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

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Project
» U.S. Arctic GEOTRACES Study (GN01) (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)

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Abstract
This dataset contains concentrations of dissolved thorium and protactinium isotopes (Th-232, Th-230, Pa-231) in seawater, sea ice, and melt ponds 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.

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Coverage

Spatial Extent: **N**:89.99 **E**:179.21 **S**:60.252 **W**:-179.808
Temporal Extent: 2015-08-12 - 2015-10-07

Dataset Description

This dataset contains concentrations of dissolved thorium and protactinium isotopes (Th-232, Th-230, Pa-231) in seawater, sea ice, and melt ponds 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_D_CONC_BOTTLE" are adopted based on a recommendation from the GEOTRACES community (https://www.geotraces.org/parameter-naming-conventions/).

A GEOTRACES sample number (Sample_ID) appended with an "A" denotes the archive sample collected during the same cast and at the same depth as the sample that was originally analyzed.

"Dissolved" (D) here refers to that which passed through stacked 0.8/0.45 µm Acropak™ 500 filter capsules sampled from conventional Niskin bottles on a CTD rosette (BOTTLE; NIS and GSNIS). This is true for all dissolved samples except for a select number that were collected using GO-FLO bottles on a CTD rosette (BOTTLE; GF), a pump from a small boat (BOAT_PUMP; SMBT), a pump through sea ice into seawater (SUBICE_PUMP), a trace metal clean ice corer (CORER), and a pump into a melt pond (MELTPOND_PUMP). Sampling system is indicated by the parameter name, and in some cases by Bottle_ID. For Bottle_ID, NIS represents Niskin bottles sampled from the 12-place 30 liter ODF rosette, GSNIS represents Niskin bottles sampled from the 36-place 10 liter GO-SHIP rosette, GF represents GO-FLO bottles sampled from the 24-place 12 liter GTC clean carousel, and SMBT represents surface (1 m) seawater samples collected from a small boat upstream of the ship using a battery-powered pump and Teflon-lined PVC tubing. SUBICE_PUMP represents seawater samples collected from under the ice (at approximately 1, 5, and 20 m) with the same pumping system used for BOAT_PUMP, MELTPOND_PUMP represents melt pond water samples that were collected using a battery-powered peristaltic pump and silicone tubing, and CORER represents sea ice samples that were collected using a trace metal clean ice corer. Bulk sea ice (CORER) samples were collected as ice cores about 1 m in length and melted overnight in LDPE melting chambers before they were subsampled into 5 liter cubitainers. BOAT_PUMP, SUBICE_PUMP, and MELTPOND_PUMP samples were each stored in 25 liter carboys during sample collection and then subsampled into 5 liter cubitainers aboard the ship. GF (BOTTLE), BOAT_PUMP, MELTPOND_PUMP, and CORER samples were passed through a 0.2 µm Acropak™ 200 filter capsule, unlike NIS (BOTTLE), GSNIS (BOTTLE), and SUBICE_PUMP samples, which were passed through stacked 0.8/0.45 µm Acropak™ 500 filter capsules. All seawater, sea ice, and melt pond samples were weighed directly in the on-shore laboratory to determine sample size, taking into account acid added at sea.

Units of Measurement:
Radionuclide concentrations are given as micro-Becquerel (10e-6 Bq, µBq or micro-Bq) per kilogram water for Th-230 and Pa-231, and picomole (10e-12 mol, pmol) per kilogram water 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.

Results Publications:
These data have been published in the following:
Charette et al., 2020 – Dissolved Th-232 concentrations in upper ocean waters (Th_232_D_CONC_BOTTLE_dan73c)

Methods & Sampling

Sampling Methods at Sea:
Sampling methods at sea followed the GEOTRACES cookbook (Cutter et al., 2017). Water samples were collected with a Sea-Bird Electronics CTD carousel fitted with either 12 30-liter or 36 10-liter PVC Niskin bottles, managed and operated by Ship-based Science Technical Support in the Arctic and the Ocean Data Facility of Scripps Institution of Oceanography, or with a Sea-Bird Electronics CTD carousel fitted with 24 12-liter GO-FLO bottles (the GEOTRACES Clean carousel). The 12-place 30 L Niskin bottle rosette was used for stations 1-10 and 26, the 36-place 10 L Niskin bottle rosette was used for stations 12-19, 30-38, and 43-66, and the 24-

place 12 L GO-FLO bottle rosette was used for station 41. Carousels were lowered from the ship with steel wire. Niskin bottles were equipped with nylon-coated closure springs and Viton O-rings. After collection, seawater was drained with Teflon-lined Tygon™ tubing and filtered through Pall Acropak™ 500 filters on deck (gravity filtration, 0.8/0.45 µm pore size) into Fisher I-Chem series 300 LDPE cubitainers. Ice hole seawater samples were collected from under the ice (at approximately 1, 5, and 20 m) using a battery-powered pump and Teflon-lined PVC tubing, then filtered and stored in the same manner as seawater samples collected from a rosette using a Niskin bottle. Surface (1 m) seawater samples were also collected from a small boat upstream of the ship using the same pumping system used to collect ice hole seawater samples, except they were passed through a 0.2 µm Acropak™ 200 filter capsule before being transferred to cubitainers. Melt pond samples were collected using a battery-powered peristaltic pump and silicone tubing, bulk sea ice samples were collected using a trace metal clean ice corer and melted overnight in LDPE melting chambers, and both were also passed through a 0.2 µm Acropak™ 200 filter capsule before cubitainer storage. Approximately 4-5 liters were collected per desired depth for each dissolved sample. Prior to the cruise, the tubing, filters, and cubitainers were cleaned by immersion in dilute (1.2 M) HCl (Fisher Scientific Trace Metal Grade) for 4-5 days. Once filtered, samples were adjusted to a pH of ~2 with ultra-clean 6 M HCl (Fisher Scientific OPTIMA grade), double-bagged, stored in pallet boxes on-deck until the end of the cruise, and then at room temperature once shipped to the participating laboratories for analysis.

