

Concentrations of size-fractionated particulate thorium and protactinium isotopes (Th-232, Th-230, Pa-231) in seawater collected during the U.S. GEOTRACES Arctic cruise (HLY1502, GN01) on USCGC Healy from August to October 2015

Website: <https://www.bco-dmo.org/dataset/834741>

Data Type: Cruise Results

Version: 2

Version Date: 2021-02-23

Project

» [U.S. Arctic GEOTRACES Study](#) (U.S. GEOTRACES Arctic)

» [Collaborative Research: U.S. GEOTRACES Arctic Section: Thorium-230, Thorium-232, and Protactinium-231 tracers of trace element supply and removal.](#) (GEOTRACES Arctic Th Pa)

Program

» [U.S. GEOTRACES](#) (U.S. GEOTRACES)

Contributors	Affiliation	Role
Anderson, Robert F.	Lamont-Doherty Earth Observatory (LDEO)	Principal Investigator
Edwards, R. Lawrence	University of Minnesota, Twin Cities (UMTC)	Principal Investigator
Cheng, Hai	University of Minnesota, Twin Cities (UMTC)	Co-Principal Investigator
Fleisher, Martin Q.	Lamont-Doherty Earth Observatory (LDEO)	Co-Principal Investigator
Vivancos, Sebastian M.	Lamont-Doherty Earth Observatory (LDEO)	Contact, Analyst
Li, Xianglei	University of Minnesota, Twin Cities (UMTC)	Analyst
Zhang, Pu	University of Minnesota, Twin Cities (UMTC)	Analyst
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract

This dataset contains concentrations of size-fractionated particulate thorium and protactinium isotopes (Th-232, Th-230, Pa-231) in seawater collected during the U.S. GEOTRACES Arctic cruise (HLY1502, GN01) on USCGC Healy from August to October 2015. This is compiled data produced by two laboratories with the following associations: Lamont-Doherty Earth Observatory of Columbia University (LDEO) and the University of Minnesota (UMN). All data have been deemed intercalibrated by the International GEOTRACES Standards and Intercalibration (S&I) Committee.

Table of Contents

- [Coverage](#)
- [Dataset Description](#)
 - [Acquisition Description](#)
 - [Processing Description](#)
- [Related Publications](#)
- [Parameters](#)
- [Instruments](#)

- [Deployments](#)
 - [Project Information](#)
 - [Program Information](#)
 - [Funding](#)
-

Coverage

Spatial Extent: N:89.997 E:178.927 S:60.224 W:-180

Temporal Extent: 2015-08-12 - 2015-10-08

Dataset Description

This dataset contains concentrations of size-fractionated particulate thorium and protactinium isotopes (Th-232, Th-230, Pa-231) in seawater collected during the U.S. GEOTRACES Arctic cruise (HLY1502, GN01) on USCGC Healy from August to October 2015. This is compiled data produced by two laboratories with the following associations: Lamont-Doherty Earth Observatory of Columbia University (LDEO) and the University of Minnesota (UMN). All data have been deemed intercalibrated by the International GEOTRACES Standards and Intercalibration (S&I) Committee.

Naming Conventions:

Parameter names in the form such as "Th_232_SPT_CONC_PUMP" are adopted based on a recommendation from the GEOTRACES community (<https://www.geotraces.org/parameter-naming-conventions/>).

The "small particulate" (SPT) data refers to the particle size class 0.8-51 μm and is sometimes also called the "suspended" size fraction. The "large particulate" (LPT) data refers to particles greater than 51 μm and is sometimes referred to as the "sinking" size fraction. The particulate samples were collected by in-situ pumping over two loaded filter holders/flowpaths. One filter holder/flowpath was loaded with paired 0.8 μm Pall Supor800 polyethersulfone filters behind a 51 μm Sefar polyester mesh prefilter ("Supor-side") and the other filter holder/flowpath was loaded with paired 1 μm Whatman QMA quartz fiber filters behind a 51 μm Sefar polyester mesh prefilter ("QMA-side") (see Xiang and Lam, 2020 for particulate sampling methodology). Analysis of the paired Supor filters represents a particle size class approximating 0.45-51 μm (Bishop et al., 2012), while the top filter alone represents 0.8-51 μm and it is this size class referred to here as the "small particulate" fraction. We measured a select number of top and bottom Supor filters separately for radionuclides and found that the bottom filters had radionuclide levels that were indistinguishable from procedural blanks ("dipped" filter blanks). Therefore, whether or not samples were analyzed as paired Supor filters, or the top Supor filter alone, we infer the "small particulate" data to represent the 0.8-51 μm particle size class or "suspended" size fraction. The "large particulate" data is based on the analysis of the QMA-side 51 μm Sefar polyester mesh prefilters. Only a selection of "large particulate" samples were analyzed and those analyses were all performed at the University of Minnesota (UMN).

Units of Measurement:

Radionuclide concentrations are given as micro-Becquerel ($10\text{e-}6$ Bq, μBq or micro-Bq) per kilogram seawater for Th-230 and Pa-231, and picomole ($10\text{e-}12$ mol, pmol) per kilogram seawater for Th-232. A Becquerel is the SI unit for radioactivity and is defined as 1 disintegration per second. These units are recommended by the GEOTRACES community.

Acquisition Description

Sampling Methods at Sea:

Sampling methods at sea followed the GEOTRACES cookbook (Cutter et al., 2017). Large-volume size-fractionated particulate samples were collected using McLane Research in-situ pumps (WTS-LV) that had been modified to accommodate two flowpaths (Lam and Morris, 2013). The wire-out was used to target depths during deployment and both a self-recording Seabird 19plus CTD deployed at the end of the line

and an RBR pressure logger attached to the pump at the middle of the line were used to correct for actual depths during pumping. The RBR was used for all casts in the entire cruise, whereas the CTD was only deployed in the northbound leg due to electronic problems.

Filter holders used were 142 mm-diameter "mini-MULVFS" style filter holders with two stages for two size fractions and multiple baffle systems designed to ensure even particle distribution and prevent particle loss (Bishop et al., 2012). One filter holder/flowpath was loaded with paired 0.8 μm Pall Supor800 polyethersulfone filters behind a 51 μm Sefar polyester mesh prefilter ("Supor-side") and the other filter holder/flowpath was loaded with paired 1 μm Whatman QMA quartz fiber filters behind a 51 μm Sefar polyester mesh prefilter ("QMA-side") (see Xiang and Lam, 2020 for particulate sampling methodology). Each cast also had "dipped" filter blanks deployed. These were the full filter sets (prefilter followed by paired Supor or paired QMA filters) sandwiched within a 1 μm polyester mesh filter, loaded into perforated polypropylene containers, attached with plastic cable ties to a pump frame, and deployed. "Dipped" filter blanks were exposed to seawater for the length of the deployment, processed and analyzed as regular samples, and thus functioned as full seawater particulate procedural blanks. For the "small particulate" dataset, we analyzed either quarter top (or bottom) Supor filter cuts (LDEO) or eighth paired Supor filter cuts (UMN) from the "dipped" Supor filter blanks from 1 or more depths for nearly every station (18 of 20). For the "large particulate" dataset, UMN analyzed eighth filter cuts from the "dipped" Sefar prefilter blanks from 1 or more depths for every station where samples were selected for analysis (10 of 10).

