The role of in situ bio-optical data in ocean color satellite climate data record development

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1. INTRODUCTION

High quality in situ observations are prerequisite for satellite data product validation, remote-sensing algorithm development, and climate research on scales ranging from regional ecosystems to decadal global change. The NASA Ocean Biology Processing Group (OBPG) maintains a local repository of in situ marine and atmospheric bio-optical data, the SeaWiFS Bio-optical Archive and Storage System (SeaBASS; Werdell and Bailey 2002) to facilitate ocean color satellite validation efforts. Recently, the OBPG consolidated these data and developed a publicly available data set for bio-optical algorithm development, the NASA bio-Optical Marine Algorithm Data set (NOMAD; Werdell and Bailey 2005). NOMAD includes over 3,400 stations of coincident radiometric spectra and phytoplankton pigment concentrations, encompassing chlorophyll a concentrations, ranging from 0.012 to 72.1 mg m^{-3}. Through algorithm development and validation analyses, these data form the principal foundation for ocean color satellite climate data record development. Here, we describe the cohesive OBPG system for field data analysis and satellite data product validation, from evaluation and distribution of data and results via SeaBASS to the integration of the data into NOMAD. Further, the latest updates to NOMAD are summarized and recent OBPG algorithm development results are presented.

2. SEABASS

SeaBASS includes data from over 1,500 field campaigns, contributed by 65 funded and volunteer researchers at 14 institutions in 14 countries (Werdell and Bailey 2002). Nearly 90% were collected by participants in the NASA SIMBIOS Program (Fargion et al. 2003). Data include measurements of marine optical properties, phytoplankton pigment concentrations, and other related oceanic and atmospheric observations. To facilitate consistency amongst data contributors and instruments, the OBPG specified a priori a series of in situ data requirements and sampling strategies that ensure the observations are acceptable for algorithm development and satellite validation (Mueller et al. 2003).

3. NOMAD

To expedite community bio-optical algorithm development, the NASA OBPG generated a standalone in situ data set of remote-sensing relevant products, named NOMAD, using the data archived in SeaBASS (Werdell and Bailey 2005). It consists of consistently processed coincident surface observations of radiometric spectra, water temperatures and salinities, C_p and associated metadata, such as the time and location of data collection. NOMAD is publicly available via http://seabass.gsfc.nasa.gov/rgb-bio/nomad.cgi.

Above, we graphically describe the current geographic distribution of data included in NOMAD. Upper left: remote-sensing reflectance, R_a, maximum band ratios as a function of C_p. For reference, the operational SeaWiFS C_p algorithm (OC4 version 4; O’Reilly et al. 2000), which exploits this relationship, is shown as the solid line. Lower left: the frequency distribution of fluorometrically- and HPLC-derived C_p. Center: the spectral resolution of the radiometric data, including the frequency of occurrence of each wavelength within the data set and the heritage sensors possessing (approximately) each wavelength.

Initially, NOMAD radiometric data consisted solely of water-leaving radiances, \( L_{\text{sw}}(\lambda) \), surface irradiances, \( E(\lambda) \), and downwelling vertical attenuation coefficients, \( k(\lambda) \). Recently, NOMAD was expanded to include spectral absorption, \( a(\lambda) \), and backscattering, \( b(\lambda) \), coefficients to support the development and refinement of sea surface reflectance inversion models, as highlighted in the text box above. To date, \( a(\lambda) \) in NOMAD are derived exclusively from spectroscopy.

While NOMAD \( R_a(\lambda) \) are reasonably globally represented, coincident measurements of \( a(\lambda) \) and \( b(\lambda) \) are currently sparse. Note that a \( C_p \) value accompanies each record.

4. ALGORITHMS & VALIDATION

The NASA OBPG employs NOMAD in both its bio-optical algorithm development and satellite data product validation activities, as shown below. The OBPG also evaluates community-supplied algorithms using NOMAD, when appropriate.

Results from two recent algorithm development activities are shown on the left. Top: an \( R_a \) function, analogous to OC4, designed to estimate \( C_p \) using the MODIS 500-meter bands at 469 and 555 nm. As \( R_a(469) \) is uncommon in NOMAD, it was estimated via interpolation of four surrounding bands. Bottom: the updated form of the operational SeaWiFS \( K_a \) algorithm (O’Reilly et al. 2000). The OBPG used NOMAD to generate both empirical relationships.

Validation results for \( L_{\text{sw}}(443) \) and \( C_p \) are presented on the right for SeaWiFS (reprocessing 5.1, July 2005) and MODIS-Aqua (reprocessing 1.1, August 2005). The OBPG operationally evaluates the performance of both sensors using NOMAD as ground truth. Satellite validation results are routinely posted online at http://seabass.gsfc.nasa.gov for community comment and perusal.

The volume of data contributions to SeaBASS has steadily declined since the end of the SIMBIOS era in 2003, as indicated graphically above. This absence of in situ data hinders the data product validation of the most recently launched satellite instruments, such as MODIS-Aqua, whose ocean color data stream began in June 2004. The lack of geographic variability of the observations, for example, limits the validation of MODIS-Aqua to specific regions and a narrow range of biogeochemical conditions.

5. ACKNOWLEDGEMENTS & REFERENCES


All references are available online at http://oceancolor.gsfc.nasa.gov.