On-orbit Characterization of Terra MODIS Solar Diffuser Bi-directional Reflectance Factor (BRF)

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Abstract. Remote sensing spectroradiometers often use solar diffusers (SD) as on-board calibrators for calibrating sensors' reflective solar bands (RSB), typically with wavelengths ranging from ultraviolet (UV) to short-wave infrared (SWIR), or for monitoring sensors' radiometric calibration stability [1-5]. The SD calibration accuracy and its stability monitoring capability strongly depend on the knowledge of the SD reflectance property, known as the bi-directional reflectance factor (BRF), and on the sensor's ability of tracking the on-orbit changes of the SD BRF. The Moderate Resolution Imaging Spectroradiometer (MODIS) Proto-Flight Model (PFM) is one of the five instruments on-board the NASA's Earth Observing System (EOS) Terra spacecraft launched in December 1999. Improved over its heritage sensors, the MODIS makes continuous global observations over a wide field-of-view (FOV) in 36 spectral bands covering wavelengths from 0.41 to 14.4 micrometers and at three nadir spatial resolutions: 0.25km, 0.5km, and 1km [6]. MODIS bands 1-19 and 26 are the reflective solar bands (RSB) and bands 20-25 and 27-36 are the thermal emissive bands (TEB). Figure 1 illustrates MODIS scan cavity and its on-board calibrators, including a solar diffuser (SD), a solar diffuser stability monitor (SDSM), a blackbody (BB) and a spectro-radiometric calibration assembly (SRCA) [7,8].

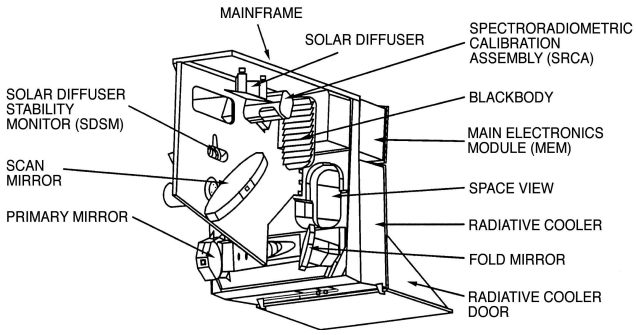

Figure 1. MODIS Scan Cavity and On-board Calibrators

The MODIS RSB calibration is reflectance based through the use of an on-board solar diffuser panel made of space-grade Spectralon materials shown in Figure 2. The MODIS SD bi-directional reflectance factor (BRF) was characterized pre-launch by the instrument vendor against reference samples traceable to NIST reflectance standards. The SD BRF measurements were made at a number of wavelengths and illumination (incident) angles (azimuth and elevation angles in the MODIS coordinates) and with the viewing angle fixed to match the sensor's on-orbit calibration configuration. The pre-launch measurements at each wavelength were fitted to a second order polynomial function of solar illumination angles. For each of the MODIS reflective solar bands, its BRF was either interpolated or extrapolated from the pre-launch characterization results. Another MODIS on-board calibrator, a solar diffuser stability monitor, was designed to track the SD on-orbit degradation. Since its launch the Terra MODIS SD and SDSM system has been effectively used on-orbit for the RSB radiometric calibration.

Figure 2. MODIS solar diffuser (SD) panel

This paper describes an approach of characterizing the sensor's SD BRF using its on-orbit SD observations made during the spacecraft yaw maneuvers. This approach has the advantage of studying the SD BRF directly using the sensor's spectral bands (or detectors) and over all possible illumination angles at the same time. For Terra MODIS, two series of yaw maneuvers have been executed for this purpose. The results derived from Terra MODIS pre-launch measurements and two sets of on-orbit characterizations (yaw maneuvers) are presented in this paper to illustrate the SD BRF uniformity and to study its on-orbit degradation characteristics. Figure 3 is an example of the BRF results derived from pre-launch measurements and that from on-orbit observations for Terra MODIS band 3 at 0.47 micrometer. The difference between on-orbit and pre-launch characterization results is less

than 0.25%. Also addressed in this paper are the impacts of the SD BRF uncertainty and its on-orbit degradation on the sensor's radiometric calibration. For Terra MODIS, the SD BRF degradation has shown a strong wavelength dependency with an annual (degradation) rate varying from 3% at 0.41 micrometer to less than 0.1% at 0.91 micrometers when it's under the nominal operational conditions.

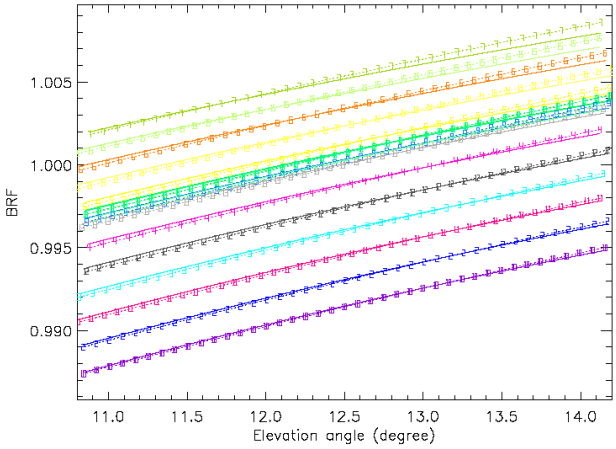

Figure 2. Comparison of pre-launch and on-orbit characterization of Terra MODIS solar diffuser (SD) BRF (band 3; solid line: pre-launch fitting; dash line: on-orbit resutls; the symbles are the spacecraft yaw numbers for differnt azimuth angles)

Acknowledgments

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