Time-series Niskin-bottle sample data from R/V Hermano Gines cruises in the Cariaco Basin from 1995 through 2017 (CARIACO Ocean Time-Series Program)

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Project

» CARIACO Ocean Time-Series Program (CARIACO)

Programs

» Ocean Carbon and Biogeochemistry (OCB)

» U.S. Joint Global Ocean Flux Study (U.S. JGOFS)

» Ocean Time-series Sites (Ocean Time-series)

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Abstract

The CARIACO Ocean Time-Series Program (formerly known as CArbon Retention In A Colored Ocean) started on November 1995 (CAR-001) and ended on January 2017 (CAR-232). Monthly cruises were conducted to the CARIACO station (10.50° N, 64.67° W) onboard the R/V Hermano Ginés of the Fundación La Salle de Ciencias Naturales de Venezuela. During each cruise, a minimum of four hydrocasts were performed to collect a suite of core monthly observations. We conducted separate shallow and deep casts to obtain a better vertical resolution of in-situ Niskin-bottles samples for chemical observations, and for productivity, phytoplankton, and pigment observations.

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Coverage

Spatial Extent: **N**:10.683 **E**:-64.367 **S**:10.492 **W**:-64.735

Temporal Extent: 1995-11-08 - 2017-01-12

Dataset Description

The CARIACO Ocean Time-Series Program (formerly known as CArbon Retention In A Colored Ocean) started on November 1995 (CAR-001) and ended on January 2017 (CAR-232). Monthly cruises were conducted to the CARIACO station (10.50° N, 64.67° W) onboard the R/V *Hermano Ginés* of the Fundación La Salle de Ciencias Naturales de Venezuela. The following sections describe the methods used in collecting the core observations at the CARIACO station.

Methodology published at CARIACO site (http://imars.usf.edu/publications/methods-cariaco)
CARIACO Field Program general description (http://www.imars.usf.edu/cariaco)

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Inter-American Institute for Global Change Research, IAI (IAI-CRN3094).

Acquisition Description

Hydrocasts: CTD and Rosette Sample
During each cruise, a minimum of four hydrocasts were performed to collect a suite of core monthly observations. Additional hydrocasts were performed for specific process studies. We conducted separate shallow and deep casts to obtain better vertical resolution for chemical observations, and for productivity and pigment observations. Water was collected with a SeaBird rosette equipped with 12 (8 liter) teflon-coated Niskin bottles (bottle springs were also teflon-coated) at 20 depths between the surface and 1310 m. The rosette housed the CTD, which collected continuous profiles of temperature and salinity. The CTD also had a SBE-43 oxygen probe, a Wetlabs ECO fluorometer outfitted for chlorophyll-a estimates, and a C-Star transmissometer (660 nm, Wetlabs). Beam attenuation measurements were added to the time series on its 11th cruise (November 1986) originally using a SeaTech transmissometer. The rosette was controlled with a SeaBird deck unit via conducting cable, but alternatively it had been actuated automatically based on pressure recordings via an Autofire Module (SBE AFM) when breaks in cable conductivity had occurred.
Between November 1995 and September 1996, three separate SBE-19 CTDs were used in repeated casts until a reliable salinity profile was obtained below the oxycline. The SBE-19 model CTDs frequently failed to provide reliable conductivity values below the oxycline in the Cariaco Basin. Starting in September 1996, the SBE-19 CTDs were replaced by SBE-

25 CTDs, which provided extremely accurate and reliable data in anoxic waters.

All CTDs were calibrated at the Sea-Bird factory once per year. The accuracy of the pressure sensor was 3.5 m and had a resolution of 0.7 m. The temperatures accuracy was 0.002°C with a resolution of 0.0003°C. The conductivity accuracy was 0.003 mmho/cm with a resolution of 0.0004 mmho/cm.

Salinity
Continuous salinity profiles were calculated from the CTD measurements. Discrete salinity samples were analyzed using a Guildline Portasal 8410 salinometer standardized with IAPSO Standard Seawater, with a precision of better than ± 0.003 and a resolution of 0.0003 mS/cm at 15° C and 35 psu, the accuracy was ±0.003 at the same set point temperature as standardization and within -2° and +4°C of ambient. These salinity values were used to check, and when necessary calibrate, the CTD salinity profiles.

Discrete Oxygen
Continuous dissolved oxygen (O2) profiles were obtained with a SBE-43 Dissolved Oxygen Sensor coupled to the SBE-25 CTD. Discrete oxygen samples were collected in duplicate using glass-stoppered bottles and analyzed by Winkler titration (Strickland and Parsons, 1972, as modified by Aminot, 1983). The analytical precision for discrete oxygen analysis was ±3 mM, based on analysis of duplicate samples, with a detection limit of 5 mM.

Nutrients
Since CAR-072 (November 2001) all samples had been filtered through a 0.8 µm Nucleopore filter within minutes of collection, as recommended by the JGOFS protocol, and frozen in plastic bottles until analysis at the University of South Florida (USF). Previous to November 2001, nutrients were filtered through a 0.7 µm GF/F filter before freezing. This data was still considered reliable, as tests using glass fiber filters show no significant contamination. The analyses follow the standard techniques described by Strickland and Parsons (1972). USF follows the recommendations of Gordon et al. (1993) for the WOCE WHP project for nutrient analysis.

Since CAR-069 (August 2001) all silica samples were kept unfrozen; they were refrigerated and kept in the dark. Prior to CAR-069, silicates were frozen and those exhibiting high concentration of silica (> 40µM below 300m in CARIACO) were affected by polymerization. All deep samples that were frozen showed low values due to polymerization loss, except CAR-063 and CAR-068 which showed high values. CAR-069 was analyzed by Yrene Astor at EDIMAR from the separate unfrozen bottlesand at USF from other, frozen, bottles. Unfrozen CAR-069 resulted higher with deep values close to what was expected (e.g. ~92µM at 1310m).

