Primary productivity measurements from the Hawaii Ocean Time-Series (HOT) project from 1989-09-22 to 2016-10-15 at station ALOHA.

Website: https://www.bco-dmo.org/dataset/737163
Data Type: Cruise Results
Version: 1
Version Date: 2018-05-18

Project

» Hawaii Ocean Time-series (HOT): Sustaining ocean ecosystem and climate observations in the North Pacific Subtropical Gyre (HOT)

Programs

» Ocean Carbon and Biogeochemistry (OCB)
» U.S. Joint Global Ocean Flux Study (U.S. JGOFS)
» Ocean Time-series Sites (Ocean Time-series)

Contributors	Affiliation	Role
Karl, David M.	University of Hawaii at Manoa (SOEST)	Principal Investigator
Fujieki, Lance A	University of Hawaii at Manoa (SOEST)	Contact
Biddle, Mathew	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract

Primary productivity measurements from the Hawaii Ocean Time-Series (HOT). Photosynthetic production of organic matter was measured by the 14C tracer method. All incubations from 1990 through mid-2000 were conducted in situ at eight depths (5, 25, 45, 75, 100, 125, 150 and 175m) over one daylight period using a free-drifting array as described by Winn et al. (1991). Starting HOT-119 (October 2000), we collected samples from only the upper six depths & modeled the lower two depths based on the monthly climatology. During 2015, all incubations were conducted in situ on a free floating, surface tethered array. Integrated carbon assimilation rates were calculated using the trapezoid rule with the shallowest value extended to 0 meters and the deepest extrapolated to a value of zero at 200 meters.

Table of Contents

Coverage

Spatial Extent: **Lat**:22.75 **Lon**:-158
Temporal Extent: 1989-09-22 - 2016-10-15

Dataset Description

Monthly measurements of primary production were collected at station ALOHA as part of the HOT program.

Acquisition Description

Photosynthetic production of organic matter was measured by the 14C tracer method. All incubations from 1990 through mid-2000 were conducted in situ at eight depths (5, 25, 45, 75, 100, 125, 150 and 175m) over one daylight period using a free-drifting array as described by Winn et al. (1991). Starting HOT-119 (October 2000), we collected samples from only the upper six depths & modeled the lower two depths based on the monthly climatology. During 2015, all incubations were conducted in situ on a free floating, surface tethered array. Integrated carbon assimilation rates were calculated using the trapezoid rule with the shallowest value extended to 0 meters and the deepest extrapolated to a value of zero at 200 meters.

The information below has been copied from the HOT Field & Laboratory Protocols page, found at http://hahana.soest.hawaii.edu/hot/protocols/protocols.html# (last visited on 2018-05-21).

SUMMARY: The 14C-radiotracer method is used to measure the assimilation of dissolved inorganic carbon (DIC) by phytoplankton as an estimate of the rate of photosynthetic production

of organic matter in the euphotic zone.

1. Principle

The 14C method, originally proposed by Steeman-Nielsen (1952), is used to estimate the uptake of dissolved inorganic carbon (DIC) by planktonic algae in the water column. The method is based on the fact that the biological uptake of14C-labeled DIC is proportional to the biological uptake of 12C-DIC. If one knows the initial concentration of DIC in a water sample, the amount of 14C-DIC added, the 14C retained in particulate organic matter (14C-POC) at the end of the incubation and the metabolic discrimination between the two isotopes of carbon (i.e., 5% discrimination against the heavier 14C isotope), then it is possible to estimate the total uptake of carbon from the following relationship:

$$\text{C uptake} = \frac{\text{DIC} * \text{14C-POC} * 1.05}{\text{14C-DIC added}}$$

Due to the potentially toxic effects of trace metals on phytoplankton metabolism in oligotrophic waters, the following procedure is used to minimize the contact between water samples and possible sources of contamination.

2. Cleaning

2.1.

HCl (Baker Instra-Analyzed) solution (1M) is prepared with high purity hydrochloric acid and freshly-prepared glass distilled deionized water (DDW).

2.2.

500 ml polycarbonate bottles are rinsed twice with 1M HCl (Baker Instra-Analyzed) and left overnight filled with the same acid solution. The acid is removed by rinsing the bottles three times with DDW before air drying.

2.3.

