Chapter 17

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

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17.1 INTRODUCTION

This SIMBIOS investigation focuses on validating ocean color satellite products using monthly observations from the Cariaco Basin (a coastal upwelling site), and seasonal extreme measurements within the plume of the Orinoco River. During 1998-1999, this SIMBIOS Project focused on three major areas:

• monthly bio-optical data collections at 10.5 N, 64.67 W (the multidisciplinary Carbon Retention In A Colored Ocean / CARIACO station),
• bio-optical sampling of seasonal extremes of the Orinoco River plume,
• radiometric and atmospheric correction of SeaWiFS data.

Our main objective was to augment the SeaWiFS match-up database and a database of observations in Case-II waters. We also participated in other SIMBIOS activities, including the SIMBIOS PI meeting in Annapolis and cal/val activities under Ken Carder's SIMBIOS program. We have actively pursued the characterization of the calibration of SeaWiFS satellite data, contributed to the improvement of SeaWiFS data processing software, particularly the SeaDAS package, and developed a scheme for atmospheric correction over turbid waters. Our second-year activities are summarized below.

17.2 RESEARCH ACTIVITIES

The core of this SIMBIOS Project continues to be the CARIACO oceanographic time series station described in the SIMBIOS Project 1998 Annual Report. The series station is located at 10.50 N, 64.66 W, and our observations consist of:

• 1 to 3 monthly cruises with a fully-equipped, modern oceanographic vessel;
• monthly bio-optical data collections at 10.5 N, 64.67 W (the multidisciplinary Carbon Retention In A Colored Ocean / CARIACO station),
• bio-optical sampling of seasonal extremes of the Orinoco River plume,
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Prior to October 1998, we conducted subsurface radiance/irradiance profiles using a Biospherical Instruments MER2048 in conjunction with a MER2041 Deck Cell. Since October 1998, we have used a split-level PRR-600. Both MER and PRR-600 casts were performed in October to help cross-reference the observations made with these instruments. The PRR-600 is more appropriate for measurements in some of the high-chlorophyll waters sampled. The PRR-600 bands are:

• 7 bands Ed, Es (412, 443, 490, 532, 555, 665, 683 nm)
• 7 bands Lu (412, 443, 490, 532, 555, 665, 683).

Above-water measurements are made with a Photo Research Hyperspectral Colorimeter Model PR650, which is a calibrated, hand-held radiometer (8 nm resolution). 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 and pigment absorption, HPLC, fluorometric determinations of Chl concentration, pH, Alkalinity, Primary Productivity, POC, DOC absorption and concentration, nutrients, sun photometry, oxygen, and salinity.
Cruise reports for each cruise, detailing station location and observations collected, have been submitted to the SIMBIOS Project.

Our emphasis to date in data analysis has been to characterize the relationship between vertical flux and primary productivity, as a necessary step prior to examining the connection between bio-optical properties and various flux parameters. Primary production followed a seasonal cycle, with significantly higher production observed starting in January and lasting through May each year. Average depth-integrated production between January and April 1996 was 1,784 mg C m\(^{-2}\) d\(^{-1}\) but reached 2,674 mg C m\(^{-2}\) d\(^{-1}\) in 1997. May 1996 showed an extreme production value of 6,860 mg C m\(^{-2}\) d\(^{-1}\), while May 1997 was about 2,500 mg C m\(^{-2}\) d\(^{-1}\), or close to the seasonal average for that year.

We are now starting to examine the values for 1998, which yield a total of about 1,360 mg C m\(^{-2}\) d\(^{-1}\) between January and April 1998. Clearly, 1998 was strongly affected by El Niño. The upwelling cycle of 1997 showed higher seasonal production primarily as a result of the more frequent ventilation events. In contrast, productivity during June-December was 1,051 mg C m\(^{-2}\) d\(^{-1}\) and 865 mg C m\(^{-2}\) d\(^{-1}\) in 1996 and 1997, respectively. Annual integrated production was 686 gC m\(^{-2}\) y\(^{-1}\) and 536 gC m\(^{-2}\) y\(^{-1}\) in 1996 and 1997, respectively. Vertical flux of carbon was a minimum in January, with about 0.03 mgC m\(^{-2}\) d\(^{-1}\) at 275 m, and 0.006 gC m\(^{-2}\) d\(^{-1}\) at 1,225 m. By March flux had increased to 0.17 gC m\(^{-2}\) d\(^{-1}\) at 275 m and 0.06 gC m\(^{-2}\) d\(^{-1}\) at 1,225 m. Over the course of the sampling period, settling carbon flux was 5.6% of integrated primary production at 275 m and about 1.7% at 1,225 m. There was no seasonality in the proportion of vertical flux to primary production, in contrast with the prevailing view of the relationship between new production and total production.