Analytical Methods at LDEO:
In the on-shore laboratory, seawater, sea ice, and melt pond samples were weighed to determine sample size, taking into account the weight of the cubitainer and of the acid added at sea. Then, weighed aliquots of the artificial isotope yield monitors Th-229 (1 pg) and Pa-233 (0.05-0.17 pg) and 25 mg dissolved Fe were added to each sample. After allowing 1 day for spike equilibration, the pH of each sample was raised to 8.3-8.7 by adding ~12 mL of concentrated NH4OH (Fisher Scientific OPTIMA grade) which caused iron (oxy)hydroxide precipitates to form. Each sample cubitainer was fitted with a nozzle cap, inverted, and the Fe precipitate was allowed to settle for 2 days. After 2 days, the nozzle caps were opened and the pH~8.3-8.7 water was slowly drained, leaving only the iron oxyhydroxide precipitate and 250-500 mL of water. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with Milli-Q H2O (>18 MΩ) to remove the major seawater ions. The precipitate was then dissolved in concentrated (16 M) HNO3 (Fisher Scientific OPTIMA grade) and transferred to a Teflon beaker for a high-temperature (180-200°C) digestion with concentrated HClO4 and HF (Fisher Scientific OPTIMA grade) on a hotplate in a HEPA-filtered laminar flow hood. After total dissolution of the sample, another precipitation of iron (oxy)hydroxide followed and the precipitate was washed with Milli-Q H2O, centrifuged, and dissolved in concentrated (16 M) HNO3 (Fisher Scientific OPTIMA grade) for a series of anion-exchange chromatography using 6 mL polypropylene columns each containing a 1 mL bed of Bio-rad resin (AG1-X8, 100-200 mesh size) and a 45 µm porous polyethylene frit (Anderson et al., 2012). The final column elutions 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 (Fisher Scientific OPTIMA grade) 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 (Δm/M≈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 -0.5%/amu to 0.2%/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 1.1). 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.

Water samples were analyzed in batches of 15. Procedural blanks were determined by processing 4-5 L of Milli-Q H2O in an acid-cleaned cubitainer acidified to pH ~2 with 6 M HCl (Fisher Scientific OPTIMA grade) as a sample in each batch. Two procedural blanks were processed with each batch, with about half of the procedural blanks acidified at sea during HLY1502 and the other half acidified in the on-shore laboratory before sample processing. The difference in the procedural blank values for Th-232, Th-230, and Pa-231 between acidifying procedural blanks at sea or in the on-shore laboratory was statistically insignificant. 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 samples with each batch. Samples were corrected using the pooled average of all procedural blanks analyzed during processing of HLY1502 dissolved samples. The average procedural blanks for Th-232, Th-230, and Pa-231 were 5.72 ± 3.22 pg, 0.14 ± 0.08 fg, and 0.07 ± 0.08 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 12.15 pg, 0.29 fg, and 0.23 fg, respectively, or about 2.1x, 2.1x, and 3.1x greater than the blank amount, respectively.

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

Analytical Methods at UMN:
In the on-shore laboratory, 1-liter aliquots of the seawater, sea ice, and melt pond samples were weighed to determine sample size, taking into account the weight of the subsample container and of the acid added at sea. Then, weighed aliquots of the artificial isotope yield monitors Th-229 (1 pg) and Pa-233 (0.2-0.6 pg) and 3 mg dissolved Fe were added to each sample. After allowing 3 days for spike equilibration (at a temperature of about 40°C), the pH of each sample was raised to 8.0-8.5 by adding concentrated NH4OH which caused iron (oxy)hydroxide precipitates to form. This precipitate was allowed to settle for 1-2 days before the overlaying seawater was siphoned off. The Fe precipitate was transferred to centrifuge tubes for centrifugation and rinsing with deionized H2O (>18 MΩ) to remove the major seawater ions. The precipitate was then 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 with a 0.75 mL column volume (CV). The sample was loaded in 0.75 mL (1 CV) of 7 M HNO3, followed by 1.125 mL (1.5 CV) of 7 M HNO3 (to wash Fe and other undesired elements off the resin), 2.25 mL (3 CV) of 8 M HCl (to collect Th fraction), and 2.25 mL (3 CV) of 8 M HCl/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 0.5 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), which was used to correct for the instrument background count rates on the masses measured.

