The CARIACO Ocean Time-Series Program
University of South Florida, College of Marine Science
NSF Annual Report for Award # 0963028
Period Covered: November 2011 – November 2012
Report updated 3 September, 2012

SUMMARY

This document summarizes activities, new results, and findings of the CARIACO Ocean Time-Series Program conducted by the University of South Florida (USF) for the year 2011-2012. 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 an extensive suite of hydrographic and biogeochemical observations throughout the water column. In addition, the CARIACO time-series program 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 Tortuga Channel located to the north of the CARIACO station (the 'navigation channel'). The ADCP mooring 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 November 2011 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 logistical, methodological, and data processing issues that concern the CARIACO time-series program were discussed. CARIACO also participated in the 2011 IX Congreso de Ecología (Venezuelan Ecology Congress) in Margarita Island in November 2011 and in the 2012 Ocean Sciences Meeting (20-24 February 2012, Salt Lake City, UT).

Over the 2011-2012 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.

Between 2011-2012, fifteen manuscripts were submitted to peer-reviewed journals, eleven of which were accepted and are currently published or in press.

In late 2011 the Venezuelan component of CARIACO, led by Yrene Astor (Fundación La Salle de Ciencias Naturales de Venezuela), received a grant from the Venezuelan Ministry of Science (FONACIT). This will provide funding for the Venezuelan CARIACO component for the next 2 years. This includes an expansion of the study of higher trophic levels in the Cariaco Basin (Ichthyoplankton; led by Baumar Marin, UDO), a renewed effort to process nutrient samples in Venezuela (led by Tibisay Perez, IVIC) and new research on the bacterial community of the basin (led by Paula Suarez, USB and Walter Betancourt, IVIC). Each institution, in addition, is committed to support the salaries of each investigator and their technicians.

BUDGET REQUEST: We request NSF support as per our original budget request.

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.

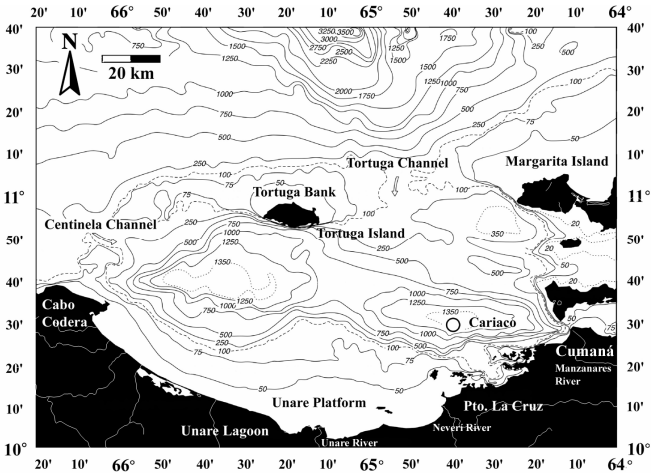

Figure 1: The Cariaco Basin. Location of the CARIACO time-series station is indicated (from Muller-Karger et al., 2001)

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.bco-dmo.org/project.cfm?flag=view&id=12&sortby=project) and in Spanish through the INTECMAR/USB server in Venezuela (http://cariaco.intecmar.usb.ve/). CARIACO data are also available through the CDIAC Time Series and Moorings web site: http://cdiac.ornl.gov/oceans/Moorings/. In addition, data are submitted regularly and on a timely basis to NODC, and to the NASA SeaBASS system. Upon request of the Venezuelan government (Min. Science and Technology) we are working with the Instituto Venezolano de Investigaciones Científicas (IVIC) to implement a comprehensive online CARIACO database to be served from IVIC computer servers.

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 1,310 m. A variety of bio-geochemical determinations are made using samples collected with bottles and pumps at discrete depths, including primary productivity, particle concentration, nutrient concentrations, and many other measurements. We also make a series of continuous and discrete profiles of bio-optical parameters.

Only modifications, additions or existing issues on methods will be discussed here. Methods have been described in the past (see Muller-Karger et al., 2001).

