Estimation of MODIS-Terra Near-Infrared (748, 869nm) Water-leaving Radiance in East US Coastal Region

Wei Shi
University of Maryland Baltimore County
Code 970.2, NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

Menghua Wang
NOAA NESDIS
Office of Research and Applications
Camp Springs, Maryland 20746

Abstract

The Case-2 water could contribute significant amount of radiance to the NIR channels (748, 869nm) in the coastal region. In this presentation, MODIS Terra band 5 (1240 nm) and band 6 (1640 nm) are used to evaluate the ocean contribution in band 15 (748 nm) and band 16(869 nm). Examples of two granules (2004071.1515 and 2004107.1625) off US east coast show that ocean could contribute reflectance of 3% and1.8% for band 15 and 16 in the coastal region around Outer Banks, while in Chesapeake Bay region it could reach mean values of 0.28% and 0.12%, respectively. This suggests the ocean contributed reflectance in these two NIR bands for atmospheric correction could cause significant error in MODIS ocean color products for Case-2 water in the coastal regions.

Water Leaving Radiance in NIR Bands

It has been well recognized that Case-2 water could contribute significant amount of radiance to the NIR channels (748, 869 nm) in the coastal region(Siegel *et al* , 2000; Stumpf *et al*., 2003). Figure 1 shows MODIS Terra NIR reflectance after removing the Raleigh reflectance. In general in the open ocean, the reflectance is consistent and within a range of ~ 0.5% for band 15 and 16 (748 nm and 869 nm) indicating that the values in the open ocean are the reflectance from aerosol scattering. These are quite different in the coastal regions. The reflectance can reach extreme value of 3-4% in the east US coast especially in the mid-Atlantic region (Outer Banks).

