Evaluation of MISR land surface BRF measurements: Intercomparison with coincident airborne and ground field measurements.

Wedad A. Abdou[1], Mark C. Helmlinger[1], Veljko M. Jovanovic[1], John V. Martonchik[1], David J. Diner[1], Charles K. Gatebe[2] and Michael D. King[2]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.
[2] NASA/GSFC, Greenbelt, MD 20771.

Abstract: **The bidirectional reflectance factor, BRF, retrieved by the Multiangle Imaging SpectroRadiometer, MISR, is compared with those coincidently measured from aircraft, by the Cloud Absorption Radiometer, CAR, and MISR airborne simulator, AirMISR, and on the ground, by the Portable Apparatus for Rabid Acquisition of Bidirectional Observations of Land and Atmosphere, PARABOLA III. The intercomparisons are made for six types of surfaces: bright desert, salt pans, grassland, forests, snow and the Dismal Swamp. The results show that MISR BRF values are mostly within ± 10% in agreement with the corresponding airborne and ground measurements, independent of the surface type. This study is part of an effort to evaluate and validate MISR surface products.**

1. Introduction

The Multiangle Imaging SpectroRadiometer, MISR, launched on December 1999 aboard the Earth Observing System, EOS Terra platform, continues to make observations of top-of-atmosphere (TOA) radiances in four spectral bands (centered at 446, 558, 672 and 866 nm) and at nine fixed angles (nadir and 70.5°, 60.0°, 45.6°, and 26.1° forward and aftward of nadir) in the along-track direction [Diner et al., 1998a, 2002]. From these observations, atmospheric aerosol optical depths and surface bidirectional reflectance factor, BRF, among other atmospheric parameters, are routinely retrieved, archived and distributed to the community at the NASA Langley Distributed Active Archive Center (DAAC) [Bothwell et al., 2002]. This work, which is part of an ongoing effort to validate MISR surface products, is focussed on evaluating MISR BRF retrievals by comparing their values to those obtained coincidently by airborne and/or ground-field measurements that are made independently by one or more calibrated instruments and validated techniques. Specifically, this study compares MISR BRF with values obtained by at least one of three different instruments: The Cloud Absorption Radiometer, CAR [King et al., 1986], the MISR airborne simulator, AirMISR [Diner et al., 1998b] and the ground-based Portable Apparatus for Rabid Acquisition of Bidirectional Observations of Land and Atmosphere, PARABOLA III [Bruegge et al., 2000]. These instruments were deployed, together or separately, during comprehensive observational campaigns designed for atmosphere-surface characterizations and for other specific purposes, such as satellite validation and/or calibration. A total of 20 groups of data collected over six different surface types including: bright desert, salt pans, dark grassland, forests, snow and the Dismal Swamp, were selected for the current analyses. Each of these groups consists of a BRF data set retrieved from MISR and one retrieved from simultaneous measurements by one of the above mentioned field instruments. The BRF is an inherent property that describes the anisotropy pattern of the surface reflectance as function of the illuminating geometry. It is defined as the ratio of the radiance reflected by the target surface in a specific direction to that reflected in the same direction by a perfect Lambertian surface under the same parallel beam Ii.e., direct) illumination.

2. MISR BRF retrieval strategy.

MISR is uniquely designed to observe the same scene on the ground in nine angles and four spectral within 7 minutes. It is reasonable to assume that during these 36 near-simultaneous observations, the atmosphere remains constant and that the effects due to the small changes in the sun angle are negligible. Due to surface projection effects, the cameras' footprints vary in size from 214 m X 250 m in the nadir to 707 m X 275 at the most oblique cameras. However, MISR radiances are sampled with 275 m along-track spacing for all cameras and the MISR georectification process resamples the data from all cameras to a 275-m resolution grid [Jovanovic et al., 1998]. To make sure that all MISR's 36 observations are associated with the same scene on the ground, the surface retrieval algorithm is performed on a group of 16 (4 x 4) of the high-resolution samples, creating a 1.1 km area (known as a subregion), reducing the surface projection effect among the camera footprints.

The BRF retrieval requires prior knowledge of the atmospheric parameters. These parameters are determined from the MISR aerosol retrieval process [Martonchik et al., 1998]. The MISR aerosol retrieval algorithm is based on a procedure that does not require knowledge of the absolute surface reflectance or its spectral characteristics. The multi-angle viewing establishes a representation of the angular shape of the surface component of the observed radiances. The aerosol properties are then derived from fitting the angular shape of the remaining signal to modeled atmospheric path radiances. The latter are simulated for a set of preselected aerosol mixtures, each containing a maximum of three pure particle types in specified proportions. Successful retrievals are those for which the mean-squared differences between observations and simulated radiances are smaller than a specified threshold. The mean optical depth, and other atmospheric parameters, averaged over all successful models, is then used for the retrieval of the surface products. For details of the MISR aerosol and surface retrieval methodologies, see Martonchik et al., [1998a,b].

