The CARIACO (CArbon Retention In A Colored Ocean) Time Series Program

University of South Florida, College of Marine Science

NSF Annual Report for Award # 0963028

Period Covered:

November 2010 – November 2011

Report updated 22 September, 2011

SUMMARY

This document summarizes new results and findings of the CARIACO (CArbon Retention In A Colored Ocean) Time-Series Program conducted by the University of South Florida (USF) for the year 2010-2011. CARIACO is supported by the National Science Foundation Grant No. 0963028. The program is carried out in close collaboration with the marine research station of the Fundación La Salle de Ciencias Naturales de Venezuela. Monthly cruises are carried out to 10°30'N, 64°40'W, to collect hydrographic and biogeochemical data throughout the water column. The CARIACO time-series program also includes seasonal cruises to examine microbial processes (SUNY group) and the deployment of a sediment trap mooring (U. South Carolina). The sediment trap mooring has five sediment traps (150, 226, 407, 807, and 1,205m) which provide bi-weekly sample collections at each depth. A bottom-mounted ADCP was purchased for deployment in the navigation channel and was deployed in November 2009. The bottom mount was recovered in June 2010 and provided 4 months of measurements in the basin's navigation channel. A Lowered ADCP (LADCP) is deployed regularly in the monthly cruises to collect current data from the surface (~5m) to intermediate depths (~400m). The CARIACO All-Hands meeting was held in December 2010 at the Fundación La Salle de Ciencias Naturales in Margarita Island where the ship and shore laboratories for the program are located. Scientific progress and issues the CARIACO time-series program were discussed. CARIACO collaborated with the HOT and BATS Time-Series programs to host an OCB Scoping Workshop on biogeochemical time series in Hawaii in September 2010. CARIACO also co-chaired sessions on OCB time series at the 2010 Meeting of the Americas (8–12 August, Foz do Iguaçu, Brazil), and at the 2011 ASLO Aquatic Sciences Meeting (13-18 February 2011, San Juan, Puerto Rico).

Over the 2010-2011 period, the time-series infrastructure continued to serve as a community facility, assisting international researchers from a variety of universities with the logistical and personnel support to carry out their research in the Cariaco Basin. In May 2010 Dr. David Black participated in a CARIACO cruise to recover a sediment core. Between 2010-2011, sixteen manuscripts were submitted to peer-reviewed journals, eleven of which were accepted and are currently published or in press.

In June 2011 CARIACO received a letter of support from the IOC, which emphasized the importance of the program. The Venezuelan delegation for the IOC participated in the 26th IOC Assembly, between 22 June and 5 July 2011, and acknowledged the importance of the time-series. The IOC plans to publish an article featuring CARIACO on the IOC website.

INTRODUCTION

The CARIACO Time-Series Project has collected measurements in the Cariaco Basin (10° 30' N, 64° 40' W) since November 1995. The Cariaco Basin is a 1,400-m deep depression of tectonic origin located off the coast of Eastern Venezuela. The basin is connected to the Caribbean Sea by two shallow (~140 m) sills, one to the north and one to the north-west (Figure 1). Time-series cruises to the Cariaco station are carried out monthly to collect a series of "core" observations. Additional cruises are conducted periodically at a frequency varying between bi-monthly and seasonally to collect zooplankton samples and perform microbial process studies, as well as to service a mooring holding sediment traps at different depths.

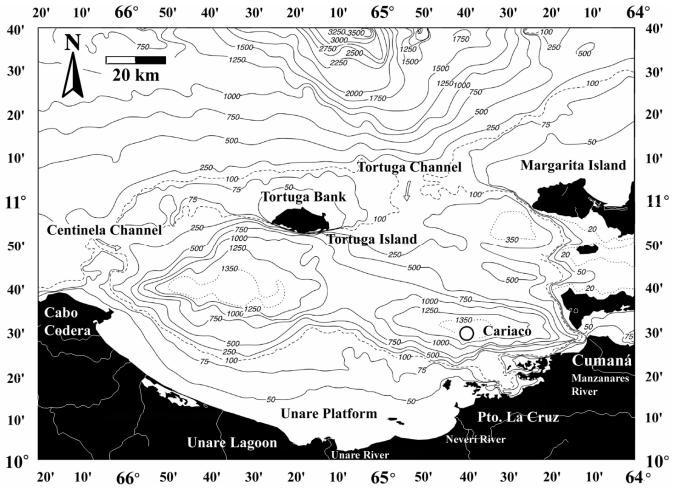

Figure 1: The Cariaco Basin. Location of the CARIACO time-series station is indicated (from Muller-Karger et al., 2001)

