Niskin bottle water samples and CTD measurements from the Hawaii Ocean Time-Series cruises from 1988-2021 (HOT project)

Website: https://www.bco-dmo.org/dataset/3773
Data Type: Cruise Results
Version: 2
Version Date: 2021-04-19

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

Contributors	Affiliation	Role
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Abstract
Monthly measurements of the thermohaline structure, water column chemistry, and primary production were collected at station ALOHA as part of the Hawaii Ocean Time-series (HOT) program.

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Coverage

Spatial Extent: **N**:23.4375 **E**:-157.4567 **S**:21.2283 **W**:-158.8575
Temporal Extent: 1988-10-30 - 2019-12-20

Dataset Description

Monthly measurements of the thermohaline structure, water column chemistry, and primary production were collected at station ALOHA as part of the HOT program.

Methods & Sampling

Biogeochemistry
Sampling at Station ALOHA typically begins with sediment trap deployment followed by a deep (> 4700 m) CTD cast and a "burst series" of at least 13 consecutive 1000 m casts, on 3 hour intervals, to span the local inertial period (~ 31 hours) and three semidiurnal tidal cycles. The repeated CTD casts enable us to calculate an average density profile from which variability on tidal and near-inertial time scales has been removed. These average density profiles are useful for the comparison of dynamic height and for the comparison of the depth distribution of chemical parameters from different casts and at monthly intervals. This sampling strategy is designed to assess variability on time scales of a few hours to a few years. Very high frequency variability (< 6 hours) and variability on time scales of between 3-60 days are not adequately sampled with our ship-based operations.

Water samples for a variety of chemical and biological measurements are routinely collected from the surface to within 10 m of the seafloor. To the extent possible, we collect samples for complementary biogeochemical measurements from the same or from contiguous casts to minimize aliasing caused by time-dependent changes in the density field. This approach is especially important for samples collected in the upper 350 m of the water column. Furthermore, we attempt to sample from common depths and specific density horizons each month to facilitate comparisons between cruises. Water samples for salinity determinations are collected from every water bottle to identify sampling errors. Approximately 20% of the water samples are collected and analyzed in duplicate or triplicate to assess and track our precision in sample analyses.

Water samples for chemical analyses were collected from discrete depths using 12 liter PVC bottles with nylon coated internal springs as closing mechanisms. Sampling strategies and procedures are well documented in the previous Data Reports and in the HOT Program Field and Laboratory Protocols manual
*Data Reports: https://hahana.soest.hawaii.edu/hot/reports/reports.html
*HOT Program Field and Laboratory Protocols manual: https://hahana.soest.hawaii.edu/hot/methods/results.html

Data Processing Description

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

Quality Indicator Flags:
1 = not quality controlled
2 = good data
3 = suspect (i.e. questionable) data
4 = bad data
5 = missing data
9 = variable not measured during this cast

BCO-DMO Processing Description

BCO-DMO Processing Notes:
- transferred the data from the University of Hawaii ftp site to the BCO-DMO servers (v1, v2).
- combined all data files into csv and added columns for the information from the first header line (v2)
- added cruise summary information (v1, v2).
- merged new data with previous data (v2)
- created Filename field, which is the name of the summary file or original data file (v1, v2).
- added Latitude and Longitude values from cruise summary information and converted to decimal degrees
- combined separate dates and times to create a Sampling_Datetime field (v2)
- adjusted field/parameter names to comply with database requirements (v1, v2)
- updated the version date in the served data to the date the data was updated (v1, v2)
- added field for Vessel based on the EXPOCODE (v2)
- added field for HOT_ID based on EXPOCODE and filename (v2)

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Data Files

File
niskin_v2.csv (Comma Separated Values (.csv), 40.89 MB) MD5:6230663827b3624f5a0aef95963d6703 Primary data file for dataset ID 3773

