# Rainwater aluminum measurements of samples collected November 2018 to March 2020 at Tudor Hill, Bermuda as part of the Bermuda Atlantic Iron Timeseries project

**Website**: https://www.bco-dmo.org/dataset/956635
**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 |
|---|---|---|
| Sedwick, Peter N. | Old Dominion University (ODU) | Principal Investigator |
| Sohst, Bettina | Old Dominion University (ODU) | Technician |
| Gerlach, Dana Stuart | Woods Hole Oceanographic Institution (WHOI BCO-DMO) | BCO-DMO Data Manager |

**Abstract**

These data include total-dissolvable aluminum concentrations in rainwater and corresponding rainfall amounts for composite 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 wet 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 rain samples were collected by staff of the Bermuda Institute of Ocean Sciences (the Tudor Hill tower facility is managed by Dr. Andrew Peters, with funding from NSF), and sample processing and analyses were completed in the laboratory of Dr. Peter Sedwick at Old Dominion University.

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## Table of Contents

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## Coverage

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

### Methods & Sampling

Composite samples of bulk rainwater 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. Rainwater samples were collected in acid-cleaned 2-Liter wide-mouth fluorinated high-density polyethylene bottles (Nalgene) using an automatic rain sampler (N-Con Systems ADS 00-120); rain samples were subsequently acidified to 0.4% (v/v) with 6 M ultrapure hydrochloric acid (Fisher Optima) in the collection bottles, and then after two months the acidified, unfiltered samples were transferred into acid-cleaned 125 mL low-density polyethylene bottles (Nalgene) for analysis of "total-dissolvable Al" (TDAl; Tian et al. 2008). Field blanks for the rainwater (125 mL ultrapure deionized water) were deployed on the Tudor Hill tower and processed in the same manner as samples, but without opening the rain sampler.

Aluminum concentrations in the acidified rainwater were determined by inductively-coupled plasma mass spectrometry (ICP-MS, Thermo Fisher Scientific ElementXR) without preconcentration, using calibration standards prepared in 0.4% ultrapure hydrochloric acid (Fisher Optima) and yttrium as an internal standard. The field blank value for rainwater was 0.015 µmol TDAl, which equates to a concentration of 0.15 µmol $L^{-1}$TDAl for a typical rain sample volume of 100 mL. The limit of detection for aluminum in blank-corrected rain samples was estimated as 0.90 nmol per sample, from three times the standard deviation on the mean of replicate analyses of the single field blank (in the absence of a replicate field blank for rain). In the absence of duplicate samples for rainwater, we assume an overall uncertainty on TDAl concentrations of less than ±10% (one-sigma), based on duplicate, separate-day analyses of rain samples by ICP-MS.

### Data Processing Description

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_Rain_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 time (Atlantic/Bermuda Time) to ISO8601 format in UTC/GMT time zone
- Added latitude and longitude coordinates of Tudor Hill sampling tower

### Problem Description

For some sampling periods there were problems with the rain sampler closing, or with spillage and/or loss of the sample bottle, or issues with the rain gauge; in these cases data are labelled with a QC flag of 2. No rain 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.

[ table of contents | back to top ]

## Data Files

| File | |
|---|---|
| **956635_v1_rain_aluminum.csv** | (Comma Separated Values (.csv), 3.17 KB)<br>MD5:1b796b9f8e35c84f04c7f39bbc14748e |
| Primary data file for dataset ID 956635, version 1; Rainwater aluminum measurements taken at Tudor Hill, Bermuda sampling tower between November 2018 and March 2020 | |

[ table of contents | back to top ]

## Related Publications

Tian, Z., Ollivier, P., Véron, A., & Church, T. M. (2008). Atmospheric Fe deposition modes at Bermuda and the adjacent Sargasso Sea. Geochemistry, Geophysics, Geosystems, 9(8). Portico. https://doi.org/10.1029/2007gc001868 https://doi.org/10.1029/2007GC001868
*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*

[ table of contents | back to top ]

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## Related Datasets

### IsRelatedTo

Sedwick, P. N., Sohst, B., Williams, T. E. (2025) **Aerosol aluminum measurements from Tudor Hill, Bermuda collected December 2018 to March 2020 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.956140.1 [view at BCO-DMO]

[ table of contents | back to top ]

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## Parameters

| Parameter | Description | Units |
|---|---|---|
| Sample_ID | Unique identifier for each rainwater sample | unitless |
| Start_Date | Date when rainwater sampling began | unitless |
| End_Date | Date when rainwater sampling ended | unitless |
| Sampling_period | Number of days over which rainwater was collected | day |
| TDAl | Total-Dissolvable Aluminum concentration | nanomoles per liter (nmol L-1) |
| Rainfall | Rainfall during sampling period (from rain gauge) | millimeters (mm) |
| Sample_flag | Data quality flag that applies to TDAl and/or Rainfall, where 1=good sample; 2=rain sample or rain gauge malfunction; 3=sample volume insufficient for analysis | unitless |
| Latitude | Latitude of Tudor Hill sampling tower | decimal degrees |
| Longitude | Longitude of Tudor Hill sampling tower | decimal degrees |

[ table of contents | back to top ]

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## Instruments

| | |
|---|---|
| **Dataset-specific Instrument Name** | Rain gauge |
| **Generic Instrument Name** | Precipitation Gauge |
| **Dataset-specific Description** | For some sampling periods there were problems with the rain sampler closing, or issues with the rain gauge |
| **Generic Instrument Description** | measures rain or snow precipitation |

| | |
|---|---|
| **Dataset-specific Instrument Name** | N-Con Systems ADS 00-120 |
| **Generic Instrument Name** | Precipitation Sampler |
| **Dataset-specific Description** | Rainwater samples were collected in acid-cleaned bottles using an automatic rain sampler (N-Con Systems ADS 00-120) |
| **Generic Instrument Description** | A device that collects a sample of precipitation (rain, hail or snow) as it falls. |

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|---|---|
| **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. |

[ table of contents | back to top ]

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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).

[ table of contents | back to top ]

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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.

[ table of contents | back to top ]

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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 |

[ table of contents | back to top ]