ANNUAL REPORT ON US GEOTRACES ACTIVITIES FOR THE PERIOD

May 1st, 2023 to April 30th, 2024

New GEOTRACES or GEOTRACES relevant scientific results

With 32 peer-reviewed publications in the past year (see attached list) there are too many results to describe them all. Therefore, the approach here is to begin by listing the projects involving US GEOTRACES investigators that were featured as GEOTRACES science highlights during the reporting period. See: < https://www.geotraces.org/category/science/newsflash/>. Following that we will report briefly on the status of GEOTRACES section GP17-ANT, completed in January 2024, and then on US GEOTRACES process studies.

Science highlights, in reverse chronological order, with the name of the lead investigator, included:

Highlight Date	Lead P.I.	Synopsis
March 20, 2024	W.S. Moore	*Moore and colleagues* establish radium-228 (^{228}Ra, half-life of 5.7 years) distributions along the GP15 meridional transect from Alaska to Tahiti. Because ^{228}Ra is sourced from sediments, regions of enhanced activity represent water that has recently interacted with sediments on the continental margin or seabed. The ^{228}Ra data allow the authors to trace surface and subsurface ocean current patterns in the Pacific and to compare with earlier measurements of ^{228}Ra to reveal the origins of the enriched regions. An enriched region at the Alaska margin was source locally. A large shallow region between 47° and 32°N. was sourced from the west by the North Pacific Current; another shallow enriched region between 11° and 5°N was also sourced from the west by the North Equatorial Countercurrent. Subsurface enrichments (100–400 m) between 18 and 47°N were associated with Central Mode Water and North Pacific Intermediate Water. Near the seabed they discovered a region of enhanced ^{228}Ra activity indicating intense sediment-water interactions. For example, between 27 and 47°N near-bottom inventories average four times greater than the other stations on GP15, likely resulting from a sluggish circulation in this region, leading to long water residence times and ^{228}Ra build-up. Such regions may control the release of trace elements and isotopes (TEIs) from the seabed to the water column. On global scales, the study compares ^{228}Ra distributions integrated in the near-surface in the Pacific, Indian and Atlantic oceans. The different ^{228}Ra distributions emphasize how ocean circulation features are reflected in the ^{228}Ra abundances. *doi: 10.1029/2023JC020564*

February 21, 2024	Y. Gu	*Gu and co-authors* investigate the interannual variability in dFe concentrations and their response to El Niño–Southern Oscillation (ENSO) events from multiple cruise campaigns during the period 1984-2017, including GEOTRACES GP16 section among those. Oxygen minimum zones are well recognized as hotspots of redox sensitive trace metal cycling, often featuring especially high concentrations of the micronutrient iron (Fe). The Peruvian shelf, particularly between 9° S and 17°S where the shelf is broad, is extremely productive and known to feature benthic dFe effluxes which are amongst the highest measured globally. The authors find that, in a narrow coastal band Fe correlates to the ENSO index with lower Fe concentrations during El Niño events and higher, more variable, concentrations during cold ENSO phases. Both surface and subsurface layers dFe concentrations tend to be lower as wind speed increases. In contrast, upwelling intensity has a limited impact on dFe concentrations in the surface layer. In northern Peru, where the shelf is broader, interannual variability in offshore surface Chl-a is correlated with dFe concentrations, and no significant correlation was found for the southern Peru coastal region. *doi: 10.1016/j.pocean.2024.103208*
January 31, 2024	C.-Y. Chang	*Chang and co-authors* report the distribution of the dissolved and labile particulate aluminum (Al), manganese (Mn), iron (Fe), cobalt (Co), and lead (Pb) in the subarctic Pacific Ocean during the GEOTRACES Japan KH-17-3 cruise and along the 47° N zonal transect (GEOTRACES GP02). In addition, vertical distributions of dCo were compared at crossover stations (GP15). The study provides a comprehensive view of dissolved and particulate trace metal distribution in the subarctic Pacific Ocean. An intensive boundary scavenging occurs off the coast of Alaska covering ca. 250 km width, limiting the impact of the continental sources (fluvial and sediment inputs) in this area. At the easternmost station, the effect of the hydrothermal activity of the Juan de Fuca Ridge influences the distribution of deep-water trace metals. The authors also analyze the full-depth transport of dMn and lpMn along isopycnal surfaces along the GP02 section. In addition, the temporal study of Pb distributions confirms that declining of anthropogenic emissions of Pb resulted in a decadal change in dPb in the center of the subarctic gyre. *doi: 10.1007/s10872-023-00710-8*
November 21, 2023	M. Fourquez	*Fourquez and co-authors* conducted dissolved iron (dFe) uptake experiments with *Phaeocystis antarctica*, in order to establish processes controlling the dFe bioavailability in natural samples of the Southern Ocean. They show that the degree of bioavailability varied regardless of in situ dFe concentration and depth. This first result challenges the consensus that sole dFe concentrations can be used to predict Fe uptake in modeling studies. In addition, the range of this degree of

