Aerosol aluminum measurements from Tudor Hill, Bermuda collected November 2018 to March 2020 as part of the Bermuda Atlantic Iron Timeseries project

Website: https://www.bco-dmo.org/dataset/956140
Data Type: Other Field 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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Williams, Tara E.	Old Dominion University (ODU)	Student
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Abstract

These data include the atmospheric concentrations of aerosol aluminum (total, deionized-water-soluble, and dilute-acetic-acid-soluble) derived from analysis of composite aerosol samples collected during approximately weekly intervals on the sampling tower at Tudor Hill, Bermuda, between November 2018 and March 2020. The data allow estimates of the dry deposition of aluminum to the Bermuda region over the period of the BAIT project, which included cruises in the Bermuda Atlantic Time-series Study (BATS) region in March, May, August and November 2019. The aerosol samples were collected by staff of the Bermuda Institute of Ocean Sciences from the Tudor Hill tower facility that is managed by Dr. Andrew Peters with funding from NSF. Sample processing and analyses were completed in the laboratory of Dr. Peter Sedwick at Old Dominion University.

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Coverage

Location: Tudor Hill, Bermuda, 32.265°N, 64.879°W, sampling tower platform approx. 30 meters asl
Spatial Extent: **Lat**:32.2645 **Lon**:-64.879
Temporal Extent: 2018-11-26 - 2020-03-16

Methods & Sampling

Composite samples of bulk aerosol were collected atop the 23 meter height sampling tower at Tudor Hill, Bermuda (https://bios.asu.edu/tudorhill/facility-description), on an approximately weekly basis from November 2018 through March 2020, bracketing the four BAIT project cruises. A high-volume (~700 Liters per minute) air sampler was used to collect aerosoils on acid-cleaned Whatman-41 cellulose filters (8"x10", 20 µm nominal pore size), which collect particles as small as 1 µm with >90% efficiency (e.g., Stafford and Ettinger, 1972). The coastal Tudor Hill site faces into the prevailing southwesterly winds, so aerosols were only collected during winds >1 m s-1 from the 210°-315° sector in order to avoid local sources. Sample filters were stored in zip-lock polyethylene bags in a vacuum desiccator at room temperature. For analysis of total aerosol aluminum, 1/16 portions of the aerosol sample filters were digested with a mixture of ultrapure concentrated nitric and hydrofluoric acids and hydrogen peroxide (Fisher Optima) in Teflon vessels (Morton et al., 2013), using a microwave heating system (CEM MARS 6), then evaporated on a hot plate and diluted to volume with 2% (v/v) ultrapure nitric acid. The efficiency of this aerosol digestion procedure was verified using Arizona Test Dust (ISO 12103-1, A1 Ultrafine Test Dust, Powder Technologies, Inc.), which the GEOTRACES program recommends as a reference material for assessing digestion methodology for analysis of total aerosol trace elements. In digests of subsamples of this material, we measured 63878 ± 4485 ppm aluminum (n = 3), which compares well with the stated composition of 66153 ppm. Replicate 1/16 portions of the aerosol filters were also subjected to a flow-through leaching procedure modified from Buck et al. (2006). Briefly, the aerosol filter portions were placed atop an acid-washed 0.2 µm pore polycarbonate membrane filter loaded into a perfluoroalkoxy (PFA) resin filtrastion tower (Savillex), leached with 250 mL of high-purity deionized water (DIW, Barnstead Nanopure, >18.2 MΩ-cm resistivity), and the leachate acidified to 0.4% (v/v) with 6 M ultrapure hydrochloric acid (Fisher Optima) for analysis of "DIW-soluble aerosol aluminum". The same filter portions were then subjected to a batch leaching procedure modified from Kadko et al. (2019) using 25% acetic acid (HOAc, Fisher Optima) and 0.02 M hydroxylamine hydrochloride (Sigma) at 90°C, and the supernatant leachate was evaporated and then diluted in 2% ultrapure nitric acid (Fisher Optima) for analysis of "HOAc-soluble aerosol aluminum". Field blanks for the aerosols (an acid-cleaned filter) were deployed on the Tudor Hill tower and processed in the same manner as samples, but without operating the aerosol sampler pump.

