Iron uptake rates from Hawaii Ocean Time-series (HOT) cruises on R/V Kilo Moana at Station ALOHA in the North Pacific Subtropical Gyre from May 2021 to September 2023

Website: https://www.bco-dmo.org/dataset/994200
Data Type: Cruise Results
Version: 1
Version Date: 2026-02-19

Project
» Quantifying Iron Turnover in the Upper Ocean via Time-series Measurements at Station ALOHA (HOT Trace Metals)

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

Contributors	Affiliation	Role
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Abstract
Iron (Fe) uptake rates were measured on Hawaii Ocean Time-series (HOT) cruises between May 2021 and September 2023. All samples were collected at Station ALOHA using a trace metal rosette. Fe uptake incubations were performed using seawater from the surface mixed layer (25 meters) following a low-level 57Fe-58Fe isotope double spike technique. Particulate and dissolved samples at the end of the 24-hour uptake experiment were analyzed by multi-collector inductively coupled plasma mass spectrometry at the University of Southern California using a Thermo Scientific Neptune mass spectrometer. This dataset is part of a larger study focused on the cycling of trace metals in the North Pacific Subtropical Gyre, and is embedded within the HOT program.

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Coverage

Location: Station ALOHA, North Pacific Subtropical Gyre
Spatial Extent: **Lat**:22.75 **Lon**:-158
Temporal Extent: 2021-05-17 - 2023-09-19

Methods & Sampling

Uptake Incubations:
Fe uptake incubations were performed on 12 Hawaii Ocean Time-series (HOT) cruises, onboard the R/V Kilo Moana throughout 2021-2023. All samples were collected at Station ALOHA (22°45' N, 158°0' W) following trace metal clean procedures. Incubations were performed and harvested following the method described in Hawco et al. (2022), with minor modifications. See the attached supplemental file for a listing of specific cruise IDs.

For all cruises except October 2021, trace metal clean seawater was collected using a powder-coated aluminum framed 12-place 'trace metal' rosette (Seabird) with 8-liter (L) external spring sampling bottles (Ocean Test Equipment), deployed using metal-free line (Amsteel). For the October 2021 cruise, samples were collected with C-Free bottles (Ocean Test Equipment) that were attached directly to the metal-free line and triggered with Teflon-coated messengers. Prior to collection, sampling bottles were subjected to a ca. 18 hour soak in seawater collected at a test station near Oahu. Prior to each cruise, all materials were soaked in Citranox for one day, soaked in 10% HCl for 7 days, and rinsed multiple times with 18.2 M-Ohm Milli-Q water (Millipore).

To condition the Fe spike at low nanomolar (nM) concentrations in seawater, seawater was collected at 25 meters (m) to "pre-incubate" the isotope spike with natural iron binding ligands present in seawater. Upon recovery, sampling bottles were taken to a positive pressure clean van onboard. For each "pre-incubation", 100 milliliters (mL) of seawater was filtered through a 0.2 micrometer (um) Acropak filter into an acid-cleaned 150 mL PC bottle. The seawater was amended with 100 microliters (uL) of a ~1 micromolar (uM) Fe double spike (Fe_{DS}) containing 57Fe and 58Fe and left in the dark at room temperature for approximately 24 hours.

Seawater for the incubations was collected after sunset from the mixed layer (25 m). The incubations were set up in the clean van under red light to minimize light shock. The 100 mL of pre-equilibrated solution was added to a 2 L acid-cleaned polycarbonate bottle, pre-rinsed with filtered seawater, which was then filled with seawater. The incubations were performed in triplicate, alongside a control incubation that was filtered at 0.2 um. Incubation bottles were placed in an on-deck flow-through incubator, shaded to light levels equivalent to a depth of 25 m and temperatures matching the surface mixed layer. At 24 hours, the incubations were removed and harvested via vacuum filtration onto acid-cleaned 0.2 millimeter (mm) polyethersulfone filters (47 mm), with the filtrate collected in 1 L bottles.

Sample Purification and Measurement:
Filtrate from the incubations was acidified to pH 1.8 using Optima grade hydrochloric acid and left to equilibrate for a minimum of 2 months.

Laboratory processing of samples followed methods described in Hawco et al. (2022). Briefly, filters were digested overnight in 50% nitric acid (optima grade) in perfluoroalkoxyl vials (Savillex) at 95 degrees Celsius. Dissolved iron in acidified filtrates was extracted using Nobias PA-1 resin after adjusting sample pH to ~6, rinsed with water and eluted in 1M nitric acid. Both sample types were then evaporated to dryness, heated in a 1:1 HNO_3:HCl solution for 2 hours, dried down again, and then resuspended in 10 M HCl for column chemistry purification of Fe with AG-MP1 resin. Sample was loaded at 10 M HCl, rinsed at 5M HCl, and then Fe was eluted at 1 M HCl. Following resin extraction, samples were again dried down and resuspended in 0.1 M HNO_3 for MC-ICP-MS analysis.