Water samples were analyzed in batches of 28-56. Procedural blanks were determined by performing a complete chemical procedure on 1 L of Milli-Q water with each batch of samples. 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. HLY1502 dissolved samples were corrected using the procedural blank analyzed during the same sample batch. The average procedural blanks for Th-232, Th-230, and Pa-231 were 0.83 ± 0.80 pg, 0.03 ± 0.03 fg, and 0.02 ± 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 2.44 pg, 0.09 fg, and

0.08 fg, respectively, or about 2.9x, 2.5x, and 3.1x 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_D_XS_CONC_BOTTLE:
The dissolved excess Th-230 concentration refers to the measured dissolved Th-230 corrected for a contribution of Th-230 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Th-230 produced in the water by decay of dissolved uranium-234. We estimate the lithogenic Th-230 using measured dissolved 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 a conversion factor to convert picomoles to micro-Becquerels.

Th_230_D_XS_CONC_BOTTLE = Th_230_D_CONC_BOTTLE – 4.0e-6 * 1.7473e5 * Th_232_D_CONC_BOTTLE

Pa_231_D_XS_CONC_BOTTLE:
The dissolved excess Pa-231 concentration refers to the measured dissolved Pa-231 corrected for a contribution of Pa-231 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Pa-231 produced in the water by decay of dissolved uranium-235. We estimate the lithogenic Pa-231 using measured dissolved 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. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_D_XS_CONC_BOTTLE = Pa_231_D_CONC_BOTTLE – 8.8e-8 * 4.0370e5 * Th_232_D_CONC_BOTTLE

Th_230_D_XS_CONC_BOAT_PUMP:
The dissolved excess Th-230 concentration refers to the measured dissolved Th-230 corrected for a contribution of Th-230 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Th-230 produced in the water by decay of dissolved uranium-234. We estimate the lithogenic Th-230 using measured dissolved 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 a conversion factor to convert picomoles to micro-Becquerels.

Th_230_D_XS_CONC_BOAT_PUMP = Th_230_D_CONC_BOAT_PUMP – 4.0e-6 * 1.7473e5 * Th_232_D_CONC_BOAT_PUMP

Pa_231_D_XS_CONC_BOAT_PUMP:
The dissolved excess Pa-231 concentration refers to the measured dissolved Pa-231 corrected for a contribution of Pa-231 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Pa-231 produced in the water by decay of dissolved uranium-235. We estimate the lithogenic Pa-231 using measured dissolved 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. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_D_XS_CONC_BOAT_PUMP = Pa_231_D_CONC_BOAT_PUMP – 8.8e-8 * 4.0370e5 * Th_232_D_CONC_BOAT_PUMP

Th_230_D_XS_CONC_SUBICE_PUMP:
The dissolved excess Th-230 concentration refers to the measured dissolved Th-230 corrected for a contribution of Th-230 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Th-230 produced in the water by decay of dissolved uranium-234. We estimate the lithogenic Th-230 using measured dissolved 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 a conversion factor to convert picomoles to micro-Becquerels.

Th_230_D_XS_CONC_SUBICE_PUMP = Th_230_D_CONC_SUBICE_PUMP – 4.0e-6 * 1.7473e5 * Th_232_D_CONC_SUBICE_PUMP

Pa_231_D_XS_CONC_SUBICE_PUMP:
The dissolved excess Pa-231 concentration refers to the measured dissolved Pa-231 corrected for a contribution of Pa-231 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Pa-231 produced in the water by decay of dissolved

uranium-235. We estimate the lithogenic Pa-231 using measured dissolved 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. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_D_XS_CONC_SUBICE_PUMP = Pa_231_D_CONC_SUBICE_PUMP – 8.8e-8 * 4.0370e5 * Th_232_D_CONC_SUBICE_PUMP

Th_230_ICE_D_XS_CONC_CORER:
The dissolved excess Th-230 concentration refers to the measured dissolved Th-230 corrected for a contribution of Th-230 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Th-230 produced in the water by decay of dissolved uranium-234. We estimate the lithogenic Th-230 using measured dissolved 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 a conversion factor to convert picomoles to micro-Becquerels.

Th_230_ICE_D_XS_CONC_CORER = Th_230_ICE_D_CONC_CORER – 4.0e-6 * 1.7473e5 * Th_232_ICE_D_CONC_CORER

Pa_231_ICE_D_XS_CONC_CORER:
The dissolved excess Pa-231 concentration refers to the measured dissolved Pa-231 corrected for a contribution of Pa-231 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Pa-231 produced in the water by decay of dissolved uranium-235. We estimate the lithogenic Pa-231 using measured dissolved 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. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_ICE_D_XS_CONC_CORER = Pa_231_ICE_D_CONC_CORER – 8.8e-8 * 4.0370e5 * Th_232_ICE_D_CONC_CORER

Th_230_D_XS_CONC_MELTPOND_PUMP:
The dissolved excess Th-230 concentration refers to the measured dissolved Th-230 corrected for a contribution of Th-230 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Th-230 produced in the water by decay of dissolved uranium-234. We estimate the lithogenic Th-230 using measured dissolved 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 a conversion factor to convert picomoles to micro-Becquerels.

Th_230_D_XS_CONC_MELTPOND_PUMP = Th_230_D_CONC_MELTPOND_PUMP – 4.0e-6 * 1.7473e5 * Th_232_D_CONC_MELTPOND_PUMP

Pa_231_D_XS_CONC_MELTPOND_PUMP:
The dissolved excess Pa-231 concentration refers to the measured dissolved Pa-231 corrected for a contribution of Pa-231 due to the partial dissolution of uranium-bearing minerals, or lithogenics. Thereby the dissolved excess represents solely the fraction of Pa-231 produced in the water by decay of dissolved uranium-235. We estimate the lithogenic Pa-231 using measured dissolved 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. An additional conversion factor is needed to convert picomoles to micro-Becquerels.