The CARIACO data are publicly available via an Internet server (http://www.imars.usf.edu/CAR/index.html) upon passing quality control, within periods ranging from weeks to about 6 months depending on the difficulty of processing an observation. CARIACO data are also available through the OCB Data Management Office (BCO-DMO, http://osprey.bcodmo.org/project.cfm?flag=viewd&id=12, http://mapservice.bco-dmo.org/maps-bin/global/map) and in Spanish through the INTECMAR/USB server in Venezuela (http://cariaco.intecmar.usb.ve/). In addition, data are submitted regularly and on a timely basis to NODC, and to the NASA SeaBASS system.

Methods

During each monthly core cruise (Table 1) a set of key parameters (Table 2) is collected. This includes a series of CTD casts to obtain temperature, salinity, and oxygen profiles from 0 to 1310 m, a variety of bio-geochemical determinations at discrete depths, primary productivity, particle concentration, and continuous profiles of optical parameters.

Only modifications, additions or existing issues on methods will be discussed here. Methods have been described in the past (see Muller-Karger, F. E. R. Varela, R. Thunell, M. Scranton, R. Bohrer, G. Taylor, J. Capelo, Y. Astor, E. Tappa, T. Y. Ho, and J. J. Walsh. 2001. Annual Cycle of Primary Production in the Cariaco Basin: Response to upwelling and implications for vertical export. J. of Geophys. Res., 106 (C3): 4527-4542).

Primary production

In order to continue the primary production analyses, ^{14}C was purchased in Spain during October 2010, but the issue of ^{14}C availability in Venezuela still persists. For this reason, primary productivity is being measured at only 6 of the 8 typical depths. The depths excluded are 7m and 100m. The 7m depth is done only when phytoplankton is concentrated at the surface, and in this case 75m and 100m are excluded.

Inorganic Nutrients

Nutrient analyses continue at USF's Nutrient Lab (Kent Fanning). There have been some transportation issues which have affected some of the high quality of the data, but we are working closely with Dr. Robert Masserini and Co-I Kent Fanning to ensure the data processed for the project is of the highest quality. The IVIC (Venezuela) continues to be committed to work with CARIACO, and hope that local funding will allow them to begin processing inorganic nutrients regularly.

Table 1: Cruise number and dates since November 2009 (including cruises planned into 2012).

Cruise number	Date	Cruise number	Date
163	Nov/10/2009	177	Feb/8/2011
164	Dec/8/200	178	Mar/15/2011
165	Jan/12/2010	179	Apr/12/2011
166	Feb/9/2010	180	May/10/2011
167	Mar/8/2010	181	Jun/9/2011
168	Apr/12/2010	182	Jul/7/2011
169	May/11/2010	183	Aug/9/2011
170	Jun/8/2010	184	Sept/6/2011
171	Aug/4/2010	185	Oct/4/2011
172	Sept/15/2010	186	Nov/18/2011
173	Oct/4/2010	187	Dec/13/2011
174	Nov/9/2010	188	Jan/10/2012
175	Dec/8/2010	189	Feb/7/2012
176	Jan/11/2011	190	Mar/6/2012

Table 2: List of parameters collected during each CARIACO cruise.