Aluminum concentrations in aerosol digest solutions and aerosol leachate solutions were determined by inductively coupled plasma mass spectrometry without preconcentration, using calibration standards prepared in 2% ultrapure nitric acid (Fisher Optima, for aerosol digests and HOAc leachates) or 0.4% ultrapure hydrochloric acid (Fisher Optima, for DIW leachates) and yttrium as an internal standard. Field blank values for total aerosol aluminum, DIW-soluble aerosol aluminum and HOAc-soluble aerosol aluminum were 0.132, 0.627 and 0.033 µmol per filter, respectively, which equate to atmospheric loadings of 0.044, 0.209 and 0.011 nmol m-3 for a typical sampled air volume of around 3,000 m3. Limits of detection for aluminum in blank-corrected aerosol samples were estimated from three times the standard deviation on the mean of field blank values; the thus-defined limits of detection for total aerosol aluminum, DIW-soluble aerosol aluminum and HOAc-soluble aerosol aluminum were 0.063, 0.378 and 0.008 µmol per filter, respectively, which equate to atmospheric loadings of 0.021, 0.126 and 0.003 nmol m-3 for a typical sampled air volume of around 3,000 m3. Overall uncertainty on the total aerosol aluminum concentrations is less than ±10% (one-sigma), based on duplicate, separate-day analyses of filter digests. In the absence of duplicate samples for the aerosol leaches, we assume an overall analytical uncertainty of less than ±10% (one-sigma) for DIW-soluble and HOAc-soluble aerosol aluminum, similar to that estimated for total aerosol aluminum.

Data Processing Description

Field:
A Campbell Scientific CR 1000 data logging system using PC-based LoggerNet software was used for controlling peripherals, such as the wind speed and sector-control for the aerosol sampler, and for acquiring data such as pump running time and corresponding air flow rates (see: https://bios.asu.edu/tudorhill/facility-description).

Laboratory:
Inductively-coupled plasma mass spectrometer instrumental data were collected using ElementXR processing software (Thermo Fisher Scientific).
Post-analysis calculations were performed using Microsoft Excel

BCO-DMO Processing Description

- Imported data from source file "BAIT_Aerosol_Al_Data_9Feb25.xlsx" into the BCO-DMO data system. Data file imported using missing data identifier "ND"
- Replaced spaces and dashes with underscores in parameter (column) names
- Converted datetimes from local datetime (Atlantic/Bermuda Time) to ISO8601 format in UTC/GMT timezone
- Added latitude and longitude coordinates of Tudor Hill sampling tower

Problem Description

No aerosol samples were collected during the period of 16 September-October 14, 2019, owing to the passage of Hurricane Humberto and subsequent loss of electrical power at the Tudor Hill sampling site.

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Data Files

File	
956140_v1_aerosol_aluminum.csv	(Comma Separated Values (.csv), 5.99 KB) MD5:04e026bde30976bbcc5090241cb0c99a
Primary data file for dataset ID 956140, version 1; Aerosol aluminum measurements taken at Tudor Hill, Bermuda sampling tower between December 2018 and March 2020	

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Related Publications

Bermuda Institute of Ocean Sciences. (n.d.). Tudor Hill Facility Description. BIOS/Arizona State University Julie Ann Wrigley Global Futures Laboratory. Retrieved 2025-03-14 from https://bios.asu.edu/tudorhill/facility-description.
Related Research

Buck, C. S., Landing, W. M., Resing, J. A., & Lebon, G. T. (2006). Aerosol iron and aluminum solubility in the northwest Pacific Ocean: Results from the 2002 IOC cruise. Geochemistry, Geophysics, Geosystems, 7(4), n/a–n/a. doi:10.1029/2005gc000977
Methods

Kadko, D., Aguilar-Islas, A., Bolt, C., Buck, C. S., Fitzsimmons, J. N., Jensen, L. T., Landing, W. M., Marsay, C. M., Rember, R., Shiller, A. M., Whitmore, L. M., & Anderson, R. F. (2019). The residence times of trace elements determined in the surface Arctic Ocean during the 2015 US Arctic GEOTRACES expedition. Marine Chemistry, 208, 56–69. https://doi.org/10.1016/j.marchem.2018.10.011
Methods

Morton, P. L., Landing, W. M., Hsu, S.-C., Milne, A., Aguilar-Islas, A. M., Baker, A. R., ... Zamora, L. M. (2013). Methods for the sampling and analysis of marine aerosols: results from the 2008 GEOTRACES aerosol intercalibration experiment. Limnology and Oceanography: Methods, 11(2), 62–78. doi:10.4319/lom.2013.11.62
Methods

Stafford, R. G., & Ettinger, H. J. (1972). Filter efficiency as a function of particle size and velocity. Atmospheric Environment (1967), 6(5), 353–362. https://doi.org/10.1016/0004-6981(72)90201-6
Methods

