

Two decibar-averaged CTD profiles from the Hawaii Ocean Time-Series cruises from 1988-2016 (HOT project)

Website: <https://www.bco-dmo.org/dataset/3937>

Data Type: Cruise Results

Version: 1

Version Date: 2018-04-06

Project

» [\[Current\] Hawaii Ocean Time-series \(HOT\): 2023-2028; \[Previous\] Hawaii Ocean Time-series \(HOT\): Sustaining ocean ecosystem and climate observations in the North Pacific Subtropical Gyre \(HOT\)](#)

Programs

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

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Abstract

HOT CTD data are collected using a SeaBird CTD 9-11 (9-11 Plus with dual sensors as of HOT-54) at the maximum sampling rate of 24 samples per second (24 Hz). They are screened for errors and processed to 2-dbar averages. The majority of the sampling effort, approximately 60-72 h per standard HOT cruise, is spent at Station ALOHA. High vertical resolution environmental data are collected with a Sea-Bird CTD having external temperature (T), conductivity (C), dissolved oxygen (DO) and fluorescence (F) sensors and an internal pressure (P) sensor. A Sea-Bird 24-place carousel and an aluminum rosette that is capable of supporting 24 12-L PVC bottles are used to obtain water samples from desired depths. The CTD and rosette are deployed on a 3-conductor cable allowing for real-time display of data and for tripping the bottles at specific depths of interest.

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Coverage

Spatial Extent: N:23.4375 E:-157.4567 S:21.2283 W:-158.8575

Temporal Extent: 1988-10-30 - 2016-11-28

Dataset Description

HOT CTD data are collected using a SeaBird CTD 9-11 (9-11 Plus with dual sensors as of HOT-54) at the maximum sampling rate of 24 samples per second (24 Hz). They are screened for errors and processed to 2-dbar averages. Details of the CTD processing for each year can be found in HOT Data Reports #1-8 (see the file Readme.first for information on how to obtain these Data Reports).

CTD data are written to files using formats specified by the WOCE Hydrographic Programme Office. These formats are based on NODC formats, and are detailed in the WHP Office Report WHPO 90-1, available from Steve Diggs, WHPO Data Manager, Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0214.

The files contain pressure, temperature and salinity profiles for all casts. Some casts also have dissolved oxygen, light transmission, and fluorescence. The data format consists of a self-documenting header followed by the data. The data records are written so that they can be read with a simple FORTRAN read statement. Details of this format are given in the file Readme.format.

The first year's temperatures are reported in IPTS-68. Subsequent temperatures are reported in ITS-90 units. Since temperature sensor calibrations were done in IPTS-68 units, and the UNESCO routines require IPTS-68 temperature, all intermediate processing was done in IPTS-68. As a final step, temperature and potential temperature were converted to ITS-90 using $t_{90} = 0.99976 t_{68}$.

Since November 2001 CTD fluorescence data have been regularly calibrated against Chlorophyll bottle data and reported in the CTD files as Chloropigments (CHLPIG) in microgram/liter ($\mu\text{G/L}$). Bottle Fluorometric Chlorophyll-a plus Pheopigments above 175 dbar are matched against the upcast CTD Fluorometry to calibrate the downcast Fluorescence reported in the CTD files. All CTD files for prior cruises were calibrated and updated to reflect this change.

Starting HOT-177 (2006), the Transmissometer data that used to be included in the CTD files have been replaced by continuous Nitrate measured using Satlantic's InSitu Underwater Spectrometer (ISUS V2). Satlantic's ISUS V2 is a chemical free sensor that uses UV absorption technology to provide accurate nitrate concentration measurements in real-time. These data are not included since they were uncalibrated and of questionable quality.

Methods & Sampling

[HOT CTD yearly reports](#)

Data Processing Description

Please see HOT's "[CTD Data Format Document](#)" for detailed description of original HOT data formatting, original parameter names and Quality Word definitions.