Pa_231_D_XS_CONC_MELTPOND_PUMP = Pa_231_D_CONC_MELTPOND_PUMP – 8.8e-8 * 4.0370e5 * Th_232_D_CONC_MELTPOND_PUMP

Data 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 LDEO, samples were corrected for blanks using the pooled average of all procedural blanks analyzed during processing of HLY1502 dissolved samples, while for UMN, samples were corrected for blanks using the procedural blank analyzed during the same sample batch.

Analysis of all samples was completed over the course of several years. A correction was made to account for the ingrowth of Th-230 and Pa-231 due to the decay of the natural U-234 and U-235 preserved in the acidified samples during the period of time between sample collection and U-Th/Pa separation during anion exchange chromatography. Thus, the reported Th-230 and Pa-231 concentrations have been corrected to represent their concentrations at the time of sampling. U concentrations in the samples were estimated using the bottle salinity (S) measured from the CTD and the U-Salinity relationship in seawater (Owens et al., 2011), [U] = (0.100 * S – 0.326) ng U (g seawater)-1. We used seawater U-isotopic compositions of U-234/U-238 = 1.1468 activity ratio (Andersen et al., 2010), and U-238/U-235 = 137.824 mole ratio (Weyer et al., 2008), to calculate [U-234] and [U-235] respectively based on [U].

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 dissolved samples at LDEO, the reproducibility for each isotope was 0.87% for Th-232, 0.86% for Th-230, and 1.63% for Pa-231 on SW STD 2010-1, and was 4.78% for Th-232, 0.71% for Th-230, and 3.24% 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").

Version History:
-2020-12-29: version 1 published.
- 2021-02-23: replaced with data file received 2021-01-28 (version 2); includes changes to some data values.
- 2021-08-25: replaced with data file receive 2021-08-01 (version 3); includes the following changes:
Start_Time_UTC for:
Event 6036 from “00:00” to “07:23”
Event 6213 from “nd” to “20:15”
Event 6421 from “12:xx” to “13:53”
Event 6228 from “nd” to “08:00”
Event 6224 from “nd” to “08:00”
Event 6225 from “nd” to “08:00”
Event 6308 from “nd” to “18:00”
Event 6309 from “nd” to “21:00”
Event 6337 from “nd” to “23:00”

Start_ISO_DateTime_UTC for:
Event 6036 from “2015-08-16T00:00Z” to “2015-08-16T07:23Z”
Event 6213 from “nd” to “2015-09-05T20:15Z”
Event 6421 from “2015-09-29T12:xxZ” to “2015-09-29T13:53Z”
Event 6228 from “nd” to “2015-09-07T08:00Z”
Event 6224 from “nd” to “2015-09-07T08:00Z”
Event 6225 from “nd” to “2015-09-07T08:00Z”
Event 6308 from “nd” to “2015-09-16T18:00Z”
Event 6309 from “nd” to “2015-09-16T21:00Z”
Event 6337 from “nd” to “2015-09-19T23:00Z”

End_Date_UTC for:
Event 6337 from “19/09/2015” to “20/09/2015”

End_Time_UTC& for:
Event 6228 from “nd” to “20:00”
Event 6224 from “nd” to “20:00”
Event 6225 from “nd” to “20:00”
Event 6312 from “nd” to “20:00”
Event 6308 from “nd” to “21:00”
Event 6309 from “nd” to “23:59”
Event 6337 from “nd” to “01:30”

End_ISO_DateTime_UTC for:
Event 6228 from “nd” to “2015-09-07T20:00Z”
Event 6224 from “nd” to “2015-09-07T20:00Z”
Event 6225 from “nd” to “2015-09-07T20:00Z”
Event 6312 from “nd” to “2015-09-16T20:00Z”
Event 6308 from “nd” to “2015-09-16T21:00Z”
Event 6309 from “nd” to “2015-09-16T23:59Z”
Event 6337 from “nd” to “2015-09-20T01:30Z”

Start_Latitude for:
Event 6213 from “89.988” to “89.987”

Start_Longitude for:
Event 6228 from “89.253” to “89.250”
Event 6224 from “89.253” to “89.250”
Event 6225 from “89.253” to “89.250”

Cast_ID for:
Event 6201 from “nd” to “30”
Event 6224 from “nd” to “30”

Sample_Depth for:
Sample 11221 from “nd” to “0.5”
Sample 11327 from “nd” to “0.5”
Sample 11459 from “nd” to “0.5”
Sample 11491 from “nd” to “0.5”

Sample 11623 from “nd” to “0.5”
Sample 11717 from “nd” to “0.5”

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Data Files

File
Th_Pa_Dissolved.csv (Comma Separated Values (.csv), 146.51 KB) MD5:a8787bd2258ddb07a94f41af605cc2df Primary data file for dataset ID 833887

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Related Publications

Andersen, M. B., Stirling, C. H., Zimmermann, B., & Halliday, A. N. (2010). Precise determination of the open ocean 234U/238U composition. Geochemistry, Geophysics, Geosystems, 11(12), n/a–n/a. doi:10.1029/2010gc003318
Methods

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
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
General

