Element quotas of individual phytoplankton cells from four Bermuda Atlantic Iron Time-Series (BAIT) cruises in 2019

Website: https://www.bco-dmo.org/dataset/956540
Data Type: Cruise Results
Version: 1
Version Date: 2025-03-19

Project
» NSFGEO-NERC: Collaborative Research: Using Time-series Field Observations to Constrain an Ocean Iron Model (BAIT)

Program
» U.S. GEOTRACES (U.S. GEOTRACES)

Contributors	Affiliation	Role
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Abstract
Individual phytoplankton cells were collected on four cruises (March, May, August, and November 2019) as part of the Bermuda Atlantic Iron Time-Series (BAIT) Project. The elemental (Si, P, S, Mn, Fe, Co, Ni, Cu, Zn) content of each cell was measured with synchrotron x-ray fluorescence (SXRF). Carbon was calculated from biovolume. These data can be used to assess biogenic particulate metal fraction, as well as changes in the accumulation of these elements across seasons.

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Coverage

Location: Bermuda Atlantic Time-Series Study region
Spatial Extent: **N**:32.151 **E**:-63.5636 **S**:31.1769 **W**:-64.8234
Temporal Extent: 2019-03-11 - 2019-11-21

Methods & Sampling

Samples were collected on 4 cruises (AE1909, AE1921, AE1930, and EN63) in the Western North Atlantic at the Bermuda Atlantic Time-Series Study region. Single-cell synchrotron x-ray fluorescence (SXRF) samples were collected from the surface mixed layer using the GEOTRACES rosette. Whole water samples were preserved with 0.25% trace-metal clean buffered glutaraldehyde (Twining et al., 2003) and centrifuged onto SiN TEM windows. Windows were briefly rinsed with a drop of ultrapure water and dried in a Class-100 cabinet. SXRF analysis was performed using the 2-ID-E beamline at the Advanced Photon source (Argonne National Laboratory) following the protocols of Twining et al. (2011). Each cell was raster scanned with a focused 10 keV x-ray beam with a diameter of approximately 0.5 micrometers (um).

Data Processing Description

Fluorescence spectra from the pixels covering the cell were averaged to calculate whole-cell quotas, and a fluorescence spectrum from a neighboring empty section of the grid was subtracted. Cellular elemental fluorescence intensities were fit with a modified-Gaussian model using custom software and peak areas converted to areal element concentrations using NBS-certified standard reference materials (Núnez-Milland et al., 2010; Twining et al., 2011). Spatial regions of interest (ROI) representing the whole cell (including any adsorbed elements, if present) were prepared for each cell and used to calculate element quotas. Cellular C quotas were calculated from cell biovolume using the equations of Menden-Deuer and Lessard (2000). Cell biovolume was calculated for each cell from measurements of cell diameter, length and height using digital image processing software Image J. Shape and volume equations were taken from Hillebrand et al. (1999).

BCO-DMO Processing Description

- Imported original file "BAIT_SXRF.csv" into the BCO-DMO system.
- Flagged "NA" as a missing data value (missing data are emtpy/blank in the final CSV file).
- Renamed fields to comply with BCO-DMO naming conventions (replaced "." with underscore).
- Saved the final file as "956540_v1_bait_phytoplankton_element_quotas.csv".

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Related Publications

Hillebrand, H., Dürselen, C.-D., Kirschtel, D., Pollingher, U., & Zohary, T. (1999). Biovolume calculation for pelagic and benthic microalgae. Journal of Phycology, 35(2), 403–424. doi:10.1046/j.1529-8817.1999.3520403.x
Methods

Menden-Deuer, S., & Lessard, E. J. (2000). Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton. Limnology and Oceanography, 45(3), 569–579. doi:10.4319/lo.2000.45.3.0569
Methods

Núñez-Milland, D. R., Baines, S. B., Vogt, S., & Twining, B. S. (2010). Quantification of phosphorus in single cells using synchrotron X-ray fluorescence. Journal of Synchrotron Radiation, 17(4), 560–566. https://doi.org/10.1107/s0909049510014020
Methods

Sofen, L. E., Antipova, O. A., Buck, K. N., Caprara, S., Chacho, L., Johnson, R. J., Kim, G., Morton, P., Ohnemus, D. C., Rauschenberg, S., Sedwick, P. N., Tagliabue, A., & Twining, B. S. (2023). Authigenic Iron Is a Significant Component of Oceanic Labile Particulate Iron Inventories. Global Biogeochemical Cycles, 37(12). Portico. https://doi.org/10.1029/2023gb007837 https://doi.org/10.1029/2023GB007837
Results

Tagliabue, A., Buck, K. N., Sofen, L. E., Twining, B. S., Aumont, O., Boyd, P. W., Caprara, S., Homoky, W. B., Johnson, R., König, D., Ohnemus, D. C., Sohst, B., & Sedwick, P. (2023). Authigenic mineral phases as a driver of the upper-ocean iron cycle. Nature, 620(7972), 104–109. https://doi.org/10.1038/s41586-023-06210-5
Results

