

The fraction of water last ventilated in a given region in a time less than or equal to 160 years ago based on samples collected from R/V Knorr cruises KN199-04 and KN204-01 during 2010-2011

Website: <https://www.bco-dmo.org/dataset/810784>

Data Type: Cruise Results

Version: 1

Version Date: 2020-05-07

Project

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Contributors	Affiliation	Role
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Abstract

Water mass fractions and ages calculated from hydrographic and tracer data using a maximum-entropy inversion technique. This dataset contains the fraction of water last ventilated in a given region in a time less than or equal to 160 years ago as well as the corresponding ensemble standard deviations.

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Coverage

Spatial Extent: N:39.701 E:-9.662 S:17.351 W:-69.827

Temporal Extent: 2010-10-16 - 2011-12-10

Dataset Description

Water mass fractions and ages calculated from hydrographic and tracer data using a maximum-entropy inversion technique.

This dataset contains the fraction of water last ventilated in a given region in a time less than or equal to 160 years ago as well as the corresponding ensemble standard deviations.

Data File Formats:

For a .csv or .tsv format of these data, use the "Get Data" button at the top of the BCO-DMO metadata page.

For a Matlab file containing all of the water mass fraction data from this project, see the "Data Files" section of the BCO-DMO metadata page.

Acquisition Description

A maximum-entropy inversion technique was applied to CFC and SF6 measurements made on the U.S. GEOTRACES North Atlantic Transect, and radiocarbon concentrations interpolated to sample locations along the transect from gridded data reported in the GLODAP data compilation, to determine mean ages and source water compositions of each water sample. Details are described in Holzer et al. (2018).

See the attached README file (GA03_transit-time_partitioned_water-mass_fractions_v2_README.pdf) for more information on methods and a map of region locations.

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Data Files

File	Version
<p>Matlab structure containing GA03 water-mass fraction data</p> <p>filename: wmf_ages_bottleIDs_GA03.mat</p> <p>(MATLAB Data (.mat), 279.73 KB) MD5:b1c644f9f0726e2c8e6b5d453be80293</p> <p><i>Water-mass fractions (wmf) are organized into 668x8 matrices: There are 668 bottle locations along section GA03 and the columns are the fraction of water last ventilated in one of 8 surface regions. This file contains the single matlab structure GA03, which has the following double-precision fields:</i></p> <p><i>field name size precision units</i></p> <p>-----</p> <p><i>wmf_tau_all_yr [668x8 double] fraction of unity</i> <i>wmf_tau_all_yr_uncert [668x8 double] fraction of unity</i> <i>wmf_tau_le160yr [668x8 double] fraction of unity</i> <i>wmf_tau_le160yr_uncert [668x8 double] fraction of unity</i> <i>wmf_tau_le39yr [668x8 double] fraction of unity</i> <i>wmf_tau_le39yr_uncert [668x8 double] fraction of unity</i> <i>age_regional [668x7 double] years</i> <i>age_regional_uncert [668x7 double] years</i> <i>ideal_mean_age [668x1 double] years</i> <i>ideal_mean_age_uncert [668x1 double] years</i> <i>depth [668x1 double] m</i> <i>lat [668x1 double] degrees north</i> <i>lon [668x1 double] degrees east</i> <i>dist_east [668x1 double] km</i></p>	1

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Related Publications

Holzer, M., Smethie, W. M., & Ting, Y.-H. (2018). Ventilation of the Subtropical North Atlantic: Locations and Times of Last Ventilation Estimated Using Tracer Constraints From GEOTRACES Section GA03. *Journal of Geophysical Research: Oceans*, 123(4), 2332–2352. doi:10.1002/2017jc013698