Go-Flo bottles, fitted with teflon-coated springs, are rinsed three times with 1M HCl and DDW before use.

2.4.

Pipette tips used in the preparation of the isotope stock and in the inoculation of samples are rinsed three times with concentrated HCl (Baker Instra-Analyzed), three times with DDW and once with the sodium carbonate solution (Chapter 14, section 3.2) and stored in a clean polyethylene glove until used.

3. Isotope Stock

3.1.

The preparation of the isotope stock is performed wearing polyethylene gloves. A 25 ml acid-washed teflon bottle and a 50 ml acid-washed polypropylene centifuge tube are rinsed three times with DDW.

3.2.

0.032 g of anhydrous Na2CO3 (ALDRICH 20,442-0, 99.999% purity) are dissolved in 50 ml DDW in the centrifuge tube to provide a solution of 6 mmol Na2CO3 per liter.

3.3.
3.5 ml of NaH-14CO3 (53 mCi mmol-1; Research Products Inc.) are mixed with 16.5 ml of the above prepared Na2CO3 solution in the teflon bottle.
3.4.
The new stock activity is checked by counting triplicate 10 µl samples with 1 ml β-phenethylamine in 10 ml Aquasol-II.
3.5.
Triplicate 10 µl stock samples are also acidified with 1 ml of 2 M HCl, mixed intermittently for 1-2 hours and counted in 10 ml Aquasol-II to confirm that there is no 14C-organic carbon contamination. The acidification is done under the hood. The acidified dpm should be <0.001% of the total dpm of the 14C preparation.
4. Incubation Systems
Typically we measure primary production using in situ incubation techniques.
4.1.
A free-floating array equipped with VHF radio and strobe light is used for the in situ incubations. Incubation bottles are attached to a horizontal polycarbonate spreader bar which is then attached to the 200 m, 1/2" polypropylene in situ line at the depths corresponding to the sample collections.
4.2.
Generally eight incubation depths are selected (5-175 m, approximately).
5. Sampling
5.1.
Approximately 3 hours before local sunrise, seawater samples are collected with acid- washed, 12-liter Go-Flo bottles using Kevlar line, metal-free sheave, teflon messengers and a stainless steel bottom weight. A dedicated hydrowinch is used for the primary productivity sampling procedures in a further effort to reduce/eliminate all sources of trace metal contamination.
5.2.
Under low light conditions, water samples are transferred to the incubation bottles (500 ml polycarbonate bottles) and stored in the dark. Polyethylene gloves are worn during sample collection and inoculation procedures. No drawing tubes are used.
6. Isotope Addition and Sample Incubation
6.1.
Three light bottles, three dark bottles and 1 time-zero control (see Chapter 14, section 8) are collected at each depth for in situ incubation. In situ dark bottles are deployed in specially-designed, double-layered cloth bags with VelcroR closures.
6.2.
After all water samples have been drawn from the appropriate Go-Flo bottles, 250 µl of the 14C-sodium carbonate stock solution is added to each sample using a specially-cleaned pipette tip. The samples are deployed before dawn on a free-floating, drifter buoy array.
6.3.

At local sunset, the free-floating array is recovered and all in situ bottles are immediately placed in the dark and processed as soon as possible. The time of recovery is recorded.
7. Filtration
7.1.
Filtration of the samples is done under low light conditions and begins as soon as the incubation bottles are recovered from the in situ array.
7.2.
200 µl are removed and placed into a second LSC vial containing 0.5 ml of β-phenethylamine. This sample is used for the determination of total radioactivity in each sample.
7.3.
The remainder is filtered through a 25 mm diameter GF/F filters. The filters are placed into prelabelled, clean glass liquid scintillation counting vials (LSC vials) and stored at -20 °C.
8. 14C Sample Processing
8.1.
One ml of 2 M HCl is added to each sample vial (under the hood). Vials are covered with their respective caps and shaken in a vortex mixer for at least 1 hour with venting at 20 minute intervals. To vent, the vials are removed from the shaker, and the cap opened (under the hood). After shaking is completed, the vials are left open to vent under the hood for an additional 24 hours.
8.2.
Ten ml of Aquasol-II are added per vial (including vials for total 14C radioactivity) and the samples are counted in a liquid scintillation counter. Samples are counted again after 2 and 4 weeks, before discarding. Counts have shown a consistent increase during the first two weeks and become stable between the second and the fourth week. This is probably the result of sample hydrolysis or diffusion of radioactivity from the GF/F filter matrix, thereby reducing the extent of self-absorption. Only the 4-week count is used for 14C calculations. Counts per min (CPM) are converted to disintegration per min (DPM) using the channels ratio program supplied by the the manufacturer (Packard Instrument Co.)