Parameter	Depth Range	Instrument/Method	Processed Data (Cruise No. or year)
1. Continuous Parameters			
Pressure (Depth)	0-1310 m	SBE-25 (SeaBird)	1-184
Temperature	0-1310 m	SBE-25 (SeaBird)	1-184
Conductivity (Salinity)	0-1310 m	SBE-25 (SeaBird)	1-184
Dissolved Oxygen	0-1310 m	SBE-43 (SeaBird)	1-184
Fluorescence (Chl)	0-1310	ECO Fluor. (WetLabs)	1-184
Beam attenuation (c660)	0-1310	C-Star (WetLabs)	1-184
2. Water Column Chemical Measurements			
Dissolved Oxygen	0-1310 m	Titration	1-184
DOC & TOC	0-1310 m	High Temp Comb	1-63; 110-184
Total Alkalinity	0-1310 m	Gran Titration	1-184
pH	0-1310 m	Spectrophotometer	1-184
Salinity	0-1310 m	Guildline Portasal 8410	1-184
Nitrate	0-1310 m	Technicon AA	1-184
Nitrite	0-1310 m	Technicon AA	1-184
Ammonia	0-1310 m	Technicon AA	1-184
Phosphorus	0-1310 m	Technicon AA	1-184
Silicate	0-1310 m	Technicon AA	1-184
Diss. Org. Nitrogen	0-1310 m	Persulfate oxidation	102-161
Diss. Org. Phosphorous	0-1310 m	Persulfate oxidation	102-161
Partic. Organic Carbon	0-1310 m	Elemental Analyzer (EA)	1-184
Partic. Organic Nitrogen	0-1310 m	Elemental Analyzer (EA)	1-184
3. Biomass Measurements			
Chl. *a* and Phaeopig.	0-100 m	Fluorometry (Turner)	1-184
Bacteria	0-1310 m	(Various/SUNY)	(see SUNY report)
4. Carbon Assimilation and Particle Flux			
Primary Production	0-100 m	^{14}C	1-184
Bacterial Production and Respiration	0-1310 m	(Various/SUNY)	(see SUNY report)
Protozoan grazing	0-1310 m	(Various/SUNY)	(see SUNY report)
5. Optical Measurements			
Incident Irradiance	Surface	Spectrascan PR-655	1-184(some months missing due to instrument repair)
Upwelling Radiance and Downwelling Irradiance	0-150 m	PRR-600	1-184 (some months missing due to instrument repair)
6. Moored Instruments			
Sediment Traps	150, 275, 450, 900, 1200	(U. South Carolina)	(see USC report)
Acoustic Doppler Current Profiler (ADCP)	<100 m	ADCP (RDI)	2009-2010
Lowered ADCP	1-400 m	WH Sentinel 300 (RDI)	2005-2011

FINDINGS AND RESULTS

As described in previous reports, there has been a tendency for upwelling to decrease in strength markedly during the second half of the decade of 2000. Although the period 2007-2009 showed a hint of recovery with regards to upwelling strength, 2010 and 2011 had the lowest primary production recorded in the history of the CARIACO time series (Figure 1). During the 2010 upwelling period (usually December-January through April), only one month out of each year had production rates higher than 1 mg C m^{-2} d^{-1}. During the upwelling period of 2011 the same behavior was observed, with only the month of February yielding production rates higher than 1 mg C m^{-2} d^{-1}. Since March 2011, there seems to be strong stratification of the surface waters (<25m), which reached a maximum in June 2011. During this month the lowest record of primary production for the entire time-series was measured - there was virtually no primary production at 1 m.

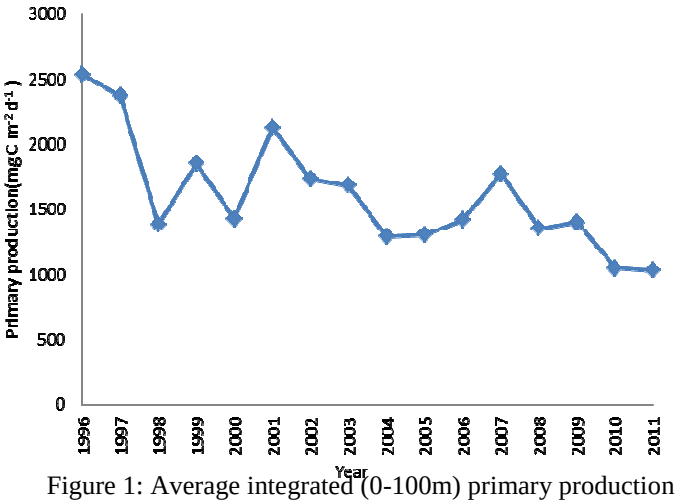

Figure 1: Average integrated (0-100m) primary production for the first six months of each year (January-June)

Sea surface temperatures recorded during 2009-2011 were the warmest recorded since 1996. The coldest temperature in 2010 was 23.55 °C (February), while in 2011 surface temperature was always above 24 °C (24.61 °C, February 2011). Figure 2 shows the sea surface temperature and the measurements of integrated chlorophyll concentration (0-100m) at the CARIACO station for the entire time-series.