All filters and filter holders were acid leached prior to use according to methods recommended in the GEOTRACES cookbook (Cutter et al., 2017).

Analytical Methods at LDEO:

Quarter filter cuts of the Supor filters ("small particulate", 0.8-51 μm particle size class, "suspended" size fraction) were folded into 60 mL Teflon jars and weighed aliquots of artificial isotope yield monitors Th-229 (1 pg) and Pa-233 (0.05-0.12 pg) and 5 mg dissolved Fe were added to each sample, which then sat overnight in 5 mL concentrated (16 M) HNO₃ (Fisher Scientific OPTIMA grade). The next day, the filters were heated for ~1 hour at 180°C, at which point 4-5 mL of concentrated HClO₄ (Fisher Scientific OPTIMA grade) were added and the hot plate temperature was increased to 220°C. Samples were heated until dense white perchloric fumes appeared. After 10-20 minutes, the samples were covered with a Teflon watch glass. After 30-60 minutes, rapid oxidation of the Supor material would occur, at which point the Supor material was almost completely broken down. The watch glasses were removed and jar walls were rinsed down with 2 mL concentrated (16 M) HNO₃ (Fisher Scientific OPTIMA grade) and placed back on the hot plate at 220°C. Once the samples were back to fuming perchloric, 0.5 mL of concentrated HF (Fisher Scientific OPTIMA grade) were added to the samples and heated at 220°C back to perchloric fumes before another 0.25-0.50 mL of concentrated HF (Fisher Scientific OPTIMA grade) were added. Following the second addition of concentrated HF, the samples were dried down at 220°C to a viscous residue.

The sample residue was taken up in dilute (0.6 M) HCl and transferred to 50 mL centrifuge tubes with Milli-Q H₂O rinses. Then, ~1.5 mL of concentrated NH₄OH (Fisher Scientific OPTIMA grade) were added to raise the pH to 8.0-8.5 when iron (oxy)hydroxide precipitated. This precipitate was then centrifuged and the supernatant was decanted. The precipitate was then dissolved in concentrated (16 M) HNO₃ (Fisher Scientific OPTIMA grade), ready for a series of anion-exchange chromatography steps to purify Th and Pa, as outlined in Anderson et. al., 2012. The purified Th and Pa solutions were dried down at 180-200°C in the presence of 2 drops of concentrated HClO₄ (Fisher Scientific OPTIMA grade) and taken up in 0.5 mL of 0.16 M HNO₃/0.026 M HF for mass spectrometric analysis.

Concentrations of Th-232, Th-230 and Pa-231 were calculated by isotope dilution, relative to the calibrated tracers Th-229 and Pa-233 added at the beginning of sample processing. Analyses were carried out on a Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS, equipped with a high-performance Interface pump (Jet Pump Aridus I™), and specially designed sample (Jet) and skimmer (X) cones to ensure the highest possible sensitivity. All measurements were made in low resolution mode ($\Delta m/M \approx 300$), peak jumping in Escan mode across the central 5% of the flat-topped peaks. Measurements were made on a MasCom™ SEM; Th-229, Th-230, Pa-231, and Pa-233 were measured in Counting mode, while the Th-232 signals were large enough that they were measured in Analog mode. Two solutions of SRM129, a natural U standard, were run multiple times throughout each run. One solution was in a concentration range where U-238 and U-235 were both measured in Counting mode, allowing us to

determine the mass bias/amu (typical values varied from -0.6%/amu to 0.3%/amu). In the other, more concentrated solution, U-238 was measured in Analog mode and U-235 was measured in Counting mode, yielding a measurement of the Analog/Counting Correction Factor (typical values varied from 0.9 to 1.3). These corrections assume that the mass bias and Analog/Counting Correction Factor measured on U isotopes can be applied to Th and Pa isotope measurements. Each sample measurement was bracketed by measurement of an aliquot of the run solution (0.16 M HNO₃/0.026 M HF), which was used to correct for the instrumental background count rates. To correct for tailing of Th-232 into the minor Th and Pa isotopes, a series of Th-232 standards were run at concentrations bracketing the expected Th-232 concentrations in the samples. The analysis routine for these standards was identical to the analysis routine for samples, so we could see the changing beam intensities at the minor masses as we increased the concentration of the Th-232 standards. The Th-232 count rates in our Pa fractions were quite low after separation of Pa from Th during anion-exchange chromatography, reflecting mainly reagent blanks, compared to the Th-232 signal intensity in the Th fraction. The regressions of Th-229, Th-230, Pa-231, and Pa-233 signals as a function of the Th-232 signal in the standards was used to correct for tailing of Th-232 in samples. Only in rare cases was a tail correction of Th-232 on Pa-231 and Pa-233 necessary, while it was always the case that tail corrections of Th-232 on Th-229 and Th-230 were performed.

"Small particulate" samples (0.8-51 μm particle size class, "suspended" size fraction) were analyzed in batches of 15. Analysis of the paired Supor filters represents a particle size class approximating 0.45-51 μm (Bishop et al., 2012), while the top filter alone represents 0.8-51 μm and it is this size class referred to here as "small particulate". A selection of 14 top and bottom Supor filters were measured separately for radionuclides and it was found that the bottom filters had radionuclide levels that were indistinguishable from procedural blanks ("dipped" filter blanks). Therefore, whether or not samples were analyzed as paired Supor filters, or the top Supor filter alone, the "small particulate" data was inferred to represent the 0.8-51 μm particle size class or "suspended" size fraction. "Small particulate" samples were analyzed as top Supor filter alone and procedural blanks ("dipped" filter blanks) were analyzed as top or bottom Supor filter alone (top and bottom "dipped" filter blanks had radionuclide levels that were indistinguishable from one another). Procedural blanks were determined by analyzing "dipped" filter blanks, mentioned above, which represent the total blank associated with sample collection and handling in addition to the laboratory procedure. An aliquot of two intercalibrated working standard solutions of Th-232, Th-230, and Pa-231, SW STD 2010-1 referred to by Anderson et al. (2012) and SW STD 2015-1 which has ~ 6 times lower Th-232 activity, were added to separate acid-cleaned Teflon beakers along with weighed aliquots of Th-229 and Pa-233 spike. Spikes and SW STD were equilibrated for at least 1 day. They were then dried down and dissolved in concentrated (12 M) HCl (Fisher Scientific OPTIMA grade) for a series of anion-exchange chromatography and processed like a sample with each batch. Samples were corrected using the pooled average of all procedural blanks ("dipped" filter blanks) analyzed during processing of HLY1502 particulate samples. The average procedural blanks ("dipped" filter blanks) for the "small particulate" data from HLY1502 for a quarter filter cut of top (or bottom) Supor filters for Th-232, Th-230, and Pa-231 were 18.78 ± 7.42 pg, 0.89 ± 0.49 fg, and 0.04 ± 0.03 fg, respectively. The limit of detection (LOD) is the smallest quantity of each isotope in samples that can reliably be detected or that can be statistically distinguished from a procedural blank. The LOD was considered to be 2 standard deviations above the average of the procedural blanks. Our LOD for Th-232, Th-230, and Pa-231 were 33.61 pg, 1.86 fg, and 0.09 fg, respectively, or about 1.8x, 2.1x, and 2.5x greater than the blank amount, respectively.

