

Dissolved iron concentrations and stable isotope ratios from water column samples collected during four Bermuda Atlantic Iron Time-series (BAIT) cruises EN631, AE1909, AE1921, AE1930 in the Western Subtropical North Atlantic Gyre in 2019

Website: <https://www.bco-dmo.org/dataset/936824>

Data Type: Cruise Results

Version: 1

Version Date: 2024-09-17

Project

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

» [Collaborative Research: Determining the isotopic signature of iron released via ligand-mediated dissolution of atmospheric dust in the surface ocean](#) (Dust Ligand Interactions)

Program

» [U.S. GEOTRACES](#) (U.S. GEOTRACES)

Contributors	Affiliation	Role
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Abstract

These data include dissolved iron (Fe) concentrations and stable isotope ratios ($\delta^{56}\text{Fe}$ relative to IRMM-014) from water column samples collected during four Bermuda Atlantic Iron Time-Series (BAIT) cruises (GApr13) in the Bermuda Atlantic Time-series Study (BATS) region in March, May, August, and November 2019. Analyses were carried out at the University of South Florida.

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Coverage

Location: BATS site

Spatial Extent: N:32.151 E:-63.58 S:31.177 W:-64.815

Temporal Extent: 2019-03-11 - 2019-11-21

Dataset Description

The primary data file "936824_v1_bait_dissolved_fe_and_isotopes.csv" includes data from all four cruises. Data from each cruise is also provided separately in the attached Supplemental Files (csv format). The Supplemental Files include the unique GEOTRACES barcodes assigned to each parameter from each cruise. These barcodes are used by the GEOTRACES program for data tracking purposes.

Methods & Sampling

Water-column samples for trace metal measurements were collected from the Bermuda Atlantic Time-Series (BATS) site (31°40'N, 64°10'W) and adjacent BATS spatial stations during cruises in March (spring), May (early summer), August (late summer) and November (fall) 2019 aboard R/V Atlantic Explorer and R/V Endeavor.

Seawater samples and hydrographic data were collected using a trace-metal clean conductivity-temperature-depth sensor (SBE 19 plus, SeaBird Electronics) mounted on a custom-built trace-metal clean carousel (SeaBird Electronics) fitted with custom-modified 5-liter (L) Teflon-lined external-closure Niskin-X samplers (General Oceanics) and deployed on an Amsteel non-metallic line. On the August cruise, we also collected near-surface samples (small boat) (~0.3 meters (m) depth) in a Niskin-X sampler deployed from an inflatable dinghy ~500 m upwind of the research vessel, to avoid contamination from the ship. After recovery, the seawater samples were filtered through pre-cleaned 0.2-micrometer (μm) pore AcroPak Supor filter capsules (Pall) using filtered nitrogen gas inside a shipboard clean laboratory (Sedwick et al., 2020; Tagliabue et al., 2023) into acid-cleaned 1L LDPE bottles.

Samples were acidified back on shore at the University of South Florida (USF) using 1.2 milliliter (mL) 10 M Teflon-distilled HCl per liter of sample and stored for at least 12 months before processing. Seawater samples were then processed for dissolved iron (Fe) isotope and concentration analysis at the University of South Florida following Sieber et al. (2019), modified from Conway et al. (2013). Briefly, an Fe double-spike was added prior to batch extraction using Nobias PA-1 chelating resin, followed by purification by anion-exchange chromatography using AG-MP1 resin. Concentration and isotope analyses were performed on a Thermo Neptune Plus MC-ICPMS in the Tampa Bay Plasma Facility at the University of South Florida using the double spike technique via a ~100 microliters per minute ($\mu\text{L min}^{-1}$) PFA nebulizer and Apex Ω introduction introduction system, Pt Jet Sampler cone and an Al X skimmer cone.

Fe stable isotope ratios are expressed in delta notation ($\delta^{56}\text{Fe}$) relative to the IRMM-014 standard. A secondary Fe standard, NIST-3126, was analyzed over 44 sessions to provide an estimate of long-term instrumental precision. We obtain a value of $+0.36 \pm 0.05\text{‰}$ (2SD, $n = 524$; runs = 37), in agreement with consensus values (Hunt et al. 2022; Conway et al., 2013). Therefore, we consider a 2SD uncertainty of 0.05‰ as an estimate of analytical precision, and have applied it to all samples, except for low concentration samples where the larger internal error is considered a more conservative estimate of uncertainty. Concentrations were calculated using the isotope dilution technique based on on-peak blank, interference and mass-bias corrected $^{57}\text{Fe}/^{56}\text{Fe}$ ratios measured simultaneously with isotope analysis. We express uncertainty (1SD) on Fe concentrations as 2%, based on Conway et al. (2013).

