Atmospheric concentrations of aerosol iron from samples collected at Tudor Hill Bermuda between November 2018 and March 2020.

Website: https://www.bco-dmo.org/dataset/906770
Data Type: Other Field Results
Version: 1
Version Date: 2023-08-26

Project
» Operation of a Community Marine-Atmospheric Sampling Facility at Tudor Hill, Bermuda (THMAO)
» NSFGEO-NERC: Collaborative Research: Using Time-series Field Observations to Constrain an Ocean Iron Model (BAIT)

Programs
» United States Surface Ocean Lower Atmosphere Study (U.S. SOLAS)
» U.S. GEOTRACES (U.S. GEOTRACES)

Contributors	Affiliation	Role
Sedwick, Peter N.	Old Dominion University (ODU)	Principal Investigator
Williams, Tara E.	Old Dominion University (ODU)	Student
Sohst, Bettina	Old Dominion University (ODU)	Technician

Abstract
These data include the atmospheric concentrations of aerosol iron (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 iron 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.

Table of Contents

Coverage

Spatial Extent: **Lat**:32.265 **Lon**:-64.879
Temporal Extent: 2018-11-26 - 2020-03-16

Dataset Description

Weekly sampling was conducted at Tudor Hill, Bermuda from November 2018 to March 2020. The sampling

tower platform is approximately 30 meters above sea level with coordinates of 32.265°N, 64.879°W.

Methods & Sampling

Composite samples of bulk aerosol were collected atop the 23 meter height sampling tower at Tudor Hill, Bermuda, on an approximately weekly basis from November 2018 through March 2020, bracketing the four BAIT project cruises. A high-volume (~700 L min^{-1}) air sampler was used to collect aerosols 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 (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 iron, 1/16th 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. 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 filtration 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 iron". 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 iron". 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.

Iron concentrations in aerosol digest solutions and aerosol leachate solutions were determined by ICP-MS 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 iron, DIW-soluble aerosol iron and HOAc-soluble aerosol iron were 0.105, 0.018 and 0.028 µmol per filter, respectively, which equate to atmospheric loadings of 0.035, 0.006 and 0.009 nmol m^{-3} for a typical sampled air volume of around 3,000 m^3. Limits of detection for iron 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 were 0.159, 0.011 and 0.011 µmol per filter, for total aerosol iron, DIW-soluble aerosol iron and HOAc-soluble aerosol iron, respectively. Overall uncertainty on the total aerosol iron concentrations is less than ±25% (one-sigma), based on analyses of duplicate filter digests. Repeat ICP-MS analyses of iron in the aerosol leachate samples indicate an analytical uncertainty of less than ±5% (one-sigma). In the absence of duplicate samples for the aerosol leaches, we assume an overall analytical uncertainty of less than ±25% (one-sigma) for DIW-soluble and HOAc-soluble aerosol iron, similar to that estimated for total aerosol iron.

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

Data Processing Description

LabView software was used to control the aerosol sample collection and collect data on pump running time and corresponding air flow rates.

Inductively-coupled plasma mass spectrometer: Instrumental data were collected using ElementXR processing software (Thermo Fisher Scientific), and post-analysis calculations were performed using Microsoft Excel.

BCO-DMO Processing Description

- Imported data from source file "BAIT_Aerosol_Fe_Data.xlsx" into the BCO-DMO data system

- Added columns for latitude and longitude of sampling tower
- Modified parameter (column) names to conform with BCO-DMO naming conventions
- Replaced spaces with underscores in parameter (column) names
- Converted datetimes to UTC using ISO Date 8601 format

[table of contents | back to top]

Data Files

File
906770_v1_bait_aerosol_fe.csv (Comma Separated Values (.csv), 8.03 KB) MD5:b05cd7f067ffdb7feb734c3603988da1 Primary data file for dataset ID 906770 version 1

[table of contents | back to top]

Related Publications

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 https://doi.org/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

National Instruments Corporation (2011). LabView 2011, Service Pack 1, Version 11.0.1f2, 32-bit. Available from https://www.ni.com/pdf/manuals/lv2011SP1.html
Software

Sedwick, P. N., Sohst, B. M., Buck, K. N., Caprara, S., Johnson, R. J., Ohnemus, D. C., Sofen, L. E., Tagliabue, A., Twining, B. S., & Williams, T. E. (2023). Atmospheric Input and Seasonal Inventory of Dissolved Iron in the Sargasso Sea: Implications for Iron Dynamics in Surface Waters of the Subtropical Ocean. Geophysical Research Letters, 50(6). Portico. https://doi.org/10.1029/2022gl102594 https://doi.org/10.1029/2022GL102594
Results

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

[table of contents | back to top]