Further details on analysis of seawater particulate radionuclides are given by Anderson et al. (2012).

Analytical Methods at UMN:

Eighth filter cuts of the paired (top and bottom) Supor filters ("small particulate", 0.8-51 μm particle size class, "suspended" size fraction) and the Sefar prefilters ("large particulate", >51 μm particle size class, "sinking" size fraction) were folded into 30 mL Teflon beaker and weighed aliquots of the artificial isotope yield monitors Th-229 (1 pg) and Pa-233 (0.2-0.6 pg) were added to the filters. Filters were then completely submerged in 20-25 mL of 7 M HNO₃ combined with 10 drops of concentrated HF, tightly covered with a Teflon threaded cap and heated for 10 hours at $\sim 90^\circ\text{C}$ so that the particulate sample was dissolved/leached under pressure. The leachate and the rinse solution (rinsed twice with ICP-MS solution, 0.16 M HNO₃/0.026 M HF) were then transferred to a second acid-cleaned Teflon beaker separate from the residual filter. Five drops of concentrated HClO₄ were then added to the leach solution in the second beaker. The original beaker walls and caps were washed with small amounts of weak HNO₃ and the

resulting solution added to the second beaker. The solution was then dried down and taken up in dilute (2 M) HCl and transferred to 15 mL centrifuge tubes along with a dilute (2 M) HCl rinse. About 0.5 mg of dissolved Fe (one drop of FeCl₃ solution with Fe³⁺ concentration at ~1%) and six to nine drops of concentrated NH₄OH were added to raise the pH to 8.0-8.5 at which time iron (oxy)hydroxide precipitated. This precipitate was then centrifuged, decanted, washed with deionized H₂O (>18 MΩ), centrifuged, dissolved in 14 M HNO₃, and transferred to a Teflon beaker.

It was then dried down and taken up in 7 M HNO₃ for anion-exchange chromatography using Bio-rad resin (AG1-X8, 100-200 mesh size) and a polyethylene frit. Initial separation was done on Teflon columns (internal diameter ~0.35 cm) with a 0.55 mL column volume (CV). The sample was loaded in 0.55 mL (1 CV) of 7 M HNO₃, followed by 0.825 mL (1.5 CV) of 7 M HNO₃ (to wash Fe and other undesired elements off the resin), 1.65 mL (3 CV) of 8 M HCl (to collect Th fraction), and 1.65 mL (3 CV) of 8 M HCl combined with 0.015 M HF (to collect Pa fraction). The Pa and Th fractions were then dried down in the presence of 2 drops of concentrated HClO₄ and taken up in 7 M HNO₃. They were each passed through second and third columns (each with 0.55 mL column volumes) using similar elution schemes. The final Pa and Th fractions were then dried down in the presence of 2 drops of concentrated HClO₄ and dissolved in weak nitric acid for analysis on the mass spectrometer.

Concentrations of Th-232, Th-230, and Pa-231 were calculated by isotope dilution using nuclide ratios determined on a Thermo-Finnigan Neptune Multicollector ICP-MS. All measurements were done using a peak jumping routine in ion Counting mode on the discreet dynode multiplier behind the retarding potential quadrupole. A solution of U-233-U-236 tracer was run to determine the mass bias correction (assuming that the mass fractionation for Th and Pa are the same as for U). Each sample measurement was bracketed by measurement of an aliquot of the run solution (weak nitric acid) used to correct for the instrument background count rates on the masses measured.

"Small particulate" (0.8-51 μm particle size class, "suspended" size fraction) and "large particulate" (>51 μm particle size class, "sinking" size fraction) samples were analyzed in batches of 37-39. Analysis of the paired Supor filters represents a particle size class approximating 0.45-51 μm (Bishop et al., 2012), while the top filter alone represents 0.8-51 μm and it is this size class referred to here as "small particulate". A selection of 14 top and bottom Supor filters were measured separately for radionuclides at LDEO and it was found that the bottom filters had radionuclide levels that were indistinguishable from procedural blanks ("dipped" filter blanks). Therefore, whether or not samples were analyzed as paired Supor filters, or the top Supor filter alone, the "small particulate" data was inferred to represent the 0.8-51 μm particle size class or "suspended" size fraction. "Small particulate" samples and procedural blanks ("dipped" filter blanks) were analyzed as paired Supor filters. Procedural blanks were determined by analyzing "dipped" filter blanks, mentioned above, which represent the total blank associated with the sample collection and handling in addition to the laboratory procedure. An aliquot of one of two intercalibrated working standard solutions of Th-232, Th-230, and Pa-231, SW STD 2010-1 referred to by Anderson et al. (2012) and SW STD 2015-1 which has ~6 times lower Th-232 activity, was added to a separate acid-cleaned Teflon beaker along with weighed aliquots of Th-229 and Pa-233 spike. Spikes and SW STD were equilibrated for 3 days. They were then dried down and taken up in 7 M HNO₃ for anion-exchange chromatography and processed like a sample with each batch. Samples were corrected using the pooled average of all procedural blanks ("dipped" filter blanks) analyzed during processing of HLY1502 particulate samples. The average procedural blanks ("dipped" filter blanks) for the HLY1502 "small particulate" dataset for an eighth filter cut of paired Supor filters for Th-232, Th-230, and Pa-231 were 11.36 ± 3.20 pg, 0.64 ± 0.30 fg, and 0.01 ± 0.01 fg, respectively. The average procedural blanks ("dipped" filter blanks) for the HLY1502 "large particulate" dataset for an eighth filter cut of Sefar prefilters for Th-232, Th-230, and Pa-231 were 12.55 ± 8.26 pg, 0.35 ± 0.15 fg, and 0.01 ± 0.01 fg, respectively. The limit of detection (LOD) is the smallest quantity of each isotope in samples that can reliably be detected or that can be statistically distinguished from a procedural blank. The LOD was considered to be 2 standard deviations above the average of the procedural blanks. For the HLY1502 "small particulate" dataset, our LOD for Th-232, Th-230, and Pa-231 were 17.76 pg, 1.23 fg, and 0.02 fg, respectively, or about 1.6x, 1.9x, and 1.9x greater than the blank amount, respectively. For the HLY1502 "large particulate" dataset, our LOD for Th-232, Th-230, and Pa-231 were 29.07 pg, 0.65 fg, and 0.04 fg, respectively, or about 2.3x, 1.8x, and 2.9x greater than the blank amount, respectively.

Further details on Pa and Th analysis at University of Minnesota are given in Shen et al. (2002, 2003,

2012), and Cheng et al. (2000, 2013).