3. BRF intercomparison data.

The BRF data employed in this study were obtained during various field campaigns where at least one instrument that measures the BRF was present during MISR overpass. As mentioned in the introduction, 20 groups of data that cover a wide variety of surface types were available for the present analyses. Each group consists of one set of MISR data and one or more data set obtained with one or more of the field instruments. Ideally, each group of data should be coincident and simultaneous, i.e., made at the same site and under the same illumination and clear atmospheric conditions. However, during a few of the measurement campaigns, for logistic reasons, the field data were not simultaneously obtained with MISR. But since, as defined in section 1, the BRF is an inherent property that depends only on the surface viewing and illumination geometry and is independent of the atmospheric aerosol, therefore, the intercomparisons of MISR BRF with those measured by other sensors are always valid when the latter are interpolated in MISR's viewing and illuminating geometry. Such interpolation is possible since the field instruments used in measuring the BRF usually obtain these measurements in numerous viewing and illuminating directions. It is also important, in comparing non-simultaneous data, to make sure that all the data were collected during clear (no clouds) atmosphere and that the surface condition has not changed, for example due to rain, between the sensors' measurements. The following section describes the field instruments and observations that are involved in the present work.

3.1. Field instruments and observations.

3.1.1. The PARABOLA III. The Portable Apparatus for Rabid Acquisition of Bidirectional Observations of Land and Atmosphere, the PARABOLA III, measures the complete hemispheric incident and reflected radiance at a point on the surface in 5° spherical grid, in eight spectral channels at 444, 551, 650, 860, 944, 1028, 1650, and 400-700 nm. The first four of these channels nearly coincide with MISR four spectral bands, both in center wavelength and band pass. A complete spherical scan takes ~3 minutes and represents one data record consisting of radiance in 37 X 72 elevation and azimuthal angles, respectively. The instrument spatial resolution varies from few centimeters in the nadir to several meters near horizon viewing. Detailed description of the PARABOLA, its calibration and performance in the field are presented by Bruegge et al., (2000).
The PARABOLA data are used to retrieve the surface BRF using the methodology and algorithm developed by Martonchik, (1994). A portable spectrometer, manufactured by analytical spectral devices (ASD), is one of the supporting instruments that is used to compliment the PARABOLA. The ASD provides measurements of the surface reflectance in the nadir direction and over the spectral range 350 to 2500 nm. It is used to to account for the differences in surface brightness at various location on the surface. The portable ASD is used to scan a large area of the surface surrounding the PARABOLA without significant changes in the illumination or atmospheric conditions during the Terra overpass time. The PARABOLA data are then normalized to the average reflectance estimated from the ASD scans. A complete description of how the PARABOLA observations are processed and used to determine the surface BRF is given in Abdou et al., (2000).

The PARABOLA was used in all of MISR vicarious calibration campaigns [Abdou et al., 2002] that were carried out bi-annually at arid bright desert sites such as, Lunar dry Lake (38.4° N, 115.99°W) and Railroad Valley (38.5°N, 115.67°W), Nevada, CA, where the atmosphere is usually clear. At JPL, MISR home institute, there are several sets of these vicarious calibration data over the 2000-2004 period. Eight sets were selected that include both PARABOLA and MISR coincident and simultaneous data. Other sets of PARABOLA data collected over snow at Steamboat, Colorado, on March 8, 2001, during a study of snow albedo by the university of Colorado, and over salt pans during the Southern Africa Regional Science Initiative (SAFARI 2000) [Swap et al., 2002], are also used in the present analyses.

3.1.2. The CAR instrument. The Cloud Absorption Radiometer (CAR) instrument is an airborne multi spectral scanning radiometer developed at Goddard Space Flight Center originally for the study of cloud absorption [King et al., 1986]. The instrument is designed to scan the sky downwelling and the ground upwelling radiances from zenith to nadir in 1° field of view in 14 spectral channels (340-2300 nm). The CAR is is usually deployed aboard the University of Washington Convair CV-580 research aircraft. At ~600 m altitude, the resolution of the CAR is ~10 m at nadir and ~270 m at 80° view. The multiangle viewing geometry of the CAR allows determination of the directional reflectance properties of terrestrial surfaces [Tsay et al., 1998; Soulen et al., 2000; Gatebe et al., 2001]. Multiple circular orbits are usually made in order to average out any variations in surface brightness. The surface BRF are retrieved from the CAR measurements after applying an atmospheric correction to remove the radiances scattered by the ambient atmosphere, using simultaneous field measurements of the atmospheric optical depth [Gatebe et al., 2003]. The CAR data used in this study were collected over Southern african sites during the SAFARI 2000 campaign, and over the Dismal Swamp during the Chesapeake lighthouse and Aircraft Measurements for Satellites, CLAMS, campaign that was launched on 10 July to August 2, 2001 to validate the Terra data products.

3.1.3. *AirMISR instrument.* The AirMISR is an airborne MISR simulator designed to support the validation, in-flight

August 2, 2001 to validate the Terra data products.