Williams, T. E., Sedwick, P. N., Sohst, B. M., Buck, K. N., Caprara, S., Johnson, R. J., Ohnemus, D. C., Resing, J. A., Sofen, L. E., Tagliabue, A., & Twining, B. S. (2025) Dust deposition to the Sargasso Sea: A comparison of estimates using aluminum in the surface ocean versus aerosols and rainwater. (accepted for publication in Geophysical Research Letters).
Results

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Related Datasets

IsRelatedTo

Sedwick, P. N., Sohst, B. (2025) **Rainwater aluminum measurements of samples collected November 2018 to March 2020 at Tudor Hill, Bermuda as part of the Bermuda Atlantic Iron Timeseries project.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-03-19 doi:10.26008/1912/bco-dmo.956635.1 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
Aerosol_sample_ID	Unique identifier for each aerosol sample	unitless
Start_ISO_DateTime_UTC	Date and time when aerosol sampling began (GMT/UTC)	unitless
End_ISO_DateTime_UTC	Date and time when aerosol sampling ended (GMT/UTC)	unitless
Sampling_period	Number of days over which aerosols were collected	day
Pump_time	Number of hours the aerosol sampler pumps were running	hour
Air_volume	Total volume of air pumped through filter	liters (L)
Total_aerosol_Al	Atmospheric concentration of total aerosol aluminum	nanomoles per cubic meter (nmol m-3)
DIW_soluble_aerosol_Al	Atmospheric concentration of aerosol aluminum that is soluble in deionized water (DIW-soluble)	nanomoles per cubic meter (nmol m-3)
HOAc_soluble_aerosol_Al	Atmospheric concentration of aerosol aluminum that is soluble in acetic acid (HOAc-soluble)	nanomoles per cubic meter (nmol m-3)

Sample_flag	Data quality flag that applies to Pump time, Air volume, Total aerosol Al, DIW-soluble aerosol Al, and/or HOAc-soluble aerosol aluminum where 1=good sample; 2=flow-meter or sampler malfunction; 3=concentration of aluminum in DIW-leachate solution was less than that in corresponding field-blank leachate solution; in such cases the atmospheric loading of DIW-soluble aluminum was conservatively estimated using a leachate solution concentration equivalent to analytical limit of detection (i.e., 0.378 µmol per filter); 4=HOAc-soluble aluminum concentration below analytical limit of detection	unitless
Latitude	Latitude of Tudor Hill sampling tower	decimal degrees
Longitude	Longitude of Tudor Hill sampling tower	decimal degrees

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Instruments

Dataset-specific Instrument Name	Custom-built high-volume bulk aerosol sampler (University of Miami RSMAS)
Generic Instrument Name	Aerosol Sampler
Dataset-specific Description	A high-volume bulk aerosol sampler was custom built at the University of Miami Rosenstiel School of Marine, Atmospheric, and Earth Science.
Generic Instrument Description	A device that collects a sample of aerosol (dry particles or liquid droplets) from the atmosphere.

Dataset-specific Instrument Name	Campbell Scientific CR 1000 data logging system
Generic Instrument Name	Data Logger
Dataset-specific Description	A Campbell Scientific CR 1000 data logging system using PC-based LoggerNet software was used for controlling peripherals, such as the wind speed and sector-control for the aerosol sampler
Generic Instrument Description	Electronic devices that record data over time or in relation to location either with a built-in instrument or sensor or via external instruments and sensors.

Dataset-specific Instrument Name	CEM MARS 6
Generic Instrument Name	Microwave Digestion Platform
Dataset-specific Description	For analysis of total aerosol aluminum, 1/16 portions of the aerosol sample filters were digested with a mixture of ultrapure concentrated nitric and hydrofluoric acids and hydrogen peroxide using a CEM MARS 6 microwave heating system.
Generic Instrument Description	Microwave digestion is a chemical technique used to decompose sample material into a solution suitable for quantitative elemental analysis

Dataset-specific Instrument Name	Thermo Fisher Scientific ElementXR inductively coupled plasma mass spectrometer
Generic Instrument Name	Thermo Scientific ELEMENT XR high resolution inductively coupled plasma mass spectrometer
Dataset-specific Description	Aluminum concentrations in aerosol digest solutions and aerosol leachate solutions were determined using an inductively coupled plasma mass spectrometer (ThermoFisherScientific ElementXR)
Generic Instrument Description	A high-resolution (HR) inductively coupled plasma (ICP) mass spectrometer (MS) composed of a dual mode secondary electron multiplier (SEM) and a Faraday detector. The ELEMENT XR instrument has a dynamic range of 5 x 10^7 to 1 x 10^12 counts per second (cps), and allows simultaneous measurement of elements at concentrations over 1000 ug/g.

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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-1829833
NSF Division of Ocean Sciences (NSF OCE)	OCE-1829686

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