Notes on Derived Parameters:

Th_230_SPT_XS_CONC_PUMP:

The small particulate excess Th-230 refers to the measured small particulate Th-230 corrected for a contribution of Th-230 originating from U-bearing minerals or lithogenic Th-230. Some of this lithogenic Th-230 will be still intact within minerals and some after partial dissolution will have adsorbed to particle surface to contribute in part to the total adsorbed Th-230. Using the measured small particulate Th-232 and a lithogenic Th-230/Th-232 ratio of 4.0e-6 (atom ratio) as determined by Roy-Barman et al. (2002), and not taking into account the fact that some of the measured particulate Th-232 is adsorbed, corrects for all of the lithogenic Th-230 whether it be adsorbed or within intact minerals. This excess Th-230 is what should be used in scavenging or particle flux studies where it is desired to compare particulate Th-230 concentrations to Th-230 production by decay of uranium dissolved in seawater. An additional conversion factor converts picomoles to micro-Becquerels.

$$\text{Th}_{230_SPT_XS_CONC_PUMP} = \text{Th}_{230_SPT_CONC_PUMP} - 4.0e-6 * 1.7473e5 * \text{Th}_{232_SPT_CONC_PUMP}$$

Pa_231_SPT_XS_CONC_PUMP:

The small particulate excess Pa-231 refers to the measured small particulate Pa-231 corrected for a contribution of Pa-231 originating from U-bearing minerals or lithogenic Pa-231. Some of this lithogenic Pa-231 will be still intact within minerals and some after partial dissolution will have adsorbed to particle surface to contribute in part to the total adsorbed Pa-231. Using the measured small particulate Th-232 and a lithogenic Pa-231/Th-232 ratio of 8.8e-8 (atom ratio) which is derived from assuming an average upper continental crustal U/Th ratio (Taylor and McClennan, 1995) and secular equilibrium between Pa-231 and U-235 in the lithogenic material, and not taking into account the fact that some of the measured particulate Th-232 is adsorbed, corrects for all of the lithogenic Pa-231 whether it be adsorbed or within intact minerals. This excess Pa-231 is what should be used in scavenging or particle flux studies where it is desired to compare particulate Pa-231 concentrations to Pa-231 production by decay of uranium dissolved in seawater. An additional conversion factor converts picomoles to micro-Becquerels.

$$\text{Pa}_{231_SPT_XS_CONC_PUMP} = \text{Pa}_{231_SPT_CONC_PUMP} - 8.8e-8 * 4.0370e5 * \text{Th}_{232_SPT_CONC_PUMP}$$

Th_230_LPT_XS_CONC_PUMP:

The large particulate excess Th-230 refers to the measured large particulate Th-230 corrected for a contribution of Th-230 originating from U-bearing minerals or lithogenic Th-230. Some of this lithogenic Th-230 will be still intact within minerals and some after partial dissolution will have adsorbed to particle surface to contribute in part to the total adsorbed Th-230. Using the measured large particulate Th-232 and a lithogenic Th-230/Th-232 ratio of 4.0e-6 (atom ratio) as determined by Roy-Barman et al. (2002), and not taking into account the fact that some of the measured particulate Th-232 is adsorbed, corrects for all of the lithogenic Th-230 whether it be adsorbed or within intact minerals. This excess Th-230 is what should be used in scavenging or particle flux studies where it is desired to compare particulate Th-230 concentrations to Th-230 production by decay of uranium dissolved in seawater. An additional conversion factor converts picomoles to micro-Becquerels.

$$\text{Th}_{230_LPT_XS_CONC_PUMP} = \text{Th}_{230_LPT_CONC_PUMP} - 4.0e-6 * 1.7473e5 * \text{Th}_{232_LPT_CONC_PUMP}$$

Pa_231_LPT_XS_CONC_PUMP:

The large particulate excess Pa-231 refers to the measured large particulate Pa-231 corrected for a contribution of Pa-231 originating from U-bearing minerals or lithogenic Pa-231. Some of this lithogenic Pa-231 will be still intact within minerals and some after partial dissolution will have adsorbed to particle surface to contribute in part to the total adsorbed Pa-231. Using the measured large particulate Th-232 and a lithogenic Pa-231/Th-232 ratio of 8.8e-8 (atom ratio) which is derived from assuming an average upper continental crustal U/Th ratio (Taylor and McClennan, 1995) and secular equilibrium between Pa-231 and U-235 in the lithogenic material, and not taking into account the fact that some of the measured particulate Th-232 is adsorbed, corrects for all of the lithogenic Pa-231 whether it be adsorbed or within

intact minerals. This excess Pa-231 is what should be used in scavenging or particle flux studies where it is desired to compare particulate Pa-231 concentrations to Pa-231 production by decay of uranium dissolved in seawater. An additional conversion factor converts picomoles to micro-Becquerels.

$$\text{Pa}_{231_LPT_XS_CONC_PUMP} = \text{Pa}_{231_LPT_CONC_PUMP} - 8.8\text{e-}8 * 4.0370\text{e}5 * \text{Th}_{232_LPT_CONC_PUMP}$$

Th_230_SPT_ADS_CONC_PUMP:

The small particulate adsorbed Th-230 concentration refers to the measured small particulate Th-230 corrected for a contribution of Th-230 locked within mineral lattices. To estimate the particulate Th-230 supported by decay of U within mineral lattices, we use measured small particulate Th-232 and a lithogenic Th-230/Th-232 ratio of 4.0e-6 (atom ratio) as determined by Roy-Barman et al. (2002). However, because some fraction of the Th-232 is also adsorbed (and not merely found within mineral lattices), we use the dissolved Th-232/Th-230 ratio to estimate the fraction of the small particulate Th-232 that is adsorbed and furthermore to calculate the correction for adsorbed Th-230. Conversion factors are also necessary to convert picomoles to micro-Becquerels. When dissolved Th data do not exist at the same depth as the particulate samples, we linearly interpolated the dissolved data onto the depths of the particulate samples. See Hayes et al. (2015) for more details.

$$\text{Th}_{230_SPT_ADS_CONC_PUMP} = [\text{Th}_{230_SPT_CONC_PUMP} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_SPT_CONC_PUMP}] / [1 - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_D_CONC_BOTTLE} / \text{Th}_{230_D_CONC_BOTTLE}]$$

Pa_231_SPT_ADS_CONC_PUMP:

The small particulate adsorbed Pa-231 concentration refers to the measured small particulate Pa-231 corrected for a contribution of Pa-231 locked within mineral lattices (as opposed to adsorbed onto particle surfaces). To estimate the particulate Pa-231 supported by decay of U within mineral lattices, we use measured small particulate Th-232 and a lithogenic Pa-231/Th-232 ratio of 8.8e-8 (atom ratio) which is derived from assuming an average upper continental crustal U/Th ratio (Taylor and McClennan, 1995) and secular equilibrium between Pa-231 and U-235 in the lithogenic material. However, because some fraction of the Th-232 is also adsorbed (and not merely found within mineral lattices), we use the dissolved and particulate Th-232/Th-230 ratio to estimate what fraction of the small particulate Th-232 is adsorbed and furthermore to calculate the correction for adsorbed Pa-231. Conversion factors are also necessary to convert picomoles to micro-Becquerels. When dissolved Pa data do not exist at the same depth as the particulate samples, we linearly interpolate the dissolved data onto the depths of the particulate samples. See Hayes et al. (2015) for more details.

$$\text{Pa}_{231_SPT_ADS_CONC_PUMP} = \text{Pa}_{231_SPT_CONC_PUMP} - 8.8\text{e-}8 * 4.0370\text{e}5 * (\text{Th}_{232_SPT_CONC_PUMP} - \text{Th}_{232_D_CONC_BOTTLE} * [(\text{Th}_{230_SPT_CONC_PUMP} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_SPT_CONC_PUMP}) / (\text{Th}_{230_D_CONC_BOTTLE} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_D_CONC_BOTTLE})])$$

