5 MODIS Calibration and Characterization

Xiaoxiong Xiong and William Barnes

5.1 Instrument Background

The Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the key instruments for the NASA's Earth Observing System (EOS). It was developed based on the desire of the science community for frequent global observations of the Earth's land, oceans, and atmosphere at a moderated spatial resolution with carefully selected spectral bands at wavelengths ranging from the visible (VIS) through the long-wave infrared (LWIR). The MODIS is a major advance over its heritage sensors in terms of its spectral, spatial, and temporal resolutions and its broad range of science applications. A detailed description of the MODIS development history, science data products, and data processing is provided in Volume Ⅰ Chapter 2 "Introduction to MODIS and an Overview of Associated Activities", and Table 2.1 (MODIS design parameters) provides an overview of key MODIS design parameters. Two nearly identical copies of the MODIS instrument, the Protoflight Model (PFM) and the Flight Model 1 (FM1), were built by the instrument contractor—Raytheon/Santa Barbara Remote Sensing (SBRS) previously known as Hughes/Santa Barbara Research Center (SBRC). The MODIS PFM was launched in December 1999 on-board the EOS Terra (EOS-AM) spacecraft and the FM1 in May 2002 on-board the EOS Aqua (EOS-PM) spacecraft.

The MODIS has 36 spectral bands with center wavelengths from 0.41 to 14.5 μm. It is a passive cross-track scanning (whisk-broom) radiometer with a double-sided paddle wheel scan mirror that continuously rotates at 20.3 rpm. Each scan of 1.478 s produces a swath of 10 km (nadir) in the along track direction and 2,330 km in the along scan direction, thus providing complete global coverage of the Earth every two days. MODIS makes measurements at three different nadir spatial resolutions: 250 m for bands 1 – 2 (40 detectors/band), 500 m for bands 3 – 7 (20 detectors/band), and 1,000 m for bands 8 – 36 (10 detectors/band). The 36 spectral bands are located on four focal plane assemblies (FPAs): VIS, NIR, short-and mid-wave infrared (SMIR), and long-wave infrared (LWIR) as shown in Fig. 5.1. Two of the spectral bands (bands 13 and 14), each with two columns of 10 detectors, output data at low and high gains through the use of time-delay and integration (TDI). Thus, there are a total

of 490 detectors. For each 1 km cross-track integration period (frame), there are 4 sub-frames for the 250 m resolution bands and 2 sub-frames for the 500 m resolution bands.

The scene radiant flux reflects from the scan mirror and then impinges upon a fold mirror followed by an off-axis telescope with a primary and secondary mirror. The aft optics include a dichroic beam splitter assembly consisting of 3 beam splitters, four objective assemblies for the VIS, NIR, SMIR, and LWIR FPAs, fold mirrors, and blocking and spectral band-pass filters. The VIS and NIR detector arrays are photovoltaic (PV) silicon hybrids that are operated at instrument ambient temperature. The SMIR FPA uses PV HgCdTe hybrid arrays. The LWIR FPA consists of PV HgCdTe detector arrays for bands with wavelengths less than 10 μm and photoconductive (PC) HgCdTe detectors for bands beyond 10 μm. Both the SMIR and LWIR FPAs are operated at 83 K on-orbit via a three stage passive radiative cooler.

The analog output signals produced by the PV FPAs are buffered and digitized by the space-view analog module (SAM). The signals produced by the PC detectors on the LWIR FPA are pre-amplified by the cooler located amplifier module (CLAM) and then post-amplified and digitized by the forward-viewing analog module (FAM). The digital outputs from SAM and FAM are formatted into science data packets by a formatter processor in the main electronics module (MEM). They are then buffered and sent to the spacecraft through a first-in first-out (FIFO) buffer and fiber distributed data interface (FDDI) circuits.

As shown in Fig. 2.1 (Vol. Ⅰ: Chapter 2), the MODIS OBCs include a solar diffuser (SD), a blackbody (BB), and a spectro-radiometric calibration assembly (SRCA). In addition, there is a space view (SV) port that is used to provide a zero reference. The on-orbit degradation of the SD is monitored by the solar diffuser stability monitor (SDSM).

Utilizing the rotating scan mirror, the sensor takes data each scan from the OBC and Earth view (EV) sectors: 50 frames of data from the SD sector, 10 from the SRCA, 50 from the BB, 50 from the SV, and 1,354 from the EV. The SD/SDSM system is used for the on-orbit radiometric calibration of the sensor's 20 reflective solar bands (RSB) with wavelengths from 0.41 μm to 2.1 μm and the BB for the radiometric calibration of the 16 thermal emissive bands (TEB) with wavelengths above 3.7 μm. The SDSM only takes data during scheduled SD calibrations. The SRCA is used primarily for spatial (all bands) and spectral (RSB only) characterization. It also provides limited radiometric monitoring capability for the RSB.

Overall, the two MODIS instruments (PFM and FM1) have been performing very well, exceeding the majority of the design specifications and science requirements (Barnes et al., 2002; Salomonson et al., 2002). The OBCs have been functioning as designed, providing continuous on-orbit instrument calibration and characterization in support of the production of high quality data products for the studies of short- and long-term global and regional Earth processes and trends (Xiong et al., 2003a; 2003b).