HICO-Based NIR–Red Models for Estimating Chlorophyll-α Concentration in Productive Coastal Waters

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Abstract—We present here results that demonstrate the potential of near-infrared (NIR–red) models to estimate chlorophyll-α (chl-α) concentration in coastal waters using data from the spaceborne HyperSpectral Imager for the Coastal Ocean (HICO). Since the recent demise of the MERidional Resolution Imaging Spectrometer (MERIS), the use of sensors such as HICO has become critical for coastal ocean color research. Algorithms based on two- and three-band NIR–red models, which were previously used very successfully with MERIS data, were applied to HICO images. The two- and three-band NIR–red algorithms yielded accurate estimates of chl-α concentration, with mean absolute errors that were only 10.92% and 9.58%, respectively, of the total range of chl-α concentrations measured over a period of several months in 2012 and 2013 on the Taganrog Bay in Russia. Given the uncertainties in the radiometric calibration of HICO, the results illustrate the robustness of the NIR–red algorithms and validate the radiometric, spectral, and atmospheric corrections applied to HICO data as they relate to estimating chl-α concentration in productive coastal waters. Inherent limitations due to the characteristics of the sensor and its orbit prohibit HICO from providing anywhere near the level of frequent global coverage as provided by standard multispectral ocean color sensors. Nevertheless, the results demonstrate the utility of HICO as a tool for determining water quality in select coastal areas and the cross-sensor applicability of NIR–red models and provide an indication of what could be achieved with future spaceborne hyperspectral sensors in estimating coastal water quality.

Index Terms—Chlorophyll-α, International Space Station (ISS), near-infrared (NIR–red) algorithms, productive coastal waters, remote sensing.

I. INTRODUCTION

REMOTE sensing has become a very valuable and virtually indispensable tool for determining water quality in inland and coastal waters. The concentration of chlorophyll-α (chl-α) in water is a key indicator of the biophysical status of a water body (e.g., [1]) and is one of the primary water quality parameters. The optical complexity of turbid productive coastal waters renders conventional blue–green algorithms unreliable for estimating chl-α concentration (e.g., [2]). Numerous algorithms based on analytical and semi-analytical spectral inversion techniques and band combinations in the red and near-infrared (NIR) regions of the spectrum have been recently developed and successfully validated for estimating chl-α concentration in inland and coastal waters. Matthews [3] and Odermatt et al. [4] have provided comprehensive lists of such algorithms and their associated accuracy values in estimating chl-α concentration.

Many of these algorithms were regionally tuned using data from specific water bodies and are limited in their bio-geo-optic scope of application, whereas some algorithms have demonstrated a potential for quasi-universal application to turbid and productive inland and coastal waters from various locations [5]–[10].

The aforementioned reports [3], [4] contain several algorithms that were developed based on data from the MERidional Resolution Imaging Spectrometer (MERIS). MERIS has been a reliable tool for monitoring water quality in coastal waters. The availability of a spectral channel at 708 nm made MERIS preferable over the MODerate Resolution Imaging Spectroradiometer (MODIS) for estimating chl-α concentration in turbid productive waters, particularly at low-to-moderate chl-α concentrations, where the results from MODIS are unreliable (e.g., [5] and [6]).

The demise of MERIS in April 2012 has caused a gap in the availability of reliable ocean color data for coastal waters. This data gap is crucial because no hyperspectral or multispectral sensor with similar or better spectral, spatial, and temporal characteristics is scheduled to be launched in the immediate future. The Ocean Land Colour Instrument, which is MERIS' replacement and will have all the spectral channels of MERIS in addition to a few extra channels, is scheduled to be launched onboard the satellite Sentinel-3 in 2014. Several hyperspectral sensors, such as the Japanese mission Hyperspectral Imager SUIte (HISUI), the Italian mission Precursore IperSpettrale della Missione Applicativa (PRISMA), and the German mission Environmental Mapping and Analysis Program (EnMAP), are either under design or development, with EnMAP being the closest to a launch date, which is tentatively set around 2017–2018.