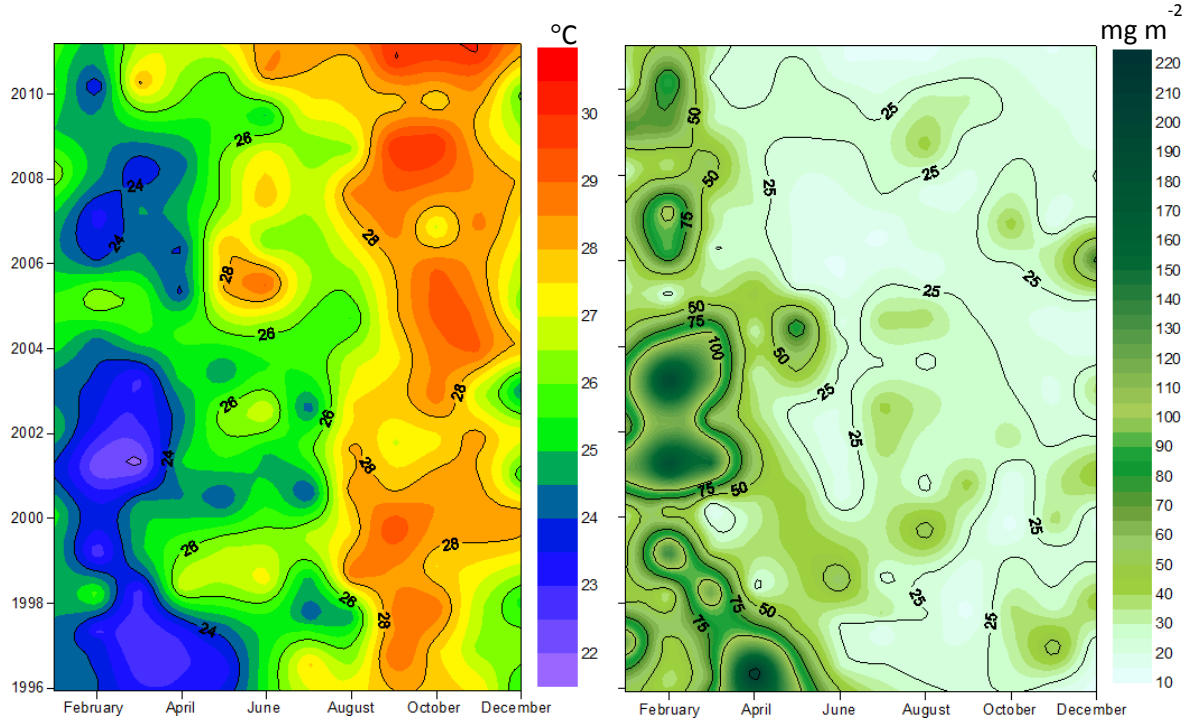

Figure 2: sea surface temperature (left) and integrated chlorophyll concentration (0-100m, right) at the CARIACO time-series site

Winds for 2009-2011 were also outside of their normal behavior. During 2009-2010 wind speeds were more variable than usual, and in 2011 wind speed was consistently low for the first few months of the year (Figure 3). Precipitation was also abnormal: while high precipitation is expected between May and November, with a peak in September, in 2010 precipitation events occurred in July and in November-December (Figure 3).