<https://doi.org/10.1002/2017JC013698>

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Parameters

Parameter	Description	Units
LBIR_Fraction	fraction of water last ventilated in the LBIR region; LBIR = Labrador and Irminger Seas	unitless (fraction)
LBIR_Fraction_Uncert	ensemble standard deviation of the LBIR_Fraction	unitless (fraction)
AONG_Fraction	fraction of water last ventilated in the AONG region; AONG = Arctic Ocean, Greenland, and Norwegian Seas	unitless (fraction)
AONG_Fraction_Uncert	ensemble standard deviation of the AONG_Fraction	unitless (fraction)
SPNA_Fraction	fraction of water last ventilated in the SPNA region; SPNA = SubPolar North Atlantic	unitless (fraction)
SPNA_Fraction_Uncert	ensemble standard deviation of the SPNA_Fraction	unitless (fraction)
STNA_Fraction	fraction of water last ventilated in the STNA region; STNA = SubTropical North Atlantic	unitless (fraction)
STNA_Fraction_Uncert	ensemble standard deviation of the STNA_Fraction	unitless (fraction)
MED_Fraction	fraction of water last ventilated in the MED region; MED = Mediterranean Sea	unitless (fraction)
MED_Fraction_Uncert	ensemble standard deviation of the MED_Fraction	unitless (fraction)
NAAD_Fraction	fraction of water last ventilated in the NAAD region; NAAD = North of the Antarctic Divergence	unitless (fraction)
NAAD_Fraction_Uncert	ensemble standard deviation of the NAAD_Fraction	unitless (fraction)
SAAD_Fraction	fraction of water last ventilated in the SAAD region; SAAD = South of the Antarctic Divergence	unitless (fraction)
SAAD_Fraction_Uncert	ensemble standard deviation of the SAAD_Fraction	unitless (fraction)
OTHER_Fraction	fraction of water last ventilated in the OTHER region; OTHER = the rest of the global sea surface, excluding the other defined areas	unitless (fraction)
OTHER_Fraction_Uncert	ensemble standard deviation of the OTHER_Fraction	unitless (fraction)
Ideal_Mean_Age	estimate of the ideal mean age (regardless of last ventilation location) at each of the 668 bottle locations	years
Ideal_Mean_Age_Uncert	ensemble standard deviation of the Ideal_Mean_Age	years
Depth	Bottle sample depth	meters (m)
Latitude	Bottle sample latitude	degrees North
Longitude	Bottle sample longitude	degrees East
Distance_East	The distance in kilometers along the combined cruise tracks of the KN199-04 and KN204-01 from the easternmost station (KN204-01 station 1).	kilometers (km)
Cruise_ID	Cruise identifier	unitless

Station_No	Station number	unitless
Cast_No	Cast number	unitless
Sample_Bottle	Bottle number	unitless
Date	Sampling date; format: yyyyymmdd	unitless