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Related Datasets

IsSourceOf

Lange, N., Fiedler, B., Álvarez, M., Benoit-Cattin, A., Benway, H., Buttigieg, P. L., Coppola, L., Currie, K. I., Flecha, S., Gerlach, D. S., Honda, M. C., Huertas, E. I., Kinkade, D., Muller-Karger, F., Lauvset, S. K., Körtzinger, A., O'Brien, K. M., Ólafsdóttir, S., Pacheco, F. C., Rueda-Roa, D., Skjelvan, I., Wakita, M., White, A. E., Tanhua, T. (2024) **Synthesis Product for Ocean Time Series (SPOTS).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 2) Version Date 2024-02-22 doi:10.26008/1912/bco-dmo.896862.2 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
Cruise	Cruise identifier	unitless
EXPOCODE	Expedition code: 4 character NODC country-ship code, followed by cruise number and leg.	unitless
WHPID	The WOCE Hydrographic Program (WHP) section identifier	unitless
STNNBR	Station number	unitless
CASTNO	Cast number	unitless
ISO_DateTime_UTC	Time in ISO-8601 format following the convention YYYY-mm-ddTHH:MM:SS[.xx]Z (UTC time)	unitless
Time_Code	Code for when the time was taken--at the beginning (BE); bottom (BO); or completion (EN) of the cast	unitless
Latitude	Latitude of sample collection (South is negative)	decimal degrees
Longitude	Longitude of sample collection (West is negative)	decimal degrees
Depth_max	Depth measured by shipboard echo sounder. The nominal depth for Station 1 = 1500m and for Station 2 = 4750m.	meters (m)
Height_max	Bottom depth less the maximum pressure sampled	meters (m)
Pressure_max	The deepest pressure sampled	decibars (db)
Parameters	A list of the parameters measured on water samples collected during the cast (1=Salinity, 2=Oxygen, 3=Silicate, 4=Nitrate, 5=Nitrite, 6=Phosphate)	unitless
ROSETTE_POS	Position of Niskin bottle in the CTD rosette sampler	unitless
CTDPRS	CTD Pressure	decibars (db)
CTDTMP	CTD Temperature on ITS-90 scale	degrees Celsius
CTDSAL	CTD Salinity on PSS-78 scale	unitless

CTDOXY	CTD Oxygen	micromole per kilogram (umol/kg)
THETA_ITS90	Potential Temperature on ITS-90 scale	degrees Celsius
SIGMA	Potential Density	kilogram per cubic meter (kg/m^3)
SALINITY	Bottle salinity on PSS-78 scale	unitless
OXYGEN	Bottle dissolved oxygen	micromole per kilogram (umol/kg)
DIC	Dissolved Inorganic Carbon	micromole per kilogram (umol/kg)
pH	pH (pre-1992 was NBS25 and 1993 onward is TOT25)	unitless
ALKALIN	Alkalinity	microequivalent per kilogram (ueq/kg)
pCO2	Partial pressure of carbon dioxide (pCO2)	microatmospheres (uatm)
PHSPHT	Phosphate	micromole per kilogram (umol/kg)
NO2_NO3	Nitrate + nitrite (NO2+NO3)	micromole per kilogram (umol/kg)
SILCAT	Silicate (SiO4)	micromole per kilogram (umol/kg)
DOP	Dissolved Organic Phosphorus	micromole per kilogram (umol/kg)
DON	Dissolved Organic Nitrogen	micromole per kilogram (umol/kg)
DOC	Dissolved Organic Carbon	micromole per kilogram (umol/kg)
TDP	Total Dissolved Phosphorus	micromole per kilogram (umol/kg)
TDN	Total Dissolved Nitrogen (TDN)	micromole per kilogram (umol/kg)
PC	Particulate Carbon	micromole per kilogram (umol/kg)
PN	Particulate Nitrogen	micromole per kilogram (umol/kg)
PP	Particulate Phosphorus	nanomole per kilogram (nmol/kg)
LLN	Low-level Nitrogen	nanomole per kilogram (nmol/kg)
LLP	Low-level Phosphorus	nanomole per kilogram (nmol/kg)
LLSi	Low-level Silica	micromole per kilogram (umol/kg)
CHL_A	Fluorometric Chlorophyll a	microgram per liter (ug/L)
PHEO	Pheopigments	microgram per liter (ug/L)