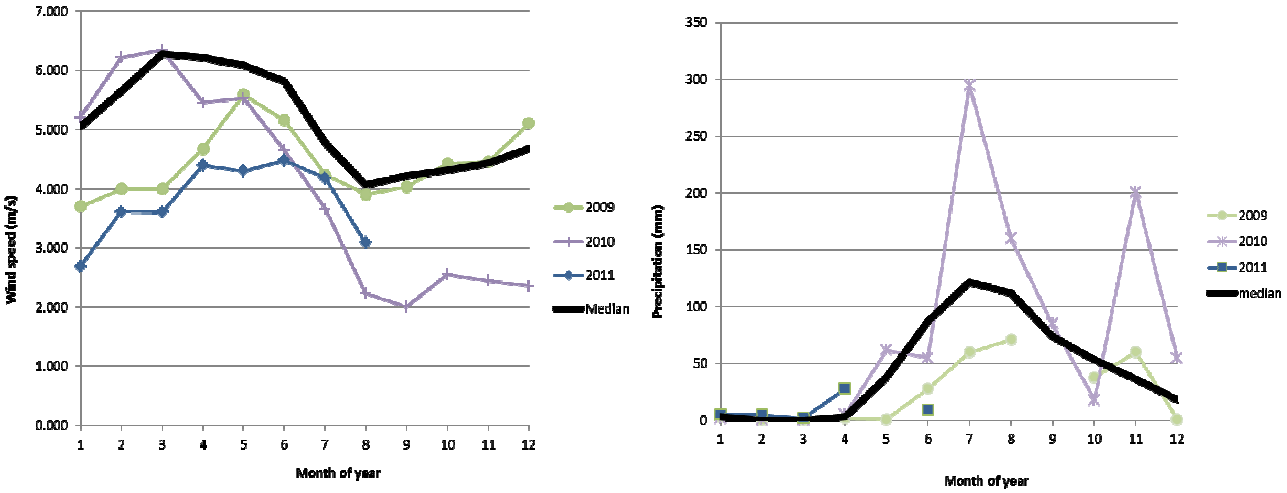

Figure 3: (Left) Wind speed measured at Margarita Island, Venezuela. (Right) Precipitation recorded at the Barcelona station. A 15-year median (1995-2010) is shown in black for both variables.

In November 2009, a bottom-mounted ADCP was deployed at ~68 m water depth in the navigation channel between Margarita Island and La Tortuga, one of the main passageways of Subtropical Underwater into the Cariaco Basin. The bottom-mounted ADCP recorded 4 months of data, between November 2009 and March 2010 *(119 days)*. Recovery of the bottom mount was carried out in June 2010. Figure 4 shows the unprocessed current direction data for the water column at the Tortuga deployment location. Throughout the 4-month deployment, several mid-water current reversals appear to have occurred. In November 2009, the current near the bottom appeared to have been flowing northward (magenta), while in December the current shifted

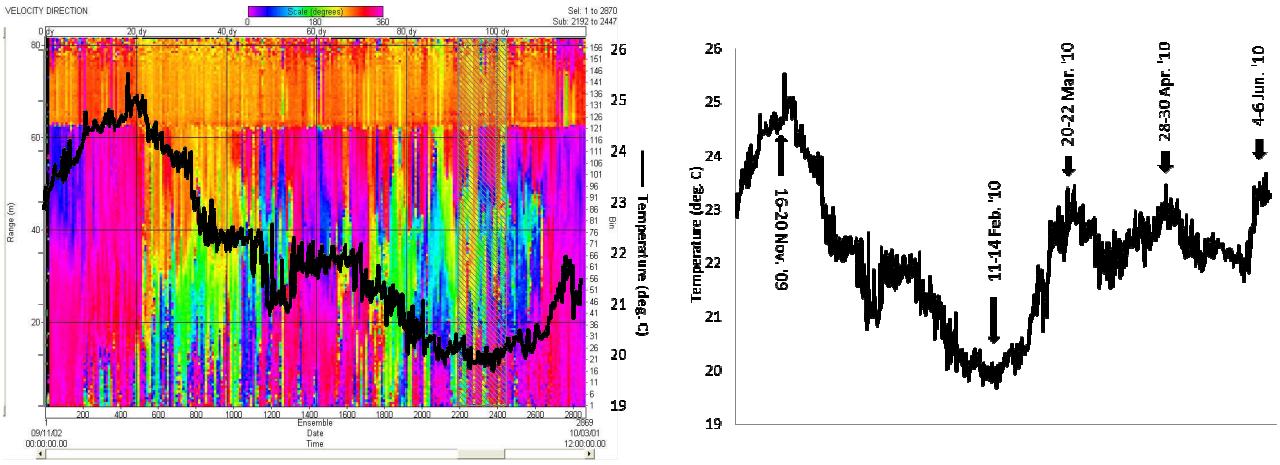

Figure 4: (left) Unprocessed current direction in degrees relative to North measured with the bottom mounted ADCP deployed in the Tortuga navigation channel; water temperature measured at the bottom mount location is overlaid in black in degrees Centigrade. (right) Water temperature at ~68 m depth measured with a SBE 39 deployed with the bottom mount.