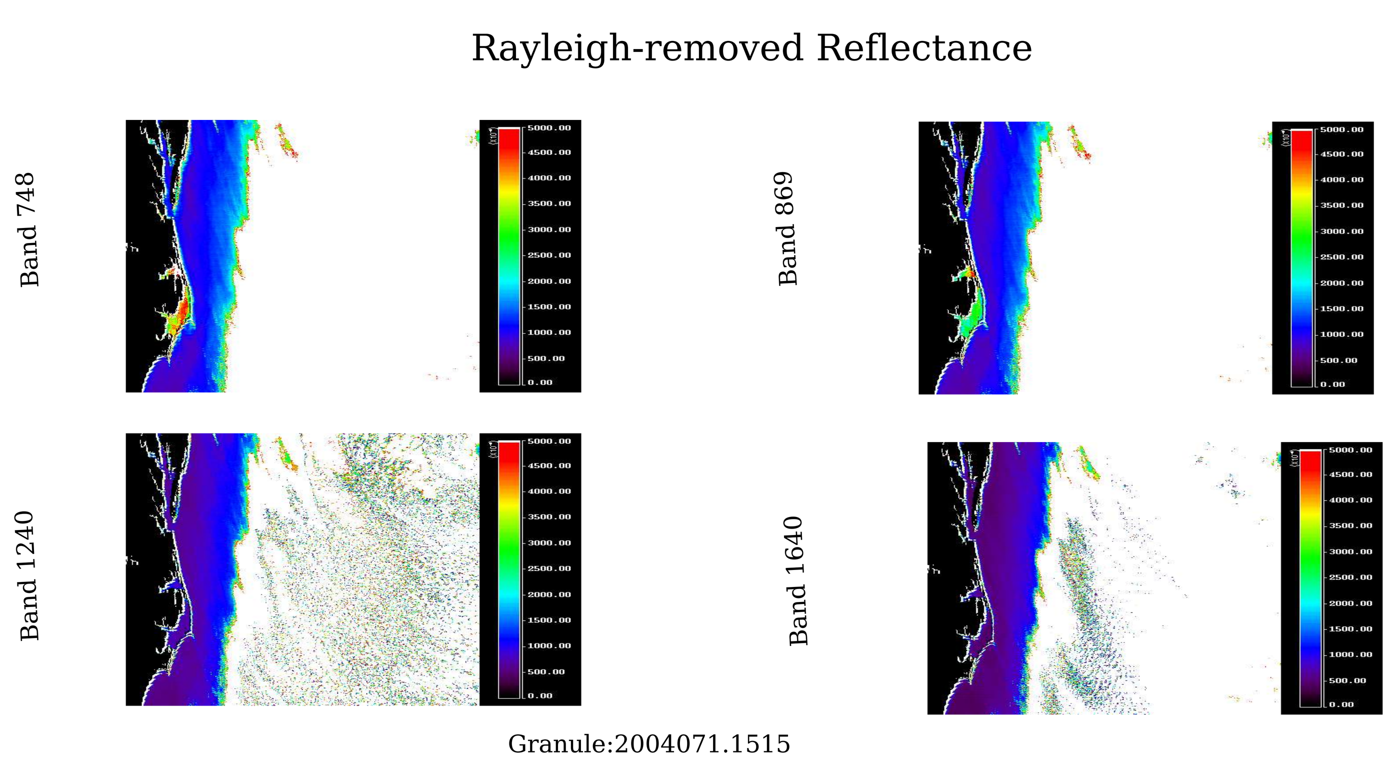

Fig. 1 Reflectance in each band after Raleigh reflectance is removed.

MODIS atmospheric correction algorithm

The MODIS atmospheric correction algorithm uses aerosol information (single-scattering epsilon) derived from two NIR bands (band 15 centered at 748 nm and band 16 at 869 nm) to extrapolate aerosol optical and radiative properties into the visible bands for the retrieval of the ocean products (Wang and Gordon,1994; Wang and Gordon, 1994). The ocean at the NIR bands is assumed to be black at the open ocean waters, while some modification can be applied for high productive waters using the bio-optical model (Siegel *et al*., 2000; Stumpf *et al*., 2003)

Method

The major assumption for atmospheric correction with band 15 and band 16 is the black pixel assumption. Since we know this is not valid for the coastal Case-2 waters, some other bands are added for the atmospheric correction purpose. Raleigh-removed reflectance in band 5 and band 6 (1240 nm and 1640 nm) in Fig. 1 suggests we could use band 5 and band 6 as the standard bands for retrieving the aerosol information and then extrapolate it into NIR wavelengths (748 nm and 869 nm) to compute the theoretical values of these two wavelengths where there is no radiance of ocean contribution in these two bands. With the no-ocean-contributed reflectance from above computation and the real measurements from MODIS Terra L1b data for the two bands, the reflectance from ocean contribution could then be estimated.

Figure 2 shows the details of the procedures to conduct above ocean contribution estimations in the two NIR bands (748nm and 869nm).

Procedures For B748 and B869 Ocean-Contributed Reflectance Estimation

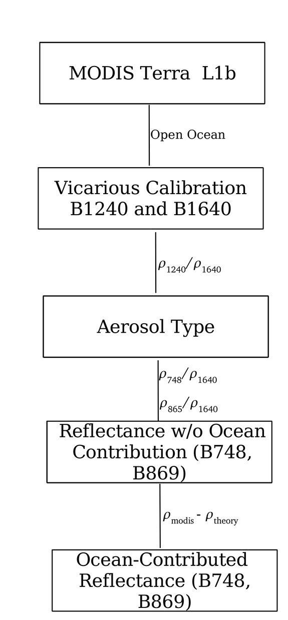

Fig. 2 Schematic chart showing the procedures to conduct the computation of the ocean-contributed reflectance in MODIS band 15 and band 16

Results

We choose two granules from MODIS Terra L1b with clear atmosphere in the coastal region to carry out this computation. Two cases are from granule 2004071.1515 (March 11, 2004) and granule 2004107.1625 (April 16, 2004), respectively.

Figure 3 shows the geographic distribution of the ocean-contributed reflectance in bands 15 and 16. For the granule of 2004071.1515, along the east US coast, the ocean contributes significant amount of radiance in the region of Outer Banks, the ocean-contributed reflectance could reach above 1.5% for band 15 and ~1.5% in most of the outer banks region for band 16. In the Chesapeake Bay region, the ocean contribution is also obvious along the coast with a value of ~0.4-0.5% for band 15 and ~0.25% for band 16.

For the granule 2004107.1625, we could still see apparent ocean-contributed reflectance along the east coast even though it is not as significant as from granule 2004071.1515. In Chesapeake Bay region , the ocean contribution along the coast is still noticeable with a weaker value. In the central Chesapeake Bay region, there is no significant ocean contributions.