		bioavailability is wider than previously thought (<1 to ~200% compared to free inorganic Fe') with higher bioavailability found near glacial sources. The study's coupled dataset of Fe-binding ligands, dFe bioavailability, and δ^{56}Fe offers a chance to tease apart these processes further. Contrasting again with previous assumptions, they observe a negative correlation between dissolved δ^{56}Fe and total ligand concentrations, which might suggest against a role for complexation in driving dissolved δ^{56}Fe toward higher values. *doi: 10.1126/sciadv.adf9696*
October 17, 2023	Ö. Z. Mete	*Mete and colleagues* used Machine Learning (ML) to predict the global distribution of oceanic barium (Ba). Models were first trained to predict [Ba] from standard oceanographic observations using GEOTRACES data from the Arctic (GIPY11, GN01), Atlantic (GA03, GA10, GA02), Pacific (GP15, GP16), and Southern oceans (GIPY04, GIPY05). Model predictions of [Ba] were then compared with actual [Ba] data from the Indian Ocean (GEOSECS, INDIGO 1-3, SR3, SS259) with the best models achieving a mean absolute percentage error of just 6.0 %. This successful comparison allowed the authors to calculate the global distribution of [Ba], Ba*, and marine barite saturation using data from the World Ocean Atlas 2018. This approach revealed four significant findings: 1) the ocean contains 122±7 Tmol of dissolved Ba; 2) the variability in the barium–silicon relationship is consistent with the biogeochemical characteristics of both elements; 3) marine barite saturation exhibits systematic spatial and vertical variations; 4) taken as a whole, the ocean below 1000 m is at equilibrium with respect to barite. These results have broad implications, both for the modern ocean and for interpreting paleo-records of barite, with minor adjustments, their approach could be employed to make predictions for other dissolved tracers in the sea. The model, the data used in training and validation, and global outputs are available in Horner and Mete (2023, https://doi.org/10.26008/1912/bco-dmo.885506.2). *doi: 10.5194/essd-15-4023-2023*
October 16, 2023	N. Kemnitz	*Kemnitz and co-authors* examine Actinium-227 (^{227}Ac), radium-226 (^{226}Ra) and radium-228 (^{228}Ra) profiles in sediments that were measured and modeled at 5 stations in the Northeast Pacific Basin with the objective of characterizing their behavior and fluxes into the overlying water column. Data allowed the distribution coefficient (Kd) between the solid and liquid phases for Ac and Ra. A strong positive correlation is observed between Ra and ^{227}Ac Kd values, with ^{227}Ac being almost 6.6 times higher than Ra Kd values, and both co-varying with the MnO2 in solid phases. The source function of ^{227}Ac in the Northeast Pacific was determined by two independent methods: core incubation and reaction transport models. The authors also established the Ra fluxes. The largest ^{227}Ac