Th_230_LPT_ADS_CONC_PUMP:

The large particulate adsorbed Th-230 concentration refers to the measured large particulate Th-230 corrected for a contribution of Th-230 locked within mineral lattices. To estimate the particulate Th-230 supported by decay of U within mineral lattices, we use measured large particulate Th-232 and a lithogenic Th-230/Th-232 ratio of 4.0e-6 (atom ratio) as determined by Roy-Barman et al. (2002). However, because some fraction of the Th-232 is also adsorbed (and not merely found within mineral lattices), we use the dissolved Th-232/Th-230 ratio to estimate what fraction of the large particulate Th-232 is adsorbed and furthermore to calculate the correction for adsorbed Th-230. Conversion factors are also necessary to convert picomoles to micro-Becquerels. When dissolved data do not exist at the same depth as the particulate samples, we linearly interpolated the dissolved data onto the depths of the particulate samples. See Hayes et al. (2015) for more details.

$$\text{Th}_{230_LPT_ADS_CONC_PUMP} = [\text{Th}_{230_LPT_CONC_PUMP} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_LPT_CONC_PUMP}] / [1 - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_D_CONC_BOTTLE} / \text{Th}_{230_D_CONC_BOTTLE}]$$

Pa_231_LPT_ADS_CONC_PUMP:

The large particulate adsorbed Pa-231 concentration refers to the measured large particulate Pa-231 corrected for a contribution of Pa-231 locked within mineral lattices (as opposed to adsorbed on to particle surfaces). To estimate the particulate Pa-231 supported by decay of U within mineral lattices, we use measured large particulate Th-232 and a lithogenic Pa-231/Th-232 ratio of 8.8e-8 (atom ratio) which is derived from assuming an average upper continental crustal U/Th ratio (Taylor and McLennan, 1995) and secular equilibrium between Pa-231 and U-235 in the lithogenic material. However, because some fraction of the Th-232 is also adsorbed (and not merely found within mineral lattices), we use the dissolved and particulate Th-232/Th-230 ratio to estimate what fraction of the large particulate Th-232 is adsorbed and furthermore to calculate the correction for adsorbed Pa-231. Conversion factors are also necessary to convert picomoles to micro-Becquerels. When dissolved Pa data do not exist at the same depth as the particulate samples, we linearly interpolate the dissolved data onto the depths of the particulate samples. See Hayes et al. (2015) for more details.

$$\text{Pa}_{231_LPT_ADS_CONC_PUMP} = \text{Pa}_{231_LPT_CONC_PUMP} - 8.8\text{e-}8 * 4.0370\text{e}5 * (\text{Th}_{232_LPT_CONC_PUMP} - \text{Th}_{232_D_CONC_BOTTLE} * [(\text{Th}_{230_LPT_CONC_PUMP} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_LPT_CONC_PUMP}) / (\text{Th}_{230_D_CONC_BOTTLE} - 4.0\text{e-}6 * 1.7473\text{e}5 * \text{Th}_{232_D_CONC_BOTTLE})])$$

Processing Description

Data Processing:

The reported errors for radionuclide concentrations represent the propagation of one sigma errors based on the standard isotope ratios collected by ICP-MS, estimated error in the Th-229 or Pa-233 spike concentration, and the blank correction of the individual isotopes. For each laboratory (LDEO and UMN), samples were corrected for blanks using the pooled average of all procedural blanks (or "dipped" filter blanks) analyzed during processing of HLY1502 seawater particulate samples.

Individual uncertainties for protactinium and thorium were calculated to include contributions from (a) blank correction using the variance of the blanks measured over the course of the analyses, (b) standard error of the ratios of the analysis (typically close to counting statistics) and (c) spike calibration. For protactinium we also included assessment of the correction from the yield correction, mass bias and instrument background. In order to assess the reproducibility of the procedure, repeat analyses were performed on the GEOTRACES 2010-1 and 2015-1 standards. For standards run alongside GN01 particulate samples at LDEO, the reproducibility for each isotope was 1.04% for Th-232, 0.88% for Th-230, and 1.97% for Pa-231 on SW STD 2010-1, and was 3.52% for Th-232, 0.82% for Th-230, and 2.32% for Pa-231 on SW STD 2015-1. At UMN, the reproducibility for each isotope was 1.09% for Th-232, 0.86% for Th-230, and 1.44% for Pa-231 on SW STD 2010-1, and was 0.34% for Th-232, 0.35% for Th-230, and 1.17% for Pa-231 on SW STD 2015-1.

Quality Flags:

SeaDataNet quality flags have been assigned to all measured and derived parameters. More information on SeaDataNet quality flags is available from GEOTRACES at <https://www.geotraces.org/geotraces-quality-flag-policy/> and from SeaDataNet at <https://www.seadatanet.org/Standards/Data-Quality-Control>. In summary:

- 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.

The SeaDataNet quality flags assigned to the derived parameters are based on the SeaDataNet quality flags assigned to the measured parameters and are defined as:

1 = good value = both Th-230 (Pa-231) and Th-232 are flagged as good (1);

2 = probably good value = either Th-230 (Pa-231) is flagged as good (1) and Th-232 is flagged as probably good (2), probably bad (3), or bad (4), or Th-230 (Pa-231) is flagged as probably good (2) and Th-232 is flagged as good (1), probably good (2), probably bad (3), or bad (4);

3 = probably bad value = Th-230 (Pa-231) is flagged as probably bad (3) and Th-232 is flagged as good (1), probably good (2), probably bad (3), or bad (4);

4 = bad value = Th-230 (Pa-231) is flagged as bad (4) and Th-232 is flagged as good (1), probably good (2), probably bad (3), or bad (4);

6 = value below detection = either or both Th-230 (Pa-231) and Th-232 are flagged as below detection (6) and neither are flagged as missing (9);

9 = missing value = either or both Th-230 (Pa-231) and Th-232 are flagged as missing (9).

Concentrations below the limit of detection (LOD) are indicated as "nd" and flagged with "6". The missing data identifier, "nd", also refers to no data available when flagged with "9" (i.e., no analysis).

BCO-DMO Processing:

- modified parameter names to conform with BCO-DMO naming conventions (replaced "::" with an underscore and changed "1SD" to "SD1");

- 2021-02-23: replaced with data file received 2021-01-28 (version 2); includes changes to some data values.