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Deployments

KN199-04

Website	https://www.bco-dmo.org/deployment/58066
Platform	R/V Knorr
Report	http://bcodata.whoi.edu/US_GEOTRACES/AtlanticSection/Cruise_Report_for_Knorr_199_Final_v3.pdf
Start Date	2010-10-15
End Date	2010-11-04
Description	<p>KN199-04 is the US GEOTRACES Zonal North Atlantic Survey Section cruise planned for late Fall 2010 from Lisboa, Portugal to Woods Hole, MA, USA. 4 November 2010 update: Due to engine failure, the scheduled science activities were canceled on 2 November 2010. On 4 November the R/V KNORR put in at Porto Grande, Cape Verde and is scheduled to depart November 8, under the direction of Acting Chief Scientist Oliver Wurl of Old Dominion University. The objective of this leg is to carry the vessel in transit to Charleston, SC while conducting science activities modified from the original plan. Planned scientific activities and operations area during this transit will be as follows: the ship's track will cross from the highly productive region off West Africa into the oligotrophic central subtropical gyre waters, then across the western boundary current (Gulf Stream), and into the productive coastal waters of North America. During this transit, underway surface sampling will be done using the towed fish for trace metals, nanomolar nutrients, and arsenic speciation. In addition, a port-side high volume pumping system will be used to acquire samples for radium isotopes. Finally, routine aerosol and rain sampling will be done for trace elements. This section will provide important information regarding atmospheric deposition, surface transport, and transformations of many trace elements. The vessel is scheduled to arrive at the port of Charleston, SC, on 26 November 2010. The original cruise was intended to be 55 days duration with arrival in Norfolk, VA on 5 December 2010. funding: NSF OCE award 0926423 Science Objectives are to obtain state of the art trace metal and isotope measurements on a suite of samples taken on a mid-latitude zonal transect of the North Atlantic. In particular sampling will target the oxygen minimum zone extending off the west African coast near Mauritania, the TAG hydrothermal field, and the western boundary current system along Line W. In addition, the major biogeochemical provinces of the subtropical North Atlantic will be characterized. For additional information, please refer to the GEOTRACES program Web site (GEOTRACES.org) for overall program objectives and a summary of properties to be measured. Science Activities include seawater sampling via GoFLO and Niskin carousels, in situ pumping (and filtration), CTDO2 and transmissometer sensors, underway pumped sampling of surface waters, and collection of aerosols and rain. Hydrography, CTD and nutrient measurements will be supported by the Ocean Data Facility (J. Swift) at Scripps Institution of Oceanography and funded through NSF Facilities. They will be providing an additional CTD rosette system along with nephelometer and LADCP. A trace metal clean Go-Flo Rosette and winch will be provided by the group at Old Dominion University (G. Cutter) along with a towed underway pumping system. List of cruise participants: [PDF] Cruise track: JPEG image (from Woods Hole Oceanographic Institution, vessel operator) Additional information may still be available from the vessel operator: WHOI cruise planning synopsis Cruise information and original data are available from the NSF R2R data catalog. ADCP data are available from the Currents ADCP group at the University of Hawaii: KN199-04 ADCP</p>

KN204-01

Website	https://www.bco-dmo.org/deployment/58786
Platform	R/V Knorr
Report	http://bcodata.whoi.edu/US_GEOTRACES/AtlanticSection/STS_Prelim_GT11_Doc.pdf
Start Date	2011-11-06
End Date	2011-12-11
Description	<p>The US GEOTRACES North Atlantic cruise aboard the R/V Knorr completed the section between Lisbon and Woods Hole that began in October 2010 but was rescheduled for November-December 2011. The R/V Knorr made a brief stop in Bermuda to exchange samples and personnel before continuing across the basin. Scientists disembarked in Praia, Cape Verde, on 11 December. The cruise was identified as KN204-01A (first part before Bermuda) and KN204-01B (after the Bermuda stop). However, the official deployment name for this cruise is KN204-01 and includes both part A and B. Science activities included: ODF 30 liter rosette CTD casts, ODU Trace metal rosette CTD casts, McLane particulate pump casts, underway sampling with towed fish and sampling from the shipboard "uncontaminated" flow-through system. Full depth stations are shown in the accompanying figure (see below). Additional stations to sample for selected trace metals to a depth of 1000 m are not shown. Standard stations are shown in red (as are the ports) and "super" stations, with extra casts to provide large-volume samples for selected parameters, are shown in green. Station spacing is concentrated along the western margin to evaluate the transport of trace elements and isotopes by western boundary currents. Stations across the gyre will allow scientists to examine trace element supply by Saharan dust, while also contrasting trace element and isotope distributions in the oligotrophic gyre with conditions near biologically productive ocean margins, both in the west, to be sampled now, and within the eastern boundary upwelling system off Mauritania, sampled last year. The cruise was funded by NSF OCE awards 0926204, 0926433 and 0926659. Additional information may be available from the vessel operator site, URL: http://www.whoi.edu/cruiseplanning/synopsis.do?id=1662. Cruise information and original data are available from the NSF R2R data catalog. ADCP data are available from the Currents ADCP group at the University of Hawaii at the links below: KN204-01A (part 1 of 2011 cruise; Woods Hole, MA to Bermuda) KN204-01B (part 2 of 2011 cruise; Bermuda to Cape Verde)</p>

