A New Method for Retrieving Band 6 of Aqua MODIS

Lingli Wang, John J. Qu, *Member, IEEE*, Xiaoxiong Xiong, Xianjun Hao, *Student Member, IEEE*, Yong Xie, and Nianzeng Che

***Abstract*—The Moderate Resolution Imaging Spectroradiometer (MODIS) is a key research instrument for the NASA Earth Observing System (EOS) mission. It was successfully launched onboard the Terra satellite in December 1999 and Aqua satellite in May 2002. Both MODIS instruments have been working well except that 15 of the 20 detectors in Aqua MODIS band 6 (1.628–1.652 μm) are either nonfunctional or noisy. The striping in Aqua MODIS band 6 caused by its nonfunctional or noisy detectors has been a serious problem for MODIS snow products, which use band 6 primarily for snow detection. MODIS scientists have been using Aqua MODIS band 7 (2.105–2.155 μm) instead of band 6 for computing the normalized difference snow index to continue detecting global snow coverage. The main objective of this letter is to retrieve Aqua MODIS band 6 using other bands based on their relationships in Terra MODIS. The band retrieval approach proposed in this letter is also very useful for the next generation of MODIS sensor—the Visible/Infrared Imager/Radiometer Suite (VIIRS) band M10 proxy data generation. Such proxy data can support the VIIRS prelaunch end-to-end testing, postlaunch calibration/validation, and data quality checking.**

***Index Terms*—Aqua, band 6, Moderate Resolution Imaging Spectroradiometer (MODIS), normalized difference snow index (NDSI), retrieval, Terra.**

I. Introduction

THE Moderate Resolution Imaging Spectroradiometer (MODIS) is a key research instrument for the NASA Earth Observing System (EOS) mission [1]. The first MODIS instrument was launched onboard the EOS Terra satellite in December 1999 and the second onboard the EOS Aqua satellite in May 2002 [2], [3] (see also http://modis.gsfc.nasa.gov). Because MODIS senses all the Earth's surface in 36 spectral bands spanning the visible [(VIS) 0.415 μm] to infrared [(IR) 14.235 μm] spectrum at nadir spatial resolutions of 1 km, 500 m, and 250 m, the MODIS remote sensing applications are of interest not only to land, ocean, and atmosphere researchers but to application, interdisciplinary, and environmental scientists [4]–[6].

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L. Wang, X. Hao, and Y. Xie are with George Mason University, Fairfax, VA 22030 USA (e-mail: lwang2@gmu.edu).

J. J. Qu is with the NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA and also with George Mason University, Fairfax, VA 22030 USA.

X. Xiong is with the NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA.

N. Che is with Science Systems and Applications, Inc., Lanham, MD 20706 USA.

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The Aqua MODIS instrument has been performing well since its launch with the exception of band 6 (1.628–1.652 μm). Fifteen of the 20 detectors in Aqua MODIS band 6 are either nonfunctional or noisy. The striping in Aqua MODIS band 6 caused by its nonfunctional or noisy detectors is a serious problem for MODIS snow products, which use band 6 primarily for snow and cloud detection. Because of this the quality of both snow and cloud products in Aqua MODIS is degraded. To continue monitoring global snow coverage, the MODIS scientists have been using Aqua MODIS band 7 (2.105–2.155 μm) instead of band 6 to compute the normalized difference snow index (NDSI). Since snow has similar reflectance characteristics in MODIS bands 6 and 7 relative to other bands, band 7 is considered a reasonable replacement for band 6 in snow mapping and snow monitoring.[1] However, the snow reflectance is typically a few percent lower in band 7 than in band 6. This difference results in higher NDSI values and subtle changes in the ability to detect snow and clouds in some situations [7]. Therefore, it is necessary to further investigate the relationship between MODIS bands 6 and 7 and possibly identify another alternative for NDSI retrieval as a replacement for band 6. The first MODIS instrument onboard the Terra satellite still performs well, thus providing an opportunity to identify the relationship among MODIS bands and to apply the relationship to Aqua MODIS. The five good detectors of Aqua MODIS band 6 can be used for validating band retrieval results.

The objectives of this letter are: 1) to identify the relationship between MODIS bands 6 and 7 using Terra measurements; 2) to retrieve Aqua MODIS band 6 based on the relationship between Terra MODIS bands 6 and 7; 3) to identify another alternative for NDSI retrieval as a replacement for band 6 instead of using Aqua MODIS band 7; and 4) to validate the band 6 retrieval approach using the measurements made by the five functioning detectors in Aqua MODIS band 6.

II. Methodology

Each MODIS, either on the Terra or on the Aqua satellite, has 20 reflective solar bands (RSBs) from the VIS to near-IR and short wavelength IR (SWIR), making observations at three different nadir spatial resolutions: 250 m (bands 1–2), 500 m (bands 3–7), and 1000 m (bands 8–19, and 26). The 250-, 500-, and l000-m bands have 40, 20, and 10 detectors per band, respectively. The RSBs with wavelengths from 0.41–2.13 μm are calibrated on-orbit by a solar diffuser [8], [9]. Table I shows the MODIS 250- and 500-m bands specifications.