Charette, M. A., Kipp, L. E., Jensen, L. T., Dabrowski, J. S., Whitmore, L. M., Fitzsimmons, J. N., … Zhang, R. (2020). The Transpolar Drift as a Source of Riverine and Shelf-Derived Trace Elements to the Central Arctic Ocean. Journal of Geophysical Research: Oceans, 125(5). doi:10.1029/2019jc015920
Results

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
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
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
Methods

Cutter, Gregory, Casciotti, Karen, Croot, Peter, Geibert, Walter, Heimbürger, Lars-Eric, Lohan, Maeve, Planquette, Hélène, van de Flierdt, Tina (2017) Sampling and Sample-handling Protocols for GEOTRACES Cruises. Version 3, August 2017. Toulouse, France, GEOTRACES International Project Office, 139pp. & Appendices. DOI: http://dx.doi.org/10.25607/OBP-2
Methods

Owens, S. A., Buesseler, K. O., & Sims, K. W. W. (2011). Re-evaluating the 238U-salinity relationship in seawater: Implications for the 238U–234Th disequilibrium method. Marine Chemistry, 127(1-4), 31–39. doi:10.1016/j.marchem.2011.07.005
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
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
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
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
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
Methods

Weyer, S., Anbar, A. D., Gerdes, A., Gordon, G. W., Algeo, T. J., & Boyle, E. A. (2008). Natural fractionation of 238U/235U. Geochimica et Cosmochimica Acta, 72(2), 345–359. doi:10.1016/j.gca.2007.11.012
Methods

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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
Bottle_ID	Bottle number	unitless
Flag_Bottle_ID	SeaDataNet quality flag for Bottle_ID	unitless
Sample_ID	GEOTRACES sample number	unitless
Lab_ID_D	Lab identifier for dissolved (D) sample analysis	unitless
Sample_Pressure	Sample pressure	decibars (dbar)
Sample_Depth	Sample depth	meters (m)
Th_232_D_CONC_BOTTLE_dan73c	Concentration of dissolved Th-232 in seawater collected using a Niskin or GO-FLO bottle on a CTD rosette	picomoles per kilogram (pmol/kg)
SD1_Th_232_D_CONC_BOTTLE_dan73c	One standard deviation of Th_232_D_CONC_BOTTLE_dan73c	picomoles per kilogram (pmol/kg)
Flag_Th_232_D_CONC_BOTTLE_dan73c	SeaDataNet quality flag for Th_232_D_CONC_BOTTLE_dan73c	unitless
Th_230_D_CONC_BOTTLE_hhpkuh	Concentration of dissolved Th-230 in seawater collected using a Niskin or GO-FLO bottle on a CTD rosette	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_CONC_BOTTLE_hhpkuh	One standard deviation of Th_230_D_CONC_BOTTLE_hhpkuh	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_CONC_BOTTLE_hhpkuh	SeaDataNet quality flag for Th_230_D_CONC_BOTTLE_hhpkuh	unitless
Pa_231_D_CONC_BOTTLE_x1ssip	Concentration of dissolved Pa-231 in seawater collected using a Niskin or GO-FLO bottle on a CTD rosette	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_CONC_BOTTLE_x1ssip	One standard deviation of Pa_231_D_CONC_BOTTLE_x1ssip	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_CONC_BOTTLE_x1ssip	SeaDataNet quality flag for Pa_231_D_CONC_BOTTLE_x1ssip	unitless
Th_232_D_CONC_BOAT_PUMP_meanoj	Concentration of dissolved Th-232 in seawater collected using a pump from a small boat	picomoles per kilogram (pmol/kg)

SD1_Th_232_D_CONC_BOAT_PUMP_meanoj	One standard deviation of Th_232_D_CONC_BOAT_PUMP_meanoj	picomoles per kilogram (pmol/kg)
Flag_Th_232_D_CONC_BOAT_PUMP_meanoj	SeaDataNet quality flag for Th_232_D_CONC_BOAT_PUMP_meanoj	unitless
Th_230_D_CONC_BOAT_PUMP_hgjzry	Concentration of dissolved Th-230 in seawater collected using a pump from a small boat	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_CONC_BOAT_PUMP_hgjzry	One standard deviation of Th_230_D_CONC_BOAT_PUMP_hgjzry	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_CONC_BOAT_PUMP_hgjzry	SeaDataNet quality flag for Th_230_D_CONC_BOAT_PUMP_hgjzry	unitless
Pa_231_D_CONC_BOAT_PUMP_rmnjwu	Concentration of dissolved Pa-231 in seawater collected using a pump from a small boat	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_CONC_BOAT_PUMP_rmnjwu	One standard deviation of Pa_231_D_CONC_BOAT_PUMP_rmnjwu	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_CONC_BOAT_PUMP_rmnjwu	SeaDataNet quality flag for Pa_231_D_CONC_BOAT_PUMP_rmnjwu	unitless
Th_232_D_CONC_SUBICE_PUMP_k4fwfy	Concentration of dissolved Th-232 in seawater collected using a pump through sea ice into seawater	picomoles per kilogram (pmol/kg)
SD1_Th_232_D_CONC_SUBICE_PUMP_k4fwfy	One standard deviation of Th_232_D_CONC_SUBICE_PUMP_k4fwfy	picomoles per kilogram (pmol/kg)
Flag_Th_232_D_CONC_SUBICE_PUMP_k4fwfy	SeaDataNet quality flag for Th_232_D_CONC_SUBICE_PUMP_k4fwfy	unitless
Th_230_D_CONC_SUBICE_PUMP_ekirbo	Concentration of dissolved Th-230 in seawater collected using a pump through sea ice into seawater	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_CONC_SUBICE_PUMP_ekirbo	One standard deviation of Th_230_D_CONC_SUBICE_PUMP_ekirbo	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_CONC_SUBICE_PUMP_ekirbo	SeaDataNet quality flag for Th_230_D_CONC_SUBICE_PUMP_ekirbo	unitless

