CARIACO Time Series Project

Progress Review: 2001 - 2002

Logistics:

In October 2001, the CARIACO time series completed six years of monthly hydrographic observations and the series continues with a robust monthly cruise plan. During the period of performance to date (October 2001-August 2002) we conducted 12 monthly cruises and deployed a current meter mooring (separate from the sediment trap mooring). The current meter mooring deployed in July 2002 will remain in place for one full year prior to recovery. This mooring has two Acoustic Doppler Current Profilers, one looking down and one looking up from 200 m to provide good vertical coverage of most of the water column.

Preliminary results:

The upwelling season of 2000-2001 began in December 2000 and reached peak values in early March 2001. Surface temperature decreased from 27^{o}C in November 2000 to 21.5^{o}C in February and March 2001. Prior to this and since the initiation of the CARIACO series in October 1995, surface temperatures as low as 21.5^{o}C had only been observed in March of 1997. This upwelling cycle was associated with a significant increase of surface chlorophyll-a and primary production compared to the upwelling cycles of 1998, 1999, and 2000. The chlorophyll changed from 0.16 mg/m^3 in November 2000 to of 7.3 mg/m^3 in March 2001, while the primary production increased from 1.35 mgC/m^3/hr in November 2000 to 25.84 mgC/m^3/hr in March 2001. The bulk of the chlorophyll and production during this upwelling was concentrated in the upper 55 meters, and values decreased with depth below that. In March, the high concentration of phytoplankton decreased the euphotic depth and limited phytoplankton growth mostly to the upper 25 m. Surface pH decreased from 8.10 in November to 8.00 in March.

As in 1997, the upwelling effects of the winter-spring season of 2001 were felt deeper than the depth of the Cariaco Basin sill (~145 m). The 19^{o}C isotherm, which usually is located at the depth of the sill, was raised ~50m for several months during the upwelling cycles of 1997 and 2001, and for less than a month in early 1998. The 18 ^{o}C isotherm moved up to 200 m in early 1997 and it remained there until our more recent observations.

Maximum oxygen levels were typically found in the upper 20 m. Below 20 m the oxygen concentration gradually decreased reaching values of less than 5 μM, which is considered the upper boundary of the oxic/anoxic interface. This boundary has fluctuated over 150 m in depth since November 1995. Throughout 2001 and the first quarter of 2002, the oxygen boundary moved up 60 m, reaching a minimum depth of 260 m in February 2001. During the non-upwelling season the boundary was relocated to ~300 m.

The uplift of the Subtropical Underwater mass during the winter-spring upwelling cycles of 1998 and 2002, and the exceptionally strong upwelling of 1997 and 2001, appears to have forced ventilation of the Cariaco Basin at depths greater than the sill depth. The ventilation events of 2001 were not observed until April of that year, i.e. at the end of the upwelling cycle. The positive oxygen anomaly (ventilation) was observed for 5 months after its initial detection in the continuous oxygen profiles collected monthly.

The intrusions in 2001 were also evident in the nitrate data. The maximum concentration of nitrate is generally between 120 and 160 m, as a result of nitrification. Below 200 m, denitrification rates increase. The ventilation of these deeper waters helps build local nitrate levels.

The strong upwelling conditions of 2001 were sustained until the end of March, when the situation was drastically reversed. Downwelling seemed to take place between April and June, immediately prior to the second (summer) upwelling of the year. The summer upwelling peaked in July, similar to what was observed every year since 1996. In contrast to what was observed in 1997 and 2000, the 2001 summer upwelling did not reach the surface. High nutrients were not lifted completely to the surface, and clear surface waters allowed deeper light penetration. These conditions changed the vertical phytoplankton distribution. Similar to previous summer upwelling, the subsurface peaks in chlorophyll biomass and primary production moved downward to a depth of ~20m. In early August the upwelling relaxed, the surface salinity decreased, and the temperature increased to 28.16^{o}C. As in 1996, a weaker upwelling event was seen in September-October 2001, but surface temperatures remained warm and only decreased to 26.87^{o}C. Conditions remained well stratified until the end of the year when the 21^{o}C isotherm reached its maximum depth at 120 m.

