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VICARIOUS CALIBRATION OF AQUA AND TERRA MODIS

K. Thome, J. Czapla-Myers, S. Biggar
Remote Sensing Group, Optical Sciences Center, University of Arizona, Tucson AZ 85721

ABSTRACT

The Moderate Resolution Imaging Spectroradiometer (MODIS) is onboard both the Terra and Aqua platforms. An important aspect of the use of MODIS, and other Earth Science Enterprise sensors, has been the characterization and calibration of the sensors and validation of their data products. The Remote Sensing Group at the University of Arizona has been active in this area through the use of ground-based test sites. This paper presents the results from the reflectance-base approach using the Railroad Valley Playa test site in Nevada for both Aqua and Terra MODIS. The key to the approach is the measurement of surface reflectance over a 1-km^2 area of the playa and results from this method shows agreement with both MODIS sensors to better than 5%. Early results indicate that while the two sensors both agree with the ground-based measurements to within the uncertainties of the reflectance-based approach, there were significant differences between the Aqua and Terra MODIS for data prior to September 2002. Recent results indicate that this bias, if any, is now within the uncertainties of the reflectance-based method of calibration.

Keywords: Absolute-radiometric calibration, vicarious calibration, atmospheric correction

1. INTRODUCTION

The launch of Landsat-7 in April 1999 started a sequence of launches of an unprecedented number of earth-imaging sensors put into orbit for both land-based and ocean-based remote sensing. These include sensors ranging in spatial resolution from 0.6 to 1000 m and spectral resolution ranging from multispectral to hyperspectral spanning the wavelength regions from visible, near-infrared, through the thermal infrared and beyond to radar wavelengths. Swath widths and repeat visits also span a wide range of values all leading to an opportunity to study earth-processes on a global scale. A good example of one of these sensors was the launch of the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra platform in December 1999 and on the Aqua platform launched in May 2002. The MODIS is one of five sensors onboard the Terra platform and one of four sensors on the Aqua platform. Both platforms are part of NASA's Earth Observing System (EOS) with the sensors on the Terra platform providing data from a morning crossing time in a descending mode and Aqua having an afternoon crossing time in ascending mode.[1] The two MODIS sensors are identical in design with 36 spectral bands covering the visible and near infrared portion to the thermal infrared. The spatial resolution of the sensor varies with spectral band with values of 250 m, 500 m, and 1000 m depending upon the specific application and signal-to-noise characteristics of the particular band.

One of the primary efforts to the use of MODIS data is to develop synergy between the morning and afternoon data sets to improve understanding of land, ocean, and atmospheric processes. This type of work clearly requires that data from the two sensors are consistent from a radiometric standpoint. That is, the two sensors should report the same band-averaged spectral radiances when subject to the same input spectral radiances. Such consistency necessitates an accurate radiometric calibration of the two MODIS. While both sensors were built, characterized, and calibrated by SBRS (Santa Barbara Remote Sensing) prior to launch, it is expected that both sensors could degrade once on orbit. Thus, the use of onboard calibration techniques is integral to the accurate retrieval of at-sensor spectral radiance throughout the lifetime of both sensors.

Unfortunately, it is still possible that biases could exist between the sensors due to the nearly three years between their characterizations and launches. Thus, it is required to rely on vicarious approaches to ensure that data from the two separate sensors are consistent because it is not possible to do inflight cross-calibration between the two MODIS using onboard approaches. The Remote Sensing Group (RSG) at the University of Arizona has exploited these vicarious

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methods to calibrate both low- and high-spatial-resolution sensors with accuracies in the 2-5% range.[2,3,4,5,6,7,8] Application of these approaches to MODIS required modification to account for the much larger spatial resolution of the 1-km bands of the sensor. This work briefly describes these modifications and presents results of applying the reflectance-based approach to MODIS on both the Aqua and Terra platforms. Early data sets from the Aqua platform sensor indicated a possible bias between the two MODIS sensors, but more recent results shows that any bias is well within the uncertainties of the vicarious calibration approach. Comparison of the early Aqua MODIS results to data collected for other sensors indicates that the ground data were not in error, thus it is not clear at this stage for the reason for the disparity between the vicarious predictions of at-sensor radiance and those reported by Aqua MODIS. The results from both Terra and Aqua MODIS agree with the vicarious results to an accuracy of better than +/-3% in most bands and both sensors show good agreement with Landast-7 ETM+ when using the vicarious calibration as a proxy for cross-calibration.

2. RAILROAD VALLEY TEST SITE

The test site used in this work is the Railroad Valley Playa that is on Bureau of Land Management land in central Nevada. The overall size of the playa is approximately 15 km by 15 km at an elevation of approximately 1.5 km. The RSG has been using this site for the radiometric calibration of terrestrial imagers since 1998. The playa's location in a region with high expectations of clear weather and low aerosol loading, coupled with the surface's high reflectance, makes it a good site for the reflectance-based approach described below. Ground-based atmospheric measurements are made at a latitude and longitude of 38.504 degrees North and 115.692 degrees West. The test site that the RSG uses for the reflectance-based calibration of sensors with spatial resolutions of 50 m or less is located approximately 100 m to the east of the atmospheric measurements. The center of the area used for the reflectance-based calibration of large footprint sensors is located at 38.497 North and 115.691 West, approximately 700 m south of the atmospheric instrumentation. This area has been measured consistently since 2000.

Figure 1 shows a full-scene, 185-km wide swath, ETM+ image with Railroad Valley Playa highlighted by the outer box in the lower portion of the figure. The inner box in this figure highlights the region of the playa that is shown in the image in Figure 2. This image is from Space Imaging's Ikonos sensor supplied via NASA's Commercial Data Buy with a spatial resolution of approximately 1 m. The areas of the playa used by the RSG for its work are indicated in this figure. Figure 3 shows a Terra MODIS 500-m resolution image of the playa. While it is clear that surface features plainly evident in the high-resolution data sets are no longer evident in the MODIS imagery, boundaries of the playa, and spatial features in the playa make locating specific regions of the playa possible in the MODIS data. Using ground control points in the MODIS and ETM+ images along with the geolocation information supplied with the MODIS data, makes it possible to locate the low-resolution test site to better than a pixel in the MODIS imagery.

Typical atmospheric conditions at the site include an aerosol optical depth at 550 nm that is less than 0.05 and horizontal visibilities in excess of 60 km. Measurements of atmospheric aerosols using solar radiometer techniques show that variations over time of the optical depth are typically at the noise level of the measurements. Since these measurements typically cover >4 hours, it implies that the horizontal variability of the aerosols over the playa is quite small for a normal, clear-sky day. However, aerosols can vary dramatically across the playa on dates for which clouds are present and for dates on which there are extreme wind conditions. Peak precipitation occurs in winter between December and March and also during the summer months of July and August. There is an additional feature to the Railroad Valley site that is not seen at other test sites used by the RSG. This is that a large amount of aircraft contrails can form and then dominate the sky under conditions that might normally have clear skies or very thin cirrus. The contrails are a result of the large amount of commercial aircraft traveling to and from the west coast that are forced over the playa area by several military air space restrictions that are south of Railroad Valley.

The reflectance of the playa is generally greater than 0.3 and relatively flat spectrally except for the blue portion of the spectrum and an absorption feature in the shortwave infrared (an example of the spectral reflectance can be seen in Figure 8). Ideally, this reflectance would be constant throughout the year, but experience with this site shows that there are significant changes in reflectance with changes in surface moisture. These effects occur primarily in the winter months from large-scale weather systems and in summer months from periodic episodes of heavy rain. Ground-based