[1]http://modis-snow-ice.gsfc.nasa.gov/new.html

TABLE I
MODIS 250- AND 500-m BANDS SPECIFICATIONS

Band	Central Wavelength (μm)	Bandwidth (μm)	Spectral Radiance[1]	SNR[2]
1	0.645	0.620-0.670	21.8	128
2	0.858	0.841-0.876	24.7	201
3	0.469	0.459-0.479	35.3	243
4	0.555	0.545-0.565	29.0	228
5	1.240	1.230-1.250	5.4	74
6	1.640	1.628-1.652	7.3	275
7	2.130	2.105-2.155	1.0	110

[1](W/m^2-μm-sr), and [2]SNR=Signal-to-Noise Ratio

MODIS is especially suited for remote sensing of snow because its bands cover the VIS and SWIR wavelengths. Snow characteristically has high reflectance in the VIS and low reflectance in the SWIR at about 1.6 μm, a characteristic that allows for snow detection by a normalized ratio of VIS and SWIR bands. That characteristic of snow is fairly constant over a wide range of land surfaces and illumination conditions [10]. The automated MODIS snow-mapping algorithm uses at-satellite reflectance in MODIS VIS band 4 (0.545–0.565 μm) and SWIR band 6 (1.628–1.652 μm) to calculate NDSI [11]

$$\text{NDSI} = \frac{\text{band4} - \text{band6}}{\text{band4} + \text{band6}}.$$

Based on analysis of Terra MODIS bands 6 and 7, Aqua MODIS band 6 can be retrieved using band 7 measurements. Because band 6 is mainly used in the MODIS snow product, Terra MODIS Level 1B calibrated radiance data with snow coverage were selected to determine the relationship between Terra bands 6 and 7. Statistics for correlation of reflectance of these two bands and NDSI values were analyzed. Subsequently, specific band 6 retrieval algorithms for Aqua MODIS were developed, applied, and validated with Terra MODIS and Aqua MODIS measurements.

III. CASE STUDIES AND ANALYSIS

A. Data Collection

For band retrieval algorithm construction, application, and validation, four granule MODIS datasets of both Terra and Aqua selected from different quarters (February 13, 2003, June 21, 2003, September 25, 2003, and December 30, 2003) were studied, including MODIS Level 1B calibrated radiance (1 km, version 4) and MODIS Level 1A geolocation (1 km, version 4) data.

MODIS Level 1B 1 km Calibrated Radiances contains calibrated and geolocated radiances at-aperture for all 36 MODIS spectral bands at 1-km resolution.

MODIS Level 1A Geolocation Data contains geodetic latitude and longitude, surface height above geoid, solar zenith and azimuth angles, satellite zenith and azimuth angles, and a land/sea mask for each 1-km sample.

IV. DISCUSSION AND CONCLUSION

In this letter, we demonstrated: 1) the approach of retrieving Aqua MODIS band 6 using the analytical relationship between Terra MODIS bands 6 and 7 is feasible and 2) good agreement of two band 6 retrieval algorithms suggesting that MODIS bands 6 and 7 are highly correlated and the relationship is stable over snow coverage. The relationship between these two bands also depends on many factors, such as land cover types, spectral characteristics, and scan geometry. Retrieval accuracies are functions of surface type, band and sensor viewing geometry, etc. For further understanding of the relationship between MODIS bands 6 and 7, analysis of the retrieval algorithm should account for above factors. Future studies will focus on analyzing surface types, solar zenith, and view angles.

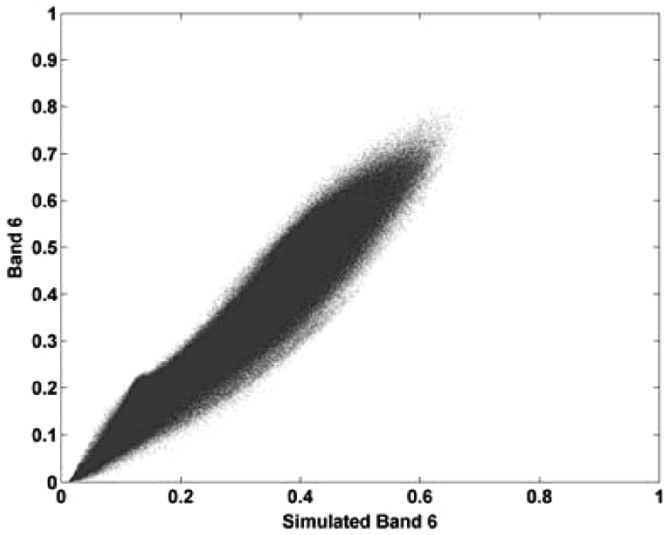

Fig. 4. Scatter plot of band 6 good detectors measured to simulated reflectances on June 21, 2003.

The band 6 retrieval in this letter presents an approach in future analyses for snow mapping, possibly to find another alternative for Aqua MODIS NDSI retrieval, and to keep the continuity and consistency of MODIS snow products. The band retrieval approach can be applied to other applications, such as proxy data generation. These analytical techniques will prove useful for the next generation of MODIS sensor—the Visible/Infrared Imager/Radiometer Suite band M10 proxy data generation. Such proxy data can support the VIIRS prelaunch end-to-end testing, postlaunch calibration/validation, and data quality checking.