Primary production
The issue of availability of ^{14}C in Venezuela still persists. To stretch the amount of isotope available until we can obtain more and place it in Venezuela, primary productivity is 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 that case 75m and 100m are excluded. We are exploring other ways ^{14}C can be obtained, including purchase through our colleagues in the ANTARES network (http://home.antares.ws/).

Inorganic Nutrients
Nutrient analyses continue at USF's Nutrient Lab (Kent Fanning). Traditionally, our nutrients have always been filtered through a Nuclepore membrane filter (0.8 µm pore diameter), in order to avoid the potential contamination of samples when cell breakage occurs upon freezing. However, contamination in some of the samples this year prompted us to conduct a thorough study of filtered vs. unfiltered nutrient samples during both the upwelling and non-upwelling periods of 2011-2012. The study suggested that there is no significant difference between the samples and that in some instances filtration may be introducing contamination to the sample. It was decided that, starting in August 2012, filtration of nutrients was going to be stopped. Upwelling in the last years has been significantly weaker than that observed at the beginning of the time-series. Also, phytoplankton cells present during upwelling are smaller than they used to be (community structure has changed). If in future upwelling months larger and more numerous phytoplankton are observed, a duplicate sample set of filtered vs. unfiltered nutrients will be taken, to compare nutrient concentrations under that regime.

The IVIC (Venezuela) continues to be committed to work with CARIACO and scientists there will ramp up their engagement. The new funding provided by Min. Ciencias y Tecnología will allow IVIC to begin processing samples for inorganic nutrient observations regularly. We will compare nutrient samples processed at USF with those at IVIC to ensure high data quality desired is achieved and maintained in Venezuela.

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

Cruise number	Date	Cruise number	Date
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	Jan/10/2011
174	Nov/9/2010	188	Feb/7/2012
175	Dec/8/2010	189	Mar/16/2012
176	Jan/11/2011	190	Apr/10/2012
177	Feb/8/2011	191	May/15/2012
178	Mar/15/2011	192	Jun/5/2012
179	Apr/12/2011	193	Jul/26/2012
180	May/10/2011	194	Aug/14/2012
181	Jun/9/2011	195	Sept/11/2012
182	Jul/7/2011	196	Oct/9/2012
183	Aug/9/2011	197	Nov/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)	1-194
Temperature	0-1310 m	SBE-25 (SeaBird)	1-194
Conductivity (Salinity)	0-1310 m	SBE-25 (SeaBird)	1-194
Dissolved Oxygen	0-1310 m	SBE-43 (SeaBird)	1-194
Fluorescence (Chl)	0-1310	ECO Fluor. (WetLabs)	1-194
Beam attenuation (c660)	0-1310	C-Star (WetLabs)	1-194
2. Water Column Chemical Measurements			
Dissolved Oxygen	0-1310 m	Titration	1-194
DOC & TOC	0-1310 m	High Temp Comb	1-63; 110-194
Total Alkalinity	0-1310 m	Gran Titration	1-194
pH	0-1310 m	Spectrophotometer	1-194
Salinity	0-1310 m	Guildline Portasal 8410	1-194
Nitrate	0-1310 m	Technicon AA	1-194
Nitrite	0-1310 m	Technicon AA	1-194
Ammonia	0-1310 m	Technicon AA	1-194
Phosphorus	0-1310 m	Technicon AA	1-194
Silicate	0-1310 m	Technicon AA	1-194
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)	1-194
Partic. Organic Nitrogen	0-1310 m	Elemental Analyzer (EA)	1-194
3. Biomass Measurements			
Chl. *a* and Phaeopig.	0-100 m	Fluorometry (Turner)	1-194
Bacteria	0-1310 m	(Various/SUNY)	(see SUNY report)
4. Carbon Assimilation and Particle Flux			
Primary Production	0-100 m	^{14}C	1-194
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	1-190(some months missing due to instrument repair)
Upwelling Radiance and Downwelling Irradiance	0-150 m	PRR-600	1-194 (some months missing due to instrument repair)
6. Moored Instruments			
Sediment Traps	150, 275, 450, 900, 1200	(U. South Carolina)	(see USC report)
Lowered ADCP	1-400 m	WH Sentinel 300 (RDI)	2005-2012

