

DOCTORAL THESIS

Ocean color atmospheric correction based on black pixel assumption over turbid waters

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Abstract

Accurate retrieval of water-leaving reflectance from satellite-sensed signal is decisive for ocean color applications, because water-leaving radiance only account for less than 10% of satellite-sensed radiance. The standard atmospheric correction algorithm relies on black pixel assumption, which assumes negligible water-radiance reflectance at the near-infrared (NIR) bands. The standard NIR-based algorithm generally works well for waters where the NIR water-leaving radiance is negligible or can be properly accounted for. However, the black pixel assumption does not hold over turbid waters, which results in biased retrievals of remote sensing reflectance (R_{rs}).

Therefore, this study aimed to improve atmospheric correction over turbid waters. Based on Sentinel-3, two ways to cope with nonzero NIR water-leaving reflectance were explored. First, this study proposed to use artificial neural networks to estimate and correct NIR water-leaving reflectance at TOA (ANN-NIR algorithm). The rationale of it is that hydrosol optical properties are much simpler at NIR spectral region, where pure water absorptions are the dominant factor. The proposed algorithm outperformed the standard NIR-based algorithm over highly turbid waters. Considering results demonstrated in this study, ANN-NIR algorithm should be useful for ocean color sensors with less than two SWIR bands.

Second, this study adapted the SWIR-based algorithm for atmospheric correction of Sentinel-3 OLCI by coupling with the two SWIR bands of SLSTR. Three SWIR band combinations were tested: 1020 and 1613, 1020 and 2256, and 1613 and 2256 nm. The SWIR-based algorithm obviously performed better than NIR-based algorithm over highly turbid waters, while the NIR-based is still preferred for clear to moderately turbid waters. The SWIR band of 1020 nm combined with either SWIR band of 1613 or 2256 nm is recommended for the SWIR-based algorithm except for extremely turbid waters, because the band of 1020 nm has better radiometric performance. Over extremely turbid waters, the band combination of 1613 and 2256 nm should be used, since the water-leaving reflectance is still non-negligible at the band of 1020 nm over these waters.

Considering atmospheric correction performance obtained by the NIR- and SWIR-based algorithms, the NIR-based and SWIR-based algorithm are practically applied over clear and turbid waters, respectively. This study revisited the effectiveness of the turbidity index for the current NIR-SWIR switching scheme. The turbidity index calculated from aerosol reflectance varies from 0.7 to 2.2, which is not close to one as expected. In addition to water-leaving reflectance, its value also depends on the spectral shape of aerosol reflectance, which varies with aerosol size distributions, aerosol optical thickness, relative humidity and observing geometries.

To address this problem, this study proposed a framework to determine switching threshold for the NIR-SWIR algorithm. An R_{rs} threshold was determined for each MODIS land band centered at 469, 555, 645 and 859 nm, respectively. Their thresholds are 0.009, 0.016, 0.009 and 0.0006 sr^{-1} , respectively. However, $R_{rs}(469)$ tends to select SWIR-based algorithm wrongly for clear waters, while NIR-SWIR switching based on $R_{rs}(859)$ tends to produce patchy patterns. By contrast, NIR-SWIR switching based on $R_{rs}(555)$ with a threshold of 0.016 sr^{-1} and $R_{rs}(645)$ with a threshold of 0.009 sr^{-1} produced reasonable results. Considering the contrasted estuarine and coastal waters, combined applications of NIR- and SWIR-based algorithm with the switching scheme should be useful for these waters.

This study will contribute to better ocean color atmospheric corrections over turbid waters. Atmospheric correction algorithms based on black pixel assumption have been implemented and tested in this study, while combined applications of NIR-based and SWIR-based algorithms are recommended over contrasted transitional waters. However, further studies would still be required to further improve and validate atmospheric correction algorithms over turbid waters.

Keywords: Ocean color remote sensing; Atmospheric correction; Black pixel assumption; Turbidity index; Near-infrared; Shortwave infrared.

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