Four Years of TRMM/VIRS On-Orbit Calibrations and Characterization Using Lunar Models and Data from *Terra*/MODIS

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ABSTRACT

Four years of on-orbit solar calibration data have been used to quantify the temporal degradation of the two reflected solar bands of the Visible and Infrared Scanner (VIRS) aboard the Tropical Rainfall Measuring Mission (TRMM) satellite. Solar calibrations, performed using an onboard solar diffuser, show no significant changes in the VIRS 1.61-μm data. The responsivity (digital counts per radiance unit) of the 0.62-μm band has changed and, as a function of days since 1998, is given by $R_1(\text{day}) = 69.782 - 0.0022 \times \text{day}$, with an annual degradation of 1.15%. Four years of on-orbit lunar measurements were also examined in an attempt to quantify any degradation in the solar diffuser. The integrated lunar reflectance with phase angles ranging from 1.6° to 106° were fit with the lunar photometric model of Hapke. A good fit was made to the 0.62-μm data, but overall, the quality of the data did not support efforts to quantify any diffuser degradation. The quality of the VIRS radiometry was also examined by comparing data from the five VIRS spectral bands with similar *Terra*/Moderate Resolution Imaging Spectroradiometer (MODIS) bands while viewing near-coincident nadir scenes. The median reflectance differences, VIRS − MODIS, are −1.4% and −12.1% for the solar bands (VIRS 0.62 and 1.61 μm; MODIS 0.65 and 1.64 μm). The median brightness temperature differences for the thermal bands at 3.78, 10.83, and 12.03 μm, respectively, are −0.53, 0.04, and −0.76 K. These values compare well with the values from Minnis et al. The large difference in the 1.61-μm bands and day–night differences in the thermal emissive bands are discussed.

1. Introduction

Since its launch on 28 November 1997 and subsequent operational phase starting in January 1998, the Visible and Infrared Scanner (VIRS) on board the Tropical Rainfall Measuring Mission (TRMM) satellite has been producing radiometrically calibrated imagery from five spectral bands. These bands, centered at 0.62, 1.61, 3.78, 10.83, and 12.03 μm, are located on a single focal plane that is passively cooled to approximately 110 K. Radiometric calibration of the VIRS bands is performed on-orbit using separate algorithms for the reflected solar bands (0.62 and 1.61 μm) and the thermal emissive bands (3.78, 10.83, and 12.03 μm). The reflected bands undergo a two-point linear calibration by periodically viewing the sun via a diffuser plate and space through a port in the side of the sensor. The linear terms for the thermal band quadratic calibrations are similarly determined using an onboard blackbody and a view of space. These linear gains are used in converting the digital counts (DN) of the sensor to radiance (Barnes et al. 2000; Lyu et al. 2000, hereafter called papers Ia and Ib, respectively).

As sensors age, their response (sensitivity) often declines. This loss of sensitivity has only minimal impact on the system's radiometric fidelity since the sensitivity (or gain) of each spectral band is updated frequently. However, in the case of the reflected solar bands, there is a possibility that any observed degradation might not be due to the sensor but to a change in the bidirectional reflectance distribution function (BRDF) of the diffuser. If, as is the case for VIRS, the sensor can view the moon occasionally, the diffuser is no longer in the optical train and any observed change in response must be due to the sensor.

This paper examines nearly 5 yr of VIRS data to determine whether or not there has been any change in the response of the VIRS reflected solar bands and partitions any observed change between the sensor and the BRDF of the diffuser. This information is used to generate time-dependent gains to be adopted prior to the planned TRMM reprocessing (VIRS level 1B, version 6).