Detection limits for CARIACO nutrient analysis

The limits below were determined by calculating the concentrations in triplicate standards, averaging the results within each triplicate group, calculating the standard deviation for each group, averaging the standard deviations, and finally doubling the averages to get the detection limits. These samples were analyzed on an ALPKEM RFA II. Subsequent Cariaco analyses were performed on a Technicon Analyzer II

	ALPKEM RFA II	**Technicon Analyzer II**	
Nutrient Type			
	Detection limits	**Errors of analysis**	**Detection limits**
PO_4 Phosphate	0.03 µmol	<0.01 µM	0.02 µM
$Si(OH)_4$ Silica	0.14 µmol	0.2 µM	0.4 µM
NO_3 Nitrate	0.06 µmol	0.02 µM	0.04 µM
NO_2 Nitrite	0.02 µmol	<0.01 µM	0.01 µM
NH_4 Ammonium	0.07 µmol	0.05 µM	0.1 µM

Primary Production

Primary productivity measurements were made using a modified Steeman Nielsen (1952) NaH14CO3 uptake assay. The productivity measurements consisted of in situ incubations of water collected at 8 depths and inoculated with 14C-labeled bicarbonate. One hour before sunrise, a shallow cast was performed to obtain water from 1, 7, 15, 25, 35, 55, 75, and 100 meters. As the productivity cast was taken, a Licor Photosynthetically-Active Radiation (PAR) integrator, placed high above the ship's bridge, was activated. Water was poured directly from the Niskin bottle under low light conditions into 250 ml clear polycarbonate bottles. These bottles had been previously acid-washed, rinsed, and soaked in de-ionized water for over 48 hours. Bottles were rinsed three times before filling, a near total fill (the volume within the bottles was actually 290 ml of sea water). Four clear polycarbonate bottles were filled from each depth. We wrap one inoculated bottle from each depth in aluminum foil to obtain the dark 14-C uptake rates. An extra bottle for 1, 15, 35, and 75 m was filled, but not inoculated, to provide time-zero (t0) filter and seawater blanks. The t0 samples were kept in the dark in the laboratory and were filtered after deploying the floating incubation buoy.

We inoculated each sample under low light conditions with 1,000 ml (4 mCi) of the 14C sodium bicarbonate working solution. A 200 ml aliquot for counting total added 14C activity was removed from one of the 3 bottles from each depth and placed in a 20 ml glass scintillation vial containing 250 ml ethanolamine. The mixture was held at 5°C until subsequent liquid scintillation analysis on shore. We also placed 50 ml of the 14C working solution in a vial with ethanolamine (250 ml) for reference counting.

The dark bottle and 3 light bottles were hooked together with a combination of plastic tie wraps and nylon cord, and kept in the dark while preparations were made for deployment of the productivity incubation float. At approximately 07:00 hours, the productivity array was deployed. The entire productivity ensemble was attached to a buoy equipped with a flag and radar reflector.

Productivity observations were initiated on December 1995. Between December 1995 and November 1996, we incubated samples from 06:00 to 10:00 hours. Starting December 1996, we changed our protocol to incubate between 07:00 and 11:00 hours. This more accurately represents 1/3 of the daily photoperiod and 1/3 of the total energy received in one day on a year-round basis at 10°30'N, as verified with the PAR light sensor.

Approximately 4 hours after deployment, the productivity array was recovered. We decided to use 4-hour incubation periods due to the potentially high productivity (>1,000 mg/(m^2d)) of this continental margin. Sample bottles were detached from the line and placed in labeled, dark plastic bags until filtration. Time and position of recovery were recorded. Maintaining low light conditions, a 50 ml aliquot was withdrawn from each productivity bottle using a 50 ml plastic syringe. This aliquot was filtered onto a 25 mm Whatman GF/F glass fiber filter, maintaining vacuum levels of ~1/3 atm. The filter was rinsed with 0.25 ml 0.5 N HCl, and placed in a 20 ml glass scintillation vial, covered, and held at 5°C until subsequent processing on shore. At the shore laboratory, immediately upon return and within 15 hours of sample collection, 10 ml of liquid scintillation cocktail were added to the vials with the filters. These vials were refrigerated until they were ready for analysis on a BetaScout (PerkinElmer)scintillation counter.

Carbon uptake calculations followed the standard formulation outlined in the JGOFS manual (UNESCO, 1994), taking into consideration a (very low) quenching curve. Specifically, we subtracted the blank from all bottles, and then subtracted the dark bottle uptake from the average uptake in the light bottles to correct for non-photoautotrophic carbon fixation or absorption. Dark uptake values had always been very low. A scaling factor (~3) was applied to convert the hourly production value to a "daily mean hourly average". This factor varies slightly, as it was based on the fraction of the energy received during the

incubation period relative to the total energy received in a day. Daily rates were derived by multiplying the hourly rate by 12. Gieskes and Van Bennekom (1973), Peterson (1980), and Carpenter and Lively (1980) review the historical background, problems, and assumptions involved in the application of the radiocarbon technique to aquatic productivity. Muller-Karger (1984) also summarizes the technique and corrections involved.

pH and Alkalinity

pH samples were collected directly in 10-cm cells and analyzed on board. We measured pH and total Alkalinity estimates using the precise spectrophotometric dye methods developed by Robert-Baldo et al. (1985), Byrne and Breland (1989), and which we modified from Clayton and Byrne (1993) and Breland and Byrne (1993). These methods circumvent the problem that arises when potentiometric electrodes were transferred from dilute buffers to sea water samples due to the sample's high ionic strength. All the pH values were reported in the Master file for CARIACO data at 25 °C to avoid the effects of temperature on the solution chemistry. Measurement analytical precision for pHT at 25° C (total_hydrogen_ion_scale) = ±0.003, and for Total_alkalinity (mmol/kg), the precision is = 5 mmol/kg.

