GP17-ANT aerosol and seawater beryllium-7 concentrations

Website: https://www.bco-dmo.org/dataset/1003205
Data Type: Cruise Results
Version: 1
Version Date: 2026-07-29

Project
» US GEOTRACES GP17-OCE and GP17-ANT: Atmospheric Deposition and Aerosol Fractional Solubility in Remote Ocean Regions (GP17-OCE and GP17-ANT Remote Ocean Aerosols)

Contributors	Affiliation	Role
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Abstract
Beryllium-7 (Be-7) is a radioactive isotope with a half-life of 53.3 days. It is formed in the atmosphere, attaches to aerosol particles, and is subsequently deposited to the Earth's surface by wet and dry deposition processes. As part of the GEOTRACES GP17-ANT project, we measured Be-7 concentrations in surface ocean seawater (depths <200 meters) samples collected from six stations and bulk aerosol particles collected across eight deployments in the Southern Ocean and Amundsen Sea region. Samples were collected aboard the research vessel ice breaker Nathaniel B. Palmer during cruise NBP2401 (29 November 2023 to 28 January 2024). The dataset will be used to calculate bulk atmospheric deposition velocities across the study region, based on the premise that Be-7 inventory in the surface ocean is controlled primarily by atmospheric deposition and radioactive decay. Thus, from the surface Be-7 inventory, its deposition flux can be determined, and from that and the aerosol Be-7 concentration, we can determine deposition velocity. The determined deposition velocity will then be used with aerosol concentrations of trace elements measured during the same study to determine rates of atmospheric supply of trace elements to the region.

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Coverage

Location: Amundsen Sea and Southern Ocean
Spatial Extent: **N**:-52.619 **E**:-63.926 **S**:-74.368 **W**:-176.366
Temporal Extent: 2023-12-01 - 2024-01-20

Methods & Sampling

Seawater sampling: Procedures used during GEOTRACES GP17-ANT were identical to those described for previous U.S. GEOTRACES cruises (Kadko, 2017; Kadko et al., 2020; He et al., 2025). Briefly, a centrifugal pump on deck was used to draw 500-750 liters (L) of seawater from predetermined depths via a 1.5-inch PVC hose to fill large plastic tanks on deck. Be-7 was then extracted by pumping this seawater through 200 grams of iron-

impregnated acrylic fibers at a flowrate of ~10 L per minute (Lai et al., 1988; Krishnaswami et al., 1972; Lee et al., 1991). A temperature/depth recorder was attached close to the end of the hose to confirm an accurate sampling depth.

Aerosol sampling: Bulk aerosol samples were collected following procedures described for previous U.S. GEOTRACES cruises (Shelley et al., 2015; Buck et al., 2019; Marsay et al., 2018, 2022). Briefly, for each deployment, one of five Tisch Environmental high-volume (~1 cubic meter air per minute) aerosol samplers was loaded with 12 replicate 47-millimeter (mm) diameter Whatman 41 filters on open-face filter holders (Advantec MFS) installed on a PVC adaptor plate (Shelley et al., 2015). Filters were acid-washed before use to lower trace element blanks (Morton et al., 2013). Samplers were installed above the bridge of RVIB Nathaniel B. Palmer and operation was controlled by wind speed and direction through a Campbell Scientific CR800 data-logger interfaced with a sonic anemometer set up alongside the samplers. In this way, sampling was restricted to periods when relative wind speed and direction were >0.5 meters per second and from within ±60 degrees of the bow of the ship for at least five continuous minutes.

Analytical procedures: Samples were counted for Be-7 using low-background germanium gamma detectors at Florida International University (FIU). For aerosols, three replicate filters from each deployment were stacked in a petri dish for counting. For seawater, the fibers were dried and then ashed. The iron hydroxide powder remaining after ashing was pressed into a 5.8-centimeter (cm) diameter pellet and the pellet thickness measured, then placed in a petri dish for counting. Be-7 has a readily identifiable peak at 478 kiloelectron volts (keV), and the spectra were evaluated using Maestro (Ortec) or Genie 2000 Canberra software. The detectors were calibrated for each geometry by adding a commercially prepared mixed isotope solution of known gamma activities (Eckert & Ziegler Mixed Nuclide Solution 7500) to three W41 filters (for aerosol samples) and pellets of various thickness (for seawater samples) to derive calibration curves using peaks associated with the following isotopes: Sn-113 at 392 keV, Sr-85 at 514 keV, Cs-137 at 662 keV. Counting efficiencies of the four detectors at FIU ranged from 0.035304 to 0.05686 for Be-7 on aerosol filters, and from 0.07873 to 0.083779 for pellets derived from seawater samples.