		and Ra isotope fluxes are near the center of the Northeast Pacific (~37ºN). Smaller ^{227}Ac, ^{228}Ra and ^{226}Ra fluxes occur north of 40ºN, primarily due to dilution of their protactinium and thorium ancestors by higher sediment accumulation rates. *doi: j.marchem.2022.104180*
July 3, 2023	N. Lanning	The ratios of stable dissolved Pb (dPb) isotopes ($^{206}Pb/^{207}Pb$ & $^{208}Pb/^{206}Pb$) have been used to trace the origin of oceanic dPb capable of distinguishing anthropogenic versus natural sources. In the modern North Pacific, anthropogenic dPb input from Asia is the dominant Pb source to the upper ocean, exhibiting a characteristic isotope signature. dPb concentrations deep in the North Pacific water column have also been progressively increasing. This is hypothesized to result from intense scavenging of anthropogenic dPb isotopes to sinking particles in the upper ocean with subsequent 'reversible-scavenging' desorbing Pb back into the dissolved phase of the deep ocean as the particles sink. *Lanning and co-authors* have observed how changes in scavenging intensity and particle loading influence this isotope exchange on a basin-scale. The authors assessed the role of particle-rich 'veils' in the vertical transport of anthropogenic dPb isotopes using the GEOTRACES GP15 section. Only within the particle veils do anthropogenic dPb isotope ratios extend from the upper ocean to the seafloor, overprinting the background pre-industrial water column isotope signatures. These isotope effects coincide with elevated particulate inorganic carbon (PIC) and suspended particulate matter, emphasizing the importance of high particle-loading to facilitate sufficient isotope exchange. A 1-D box model was implemented to quantify how only within high-flux veils is reversible dPb isotope exchange between the particulate and dissolved phases fast enough to supply anthropogenic dPb from the upper ocean to depth. The work further contains the role that reversible scavenging may play in the cycling of Pb in the ocean, an ever-evolving global experiment where Pb contamination can be tracked in real-time. *doi: 10.1073/pnas.2219688120*
May 17, 2023	M. Sieber	*Sieber and co-authors* explain some of the mechanisms that control the behavior of Zn in the Pacific Ocean, and more globally, from measurements of dissolved Zn concentration and isotopic compositions ($\delta^{66}Zn$) along the GEOTRACES GP15 section (from Alaska to Tahiti along 152°W). Their data reveal a relationship between Zn and Si in the north Pacific, contrasting with a linear relationship in the Southern part of the section (equatorial and tropical parts). The main findings of this study are: 1) reversible scavenging is required as an additional process transferring Zn from surface to depth, explaining a deep Zn concentration maximum below the PO4 maximum that is not specifically linked to Si and 2) reversible scavenging together with fractionation during ligand assimilation provides an explanation for

		the observed isotope distribution, leaving subsurface upper ocean waters imprinted by lower $\delta^{66}Zn$. Deeper, release of heavy Zn then coincides with the PO_4 maximum during particle remineralization, causing a subtle mid-depth $\delta^{66}Zn$ maximum. Moreover, making use of $\delta^{66}Zn$ data from a crossover station between US GEOTRACES GP15 and Japanese GP02, the authors were able to show that this mechanism of scavenging of isotopically heavy zinc is linked to seasonal physical stratification and is an important process influencing surface and subsurface $\delta^{66}Zn$ signals in the North Pacific Ocean. Globally, it also provides an explanation for isotopically light Zn at shallow depths and corresponding elevated mid-depth $\delta^{66}Zn$ signals, seen dominantly in ocean regions away from strong Southern Ocean control. *doi:* [10.1029/2022jc019419](https://doi.org/10.1029/2022jc019419)
May 16, 2023	M. Sieber	*Sieber and colleagues* established the distribution of dissolved cadmium (Cd) concentrations and isotopes at 23 stations (represented as $\delta^{114}Cd$) along the meridional GEOTRACES GP15 section from Alaska to Tahiti along 152°W. The data reveal northern Cd-rich high-nutrient low-chlorophyll waters and Cd-depleted waters in the subtropical and equatorial Pacific. In the open ocean, a biogeochemical model simulates the data in Cd-depleted surface waters, with the lowest Cd concentrations influenced by atmospheric inputs of isotopically light Cd. Below the surface (and surprisingly even in the North Pacific Ocean), Cd parameter distributions are essentially controlled by Southern Ocean processes, water mass mixing and regeneration. Cd-depleted Antarctic Intermediate Water has a far-reaching effect on North Pacific intermediate waters as far as 47°N, contrasting with northern-sourced Cd signatures in North Pacific Intermediate Water. The study also reveals that a correlation between the North Pacific phosphate maximum and a negative Cd* signal at depth in the North Pacific Ocean reflects a regeneration signal of Cd and PO_4 at a slightly lower Cd:P ratio than the deep ocean ratio (0.35 mmol mol^{-1}), contradicting the hypothesis that a negative Cd* signal is due to in situ removal processes in low-oxygen waters. *doi:* [10.1029/2022gb007441](https://doi.org/10.1029/2022gb007441)
May 12, 2023	M. Grenier	*Grenier and co-authors* measured the ^{7}Be activity in suspended particles collected in and below the mixed layer in oceanic regions of the Mediterranean Sea, the Southern Ocean and the subpolar Atlantic (section GEOVIDE/GEOTRACES GA01). While the $^{7}Be_p$ activity generally monotonically decreases with depth below the mixed layer, they reveal that, at least in some oceanic regions, the removal of ^{7}Be by marine particles may be significant. The $^{7}Be_p$ fraction ranges from 2% to 32% of the total ^{7}Be activity along the GEOVIDE section in the North Atlantic. In the Labrador Sea, the comparison of the $^{7}Be_p$ inventories with the dry ^{7}Be deposition fluxes estimated from aerosol samples