Corrections of pH for dye indicator impurities: The pH method uses the dye meta-cresol purple (mCP) as the pH indicator. The mCP dye used in CARIACO was in its unpurified form. Impurities in the indicator dye may cause uncertainty in measured pH values (Yao et al., 2007). Unpurified forms of the dye absorb significantly at the wavelength of maximum absorption for the acid species, HI- (434 nm) (Liu et al., 2011). The ratio of indicator absorbance at wavelengths 578 (base specie, I2-) and 434 (R = A578/A434) is used to calculate pH. Therefore, the effect of the impurities translates into apparent lower pH calculated values, especially at surface waters where pH > 8.0 (Yao et al., 2007). The effect of the impurities varies from one indicator manufacturer to another, and from different batches of the same manufacturer (Yao et al., 2007). Fortunately, the indicator used for the whole dataset in CARIACO came from the same batch. Hence, a correction for mCP impurities was applied following the method developed by Douglas and Byrne (2017) to each set of data for each cruise. This correction translated to ~ -0.01 units at pH ~ 8.1, decreasing to ~ - 0.008 units at pH ~ 7.6. The corrections were applied to the whole dataset, and values for DIC and fCO2 were recalculated in the Master file. All the pH values were reported in the Master file for CARIACO data at 25 °C to avoid the effects of temperature on the solution chemistry.

Chlorophyll

Chlorophyll sample collection and storage: water samples were collected from Niskin bottles into 1 L dark polyethylene bottles. These samples were immediately filtered through 25 mm Whatman GF/F filters using a vacuum of less than 100 mm Hg. During the upwelling

season (approx. January-May) we filtered 250 ml seawater, and during the rest of the year we filtered 500 ml. Three replicates were taken per depth during the upwelling season, but only two were collected when biomass was obviously at its minimum, during the non-upwelling season. Filters were folded in half twice and placed in glass centrifuge tubes, labeled and frozen. Storage time was kept as short as possible (less than a week) before measurement.

Chlorophyll procedure: after removal from the freezer, the filters were extracted in 10 ml of methanol. The samples were allowed to extract for 24 hours in the refrigerator. Following extraction, samples were centrifuged for 20 minutes to remove debris. The fluorometer (Turner fluorometer model 10-AU-005) was allowed to warm up and stabilize for 30 minutes prior to use. Pure methanol was measured to confirm the zero position. Samples were transferred to 1-cm cells and they were measured directly into the fluorometer (Fo). 100 µl of 0.48N HCl was added to each cell. A second reading was taken from the fluorometer for each cell (Fa). Standardization. The fluorometer was calibrated every year with a commercially available chlorophyll a standard (Σ). The concentration of chlorophyll-an and phaeopigments in the sample were calculated using Yentsh and Menzel (1963) equation, with a specific absorption coefficient of 74.5 (chlorophyll in methanol).

HPLC

HPLC analysis was restarted in July 2006 (CAR-123). Samples were filtered 47 mm Whatman GF/F filters at 8 depths (1, 7, 15, 25, 35, 55, 75 and 100m). The volume filtered depends on the amount of particles in the water. Replicates were taken at the 1m depth. Filters were stored in aluminum envelopes and stored in the fridge until reaching shore. Once on shore, samples were stored at -40°C until transportation to the US. Horn Point Laboratory (http://www.hpl.umces.edu/) performs the analyses through a collaborative agreement with NASA. The method used was Van Heukelem and Thomas (2001).

POC and PON

POC and PON sample collection and storage: water samples were collected from Niskin bottles into 2 L dark polyethylene bottles. These samples were immediately filtered through 25 mm Whatman GF/F filters (precombusted for 5 hours at 450°C) using a vacuum of less than 100 mm Hg. Since July 2007 (CAR-135) filters were acidified (10% HCl) after combustion and prior to sample collection. A portion of these filters was used for POP analysis (see below). Filters were placed on expendable tin disks and then into aluminum foil envelops (also precombusted for 5 hours at 450°C) labeled and frozen. In the laboratory, filters were dried at 65°C for 12-15 hours then stored with silica gel.
Measurement: The filters were folded inside a tin disk and analyzed on a Perkin Elmer 2400 Elemental Analyzer. The samples were combusted at 1200-1300°C and then passed through a reduction tube to removes the oxygen added to raise the combustion temperature.

Filers were not acid fumed prior to analysis. The C and N were then separated in a chromatographic column and were measured on a Thermal Conductivity Detector. Carbon and nitrogen standards, and blank filters were used to calibrate the data. The accuracy of the instrument was <0.3% and the precision of the instrument was <0.2%. These were published values and we find that we were always within these limits (usually ±0.15% for carbon and ±0.1% for nitrogen). We ran cystine as our standard (29.99% Carbon, 11.66% Nitrogen). The analytical range of the instrument is: Carbon= .001 to 3.6 mg and Nitrogen= 0.001 to 6.0 mg.

POP

POP was analyzed from the same POC/PON filters. The method used for the SRP analysis was based on Koroleff (1983).

Dissolved organic Carbon, Nitrogen and Phosphorous (DOC, DON and DOP)

Measurements of DOC were taken since the beginning of the project in November 1995 but suspended in February 2001 (CAR-062) due to irregularity of results. DOC was reinitiated in March 2005 (CAR-110) using a new protocol. DOC samples were collected monthly and analyzed at the Organic Biogeochemistry Lab in the Rosenstiel School of Marine & Atmospheric Science at the University of Miami. Samples were gravity-filtered directly from the Niskin bottles through 45 mm GF/F precombusted filters using acid cleaned polycarbonate in-line filter holder. Immediately after filtration the polyethylene bottles were frozen at -20°C until analysis.

DON and DOP measurements were added to the regular CARIACO cruises in July 2004 (CAR-101). Samples were filtered through GF/F filters using a specially built vacuum filter rack. The DON method was based on Solorzano and Sharp (1980). This procedure produces a filtered seawater sample for analysis of total dissolved fixed nitrogen (=nitrate + nitrite + ammonium + DON). DON concentration was obtained by difference from nitrate, nitrite, and ammonium measured in the standard nutrient protocol. DOP was analyzed in the same persulfate-oxidized filtrate solution as DON. That solution yields total inorganic phosphate concentration, which was composed of the inorganic phosphate concentration originally in the seawater, plus an additional phosphate concentration due to the conversion of DOP to phosphate. DOP concentration was then obtained by difference from the inorganic phosphate in the unoxidized sample measured through the standard nutrient protocol.