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Project Information

U.S. GEOTRACES North Atlantic Transect (U.S. GEOTRACES NAT)

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

Coverage: Subtropical western and eastern North Atlantic Ocean

Much of this text appeared in an article published in OCB News, October 2008, by the OCB Project Office. The first U.S. GEOTRACES Atlantic Section will be specifically centered around a sampling cruise to be carried out in the North Atlantic in 2010. Ed Boyle (MIT) and Bill Jenkins (WHOI) organized a three-day planning workshop that was held September 22-24, 2008 at the Woods Hole Oceanographic Institution. The main goal of the workshop, sponsored by the National Science Foundation and the U.S. GEOTRACES Scientific Steering Committee, was to design the implementation plan for the first U.S. GEOTRACES Atlantic Section. The primary cruise design motivation was to improve knowledge of the sources, sinks and internal cycling of Trace Elements and their Isotopes (TEIs) by studying their distributions along a section in the North Atlantic (Figure 1). The North Atlantic has the full suite of processes that affect TEIs, including strong meridional advection, boundary scavenging and source effects, aeolian deposition, and the salty Mediterranean Outflow. The North Atlantic is particularly important as it lies at the "origin" of the global Meridional Overturning Circulation. It is well understood that many trace metals play important roles in biogeochemical processes and the carbon cycle, yet very little is known about their large-scale distributions and the regional scale processes that affect them. Recent advances in sampling and analytical techniques, along with advances in our understanding of their roles in enzymatic and

catalytic processes in the open ocean provide a natural opportunity to make substantial advances in our understanding of these important elements. Moreover, we are motivated by the prospect of global change and the need to understand the present and future workings of the ocean's biogeochemistry. The GEOTRACES strategy is to measure a broad suite of TEIs to constrain the critical biogeochemical processes that influence their distributions. In addition to these "exotic" substances, more traditional properties, including macronutrients (at micromolar and nanomolar levels), CTD, bio-optical parameters, and carbon system characteristics will be measured. The cruise starts at Line W, a repeat hydrographic section southeast of Cape Cod, extends to Bermuda and subsequently through the North Atlantic oligotrophic subtropical gyre, then transects into the African coast in the northern limb of the coastal upwelling region. From there, the cruise goes northward into the Mediterranean outflow. The station locations shown on the map are for the "fulldepth TEI" stations, and constitute approximately half of the stations to be ultimately occupied. Figure 1. The proposed 2010 Atlantic GEOTRACES cruise track plotted on dissolved oxygen at 400 m depth. Data from the World Ocean Atlas (Levitus et al., 2005) were plotted using Ocean Data View (courtesy Reiner Schlitzer). [click on the image to view a larger version] Hydrography, CTD and nutrient measurements will be supported by the Ocean Data Facility (J. Swift) at Scripps Institution of Oceanography and funded through NSF Facilities. They will be providing an additional CTD rosette system along with nephelometer and LADCP. A trace metal clean Go-Flo Rosette and winch will be provided by the group at Old Dominion University (G. Cutter) along with a towed underway pumping system. The North Atlantic Transect cruise began in 2010 with KN199 leg 4 (station sampling) and leg 5 (underway sampling only) (Figure 2). KN199-04 Cruise Report (PDF) Figure 2. The red line shows the cruise track for the first leg of the US Geotraces North Atlantic Transect on the R/V Knorr in October 2010. The rest of the stations (beginning with 13) will be completed in October-December 2011 on the R/V Knorr (courtesy of Bill Jenkins, Chief Scientist, GNAT first leg). [click on the image to view a larger version] The section completion effort resumed again in November 2011 with KN204-01A,B (Figure 3). KN204-01A,B Cruise Report (PDF) Figure 3. Station locations occupied on the US Geotraces North Atlantic Transect on the R/V Knorr in November 2011. [click on the image to view a larger version] Data from the North Atlantic Transect cruises are available under the Datasets heading below, and consensus values for the SAFE and North Atlantic GEOTRACES Reference Seawater Samples are available from the GEOTRACES Program Office: Standards and Reference Materials ADCP data are available from the Currents ADCP group at the University of Hawaii at the links below: KN199-04 (leg 1 of 2010 cruise; Lisbon to Cape Verde) KN199-05 (leg 2 of 2010 cruise; Cape Verde to Charleston, NC) KN204-01A (part 1 of 2011 cruise; Woods Hole, MA to Bermuda) KN204-01B (part 2 of 2011 cruise; Bermuda to Cape Verde)

