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# Analysis of MODIS–MISR calibration differences using surface albedo around AERONET sites and cloud reflectance

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**Abstract**

MODIS and MISR are two Earth Observing System instruments flown onboard the Terra satellite. Their synergistic use could greatly benefit the broad user community by ensuring a global view of the Earth with high-quality products. A necessary condition for data fusion is radiometric calibration agreement between the two instruments. Earlier studies showed about 3% absolute radiometric difference between MISR and respective MODIS *land* bands in the visible and near-IR spectrum, which are also used in aerosol and cloud research. This study compared two surface albedo products derived from MODIS and MISR L1B data using the AERONET-based Surface Reflectance Validation Network (ASRVN). The ASRVN shows a positive MISR–MODIS albedo bias of +(0.01–0.03). Cross-sensor calibration inconsistencies were identified as a primary cause of the albedo biases. To establish an independent MODIS–MISR calibration link, top-of-atmosphere MODIS and MISR reflectances were regressed against each other over liquid water clouds. The empirical regression results have been adjusted for the differences in the respective MISR and MODIS spectral responses using radiative transfer simulations. The MISR–MODIS band gain differences for the top-of-atmosphere reflectance estimated with this technique are +6.0% in the Blue, +3.3% in the Green, +2.7% in the Red, and +0.8% in the NIR band. Applying the derived values to rescale the MODIS or MISR L1B data is shown to significantly reduce the cross-sensor ASRVN surface albedo biases. An absolute calibration scale for both sensors could be established based on independent ground-based measurements of the surface albedo at selected AERONET sites.


*Keywords:* MODIS; MISR; Calibration; AERONET; Surface albedo; Cloud regression

## 1. Introduction

MODIS and MISR are two major Earth Observing System (EOS) (NASA, 1999) instruments flown onboard of TERRA satellite, and used to produce global information about aerosol, cloud and land surface parameters. Each instrument has advantages, such as the large number of spectral bands and daily global coverage of MODIS, and the unique multi-view-angle capabilities of MISR. An optimal synergy of MODIS–MISR products could greatly benefit the broad user community by ensuring consistent, high-quality products providing a global view of Earth's land, ocean and atmosphere.

At present, the absolute radiometric scales of MISR spectral bands and respective MODIS *land* bands are known to differ by about 3% over most of the visible spectrum (Bruegge et al., 2004; Thome et al., 2004; Xiong et al., 2005b). The two instruments employ different calibration strategies, and the differences of about 3% are within the uncertainties of the respective calibration methods. A brief overview of the MODIS and MISR calibration procedures and associated accuracies is given in Section 2.

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The goal of this work is to characterize the difference in the MODIS–MISR relative calibration using the AERONET-based Surface Reflectance Validation Network (ASRVN). The ASRVN [*in preparation*] is an operational processing system that receives MODIS and MISR calibrated top-of-atmosphere (TOA) reflectance (L1B) data around AERosol RObotic NETwork (AERONET) (Holben et al., 1998) sites globally, and uses AERONET well-calibrated aerosol and water vapor data to independently and self-consistently derive surface bi-directional reflectance factor (BRF) and albedo. The ASRVN retrievals show a systematic positive MISR–MODIS bias of +(0.01–0.03). Because spectral band differences are accounted for through the radiative transfer, the most likely explanation for the bias is a calibration inconsistency between the sensors. The ASRVN is briefly introduced in Section 3, and albedo comparison is described in Section 4.

To independently assess the MISR–MODIS calibration differences, a new ASRVN function was developed for this study. It regresses MISR–MODIS TOA reflectances over liquid water clouds, with a theoretical correction for the sensors spectral differences. The methodology and results of the regression analysis are described in Section 5. This section also investigates the effect of different solar irradiance models used in MODIS and MISR calibration that affects radiances and fluxes in the Blue band. Section 6 demonstrates that normalizing MODIS or MISR reflectances to a common radiometric scale using the adjustment factors derived in Section 5 significantly reduces the surface albedo biases in all bands. Finally, Section 7 summarizes and concludes this study.