		collected during GEOVIDE suggest that a significant portion of ^7Be_p may be removed by sinking particles. The authors propose that future research should focus on quantifying the downward export of ^7Be_p to deep waters, and on assessing its temporal and spatial variability and recommend that future sampling programs should aim to collect seawater and particulate samples at the same locations, depths and time. *doi: 10.1016/j.dsr.2023.103967*

GEOTRACES or GEOTRACES relevant cruises

Section Cruises

During the reported period, GEOTRACES Section GP17 was completed. GP17 was planned as a two-leg expedition, with its first leg (GP17-OCE) as a southward extension of the 2018 GP15 Alaska-Tahiti expedition and the second leg (GP17-ANT) sailing into coastal and shelf waters of Antarctica's Amundsen Sea.

The U.S. GEOTRACES GP17-ANT expedition departed Punta Arenas, Chile on November 29th, 2023 and arrived in Lyttelton, New Zealand on January 29th, 2024. The cruise took place in the Amundsen Sea aboard the R/V Nathaniel B. Palmer with a team of 35 scientists led by Peter Sedwick (Old Dominion University), Phoebe Lam (University of California, Santa Cruz) and Robert Sherrell (Rutgers University).

A primary objective of this cruise was to determine the sources of trace element nutrients that support the intense phytoplankton blooms that are often observed in coastal regions around Antarctica. Essential micronutrients include iron, zinc, manganese, copper, nickel and cobalt. Other trace elements and isotopes (TEIs; e.g., aluminum, manganese, and isotopes of nitrogen, thorium and neodymium) are intended to help constrain the source(es) of micronutrients. In the Southern Ocean, the Antarctic continental margins are important as sources of micronutrient trace elements such as iron, which fuels biological production and carbon export over the Antarctic shelf and in offshore waters of the Antarctic Circumpolar Current. Moreover, these regions are experiencing rapid environmental changes that are expected to impact oceanic circulation and biogeochemical cycles, for which TEIs provide crucial tracers and provide data needed to test and refine numerical models of the Earth system. The Amundsen Sea sector holds particular interest because of the pronounced, decadal-scale increases in the basal melt rates of glacial ice shelves that border the region, driven by intrusions of warm Circumpolar Deep Water (CDW) onto the continental shelf. This melting has potentially major impacts on global sea level, on the formation of Antarctic Bottom Water in the Ross Sea, and on primary production via mobilization of benthic and glacial iron and other TEIs mediated by these processes. This cruise was designed to address a wide range of topics such as the sources, fate and impacts of bioactive trace elements; the distribution and transport of glacial melt; the compositional evolution of CDW as it upwells and circulates on the shelf; the rates and elemental stoichiometry of biological and biogeochemical processes; and the veracity of paleoenvironmental proxies and numerical model simulations.

The almost two-month cruise was largely successful in achieving its science goals, with 21 stations over the Amundsen Sea continental shelf, 3 stations over the continental slope and 3 off-shelf stations, including one deep-ocean station as a crossover with the preceding GP17-OCE cruise. All stations included collections of samples with a near-surface towfish, a conventional CTD-rosette, a trace-metal clean CTD-rosette, and McLane in-situ pumps. Additional sampling activities included the collection of aerosols, precipitation, sea ice and snow as well as sediment cores for pore-fluid extraction and high-volume pumped seawater samples for radium isotopes and beryllium-7. The heavy sea ice cover prevented access to a number of planned stations including the Thwaites Ice Shelf, Pine Island Bay and the eastern portion of the outer Amundsen Sea shelf. Nonetheless, samples were collected from stations adjacent to the Dotson and Getz Ice Shelves, as well as on- and off-shelf stations impacted by melting sea ice, polynya stations where phytoplankton biomass was extraordinarily high (up to 30 µg chl/liter), and a station adjacent to fast ice with near-zero chlorophyll fluorescence. With support from the U.S. National Science Foundation samples were collected for 23 separate science projects, which together encompass measurements of nearly all of the GEOTRACES key trace elements and isotopes.