Data Processing Description

Data were processed in Microsoft Excel using an-in house double spike reduction scheme from Sieber et al. (2021), based on Siebert et al. (2001).

BCO-DMO Processing Description

To create the combined data file:

- Imported 4 original files into the BCO-DMO system: "AE1909_dataTemplate.xlsx", "AE1921_dataTemplate.xlsx", "AE1930_dataTemplate.xlsx", and "EN631_dataTemplate.xlsx".
- Renamed fields to comply with BCO-DMO naming conventions.
- Renamed "SD2_Fe_56_54_D_DELTA_BOTTLE" to "SD1_Fe_56_54_D_DELTA_BOTTLE" (AE1909 file).
- Concatenated data from separate cruises into a single data file; added column for Cruise_ID.
- Converted date column to YYYY-MM-DD format.
- Removed empty columns: Event_ID, Gear_ID, Start_Time_UTC, End_Date_UTC, End_Time_UTC, End_Latitude, End_Longitude, Rosette_Position.
- Saved the final file as "936824_v1_bait_dissolved_fe_and_isotopes.csv".

For the supplemental files:

- Imported 4 original files into the BCO-DMO system: "AE1909_dataTemplate.xlsx", "AE1921_dataTemplate.xlsx", "AE1930_dataTemplate.xlsx", and "EN631_dataTemplate.xlsx".
- Saved the files in CSV format.

Problem Description

We use the SeaDataNet scheme to flag data, as recommended by GEOTRACES, where data we believe is accurate is flagged as 2.

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Data Files

File
936824_v1_bait_dissolved_fe_and_isotopes.csv (Comma Separated Values (.csv), 13.62 KB) MD5:79d386f541db2eecd1f5bbe063ab06aa
Primary data file for dataset ID 936824, version 1

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Supplemental Files

File
ae1909_bait_dissolved_iron_concentration_and_isotopes.csv (Comma Separated Values (.csv), 3.54 KB) MD5:fae2cd1cf7367da00818953f68f16f38
Supplemental file for dataset ID 936824, version 1. This file contains the data for cruise AE1909 only and includes the GEOTRACES barcode names.
ae1921_bait_dissolved_iron_concentration_and_isotopes.csv (Comma Separated Values (.csv), 4.34 KB) MD5:3b18cfecb1e9be5752b80157544c9c07
Supplemental file for dataset ID 936824, version 1. This file contains the data for cruise AE1921 only and includes the GEOTRACES barcode names.
ae1930_bait_dissolved_iron_concentration_and_isotopes.csv (Comma Separated Values (.csv), 3.51 KB) MD5:30142a16485ab9b32e6f5362023acb20
Supplemental file for dataset ID 936824, version 1. This file contains the data for cruise AE1930 only and includes the GEOTRACES barcode names.
en631_bait_dissolved_iron_concentration_and_isotopes.csv (Comma Separated Values (.csv), 3.50 KB) MD5:65e2487c28061781214e63d6c766ef7b
Supplemental file for dataset ID 936824, version 1. This file contains the data for cruise EN631 only and includes the GEOTRACES barcode names.

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Related Publications

Conway, T. M., Rosenberg, A. D., Adkins, J. F., & John, S. G. (2013). A new method for precise determination of iron, zinc and cadmium stable isotope ratios in seawater by double-spike mass spectrometry. *Analytica Chimica Acta*, 793, 44–52. doi:[10.1016/j.aca.2013.07.025](https://doi.org/10.1016/j.aca.2013.07.025)
Methods

Hunt, H. R., Summers, B. A., Sieber, M., Krisch, S., Al-Hashem, A., Hopwood, M., Achterberg, E. P., & Conway, T. M. (2022). Distinguishing the influence of sediments, the Congo River, and water-mass mixing on the distribution of iron and its isotopes in the Southeast Atlantic Ocean. *Marine Chemistry*, 247, 104181.
<https://doi.org/10.1016/j.marchem.2022.104181>