U.S. GEOTRACES North Atlantic Section: CFC and SF6 Measurements (GT NAT CFC and SF6)

NSF Award Abstract: This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5). The objectives of the GEOTRACES program are: 1) to determine the global distributions of selected trace elements and isotopes and evaluate the sources, sinks and internal cycling of these species to better understand the physical, chemical and biological processes regulating their distributions, 2) to develop an understanding of the processes involved in oceanic trace element cycles sufficiently well that the response of these cycles to global change can be predicted and their impact on the carbon cycle and climate understood, and 3) 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. Understanding how the physical processes of advection, mixing, and water mass formation affect the distributions of trace elements and isotopes is critical to meeting these objectives. The evolving CFC and SF6 distributions in the ocean provide strong constraints on these processes. CFCs have been measured extensively in the global ocean for the past two and a half decades as part of several large scale oceanographic programs (e.g. SAVE, WOCE, CLIVAR) as well as many smaller programs and SF6 has become a standard measurement on the CLIVAR cruises. Measurement of CFCs and SF6 on the GEOTRACES program places the GEOTRACES data in the context of large scale ventilation patterns established by CFC/SF6 measurements on these cruises. In this project, researchers at the Lamont-Dougherty Earth Observatory of Columbia University will measure the CFC-11, CFC-12 and SF6 distributions along the US GEOTRACES North Atlantic cruise track. They will use these data to identify the most recently ventilated cores of the North Atlantic water masses, to estimate transit times of these water masses from their source regions, and to estimate oxygen consumption rates and rates of production or decomposition of selected trace elements measured on this program using the transit time information. Broader Impacts: In addition to providing information on ventilation and transit times for the GEOTRACES project, the CFC and SF6 data collected on this cruise will also expand the transient tracer data base for the North Atlantic Ocean. The data will be disseminated widely to the research community following NSF guidelines. Several CLIVAR cruises to the North Atlantic are planned for the 2010 - 2012 time period, and the GEOTRACES cruise will increase the coverage for CFCs and SF6. This database of the temporally evolving CFC and SF6 concentrations in the North Atlantic

Ocean is used in studies of the earth's climate and the ocean's role in the earth's climate and the global CO₂ cycle. It is used to validate models of ocean circulation and to quantify the uptake and storage of anthropogenic CO₂ in the ocean.

RAPID: Continuation of U.S. GEOTRACES North Atlantic Section: CFC and SF₆ Measurements (GT NAT RAPID CFC SF₆)