Parameters

Parameter	Description	Units
Latitude	Latitude of sampling tower at Tudor Hill, Bermuda	decimal degrees
Longitude	Longitude of sampling tower at Tudor Hill, Bermuda	decimal degrees
Aerosol_sample_ID	Unique identifier for each aerosol sample	unitless
Start_datetime_UTC	Start date of aerosol sampling in UTC using ISO8601 format	unitless
End_datetime_UTC	End date of aerosol sampling in UTC using ISO8601 format	unitless
Sampling_period	Number of days over which aerosols were collected	day
Pump_time	Length of time that aerosol pumps were running	hour
Air_volume	Total volume of air pumped through the filter	liter
Total_aerosol_Fe	Atmospheric concentration of total aerosol iron	nanomoles per cubic meter (nmol m-3)
DIW_soluble_aerosol_Fe	Atmospheric concentration of DIW-soluble aerosol iron	nanomoles per cubic meter (nmol m-3)
HOAc_soluble_aerosol_Fe	Atmospheric concentration of HOAc-soluble aerosol iron	nanomoles per cubic meter (nmol m-3)
Sample_flag	Data quality flag that applies to Pump time, Air volume, Total aerosol Fe, Rainfall, DIW-soluble aerosol Fe, and/or HOAc-soluble aerosol Fe (1=good, 2=flow-meter or sampler malfunction, 3=leachate iron concentration below analytical limit of detection)	unitless
Start_datetime_local	Local start date and time of aerosol sampling	unitless
End_datetime_local	Local end date and time of aerosol sampling	unitless

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	High-volume bulk aerosol sampler
Generic Instrument Name	Aerosol Sampler
Dataset-specific Description	A high-volume air sampler that was custom-built (University of Miami Rosenstiel School of Marine, Atmospheric, and Earth Science) was used to collect aerosols on acid-cleaned filters.
Generic Instrument Description	A device that collects a sample of aerosol (dry particles or liquid droplets) from the atmosphere.

Dataset-specific Instrument Name	Thermo Fisher Scientific ElementXR ICP-MS
Generic Instrument Name	Inductively Coupled Plasma Mass Spectrometer
Dataset-specific Description	Iron concentrations in acidified rainwater were determined by inductively-coupled plasma mass spectrometry (ICP-MS, Thermo Fisher Scientific ElementXR)
Generic Instrument Description	An ICP Mass Spec is an instrument that passes nebulized samples into an inductively-coupled gas plasma (8-10000 K) where they are atomized and ionized. Ions of specific mass-to-charge ratios are quantified in a quadrupole mass spectrometer.

[table of contents | back to top]

Project Information

Operation of a Community Marine-Atmospheric Sampling Facility at Tudor Hill, Bermuda (THMAO)

Website: https://tudorhill.bios.asu.edu/

Coverage: West Bermuda, 32.2646N 64.8791W

NSF Award OCE-2123053 Abstract:

This project supports the Tudor Hill Marine Atmospheric Observatory in Bermuda. Because of its location in the western North Atlantic Ocean, Bermuda has been an important location for many studies of the marine atmosphere. The observatory is well equipped for carrying out research, with field laboratories and a 23 meter tower at Tudor Hill. This allows scientists to study the chemistry and physics of the atmosphere over the oceans. This part of the atmosphere plays an important role in the transfer of moisture, chemicals, and energy between the ocean and the atmosphere. Routine work at the site includes the observation and recording of weather conditions, and sampling of rain and air. In addition, samples and data are collected for a number of research partners, including NOAA, NASA and many US and international universities. As well as supporting research, this project will provide a range of educational opportunities, including through the NSF-funded Research Experience for Undergraduates (REU) program, and through other internships and courses at the Bermuda Institute of Ocean Sciences.

The continued operation and maintenance of the Tudor Hill Marine Atmospheric Observatory facilitates research concerning the chemistry and physics of the marine troposphere and ocean-atmosphere exchange processes. The specific objectives of the project are to: 1) Operate and maintain the atmospheric sampling facility at Tudor Hill, Bermuda; 2) Continue collection of continuous meteorological data and weekly bulk-aerosol and rain samples, which will be archived at BIOS and made freely available to other researchers; and 3) Collect additional atmospheric samples and data for external investigators, and provide for the use of the facility by external investigators. Ongoing partner activities at the facility include monitoring and data acquisition for NASA (AERONET) and NOAA programs (Ozone and greenhouse gas monitoring), and a new sampling location will be established for the US National Atmospheric Deposition Program (NADP) in 2021. The THMAO site will enable research to be undertaken that is central to international initiatives such as IGAC, SOLAS and GEOTRACES. In a regional context, the Tudor Hill facility will complement ongoing oceanographic time-series research in the Sargasso Sea, including Hydrostation S and BATS.