BCO-DMO Processing Description

- Transferred the data from the University of Hawaii ftp site to the BCO-DMO servers.
- Reformatted the data into csv and appended cruise summary information.
- Updated the version date in the served data to the date the data was updated.
- Created EXPCODE field with by taking the Ship value and replacing the "/" (forward slash) with a "_" (underscore). For example, Ship = 32MW001/1 would have a EXPCODE = 32MW001_1.
- Created field (HOT_summary_file_name) which contains the name of the summary file.
- Created Year, Month, Day fields which were extracted from the Date field.
- Converted latitude and longitude values to decimal degrees (negative west and south).
- Created cruise_name field which is extracted from the Ship field. This is composed as the last three values before the "/" in the Ship field value. For example, a value of Ship = 32MW001/1 would have a cruise_name = 001.

-Created the ISO_DateTime field which is an ISO8601 representation of the date time provided in the data.

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Data Files

File
ctd.csv (Comma Separated Values (.csv), 736.45 MB) MD5:7a7588f82ba562aa61ca974f21948492 Primary data file for dataset ID 3937

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Parameters

Parameter	Description	Units
cruise_name	cruise identifier	unitless
station	station identifier	unitless
cast	CTD cast number	unitless
depth_max	Depth measured by shipboard echo sounder in meters. The nominal depth for Station 1 = 1500m and for Station 2 = 4750m.	meters (m)
timecode	The code for when the time was taken. At the beginning (BE); bottom (BO); and completion (EN) of the cast.	unitless
HOT_summary_file_name	Filename from which the cruise summary information was obtained	unitless
parameters	A list of the parameters measured from the water samples collected during the cast. The identification numbers are listed here. 1 = Salinity; 2 = Oxygen; 3 = Silicate; 4 = Nitrate; 5 = Nitrite; 6 = Phosphate; 7 = Freon 11; 8 = Freon 12; 9 = Tritium; 10= Helium; 11= Carbon 14; 12= Carbon 13; 13= Krypton 85; 14= Argon; 15= Argon 39; 16= Neon; 17= Radium; 18= Radium 226; 19= o18/o16 ratio; 20= Stronitum 90; 21= Cesium 137	unitless
num_bottles	The number of bottles used during the cast.	unitless
section	The WHP section designator.	unitless
lon	longitude with west being negative	decimal degrees
comments	cast comments	unitless
Date	The date of the cast in MMDDYY.	unitless
Day	Day of the month value as extracted from the Date field	unitless
EXPCODE	This code allows for the identification of cast. It consists of a 4 character NODC country-ship code; a maximum of 8 character cruise number followed by a "_" and leg number.	unitless
lat	latitude with south being negative	decimal degrees
nav_code	navigation system code	unitless
pres_max	The deepest pressure sampled.	decibars (db)
depth_hgt	Bottom depth less the maximum pressure sampled.	meters (m)
Month	Month of the year value as extracted from the Date field	unitless

timeutc	time in UTC	unitless
Year	Four digit year as extracted from the Date field	unitless
Ship	This code allows for the identification of cast. It consists of a 4 character NODC country-ship code; a maximum of 8 character cruise number followed by a "/" and leg number.	unitless
CTDTMP	Temperature (Degrees Celsius International Temperature Scale of 1988)	Degrees Celsius
NUMBER	Number of observations averaged at this pressure level	count
CTDPRS	Pressure (Decibars)	Decibars (db)
CTDOXY	Oxygen (micromoles per kilogram)	micromoles per kilogram (umol/kg)
XMISS	Transmission (% transmission)	percent transmission (%)
QUALT1	Quality (defined by investigator); The quality word is the left-to-right concatenation of required quality bytes for the variables measured. They are defined as follows: 1 = Not calibrated with water samples; 2 = Acceptable measurement; 3 = Questionable measurement; 4 = Bad measurement; 5 = Not reported; 6 = Interpolated value; 7 = Not assigned for CTD data; 8 = Not assigned for CTD data; 9 = Not sampled	unitless
CTDSAL	Salinity (1978 International Practical Salinity Scale)	PSU
CHLPIG	Chloropigments (microgram/liter)	microgram per liter (ug/L)
NITRATE	Nitrate (micromoles per kilogram) after HOT-176	micromoles per kilogram (umol/kg)
FLUOR	fluorescence	mVOLTS
ISO_DateTime	time in ISO-8601 format following the convention YYYY-mm-ddTHH:MM:SS[.xx]Z (UTC time)	unitless