Optical measurements

In-water measurements: a PRR-600 (Biospherical) was used to retrieve downwelling irradiance and upwelling radiance. From these, PAR, Kd and reflectance can be calculated. Beam attenuation coefficient (Cp) was measured using a C-Star transmissometer (see

section Hydrocasts: CTD and Rosette Sample), which provides measurements at 660 nm throughout the entire water column.

CDOM samples were measured at four depths (1m, 15m, 25m, 50m) by filtration through a 0.2 µm pore size filter and immediately frozen at -20°C. Before being analyzed, they were thawed and re-filtered to eliminate any salt crystals that may had formed. CDOM was measured between 200 and 800 nm, with a 0.3 nm interval, using a dual fiber optic spectrometer (Ocean Optics) equipped with 10-cm quartz cuvettes and distilled water as a blank.

Above water measurements: a PR-650 (Photoresearch) measures sky radiance (Ls), water leaving radiance (Lw) and total irradiance (Es) at an angle of 30°. From these measurements, remote sensing reflectance (Rrs = Lw/Es) can be calculated and used in satellite sensor (such as MODIS and SeaWiFS) calibration.

Methods compiled by John Akl, July 2002. Revised November 2005 by Laura Lorenzoni. Revised April 2019 by Digna Rueda-Roa

The CARIACO Ocean Time-Series Program (November 1995 – January 2017)

For a detailed log for each cruise, please refer to the supplemental document Cruise Data Acquisition Report (https://datadocs.bco-dmo.org/docs/302/CARIACO/data_docs/3092/1/Cruise_da...)

Processing Description

BCO-DMO Processing Notes:
- added conventional header with dataset name, PI name, version date
- modified parameter names to conform with BCO-DMO naming conventions
- added latitude and longitude information from additional LatLon.csv file.
- reformatted the date from yyyymmdd to ISO convention yyyy-mm-dd

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Related Publications

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Parameters

Parameter	Description	Units
Cruise_number	number of cruise	integer (nnn)
Cruise_ID_1	cruise ID for OCB	alphanumeric
Cruise_ID_2	cruise ID for the CARIACO project	alphanumeric
Leg	number of cruise in the same month	integer (n)
Day	day of sampling in dd format	unitless
Month	month of sampling in mm format	unitless

Year	year of sampling in yyyy format	unitless
Hydro_cast_no	hydrographic CTD cast number	integer (n)
ISO_DateTime_start_hc_local	start date and time of hydrocast in Venezuelan Standard Time (VET) in ISO 8601 format	unitless
ISO_DateTime_end_hc_local	end date and time of hydrocast in Venezuelan Standard Time (VET) in ISO 8601 format	unitless
Depth_target	depth target (nominal)	meters (m)
Depth_real	depth of sample	meters (m)
O2_ml_L	dissolved oxygen (average in ml/L)	milliliters/liter (ml/L)
q_O2_ml_L	quality flag for O2_(ml/L)	dimensionless
O2_umol_kg	dissolved oxygen (average in µmol/kg)	micromoles/kilogram (µmol/kg)
q_O2_umol_kg	quality flag for O2_(µmol/kg)	dimensionless
NO3_UDO	nitrate UDO (average)	micromolar (µM)
q_NO3_UDO	quality flag for nitrate UDO	dimensionless
PO4_UDO	phosphate UDO (average)	micromolar (µM)
q_PO4_UDO	quality flag for phosphate UDO	dimensionless
SiO4_UDO	silica UDO	micromolar (µM)
q_SiO4_UDO	quality flag for silica UDO	dimensionless
NH4_USF	ammonia USF	micromolar (µM)
q_NH4_USF	quality flag for ammonia USF	dimensionless
NO2_USF	nitrite USF	micromolar (µM)
q_NO2_USF	quality flag for nitrite USF	dimensionless
NO3_NO2_USF	nitrate plus nitrite USF	micromolar (µM)
q_NO3_NO3_USF	quality flag for nitrate plus nitrite USF	dimensionless
PO4_USF	phosphate USF	micromolar (µM)
q_PO4_USF	quality flag for phosphate USF	dimensionless
SiO4_USF	silica USF	micromolar (µM)

q_SiO4_USF	quality flag for silica USF	dimensionless
pH	pH average total hydrogen (at 25 deg. C) no corrected for dye impurities	ion scale (pH)
q_pH	quality flag for pH	dimensionless
Alkalinity_mol_kg	total alkalinity	moles/kilogram (mol/kg)
q_Alkalinity_mol_kg	quality flag for total alkalinity (mol/kg)	dimensionless
Alkalinity_umol_kg	total alkalinity	micromoles/kilogram (µmol/kg)
q_Alkalinity_umol_kg	quality flag for total alkalinity (µmol/kg)	dimensionless
TCO2	total carbon dioxide in seawater (no corrected)	micromoles/kilogram (µmol/kg)
q_TCO2	quality flag for total carbon dioxide in seawater (no corrected)	dimensionless
fCO2	fugacity of CO2 in sea water (no corrected)	microatmospheres (µatm)
q_fCO2	quality flag for fugacity of CO2 in sea water (no corrected)	dimensionless
pH_corrected	pH average total hydrogen (at 25 deg. C) corrected for dye impurities	ion scale (pH)
q_pH_corrected	quality flag for pH_corrected	dimensionless
TCO2_corrected	total carbon dioxide in seawater (recalculated with corrected pH)	micromoles/kilogram (µmol/kg)
q_TCO2_corrected	quality flag for total carbon dioxide in seawate recalculated	dimensionless
fCO2_corrected	fugacity of total carbon dioxide in seawate recalculated	microatmospheres (µatm)
q_fCO2_corrected	quality flag for ffugacity of total carbon dioxide recalculated	dimensionless
Salinity_bottles	salinity from salinometer	PSU (PSU)
q_Salinity_bottles	quality flag for salinity from salinometer	dimensionless