[[table of contents](#) | [back to top](#)]

Related Publications

Anderson, R. F., Fleisher, M. Q., Robinson, L. F., Edwards, R. L., Hoff, J. A., Moran, S. B., ... Francois, R. (2012). GEOTRACES intercalibration of ²³⁰Th, ²³²Th, ²³¹Pa, and prospects for ¹⁰Be. *Limnology and Oceanography: Methods*, 10(4), 179–213. doi:[10.4319/lom.2012.10.179](https://doi.org/10.4319/lom.2012.10.179)
Methods

Auro, M. E., Robinson, L. F., Burke, A., Bradtmiller, L. I., Fleisher, M. Q., & Anderson, R. F. (2012). Improvements to ²³²-thorium, ²³⁰-thorium, and ²³¹-protactinium analysis in seawater arising from GEOTRACES intercalibration. *Limnology and Oceanography: Methods*, 10(7), 464–474.

doi:[10.4319/lom.2012.10.464](https://doi.org/10.4319/lom.2012.10.464)

General

Bishop, J. K. B., Lam, P. J., & Wood, T. J. (2012). Getting good particles: Accurate sampling of particles by large volume in-situ filtration. *Limnology and Oceanography: Methods*, 10(9), 681–710.

doi:[10.4319/lom.2012.10.681](https://doi.org/10.4319/lom.2012.10.681)

Methods

Chen, J. H., Edwards, R. L., & Wasserburg, G. J. (1986). ²³⁸U, ²³⁴U and ²³²Th in seawater. *Earth and Planetary Science Letters*, 80(3-4), 241–251. doi:[10.1016/0012-821x\(86\)90108-1](https://doi.org/10.1016/0012-821x(86)90108-1)

General

Cheng, H., Edwards, R. L., Hoff, J., Gallup, C. D., Richards, D. A., & Asmerom, Y. (2000). The half-lives of uranium-234 and thorium-230. *Chemical Geology*, 169(1-2), 17–33. doi:[10.1016/s0009-2541\(99\)00157-6](https://doi.org/10.1016/s0009-2541(99)00157-6)

Methods

Cheng, H., Edwards, R. L., Shen, C.-C., Polyak, V. J., Asmerom, Y., Woodhead, J., ... Alexander Jr., E. C. (2013). Improvements in ²³⁰Th dating, ²³⁰Th and ²³⁴U half-life values, and U–Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. *Earth and Planetary Science Letters*,

371-372, 82-91. doi:[10.1016/j.epsl.2013.04.006](https://doi.org/10.1016/j.epsl.2013.04.006)

Methods

Cutter, G., Casciotti, K., Croot, P., Geibert, W., Heimbürger, L.-E., Lohan, M., ... van de Flierdt, T. (2017). Sampling and Sample-handling Protocols for GEOTRACES Cruises. Version 3, August 2017. GEOTRACES International Project Office. doi:[10.25607/OBP-2](https://doi.org/10.25607/OBP-2)

Methods

Hayes, C. T., Anderson, R. F., Fleisher, M. Q., Vivancos, S. M., Lam, P. J., Ohnemus, D. C., ... Moran, S. B. (2015). Intensity of Th and Pa scavenging partitioned by particle chemistry in the North Atlantic Ocean. *Marine Chemistry*, 170, 49-60. doi:[10.1016/j.marchem.2015.01.006](https://doi.org/10.1016/j.marchem.2015.01.006)

Methods

Lam, P. J., & Morris, P. J. (2013). In situ marine sample collection system and methods (U.S. Patent Application No. 20130298702). Washington, DC: U.S. Patent and Trademark Office.

<https://patents.google.com/patent/US20130298702>

Methods

Roy-Barman, M., Coppola, L., & Souhaut, M. (2002). Thorium isotopes in the western Mediterranean Sea: an insight into the marine particle dynamics. *Earth and Planetary Science Letters*, 196(3-4), 161-174.

doi:[10.1016/s0012-821x\(01\)00606-9](https://doi.org/10.1016/s0012-821x(01)00606-9)

Methods

Shen, C.-C., Cheng, H., Edwards, R. L., Moran, S. B., Edmonds, H. N., Hoff, J. A., & Thomas, R. B. (2003). Measurement of Attogram Quantities of ²³¹Pa in Dissolved and Particulate Fractions of Seawater by Isotope Dilution Thermal Ionization Mass Spectroscopy. *Analytical Chemistry*, 75(5), 1075-1079.

doi:[10.1021/ac026247r](https://doi.org/10.1021/ac026247r)

Methods

Shen, C.-C., Edwards, R. L., Cheng, H., Dorale, J. A., Thomas, R. B., Moran, S. B., ... Edmonds, H. N. (2002). Uranium and thorium isotopic and concentration measurements by magnetic sector inductively coupled plasma mass spectrometry. *Chemical Geology*, 185(3-4), 165-178. doi:[10.1016/s0009-2541\(01\)00404-1](https://doi.org/10.1016/s0009-2541(01)00404-1)

[10.1016/s0009-2541\(01\)00404-1](https://doi.org/10.1016/s0009-2541(01)00404-1)

Methods

Shen, C.-C., Wu, C.-C., Cheng, H., Edwards, R. L., Hsieh, Y.-T., Gallet, S., ... Spötl, C. (2012). High-precision and high-resolution carbonate ²³⁰Th dating by MC-ICP-MS with SEM protocols. *Geochimica et Cosmochimica Acta*, 99, 71-86. doi:[10.1016/j.gca.2012.09.018](https://doi.org/10.1016/j.gca.2012.09.018)

Methods

Taylor, S. R., & McLennan, S. M. (1995). The geochemical evolution of the continental crust. *Reviews of Geophysics*, 33(2), 241. doi:[10.1029/95rg00262](https://doi.org/10.1029/95rg00262)

Methods

Xiang, Y., & Lam, P. J. (2020). Size-Fractionated Compositions of Marine Suspended Particles in the Western Arctic Ocean: Lateral and Vertical Sources. *Journal of Geophysical Research: Oceans*, 125(8).

doi:[10.1029/2020jc016144](https://doi.org/10.1029/2020jc016144)

Methods

[[table of contents](#) | [back to top](#)]

Parameters

Parameter	Description	Units
Cruise_ID	Cruise identifier	unitless
Station_ID	Station number	unitless
Event_ID	GEOTRACES event number	unitless
Cast_ID	Cast number	unitless

Start_Date_UTC	Date (UTC) at start of sample collection; format: DD/MM/YYYY	unitless
Start_Time_UTC	Time (UTC) at start of sample collection; format: hh:mm	unitless
Start_ISO_DateTime_UTC	Date and time (UTC) at start of sample collection formatted to ISO 8601 standard; format: YYYY-MM-DDThh:mmZ	unitless
End_Date_UTC	Date (UTC) at end of sample collection; format: DD/MM/YYYY	unitless
End_Time_UTC	Time (UTC) at end of sample collection; format: hh:mm	unitless
End_ISO_DateTime_UTC	Date and time (UTC) at end of sample collection formatted to ISO 8601 standard; format: YYYY-MM-DDThh:mmZ	unitless
Start_Latitude	Latitude at start of sample collection	decimal degrees North
Start_Longitude	Longitude at start of sample collection	decimal degrees East
End_Latitude	Latitude at end of sample collection	decimal degrees North
End_Longitude	Longitude at end of sample collection	decimal degrees East
Pump_ID	Pump number	unitless
Flag_Pump_ID	SeaDataNet quality flag for Pump_ID	unitless
Sample_ID	GEOTRACES sample number	unitless
Lab_ID_SPT	Lab identifier for small particulate (SPT) sample analysis	unitless
Lab_ID_LPT	Lab identifier for large particulate (LPT) sample analysis	unitless
Sample_Pressure	Sample pressure	decibars (dbar)
Sample_Depth	Sample depth	meters (m)
Th_232_SPT_CONC_PUMP_kbuaq	Concentration of small particulate Th-232 in seawater collected using a McLane large volume in situ pump	picomoles per kilogram (pmol/kg)
SD1_Th_232_SPT_CONC_PUMP_kbuaq	One standard deviation of Th_232_SPT_CONC_PUMP_kbuaq	picomoles per kilogram (pmol/kg)
Flag_Th_232_SPT_CONC_PUMP_kbuaq	SeaDataNet quality flag for Th_232_SPT_CONC_PUMP_kbuaq	unitless