Processing Description

From the data derived we can estimate several properties of the phytoplankton populations at Station ALOHA. Total daylight organic carbon production is calculated from the 12-hour uptake data (after corrections for 12-hour dark activities). Net daily organic carbon production is calculated from the 24-hour light/dark samples (corrected for the time-zero blank activities). Phytoplankton population respiration is taken as the difference between the 12-hour light and the 24-hour light/dark incubations. Net primary production is used as the estimate of phytoplankton carbon production for the purposes of comparison to other ecosystem-level processes (e.g., standing stock assessments, vertical C-flux, etc.).

Please see HOT's "Primary Productivity Data Format Document" for detailed description of original HOT data formatting, original parameter names and Quality Word definitions.

BCO-DMO Processing Notes:

- transferred the data from the University of Hawaii ftp site to the BCO-DMO servers.
- reformatted the data into csv.
- updated the version date in the served data to the date the data was updated.
- created ISO8601 start_date_time and end_date_time fields which were extracted from the Date and Start_time, End_time fields, respectively.
- appended latitude, longitude values as provided by University of Hawaii.

[table of contents | back to top]

Related Publications

Nielsen, E. S. (1952). The Use of Radio-active Carbon (C14) for Measuring Organic Production in the Sea. ICES Journal of Marine Science, 18(2), 117–140. doi:10.1093/icesjms/18.2.117

Winn, C., C. Sabine, D. Hebel, F. Mackenzie and D. M. Karl. (1991) Inorganic carbon system dynamics in the central Pacific Ocean: Results of the Hawaii Ocean Time-series program. EOS, Transactions of the American Geophysical Union 72, 70.

[table of contents | back to top]

Parameters

Parameter	Description	Units
Incubation_type	O - GO-FLO sampled on-deck Incubation; I - GO-FLO sampled in-situ Incubation; R - Rosette sampled in-situ Incubation; N - External closing niskin sampled in-situ Incubation.	unitless
Chl_a_mean	Chlorophyll a. Mean	miligrams per cubic meter (mg/m3)
Euk	Eukaryotes	count per mililiter

Prochl	Prochlorococcus	count per mililiter
Hetero	Heterotrophic Bacteria	count per mililiter
Synecho	Synechococcus	count per mililiter
PrimProd_filename	Original filename of the primary production data from HOT	unitless
Depth	Depth	meters (m)
end_date_time	end date and time in ISO 8601 format	unitless
End_time	End Time in HHMM format	unitless
Time	Incubation Time	hours
lat	Latitude with South negative	decimal degrees
Salt	Salinity (PSS-78)	unitless
Dark_rep3	Dark - replicate #3	miligrams Carbon per cubic meter (mg C/m3)
Dark_rep2	Dark - replicate #2	miligrams Carbon per cubic meter (mg C/m3)
start_date_time	start date and time in ISO 8601 format	unitless
Light_rep2	Light - replicate #2	miligrams Carbon per cubic meter (mg C/m3)

Light_rep3	Light - replicate #3	miligrams Carbon per cubic meter (mg C/m3)
Light_rep1	Light - replicate #1	miligrams Carbon per cubic meter (mg C/m3)
Dark_rep1	Dark - replicate #1	miligrams Carbon per cubic meter (mg C/m3)
Start_time	Start Time in HHMM format	unitless
lon	Longitude with East negative	decimal degrees
Pheo_sd	Pheopigments Standard Deviation	miligrams per cubic meter (mg/m3)
Flag	Quality Flags for the bottle, chlorophyll, pheopigments, light incubation, dark incubation, salinity & bacteria values respectively. Quality Indicators: Flag: Meaning 1: unquality controlled 2: good data 3: suspect (i.e. questionable) data 4: bad data 5: missing value 9: variable not measured during this cast	unitless
Cruise	Cruise Number	unitless
Date	Date in YYMMDD format	unitless

Chl_a_sd	Chlroropyll a. Standard Deviation	miligrams per cubic meter (mg/m3)
Pheo_mean	Pheopigments Mean	miligrams per cubic meter (mg/m3)

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	Go-Flo bottles
Generic Instrument Name	GO-FLO Bottle
Dataset-specific Description	Go-Flo bottles
Generic Instrument Description	GO-FLO bottle cast used to collect water samples for pigment, nutrient, plankton, etc. The GO-FLO sampling bottle is specially designed to avoid sample contamination at the surface, internal spring contamination, loss of sample on deck (internal seals), and exchange of water from different depths.