Salinity_CTD	salinity from CTD	PSU (PSU)
q_Salinity_CTD	quality flag for salinity from CTD	dimensionless
Temperature	temperature from CTD ITS-90 scale	degrees Celsius (degC (°C))
q_Temperature	quality flag for temperature from CTD	dimensionless
Sigma_t	density	kilograms/meter^3 (Kg/m^3)
q_Sigma_t	quality flag for density	dimensionless
TPP	total particulate phosphorus	nanomolar (nM)
q_TPP	quality flag for total particulate phosphorus	dimensionless
PIP	particulate inorganic phosphorus	nanomolar (nM)
q_PIP	quality flag for particulate inorganic phosphorus	dimensionless
POC_ug_kg	particulate organic carbon	micrograms/liter (µg/kg)
q_POC_ug_kg	quality flag for particulate organic carbon (µg/kg)	dimensionless
PON_ug_kg	particulate organic nitrogen	micrograms/liter (µg/kg)
q_PON_ug_kg	quality flag for particulate organic nitrogen (µg/kg)	dimensionless
POC_ug_L	particulate organic carbon	micrograms/liter (µg/L)
q_POC_ug_L	quality flag for particulate organic carbon (µg/L)	dimensionless
PN_ug_L	particulate organic nitrogen	micrograms/liter (µg/L)
q_PN_ug_L	quality flag for particulate organic nitrogen (µg/L)	dimensionless
C_N_particulate	carbon to nitrogen ratio of particulate C to N	mole/mole (mol/mol)

q_C_N_particulate	quality flag for C to N particulate	dimensionless
DON	dissolved organic nitrogen USF	micromolar (µM)
q_DON	quality flag for dissolved organic nitrogen USF	dimensionless
DOP	dissolved organic phosporus USF	micromolar (µM)
q_DOP	quality flag for dissolved organic phosporus USF	dimensionless
DOC	dissolved organic carbon	micromolar (µM)
q_DOC	quality flag for dissolved organic carbon	dimensionless
TOC	total organic carbon	micromolar (µM)
q_TOC	quality flag for total organic carbon	dimensionless
PrimaryProductivity	primary production	milligrams Carbon/meter^3/hour (mgC/m^3/hr)
q_PrimaryProductivity	quality flag for primary production	dimensionless
Chlorophyll	chlorophyll a	milligrams/meter^3 (mg/m^3)
q_Chlorophyll	quality flag for chlorophyll a	dimensionless
Phaeopigments	phaeopigment	milligrams/meter^3 (mg/m^3)
q_Phaeopigments	quality flag for phaeopigment	dimensionless
Total_Prokaryotes	number of prokaryotes cells	(cells/L)10^8 ((cells_x_10^8/L))
Bact_Biomass_mgC_m3	bacterial biomass (mgC/m^3)	milligrams Carbon/meter^3 (mgC/m^3)
Bact_Biomass_uMC	bacterial biomass (µMC)	microMolar Carbon (µMC)
Bio_cast_no	biological CTD cast number (primary production chlorophyll and phaeopigments)	integer (n)

ISO_DateTime_start_bc_local	start date and time of biocast in Venezuelan Standard Time (VET) in ISO 8601 format	unitless
ISO_DateTime_end_bc_local	end date and time of biocast in Venezuelan Standard Time (VET) in ISO 8601 format	unitless
ISO_DateTime_start_hc_UTC	start date and time of hydrocast in UTC in ISO 8601 format	unitless
ISO_DateTime_end_hc_UTC	end date and time of hydrocast in UTC in ISO 8601 format	unitless
ISO_DateTime_start_bc_UTC	start time of biocast in UTC in ISO 8601 format	unitless
ISO_DateTime_end_bc_UTC	end time of biocast in UTC in ISO 8601 format	unitless
Latitude	Latitude of observations with positive values indicating North	decimal degrees
Longitude	Longitude of observations with negative values indicating West	decimal dgrees

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Instruments

Dataset-specific Instrument Name	Niskin Bottle
Generic Instrument Name	Niskin bottle
Generic Instrument Description	A Niskin bottle (a next generation water sampler based on the Nansen bottle) is a cylindrical, non-metallic water collection device with stoppers at both ends. The bottles can be attached individually on a hydrowire or deployed in 12, 24 or 36 bottle Rosette systems mounted on a frame and combined with a CTD. Niskin bottles are used to collect discrete water samples for a range of measurements including pigments, nutrients, plankton, etc.

Dataset-specific Instrument Name	SBE-19
Generic Instrument Name	CTD Sea-Bird SEACAT 19
Dataset-specific Description	Between November 1995 and September 1996, three separate SBE-19 CTDs were used in repeated casts until a reliable salinity profile was obtained below the oxycline. The SBE-19 model CTDs frequently failed to provide reliable conductivity values below the oxycline in the Cariaco Basin.
Generic Instrument Description	The Sea-Bird SBE 19 SEACAT Recorder measures conductivity, temperature, and pressure (depth). The SEACAT is self-powered and self-contained and can be deployed in profiling or moored mode. The SBE 19 SEACAT was replaced in 2001 by the 19plus. more information from Sea-Bird Electronics

Dataset-specific Instrument Name	SBE-25
Generic Instrument Name	CTD Sea-Bird 25
Dataset-specific Description	Starting in September 1996, the SBE-19 CTDs were replaced by SBE-25 CTDs, which provided extremely accurate and reliable data in anoxic waters.
Generic Instrument Description	The Sea-Bird SBE 25 SEALOGGER CTD is battery powered and is typically used to record data in memory, eliminating the need for a large vessel, electrical sea cable, and on-board computer. All SBE 25s can also operate in real-time, transmitting data via an opto-isolated RS-232 serial port. Temperature and conductivity are measured by the SBE 3F Temperature sensor and SBE 4 Conductivity sensor (same as those used on the premium SBE 9plus CTD). The SBE 25 also includes the SBE 5P (plastic) or 5T (titanium) Submersible Pump and TC Duct. The pump-controlled, TC-ducted flow configuration significantly reduces salinity spiking caused by ship heave, and in calm waters allows slower descent rates for improved resolution of water column features. Pressure is measured by the modular SBE 29 Temperature Compensated Strain-Gauge Pressure sensor (available in eight depth ranges to suit the operating depth requirement). The SBE 25's modular design makes it easy to configure in the field for a wide range of auxiliary sensors, including optional dissolved oxygen (SBE 43), pH (SBE 18 or SBE 27), fluorescence, transmissivity, PAR, and optical backscatter sensors. More information from Sea-Bird Electronics: http:www.seabird.com.