Twining, B. S., Baines, S. B., Bozard, J. B., Vogt, S., Walker, E. A., & Nelson, D. M. (2011). Metal quotas of plankton in the equatorial Pacific Ocean. Deep Sea Research Part II: Topical Studies in Oceanography, 58(3-4), 325–341. doi:10.1016/j.dsr2.2010.08.018
Methods

Twining, B. S., Baines, S. B., Fisher, N. S., Maser, J., Vogt, S., Jacobsen, C., Tovar-Sanchez, A., & Sañudo-Wilhelmy, S. A. (2003). Quantifying Trace Elements in Individual Aquatic Protist Cells with a Synchrotron X-ray Fluorescence Microprobe. Analytical Chemistry, 75(15), 3806–3816. https://doi.org/10.1021/ac034227z
Methods

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Related Datasets

IsRelatedTo

Twining, B., Ohnemus, D. C., Sofen, L. (2023) **Particulate trace element concentrations measured during four cruises in 2019 at locations around the Bermuda Atlantic Time-series Study (BATS) station.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2023-02-01 doi:10.26008/1912/bco-dmo.888772.1 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
aps_run	Analysis run at Advanced Photon Source	unitless
MDA	Scan number during run	unitless
Cruise	BAIT program cruise during 2019: I = March (EN361), II = May (AE1909), III = August (AE1921), IV = November (AE1930)	unitless
Station	Station location: BATS or spatial station number	unitless
Depth_m	Depth	meters (m)
Depth	Categorical depth: surface mixed layer (20 meters) or deep chlorophyll maximum (DCM)	unitless
Vol	Cell volume	cubic micrometers (um3)
cellC_mol	Cellular C	moles (mol)
log_Si_C	logarithm of cellular Si:C	micromoles per mole (umol/mol)
log_Fe_C	logarithm of cellular Fe:C	micromoles per mole (umol/mol)
log_Cu_C	logarithm of cellular Cu:C	micromoles per mole (umol/mol)
log_Zn_C	logarithm of cellular Zn:C	micromoles per mole (umol/mol)
log_P_C	logarithm of cellular P:C	micromoles per mole (umol/mol)
log_S_C	logarithm of cellular S:C	micromoles per mole (umol/mol)

log_Mn_C	logarithm of cellular Mn:C	micromoles per mole (umol/mol)
log_Co_C	logarithm of cellular Co:C	micromoles per mole (umol/mol)
log_Ni_C	logarithm of cellular Ni:C	micromoles per mole (umol/mol)
log_C_P	logarithm of cellular C:P	micromoles per mole (umol/mol)
flag_C_P	quality flag for cellular C:P ratio	unitless
flag_Fe_C	quality flag for cellular Fe:C ratio	unitless
flag_Zn_C	quality flag for cellular Fe:C ratio	unitless
flag_Mn_C	quality flag for cellular Fe:C ratio	unitless
flag_Ni_C	quality flag for cellular Fe:C ratio	unitless
flag_Co_C	quality flag for cellular Fe:C ratio	unitless
flag_Cu_C	quality flag for cellular Fe:C ratio	unitless
bf_image_filename	Filename of brightfield image of cell	unitless
maps_filename	Filename of elemental maps	unitless
spectra_filename	Filename of SXRF spectra	unitless

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Instruments

Dataset-specific Instrument Name	Synchrotron X-ray Fluorescence microscope
Generic Instrument Name	X-ray fluorescence analyzer
Dataset-specific Description	SXRF analysis was performed on the 2-ID-E beamline at the Advanced Photon source (Argonne National Laboratory). The synchrotron consists of a storage ring which produces high energy electromagnetic radiation. X-rays diverted to the 2-ID-E beamline are used for x-ray fluorescence mapping of biological samples. X-rays were tuned to an energy of 10 keV to enable the excition of K-alpha fluorescence for the elements reported. The beam is focused using Fresnel zoneplates to achieve high spatial resolution; for our application a focused spot size of 0.5 micrometers (um) was used. A multi-element germanium energy dispersive detector is used to record the X-ray fluorescence spectrum.
Generic Instrument Description	Instruments that identify and quantify the elemental constituents of a sample from the spectrum of electromagnetic radiation emitted by the atoms in the sample when excited by X-ray radiation.