Methods

Sedwick, P. N., Bowie, A. R., Church, T. M., Cullen, J. T., Johnson, R. J., Lohan, M. C., Marsay, C. M., McGillicuddy, D. J., Sohst, B. M., Tagliabue, A., & Ussher, S. J. (2020). Dissolved iron in the Bermuda region of the subtropical North Atlantic Ocean: Seasonal dynamics, mesoscale variability, and physicochemical speciation. *Marine Chemistry*, 219, 103748. <https://doi.org/10.1016/j.marchem.2019.103748>

Methods

Sieber, M., Conway, T. M., de Souza, G. F., Hassler, C. S., Ellwood, M. J., & Vance, D. (2021). Isotopic fingerprinting of biogeochemical processes and iron sources in the iron-limited surface Southern Ocean. *Earth and Planetary Science Letters*, 567, 116967. <https://doi.org/10.1016/j.epsl.2021.116967>

Methods

Sieber, M., Conway, T. M., de Souza, G. F., Obata, H., Takano, S., Sohrin, Y., & Vance, D. (2019). Physical and biogeochemical controls on the distribution of dissolved cadmium and its isotopes in the Southwest Pacific Ocean. *Chemical Geology*, 511, 494–509. doi:[10.1016/j.chemgeo.2018.07.021](https://doi.org/10.1016/j.chemgeo.2018.07.021)

Methods

Siebert, C., Nägler, T. F., & Kramers, J. D. (2001). Determination of molybdenum isotope fractionation by double-spike multicollector inductively coupled plasma mass spectrometry. *Geochemistry, Geophysics, Geosystems*, 2(7), n/a–n/a. doi:[10.1029/2000gc000124](https://doi.org/10.1029/2000gc000124)

Methods

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>

Methods

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Parameters

Parameter	Description	Units
Cruise_ID	Cruise ID	unitless
Station_ID	Sampling station ID	unitless
Start_Date_UTC	Sampling date	unitless
Start_Latitude	Latitude of station location	decimal degrees North
Start_Longitude	Longitude of sampling location	decimal degrees East
Sample_ID	Unique BAIT sample number	unitless
Sample_Depth	Sample depth	meters (m)
Fe_56_54_D_DELTA_BOTTLE	Dissolved $\delta^{56}\text{Fe}$; from bottle samples	per mil (‰)
SD1_Fe_56_54_D_DELTA_BOTTLE	One standard deviation of Fe_56_54_D_DELTA_BOTTLE	per mil (‰)

Flag_Fe_56_54_D_DELTA_BOTTLE	Quality flag for Fe_56_54_D_DELTA_BOTTLE	unitless
Fe_D_CONC_BOTTLE	Dissolved iron; from bottle samples	nanomoles per kilogram (nmol/kg)
SD1_Fe_D_CONC_BOTTLE	One standard deviation of Fe_D_CONC_BOTTLE	nanomoles per kilogram (nmol/kg)
Flag_Fe_D_CONC_BOTTLE	Quality flag for Fe_D_CONC_BOTTLE	unitless
Fe_56_54_D_DELTA_BOAT_PUMP	Dissolved $\delta^{56}\text{Fe}$; near-surface samples; AE1921 cruise only	per mil (‰)
SD1_Fe_56_54_D_DELTA_BOAT_PUMP	One standard deviation of Fe_56_54_D_DELTA_BOAT_PUMP	per mil (‰)
Flag_Fe_56_54_D_DELTA_BOAT_PUMP	Quality flag for Fe_56_54_D_DELTA_BOAT_PUMP	unitless
Fe_D_CONC_BOAT_PUMP	Dissolved iron; near-surface samples; AE1921 cruise only	nanomoles per kilogram (nmol/kg)
SD1_Fe_D_CONC_BOAT_PUMP	One standard deviation of Fe_D_CONC_BOAT_PUMP	nanomoles per kilogram (nmol/kg)
Flag_Fe_D_CONC_BOAT_PUMP	Quality flag for Fe_D_CONC_BOAT_PUMP	unitless

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Instruments

Dataset-specific Instrument Name	SBE 19 plus, SeaBird Electronics
Generic Instrument Name	CTD Sea-Bird
Generic Instrument Description	Conductivity, Temperature, Depth (CTD) sensor package from SeaBird Electronics, no specific unit identified. This instrument designation is used when specific make and model are not known. See also other SeaBird instruments listed under CTD. More information from Sea-Bird Electronics.

