Multi-Year Lunar Observations from TRMM/VIRS, Terra/MODIS and Aqua/MODIS

C. Lyu[a], J. Sun[a], X. Xiong[b], and W.L. Barnes[c]
[a]Science Systems and Applications, Inc., 10210 Greenbelt Rd, Lanham, MD 20706
[b]Earth Sciences Directorate, NASA/GSFC, Greenbelt, MD 20771
[c]University of Maryland, Baltimore County, Baltimore, MD 21250

ABSTRACT

This work demonstrates how lunar data are used by three different imaging radiometers: the Visible and InfraRed Scanner (VIRS) onboard the Tropical Rainfall Measuring Mission (TRMM) and the MODerate resolution Imaging Spectroradiometers (MODIS) onboard the EOS Terra and Aqua satellites. Using the measured lunar data, radiometric models have been developed for the on-orbit calibration of the remote sensing systems' reflected solar bands. For the VIRS with spectral bands nearly identical to several of the MODIS bands, the integrated lunar reflectance data were measured, from Jan 1998 to Jun 2006, at phase angles ranging from 1.2° to 120.2°. For the two nearly identical MODIS instruments, the lunar irradiance was measured at phase angles from 54° to 56°. We present stability trending of the lunar data at selected phase angles over periods of four to eight years and use these observations to examine instrument radiometric stability. Moreover, we discuss implications of these results.

Keywords: Moon, Solar Bands, Radiometric Model, Radiometric Stability, TRMM/VIRS, Terra/MODIS, Aqua/MODIS

1. INTRODUCTION

The lunar surface in the visible through shortwave infrared spectrum has been studied extensively by a number of investigators[1,2,3]. Previous studies[3,4] have shown that photometric stability of the lunar surface for radiometric calibration uses has a characteristic time scale of 1×10^9 years. Together with well characterized solar illumination, the moon has been a target for various sensors' radiometric calibrations and validations. Because of changes in lunar phase and libration, different radiometric models[5,6,7] were developed for the on-orbit calibration of remote sensing systems operating in the visible, near and shortwave infrared portions of the solar spectrum.

Designed for long term studies of global climate, NASA's Earth Observing System (EOS) has developed missions which take advantage of using the lunar surface to validate sensor performance. In these missions, the Visible and Infrared Scanner (VIRS) onboard the TRMM satellite was placed in a non-sun-synchronous 350 km (400 km after altitude maneuver on 24 August 2001) altitude orbit, at 35° inclination, on November 28, 1997. The Moderate Resolution Imaging Spectroradiometer (MODIS) is onboard the Terra and Aqua spacecraft which were launched on 18 December 2000 and on 4 May 2002, respectively. These missions, however, fly in very different orbits from VIRS. Both the Terra and Aqua are polar orbiting satellites in sun-synchronous orbits at a nominal altitude of 705 km, inclined at about 98.2°. Because the measured lunar irradiance depends on the observing geometry, even measurements from the Terra and Aqua cannot be directly compared unless acquired at the same time and location[8]. Nevertheless, the intrinsic stability of the lunar surface photometric properties means that a lunar irradiance model can be developed and

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applied to any set of observations. This enables us to interrelate the calibration scales of all sensors that view the Moon. SeaWiFS has demonstrated that after lunar measurements have been collected over a number of years, it is possible to discern instrument degradation rates as low as 0.1 % per year[9,10].

In order to compare the lunar results from TRMM/VIRS, Terra/MODIS and Aqua/MODIS, we use data collected over periods of four to eight years. For the VIRS with spectral bands nearly identical to several of the MODIS bands, the integrated lunar reflectance data were collected, from Jan 1998 to Jun 2006, at phase angles ranging from 1.2° to 120.2°. For the two nearly identical MODIS instruments, the lunar irradiances were measured at phase angles from 54° to 56°. Terra views a waning Moon while Aqua views a waxing Moon. The lunar irradiances obtained at lower phase angles are used for reference only. In this study we present stability trending via the lunar data using all lunar phase angles for VIRS over eight and a half years, and using selected phase angles for MODIS over four to six years. We use these observations to assess instrument radiometric stability and discuss implications of these results.

5. CONCLUDING REMARKS

Since the lunar surface reflectance properties are relatively stable, the Moon can be used for inter-comparing multiple Earth-observing sensors. For MODIS, the Moon has been used to monitor radiometric calibration stability of the sensor's reflective solar band (RSB) and to update the sensor's response versus scan-angle when used together with other on-board calibrators. It has also been successfully used to assess the RSB on-orbit calibration consistency between the Terra and Aqua sensors. Similarly, the VIRS has used the Moon in an attempt to examine its solar diffuser's on-orbit degradation. All the examples (results) presented have shown that the Moon can be effectively used for on-orbit radiometric calibration by using carefully selected lunar observations and proper normalization factors to remove the differences among observation conditions. Currently the RObotic Lunar Observatory (ROLO) model[8] is being developed to establish a spectral irradiance model of the Moon to account for variations with lunar phase, lunar librations, and the location of the Earth-orbiting spacecraft. This program is capable of characterizing the brightness of the Moon for the on-orbit calibration of Earth remote sensing imaging instruments. In adopting this ROLO model, we should be able to find appropriately integrated lunar irradiance for each of the VIRS lunar measurements. This will enable us to improve our on-orbit radiometric calibrations and to more directly track changes in sensor response.

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