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Deployments

AE1909

Website	https://www.bco-dmo.org/deployment/869175
Platform	R/V Atlantic Explorer
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/atlanticexplorer_ae1909.pdf
Start Date	2019-05-11
End Date	2019-05-17
Description	See additional cruise information at the Rolling Deck to Repository (R2R): https://www.rvdata.us/search/cruise/AE1909

AE1921

Website	https://www.bco-dmo.org/deployment/869176
Platform	R/V Atlantic Explorer
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/atlanticexplorer_ae1921.pdf
Start Date	2019-08-16
End Date	2019-08-22
Description	See additional cruise information at the Rolling Deck to Repository (R2R): https://www.rvdata.us/search/cruise/AE1921

AE1930

Website	https://www.bco-dmo.org/deployment/869177
Platform	R/V Atlantic Explorer
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/atlanticexplorer_ae1930.pdf
Start Date	2019-11-15
End Date	2019-11-21
Description	See additional cruise information at the Rolling Deck to Repository (R2R): https://www.rvdata.us/search/cruise/AE1930

EN631

Website	https://www.bco-dmo.org/deployment/869159
Platform	R/V Endeavor
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/endeavor_en631.pdf
Start Date	2019-03-10
End Date	2019-03-15
Description	See additional cruise information at the Rolling Deck to Repository (R2R): https://www.rvdata.us/search/cruise/EN631

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Project Information

NSFGEO-NERC: Collaborative Research: Using Time-series Field Observations to Constrain an Ocean Iron Model (BAIT)

Coverage: Bermuda Atlantic Time-Series Study region, waters of the western Subtropical North Atlantic Gyre (ca. 30°N-33°N, 62°W-65°W)

NSF and NERC Award Abstract:
Iron is an essential nutrient for the growth of phytoplankton in the oceans. As such, iron plays key roles in regulating marine primary production and the cycling of carbon. It is thus important that models of ocean biology and chemistry consider iron, in order to explore past, present and future variations in marine productivity and the role of the ocean in the global carbon cycle. In this joint project involving researchers in the U.S. and the U.K., supported by both NSF and the Natural Environment Research Council (U.K.), field data from the Bermuda Atlantic Time-series Study (BATS) region will be combined with an established, state-of-the-art ocean biogeochemical model. By leveraging the known seasonal-scale physical, chemical and biological changes in the BATS region, the oceanographic context provided by the BATS core data, and an existing model of the regional physical circulation, the proposed study will yield process-related information that is of general applicability to the open ocean. In particular, the proposed research will focus on understanding the atmospheric input, biological uptake, regeneration and scavenging removal of dissolved iron in the oceanic water column, which have emerged as major uncertainties in the ocean iron cycle. The project will include significant educational and training contributions at the K-12, undergraduate, graduate and postdoctoral levels, as well as public outreach efforts that aim to explain the research and its importance.

The ability of ocean models to simulate iron remains crude, owing to an insufficient understanding of the mechanisms that drive variability in dissolved iron, particularly the involvement of iron-binding ligands, colloids and particles in the surface input, biological uptake, regeneration and scavenging of dissolved iron in the upper ocean. Basin-scale data produced by the GEOTRACES program provide an important resource for testing and improving models and, by extension, our mechanistic understanding of the ocean iron cycle. However such data provide only quasi-synoptic 'snapshots', which limits their utility in isolating and identifying the processes that control dissolved iron in the upper ocean. The proposed research aims to provide mechanistic insight into these governing processes by combining time-series data from the BATS region with numerical modeling experiments.

Specifically, seasonally resolved data on the vertical (upper 2,000 meters) and lateral (tens of kilometers) distributions of particulate, dissolved, colloidal, soluble and ligand-bound iron species will be obtained from the chemical analysis of water column samples collected during five cruises, spanning a full annual cycle, shared with the monthly BATS program cruises. These data, along with ancillary data from the BATS program, will be used to test and inform numerical modeling experiments, and thus derive an improved understanding of the mechanisms that control the distribution and dynamics of dissolved iron in the oceanic water column.

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.

This is a project jointly funded by the National Science Foundation's Directorate for Geosciences (NSF/GEO) and the National Environment Research Council (NERC) of the United Kingdom (UK).

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Program Information

U.S. GEOTRACES (U.S. GEOTRACES)

Website: http://www.geotraces.org/

Coverage: Global

GEOTRACES is a SCOR sponsored program; and funding for program infrastructure development is provided by the U.S. National Science Foundation.

GEOTRACES gained momentum following a special symposium, S02: Biogeochemical cycling of trace elements and isotopes in the ocean and applications to constrain contemporary marine processes (GEOSECS II), at a 2003 Goldschmidt meeting convened in Japan. The GEOSECS II acronym referred to the Geochemical Ocean Section Studies To determine full water column distributions of selected trace elements and isotopes, including their concentration, chemical speciation, and physical form, along a sufficient number of sections in each ocean basin to establish the principal relationships between these distributions and with more traditional hydrographic parameters;

* To evaluate the sources, sinks, and internal cycling of these species and thereby characterize more completely the physical, chemical and biological processes regulating their distributions, and the sensitivity of these processes to global change; and

* To understand the processes that control the concentrations of geochemical species used for proxies of the past environment, both in the water column and in the substrates that reflect the water column.

GEOTRACES will be global in scope, consisting of ocean sections complemented by regional process studies. Sections and process studies will combine fieldwork, laboratory experiments and modelling. Beyond realizing the scientific objectives identified above, a natural outcome of this work will be to build a community of marine scientists who understand the processes regulating trace element cycles sufficiently well to exploit this knowledge reliably in future interdisciplinary studies.

Expand "Projects" below for information about and data resulting from individual US GEOTRACES research projects.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1829819

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