FINDINGS AND RESULTS

Two recent manuscripts highlight the long-term changes that we have measured with the CARIACO time series. Taylor et al. (submitted, PNAS) report significant decadal scale trends. These include a sea surface temperature (SST) rise of ~1.0 ± 0.14°C, intensified stratification (increased mixed layer depth), reduced upwelling due to a weakening of the Trade Winds, a decrease in integrated phosphate between 0-100m, and declines in chlorophyll *a* concentrations (ΔChla = -2.8 ± 0.5% yr^{-1}) and in net primary production (ΔNPP = -1.5 ± 0.3% yr^{-1}). The paper documents shifts in the phytoplankton community. Our initial observations at the time series, between 12-17 years ago, showed communities dominated by diatoms, dinoflagellates, and coccolithophorids. Now, phytoplankton have shifted to smaller taxa. Changes occurred most markedly around 2004. A simultaneous biomass increase in meso-zooplankton was observed. We link these ecological changes to global climate change indices, and specifically to the northward migration of the Azores High pressure center (descending branch of Hadley cell) and a northeasterly progression of the Atlantic centroid of the Intertropical Convergence Zone or ITCZ (ascending branch of Hadley cell).

Astor et al. (accepted, Deep-Sea Research II) also examines the consequences of the ~ 1°C increase in SST in terms of changes in the dissolved inorganic carbon system of the Cariaco Basin. The authors found a positive trend of 1.75 ± 0.43 µatm $year^{-1}$ in surface fCO_{2sea} linked to the rise in temperature. The authors examine the relationships between interannual variability in the temperature anomaly with three modes of climate variability (AMO, NAO and ENSO), but their results are inconclusive.

The warming observed at the CARIACO site goes beyond the surface waters. A change in temperature has also been observed in the upper 100m of the water column. The warming is not as dramatic as what is observed in surface waters (roughly 0.08 °C yr^{-1}; Astor et al., submitted; Taylor et al., submitted), the water column between 0-100m is warming at a rate of 0.006 °C yr^{-1}. This heating has been ascribed to the progressive decrease in wind-induced upwelling in the southeastern Caribbean region. Ocean heat content (OHC) calculations of the upper 100 m of the water column also show a significant increase ($P< 0.001$) between 1996 and 2012. This linear trend is 0.026 x 10^9 J yr^{-1}. This warming is consistent with the worldwide warming described by Levitus et al. (2012).

CARIACO has experienced changes in other variables. Integrated salinity between 0-100 m shows a significant decrease ($P< 0.01$) between 1996 and 2012. In this 16-year period the upper water column has freshened roughly 0.008 salinity units (Figure 2). This freshening is consistent with observations made in the Caribbean Sea, which have been attributed to changes in circulation, rather than to changes in precipitation or river discharge (Jury et al., 2010). The amount of fixed nitrogen anomaly with respect to phosphorous (or N*; Gruber and Sarmiento, 1997), has also increased significantly in the Cariaco Basin, particularly within the Subtropical Underwater (SUW; $P< 0.001$). This increase is concurrent with observed increases of N* in the tropical North Atlantic. We don't know yet whether there is a link between these changes, but the tropical N Atlantic is where Subtropical Underwater (SUW), which enters the Caribbean Sea, is formed. The increase in N* in the North Atlantic observed over the last decade has been attributed to an acceleration of nitrogen fixation rates (Lomas et al., 2010). In the Cariaco Basin,

N/P ratios in the upper 100 m of the water column have increased, in part due to an overall decrease in PO_4. Nitrate has not changed significantly since 1998. Montes et al. (2012) observed an increase in *Trichodesmium sp.*, a nitrogen fixer, in the Cariaco Basin. Their abundance relative to the phytoplankton population has increased in the last 6 years. The changes in phytoplankton population in the basin can also be altering the nutrient stocks in the basin. Stratification favors the growth of phytoplankton groups with N:P ratios above Redfield values. Plankton communities in some nutrient-impoverished waters can be dominated by groups which have cellular N:P ratios greater than Redfield's (Bidigare et al., 2009; Lomas et al., 2010). All of these results suggest the ecosystem in the Cariaco Basin is changing. Whether this is the result of natural variability or induced by anthropogenic climatic change it is difficult to tell, especially because the CARIACO time series is still short and because there are still very few relevant data in tropical marine regions. This highlights the need for continuing the CARIACO data collections.