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Instruments

Dataset-specific Instrument Name	SeaBird CTD 9-11
Generic Instrument Name	CTD Sea-Bird 911
Dataset-specific Description	HOT CTD data are collected using a SeaBird CTD 9-11 (9-11 Plus with dual sensors as of HOT-54) at the maximum sampling rate of 24 samples per second (24 Hz).
Generic Instrument Description	The Sea-Bird SBE 911 is a type of CTD instrument package. The SBE 911 includes the SBE 9 Underwater Unit and the SBE 11 Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 and SBE 11 is called a SBE 911. The SBE 9 uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 and SBE 4). The SBE 9 CTD can be configured with auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). More information from Sea-Bird Electronics.

Dataset-specific Instrument Name	SeaBird CTD 9-11 Plus
Generic Instrument Name	CTD Sea-Bird SBE 911plus
Dataset-specific Description	HOT CTD data are collected using a SeaBird CTD 9-11 (9-11 Plus with dual sensors as of HOT-54) at the maximum sampling rate of 24 samples per second (24 Hz).
Generic Instrument Description	The Sea-Bird SBE 911 plus is a type of CTD instrument package for continuous measurement of conductivity, temperature and pressure. The SBE 911 plus includes the SBE 9plus Underwater Unit and the SBE 11plus Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 plus and SBE 11 plus is called a SBE 911 plus. The SBE 9 plus uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 plus and SBE 4). The SBE 9 plus CTD can be configured with up to eight auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). more information from Sea-Bird Electronics

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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.

Project Information

[Current] Hawaii Ocean Time-series (HOT): 2023-2028; [Previous] Hawaii Ocean Time-series (HOT): Sustaining ocean ecosystem and climate observations in the North Pacific Subtropical Gyre (HOT)

Website: <https://hahana.soest.hawaii.edu/hot/>

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

NSF Award Abstract:

Long-term observations of ocean physics, biology, and chemistry across decades provide a powerful lens for understanding the response of the oceans to environmental change. This award will continue the Hawaii Ocean Time-series (HOT) research program, which began in 1988, for an additional five years. Continuity of these observations will improve the value of the dataset for deciphering how natural and human-influenced climate signals affect ecosystem structure in the Pacific Ocean. All HOT program data are publicly available and are frequently used by researchers and policy makers around the world. HOT also serves as (1) a testbed for the development of new sensors and methodologies, (2) a calibration/validation site, (3) an invaluable training ground that attracts students and researchers from around the globe, and (4) a forum for international collaboration and capacity building.

The proposed research will rely on shipboard observations and experiments conducted on ten separate five-day expeditions per year along with near-continuous moored platform measurements of air-sea interactions, ocean mixing, and physical characteristics of the deep sea. Observations include biogeochemical and physical measurements required for continued assessment of dynamics in ocean carbon and nutrient pools and fluxes, plankton community structure, ecosystem productivity, and inherent optical properties of the water column. The major program goals and objectives over the next 5 years remain as in prior years and include: (1) sustain high quality, time-resolved oceanographic measurements on the interactions between ocean-climate and ecosystem variability in the North Pacific Subtropical Gyre (NPSG), (2) quantify time-varying (seasonal to decadal) changes in reservoirs and fluxes of carbon and associated bioelements (nitrogen, phosphorus, and silicon), (3) constrain processes controlling air-sea carbon exchange, rates of carbon transformation through the planktonic food web, and fluxes of carbon into the ocean's interior, (4) extend to 40 years a climatology of hydrographic and biogeochemical dynamics from which to gauge anomalous or extreme changes to the NPSG habitat, forming a multi-decadal baseline from which to decipher natural and anthropogenic influences on the NPSG ecosystem, (5) continue to 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 Station ALOHA, including projects implementing, testing, and validating new methodologies and transformative ocean sampling technologies, and (6) provide unique training and educational opportunities for the next generation of ocean scientists.