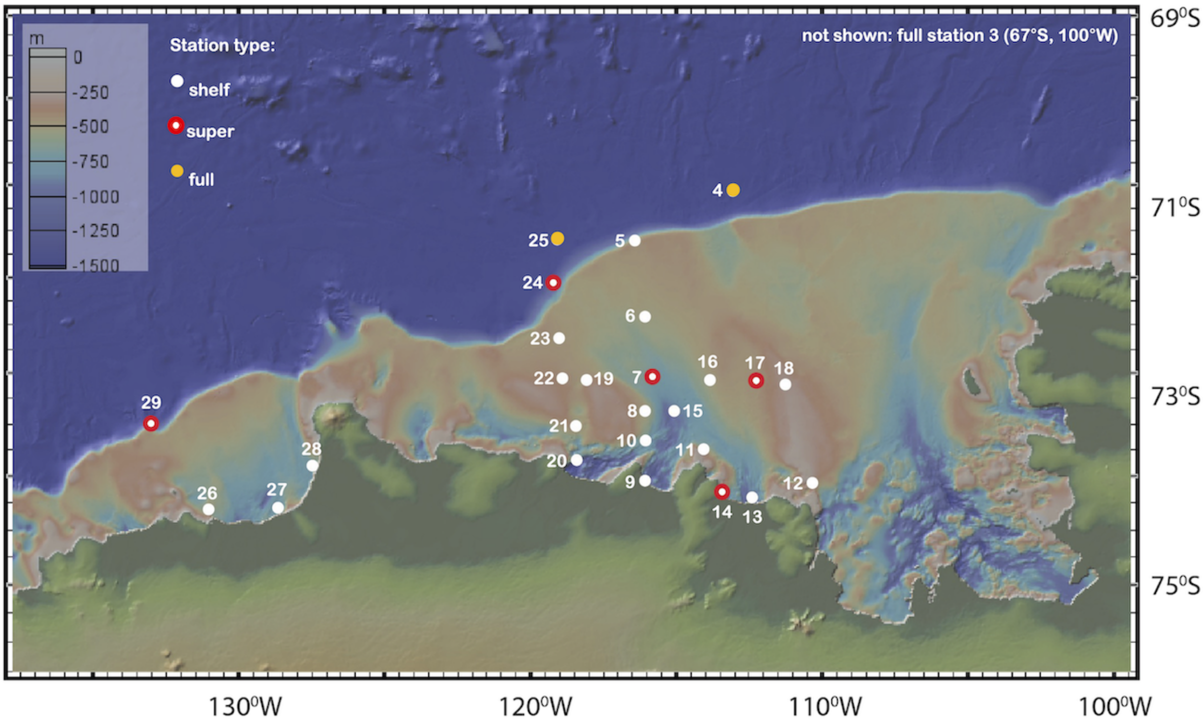

Figure US-1. Track and station locations for GEOTRACES Section GP17-ANT.

Samples that were collected on GP17-ANT for distribution to investigators in the US are summarized in the following tables.

Table US-1: GP17-ANT Sampling Stations

Here, approximate station coordinates and bottom depths are presented to the nearest 0.1' or 10 m, respectively.

Station	Latitude (S)	Longitude (W)	Type	Dates	Depth (m)
1	61°36.6'	62°46.2'	soak	2 December 2023	3450
1.5	65°25.8'	72°55.2'	towfish test	4 December 2023	ND
2	65°13.8'	78°51.6'	test	5 December 2023	4040