Dataset-specific Instrument Name	External closing niskin
Generic Instrument Name	Niskin bottle
Dataset-specific Description	External closing niskin sampled in-situ Incubation.
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	liquid scintillation counter
Generic Instrument Name	Liquid Scintillation Counter
Dataset-specific Description	liquid scintillation counter (Packard model 4640; United Technologies Inc.)
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	NORDA/USM incubation system
Generic Instrument Name	Shipboard Incubator
Dataset-specific Description	temperature- and light-controlled deck incubation system (NORDA/USM incubation system)
Generic Instrument Description	A device mounted on a ship that holds water samples under conditions of controlled temperature or controlled temperature and illumination.

[table of contents | back to top]

Deployments

HOT_cruises

Website	https://www.bco-dmo.org/deployment/58879
Platform	Unknown Platform
Report	http://hahana.soest.hawaii.edu/hot/
Start Date	1988-10-31
Description	Since October 1988, the Hawaii Ocean Time-series (HOT) program has investigated temporal dynamics in biology, physics, and chemistry at Stn. ALOHA (22°45' N, 158°W), a deep ocean field site in the oligotrophic North Pacific Subtropical Gyre (NPSG). HOT conducts near monthly ship-based sampling and makes continuous observations from moored instruments to document and study NPSG climate and ecosystem variability over semi-diurnal to decadal time scales.

[table of contents | back to top]

Project Information

Hawaii Ocean Time-series (HOT): Sustaining ocean ecosystem and climate observations in the North Pacific Subtropical Gyre (HOT)

Website: http://hahana.soest.hawaii.edu/hot/hot_jgofs.html

Coverage: North Pacific Subtropical Gyre; 22 deg 45 min N, 158 deg W

Systematic, long-term observations are essential for evaluating natural variability of Earth's climate and ecosystems and their responses to anthropogenic disturbances. Since October 1988, the Hawaii Ocean Time-series (HOT) program has investigated temporal dynamics in biology, physics, and chemistry at Stn. ALOHA (22°45' N, 158°W), a deep ocean field site in the oligotrophic North Pacific Subtropical Gyre (NPSG). HOT conducts near monthly ship-based sampling and makes continuous observations from moored instruments to document and study NPSG climate and ecosystem variability over semi-diurnal to decadal time scales. HOT was founded to understand the processes controlling the time-varying fluxes of carbon and associated biogenic elements in the ocean and to document changes in the physical structure of the water column. To achieve these broad objectives, the program has several specific goals: Quantify time-varying (seasonal to decadal) changes in reservoirs and fluxes of carbon (C) and associated bioelements (nitrogen, oxygen, phosphorus, and silicon). Identify processes controlling air-sea C exchange, rates of C transformation through the planktonic food web, and fluxes of C into the ocean's interior. Develop a climatology of hydrographic and biogeochemical dynamics from which to form a multi-decadal baseline from which to decipher natural and anthropogenic influences on the NPSG ecosystem. Provide scientific and logistical support to ancillary programs that benefit from the temporal context, interdisciplinary science, and regular access to the open sea afforded by HOT program occupation of Sta. ALOHA, including projects implementing, testing, and validating new methodologies, models, and transformative ocean sampling technologies. Over the past 24+ years, time-series research at Station ALOHA has provided an unprecedented view of temporal variability in NPSG climate and ecosystem processes. Foremost among HOT accomplishments are an increased understanding of the sensitivity of bioelemental cycling to large scale ocean-climate interactions, improved quantification of reservoirs and time varying fluxes of carbon, identification of the importance of the hydrological cycle and its influence on upper ocean biogeochemistry, and the creation of long-term data sets from which the oceanic response to anthropogenic perturbation of elemental cycles may be gauged. A defining characteristic of the NPSG is the perennially oligotrophic nature of the upper ocean waters. This biogeochemically reactive layer of the ocean is where air-sea exchange of climate reactive gases occurs, solar radiation fuels rapid biological transformation of nutrient elements, and diverse assemblages of planktonic organisms comprise the majority of living biomass and sustain productivity. The prevailing Ekman convergence and weak seasonality in surface light flux, combined with relatively mild subtropical weather and persistent stratification, result in a nutrient depleted upper ocean habitat. The resulting dearth of bioessential nutrients limits plankton standing stocks and maintains a deep (175 m) euphotic zone. Despite the oligotrophic state of the NPSG, estimates of net organic matter production at Sta. ALOHA are estimated to range ~1.4