3.1.3. *AirMISR instrument*. The AirMISR is an airborne MISR simulator designed to support the validation, in-flight radiometric calibration, and performance of MISR [Diner et al., 1998b]. It was constructed with a single camera built from MISR brassboard components. The camera is mounted on a gimbal system that provides rotation about a horizontal axis into viewing directions duplicating those of MISR (9 view angles x 4 spectral bands). The AirMISR instrument resides in the nose cone of the NASA ER-2, which flies at 20 km above sea level. At this altitude, the camera footprints varies with view angle from ~7 m cross-track by 6 m along track in the nadir view to 21 X 55 meter at the most oblique angle. The AirMISR flights are usually planned to coincide in time and configuration with MISR. The surface BRF is retrieved from AirMISR observations using an algorithm that is similar to that used with MISR but with the advantage of using the field measurements of the aerosol optical depth and type. The radionetrically calibrated and georectified output images, and the retrieved BRF data, have a resolution of 27.5 m, therefore, the comparison with MISR BRF is performed over the average over 10 X 10 of AirMISR pixels.

In August, 2003, an airborne campaign was launched by New Hampshire University, NHU, with the participation of MISR team at JPL. During this campaign, AirMISR flew aboard the ER-2 aircraft, to acquire high resolution multiple view angle remote sensing data over two intensively studied forest research sites in the northern United States: Howland (45.2°N, 68.7°W), and Harvard (42.5°N, 72.13°W). The BRF data retrieved from AirMISR radiances over these two sites are used in the present analyses. All the results of the intercomparisons of MISR BRF and those retrieved by the field instruments are discussed next.

4. Results.

The comparisons of MISR BRF data with those retrieved from the airborne and ground field instruments are illustrated in Figure 1, where all of MISR data are regressed against all the field data for all bands and viewing angles. The error bars represent MISR retrieval errors. A maximum of 10% error is assumed for both PARABOLA and AirMISR data. Like MISR and AirMISR, errors in the CAR data are sensitive to errors in the measurement of the aerosol optical depths that are used in the atmospheric correction process. Such errors are obviously enhanced at larger view angles. The 720 data points linear regression fits the line represented by the equation: $y = 0.95\ x + 0.026$. The 1-σ uncertainties in the slope and offset of this line fit are 0.01 and 0.003, respectively. The dashed lines, represented by: $y = (1.0 \pm 0.1)\ x \pm 0.03$, surround 91% of the data, i.e., MISR BRF values and the corresponding field instrument values are in general agreement within ~$\pm$10% with an offset of $\pm$0.03.

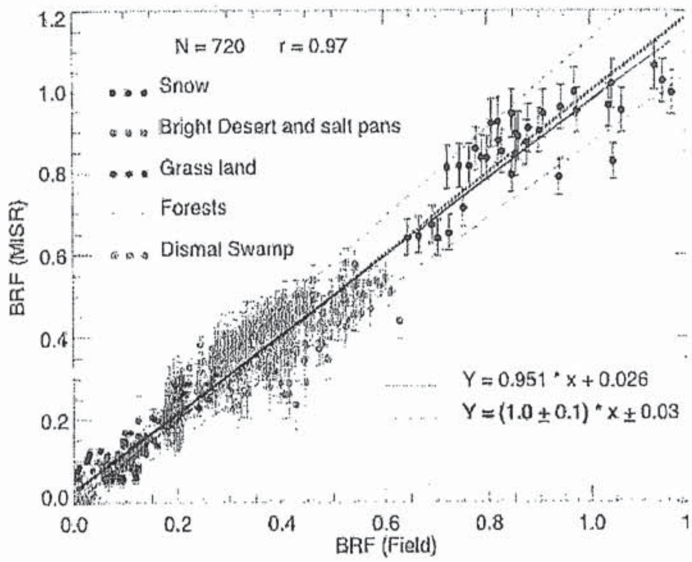

Figure 1. Figure 1. Regression of MISR BRF against corresponding values retrieved from airborne and ground instruments.

Acknowledgment

This work was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration

References

Abdou et al., (2002), IEEE Trans. Geosci. Rem. Sens. 40, 1500-1511.

Abdou et al., (2000), J. Geophys. Res., 106, 11,967-11,976.

Bothwell et al., (2002), IEEE Trans. Geosci. Rem. Sens. 40, 1467-1476.

Bruegge, C. J et al., (2000), Remote Sens. Rev., 19, 75-94,.

Diner et al. (198a), IEEE Trans. Geosci. Rem. Sens., 36, 1072-1087.

Diner et al. (198a), IEEE Trans. Geosci. Rem. Sens., 36, 1339-1349.

Gatebe, C. K. et al. (2001), IEEE Trans. Geosci. Rem. Sens. 39, 805-819.

Gatebe, C. K. et al. (2003), J. Geophy. Res., 108, D13, 8489, doi: 10.1029/2002JD002397.

Jovanovic, V.M. et al. (1998), IEEE Trans. Geosci. Remote Sens., 36, No 4.

King et al. (1986), J. Atmos. Oceanic. Tech., 3, 513-522.

First author contact: Wedad.Abdou@jpl.nasa.gov