Th_230_SPT_CONC_PUMP_qmzytn	Concentration of small particulate Th-230 in seawater collected using a McLane large volume in situ pump	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Th_230_SPT_CONC_PUMP_qmzytn	One standard deviation of Th_230_SPT_CONC_PUMP_qmzytn	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Th_230_SPT_CONC_PUMP_qmzytn	SeaDataNet quality flag for Th_230_SPT_CONC_PUMP_qmzytn	unitless
Pa_231_SPT_CONC_PUMP_6pkszt	Concentration of small particulate Pa-231 in seawater collected using a McLane large volume in situ pump	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Pa_231_SPT_CONC_PUMP_6pkszt	One standard deviation of Pa_231_SPT_CONC_PUMP_6pkszt	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Pa_231_SPT_CONC_PUMP_6pkszt	SeaDataNet quality flag for Pa_231_SPT_CONC_PUMP_6pkszt	unitless
Th_232_LPT_CONC_PUMP_zg488c	Concentration of large particulate Th-232 in seawater collected using a McLane large volume in situ pump	picomoles per kilogram (pmol/kg)
SD1_Th_232_LPT_CONC_PUMP_zg488c	One standard deviation of Th_232_LPT_CONC_PUMP_zg488c	picomoles per kilogram (pmol/kg)
Flag_Th_232_LPT_CONC_PUMP_zg488c	SeaDataNet quality flag for Th_232_LPT_CONC_PUMP_zg488c	unitless
Th_230_LPT_CONC_PUMP_o2lqui	Concentration of large particulate Th-230 in seawater collected using a McLane large volume in situ pump	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Th_230_LPT_CONC_PUMP_o2lqui	One standard deviation of Th_230_LPT_CONC_PUMP_o2lqui	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Th_230_LPT_CONC_PUMP_o2lqui	SeaDataNet quality flag for Th_230_LPT_CONC_PUMP_o2lqui	unitless

Pa_231_LPT_CONC_PUMP_slruz	Concentration of large particulate Pa-231 in seawater collected using a McLane large volume in situ pump	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Pa_231_LPT_CONC_PUMP_slruz	One standard deviation of Pa_231_LPT_CONC_PUMP_slruz	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Pa_231_LPT_CONC_PUMP_slruz	SeaDataNet quality flag for Pa_231_LPT_CONC_PUMP_slruz	unitless
Th_230_SPT_XS_CONC_PUMP	Concentration of small particulate excess Th-230 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Th_230_SPT_XS_CONC_PUMP	One standard deviation of Th_230_SPT_XS_CONC_PUMP	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Th_230_SPT_XS_CONC_PUMP	SeaDataNet quality flag for Th_230_SPT_XS_CONC_PUMP	unitless
Pa_231_SPT_XS_CONC_PUMP	Concentration of small particulate excess Pa-231 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Pa_231_SPT_XS_CONC_PUMP	One standard deviation of Pa_231_SPT_XS_CONC_PUMP	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Pa_231_SPT_XS_CONC_PUMP	SeaDataNet quality flag for Pa_231_SPT_XS_CONC_PUMP	unitless
Th_230_LPT_XS_CONC_PUMP	Concentration of large particulate excess Th-230 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Th_230_LPT_XS_CONC_PUMP	One standard deviation of Th_230_LPT_XS_CONC_PUMP	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Th_230_LPT_XS_CONC_PUMP	SeaDataNet quality flag for Th_230_LPT_XS_CONC_PUMP	unitless

Pa_231_LPT_XS_CONC_PUMP	Concentration of large particulate excess Pa-231 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram (μBq/kg)
SD1_Pa_231_LPT_XS_CONC_PUMP	One standard deviation of Pa_231_LPT_XS_CONC_PUMP	micro-Becquerel per kilogram (μBq/kg)
Flag_Pa_231_LPT_XS_CONC_PUMP	SeaDataNet quality flag for Pa_231_LPT_XS_CONC_PUMP	unitless
Th_230_SPT_ADS_CONC_PUMP	Concentration of small particulate adsorbed Th-230 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram (μBq/kg)
SD1_Th_230_SPT_ADS_CONC_PUMP	One standard deviation of Th_230_SPT_ADS_CONC_PUMP	micro-Becquerel per kilogram (μBq/kg)
Flag_Th_230_SPT_ADS_CONC_PUMP	SeaDataNet quality flag for Th_230_SPT_ADS_CONC_PUMP	unitless
Pa_231_SPT_ADS_CONC_PUMP	Concentration of small particulate adsorbed Pa-231 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram (μBq/kg)
SD1_Pa_231_SPT_ADS_CONC_PUMP	One standard deviation of Pa_231_SPT_ADS_CONC_PUMP	micro-Becquerel per kilogram (μBq/kg)
Flag_Pa_231_SPT_ADS_CONC_PUMP	SeaDataNet quality flag for Pa_231_SPT_ADS_CONC_PUMP	unitless
Th_230_LPT_ADS_CONC_PUMP	Concentration of large particulate adsorbed Th-230 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram (μBq/kg)
SD1_Th_230_LPT_ADS_CONC_PUMP	One standard deviation of Th_230_LPT_ADS_CONC_PUMP	micro-Becquerel per kilogram (μBq/kg)
Flag_Th_230_LPT_ADS_CONC_PUMP	SeaDataNet quality flag for Th_230_LPT_ADS_CONC_PUMP	unitless

Pa_231_LPT_ADS_CONC_PUMP	Concentration of large particulate adsorbed Pa-231 in seawater collected using a McLane large volume in situ pump (see metadata for full explanation)	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
SD1_Pa_231_LPT_ADS_CONC_PUMP	One standard deviation of Pa_231_LPT_ADS_CONC_PUMP	micro-Becquerel per kilogram ($\mu\text{Bq/kg}$)
Flag_Pa_231_LPT_ADS_CONC_PUMP	SeaDataNet quality flag for Pa_231_LPT_ADS_CONC_PUMP	unitless

[[table of contents](#) | [back to top](#)]

Instruments

Dataset-specific Instrument Name	Dual-flow McLane Research in-situ pumps (WTS-LV)
Generic Instrument Name	McLane Large Volume Pumping System WTS-LV
Dataset-specific Description	PUMP: McLane in-situ pumps (McLane WTS-LV) used to collect in-situ water column small and large particulate samples.
Generic Instrument Description	The Large Volume Pumping System-WTS-LV can be one of several different models of Water Transfer Systems (WTS) Large Volume (LV) pumping systems designed and manufactured by McLane Research Labs (Falmouth, MA, USA). The Large Volume Water Transfer System (WTS-LV) is a large volume single-event sampler that collects suspended and dissolved particulate samples in situ into a 142mm membrane filter. The WTS-LV allows for a choice of pump size and filter porosity for a range of specimen collection. Collection targets include chlorophyll maximum, particulate trace metals, and phytoplankton.