CHL_C3	HPLC Chlorophyll c3	nanogram per liter (ng/L)
CHLC1_2	HPLC Chlorophyll [c1+c2] & Mg 3,8 DVP4A5	nanogram per liter (ng/L)
CHL_PLUS	HPLC Chlorophyll c1 + c2 + c3	nanogram per liter (ng/L)
PERID	HPLC Peridinin	nanogram per liter (ng/L)
BUT_19	HPLC 19'-Butanoyloxyfucoxanthin	nanogram per liter (ng/L)
FUCO	HPLC Fucoxanthin	nanogram per liter (ng/L)
HEX_19	HPLC 19'-Hexanoyloxyfucoxanthin	nanogram per liter (ng/L)
PRASINO	HPLC Prasinoxanthin	nanogram per liter (ng/L)
DIADINO	HPLC Diadinoxanthin	nanogram per liter (ng/L)
ZEAXAN	HPLC Zeaxanthin	nanogram per liter (ng/L)
CHL_B	HPLC Chlorophyll b	nanogram per liter (ng/L)
HPLC_chl	HPLC Chlorophyll a	nanogram per liter (ng/L)
CHL_C4	HPLC Chloropyll c4	nanogram per liter (ng/L)
A_CAR	HPLC Alpha Carotene	nanogram per liter (ng/L)
B_CAR	HPLC Beta Carotene	nanogram per liter (ng/L)
CAROTEN	HPLC Carotenes	nanogram per liter (ng/L)
CHLDA_A	HPLC Chlorophyllide a	nanogram per liter (ng/L)
VIOL	HPLC Violaxanthin	nanogram per liter (ng/L)
LUTEIN	HPLC Lutein	nanogram per liter (ng/L)
MV_CHLA	HPLC Monovinyl Chlorophyll a	nanogram per liter (ng/L)
DV_CHLA	HPLC Divinyl Chlorophyll a	nanogram per liter (ng/L)
H_BACT	Bacteria: Heterotrophic	10^5 per milliliter (10^5/mL)
P_BACT	Bacteria: Prochlorococcus	10^5 per milliliter (10^5/mL)
S_BACT	Bacteria: Synechococcus	10^5 per milliliter (10^5/mL)
E_BACT	Bacteria: Eukaryotes	10^5 per milliliter (10^5/mL)

ATP	Adenosine 5'-Triphosphate	nanogram per kilogram (ng/kg)
GTP	Guanosine 5'-Triphosphate	nanogram per kilogram (ng/kg)
H2O2	Hydrogen Peroxide	micromole per kilogram (umol/kg)
N2O	Nitrous Oxide	nanomole per kilogram (nmol/kg)
PSi	Particulate Silica	nanomole per kilogram (nmol/kg)
PIC	Particulate Inorganic Carbon	micromole per kilogram (umol/kg)
PE_pt4u	Phycoerythrin 0.4 micron fraction	nanogram per liter (ng/L)
PE_5u	Phycoerythrin 5 micron fraction	nanogram per liter (ng/L)
PE_10u	Phycoerythrin 10 micron fraction	nanogram per liter (ng/L)
P15N	delta-15N of particulate nitrogen vs. air-N	permil vs. air-N
P13C	delta-13C of particulate carbon vs. VPDB	permil vs. VPDB
TD700A	TD700 Chlorophyll a	microgram per liter (ug/L)
TD700B	TD700 Chlorophyll b	microgram per liter (ug/L)
TD700C	TD700 Chlorophyll c	microgram per liter (ug/L)
NO2	Nitrite	nanomole per kilogram (nmol/kg)
SPEC_SI	Spectrophotometric Silicate	micromole per kilogram (umol/kg)
QUALT1	Quality flags for CTDSAL to ALKALIN	unitless
QUALT2	Quality flags for pCO2 to DOC	unitless
QUALT3	Quality flags for TDP to LLP	unitless
QUALT4	Quality flags for LLSi to PERID	unitless
QUALT5	Quality flags for BUT_19 to CHL_B	unitless
QUALT6	Quality flags for HPLCchl to CHLDA_A	unitless
QUALT7	Quality flags for VIOL to P_BACT	unitless
QUALT8	Quality flags for S_BACT to N2O	unitless
QUALT9	Quality flags for PSi to P15N	unitless
QUAL10	Quality flags for P13C to SPEC_SI	unitless
Filename	Filename (cruise summary or original)	unitless
Number_bottles	Number of bottles used during the cast	unitless
Comments	Comments	units
Date	Date of the cast in MMDDYY	unitless