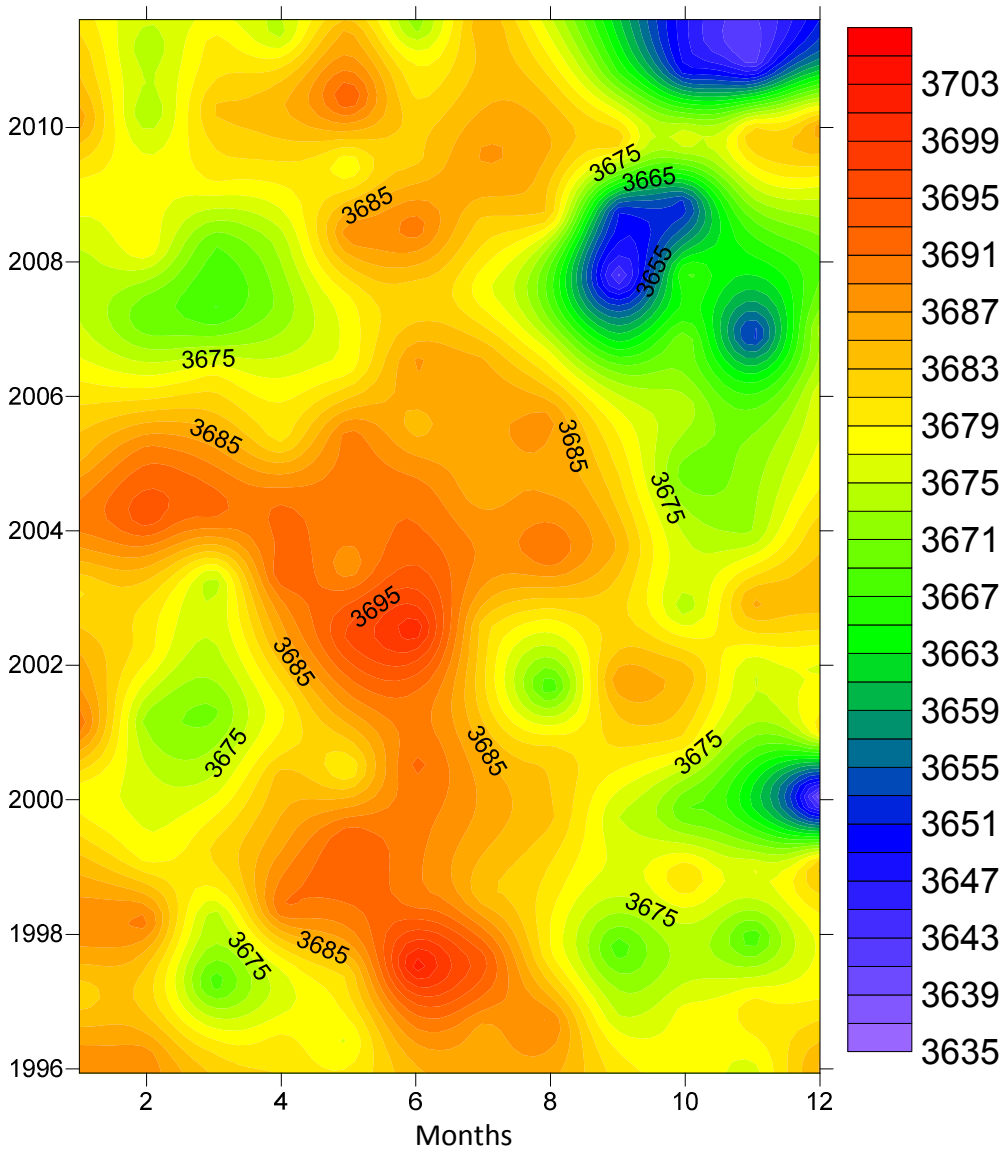

Figure 2: Integrated salinity (0-100m) between 1996-2012 at the CARIACO time-series site.