Data Processing Description

Reported Be-7 activities were corrected to the time of sampling, using the following calculation:

$[\text{Be-7, dpm m}^{-3}] = \{cpm \bullet ct \bullet \lambda \bullet \exp(\lambda \bullet d)\}/\{CE \bullet PE \bullet FE \bullet V \bullet [1-\exp(-\lambda \bullet ct)]\}$
where:

cpm = background corrected counts per minute for the region of interest

ct = count time (days)

λ = radioactive decay constant of Be-7 ($0.013\ d^{-1}$)

d = time from sample collection to start of count (days)

CE = counting efficiency

PE = photon emission probability (0.104 for Be-7)

FE = fiber extraction efficiency (92±3%)

V = volume (m^3)

Activity counts were converted from dpm to Bq for submission to BCO-CMO. The error (counts) associated with each measurement is the statistical counting error (σ) and the uncertainty in the blank, $\sqrt{(\sigma^2 + \sigma_b^2)}$, multiplied by $\{ct \bullet \lambda \bullet \exp(\lambda \bullet d)\}/\{CE \bullet PE \bullet FE \bullet V \bullet [1-\exp(-\lambda \bullet ct)]\}$. The uncertainty of the extraction efficiency (3%) and the detector efficiency (2%) was in all cases smaller than the statistical counting error.

Quality flags: Quality flags were applied following the GEOTRACES policy (https://www.geotraces.org/geotraces-quality-flag-policy/), which recommends the SeaDataNet Scheme:

0 = no quality control;
1 = good value;
2 = probably good value;
3 = probably bad value;
4 = bad value;
5 = changed value;

6 = value below detection;
7 = value in excess;
8 = interpolated value;
9 = missing value;
A = value phenomenon uncertain.

BCO-DMO Processing Description

- Imported original file "NBP2401_Be7 data_BCODMO.xlsx" (sheet 1) into the BCO-DMO processing system.
- Treated "NaN" as missing values (missing values are empty/blank in the final CSV file).
- Renamed fields to comply with BCO-DMO naming conventions.
- Combined "Start_Date_UTC" (format %m-%d-%y) and "Start_Time_UTC" (%H:%M:%S) into a new ISO 8601 datetime column "Start_ISO_DateTime_UTC" (format %Y-%m-%dT%H:%M:%SZ, UTC).
- Combined "End_Date_UTC" and "End_Time_UTC" into a new ISO 8601 datetime column "End_ISO_DateTime_UTC" (format %Y-%m-%dT%H:%M:%SZ, UTC).
- Reformatted "Start_Date_UTC" from %m-%d-%y to %Y-%m-%d; reformatted "End_Date_UTC" similarly.
- Saved the final file as "1003205_v1_gp17-ant_aerosol_and_seawater_be7.csv".

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Related Publications

Buck, C. S., Aguilar-Islas, A., Marsay, C., Kadko, D., & Landing, W. M. (2019). Trace element concentrations, elemental ratios, and enrichment factors observed in aerosol samples collected during the US GEOTRACES eastern Pacific Ocean transect (GP16). Chemical Geology, 511, 212–224. https://doi.org/10.1016/j.chemgeo.2019.01.002
Methods

He, Y., Kadko, D. C., Stephens, M. P., Sheridan, M. T., Buck, C. S., Marsay, C. M., Landing, W. M., Zheng, M., & Liu, P. (2025). Constraining aerosol deposition over the global ocean. Nature Geoscience, 18(10), 966–974. https://doi.org/10.1038/s41561-025-01785-2
Methods

Kadko, D. (2017). Upwelling and primary production during the U.S. GEOTRACES East Pacific Zonal Transect. Global Biogeochemical Cycles. doi:10.1002/2016gb005554 https://doi.org/10.1002/2016GB005554
Methods

Kadko, D., Landing, W. M., & Buck, C. S. (2020). Quantifying Atmospheric Trace Element Deposition Over the Ocean on a Global Scale With Satellite Rainfall Products. Geophysical Research Letters, 47(7). Portico. https://doi.org/10.1029/2019gl086357 https://doi.org/10.1029/2019GL086357
Methods

Krishnaswami, S., Lal, D., Somayajulu, B. L. K., Dixon, F. S., Stonecipher, S. A., & Craig, H. (1972). Silicon, radium, thorium, and lead in seawater: In-situ extraction by synthetic fibre. Earth and Planetary Science Letters, 16(1), 84–90. doi:10.1016/0012-821x(72)90240-3
Methods

Lai, D., Chung, Y., Platt, T., & Lee, T. (1988). Twin cosmogenic radiotracer studies of phosphorus recycling and chemical fluxes in the upper ocean. Limnology and Oceanography, 33(6part2), 1559–1567. doi:10.4319/lo.1988.33.6part2.1559
Methods