Time_UTC	Time in UTC	unitless
Cruise_Start_Date	Start date of cruise	unitless
Cruise_End_Date	End date of cruise	unitless

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Autosal salinometer
Dataset-specific Description	Salinity samples are collected, stored and analyzed on an Autosal salinometer
Generic Instrument Description	The salinometer is an instrument for measuring the salinity of a water sample.

Dataset-specific Instrument Name	Bran Luebbe Autoanalyzer III
Generic Instrument Name	Bran Luebbe AA3 AutoAnalyzer
Dataset-specific Description	Samples for the determination of dissolved inorganic nutrient concentrations (soluble reactive phosphorus, [nitrate+nitrite], and silicate) are run using a six-channel Bran Luebbe Autoanalyzer III, from March 2000 onward.
Generic Instrument Description	Bran Luebbe AA3 AutoAnalyzer See the description from the manufacturer.

Dataset-specific Instrument Name	Exeter Analytical CE-440 CHN Elemental Analyzer
Generic Instrument Name	CHN Elemental Analyzer
Dataset-specific Description	Samples for elemental analyses of Particulate Carbon (PC) and Nitrogen (PN) were analyzed using an Exeter Analytical CE-440 CHN Elemental Analyzer
Generic Instrument Description	A CHN Elemental Analyzer is used for the determination of carbon, hydrogen, and nitrogen content in organic and other types of materials, including solids, liquids, volatile, and viscous samples.

Dataset-specific Instrument Name	CTD Sea-Bird 911
Generic Instrument Name	CTD Sea-Bird 911
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	HPLC
Generic Instrument Name	High-Performance Liquid Chromatograph
Dataset-specific Description	Chlorophyll a and photosynthetic accessory pigments were measured by high performance liquid chromatography (HPLC) according to Wright et al. (1991).
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.

Dataset-specific Instrument Name	Satlantic ISUS V3 (#097)
Generic Instrument Name	ISUS Nitrate sensor
Dataset-specific Description	Real-time nitrate concentrations were measured with a Satlantic ISUS V3 (#097). The ISUS is a chemical-free, solid-state sensor that uses ultraviolet absorption spectroscopy to measure continuous nitrate concentrations.
Generic Instrument Description	The Satlantic ISUS nitrate sensor is an in-situ UV absorption sensor which calculates nitrate concentration from the seawater spectrum. The ISUS V2 has a 1cm path length, a 200-400 nm wavelength range., and is depth rated to 1000 m. Satlantic's ISUS V3 nitrate sensor uses advanced UV absorption technology to measure nitrate concentration in real-time.

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	Turner Luminometer
Generic Instrument Name	Photometer
Dataset-specific Description	ATP concentrations were measured on a Turner Luminometer using the firefly bioluminescence technique described by Karl and Holm-Hansen (1978).
Generic Instrument Description	An instrument that measures the light intensity emitted from a sample. [Definition Source: NCI] Photometers are used to measure illluminance, irradiance, light absorption, scattering of light, reflection of light, fluorescence, phosphorescence, and luminescence. [May include luminometers]

Dataset-specific Instrument Name	Shimadzu TOC-V CSH Total Organic Carbon Analyzer
Generic Instrument Name	Shimadzu TOC-V Analyzer
Dataset-specific Description	Total organic carbon (TOC) was determined by the high temperature catalytic oxidation method using a Shimadzu TOC-V CSH Total Organic Carbon Analyzer. This method was used from HOT-125 onward.
Generic Instrument Description	A Shimadzu TOC-V Analyzer measures DOC by high temperature combustion method.