Measurements were performed using a Thermo Scientific Neptune MC-ICP-MS at the University of Southern California, using the IRMM-014 standard to define the natural abundance ratio of Fe.

Data Processing Description

Data were processed following Hawco et al. (2022) with minor modifications. The mean particulate Fe_{DS} of all control samples (1 pM, n = 12) was subtracted from the pFe_{DS} for each sample.

Dissolved iron turnover times (in days) were calculated as:

Fe_{DS} turnover time = ((pFe_{DS} + dFe_{DS})/pFe_{DS}) x incubation duration

based on the measured concentrations of Fe double spike in the particulate (pFe_{DS}) and dissolved (dFe_{DS}) phases.

The Fe uptake rate (pM/d) was calculated as:

Fe uptake rate = [dFe] / Fe_{DS} turnover time

where [dFe] reflects the dFe concentration at 25 m measured by isotope dilution (reported in BCO-DMO dataset "Water Column Dissolved and Total Dissolvable Metal Concentrations, Hawaii Ocean Timeseries 2020-2023" (DOI: 10.26008/1912/bco-dmo.962986.2)).

BCO-DMO Processing Description

- Loaded original file "HOTFeuptake.xlsx" (sheet 1) into BCO-DMO processing system; used row 1 as headers.
- Renamed the following fields: "Time_start" to "DateTime_start_HST"; "Time_end" to "DateTime_end_HST".
- Converted "DateTime_start_HST" from HST to UTC in ISO 8601 format: parsed as python datetime with format %Y-%m-%dT%H:%M:%S; wrote to "Start_ISO_DateTime_UTC" formatted as %Y-%m-%dT%H:%M:%SZ.
- Converted "DateTime_end_HST" from HST to UTC in ISO 8601 format: parsed as python datetime with format %Y-%m-%dT%H:%M:%S; wrote to "End_ISO_DateTime_UTC" formatted as %Y-%m-%dT%H:%M:%SZ.
- Reordered columns.
- Set field types/formats.
- Saved the final file as "994200_v1_hot_fe_uptake.csv".

Problem Description

Due to logistical issues and/or inclement weather, Fe uptake experiments were not performed on all HOT cruises sampled by the project.

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Related Publications

Hawco, N. J., Yang, S., Pinedo-González, P., Black, E. E., Kenyon, J., Ferrón, S., Bian, X., & John, S. G. (2022). Recycling of dissolved iron in the North Pacific Subtropical Gyre. Limnology and Oceanography, 67(11), 2448–2465. Portico. https://doi.org/10.1002/lno.12212
Methods

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Related Datasets

IsRelatedTo

Hawco, N. J., & Bates, E. S. (2025). Water column dissolved and total dissolvable metal concentrations from Hawaii Ocean Timeseries (HOT) R/V Kilo Moana cruises at station ALOHA, North Pacific Subtropical Gyre, from December 2020 to November 2023 (Version 2) [Data set]. Biological and Chemical Oceanography Data Management Office (BCO-DMO). https://doi.org/10.26008/1912/bco-dmo.962986.2

Hawco, N. J., & Bates, E. S. (2025). Water column particulate metals from Hawaii Ocean Timeseries (HOT) R/V Kilo Moana cruises at station ALOHA, North Pacific Subtropical Gyre, from December 2020 to November 2023 (Version 1) [Data set]. Biological and Chemical Oceanography Data Management Office (BCO-DMO). https://doi.org/10.26008/1912/bco-dmo.962966.1

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Parameters

Parameter	Description	Units
Cruise	Cruise ID	unitless
DateTime_start_HST	Start date and time of incubations in HST	unitless
DateTime_end_HST	End date and time of incubations in HST	unitless
Start_ISO_DateTime_UTC	Start date and time of incubations in UTC	unitless
End_ISO_DateTime_UTC	End date and time of incubations in UTC	unitless
Longitude	Longitude of sample collection	decimal degrees
Latitude	Latitude of sample collection	decimal degrees
Depth	Depth of sample collection	meters (m)
Replicate	Replicate identifier	unitless
FeDS_turnover	Turnover time of Fe double spike in days	days
Fe_uptake_rate	Fe uptake rate	picomolar per day (pM/d)

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Instruments

Dataset-specific Instrument Name	Seabird SBE9plus CTD system with SBE32C
Generic Instrument Name	Sea-Bird SBE 9plus CTD
Generic Instrument Description	High precision and accuracy CTD comprising an SBE 9plus underwater unit (SBE 3plus temperature, SBE 4C conductivity, and Paroscientific Digiquartz pressure sensors, and an SBE 5T submersible pump). Can be used for either real-time data acquisition or for autonomous operations at a sampling speed of up to 24 Hz. The instrument package also includes a TC duct, to reduce salinity spiking caused by ship heave for improved resolution of water column features, and to ensure that temperature and conductivity measurements are made on the same parcel of water. Supplied with both an aluminium and titanium main housing, allowing for use up to 6800 and 10,500 metre depths respectively. Also capable of measuring from eight auxiliary sensors.

