmospheric correction (AC) of MISR measurements based on accurate radiative transfer theory that is not constrained by the time requirements of operational processing. Of course, our approach is not a full validation based on independent well-calibrated measurements of surface reflectance. However, it has merits that ground-based measurements do not provide, such as the capacity to allow spatial analysis over relatively large nonhomogeneous area of study. In general, with this approach we will be able to verify that 1) MISR aerosol retrievals do not change the spectral and spatial pattern of derived surface reflectance, and 2) the assumptions and operational simplifications of the MISR algorithm do not produce biases when compared to rigorous radiative transfer codes. The same spatial and spectral resolution is a strong advantage because it allows direct comparison of results. With this perspective, applying this approach to different instruments, such as Moderate Resolution Imaging Spectroradiometer (MODIS) and MISR, may help cross calibration of on-orbit sensors.

Below, we present an analysis of MISR BRF and albedo over the Mongu (Zambia) and Greenbelt, MD (hereafter referred to as GSFC) test sites for 2003 and 2004. The size of each study area is 32×32 pixels at MISR's composite resolution of 1.1 km. Among the different EOS Land Validation Core Sites [2] for which MISR subsetted data are freely provided by Langley Data Center, Mongu and GSFC have the greatest number of clear days in 2003–2004 with reprocessed MISR Collection 4 data.

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Atmospheric conditions in Mongu change dramatically in the end of the dry season when the biomass burning occurs. The surface also exhibits considerable spatial and temporal variability, from urban areas that have little seasonal change to an extensive flood plain with strong seasonal vegetative dynamics. The GSFC site has a considerable spatial variability, and typically, clear atmospheric conditions with low-absorbing aerosols.

The theory and specific implementation of the processing algorithm are described in Section II of this paper. Examples of BRF/albedo retrievals and comparisons with MISR results are given in Section III. This section also provides an analysis of the spatial distribution and time series of albedo. Section IV discusses the effect of BRF model on the retrieval results. The paper is concluded by a summary.

V. Conclusion

In this paper, we reported the first results of independent AC of MISR measurements over small areas around AERONET sunphotometer sites using aerosol parameters and column water vapor from AERONET as well-calibrated ancillary information with established accuracy. With this approach, we are able to indirectly test correctness of MISR aerosol retrievals and accuracy of the AC algorithm. Indirect validation of the MISR BRF and albedo with our data is done at the same spectral and spatial resolution, which addresses an unresolved problem of ground-based validation over heterogeneous surfaces. Our approach, if supported by periodic ground-based measurements over stable homogeneous test sites with different levels of surface brightness that would establish an absolute reference for the BRF and albedo, can be considered a full validation that is easily expandable at the regional and global level given the AERONET global infrastructure.

As an initial demonstration of this concept, we conducted a local analysis of MISR BRF and albedo products over two sites, GSFC (Greenbelt, MD) and Mongu (Zambia), for available MISR direct pass data of Collection 4 for 2003–2004. Making independent retrievals with LSRT and MRPV models of BRF, we also studied the impact of a model on retrieved BRF and albedo. Since the LSRT model is used in the MODIS land algorithm, and the MRPV model is a basis for MISR surface retrievals, such study is an important step to understanding differences between the MISR and MODIS global surface reflectance products that arise in part from the difference in models.

Summary results from this study include the following.

1) A comparison of our retrievals with the MISR BRF and albedo showed a close agreement. MISR retrieves correct BRF shapes, fully reproduces the temporal pattern of albedo and BRF, and provides accurate retrievals in difficult cases of high AOT. Among differences we found, the most important are the following.
   - —MISR BRF overall is less anisotropic in the visible bands. The difference is greatest in the blue band, decreases in the green and further in red bands, and is negligible in the near-IR band. This discrepancy originates in part in the MISR aerosol retrieval algorithm over heterogeneous land, which tends to select an aerosol model that benefits the spectrally invariant shapes of the surface BRF. The other part of discrepancy comes from the surface HDRF retrieval algorithm where the iteration loop that removes the diffuse atmospheric transmittance is currently turned off. An additional small contribution may be added from the approximate calculation of diffuse surface-reflected radiance with only two azimuthal harmonics in the MISR algorithm at high AOT; otherwise, this error is negligible.
   - —MISR albedo was on average smaller by about 0.005 in the green, red and near-IR bands. When significant aerosol absorption is present (Mongu), the albedo discrepancy is additionally biased by the difference between the MISR-retrieved and AERONET estimates of aerosol absorption (single scattering albedo).
   - —MISR albedo accurately reproduces the areas' spatial distribution of albedo. The pixel-to-pixel difference with our retrievals does not exceed $\approx$ 0.004 in all bands. A larger spatial variation ($\sim$ 0.015–0.2) in the form of mosaic may develop at a coarser resolution (17.6 km), mainly in hazy conditions, as a consequence of MISR aerosol retrievals at this scale.
2) Comparison of our retrievals performed with the MRPV and LSRT models showed the following.
   - —Overall, the models have approximately the same capacity to fit the BRF shapes derived for GSFC and Mongu sites at MISR view geometries, though MRPV model is generally preferable except in the blue band. On the other hand, due to its linearity, the LSRT model offers a significant advantage in the processing speed.
   - —The albedos from the two models are generally similar, within 0–0.015, with the average difference $\leq$ 0.005. We found that the relationship between them is site-dependent, or, in other words, it is most probably a function of aerosol absorption. The albedo from the LSRT model was systematically higher in medium and high aerosol absorption cases (Mongu), whereas MRPV albedo was higher in low aerosol absorption cases (GSFC).

Overall, our analysis leads us to conclude that MISR Collection 4 offers high quality surface reflectance products. Of the mentioned errors, the found small negative albedo bias of 0.005 is probably the most important one, if confirmed by our further research. The larger error in a form of mosaic caused by aerosol retrievals has presumably a random nature, and can be removed in a time series analysis by simple smoothing procedures, or in the time-composite global products. One should keep in mind that presented initial evaluation of MISR surface reflectance is based on a very limited number of processed cases, and serves more to demonstrate our approach rather than to give conclusive accuracy statements. In the near future, we plan to significantly increase the number of AERONET sites in our processing, which will broaden the range of land cover types and atmospheric conditions, and to extend our approach to a regional and then global scale.

There is still a significant amount of work to be done with our algorithm. For example, the BRF of the LSRT model often takes negative values at high angles, which are used in integration. A "transient" model that fixes this problem was proposed in [21], and we plan to explore its use in our algorithm. We will continue algorithm development to improve the reliability and accuracy of our retrievals in the MISR blue band, and in high AOT cases.