Dataset-specific Instrument Name	Turner fluorometer model 10-AU-005
Generic Instrument Name	Turner Designs Fluorometer -10-AU
Dataset-specific Description	Chlorophyll procedure: after removal from the freezer, the filters were extracted in 10 ml of methanol. The samples were allowed to extract for 24 hours in the refrigerator. Following extraction, samples were centrifuged for 20 minutes to remove debris. The fluorometer (Turner fluorometer model 10-AU-005) was allowed to warm up and stabilize for 30 minutes prior to use. Pure methanol was measured to confirm the zero position. Samples were transferred to 1-cm cells and they were measured directly into the fluorometer (Fo). 100 µl of 0.48N HCl was added to each cell. A second reading was taken from the fluorometer for each cell (Fa). Standardization. The fluorometer was calibrated every year with a commercially available chlorophyll a standard (Σ). The concentration of chlorophyll-an and phaeopigments in the sample were calculated using Yentsh and Menzel (1963) equation, with a specific absorption coefficient of 74.5 (chlorophyll in methanol).
Generic Instrument Description	The Turner Designs 10-AU Field Fluorometer is used to measure Chlorophyll fluorescence. The 10AU Fluorometer can be set up for continuous-flow monitoring or discrete sample analyses. A variety of compounds can be measured using application-specific optical filters available from the manufacturer. (read more from Turner Designs, turnerdesigns.com, Sunnyvale, CA, USA)

Dataset-specific Instrument Name	SeaTech transmissometer
Generic Instrument Name	Sea Tech Transmissometer
Dataset-specific Description	Beam attenuation measurements were added to the time series on its 11th cruise (November 1986) originally using a SeaTech transmissometer.
Generic Instrument Description	The Sea Tech Transmissometer can be deployed in either moored or profiling mode to estimate the concentration of suspended or particulate matter in seawater. The transmissometer measures the beam attenuation coefficient in the red spectral band (660 nm) of the laser lightsource over the instrument's path-length (e.g. 20 or 25 cm). This instrument designation is used when specific make and model are not known. The Sea Tech Transmissometer was manufactured by Sea Tech, Inc. (Corvalis, OR, USA).

Dataset-specific Instrument Name	Licor Photosynthetically-Active Radiation (PAR) integrator
Generic Instrument Name	LI-COR Biospherical PAR Sensor
Dataset-specific Description	As the productivity cast was taken, a Licor Photosynthetically-Active Radiation (PAR) integrator, placed high above the ship's bridge, was activated.
Generic Instrument Description	The LI-COR Biospherical PAR Sensor is used to measure Photosynthetically Available Radiation (PAR) in the water column. This instrument designation is used when specific make and model are not known.

Dataset-specific Instrument Name	HPLC
Generic Instrument Name	High Performance Liquid Chromatograph
Dataset-specific Description	HPLC analysis was restarted in July 2006 (CAR-123). Samples were filtered 47 mm Whatman GF/F filters at 8 depths (1, 7, 15, 25, 35, 55, 75 and 100m). The volume filtered depends on the amount of particles in the water. Replicates were taken at the 1m depth. Filters were stored in aluminum envelopes and stored in the fridge until reaching shore. Once on shore, samples were stored at -40°C until transportation to the US. Horn Point Laboratory (http://www.hpl.umces.edu/) performs the analyses through a collaborative agreement with NASA. The method used was Van Heukelem and Thomas (2001).
Generic Instrument Description	A High-performance liquid chromatograph (HPLC) is a type of liquid chromatography used to separate compounds that are dissolved in solution. HPLC instruments consist of a reservoir of the mobile phase, a pump, an injector, a separation column, and a detector. Compounds are separated by high pressure pumping of the sample mixture onto a column packed with microspheres coated with the stationary phase. The different components in the mixture pass through the column at different rates due to differences in their partitioning behavior between the mobile liquid phase and the stationary phase. (http://www.files.chem.vt.edu/chem-ed/sep/lc/hplc.html)

Dataset-specific Instrument Name	SBE-43 oxygen probe
Generic Instrument Name	Sea-Bird SBE 43 Dissolved Oxygen Sensor
Dataset-specific Description	The CTD also had a SBE-43 oxygen probe
Generic Instrument Description	The Sea-Bird SBE 43 dissolved oxygen sensor is a redesign of the Clark polarographic membrane type of dissolved oxygen sensors. more information from Sea-Bird Electronics

Dataset-specific Instrument Name	C-Star transmissometer
Generic Instrument Name	Wet Labs CSTAR Transmissometer
Dataset-specific Description	a C-Star transmissometer (660 nm, Wetlabs)
Generic Instrument Description	A highly integrated opto-electronic design to provide a low cost, compact solution for underwater measurements of beam transmittance. The instrument is capable of either free space measurements, or through the use of an optical flow tube, flow-through sampling with a pump. It can be used in profiling, moored, or underway applications. more information from Wet Labs

Dataset-specific Instrument Name	Wetlabs ECO fluorometer
Generic Instrument Name	WETStar ECO FLNTU
Dataset-specific Description	a Wetlabs ECO fluorometer outfitted for chlorophyll-a estimates
Generic Instrument Description	The ECO FLNTU is a dual-wavelength, single-angle sensor for simultaneously determining both chlorophyll fluorescence and turbidity.

