Chapter 15

Validation of Carbon Flux & Related Products for SIMBIOS: the CARIACO Continental Margin Time Series & the Orinoco River Plume

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15.1 INTRODUCTION

Between 1997 and 2000, this SIMBIOS investigation collected bio-optical measurements in the Southeastern Caribbean Sea and the tropical western Atlantic to help understand the color of coastal and continental shelf waters. Specifically, bio-optical data were collected to complement an oceanographic time series maintained within the Cariaco Basin, a site affected by seasonal coastal upwelling. Bio-optical data were also collected within the plume of the Orinoco River during seasonal extremes in discharge. This program focused on providing data to the SeaWiFS and SIMBIOS Projects for validating SeaWiFS products. The data are unique in that they provide a substantial number of observations on repeated seasonal cycles for the SeaBASS bio-optical database.

An important aspect of this SIMBIOS investigation was a focus on proper interpretation of ocean color remote sensing data from coastal and continental shelf environments. With this goal in mind, ocean color satellite data from a variety and locations and from different satellite sensors were examined to understand spatial and temporal variability in pigment concentrations, and also to conduct an in-depth study of current atmospheric correction and bio-optical algorithms.

15.2 RESEARCH ACTIVITIES

Here we provide an update on activities during 1999-2000 and a summary of contributions made to SIMBIOS over the past three years. Background information on this SIMBIOS contract is provided in Muller-Karger (1999) and Muller-Karger et al. (1999).

The CARIACO Time Series

This SIMBIOS effort conducted monthly bio-optical observations at 10.5°N, 64.67°W within the Cariaco Basin (Figure 15.1) in the southeastern Caribbean Sea. This was part of a multidisciplinary program referred to as CARIACO (Carbon Retention In A Colored Ocean) that received support from the U.S. National Science Foundation and the Consejo Nacional de Investigaciones Cientificas y Tecnologicas (CONICIT) of Venezuela for oceanographic cruises and for investigations focusing on processes affecting particulate carbon flux to the bottom of the Cariaco Basin. Initial results from the CARIACO program are presented by Muller-Karger et al. (2000a, 2000b) and Thunell et al. (2000).

During each cruise, we collected a series of bio-optical measurements. In 1997 and 1998, we used the underwater profiling Biospherical Instruments MER2048 in conjunction with a MER2041 Deck Cell. Since mid-1998, we have used a PRR-600 profiler with matching deck cell. Above water measurements were made with a Photo Research Hyperspectral Colorimeter Model PR650. Derived products include Lw (Water-Leaving Radiance), Rrs (Remote-sensed reflectance) and K (attenuation coefficient). In addition, a full suite of measurements is made which includes: particulate material concentration and absorption coefficients, HPLC, fluorometric determinations of Chl concentration, pH, Alkalinity, primary productivity, DOC absorption and concentration, nutrients, sun photometry, oxygen, and salinity.

As of October 2000, data from 30 CARIACO cruises had been submitted to the SeaBASS archive. Figure 15.2 presents results of the time series, comparing in situ observations with chlorophyll-a estimates based on above-water reflectance measurements and using the bio-optical algorithms adopted by the SeaWiFS project (O’Reilly et al., 1998; O’Reilly et al., 2000).
Muller-Karger et al. (1989) and Muller-Karger and Varela (1990) describe a seasonal cycle in the spatial structure of near-surface pigment detected with Coastal Zone Color Scanner (CZCS) data collected over the eastern Caribbean Sea. In addition to describing the seasonal occurrence of large pigment patches associated with coastal upwelling, as seen in the Cariaco Basin, they discovered that the seasonally-expanding plume of the Orinoco River reached Puerto Rico around September-October and drifted westward, slowly losing its color signature. The Orinoco dispersed pigment over >3x10^5 km² of the Caribbean Sea. Clearly, while there are phytoplankton within the plume, the plume represents Case II waters in which colored dissolved organic matter (Yellow Substance) and suspended sediment lead to erroneous satellite-derived pigment products. The Orinoco River provides a good study region for extreme Case II waters which can easily be covered by satellite observations at a variety of spatial and temporal resolutions.

We carried out five cruises to the Orinoco Delta and plume under this SIMBIOS program. Stations were occupied north of Dragon’s Mouth (the northern strait between Venezuela and Trinidad), within the Gulf of Paria, immediately off the delta of the Orinoco River south of Serpent’s Mouth (the southern strait between Venezuela and Trinidad), and within several branches of the Orinoco Delta. Figure 4 shows station locations for the first four Orinoco River cruises. As of October 2000, data from five Orinoco River cruises had been submitted to the SeaBASS archive. An additional Orinoco cruise is scheduled for late October 2000.