3	67°00.0'	100°00.0'	full	7-10 December 2023	4700
4	71°00.0'	113°00.0'	full	12-14 December 2023	2740
5	71°31.5'	116°21.2'	shelf	14-15 December 2023	1020
6	72°20.0'	116°00.0'	shelf	16 December 2023	530
7	72°57.9'	115°45.1'	super	17 December 2023	680
8	73°20.0'	116°00.0'	shelf	18 December 2023	500
9	74°04.0'	116°00.0'	shelf	19 December 2023	1070
10	73°38.5'	115°58.8'	shelf	20 December 2023	730
11	73°44.0'	114°00.0'	shelf	21 December 2023	530
12	74°05.4'	110°16.4'	shelf	22 December 2023	460
13	74°14.7'	112°20.1'	shelf	23-24 December 2023	1070
14	74°11.0'	113°22.0'	super	24-25 December 2023	550
15	73°20.0'	115°00.0'	shelf	25-26 December 2023	890
16	73°00.1'	113°46.7'	shelf	26-27 December 2023	470
17	73°00.4'	112°11.7'	super	27-28 December 2023	420
18	73°02.8'	111°11.7'	shelf	28 December 2023	320
19	73°00.0'	118°00.0'	shelf	29-30 December 2023	410
20	73°50.9'	118°20.5'	shelf	30-31 December 2023	1240
21	73°29.3'	118°22.1'	shelf	31 December 2023- 1 January 2024	580
22	72°59.0'	118°49.9'	shelf	1-2 January 2024	400
23	72°33.5'	118°56.3'	shelf	2 January 2024	470
24	71°58.3'	119°08.1'	super	3 & 6 January 2024	1410
25	71°30.9'	119°00.5'	full	4-5 January 2024	2060
26	74°22.2'	130°56.2'	shelf	9-10 January 2024	470
27	74°21.1'	128°33.5'	shelf	10-11 January 2024	820
28	73°54.5'	127°22.7'	shelf	11 January 2024	780
29	73°27.7'	132°54.0'	semi-super	12-13 January 2024	1590

Table US-2. PI, parameters, and samplers of ODF (standard) rosette system.

Role/PI(s)	**Parameter**	**Sampler**
SIO-ODF team	dissolved oxygen	Barna/Chung
SIO-ODF team	salinity, nutrients	Matthias/Mau
Loose, Seltzer	noble gases, noble gas isotopes	Passacantando
Woosley	DIC, pH, alkalinity	Woosley
Wang	$\delta^{15}N$ in nitrate, TDN, ammonium	ODF Supertechs
Wagner, Loose	$\delta^{18}O$ and $\delta^{2}H$ in H_2O	ODF Supertechs
Loose	^{3}H	Passacantando
Saito	vitamin B-12	ODF Supertechs
Resing	DMn	ODF Supertechs
Cutter	DOS	ODF Supertechs

Hayes	Th isotopes and ^{231}Pa	ODF Supertechs
Zheng	REEs	ODF Supertechs
Management team	pigments	ODF Super techs
Sherrell	F_v/F_m	Passacantando
Buesseler	^{234}Th	Bam
Charette	Ra isotopes	ODF Supertechs/Debyser
Debyser	$\delta^{32}Si$	ODF Supertechs/Debyser

Table US-3. PI, parameters, and samplers of GTC (trace metal clean) rosette system.

Membrane side			**Acropak side**	
PI	**Sample type**		**PI**	**Sample type**
Becker	Oxygen*		Becker	Salinity*
Moffett	Fe(II), I**		Becker	Nutrients*
Becker	Salinity*		Whitmore	V, Ga, Ba
Loose	$\delta^{18}O$ of seawater*		Hawco	Zn ligands
Twining	Cell quotas SXRF*		Resing	Archive ICP-MS, FIA
Morton	Diatom frustule Zn*		Resing	Shipboard DAl, DMn, DFe
Mason	Hg speciation**		Fitzsimmons	Dissolved TMs
John	Cu/Ni isotopes**		Fitzsimmons	Colloidal TMs
Mix Go-Flos	*Attach 25 mm Swinnex filter holder*		Conway	Fe/Zn/Cd isotopes
Boiteau	SPE ligands***		K. Buck/Bundy	Ligands (CSV)
Complete particle filtration – Sherrell/Morton	2 h or filter clogs*** (Acropak used to finish SPE ligand sample as necessary)		K. Buck/Bundy	Ligands (CSV)
*unfiltered sample			Saito	DCo
**Acropak filtered			Saito	Labile Co
			Boyle	Pb isotopes

Table US-4. PI and parameters from the Niskin-X sampler deployed on the multicorer.