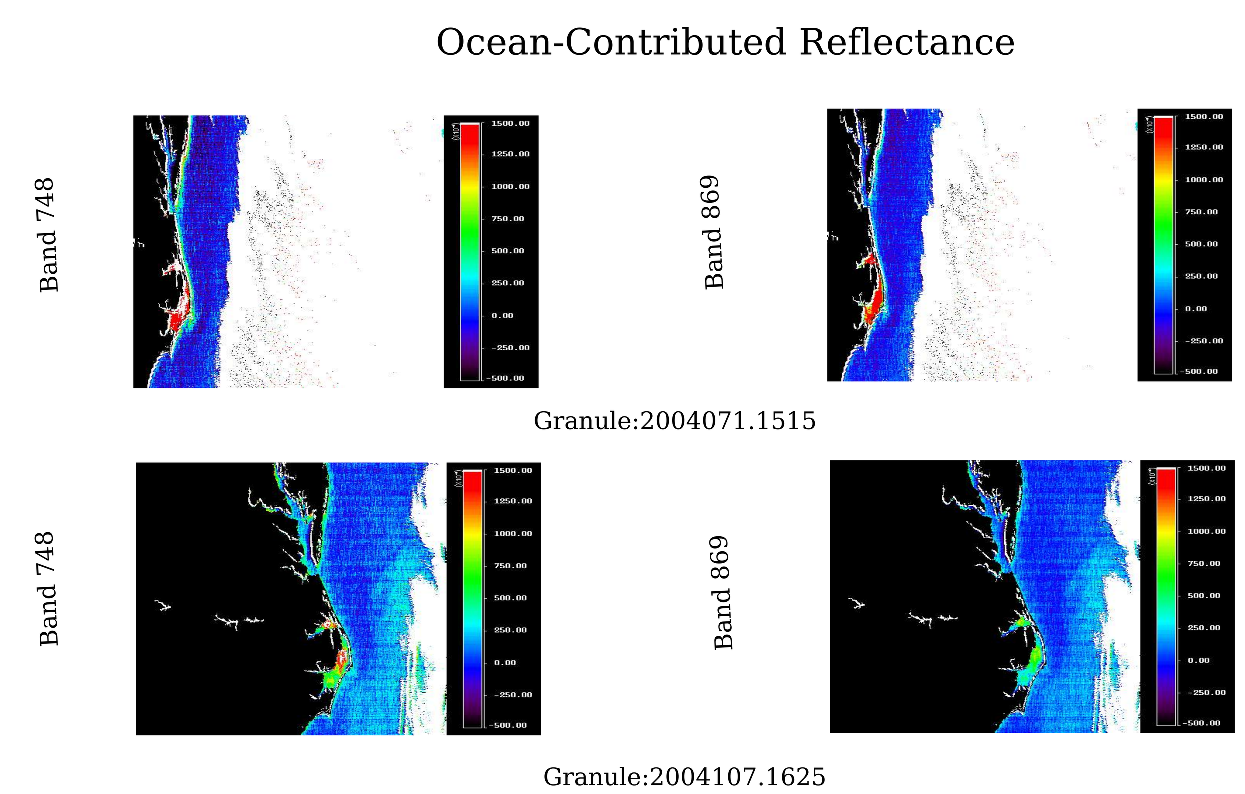

Fig. 3 Geographic distribution of ocean-contributed reflectance for (a) band 15, granule 2004071.1515. (b) band 16, granule 2004071.1515 (c) band 15, granule 2004107.1625 (d) band 16, granule 2004107.1625. The unit of the scale bar is x10^-5.

For the MODIS granule 2004071.1515, the histogram pattern (Fig. 4) seems following standard normal distribution pattern with the mean ocean-contributed reflectance being 0.215% and 0.067% separately for band 15 and band 16 in Chesapeake Bay region, respectively. The modes of the distribution are similar to the mean with the values of 0.17% and 0.07% for two bands. Different from Chesapeake Bay region, the distribution of the ocean-contributed reflectance shows a two-mode distribution. Th first mode is positioned at ~ 0 ocean-contributed reflectance which represents the open ocean contributions in this region. The second mode has a value of ~3% which indicates higher ocean contribution within Outer Banks as shown Fig. 3. As expected ,the ocean contribution is less significant in band 16 (869 nm) than in band 15 (748 nm).