The structure of this paper reflects evolution of our research from perspective of the multi-sensor data user for the land discipline applications, emphasizing the importance of a consistent calibration. It also shows how comparison of the ASRVN surface albedo, derived from different sensors with AERONET ancillary data and reduced uncertainties, may guide the multi-sensor calibration analysis. Similar approaches based on the use of derived products to detect and quantify sensor calibration uncertainties, have been previously explored in the ocean and atmospheric applications using the water leaving radiance and aerosol optical depth products, respectively (Evans & Gordon, 1994; Ignatov, 2002; Kahn et al., 2005). These approaches emphasize user's perspective to the sensor calibration and articulate the fact that an ultimate measure of the calibration is quality and consistency of the derived products, in contrast with the classical calibration approaches which attempt to characterize and reconcile satellite TOA reflectances or radiances. Furthermore, radiances or reflectances are not easy to compare from different sensors or platforms, which might have different spectral response functions (such as e.g. Terra MISR and MODIS in this study), different overpass times or different sun-view geometry (e.g. Terra MODIS versus Aqua MODIS). On the other hand, these problems can be addressed using the derived geophysical products. Studies linking multi-sensor products and calibration are expected to become more common in the near future, and will be eventually considered a part of the global calibration and validation system as the remote sensing community gears towards the Global Earth Observation System of Systems era.

## 7. Conclusions

This work started with the observation of the systematic biases between the surface albedo and BRF retrieved by ASRVN from MODIS and MISR data near AERONET sites, which is most likely explained by calibration inconsistencies between the two sensors. To verify this observation, an independent cross-calibration analysis was performed using TOA regression method over clouds.

The following cross-sensor calibration biases for L1B reflectance were found: 6.0% in the Blue, 3.3% in the Green, 2.7% in the Red, and 0.8% in the NIR bands. The difference in the MODIS–MISR solar irradiance models does not affect L1B reflectance, but it causes about 3% difference in the L1B radiance in the Blue band. These discrepancies are generally within the calibration uncertainties of the two instruments, 2–4% for MISR absolute radiance, and 2% for MODIS reflectance. However, they may lead to observable systematic differences in the geophysical parameters affecting multi-instrument data analysis and data fusion approaches. For example, the derived band gain difference is spectrally-dependent, increasing from NIR to Blue band. This can be important e.g. for the aerosol particle size and mixture composition retrievals as it affects spectral slope of aerosol optical thickness (e.g. Ignatov, 2002). Furthermore, the systematic difference in surface albedo of 0.01–0.03 in the visible part of spectrum may bias retrievals of vegetation parameters, important for global carbon analysis.

Application of the derived gain correction factors made it possible to reduce cross-instrument albedo biases effectively by a factor of 2–3 in the Blue, Green and NIR bands, although it did not cancel the differences entirely. Albedo agreement in the Red band has also improved, and the remaining bias of 0.015 may be caused by factors other than calibration, as explained in Section 6.

Regressing TOA reflectances from MISR and MODIS against each other over dense liquid water clouds to check cross-sensor calibration consistency is a promising technique when applied to data from the same platform. However, its application to data from different orbits may be subject to time–space mismatch, affecting the correlation and limiting applicability of this method. On the other hand, the relative cross-calibration can be achieved through statistical matching of ASRVN albedo products from different sensors. This method can be applied to sensors from different orbits because it corrects for the difference in the view-illumination geometry (BRF effect). Work is underway to demonstrate this.

One way to adjust the absolute radiometric scales from different orbital instruments would be to provide continuously operating reliable ground-based albedo measurements in selected highly homogeneous locations with different levels of surface brightness, next to AERONET sites. The relative spectral albedo measurements are easier in that they do not pose such rigorous calibration requirements as the absolute radiance measurements. If such measurements were available, the ASRVN could provide mutually consistent absolute calibration factors for the reflectance scales for different instruments.