Dataset-specific Instrument Name	Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS; Thermo-Finnigan Neptune Multicollector ICP-MS
Generic Instrument Name	Inductively Coupled Plasma Mass Spectrometer
Dataset-specific Description	A Thermo-Finnigan ELEMENT XR Single Collector Magnetic Sector ICP-MS, equipped with a high-performance Interface pump (Jet Pump Aridus I™), and specially designed sample (Jet) and skimmer (X) cones to ensure the highest possible sensitivity in the Lamont Doherty Earth Observatory - American Museum of Natural History ICP-MS Lab at the Lamont-Doherty Earth Observatory of Columbia University was used. A Thermo-Finnigan Neptune Multicollector ICP-MS, equipped with a high-performance Interface pump (Jet Pump Aridus II™), and specially designed sample (Jet) and skimmer (X) cones to ensure the highest possible sensitivity in the Newton Horace Winchell School of Earth and Environmental Sciences at the University of Minnesota was used.
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.

Dataset-specific Instrument Name	Centrifuge
Generic Instrument Name	Centrifuge
Generic Instrument Description	A machine with a rapidly rotating container that applies centrifugal force to its contents, typically to separate fluids of different densities (e.g., cream from milk) or liquids from solids.

[[table of contents](#) | [back to top](#)]

Deployments

HLY1502

Website	https://www.bco-dmo.org/deployment/638807
Platform	USCGC Healy
Report	https://datadocs.bco-dmo.org/docs/302/geotraces/GEOTRACES_ARCTIC/data_docs/cruise_reports/healy1502.pdf
Start Date	2015-08-09
End Date	2015-10-12
Description	Arctic transect encompassing Bering and Chukchi Shelves and the Canadian, Makarov and Amundsen sub-basins of the Arctic Ocean. The transect started in the Bering Sea (60°N) and traveled northward across the Bering Shelf, through the Bering Strait and across the Chukchi shelf, then traversing along 170-180°W across the Alpha-Mendeleev and Lomonosov Ridges to the North Pole (Amundsen basin, 90°N), and then back southward along ~150°W to terminate on the Chukchi Shelf (72°N). Additional cruise information is available in the GO-SHIP Cruise Report (PDF) and from the Rolling Deck to Repository (R2R): https://www.rvdata.us/search/cruise/HLY1502

[[table of contents](#) | [back to top](#)]

Project Information

U.S. Arctic GEOTRACES Study (U.S. GEOTRACES Arctic)

Coverage: Arctic Ocean; Sailing from Dutch Harbor to Dutch Harbor

Description from NSF award abstract:

In pursuit of its goal "to identify processes and quantify fluxes that control the distributions of key trace elements and isotopes in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions", in 2015 the International GEOTRACES Program will embark on several years of research in the Arctic Ocean. In a region where climate warming and general environmental change are occurring at amazing speed, research such as this is important for understanding the current state of Arctic Ocean geochemistry and for developing predictive capability as the regional ecosystem continues to warm and influence global oceanic and climatic conditions. The three investigators funded on this award, will manage a large team of U.S. scientists who will compete through the regular NSF proposal process to contribute their own unique expertise in marine trace metal, isotopic, and carbon cycle geochemistry to the U.S. effort. The three managers will be responsible for arranging and overseeing at-sea technical services such as hydrographic measurements, nutrient analyses, and around-the-clock management of on-deck sampling activities upon which all participants depend, and for organizing all pre- and post-cruise technical support and scientific meetings. The management team will also lead educational outreach activities for the general public in Nome and Barrow, Alaska, to explain the significance of the study to these communities and to learn from residents' insights on observed changes in the marine system. The project itself will provide for the support and training of a number of pre-doctoral students and post-doctoral researchers. Inasmuch as the Arctic Ocean is an epicenter of global climate change, findings of this study are expected to advance present capability to forecast changes in regional and global ecosystem and climate system functioning.

As the United States' contribution to the International GEOTRACES Arctic Ocean initiative, this project will be part of an ongoing multi-national effort to further scientific knowledge about trace elements and isotopes in the world ocean. This U.S. expedition will focus on the western Arctic Ocean in the boreal summer of 2015. The scientific team will consist of the management team funded through this award plus a team of scientists from U.S. academic institutions who will have successfully competed for and received NSF funds for specific science projects in time to participate in the final stages of cruise planning. The

cruise track segments will include the Bering Strait, Chukchi shelf, and the deep Canada Basin. Several stations will be designated as so-called super stations for intense study of atmospheric aerosols, sea ice, and sediment chemistry as well as water-column processes. In total, the set of coordinated international expeditions will involve the deployment of ice-capable research ships from 6 nations (US, Canada, Germany, Sweden, UK, and Russia) across different parts of the Arctic Ocean, and application of state-of-the-art methods to unravel the complex dynamics of trace metals and isotopes that are important as oceanographic and biogeochemical tracers in the sea.

Collaborative Research: U.S. GEOTRACES Arctic Section: Thorium-230, Thorium-232, and Protactinium-231 tracers of trace element supply and removal. (GEOTRACES Arctic Th Pa)

Coverage: Western Arctic Ocean

NSF Award Abstract:

In support of the 2015 U.S. GEOTRACES Arctic expedition, this project will focus on the fate and distributions of naturally-occurring radioisotopes in the Arctic Ocean. Such information is useful for understanding why other chemical substances, both natural and man-made, occur where they do in the ocean. Like other national initiatives involved in the International GEOTRACES Program, the goals of this U.S. Arctic expedition are to identify processes and quantify fluxes that control the distributions of key trace elements and isotopes (TEI) in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions. Working at sea alongside a multi-institutional team of ocean trace element experts, investigators on this project will define regions of unusually high rates of TEI removal, anticipated to be located near basin margins and near the sea floor. By combining their measurements of naturally-occurring thorium and protactinium with TEI data collected by other participating investigators, they expect to be able to translate these rates into information that can be applied to other TEIs. Like most other participating investigators, this group will include graduate students as part of the research team and will participate in a variety of public educational outreach activities for Alaskan communities.

This study will undertake measurements of the dissolved and particulate concentrations of ^{230}Th and ^{231}Pa , two isotopes designated as key or critical to the success of the GEOTRACES program. Additionally the team will measure dissolved and particulate ^{232}Th concentrations and analyze a limited number of aerosol samples, aerosol leachates, sea ice, melt pond water and surface sediments for these radionuclides. The work plan will be broken down into five tasks geared to: (1) determine the rates of boundary scavenging of ^{231}Pa and ^{230}Th associated with the particle-rich waters near the southern margin of the Canada Basin; (2) determine the rates of bottom scavenging of ^{231}Pa and ^{230}Th associated with nepheloid layers that are prevalent in the Arctic Ocean; (3) assess the contribution to scavenging in the Canada basin by MnO_2 -coated particles, formed during early diagenesis in organic-rich sediments surrounding the Arctic Ocean; (4) determine the rate of supply of lithogenic ^{232}Th from margin sediments using information derived from ^{230}Th ; and (5) determine the rate of supply of lithogenic ^{232}Th from sea ice, including the aerosols and ice-rafted sediments that they transport, by the combined study of ^{232}Th and ^{230}Th . The proposed work fulfills core scientific objectives defined in the U.S. GEOTRACES Arctic Implementation Plan.

[[table of contents](#) | [back to top](#)]

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](#)]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1434479
NSF Division of Ocean Sciences (NSF OCE)	OCE-1434886

[[table of contents](#) | [back to top](#)]