The upwelling of early 2002 peaked in March when the 21^{o}C isotherm reached 35 m. The 19^{o}C isotherm rose only ~20 m to reach the 120 m depth. A new ventilation event was detected in March 2002.

Contour plots for all parameters were created using a Delaunay triangulation method for gridding. This method involves interpolating regularly gridded values from the original values associated with vertices of triangles. To smooth the contour lines, a smooth quintic polynomial interpolation was applied. These time series may be examined at the following web (URL) addresses:

Temperature: http://imars.marine.usf.edu/cariaco/salinity.html

Salinity: http://imars.marine.usf.edu/cariaco/salinity.html

Chlorophyll-a: http://imars.marine.usf.edu/cariaco/chl.html

Phaeopigments: http://imars.marine.usf.edu/cariaco/phaeopigments.html

Primary Production: http://imars.marine.usf.edu/cariaco/pp.html

Oxygen: http://imars.marine.usf.edu/cariaco/oxygen.html

Phosphate: http://imars.marine.usf.edu/cariaco/PO4.html

Nitrate: http://imars.marine.usf.edu/cariaco/NO3.html

Nitrite: http://imars.marine.usf.edu/cariaco/NO2.html

Amonia: http://imars.marine.usf.edu/cariaco/NH4.html

Silica: http://imars.marine.usf.edu/cariaco/Si.html

pH T (at 25º C): http://imars.marine.usf.edu/cariaco/pH.html

TCO_2: http://imars.marine.usf.edu/cariaco/TCO2.html

fCO_2: http://imars.marine.usf.edu/cariaco/fCO2.html

Cruise number and dates carried out during this period of study:

Cruise #	Date
62	Jan/11/2001

63	Feb/16
64	Mar/14
65	Apr/04
66	May/05
67	May/11
68	Jul/09
69	Aug/06
70	Sep/11
71	Oct/08
72	Nov/05
73	Dec/11
74	Jan/11/2002
75	Feb/16
76	Mar/14
77	Apr/04
78	May/05

Status of the CARIACO database (parameter and cruise number up to which data have been processed)

Parameter:	Cruise Number:
Target Depth (m)	77
Corrected Depth (m)	76

O2 (ml/L)	77
O2 (umol/kg)	69
NH4 (uM)	71
NO2 (uM)	71
NO3 (uM)	71
PO4 (uM)	71
Si(OH)4 (uM)	71
pH	75
Alkalinity (mol/kg)	76
TCO2 (umol/kg)	72
fCO2 (uatm)	72
Discrete Salinity	75
CTD Salinity	73
CTD Temp	76
POC (mg/m3)	72
PON (mg/m3)	72
C/N part. (vol/vol)	72
POC (ug/kg)	72
PON (ug/kg)	72
PriPro (mgC/m3/hr)	78
Chl (mg/m3)	78
Phaeo (mg/m3)	78

Sample Collection and Processing Improvements

The following techniques were significantly improved for this performance period:

Oxygen:

Continuous dissolved O_2 profiles from the electronic sensor on the CTD have been made accessible via the web URL http://imars.marine.usf.edu/cariaco/data/CTD_DATA/. An automatic titrator with integrated burette module was incorporated into the oxygen analysis. This instrument shortened the analysis time and increased the precision. For assessment of the data quality, the mean, standard deviations and variances of series of measurements can be determined automatically this instrument.

Nutrients:

The variability of the measurements was examined by computing the standard deviation for the deep water samples (>1,300 m), where properties are expected to be relatively constant. Two sets of means +/- standard deviations are given below for the ammonia, phosphate, and silicate measurements using a set of values derived from previous cruises CAR19, 23, 25, 28, 29, 30, 31, 32, 33, 34, and 31 and values derived from cruises CAR55-71 (not including CAR56_2).