NSF Award OCE-1829686 Abstract:

This project provides continuing support for the Tudor Hill Marine Atmospheric Observatory in Bermuda. The marine boundary layer, the lower level of the atmosphere over the oceans, plays important roles in the global cycles of many chemical elements and this observatory provides a unique facility for the ocean and atmospheric chemistry research communities. At present, many aspects of atmospheric composition, atmospheric transport, and atmosphere-ocean exchange remain poorly understood. This limits our ability to

predict and mitigate the effects of anticipated future environmental change. Central to improving our understanding of these topics is the ability to observe and sample the marine boundary layer. In this regard, oceanic island observatories have played a crucial role. By virtue of its location in the western North Atlantic Ocean, Bermuda has been a key location for numerous field studies of the marine troposphere and is well equipped for such research, with the 23 meter high atmospheric sampling tower and site laboratories at Tudor Hill. Routine facility operations include the collection of continuous meteorological data and weekly bulk aerosol and rainwater samples, which are archived at the Bermuda Institute of Ocean Sciences and made freely available to the scientific community. Additionally, samples and data are collected for a variety of external research programs funded by NSF, NOAA, NASA and other agencies. This project is expected to make significant educational contributions at a number of levels, including undergraduate education opportunities through the NSF-funded Research Experience for Undergraduates (REU) program, and through other courses taught at the Bermuda Institute of Ocean Sciences.

The continued operation and maintenance of THMAO site will facilitate research topics that are central to international research initiatives such as IGAC, SOLAS and GEOTRACES. The specific objectives of the project are to: 1) Operate and maintain the atmospheric sampling facility at Tudor Hill, Bermuda; 2) Continue collection of continuous meteorological data and weekly bulk-aerosol and rain samples, which will be archived at BIOS and made freely available to other researchers; and 3) Collect additional atmospheric samples and data for external investigators, and provide for the use of the facility by external investigators. The continued operation and maintenance of the Tudor Hill site facilitates research concerning the chemistry and physics of the marine troposphere and ocean-atmosphere exchange processes. In a regional context, the Tudor Hill facility will complement ongoing time-series research in the Sargasso Sea, including Hydrostation S and BATS.

NSF Award OCE-1735504 Abstract:

This award would provide a year of continuation funding for the Tudor Hill Marine Atmospheric Observatory in Bermuda. The lower level of the atmosphere over the oceans plays important roles in the global cycles of many chemical elements and this observatory provides a unique facility for the ocean and atmospheric chemistry research communities. At present, many aspects of atmospheric composition, atmospheric transport, and atmosphere-ocean exchange remain poorly understood. This limits our ability to predict and mitigate the effects of anticipated future environmental change. Central to improving our understanding of these topics is the ability to observe and sample the marine boundary layer. In this regard, oceanic island observatories have played a crucial role. By virtue of its location in the western North Atlantic Ocean, Bermuda has been a key location for numerous field studies of the marine troposphere and is well equipped for such research, with the 23-m high atmospheric sampling tower and site laboratories at Tudor Hill. Routine facility operations include the collection of continuous meteorological data and weekly bulk aerosol and rainwater samples, which are archived at the Bermuda Institute of Ocean Sciences and made freely available to the scientific community. Additionally, samples and data are collected for a variety of external research programs funded by NSF, NOAA, NASA and other agencies.

The specific objectives of the project are to: 1) Operate and maintain the atmospheric sampling facility at Tudor Hill, Bermuda; 2) Continue collection of continuous meteorological data and weekly bulk-aerosol and rain samples, which will be archived at BIOS and made freely available to other researchers; and 3) Collect additional atmospheric samples and data for external investigators, and provide for the use of the facility by external investigators. The continued operation and maintenance of the Tudor Hill site facilitates research concerning the chemistry and physics of the marine troposphere and ocean-atmosphere exchange processes. In a regional context, the Tudor Hill facility will complement ongoing time-series research in the Sargasso Sea, including Hydrostation S and BATS. This project is expected to make significant educational contributions at a number of levels, including undergraduate education opportunities through the NSF-funded Research Experience for Undergraduates (REU) program, and through other courses taught at BIOS.

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]

Program Information

United States Surface Ocean Lower Atmosphere Study (U.S. SOLAS)

Website: http://www.us-solas.org/

Coverage: Global

The Surface Ocean Lower Atmosphere Study (SOLAS) program is designed to enable researchers from different disciplines to interact and investigate the multitude of processes and interactions between the coupled ocean and atmosphere.

Oceanographers and atmospheric scientists are working together to improve understanding of the fate, transport, and feedbacks of climate relevant compounds, and also weather and hazards that are affected by processes at the surface ocean.

Oceanographers and atmospheric scientists are working together to improve understanding of the fate, transport, and feedbacks of climate relevant compounds.

Physical, chemical, and biological research near the ocean-atmosphere interface must be performed in synergy to extend our current knowledge to adequately understand and forecast changes on short and long time

frames and over local and global spatial scales.

The findings obtained from SOLAS are used to improve knowledge at process scale that will lead to better quantification of fluxes of climate relevant compounds such as CO2, sulfur and nitrogen compounds, hydrocarbons and halocarbons, as well as dust, energy and momentum. This activity facilitates a fundamental understanding to assist the societal needs for climate change, environmental health, weather prediction, and national security.

The US SOLAS program is a component of the International SOLAS program where collaborations are forged with investigators around the world to examine SOLAS issues ubiquitous to the world's oceans and atmosphere.

Â» International SOLAS Web site

Science Implementation Strategy Reports

US-SOLAS (4 MB PDF file)
Other SOLAS reports are available for download from the US SOLAS Web site

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]

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]