PI	**Subsample type**		**PI**	**Subsample type**
1. Becker	Salinity (unfilt.)		*Acropak-filtered*	*(continued)*
2. Becker	Nutrients (unfilt.)		12. Saito	DCo
3. Loose	$\delta^{18}O$ of seawater (unfilt.)		13, Saito	Labile Co
Attach Acropak filter			14. Basak	REE
4. Moffett	Fe(II), I		15. K. Buck/Bundy	Ligands (CSV) -1
5. Whitmore	V, Ga, Ba		16. K. Buck/Bundy	Ligands (CSV) -2
6. Hawco	Zn ligands		17. Mason	Hg speciation, Acropak
7. Resing	Archive ICP-MS, FIA		18. John	Cu/Ni isotopes
8. Resing	Shipboard DAl, DMn, DFe		*Mix Niskin-X sampler*	*Attach 0.45 µm Supor membrane filter*
9. Fitzsimmons	Dissolved TMs		19. Mason	Hg

10. Fitzsimmons	Colloidal TMs		20. Boiteau	SPE ligands
11. Conway	Fe/Zn/Cd isotopes		21. Sherrell/Morton	Particles on 0.45 µm Supor membrane

Table US-5. McLane pump particle subsamples.

PI	parameter	Sample fraction and processing notes	container	representative at sea
Hayes/Anderson/ Edwards	^{230}Th/ ^{231}Pa	¼ Qp, 5/16 Supor: laminar dry	cleanroom bags	Marty Fleisher
Zheng	εNd, REE	3/16 Qp: laminar dry; Supor: share w/ Th/Pa	cleanroom bag	Marty Fleisher
Buesseler (CafeTh)	^{234}Th	¼-7/8 Sp: CafeTh rinse onto Ag then oven dry; 25 mm QMA: oven dry	150mm petri (from CafeTh)	Wokil Bam, Steve Pike
Wang/ Sigman	δ^{15}N	32 mm QMA, 1/8 Sp: laminar dry	cleanroom bag	Kameko Landry
Charette	^{226}Ra	"rest of QMA": oven dry	Ziploc bag	Margot Debyser
C. Buck/Marsay	^{7}Be	"rest of QMA": oven dry	Ziploc bag	Chris Marsay
John	TM isotopes	Supor: laminar dry	cleanroom bag	none
Ohnemus	pTM total	1/16-1/8 Qp: rinse onto 0.8 µm Supor then laminar dry; 3/16 Supor: laminar flow dry	Qp: leached petrislide; Supor: cleanroom bag	Phoebe Lam, Allison Laubach
Lam	pTM leach	1/16 Qp, 1/16 Supor: laminar dry	cleanroom bag	Phoebe Lam, Allison Laubach
	XRF	1/16 Supor: laminar dry	cleanroom bag	Phoebe Lam, Allison Laubach
	bSi	1/16 Qp, 1/16 Supor: laminar dry	cleanroom bag	Phoebe Lam, Allison Laubach
	PIC	1/16 Qp: laminar dry; 25 mm QMA: oven dry	cleanroom bag	Phoebe Lam, Allison Laubach
	C/N+ isotopes	Sp, QMA: post ^{234}Th	see ^{234}Th	Phoebe Lam, Allison Laubach
	archive	0-1/16 Qp, 0-3/4 Sp, 4*1/16 Supor: laminar dry; 32 mm QMA: oven dry	cleanroom bag	Phoebe Lam, Allison Laubach
Mason/Lamborg	pHg	2*1/16 Qp, 2*25 mm QMA: laminar dry	Qp: cleanroom bags; QMA: petrislides	Carl Lamborg, Marissa Despins
Moffett	I	25 mm QMA: oven dry	60 mm petri dish	Alexis Floback
Boiteau/Repeta	ligands	32 mm QMA: -80°C	teflon-lined Ziplocs	Nicole Coffey
Saito	proteins	1/8 Qp, 47 mm QMA: -80°C	Qp, QMA: 5 mL cryovials; QMA leftovers: Ziploc bags	Annie Stefanides

Notes: All "oven dry" QMA samples were dried on reused 150 mm polystyrene petri dishes in the Cafe-Th oven set at 55°C. All "laminar dry" samples were dried on leached eggcrate grids on eggcrate shelves in a Mystair laminar flow bench inside the bubble. The "rest of QMA" samples were the leftovers after punching out all subsamples. These were oven dried for ^{226}Ra (Charette) at 11 stations (Stations 3-10; 24, 25, 29); at the remaining 16 stations (Stations 11-23, 26-28), the "rest of QMA" samples were folded and placed fresh into Ziplocs into the fridge, then subsequently into -80°C for proteins (Saito). At

Stations 3, 4, 24, 25, 29, the upper 200 m samples will be first counted for ^{7}Be (Buck/Marsay) by Mark Stephens before sending to Charette for ^{226}Ra.