TIME-SERIES EDUCATION, PUBLICATIONS AND OUTREACH

CARIACO was highlighted in several scientific meetings in 2011-2012:

Gordon Taylor (SUNY), Frank Muller-Karger (USF), Enrique Montes (USF), Digna Rueda (USF), Laura Lorenzoni (USF), Luis Troccoli and students (UDO), Eduardo Klein (USB), Yrene Astor and students (EDIMAR), Jaimie Rojas (EDIMAR), Ruben Rojas (EDIMAR) and Luis Medina (EDIMAR) presented CARIACO-related research in the *IX Congreso Venezolano de Ecología* (21-25 November 2011, Margarita Island, Venezuela). The Congress is one of the most prominent scientific meetings in Venezuela.

CARIACO research results were presented at the *Ocean Sciences Meeting* (20-24 February 2012, Salt Lake City, UT). All of the PI's attended the meeting and took the opportunity to hold their annual CARIACO PI meeting during that week.

The CARIACO All-Hands meeting was held in Margarita Island in November 2011. This meeting marked the 16th anniversary of the series. In 2013 the 200 anniversary cruise of the time-series will be celebrated.

Between November 28-30, 2012, the international time-series methods workshop *Moving Toward Global Intercomparability in a Changing Ocean: An International Time-Series Methods Workshop* is planned at the Bermuda Institute of Ocean Sciences (BIOS). Laura Lorenzoni (CARIACO Technician) is leading the efforts in organizing the workshop in collaboration with IOCCP (Kathy Tedesco and Maciej Telszewski) and OCB (Heather Benway). The workshop will focus on biogeochemical time-series methods and data intercomparison. Participants from 25 different time-series stations distributed around the globe are expected. This workshop provides a unique opportunity for discussion amongst representatives from global marine biogeochemical time-series sites and to review current methodologies being used at the sites, with the aim of 'standardizing' sampling and analytical protocols for key biogeochemical parameters being measured across sites. The objectives of the workshop include:

- Review current oceanographic time-series core sampling and analytical methodologies and rationale behind protocol differences,
- To the extent possible, attempt to define standardized methods applicable across time-series,
- Attempt to reconcile differences in variable nomenclature,
- Examine new techniques available for more accurate and simplified measurements,
- Generate suggestions on how automated sensors may improve the type and accuracy of core measurements taken at time-series sites,
- Coordinate a best practices publication on sampling and measurement protocols to facilitate data inter-comparison across time-series sites,

The Venezuelan component of CARIACO wrote a proposal which was successful, and is now funded by the Venezuelan Ministry of Science (FONACIT) for two years starting in 2012. This effort is led by Yrene Astor. An important element is the study of higher trophic levels in the Cariaco Basin (Ichthyoplankton; led by Baumar Marin, UDO). The effort also includes a renewed effort to process nutrient samples in Venezuela (led by Tibisay Perez, IVIC) and new

research on the bacterial community of the basin (led by Paula Suarez, USB and Walter Betancourt, IVIC)

The special issue of the journal Deep Sea Research II (Lomas, editor), featuring the three NSF-funded time-series (CARIACO, HOT, BATS), is reviewing manuscripts generated by CARIACO investigators.

EDUCATION

Luis Medina, one of the technicians working with CARIACO at EDIMAR,is scheduled to participate in the 2012-2013 Observational Oceanography course in Bermuda. Luis is the second CARIACO technician to participate in the BIOS/POGO-sponsored program. Luis began working with CARIACO in May of 2011 and has since become one of the lead technicians in the time series, together with Jaimie Rojas (the current lead technician). Luis is working on his Master's degree at the Universidad de Oriente (Cumaná) and his thesis will focus on modeling of circulation and hydrography of the Cariaco Basin and adjacent Caribbean, expanding on Alvera's et al. (2009) work.