Pa_231_D_CONC_SUBICE_PUMP_hhrm9o	Concentration of dissolved Pa-231 in seawater collected using a pump through sea ice into seawater	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_CONC_SUBICE_PUMP_hhrm9o	One standard deviation of Pa_231_D_CONC_SUBICE_PUMP_hhrm9o	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_CONC_SUBICE_PUMP_hhrm9o	SeaDataNet quality flag for Pa_231_D_CONC_SUBICE_PUMP_hhrm9o	unitless
Th_232_ICE_D_CONC_CORER_z41jl6	Concentration of dissolved Th-232 in sea ice collected using a trace metal clean ice corer	picomoles per kilogram (pmol/kg)
SD1_Th_232_ICE_D_CONC_CORER_z41jl6	One standard deviation of Th_232_ICE_D_CONC_CORER_z41jl6	picomoles per kilogram (pmol/kg)
Flag_Th_232_ICE_D_CONC_CORER_z41jl6	SeaDataNet quality flag for Th_232_ICE_D_CONC_CORER_z41jl6	unitless
Th_230_ICE_D_CONC_CORER_vfv4yg	Concentration of dissolved Th-230 in sea ice collected using a trace metal clean ice corer	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_ICE_D_CONC_CORER_vfv4yg	One standard deviation of Th_230_ICE_D_CONC_CORER_vfv4yg	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_ICE_D_CONC_CORER_vfv4yg	SeaDataNet quality flag for Th_230_ICE_D_CONC_CORER_vfv4yg	unitless
Pa_231_ICE_D_CONC_CORER_mpjezi	Concentration of dissolved Pa-231 in sea ice collected using a trace metal clean ice corer	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_ICE_D_CONC_CORER_mpjezi	One standard deviation of Pa_231_ICE_D_CONC_CORER_mpjezi	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_ICE_D_CONC_CORER_mpjezi	SeaDataNet quality flag for Pa_231_ICE_D_CONC_CORER_mpjezi	unitless
Th_232_D_CONC_MELTPOND_PUMP_kgth7x	Concentration of dissolved Th-232 in melt pond water collected using a pump into a melt pond	picomoles per kilogram (pmol/kg)
SD1_Th_232_D_CONC_MELTPOND_PUMP_kgth7x	One standard deviation of Th_232_D_CONC_MELTPOND_PUMP_kgth7x	picomoles per kilogram (pmol/kg)

Flag_Th_232_D_CONC_MELTPOND_PUMP_kgth7x	SeaDataNet quality flag for Th_232_D_CONC_MELTPOND_PUMP_kgth7x	unitless
Th_230_D_CONC_MELTPOND_PUMP_iqwixv	Concentration of dissolved Th-230 in melt pond water collected using a pump into a melt pond	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_CONC_MELTPOND_PUMP_iqwixv	One standard deviation of Th_230_D_CONC_MELTPOND_PUMP_iqwixv	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_CONC_MELTPOND_PUMP_iqwixv	SeaDataNet quality flag for Th_230_D_CONC_MELTPOND_PUMP_iqwixv	unitless
Pa_231_D_CONC_MELTPOND_PUMP_mxxuva	Concentration of dissolved Pa-231 in melt pond water collected using a pump into a melt pond	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_CONC_MELTPOND_PUMP_mxxuva	One standard deviation of Pa_231_D_CONC_MELTPOND_PUMP_mxxuva	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_CONC_MELTPOND_PUMP_mxxuva	SeaDataNet quality flag for Pa_231_D_CONC_MELTPOND_PUMP_mxxuva	unitless
Th_230_D_XS_CONC_BOTTLE	Concentration of dissolved excess Th-230 in seawater collected using a Niskin or GO-FLO bottle on a CTD rosette (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_XS_CONC_BOTTLE	One standard deviation of Th_230_D_XS_CONC_BOTTLE	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_XS_CONC_BOTTLE	SeaDataNet quality flag for Th_230_D_XS_CONC_BOTTLE	unitless
Pa_231_D_XS_CONC_BOTTLE	Concentration of dissolved excess Pa-231 in seawater collected using a Niskin or GO-FLO bottle on a CTD rosette (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_XS_CONC_BOTTLE	One standard deviation of Pa_231_D_XS_CONC_BOTTLE	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_XS_CONC_BOTTLE	SeaDataNet quality flag for Pa_231_D_XS_CONC_BOTTLE	unitless
Th_230_D_XS_CONC_BOAT_PUMP	Concentration of dissolved excess Th-230 in seawater collected using a pump from a small boat (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)