CAR19, 23, 25, 28, 29, 30, 31, 32, 33, 34, and 31:

NH4	PO4	SiO2

400	7.43+/-1.47	2.75+/-.10	51.27+/-3.3
500	13.4+/-1.36	3.10+/-.14	62.44+/-4.51
750	19.26+/-.60	3.45+/-.12	74.11+/-5.68
1000	21.82+/-.91	3.55+/-.12	78.43+/-5.94
1310	23.35+/-.75	3.71+/-.04	83.29+/-6.21

CAR55 - 71 (not including CAR56_2):

	NH4	PO4	SiO2
400	7.66+/-1.14	2.90+/-.16	50.73+/-2.60
450	9.69+/-1.44	2.90+/-.26	54.60+/-3.94
500	13.43+/-1.72	3.12+/-.20	60.55+/-5.04
750	21.02+/-.96	3.59+/-.16	69.90+/-11.52
1310	25.86+/-1.53	3.79+/-.31	71.88+/-17.28

In general, variability appears to have increased. The standard deviations are higher for the more recent samples. Prolonged frozen storage of some of the samples at USF may be part of the reason for this increase in variability.

Since CAR69 all silica samples were collected using a separate bottle and have not been frozen to prevent polymerization at high concentrations. Now they are stored in the refrigerator while before they had been frozen. Previous samples with concentration of silica below 400m in CARIACO probably represent underestimates due to polymerization. Almost all deep samples that were frozen showed low values due to polymerization loss. CAR69 was analyzed by Yrene Astor at EDIMAR from separate duplicate bottles that were never frozen and a set of samples that was frozen. Unfrozen CAR69 resulted in higher values, with deep values close to what is expected (e.g. ~92uM at 1310m).

30 ml sample bottles are now being used for all the nutrients that will be analyzed at USF (unfrozen for Silica and frozen for other nutrients). The frozen samples have arrived at our lab in the U.S. completely frozen, given that the smaller bottles allow for more room in the coolers for gel-ice and dry ice. These new bottles have:

- Wider mouth for easy filling and insertion of the auto-analyzer needle without touching the bottle.
- Just enough volume (30 ml) for direct measurement in the original bottle. To insert the auto-analyzer needle in the samples, several of these bottles are placed into a rack. If the sample bottles did not fit in this rack then the samples would have to be transferred to a suitable bottle, increasing the possibility for error.
- Smaller volume for easier transportation (Porlamar - St. Petersburg).
- Mislabeling of samples had caused some errors in previous years. Now samples bottles are labeled before the cruise, and filters between samples are washed with additional sample water.

Since CAR72, all samples collected for colored dissolved organic matter (CDOM) absorption coefficient determinations have been filtered through both a 0.8 um glass fibre filter and a 0.2um nuclepore filter. Values from previous samples, while not filtered, are not incorrect. Various test have shown that the effects of filtering are insignificant for purposes of the fluorescence techniques developed in the College of Marine Science to date.

CO_2 system (pH, Alkalinity, TCO_2 and fCO_2):

Our original spectrometer/spectrophotometer PC-based card started to perform suspiciously and lose stability in early-2001. The instrument stopped working after cruise #65. Data were not collected on several cruises, but Ocean Optics provided a new double spectrometer (SD 2000) as of cruise 71. This new and improved instrument uses two identical channels to measure a divided light beam. One channel measures the sample and the other measures the stability of the light source and corrects when necessary.

New web site:

A new website has been implemented to address concerns of design, speed, and security. This new site is located at:

http://imars.marine.usf.edu/cariaco

Personnel Training:

Glenda Arias, a full time technician for the CARIACO project at EDIMAR, visited the Remote Sensing Lab. at the University of South Florida for a 4-week training exercise during Oct. 2001.