Dataset-specific Instrument Name	BetaScout (PerkinElmer) scintillation counter
Generic Instrument Name	Liquid Scintillation Counter
Dataset-specific Description	These vials were refrigerated until they were ready for analysis on a BetaScout (PerkinElmer) scintillation counter.
Generic Instrument Description	Liquid scintillation counting is an analytical technique which is defined by the incorporation of the radiolabeled analyte into uniform distribution with a liquid chemical medium capable of converting the kinetic energy of nuclear emissions into light energy. Although the liquid scintillation counter is a sophisticated laboratory counting system used the quantify the activity of particulate emitting (ß and a) radioactive samples, it can also detect the auger electrons emitted from 51Cr and 125I samples.

Dataset-specific Instrument Name	Technicon Analyzer II
Generic Instrument Name	Technicon AutoAnalyzerII
Dataset-specific Description	Subsequent Cariaco analyses were performed on a Technicon Analyzer II
Generic Instrument Description	A rapid flow analyzer that may be used to measure nutrient concentrations in seawater. It is a continuous segmented flow instrument consisting of a sampler, peristaltic pump, analytical cartridge, heating bath, and colorimeter. See more information about this instrument from the manufacturer.

Dataset-specific Instrument Name	ALPKEM RFA II
Generic Instrument Name	Alpkem RFA300
Dataset-specific Description	These samples were analyzed on an ALPKEM RFA II.
Generic Instrument Description	A rapid flow analyser (RFA) that may be used to measure nutrient concentrations in seawater. It is an air-segmented, continuous flow instrument comprising a sampler, a peristaltic pump which simultaneously pumps samples, reagents and air bubbles through the system, analytical cartridge, heating bath, colorimeter, data station, and printer. The RFA-300 was a precursor to the smaller Alpkem RFA/2 (also RFA II or RFA-2).

Dataset-specific Instrument Name	Perkin Elmer 2400 Elemental Analyzer.
Generic Instrument Name	Elemental Analyzer
Dataset-specific Description	Measurement: The filters were folded inside a tin disk and analyzed on a Perkin Elmer 2400 Elemental Analyzer. The samples were combusted at 1200-1300°C and then passed through a reduction tube to removes the oxygen added to raise the combustion temperature. Filers were not acid fumed prior to analysis. The C and N were then separated in a chromatographic column and were measured on a Thermal Conductivity Detector. Carbon and nitrogen standards, and blank filters were used to calibrate the data. The accuracy of the instrument was
Generic Instrument Description	Instruments that quantify carbon, nitrogen and sometimes other elements by combusting the sample at very high temperature and assaying the resulting gaseous oxides. Usually used for samples including organic material.

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Deployments

HG93_CARIACO

Website	https://www.bco-dmo.org/deployment/57845
Platform	B/O Hermano Gines
Start Date	1995-11-08
Description	Monthly oceanographic cruises to the CARIACO station (10.5 degrees N, 64.67 degrees W) have been conducted since November 1995 to examine the hydrography, primary production, and settling flux of particulate material. The research vessel is the 75-foot B/O (Barco Oceanografico) Hermano Gines of the Fundaciòn La Salle de Ciencias Naturales (FLASA) located on Margarita Island, Venezuela. Water is collected using a rosette ensemble equipped with twelve 8-liter bottles and a CTD (conductivity-temperature-depth meter); the CTD also has an oxygen sensor, a fluorometer for chlorophyll-a estimates, and a transmissometer. Data are read out real-time on a computer screen on board the ship as the rosette ensemble is lowered to approximately 1,380 m, the bottom of the Cariaco Basin. Water samples are analyzed for various parameters including phytoplankton biomass, dissolved and particulate nutrient and carbon concentration, primary productivity rates and total bacterial production.

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Project Information

CARIACO Ocean Time-Series Program (CARIACO)

Website: http://www.imars.usf.edu/CAR/index.html

Coverage: CARIACO basin

Since 1995, the CARIACO Ocean Time-Series (formerly known as the CArbon Retention In A Colored Ocean) Program has studied the relationship between surface primary production, physical forcing variables like the wind, and the settling flux of particulate carbon in the Cariaco Basin. This depression, located on the continental shelf of Venezuela (Map), shows marked seasonal and interannual variation in hydrographic properties and primary production (carbon fixation rates by photosynthesis of planktonic algae). This peculiar basin is anoxic below ~250 m, due its restricted circulation and high primary production (Muller-Karger et al., 2001). CARIACO observations show annual primary production rates exceed 500 gC/m2y, of which over 15-20% can be accounted for by events lasting one month or less. Such events are observed in other locations where time series observations are collected, and suggest that prior estimates of regional production based on limited sampling may have been underestimated. The annual primary production rates in the Cariaco Basin are comparable to rates estimated using time series observations for Monterey Bay (460 gC/m2y; Chavez, 1996), and higher than previous rates estimated for Georges Bank, the New York Shelf, and the Oregon Shelf (380, 300, and 190 gC/m2y, respectively; Walsh, 1988). The Cariaco Basin has long been the center of attention of scientists trying to explain paleoclimate. Due to its high rates of sedimentation (30 to >100 cm/ky; Peterson et al., 2000) and excellent preservation, the varved sediments of the Cariaco Basin offer the opportunity to study high resolution paleoclimate and better understand the role of the tropics in global climate change (Black et al., 1999; Peterson et al., 2000; Haug et al., 2001; Black et al., 2004; Hughen et al., 2004). Now, the CARIACO program provides a link between the sediment record and processes near the surface of the ocean. Sediment traps maintained by the CARIACO program show that over 5% of autochtonous material reaches 275 m depth, and that nearly 2% reaches 1,400 m. The significance of this flux is that it represents a sink for carbon and that it helps explain the record of ancient climate stored at the bottom of the Cariaco Basin. Acknowledgements: This work was supported by the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and Venezuela's Fondo Nacional de Ciencia, Tecnología e Innovación (FONACIT). For more information please see this Acknowledgements link.