and 4.2 mol C m2 yr1. Such respectable rates of productivity have highlighted the need to identify processes supplying growth limiting nutrients to the upper ocean. Over the lifetime of HOT numerous ancillary science projects have leveraged HOT science and infrastructure to examine possible sources of nutrients supporting plankton productivity. Both physical (mixing, upwelling) and biotic (N2 fixation, vertical migration) processes supply nutrients to the upper ocean in this region, and HOT has been instrumental in demonstrating that these processes are sensitive to variability in ocean climate. Station ALOHA - site selection and infrastructure Station ALOHA is a deep water (~4800 m) location approximately 100 km north of the Hawaiian Island of Oahu. Thus, the region is far enough from land to be free of coastal ocean dynamics and terrestrial inputs, but close enough to a major port (Honolulu) to make relatively short duration (45 m depth), below depths of detection by Earth-orbiting satellites. The emerging data emphasize the value of in situ measurements for validating remote and autonomous detection of plankton biomass and productivity and demonstrate that detection of potential secular-scale changes in productivity against the backdrop of significant interannual and decadal fluctuations demands a sustained sampling effort. Careful long-term measurements at Stn. ALOHA also highlight a well-resolved, though relatively weak, seasonal climatology in upper ocean primary productivity. Measurements of 14C-primary production document a ~3-fold increase during the summer months (Karl et al., 2012) that coincides with increases in plankton biomass (Landry et al., 2001; Sheridan and Landry, 2004). Moreover, phytoplankton blooms, often large enough to be detected by ocean color satellites, are a recurrent summertime feature of these waters (White et al., 2007; Dore et al., 2008; Fong et al., 2008). Analyses of ~13-years (1992-2004) of particulate C, N, P, and biogenic Si fluxes collected from bottom-moored deep-ocean (2800 m and 4000 m) sediment traps provide clues to processes underlying these seasonal changes. Unlike the gradual summertime increase in sinking particle flux observed in the upper ocean (150 m) traps, the deep sea particle flux record depicts a sharply defined summer maximum that accounts for ~20% of the annual POC flux to the deep sea, and appears driven by rapidly sinking diatom biomass (Karl et al., 2012). Analyses of the 15N isotopic signatures associated with sinking particles at Sta. ALOHA, together with genetic analyses of N2 fixing microorganisms, implicates upper ocean N2 fixation as a major control on the magnitude and efficiency of the biological carbon pump in this ecosystem (Dore et al., 2002; Church et al., 2009; Karl et al., 2012). Motivating Questions Science results from HOT continue to raise new, important questions about linkages between ocean climate and biogeochemistry that remain at the core of contemporary oceanography. Answers have begun to emerge from the existing suite of core program measurements; however, sustained sampling is needed to improve our understanding of contemporary ecosystem behavior and our ability to make informed projections of future changes to this ecosystem. HOT continues to focus on providing answers to some of the questions below: How sensitive are rates of primary production and organic matter export to short- and long-term climate variability? What processes regulate nutrient supply to the upper ocean and how sensitive are these processes to climate forcing? What processes control the magnitude of air-

sea carbon exchange and over what time scales do these processes vary? Is the strength of the NPSG CO2 sink changing in time? To what extent does advection (including eddies) contribute to the mixed layer salinity budget over annual to decadal time scales and what are the implications for upper ocean biogeochemistry? How do variations in plankton community structure influence productivity and material export? What processes trigger the formation and demise of phytoplankton blooms in a persistently stratified ocean ecosystem? References

[table of contents | back to top]

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.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0926766

[table of contents | back to top]