So far, six Venezuelan graduate students (A. Odriozola, J. R. Diaz, J. Gomez, D. Rueda E. Montes and L. Lorenzoni), and one undergraduate student (J. Akl) have studied in the U.S. under the direction of Frank Muller-Karger with support from this project. Others are studying under co-I support and advice. Odriozola, Akl and Lorenzoni also served as technicians for the CARIACO program.

Ten undergraduate students at Fundacion La Salle, four undergraduates at Universidad Simon Bolivar, two at the graduate level, six undergraduates at the Universidad Central de Venezuela, two graduate students at IVIC and several undergraduate and graduate students at the Universidad de Oriente have participated in data collection and derived theses from this work. Below is a summary of the latest publications and academic work under the CARIACO project:

CARIACO Doctoral Dissertations (Ph.D.) in 2011-2012

- Digna Rueda (Graduated Summer 2012). *On the spatial and temporal variability of upwelling in the southern Caribbean Sea and its influence on the ecology of phytoplankton and of the Spanish sardine (Sardinella aurita).* Advisor: Frank Muller-Karger (University of South Florida).
- Enrique Montes (Graduated Fall 2011). Title: *Suspended and settling particle concentration and composition within the euphotic zone of the Cariaco Basin, Venezuela.* Advisor: Frank Muller-Karger. University of South Florida
- Laura Lorenzoni (Graduated Summer 2012): Title: *Sediment transport and distribution over continental shelves: a glimpse at two different river-influenced systems, the Cariaco Basin and the Amazon Shelf.* Advisor: Frank Muller-Karger. University of South Florida.
- Maria Jose Rodríguez (Graduated Summer 2012): Title: *Bacterial Communities in the Cariaco Basin Redox Transition Zone and their Role in Sulfur and Metal Cycles.* Advisor: Andrei Chistoserdov. University of Louisiana at Lafayette
- Maria Hernandez (in progress): Title: *Vertical distribution of planktonic foraminifera in the Cariaco Basin.* Advisor: B. Marin. Universidad de Oriente, Cumana, Venezuela

- Agnieshka Podlaska (expected defense Fall 2012) *Dominant sulfur-utilizing chemoautotrophs within the Cariaco Basin's redoxcline*. Advisor: Gordon Taylor, State University of New York, Stony Brook
- Maria Balza (in progress): *Vertical distribution of different development stages of the sardine Sardinella aurita.* Advisor: B. Marin. Universidad de Oriente, Cumana, Venezuela
- Rafael Rasse (in progress): Title: TBA. Advisor: Tibisay Perez. IVIC, Caracas, Venezuela
- Kate Wejnert (Expected to defend Fall 2012): Title: *Isotopic and trace metal studies of particle fluxes in the Cariaco Basin*. Advisor: Robert Thunell, University of South Carolina.
- Brittney Marshall (in progress): Title: *Assessment of ocean acidification proxies using CARIACO sediment trap data*. Advisor: Robert Thunell, University of South Carolina.

Masters Theses in 2011-2012

- Sara Cernadas Martin (Summer 2012). Title: *Aerobic and anaerobic ammonia oxidizers in the Cariaco Basin: Identification, Quantification and Community Structure.* Advisor: Gordon Taylor, State University of New York, Stony Brook.
- Lan Thi Tong (Expected to defend Fall/Spring 2001/2013). Advisor: Mary Scranton, State University of New York, Stony Brook.

Journal Publications 2011-2012
Submitted:

Astor, Y.M., Lorenzoni, L., Thunell, R., Varela, R., Muller-Karger, F., Troccoli, L., Taylor, G.T., Scranton, M.I., Tappa, E., Rueda, D. Interannual variability in sea surface temperature and fCO_2 changes in the Cariaco Basin. Deep-Sea Research II.