Hawai'i Ocean Time-Series Project Summary

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:

1. Quantify time-varying (seasonal to decadal) changes in reservoirs and fluxes of carbon (C) and associated bioelements (nitrogen, oxygen, phosphorus, and silicon).
2. 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.
3. 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.
4. 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 yr⁻¹. 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 (<5 d) near-monthly cruises logistically and financially feasible. Sampling at this site occurs within a 10 km radius around the center of the station. On each HOT cruise, we begin each cruise with a stop at a coastal station south of the island of Oahu, approximately 10 km off Kahe Point (21° 20.6'N, 158° 16.4'W) in 1500 m of water. Station Kahe (termed Station 1 in our database) is used to test equipment and train new personnel before departing for Station ALOHA. Since August 2004, Station ALOHA has also been home to a surface mooring outfitted for meteorological and upper ocean measurements; this mooring, named WHOTS (also termed Station 50), is a collaborative project between Woods Hole Oceanographic Institution and HOT. WHOTS provides long-term, high-quality air-sea fluxes as a coordinated part of HOT, contributing to the program's goals of observing heat, fresh water and chemical fluxes. In 2011, the ALOHA Cabled Observatory (ACO) became operational. This instrumented fiber optic cabled observatory provides power and communications to the seabed (4728 m). The ACO currently configured with an array of thermistors, current meters, conductivity sensors, 2 hydrophones, and a video camera.

HOT Sampling Strategy

HOT relies on the UNOLS research vessel Kilo Moana operated by the University of Hawaii for most of our near-monthly sampling expeditions. The exact timing of HOT cruises is dictated by the vessel schedule, but to date, our sampling record is not heavily aliased by month, season, or year. When at Station ALOHA, HOT relies on a variety of sampling strategies to capture the dynamic range of time-variable physical and biogeochemical dynamics inherent to the NPSG ecosystem, including high resolution conductivity-temperature-depth (CTD) profiles; biogeochemical analyses of discrete water samples; in situ vertically profiling bio-optical instrumentation; surface tethered, free-drifting arrays for determinations of primary production and particle fluxes; bottom-moored, deep ocean (2800 m, 4000 m) sediment traps; and oblique plankton net tows. The suite of core measurements conducted by HOT has remained largely unchanged over the program's lifetime. On each HOT cruise, samples are collected from the surface ocean to near the sea bed (~4800 m), with the most intensive sampling occurring in the upper 1000 m (typically 13-15 CTD hydrocasts to 1000 m and 2 casts to ~4800 m). HOT utilizes a "burst" vertical profiling strategy where physical and biogeochemical properties are measured at 3-h intervals over a 36-h period, covering 3 semidiurnal tidal cycles and 1 inertial period (~31 h). This approach captures energetic high-frequency variability in ocean dynamics due to internal tides around Sta. ALOHA.

Scientific Background and Findings

Central to the mission of the HOT program is continued quantification of ocean carbon inventories and fluxes, with a focus on describing changes in the sizes of these pools and fluxes over time. HOT routinely quantifies the vertical distributions of the major components of the ocean carbon cycle: dissolved inorganic carbon (DIC), pH, total alkalinity, dissolved organic carbon (DOC), and particulate carbon (PC). The HOT dataset constitutes one of the longest running records from which to gauge the oceanic response to continued anthropogenic changes to the global carbon cycle. The 24+ year record of ocean carbon measurements at Station ALOHA document that the partial pressure of CO₂ (pCO₂) in the mixed layer is increasing at a rate (1.92 ± 0.13 microatm yr⁻¹), slightly greater than the trend observed in the atmosphere (1.71 ± 0.03 microatm yr⁻¹).

Moreover, mixed layer concentrations of salinity-normalized DIC are increasing at 1.03 ± 0.07 micromol kg⁻¹ yr⁻¹ (Winn et al., 1998; Dore et al., 2009). These long-term changes in upper ocean carbon inventories have been accompanied by progressive decreases in seawater pH (-0.0018 ± 0.0001 yr⁻¹) and declines in aragonite and calcite saturation states (Dore et al., 2009). Although the penetration of anthropogenic CO₂ is evidenced by long-term decreases in seawater pH throughout the upper 600 m, the rate of acidification at Sta. ALOHA varies with depth. For example, in the upper mesopelagic waters (~160-310 m) pH is decreasing at nearly twice the rate observed in the surface waters (Dore et al., 2009). Such depth-dependent differences in acidification derive from a combination of regional differences in the time-varying climate signatures imprinted on the ventilation history of the waters, mixing, and changes in biological activity associated with different water masses.