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Program Information

Ocean Carbon and Biogeochemistry (OCB)

Website: http://us-ocb.org/

Coverage: Global

The Ocean Carbon and Biogeochemistry (OCB) program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners. Important OCB-related activities currently include: the Ocean Carbon and Climate Change (OCCC) and the North American Carbon Program (NACP); U.S. contributions to IMBER, SOLAS, CARBOOCEAN; and numerous U.S. single-investigator and medium-size research projects funded by U.S. federal agencies including NASA, NOAA, and NSF. The scientific mission of OCB is to study the evolving role of the ocean in the global carbon cycle, in the face of environmental variability and change through studies of marine biogeochemical cycles and associated ecosystems. The overarching OCB science themes include improved understanding and prediction of: 1) oceanic uptake and release of atmospheric CO2 and other greenhouse gases and 2) environmental sensitivities of biogeochemical cycles, marine ecosystems, and interactions between the two. The OCB Research Priorities (updated January 2012) include: ocean acidification; terrestrial/coastal carbon fluxes and exchanges; climate sensitivities of and change in ecosystem structure and associated impacts on biogeochemical cycles; mesopelagic ecological and biogeochemical interactions; benthic-pelagic feedbacks on biogeochemical cycles; ocean carbon uptake and storage; and expanding low-oxygen conditions in the coastal and open oceans.

U.S. Joint Global Ocean Flux Study (U.S. JGOFS)

Website: http://usjgofs.whoi.edu/

Coverage: Global

The United States Joint Global Ocean Flux Study was a national component of international JGOFS and an integral part of global climate change research. The U.S. launched the Joint Global Ocean Flux Study (JGOFS) in the late 1980s to study the ocean carbon cycle. An ambitious goal was set to understand the controls on the concentrations and fluxes of carbon and associated nutrients in the ocean. A new field of ocean biogeochemistry emerged with an emphasis on quality measurements of carbon system parameters and interdisciplinary field studies of the biological, chemical and physical process which control the ocean carbon cycle. As we studied ocean biogeochemistry, we learned that our simple views of carbon uptake and transport were severely limited, and a new "wave" of ocean science was born. U.S. JGOFS has been supported primarily by the U.S. National Science Foundation in collaboration with the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the Department of Energy and the Office of Naval Research. U.S. JGOFS, ended in 2005 with the conclusion of the Synthesis and Modeling Project (SMP).

Ocean Time-series Sites (Ocean Time-series)

Coverage: Bermuda, Cariaco Basin, Hawaii

Program description text taken from Chapter 1: Introduction from the Global Intercomparability in a Changing Ocean: An International Time-Series Methods Workshop report published following the workshop held November 28-30, 2012 at the Bermuda Institute of Ocean Sciences. The full report is available from the workshop Web site hosted by US OCB: http://www.whoi.edu/website/TS-workshop/home Decades of research have demonstrated that the ocean varies across a range of time scales, with anthropogenic forcing contributing an added layer of complexity. In a growing effort to distinguish between natural and human-induced earth system variability, sustained ocean time-series measurements have taken on a renewed importance. Shipboard biogeochemical time-series represent one of the most valuable tools scientists have to characterize and quantify ocean carbon fluxes and biogeochemical processes and their links to changing climate (Karl, 2010; Chavez et al., 2011; Church et al., 2013). They provide the oceanographic community with the long, temporally resolved datasets needed to characterize ocean climate, biogeochemistry, and ecosystem change. The temporal scale of shifts in marine ecosystem variations in response to climate change are on the order of several decades. The long-term, consistent and comprehensive monitoring programs conducted by time-series sites are essential to understand large-scale atmosphere-ocean interactions that occur on interannual to decadal time scales. Ocean time-series represent one of the most valuable tools scientists have to characterize and quantify ocean carbon fluxes and biogeochemical processes and their links to changing climate. Launched in the late 1980s, the US JGOFS (Joint Global Ocean Flux

Study; http://usjgofs.whoi.edu) research program initiated two time-series measurement programs at Hawaii and Bermuda (HOT and BATS, respectively) to measure key oceanographic measurements in oligotrophic waters. Begun in 1995 as part of the US JGOFS Synthesis and Modeling Project, the CARIACO Ocean Time-Series (formerly known as the CArbon Retention In A Colored Ocean) Program has studied the relationship between surface primary production, physical forcing variables like the wind, and the settling flux of particulate carbon in the Cariaco Basin. The objective of these time-series effort is to provide well-sampled seasonal resolution of biogeochemical variability at a limited number of ocean observatories, provide support and background measurements for process-oriented research, as well as test and validate observations for biogeochemical models. Since their creation, the BATS, CARIACO and HOT time-series site data have been available for use by a large community of researchers. Data from those three US funded, ship-based, time-series sites can be accessed at each site directly or by selecting the site name from the Projects section below.

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Funding

Funding Source	Award
Fondo Nacional de Ciencia, Tecnología e Innovación of Venezuela (FONACIT)	unknown CARIACO FONACIT
NSF Division of Ocean Sciences (NSF OCE)	OCE-9401537
NSF Division of Ocean Sciences (NSF OCE)	OCE-9729697
NSF Division of Ocean Sciences (NSF OCE)	OCE-0326268
NSF Division of Ocean Sciences (NSF OCE)	OCE-9216626
NSF Division of Ocean Sciences (NSF OCE)	OCE-9711318
National Aeronautics & Space Administration (NASA)	NAS5-97128
NSF Division of Ocean Sciences (NSF OCE)	OCE-9415790
NSF Division of Ocean Sciences (NSF OCE)	OCE-9729284
National Aeronautics & Space Administration (NASA)	NAG5-6448
NSF Division of Ocean Sciences (NSF OCE)	OCE-0963028
NSF Division of Ocean Sciences (NSF OCE)	OCE-0752139
Fondo Nacional de Ciencia, Tecnología e Innovación of Venezuela (FONACIT)	96280221
NSF Division of Ocean Sciences (NSF OCE)	unknown CARIACO NSF OCE
NSF Division of Ocean Sciences (NSF OCE)	OCE-0326313
National Aeronautics & Space Administration (NASA)	NNX14AP62A

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