Lee, T., Barg, E., & Lal, D. (1991). Studies of vertical mixing in the Southern California Bight with cosmogenic radionuclides 32P and 7Be. Limnology and Oceanography, 36(5), 1044–1052. doi:10.4319/lo.1991.36.5.1044
Methods

Marsay, C. M., Kadko, D., Landing, W. M., & Buck, C. S. (2022). Bulk Aerosol Trace Element Concentrations and Deposition Fluxes During the U.S. GEOTRACES GP15 Pacific Meridional Transect. Global Biogeochemical Cycles, 36(2). Portico. https://doi.org/10.1029/2021gb007122
Methods

Marsay, C. M., Kadko, D., Landing, W. M., Morton, P. L., Summers, B. A., & Buck, C. S. (2018). Concentrations, provenance and flux of aerosol trace elements during US GEOTRACES Western Arctic cruise GN01. Chemical Geology. doi:10.1016/j.chemgeo.2018.06.007
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

Shelley, R. U., Morton, P. L., & Landing, W. M. (2015). Elemental ratios and enrichment factors in aerosols from the US-GEOTRACES North Atlantic transects. Deep Sea Research Part II: Topical Studies in Oceanography, 116, 262–272. doi:10.1016/j.dsr2.2014.12.005
Methods

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Parameters

Parameter	Description	Units
Station_ID	Station number (no station number for aerosol samples)	unitless
Event_ID	Event number in GP17-ANT cruise log	unitless
Start_ISO_DateTime_UTC	Date and time (UTC) at start of sample collection in ISO 8601 format	unitless
Start_Date_UTC	Sample collection start date (UTC)	unitless
Start_Time_UTC	Sample collection start time (UTC)	unitless
End_ISO_DateTime_UTC	Date and time (UTC) at end of sample collection in ISO 8601 format	unitless
End_Date_UTC	Sample collection end date (UTC)	unitless
End_Time_UTC	Sample collection end date (UTC)	unitless
Start_Latitude	Latitude at start of sample collection (North is positive)	Decimal degrees
Start_Longitude	Longitude at start of sample collection (East is positive)	Decimal degrees
End_Latitude	Latitude at end of sample collection (North is positive)	Decimal degrees
End_Longitude	Longitude at end of sample collection (East is positive)	Decimal degrees
Sample_ID	GEOTRACES sample number	unitless

Sample_Depth	Depth of seawater sample	meters (m)
Be_7_D_CONC_PUMP_6lx09j	Seawater beryllium-7 activity concentration	microBecquerel per kilogram (µBq/kg)
SD1_Be_7_D_CONC_PUMP_6lx09j	One standard deviation for Be_7_D_CONC_PUMP_6lx09j	microBecquerel per kilogram (µBq/kg)
Flag_Be_7_D_CONC_PUMP_6lx09j	Quality flag for Be_7_D_CONC_PUMP_6lx09j	unitless
Be_7_A_T_CONC_HIVOL_i4ryrh	Aerosol beryllium-7 activity concentration	milliBecquerel per cubic meter (mBq/m^3)
SD1_Be_7_A_T_CONC_HIVOL_i4ryrh	One standard deviation for Be_7_A_T_CONC_HIVOL_i4ryrh	milliBecquerel per cubic meter (mBq/m^3)
Flag_Be_7_A_T_CONC_HIVOL_i4ryrh	Quality flag for Be_7_A_T_CONC_HIVOL_i4ryrh	unitless

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Instruments

Dataset-specific Instrument Name	Tisch aerosol sampler (model TE-5170-BL)
Generic Instrument Name	Aerosol Sampler
Dataset-specific Description	High-volume (~1 cubic meter per minute) aerosol sampler with a brushless motor.
Generic Instrument Description	A device that collects a sample of aerosol (dry particles or liquid droplets) from the atmosphere.

Dataset-specific Instrument Name	R.M. Young anemometer (model RMY86004)
Generic Instrument Name	Anemometer
Dataset-specific Description	Sonic anemometer interfaced with the aerosol samplers to control operation with respect to wind speed and direction.
Generic Instrument Description	An anemometer is a device for measuring the velocity or the pressure of the wind. It is commonly used to measure wind speed. Aboard research vessels, it is often mounted with other meteorological instruments and sensors.

Dataset-specific Instrument Name	Campbell Scientific datalogger
Generic Instrument Name	Data Logger
Dataset-specific Description	Interfaced with the aerosol sampler and anemometer to control the aerosol sampler and to log sampler runtime.
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	Low background germanium gamma detectors
Generic Instrument Name	Germanium detector
Dataset-specific Description	Four detectors at Florida International University were used to measure Be-7 activity in aerosol and seawater samples.
Generic Instrument Description	Germanium detectors are semiconductor diodes having a p-i-n structure in which the intrinsic (i) region is sensitive to ionizing radiation, particularly x rays and gamma rays. Under reverse bias, an electric field extends across the intrinsic or depleted region. When photons interact with the material within the depleted volume of a detector, charge carriers (holes and electrons) are produced and are swept by the electric field to the p and n electrodes. This charge, which is in proportion to the energy deposited in the detector by the incoming photon, is converted into a voltage pulse by an integral charge sensitive preamplifier. Germanium detectors are mostly used for gamma spectroscopy in nuclear physics, as well as x-ray spectroscopy.