Montes, E., R. Thunell, F.E. Muller-Karger, E. Tappa, L. Lorenzoni, L. Troccoli, Y. Astor, and R. Varela . Sources of δ^{15} N variability in sinking particulate nitrogen in the Cariaco Basin, Venezuela. Deep Sea Research II

Taylor, G.T., F. Muller-Karger, R. C. Thunell, M. I. Scranton, Y. Astor, R. Varela, L. Troccoli Ghinaglia, L. Lorenzoni, K. A. Fanning, S. Hameed and O. Doherty. Ecosystem Responses in the Southern Caribbean Sea to Global Climate Change. PNAS.

2012

Lorenzoni, L., C. Benitez-Nelson, R. C. Thunell, D. Hollander, R. Varela, Y. Astor and F. E. Muller-Karger. Potential role of event-driven sediment transport on sediment accumulation in the Cariaco Basin, Venezuela. Mar. Geol. doi:10.1016/j.margeo.2011.12.009

Montes, E., F. Muller-Karger, R. C. Thunell, D. Hollander, Y. Astor, R. Varela, I. Soto and L. Lorenzoni. Vertical fluxes of particulate biogenic material through the euphotic and twilight zones in the Cariaco Basin, Venezuela. Deep-Sea Res. I, 67: 73-84. DOI: 10.1016/j.dsr.2012.05.005

Li, X. N., G. T. Taylor, Y. Astor, R. Varela and M. I. Scranton. The conundrum between chemoautotrophic production and reductant and oxidant supply: A case study from the Cariaco Basin. Deep-Sea Res. I, 61: 1-10. DOI: 10.1016/j.dsr.2011.11.001

Wakeham, Stuart G., Courtney Turich, Florence Schubotz, , Agnieszka Podlaska, Xiaona N. Li, Ramon Varela, Yrene Astor, James Saenz; Darci Rush Jaap Sinninghe Damsté, Roger E. Summons, Mary I. Scranton, Gordon T. Taylor, and Kai-Uwe Hinrichs.Biomarkers,

Chemistry and Microbiology show Chemoautotrophy in a Multilayer Chemocline in the Cariaco Basin. Deep-Sea Res. I, 63: 133-156.

2011

Alvera-Azcarate, A., A. Barth, R. H. Weisberg, J. J. Castañeda, L. Vandenbulcke and J.-M. Beckers. Thermocline characterisation in the Cariaco basin: A modelling study of the thermocline annual variation and its relation with winds and chlorophyll-a concentration. Cont. Shelf Res., 31: 73-84. DOI: 10.1016/j.csr.2010.11.006

Black, D., R. Thunell, K. Wejnert and Y. Astor. Carbon isotope composition of Caribbean Sea surface waters: Response to the uptake of anthropogenic CO_2. Geophys. Res. Letters, 38, L16609, doi:10.1029/2011GL048538

Edgcomb, V, W. Orsi, G. T. Taylor, P. Vdacny, C. Taylor, P. Suarez and S. Epstein. Accessing marine protists from the anoxic Cariaco Basin. The ISME Journal; doi:10.1038/ismej.2011.10

Edgcomb, V, W. Orsi, G. Bunge, S. Jeon, R. Christen, C. Leslin, M. Holder, G. T. Taylor, P. Suarez, R. Varela and S. Epstein. Protistan microbial observatory in the Cariaco Basin, Caribbean. I. Pyrosequencing vs Sanger insights into species richness. The ISME Journal (2011), 1–13; doi:10.1038/ismej.2011.6

Garcia-Amado, M.A., Bozo, L., Astor, Y., Chistoserdov, A. Denaturing gradient gel electrophoresis analyses of the vertical distribution and diversity of Vibrio spp. populations in the Cariaco Basin. Federation European Microbiology Society, FEMS Microbiology Ecology,77 (2): 347-352

Li, X. N., Cutter, G.A., Thunell, R.C., Tappa, E., Gilhooly III., W.P., Lyons, T.W., Yrene, A., Scranton, M. I., 2011. Particulate sulfur species in th e water column of the Cariaco Basin. Geochim. Cosmochim. Acta, 75: 148-163, doi:10.1016/j.gca.2010.09.039.