Dataset-specific Instrument Name	Single Operator Multi-parameter Metabolic Analyzer (SOMMA)
Generic Instrument Name	Single Operator Multi-parameter Metabolic Analyzer
Dataset-specific Description	Samples for dissolved inorganic carbon (DIC) were measured using a Single Operator Multi-parameter Metabolic Analyzer (SOMMA)
Generic Instrument Description	Single Operator Multi-parameter Metabolic Analyzer (SOMMA) which was manufactured at the University of Rhode Island and standardized at the Brookhaven National Laboratory.

Dataset-specific Instrument Name	
Generic Instrument Name	Spectrophotometer
Dataset-specific Description	Used for spectrophotometric seawater pH measurements
Generic Instrument Description	An instrument used to measure the relative absorption of electromagnetic radiation of different wavelengths in the near infra-red, visible and ultraviolet wavebands by samples.

Dataset-specific Instrument Name	Technicon Autoanalyzer II continuous flow system
Generic Instrument Name	Technicon AutoAnalyzer II
Dataset-specific Description	Analyses of dissolved inorganic nutrient concentrations (soluble reactive phosphorus, [nitrate+nitrite], and silicate) were conducted at room temperature on a four-channel Technicon Autoanalyzer II continuous flow system at the University of Hawaii Analytical Facility for samples up through February 2000.
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	digital thermistor
Generic Instrument Name	Thermistor
Dataset-specific Description	Calibrated digital thermistor used for dissolved oxygen procedure
Generic Instrument Description	A thermistor is a type of resistor whose resistance varies significantly with temperature, more so than in standard resistors. The word is a portmanteau of thermal and resistor. Thermistors are widely used as inrush current limiters, temperature sensors, self-resetting overcurrent protectors, and self-regulating heating elements. Thermistors differ from resistance temperature detectors (RTD) in that the material used in a thermistor is generally a ceramic or polymer, while RTDs use pure metals. The temperature response is also different; RTDs are useful over larger temperature ranges, while thermistors typically achieve a higher precision within a limited temperature range, typically 90C to 130C.

Dataset-specific Instrument Name	MQ model 1001 TOC analyzer
Generic Instrument Name	Total Organic Carbon Analyzer
Dataset-specific Description	Prior to HOT-125 (March 2001), Total organic carbon (TOC) concentrations had been measured on a commercially available MQ model 1001 TOC analyzer equipped with a LICOR infrared detector.
Generic Instrument Description	A unit that accurately determines the carbon concentrations of organic compounds typically by detecting and measuring its combustion product (CO2). See description document at: http://bcodata.whoi.edu/LaurentianGreatLakes_Chemistry/bs116.pdf

Dataset-specific Instrument Name	TD700
Generic Instrument Name	Turner Designs 700 Laboratory Fluorometer
Dataset-specific Description	Turner Designs Model TD-700 was used to measure chlorophyll and phycoerythrin
Generic Instrument Description	The TD-700 Laboratory Fluorometer is a benchtop fluorometer designed to detect fluorescence over the UV to red range. The instrument can measure concentrations of a variety of compounds, including chlorophyll-a and fluorescent dyes, and is thus suitable for a range of applications, including chlorophyll, water quality monitoring and fluorescent tracer studies. Data can be output as concentrations or raw fluorescence measurements.

Dataset-specific Instrument Name	Turner Designs Model 10-AU
Generic Instrument Name	Turner Designs Fluorometer 10-AU
Dataset-specific Description	Turner Designs Model 10-AU was used to measure fluorometric chlorophyll. Samples for Chlorophyll a (chl a) and pheopigments were collected onto glass fiber filters and measured fluorometrically on a Turner Designs Model 10-AU flourometer
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)

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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.

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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 m^2 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 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-butanoyoxyfucoxanthin (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 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:

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 CO2 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?

References

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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
NSF Division of Ocean Sciences (NSF OCE)	OCE-0926766
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