Dataset-specific Instrument Name	Centrifugal pump (Dayton 1D872)
Generic Instrument Name	Pump
Dataset-specific Description	A 1hp centrifugal shallow well pump used on deck to pull seawater from depths of
Generic Instrument Description	A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps

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Deployments

NBP2401

Website	https://www.bco-dmo.org/deployment/969543
Platform	RVIB Nathaniel B. Palmer
Report	https://www.bodc.ac.uk/resources/inventories/cruise_inventory/reports/nathanielbpalmer_nbp2401.pdf
Start Date	2023-11-28
End Date	2024-01-28
Description	See more information at: R2R https://www.rvdata.us/search/cruise/NBP2401 BODC https://www.bodc.ac.uk/resources/inventories/cruise_inventory/report/18091/ US GEOTRACES https://usgeotraces.ldeo.columbia.edu/content/gp17-ant Description: The U.S. GEOTRACES GP17-ANT expedition departed Punta Arenas, Chile on November 29th, 2023 and arrived in Lyttelton, New Zealand on January 28th, 2024. The cruise took place in the Amundsen Sea aboard the R/V Nathaniel B. Palmer with a team of 35 scientists led by Peter Sedwick (Old Dominion University), Phoebe Lam (University of California, Santa Cruz), and Robert Sherrell (Rutgers University). GP17 was planned as a two-leg expedition, with its first leg (GP17-OCE) as a southward extension of the 2018 GP15 Alaska-Tahiti expedition and this second leg (GP17-ANT) into coastal and shelf waters of Antarctica's Amundsen Sea.

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Project Information

US GEOTRACES GP17-OCE and GP17-ANT: Atmospheric Deposition and Aerosol Fractional Solubility in Remote Ocean Regions (GP17-OCE and GP17-ANT Remote Ocean Aerosols)

Coverage: Amundsen Sea and Southern Ocean

NSF Award Abstract:
Trace Elements are defined by their low concentrations in the open ocean and their addition and removal rates are key uncertainties in our understanding of ocean chemistry. In spite of their scarcity, trace elements can play an outsized role in determining where living things thrive in the open ocean. Near the coasts, these elements may be found in abundance because of features like rivers which bring source material from the continents to the ocean. Far from land, however, trace elements are scarce. The most significant source of these elements to the open ocean may come from dust and other particles falling onto the surface water either directly, or within rain droplets. An improved understanding of this process will further knowledge of element cycling in the ocean, including the carbon cycle. This project will sample the atmosphere of the South Pacific Ocean and the Pacific sector of the Southern Ocean around Antarctica. Input from the atmosphere to these waters is not well known and the research results will provide much needed information to the scientific community. This project will support an early career researcher as well as a graduate student.

The deposition and subsequent dissolution of aerosols in surface waters remains a critical research area in the oceanographic community. Much of the ocean remains poorly sampled and improvements in flux estimates, chemical characterization, and fractional solubility estimates are necessary to improve the understanding of this important trace element source. This project will include a cruise in the South Pacific Ocean and one in the Amundsen Sea sector of the Southern Ocean, both as part of the GEOTRACES program. The cruise tracks will cover regions which lie downwind of dust producing regions of Australia and where atmospheric deposition could play a role in dictating distributions of trace elements in the water column. The flux of aerosols across the air-sea interface is a key research area within GEOTRACES and the broader oceanographic community. Flux from the atmosphere to the ocean is highly episodic making the capture of this important term difficult in the open ocean. Flux rates will be determined by the use of the cosmogenic isotope 7Be, providing a rate estimate for time scales longer than the cruise period. Aerosol trace element fractional solubility remains poorly constrained and is one of the reasons that biogeochemical models show poor agreement for marine trace element distributions. Aerosol dissolution will be tested in several solution of varying chemistry to provide a range of solubility estimates which are representative of conditions in precipitation, surface seawater, and in more aggressive environments which provide a high-end solubility estimate. Calculated terms like residence time are also poorly constrained due to this uncertainty. This project will address these questions by capturing bulk and size-fractionated aerosol samples as well as samples of precipitation. The study will advance understanding of dust and soluble aerosol trace element flux from the atmosphere to the ocean and provide contextual data for complimentary studies associated with these GEOTRACES section cruises.

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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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2049305

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