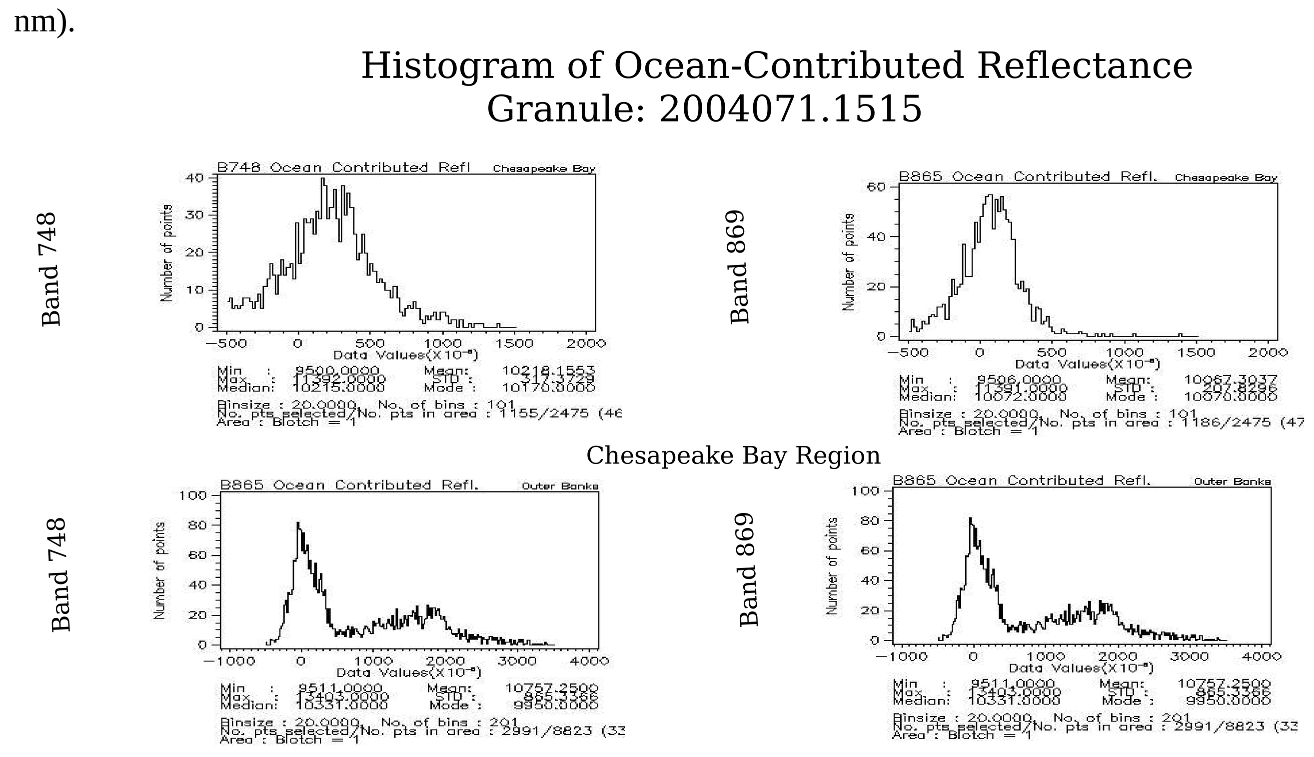

Fig. 4 Histogram of ocean-contributed reflectance for granule 2004071.1515 from (a) band 15 in Chesapeake Bay region . (b) band 16 in Chesapeake Bay region (c) band 15 in Outer Banks region (d) band 16 in Outer Banks region.

Fig.5 shows the histogram of ocean contributed reflectance in these two NIR bands for granule 2004107.1625. Some differences need to be noted in this figure. For Chesapeake Bay region, ocean contributes more reflectance during this period than the previous granule. For band 15, the mean ocean-contributed reflectance is 0.285% with a mode of 0.210% in comparison with 0.215% and mode of 0.17% for granule 2004071.1515. For band 16, the mean ocean-contributed reflectance is 0.123% with a mode of 0.10% in comparison with 0.067% and mode of 0.070% for granule 2004071.1515. For Outer Banks region, two-mode ocean contributed reflectance is less pronounced as for granule 2004071.1515. The first peak of the distribution that represents ocean contribution in Outer Banks region is slightly positive in contrast to nearly zero for granule 2004071.1515. For the second mode, the values of the mode are 1.3% and 0.7% showing weakening ocean contribution in comparison with 3.0% and 1.8% in these two bands.