Lorenzoni, L., C. Hu, R. Varela, G. Arias, L. Guzman and F. Muller-Karger. Bio-optical characteristics of Cariaco Basin (Caribbean Sea) waters. Continental Shelf Research, 31: 582–593.

Orsi, W., V. Edgcomb, S. Jeon, C. Leslin, J. Bunge, G. T. Taylor, R. Varela and S. Epstein. Protistan microbial observatory in the Cariaco Basin, Caribbean. II. Habitat specialization. The ISME Journal (2011), 1–17; doi:10.1038/ismej.2011.7

Orsi, W., Edgcomb, V., Faria, J., Foissner, W., Fowle, W. H., Hohmann, T., Suarez, P., Taylor, C., Taylor, G. T., Vdacny, P., Epstein, S. S. Class Cariacotrichea, a novel ciliate taxon from the anoxic Cariaco Basin, Venezuela. International Journal of Systematic and Evolutionary Microbiology, doi: 10.1099/ijs.0.034710-0

Books or Other One-time Publications:

Müller-Karger, Frank. E., R. Varela, R. C. Thunell, M. I. Scranton, G. T. Taylor, Y. Astor, C. R. Benitez-Nelson, L. Lorenzoni, E. Tappa, M. A. Goñi, D. Rueda, and C. Hu. 2010. The CARIACO Oceanographic Time Series. In: Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis. JGOFS Continental Margins Task Team (CMTT). Editors: Kon-Kee Liu, Larry Atkinson, Renato Quinones, Liana Talaue-McManus. Springer-Verlag, Berlin/Heidelberg.

Web/Internet Site: http://www.imars.marine.usf.edu/CAR/

BUDGET REQUEST

We request NSF support as per our original budget request.

REFERENCES

Alvera-Azcarate, A. A. Barth and R. H. Weisberg. 2009. A nested model of the Cariaco Basin (Venezuela): description of the basin's interior hydrography and interactions with the open ocean. Ocean Dynamics, DOI 10.1007/s10236-008-0169-y

Astor, Y.M., Lorenzoni, L., Thunell, R., Varela, R., Muller-Karger, F., Troccoli, L., Taylor, G.T., Scranton, M.I., Tappa, E., Rueda, D. Interannual variability in sea surface temperature and fCO_2 changes in the Cariaco Basin. Deep-Sea Research II.

Bidigare, R.R., Chai, F., Landry, M.R., Lukas, R., Hannides, C.C.S., Christensen, S.C., Karl, D.M., Shi, L., Chao, Y., 2009. Subtropical ocean ecosystem structure changes forced by North Pacific climate variations. J. of Plankton Res., 3, 1,131–1,139.

Gruber, N., and Sarmiento, J. L. (1997). Global patterns of marine nitrogen fixation and denitrification. Global Biogeochem. Cycles 11, 235–266.

Lomas, M.W., Steinberg, D.K., Dickey, T., Carlson, C.A., Nelson, N.B., Condon, R.H., Bates, N.R., 2010. Increased ocean carbon export in the Sargasso Sea linked to climate variability is countered by its enhanced mesopelagic attenuation. Biogeosciences 7, 57-70

Montes, E., R. Thunell, F.E. Muller-Karger, E. Tappa, L. Lorenzoni, L. Troccoli, Y. Astor, and R. Varela . Sources of δ^{15} N variability in sinking particulate nitrogen in the Cariaco Basin, Venezuela. Deep Sea Research II

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

Taylor, G.T., F. Muller-Karger, R. C. Thunell, M. I. Scranton, Y. Astor, R. Varela, L. Troccoli Ghinaglia, L. Lorenzoni, K. A. Fanning, S. Hameed and O. Doherty. Ecosystem Responses in the Southern Caribbean Sea to Global Climate Change. PNAS.