Above-water spectral remote-sensing reflectance was measured including corrections for sky-radiance initially using a Photo Research Hyperspectral Colorimeter Model PR650, and starting in 1999 an Analytical Spectral Devices (ASD) spectrometer which extended the spectral range of observations, namely from 380 to 1,200 nm. We also conducted underwater measurements of remote sensing reflectance using submersible MER2048 and, since 1998, PRR-600 instrumentation (Biospherical Instr.). Some observations were conducted away from the coast, where the color of the plume is influenced by colored dissolved organic matter as well as phytoplankton, but where suspended terrestrial material is expected to be minimal. We also collected data very close to the coast where the plume is extremely turbid.

Figure 15.5 shows the variability obtained in the absorption coefficient for colored dissolved organic matter relative to variation in salinity during the first four cruises. These data will help us to understand the dependence of variability in absorption to geographical location and season.

The river plume data are being used by Joe Salisbury and Charles Vorosmarty at the University of New Hampshire for automated modeling of river water impact off the continent of South America, in a model linked to terrestrial hydrology.

**SeaWiFS Data Calibration Efforts**

Dr. Chuanmin Hu from our group forwarded a Gain/CalibrationTable study summary to Chuck McClain, which we believe was used in evaluating the new SeaWiFS calibration. Specifically, during January – May 1998 we found that the normalized water leaving radiance, nLw555, for clear water was frequently lower than 0.25 (not to mention the well-accepted value, 0.28, from Gordon and Clark). After studying several images very carefully, we found that the calibration table released at that time was probably inappropriate. We forwarded detailed analyses to the SeaWiFS Project outlining our results.

**Algorithm development**

Dr. Hu (Hu et al., 2000a, b) developed and implemented a turbid-water (case II) atmospheric correction procedure for ocean color satellite sensors. It uses a nearest-neighbor method to propagate the aerosol type derived over adjacent clear water to apply over turbid water. The advantage of this procedure over an iterative approach is that the dependence on the under-water optics is minimized, therefore it can be applied to unknown type of water or shallow water where bottom reflection may contribute to the sensor signal. The procedure is particularly useful for turbid coastal or shallow inland waters.

Errors in SeaWiFS products caused by cirrus clouds, high altitude aerosols, or digitization-noise were analyzed by Hu et al. (2000c). The use of an alternative band in the atmospheric correction to avoid the O2 absorption lines can greatly reduce the errors. It was also found that the SeaWiFS mission goals, namely to estimate water-leaving radiance to within 5% uncertainly and chlorophyll to within 35% can’t always be achieved merely because of digitization round-off.
Figure 15.2 Temporal variation in chlorophyll-a at the CARIACO station (February 1997-June 1999). The values for fluorometry and HPLC were obtained at approximately 1 m depth while the values for the OC algorithms were calculated from above-water reflectance measurements above the surface.

Figure 15.3 Temporal variation in the difference (%) between SeaWiFS-derived chlorophyll-a and in situ observations of chlorophyll-a at the CARIACO station (February 1997-June 1999).
and systematic noise. Use of an alternative band in the atmospheric correction or performing a 3x3 smoothing for the atmospheric-correction bands can greatly reduce this type of errors. The results are useful for data validation protocols.

We also developed and implemented a multi-platform approach for atmospheric correction of Landsat-like sensors using SeaWiFS/MODIS derived atmospheric parameters (Hu et al, 2000d). The procedure is useful for combining the high accuracy of atmospheric correction of ocean-color satellite and high spatial resolution of Landsat-like sensors to study coastal processes.

SeaWiFS data processing improvements

Our group implemented an extensive SeaWiFS batch processing system for use with IDL™ and SeaDAS. We also implemented a series of convenient SeaWiFS data analysis tools based on IDL and IDL On the Net (ION™), to allow analyses over the world wide web.

We found several problems with SeaDAS and interacted with the SeaDAS Development Group to solve them. Specifically, we found bugs in the bl2map and histogram routines, as well as in the more recent implementation of selection menus for flag products, and pin-pointed a problem that led to a 'Windowing effect' in the level 2 processing of SeaWiFS data. Solutions were found for these problems.
We also addressed the speckling problem found in processed SeaWiFS data. We suggested to Chuck McClain that a fine tune of the epsilon retrieval software may be necessary due to the high correlation between epsilon and chlorophyll.

Additional Field Campaigns and Data Validation

Participated in the Northeast Gulf of Mexico (NEGOM) program sponsored by the US Mineral Management Services. Eight 2-week cruises have been conducted in continental margin waters to the 1000-m isobath off Florida and Alabama. Extensive data sets were collected, among which included along-track flow-through chlorophyll and CDOM fluorescence, salinity and temperature, and sample collection and optical measurement at discrete stations (~50 for each cruise). Data analysis is still underway, while some preliminary results have been presented in a number of conferences and submitted to the International Journal of Remote Sensing.

Data Synthesis

We have generated an extensive list of publications based on our SIMBIOS and related research (see section labeled “Peer-Reviewed Publications” below. There will be additional publications based on the data collected via this SIMBIOS activity. The CARIACO station and Orinoco Plume data are central to the research of four graduate students, namely two Ph. D. and two Masters students.
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REFERENCES