Superimposed on these progressive long-term trends in the seawater carbonate system are seasonal- to decadal-scale variations in climate and biogeochemical dynamics that ultimately influence CO₂ inventories, fluxes, and trends. Changes in temperature, evaporation-precipitation, and mixing all impart complex, time-varying signatures on the ocean carbon cycle. For example, interactions among low-frequency climate oscillations such as those linked to the El-Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and North Pacific Gyre Oscillation (NPGO) influence the frequency, intensity, and tracks of winter storms in the NPSG (Lukas, 2001), which in turn modifies physical forcing (wind and air-sea heat/water fluxes) and upper ocean response (stratification, currents and mixing). Such dynamics have important, often non-linear, influences on ocean carbon uptake and biogeochemistry.

Time-series measurements at HOT have also highlighted complex relationships between ecosystem dynamics and climate-driven physical forcing. Historically, the abundances and distributions of the resident plankton community of the NPSG were thought to be relatively stable in both space and time. However, HOT program measurements have identified remarkable temporal (and spatial) heterogeneity in biogeochemical processes and planktonic community structure over seasonal to interannual time scales. In many cases, climate-forced fluctuations in plankton population dynamics resonate from the base of the picoplankton food web to higher trophic levels (Karl, 1999; Karl et al., 2001; Sheridan and Landry, 2004; Corno et al., 2007; Bidigare et al., 2009). However, we currently lack a complete mechanistic understanding of the processes underlying variability in NPSG biogeochemistry.

With continued lengthening of the time series record, HOT measurements have become increasingly useful for identifying low-frequency, interannual- to decadal-scale signals in ocean climate and biogeochemistry. Upper ocean physical dynamics, nutrient availability, plankton productivity, biomass and community structure, and material export at Sta. ALOHA have all been shown to be sensitive to regional- to basin- scale climate oscillations of the Pacific (Karl et al., 1995; Karl, 1999; Dore et al., 2002; Corno et al., 2007; Bidigare et al., 2009). One of the most notable examples coincided with major phase shifts in the ENSO, PDO, and NPGO indices in 1997-1998. Fluctuations in mixing and hydrological forcing accompanying these transitions had important consequences for ocean biogeochemistry and plankton ecology, including changing upper ocean nutrients, concentrations of DIC, and ultimately influencing organic matter export (Dore et al., 2003; Corno et al., 2007; Bidigare et al., 2009). Moreover, these dynamics preceded a shift in plankton community composition, as reflected through nearly 40% increases in concentrations of 19-butanoyloxyfucoxanthin (19-but), 19-hexoyloxyfucoxanthin (19-hex), and fucoxanthin pigment biomarkers used as proxies for pelagophytes, prymnesiophytes, and diatoms, respectively (Bidigare et al., 2009). Similarly, mesozooplankton biomass increased nearly 50% during this period, suggesting sensitivity of trophodynamic coupling to interannual to subdecadal scale variations in ocean climate.

HOT also provides some of the only decadal-scale measurements of in situ primary production necessary for assessing seasonal to secular scale change. Since 1988, depth integrated (0-125 m) inventories of both chlorophyll a and ¹⁴C-based estimates of primary production at Sta. ALOHA and BATS have increased significantly (Corno et al., 2007; Saba et al., 2010). However, these long-term trends are punctuated by considerable interannual variability, much of which occurs in the mid- to lower regions of the euphotic zone (>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 ^{15}N isotopic signatures associated with sinking particles at Sta. ALOHA, together with genetic analyses of N_2 fixing microorganisms, implicates upper ocean N_2 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:

1. How sensitive are rates of primary production and organic matter export to short- and long-term climate variability?
2. What processes regulate nutrient supply to the upper ocean and how sensitive are these processes to climate forcing?
3. What processes control the magnitude of air-sea carbon exchange and over what time scales do these processes vary?
4. Is the strength of the NPSG CO_2 sink changing in time?
5. 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?
6. How do variations in plankton community structure influence productivity and material export?
7. What processes trigger the formation and demise of phytoplankton blooms in a persistently stratified ocean ecosystem?

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Program Information

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.

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).

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