SD1_Th_230_D_XS_CONC_BOAT_PUMP	One standard deviation of Th_230_D_XS_CONC_BOAT_PUMP	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_XS_CONC_BOAT_PUMP	SeaDataNet quality flag for Th_230_D_XS_CONC_BOAT_PUMP	unitless
Pa_231_D_XS_CONC_BOAT_PUMP	Concentration of dissolved excess Pa-231 in seawater collected using a pump from a small boat (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_XS_CONC_BOAT_PUMP	One standard deviation of Pa_231_D_XS_CONC_BOAT_PUMP	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_XS_CONC_BOAT_PUMP	SeaDataNet quality flag for Pa_231_D_XS_CONC_BOAT_PUMP	unitless
Th_230_D_XS_CONC_SUBICE_PUMP	Concentration of dissolved excess Th-230 in seawater collected using a pump through sea ice into seawater (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_XS_CONC_SUBICE_PUMP	One standard deviation of Th_230_D_XS_CONC_SUBICE_PUMP	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_XS_CONC_SUBICE_PUMP	SeaDataNet quality flag for Th_230_D_XS_CONC_SUBICE_PUMP	unitless
Pa_231_D_XS_CONC_SUBICE_PUMP	Concentration of dissolved excess Pa-231 in seawater collected using a pump through sea ice into seawater (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_XS_CONC_SUBICE_PUMP	One standard deviation of Pa_231_D_XS_CONC_SUBICE_PUMP	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_XS_CONC_SUBICE_PUMP	SeaDataNet quality flag for Pa_231_D_XS_CONC_SUBICE_PUMP	unitless
Th_230_ICE_D_XS_CONC_CORER	Concentration of dissolved excess Th-230 in sea ice collected using a trace metal clean ice corer (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_ICE_D_XS_CONC_CORER	One standard deviation of Th_230_ICE_D_XS_CONC_CORER	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_ICE_D_XS_CONC_CORER	SeaDataNet quality flag for Th_230_ICE_D_XS_CONC_CORER	unitless

Pa_231_ICE_D_XS_CONC_CORER	Concentration of dissolved excess Pa-231 in sea ice collected using a trace metal clean ice corer (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_ICE_D_XS_CONC_CORER	One standard deviation of Pa_231_ICE_D_XS_CONC_CORER	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_ICE_D_XS_CONC_CORER	SeaDataNet quality flag for Pa_231_ICE_D_XS_CONC_CORER	unitless
Th_230_D_XS_CONC_MELTPOND_PUMP	Concentration of dissolved excess Th-230 in melt pond water collected using a pump into a melt pond (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Th_230_D_XS_CONC_MELTPOND_PUMP	One standard deviation of Th_230_D_XS_CONC_MELTPOND_PUMP	micro-Becquerel per kilogram (µBq/kg)
Flag_Th_230_D_XS_CONC_MELTPOND_PUMP	SeaDataNet quality flag for Th_230_D_XS_CONC_MELTPOND_PUMP	unitless
Pa_231_D_XS_CONC_MELTPOND_PUMP	Concentration of dissolved excess Pa-231 in melt pond water collected using a pump into a melt pond (see metadata for full explanation)	micro-Becquerel per kilogram (µBq/kg)
SD1_Pa_231_D_XS_CONC_MELTPOND_PUMP	One standard deviation of Pa_231_D_XS_CONC_MELTPOND_PUMP	micro-Becquerel per kilogram (µBq/kg)
Flag_Pa_231_D_XS_CONC_MELTPOND_PUMP	SeaDataNet quality flag for Pa_231_D_XS_CONC_MELTPOND_PUMP	unitless

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Instruments

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.

Dataset-specific Instrument Name	CTD Sea-Bird SBE 911plus
Generic Instrument Name	CTD Sea-Bird SBE 911plus
Dataset-specific Description	The Scripps Oceanographic Data Facility (ODF) sampling system included a Seabird carousel/CTD with 12-place 30 L Niskin bottles (coded 30-ODF in event log) and 36-place 10 L Niskin bottles (coded GS in event log). The PAR calibration sheet is available (http://dmoserv3.bco-dmo.org/data_docs/GEOTRACES/Arctic/HLY1502_PAR_QCP23...). The GEOTRACES Clean Carousel (GTC) sampling system included a Dynacon winch with 7300 m of Vectran cable with conductors, clean lab, and Seabird carousel/CTD with 24-place 12 L GO-FLO bottles (and 14 spares; coded GT-C in event log).
Generic Instrument Description	The Sea-Bird SBE 911 plus is a type of CTD instrument package for continuous measurement of conductivity, temperature and pressure. The SBE 911 plus includes the SBE 9plus Underwater Unit and the SBE 11plus Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 plus and SBE 11 plus is called a SBE 911 plus. The SBE 9 plus uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 plus and SBE 4). The SBE 9 plus CTD can be configured with up to eight auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). more information from Sea-Bird Electronics

Dataset-specific Instrument Name	GO-FLO Teflon Trace Metal Bottle
Generic Instrument Name	GO-FLO Teflon Trace Metal Bottle
Dataset-specific Description	GF: GO-FLO bottles sampled from the 24-place 12 L GEOTRACES Clean Carousel (GTC) rosette. Pre-conditioned, teflon-coated 12 L GO-FLO sampling bottles (General Oceanics, Miami, FL) deployed on a polyurethane powder-coated aluminum rosette with titanium pilings and pressure housings (Sea-Bird Electronics, Inc., Bellevue, WA) attached to a Kevlar, non-metallic conducting cable.
Generic Instrument Description	GO-FLO Teflon-lined Trace Metal free sampling bottles are used for collecting water samples for trace metal, nutrient and pigment analysis. The GO-FLO sampling bottle is designed specifically to avoid sample contamination at the surface, internal spring contamination, loss of sample on deck (internal seals), and exchange of water from different depths.