NSF Award Abstract: The U.S. GEOTRACES North Atlantic campaign cruise was launched from Lisbon on the R/V/ Knorr in October, 2010. Unfortunately, in mid-course, a problem with the propulsion system developed, and the cruise had to be aborted. The Knorr went to a shipyard in Charleston, SC for repairs where scientific equipment and samples were offloaded there and shipped back to the various home institutions of the various scientists. This project addresses the efforts of one investigator originally funded through an ARRA award to participate in the North Atlantic campaign -- to resume a set of essential observations when the field program resumes in November, 2011. With support through a Grant for Rapid Response Research (RAPID), a research team at the Lamont-Dougherty earth Observatory will measure the CFC-11, CFC-12 and SF₆ distributions along the autumn 2011 continuation of the previously aborted US GEOTRACES North Atlantic transect. They will use these data to identify the most recently ventilated cores of the North Atlantic water masses, to estimate transit times of these water masses from their source regions, and to estimate oxygen consumption rates and rates of production or decomposition of selected trace elements measured on this program using the transit time information. Such measurements are critically important to understanding how the physical processes of advection, mixing, and water mass formation affect the distributions of trace elements and isotopes in the ocean. The evolving CFC and SF₆ distributions in the ocean provide strong constraints on these processes. Measurement of CFCs and SF₆ on the GEOTRACES program places the GEOTRACES data in the context of large scale ventilation patterns established by CFC/SF₆ measurements on these cruises. Broader Impacts. In addition to providing information on ventilation and transit times for the GEOTRACES project, the CFC and SF₆ data collected on this cruise will also expand the transient tracer data base for the North Atlantic Ocean. The data will be disseminated widely to the research community following NSF guidelines. Several CLIVAR cruises to the North Atlantic are planned for the 2010 - 2012 time period, and the GEOTRACES cruise will increase the coverage for CFCs and SF₆. This database of the temporally evolving CFC and SF₆ concentrations in the North Atlantic Ocean is used in studies of the role of the ocean in global climate and the global CO₂ cycle. It is used to validate models of ocean circulation and to quantify the uptake and storage of anthropogenic CO₂ in the ocean. Such information is critical for society to make sound decisions on policies to deal with climate change.

Collaborative Research: Completing a 10-Year Record of Deep Western Boundary Current Observations at Line W; A Contribution to the Atlantic Meridional Overturning Circulation Study (DWBC Obs Line W)

NSF Award Abstract: Overview: Over the last decade, a growing international research effort has focused attention on the physical state of the Atlantic Meridional Overturning Circulation (AMOC), including its climatically-vital transports of heat, mass and tracers, and the causes and consequences of its variability. Begun in 2004, the Line W program - moored and shipboard measurements of the equatorward-flowing Deep Western Boundary Current (DWBC) and poleward-flowing Gulf Stream along an altimeter track between New England and Bermuda has acquired a remarkable 10-year time series of this component of the AMOC. The goals of this project are to conduct a final Line W cruise to recover the current meter array presently in the water and reoccupy the hydrographic section, to process the recovered sensor data to final form and refurbish the sea-going equipment, and to complete the scientific analysis of the Line W data set in conjunction with fellow AMOC investigators. Intellectual Merit: Property and transport time series generated by several AMOC programs are now approaching or exceeding a decade in length and are starting to provide truly unprecedented views of the AMOC's structure, strength and variability. Synthesizing these results and combining them with state estimate models will undoubtedly result in improved understanding of the mechanics, dynamics and impacts of AMOC variability. Key foci of this project's analysis effort include careful quantification of the local variability at Line W, estimating variations in net (coast-to-coast) meridional transport of selected water masses by combining Line W observations with interior-ocean data and via models, and investigating the meridional coherence of water property anomalies and AMOC fluctuations by comparing Line-W observations with water property observations and AMOC estimates at other latitudes. Broader Impacts: A graduate student in the MIT/WHOI Joint Program will be funded to complete her Ph.D. thesis that will be based on Line W. As in past years, several students and/or

postdocs will be involved in the final Line W cruise to gain hands-on experience with hydrographic sampling procedures and physical oceanographic mooring work. In this analysis and synthesis project, the original Line W investigators are entraining a new junior scientist into the research effort. This will introduce the investigator to new observational practices and associated data reduction and analysis procedures while bringing new expertise and viewpoints to the study. It is absolutely critical to observational physical oceanography that young investigators become fully versed in modern observational methods. The project's investigators will additionally continue to showcase Line W in public outreach events as a demonstration of ocean science and climate variation studies. Beyond these human elements, the Line W program is continuing to serve as a testbed for several emerging ocean measurement technologies and associated data processing procedures.

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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-0928612
NSF Division of Ocean Sciences (NSF OCE)	OCE-1132545
NSF Division of Ocean Sciences (NSF OCE)	OCE-1332834

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