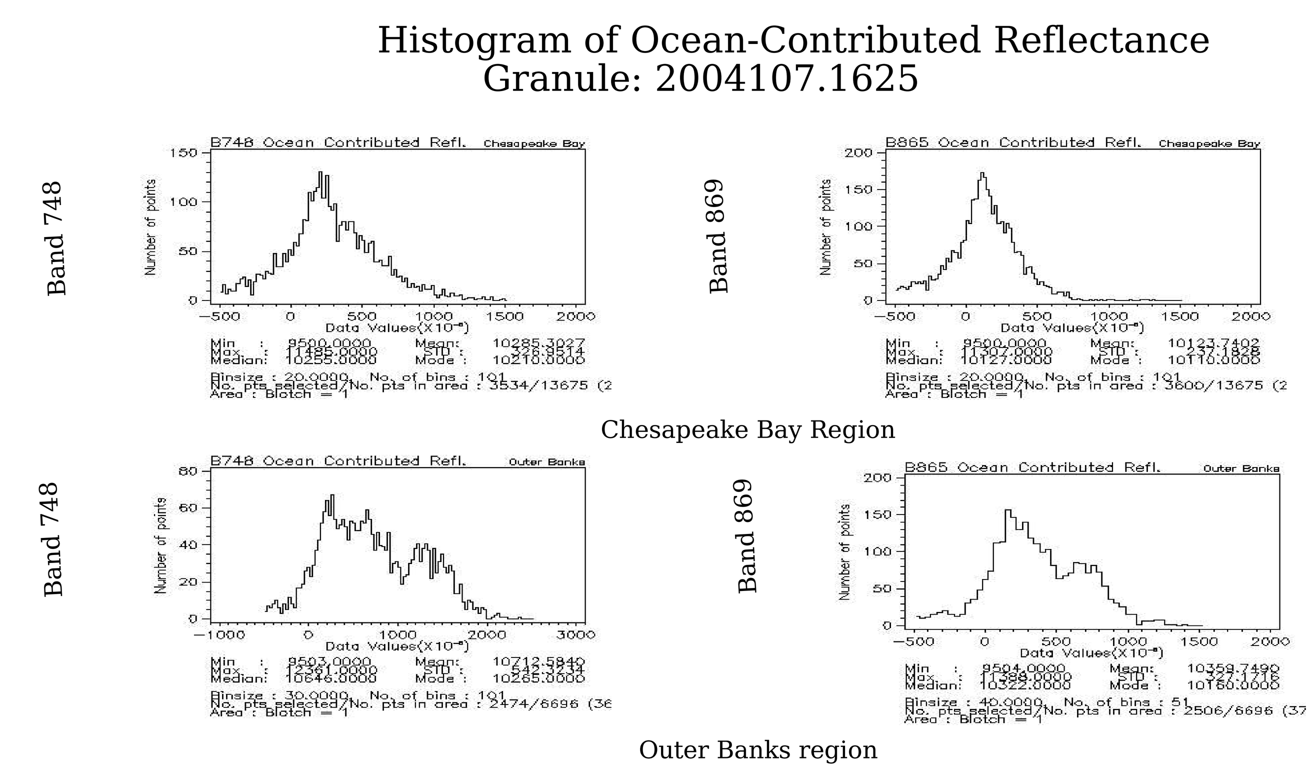

Fig. 6 Histogram of ocean-contributed reflectance for granule 2004107.1625 from (a) band 15 in Chesapeake Bay region . (b) band 16 in Chesapeake Bay region (c) band 15 in Outer Banks region (d) band 16 in Outer Banks region.

Summary and Remarks

In this presentation, we assume MODIS band 5 (1240 nm) and band 6 (1640 nm) are black for both open and coastal ocean and use MODIS band 5 and band 6 for estimating the ocean-contributed reflectance in band 15 (748 nm) and 16 (869 nm). Our results show that Case-2 water in the coastal region could contribute significant radiance in band 15 and 16. Since band 15 and 16 are used as standard bands for atmospheric correction, the over-estimation of atmospheric aerosol will consequentially cause the over-estimation of radiance in the visible bands, leading to under-estimation of the water-leaving radiances.

One obstacle for accurately estimating the ocean reflectance at visible band in Case-2 water is ocean contribution in the NIR bands and the failure of atmospheric correction algorithm developed for Case-1 waters. With traditional NIR wavelengths of 748 and 869 nm, various studies (Hu *et al.*,2000; Ruddichk *et al.* 2000; Siegel *et al*., 2000) have shown that the performance of standard Case-1 algorithms over turbid waters can be improved if the atmospheric correction procedures are modified to account for non-zero water-leaving radiances in the NIR bands. All of the above efforts are applied to the SeaWiFS that has two NIR bands. With the advantage of longer NIR bands available in MODIS, this study shows the potential using band 5 (1240 nm) and band 6 (1640 nm) for atmospheric correction to deal with Case-2 waters.

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