Dataset-specific Instrument Name	SBE32C
Generic Instrument Name	Seabird SBE 32 Carousel Water Sampler
Generic Instrument Description	The SBE 32 is a Carousel Water Sampler. With an accessory Deck Unit, the Carousel provides water sampling and real-time CTD data acquisition with any Sea-Bird profiling CTD (requires electro-mechanical cable and slip-ring equipped winch). With an accessory underwater unit, the Carousel can operate autonomously with a Sea-Bird Scientific profiling CTD and can be programmed to close bottles at selected depths, allowing deployment using non-electrical wire or line. The Carousel is available in two models: • Full-size SBE 32 for a 12 or 24-position system (36-position custom). • Compact SBE 32C for a 12-position sampler with bottles up to 8 liters, for use with limited vertical clearance.

Dataset-specific Instrument Name	Thermo Scientific Neptune MC-ICP-MS
Generic Instrument Name	Thermo Finnigan Neptune inductively coupled plasma mass spectrometer
Generic Instrument Description	A laboratory high mass resolution inductively coupled plasma mass spectrometer (ICP-MS) designed for elemental and isotopic analysis. The instrument is based on a multicollector platform, comprising eight moveable collector supports and one fixed center channel equipped with a Faraday cup and, optionally, an ion counter with or without a retardation lens. The Faraday cup is connected to a current amplifier, whose signal is digitized by a high linearity voltage to frequency converter. The instrument was originally manufactured by Thermo Finnigan, which has since been replaced by Thermo Scientific (part of Thermo Fisher Scientific). This model is no longer in production.

Dataset-specific Instrument Name	trace metal rosette (Seabird) with 8-liter (L) external spring sampling bottles
Generic Instrument Name	Trace Metal Bottle
Generic Instrument Description	Trace metal (TM) clean rosette bottle used for collecting trace metal clean seawater samples.

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Deployments

HOT_cruises

Website	https://www.bco-dmo.org/deployment/58879
Platform	Multiple Vessels
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. A cruise inventory with addtional metadata can be found here: https://hahana.soest.hawaii.edu/hot/cruises.html

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Project Information

Quantifying Iron Turnover in the Upper Ocean via Time-series Measurements at Station ALOHA (HOT Trace Metals)

Coverage: North Pacific Subtropical Gyre

NSF Award Abstract:
Phytoplankton are the base of marine food webs but their ability to grow in the open ocean by photosynthesis is limited by the scarcity of key nutrients especially iron. To understand how phytoplankton respond to global environmental changes, it is essential to predict how the nutrient content of seawater will change as well. Iron is essential to the light-harvesting machinery of phytoplankton but is an extremely small fraction of seawater (1 part per billion). Iron is much more abundant in soils and when dust storms blow these soils out to sea, the iron content of seawater increases. It is unknown how long the effects of these iron supply events last, which depends on how well the marine ecosystem can recover and reuse iron before it sinks to the seafloor. It is also unknown if human activities have added to the natural Fe supply. The proposed research will address these questions by conducting a 3 year time-series of iron measurements in the North Pacific Ocean. Here, dust supply from Asia occurs mainly during spring, allowing the loss of iron over the summer and fall months to be documented. Unique chemical signatures will be used to distinguish iron supply from the deposition of desert dust or from human sources. This record of the marine iron cycle will be important for validating ecosystem models that are used to predict how climate change will influence the growth of phytoplankton in the future. The research would make a scientific contribution to the Hawaii Ocean Time-Series, help improve biogeochemical iron models, student training at the graduate and undergraduate level, and support an early career scientist.

A 3 year time-series of iron (Fe) measurements is proposed to constrain the magnitude of external Fe input and Fe recycling in the open ocean. Near-monthly observations will be conducted in the North Pacific Subtropical Gyre onboard Hawaii Ocean Timeseries cruises, which receives regular dust input during springtime and is minimally influenced by deep mixing. Water column profiling of dissolved and particulate Fe concentrations – combined with the flux of Fe recorded in trace-metal-clean sediment traps – will define a residence time of Fe in the upper water column. Iron uptake rates will be quantified through short-term incubations using a novel stable isotope technique and will be used to derive a turnover time with respect to biological uptake. Finally, the isotopic composition of dissolved and particulate Fe in the mixed layer will be measured to evaluate the potential importance of anthropogenic and Hawaiian Fe sources, which are poorly constrained. Together, these measurements will define the tempo and variability of the open ocean Fe cycle and provide a means to validate models that simulate the biogeochemistry of this key micronutrient.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

See more information about the Hawaii Ocean Time Series (HOT) on the related project page: https://www.bco-dmo.org/project/2101

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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.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2022969

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