Dataset-specific Instrument Name	Polypropylene/titanium trace metal coring system
Generic Instrument Name	Ice Corer
Dataset-specific Description	Polypropylene/titanium trace metal coring system used to collect sea ice samples. A small subset of sea ice samples from designated "ice stations" (Stations 31, 33, 39, 42, 43, 46) were collected by drilling ice with a polypropylene/titanium trace metal coring system.
Generic Instrument Description	An ice corer is used to drill into deep ice and remove long cylinders of ice from which information about the past and present can be inferred. Polar ice cores contain a record of the past atmosphere - temperature, precipitation, gas content, chemical composition, and other properties. This can reveal a broad spectrum of information on past environmental, and particularly climatic, changes. They can also be used to study bacteria and chlorophyll production in the waters from which the ice core was extracted.

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	Niskin bottle
Generic Instrument Name	Niskin bottle
Dataset-specific Description	NIS: Niskin bottles sampled from the 12-place 30 L Scripps Oceanographic Data Facility (ODF) rosette. GSNIS: Niskin bottles sampled from the 36-place 10 L Scripps Oceanographic Data Facility (ODF) rosette.
Generic Instrument Description	A Niskin bottle (a next generation water sampler based on the Nansen bottle) is a cylindrical, non-metallic water collection device with stoppers at both ends. The bottles can be attached individually on a hydrowire or deployed in 12, 24, or 36 bottle Rosette systems mounted on a frame and combined with a CTD. Niskin bottles are used to collect discrete water samples for a range of measurements including pigments, nutrients, plankton, etc.

Dataset-specific Instrument Name	Centrifugal pump; Polyethylene pump
Generic Instrument Name	Pump
Dataset-specific Description	SMBT: Battery-powered pump and Teflon-lined PVC tubing used to collect surface (1 m) seawater samples from a small boat upstream of the ship. A small subset of samples from designated "ice stations" (Stations 31, 33, 39, 42, 43, 46) were collected under the ice (at approximately 1, 5, and 20 m) after the ice was drilled with a polypropylene/titanium trace metal coring system. Sampling was done using a polypropylene, battery-powered motor centrifugal pump with ½ inch FEP-lined Tygon tubing. At most of these same "ice stations" (Stations 33, 39, 42, 43, 46), melt pond samples were collected by clearing surface snow with an acid-cleaned polyethylene shovel and then using a polyethylene/titanium trace metal coring system to drill through the upper ice. Melt pond water was pumped using a battery-powered polyethylene pump through pre-cleaned C-flex tubing into a pre-cleaned LDPE carboy.
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

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

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Project Information

U.S. Arctic GEOTRACES Study (GN01) (U.S. GEOTRACES Arctic)

Website: https://www.geotraces.org/

Coverage: Arctic Ocean; Sailing from Dutch Harbor to Dutch Harbor (GN01)

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 activites 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 globlal 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 230Th and 231Pa, two isotopes designated as key or critical to the success of the GEOTRACES program. Additionally the team will measure dissolved and particulate 232Th 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 231Pa and 230Th associated with the particle-rich waters near the southern margin of the Canada Basin; (2) determine the rates of bottom scavenging of 231Pa and 230Th associated with nepheloid layers that are prevalent in the Arctic Ocean; (3) assess the contribution to scavenging in the Canada basin by MnO2-coated particles, formed during early diagenesis in organic-rich sediments surrounding the Arctic Ocean; (4) determine the rate of supply of lithogenic 232Th from margin sediments using information derived from 230Th; and (5) determine the rate of supply of lithogenic 232Th from sea ice, including the aerosols and ice-rafted sediments that they transport, by the combined study of 232Th and 230Th. The proposed work fulfills core scientific objectives defined in the U.S. GEOTRACES Arctic Implementation Plan.

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Program Information

U.S. GEOTRACES (U.S. GEOTRACES)

Website: http://www.geotraces.org/

Coverage: Global

GEOTRACES is a SCOR sponsored program; and funding for program infrastructure development is provided by the U.S. National Science Foundation.

GEOTRACES gained momentum following a special symposium, S02: Biogeochemical cycling of trace elements and isotopes in the ocean and applications to constrain contemporary marine processes (GEOSECS II), at a 2003 Goldschmidt meeting convened in Japan. The GEOSECS II acronym referred to the Geochemical Ocean Section Studies To determine full water column distributions of selected trace elements and isotopes, including their concentration, chemical speciation, and physical form, along a sufficient number of sections in each ocean basin to establish the principal relationships between these distributions and with more traditional hydrographic parameters;

* To evaluate the sources, sinks, and internal cycling of these species and thereby characterize more completely the physical, chemical and biological processes regulating their distributions, and the sensitivity of these processes to global change; and

* To understand the processes that control the concentrations of geochemical species used for proxies of the past environment, both in the water column and in the substrates that reflect the water column.

GEOTRACES will be global in scope, consisting of ocean sections complemented by regional process studies. Sections and process studies will combine fieldwork, laboratory experiments and modelling. Beyond realizing the scientific objectives identified above, a natural outcome of this work will be to build a community of marine scientists who understand the processes regulating trace element cycles sufficiently well to exploit this knowledge reliably in future interdisciplinary studies.

Expand "Projects" below for information about and data resulting from individual US GEOTRACES research projects.

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Funding

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

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