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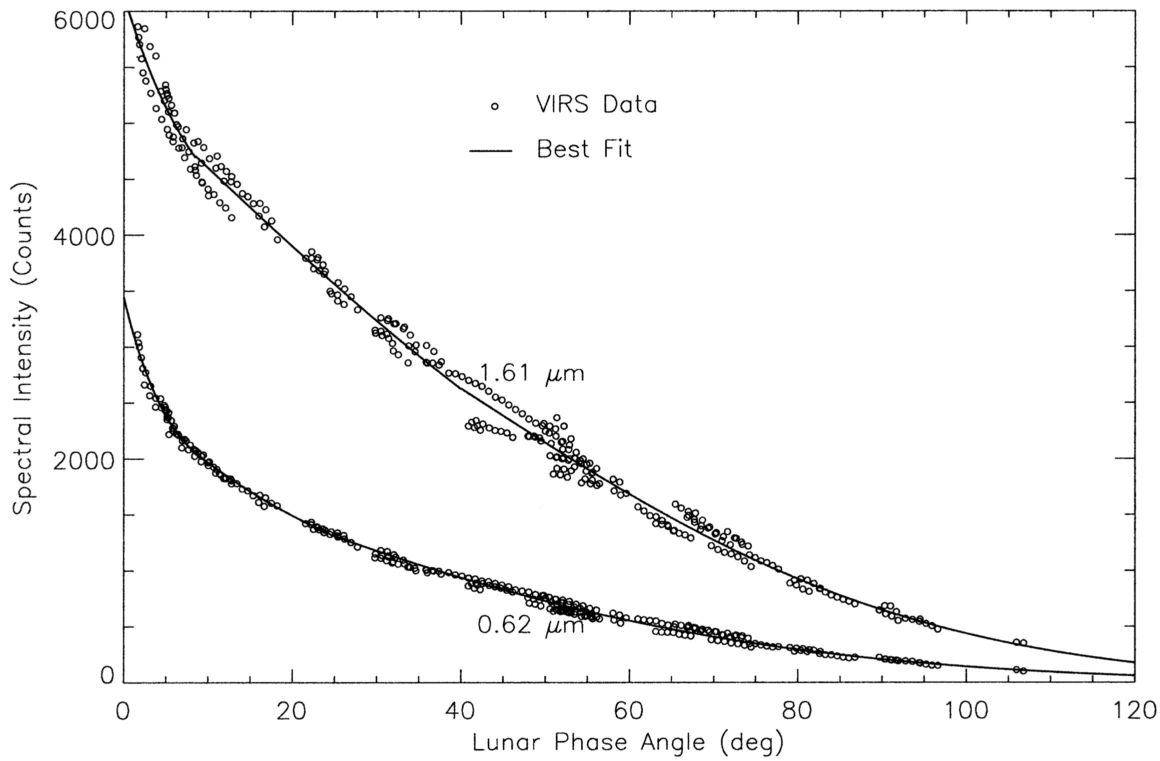

FIG. 1. Disk-integrated spectral intensity (counts) of VIRS 0.62- and 1.61-μm data vs lunar phase angle.

After the on-orbit radiometric calibration of a sensor has been established, it is necessary to validate the accuracy of the data. There is a variety of techniques for performing this task. One such technique is to compare top-of-the-atmosphere (TOA) radiances from similar sensors viewing the same near-nadir scene within a few minutes.

An imaging radiometer similar to VIRS is the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the *Terra* spacecraft, which was launched on 18 December 1999. MODIS has been collecting data from 36 spectral bands since March 2000. A second objective of this paper will be to compare the calibrated TOA spectral radiances of the five VIRS bands with those from similar MODIS bands (Barnes et al. 1998).

5. Concluding remarks

Four years of on-orbit solar calibration in Figs. 3a and 3b show fluctuations of the VIRS 1.61-μm band responsivity of less than 0.5% and no indication of any long-term trend. The solar responsivity of the 0.62-μm band has degraded. The annual degradation rate is 1.15%. The solar responsivities derived from Figs. 3a and 3b will be used for the upcoming TRMM/VIRS data reprocessing.

We have also measured 4 yr of integrated lunar reflectances for phase angles ranging from 1.6° to 106° and have constructed analytic photometric functions for the VIRS 0.62- and 1.61-μm data (Fig. 1). The best fit for the VIRS 0.62-μm band [Eqs. (1)–(3)] is comparable to previous observations from Pohn et al. (1969) and Lane and Irvine (1973). The six-parameter lunar photometric model of Hapke (1984, 1986) provides a good description of the VIRS 0.62-μm data. The Hapke model does not fit the 1.61-μm data.

The 4 yr of VIRS lunar data (Figs. 1, 3) show more scatter in the 1.61-μm data than in the 0.62-μm data. This is due to the smaller spectral radiance (and, therefore, larger gain) of the 1.61-μm band (see Table 4). Although the lunar reflectance curve from the 0.62-μm VIRS observations is in good agreement with photometric models of the moon, we were unable to use the lunar data to quantify any degradation of the solar diffuser.

Radiometric comparisons of the five spectral bands of TRMM/VIRS have been made with similar bands from the *Terra*/MODIS. These comparisons used data from two scenes that were viewed near nadir by both sensors within a few minutes of one another. The reflected solar band (VIRS 0.62 and 1.61 μm) data had median VIRS − MODIS reflectance differences of −1.4% and −12.1%. This compares with values of −6.4% (−1.5% radiance − 4.9% spectral difference from Table 4) for the 0.62-μm band (Minnis et al. 2002a) and −17.0% (−14.8% radiance − 2.2% spectral difference from Table 4) for the 1.61-μm band (P. Minnis 2001, personal communication).