Dataset-specific Instrument Name	Thermo Neptune Plus MC-ICPMS
Generic Instrument Name	Multi Collector Inductively Coupled Plasma Mass Spectrometer
Generic Instrument Description	A Multi Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICPMS) is a type of mass spectrometry where the sample is ionized in a plasma (a partially ionized gas, such as Argon, containing free electrons) that has been generated by electromagnetic induction. A series of collectors is used to detect several ion beams simultaneously. A MC-ICPMS is a hybrid mass spectrometer that combines the advantages of an inductively coupled plasma source and the precise measurements of a magnetic sector multicollector mass spectrometer. The primary advantage of the MC-ICPMS is its ability to analyze a broader range of elements, including those with high ionization potential that are difficult to analyze by Thermal Ionization Mass Spectrometry (TIMS). The ICP source also allows flexibility in how samples are introduced to the mass spectrometer and allows the analysis of samples introduced either as an aspirated solution or as an aerosol produced by laser ablation.

Dataset-specific Instrument Name	Niskin-X
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.

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Deployments

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

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

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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).

Collaborative Research: Determining the isotopic signature of iron released via ligand-mediated dissolution of atmospheric dust in the surface ocean (Dust Ligand Interactions)

Coverage: North Atlantic Subtropical Gyre

NSF Award Abstract:

Iron (Fe) is a crucial nutrient for microbial growth in the oceans, impacting the carbon cycle and the climate system, but Fe does not dissolve readily in seawater and so its availability limits phytoplankton growth over much of the surface oceans. One of the most significant ways by which Fe reaches the surface oceans is through deposition of wind-blown dust; however, for this Fe to be available for biological growth, it must dissolve and be kept in solution bound to organic molecules. Despite this known importance, the mechanisms of dust dissolution and the identity of the organic molecules keeping Fe in solution remain poorly understood. This study will focus on using laboratory and field experiments to better understand how natural organic molecules present in seawater enhance the release of Fe from Saharan desert dust, the organic molecules produced by microbes in response to dust, the isotopic fractionation of Fe associated with dust dissolution, and ultimately the role of ligand-mediation dissolution in determining the role of dust in the marine Fe cycle. For outreach activities, the proposers would tutor refugee high school students from Africa/Asia in math and science to help them get integrated into the U.S. school system and discuss science with the public by participation in the St. Petersburg Science Festival. Three graduate students and undergraduate interns would be supported and trained as part of this project.

Scientists from the University of South Florida and Oregon State University will collect natural North Atlantic dust at the Tudor Hill Tower on Bermuda over a yearly cycle and characterize the weekly bulk and water-soluble Fe isotopic and elemental composition of the dust. Appropriate subsamples of this dust, representing both the Saharan and non-Saharan (anthropogenically-influenced) seasons will then be dissolved in seawater, with dissolution mediated by ligands with a range of Fe binding stability constants (natural ligands as well as defined marine siderophores). Incubations of dust will also be carried out with natural biological communities collected from the Gulf of Mexico and at the Bermuda Atlantic Time Series site in the North Atlantic. The investigators will characterize the amount and isotopic signature of the Fe released in each experiment, the microbial community response to dust in the incubations (DNA, cell counting and identification), and the ligands present in the natural organic matter used for experiments and produced in the incubations. Comparison of the abiotic and biological experiments will allow investigation of the magnitude of the biological effects on dust dissolution. The experiments will allow the investigators to provide a mechanistic understanding of factors that affect dust

dissolution rates, especially the role of different specific organic ligands in enhancing and stabilizing the release of iron in the surface ocean, and the net signature of iron released. From this, the investigators will provide new constraints for the marine iron isotope cycle in the ocean, specifically testing the hypothesis that the net release of Fe from dust is isotopically heavy due to complexation with organic ligands, but that the size of this fractionation depends on the binding strength and presence of different ligands. The outcomes of this process study will provide a framework for models and interpretation of large scale field studies such as GEOTRACES, as well as enhancing the research community's ability to interpret aerosol and oceanic iron isotope data.

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.

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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-1829833
NSF Division of Ocean Sciences (NSF OCE)	OCE-1829643

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