southward (green color). The southward direction of the current persisted also from mid-January to the end of February, when the current reversed again towards the north. Temperature at the depth of the current meter was measured with a Seabird temperature sensor SBE39. A plot of this temperature record from the beginning of the deployment (November 2, 2009) through the day it was recovered (June 11, 2010) is shown in Figure 4.

TIME-SERIES EXPOSURE

CARIACO was highlighted in several meetings between 2010-2011:

A special session on time-series was held during the *2010 The Meeting of the Americas (8–12 August, Foz do Iguaçu, Brazil): Regional and Global Ocean Observing Systems: Assessing and Forecasting the State of Oceans and Coasts*. CARIACO was highlighted during this session through several presentations.

Between September 21-23, 2010, the OCB Scoping Workshop *Sea change: Charting the course for ecological and biogeochemical ocean time-series research* took place in Honolulu, HI (http://www.whoi.edu/sbl/liteSite.do?litesiteid=40133). The objectives of the meeting were to synthesize ongoing research at U.S. OCB time-series sites (HOT, BATS, CARIACO); identify potential areas of improvement, including strengthened connections to other marine biogeochemical time-series and observing activities; and generate a prioritized list for future activities at the sites. The meeting hosted 65 participants from 5 different countries. Participants identified scientific questions related to community structure, dynamics driven by spatial (e.g., mesoscale features like eddies) and temporal (e.g., episodic events) scales that could be effectively addressed with the time-series, as well as current and emerging technologies that could be incorporated into time-series stations (e.g. the importance of moorings in capturing small frequency events needed to understand biogeochemical cycles), and the importance of time-series as 'training facilities' for emerging oceanographers.

Participants of the OCB Scoping Workshop recommended that the time-series sites continue ship-based measurements and expressed the need for improved and more extended modeling efforts and flux estimates, along with a better integration and synthesis across the time-series sites. They also highlighted the need of fully exploiting the data that has been collected historically in the time-series sites, which has not been utilized in their full potential.

PI Muller-Karger was invited to present CARIACO at the *1er Encuentro de Oceanografía Física Española*, which took place 13-15 October 2010 in Barcelona, Spain.

A special time-series session was held in the *2011 ASLO Aquatic Sciences Meeting: Limnology and Oceanography in a Changing World* (13-18 February 2011, San Juan, Puerto Rico). The session entitled *"Ocean Biogeochemistry Time-Series and Climate"* was well attended.

A special session on OCB time-series is planned for the Ocean Sciences meeting in Santa Fe in February *2012.*

The CARIACO All-Hands meeting was held in Margarita Island in December 2010. The 2011 All-Hands meeting, scheduled for November 14-15, marks the 16th anniversary of the series.

CARIACO also received recognition from the *Intergovernmental Oceanographic Commission of UNESCO (IOC)*. The IOC drafted and sent a letter to the Venezuelan Ministry of Science highlighting the importance of the time-series. The Venezuelan delegation for the IOC met with IOC representatives prior to the biennial meeting of the IOC (26th Assembly, which took place in Paris from 22 June to 5 July 2011), and agreed on the importance of the project, both at a national and international level, recognizing that CARIACO is the scientific endeavor in Venezuela which is best known internationally.

In March 2011, CARIACO submitted a new proposal to the Venezuelan government and it was selected as one of the funded projects. The Venezuelan scientists leading this effort are currently waiting to hear from the Ministry of Science with regards to the approved budget. This marks the fourth cycle of Venezuelan funding for the project.

A special issue of the journal Deep Sea Research II, featuring the three NSF-funded time-series, is currently being put together with the coordination of Dr. Mike Lomas; CARIACO will feature four new manuscripts in this issue.

BUDGET REQUEST

We request NSF support as per our original budget request.