The Orinoco River Plume

Three cruises to the Orinoco River delta and plume have been conducted to date, namely between 23-29 June 1998 (Figure 1), 25 and 30 October 1998 (Figure 1), and 23 and 26 February 1999. We seek to build a set of robust Case-II observations to assess the validity of the SeaWiFS retrievals in the plume. These data will be important for proper interpretation of the global ocean color satellite data since river plumes cover significant areas near continental margins. We used the same instrumentation described above (MER, PRR-600) for underwater light profiles and above-water spectral remote-sensing reflectance observations. Observations were conducted both away from the coast and very close to the coast, including some of the delta tributaries. The latter observations were conducted from a small boat using only the PRR-600 and above-water, hand-held instrumentation.

The Orinoco Plume data span a very broad range of remote sensing reflectance values. Figure 2 shows a progression in hyperspectral reflectance curves going from offshore plume station 4 (Figure 1) to station 16, located within about 2 km of the mouth of Caño Macareo, the largest active tributary to the Orinoco delta. The river plume data are also 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. Cruise reports, detailing station locations and observations collected, have been submitted to the SIMBIOS Project.

Radiometric and atmospheric correction of SeaWiFS data:

Under leadership of Dr. Chuanmin Hu, a postdoctoral research associate, we have continued to study the performance of the SeaWiFS Gain and Calibration Tables. Dr. Hu also developed an alternative atmospheric correction scheme of turbid coastal waters, in which the epsilon, aerosol model number, t(765) and t(865) are optimized for “turbid” pixels. Specifically, the atmospheric correction parameters are determined through nearest-neighbor searches of adjacent Case-I water pixels, and these parameters are then applied over the respective turbid pixels.

This method yields significant improvement in estimates of chlorophyll relative to concurrent field observations, and minimizes the number of negative water-leaving radiance retrievals. The method also shows promise for applications over shallow-water regions. Dr. Hu has also implemented a band 6 / band 8 atmospheric correction algorithm in SeaDAS and is preparing a manuscript on results of comparisons with the products derived using the band 7 / band 8 algorithm. We have 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. In an effort to assess MODIS algorithms, we have continued with the implementation of Ken Carder’s algorithms in SeaDAS.

Instrumentation

We acquired a split-level PRR-660 instrument from Biospherical Instruments and a hyperspectral hand-held fiber-optic sensor from Analytical Spectral Devices. The latter will help obtain observations between 340 and 1,200 nm. Our older PR-650 instrument only provided observations between 380 and 780 nm, which is inadequate to study the near-infrared reflectance of highly turbid waters. We continue to test the ac-9, which has to date been used on 4 cruises to the Gulf of Mexico and the West Florida Shelf. We have had problems with noise in the instrument and therefore have not sent it to Venezuela on the Orinoco cruises.

The MICROTOPS unit from the SIMBIOS Project Office is used routinely at the time of bio-optical observations during each cruise. Bio-chemical and pigment samples are being analyzed at various locations, while data archival is centralized at our Remote Sensing Lab at the University of South Florida.
17.3 WORK PLAN

We will continue to occupy the CARIACO station on a monthly basis. In addition, we plan to conduct three cruises to the Orinoco River plume, specifically in October 1999 and in February and October 2000. Analysis of data and samples will continue. We are currently advancing several manuscripts that describe the seasonal cycle in bio-optical properties at the CARIACO station, the atmospheric correction for turbid waters, and digitization sensitivity of the SeaWiFS data.

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Figure 1. Cruise track for Orinoco Plume cruise SIMBIOS 1, conducted 23-29 June, 1998 (left). Cruise track for Orinoco Plume cruise SIMBIOS 2, conducted 27-30 October, 1998 (right).

Figure 2. Remote sensing reflectance data obtained with the hand-held Spectrascan PR-650 instrument.
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PEER REVIEWED PUBLICATIONS


Accepted


Submitted


Muller-Karger, F. E., 1999: The spring 1998 NEGOM cold water event: remote sensing evidence for upwelling and for eastward advection of Mississippi water (or: How an errant LC anticyclone took the NEGOM for a spin). Submitted to Gulf of Mexico Science.

PRESENTATIONS