Table US-6. Summary of cores collected during the cruise and core subsampling details.

Station	Cores collected (of possible 12)	Pore water intervals sampled	Pore water intervals sampled for REE	Sectioned solid-phase samples	Cores used for radium incubation
5	12/12	12	10	15 intervals	3 cores
7	11/12	13	10	15 intervals	1 core
10	11/12	12	12	15 intervals	1 core
14	8/12	11	12	15 intervals	–
15	12/12	12	12	15 intervals	1 core
17	11/12	11	12	15 intervals	1 core
21	12/12	12	12	15 intervals	1 core
25	10/12	11	9	13 intervals	–
27	12/12	12	10	15 intervals	–

Table US-6 (continued). Summary Core subsampling details

Station	Intervals sampled for acidified pore waters	Intervals sampled for Hg in pore waters	Intervals sampled for Fe(II) in pore waters	Intervals sampled for ligands* in pore waters	Intervals sampled for N isotopes in pore waters	Intervals sampled for nutrients in pore waters
5	12	12	11	11	12	12
7	13	11 + bulk	10	11	12	12
10	12	11	10	9	11	11
14	11	11	11	10	11	11
15	12	12	10	9	11	12
17	11	10 + bulk	10	11	11	10
21	12	11 + bulk	11	11	11	11
25	11	10 + bulk	11	11	10	11
27	12	11 + bulk	10	11	12	11

*this is the maximum number intervals sampled for the two groups measuring ligands

Table US-7. Summary of sea-ice stations and associated sampling.

Stn 4	Start	2023-12-16 04:08 UTC	-71.5345 N, -116.7368 E	Community, TM Sectioned, Seawater, Brine, DNA, Snow
Stn 4	End	2023-12-16 07:22 UTC	-71.5478 N, -116.7495 E	
Stn 12	Start	2023-12-23 06:09 UTC	-74.0674 N, -109.954 E	Community, Fe-differential Melt, Overflow, Snow (TM, Beryllium, Tritium), Tritium, Radium, Temperature
Stn 12	End	2023-12-23 13:28 UTC	-74.0674 N, -109.9539 E	
Stn 20	Start	2023-12-31 17:09 UTC	-73.6737 N, -118.4846 E	Snow, TM Sectioned, Brine, Temperature
Stn 20	End	2023-12-31 20:33 UTC	-73.6507 N, -118.5042 E	
Stn 24	Start	2024-01-07 03:06 UTC	-71.9362 N, -119.4478 E	Community, TM Sectioned, Temperature/DNA, Tritium, Radium, Snow (TM, Beryllium, Tritium)
Stn 24	End	2024-01-07 06:26 UTC	-71.939 N, -119.4411 E	
Stn 28	Start	2024-01-12 10:16 UTC	-73.9111 N, -128.0697 E	Snow (TM, Beryllium), Seawater, Slush
Stn 28	End	2024-01-12 12:15 UTC	-73.9111 N, -128.0424 E	

Process Study Cruises

A seven-PI GEOTRACES process study on the West Florida Shelf (WFS), "STING" (Submarine Groundwater discharge, Trichodesmium, Iron, and Nitrogen in the Gulf of Mexico) has completed two cross-shelf cruises in Feb/Mar and July 2023, as well as quarterly sampling of submarine groundwater wells, rivers, and estuaries. The team presented preliminary results at the Ocean Sciences Meeting in February 2024, including evidence for geochemically distinct margin sources entering the WFS from the north vs. south of Tampa Bay, as well as distinct organic matter composition and dynamics associated with Trichodesmium spp. and with a bloom of the harmful algae *Karenia brevis* encountered on the Feb/Mar cruise. Next, the team will determine cross-shelf elemental fluxes from distinct margin sources using radium isotopes mass balances. They will also evaluate whether submarine groundwater discharge is the dominant source of bioavailable organic nutrients and iron on the WFS, and whether submarine groundwater discharge-derived trace metals influence the distribution and rates of nitrogen fixation by Trichodesmium spp. on the WFS.

New projects and/or funding

- There is no new funding for US GEOTRACES during the current reporting period, but proposals for two process studies are under preparation, and we anticipate that proposals for these process studies will be submitted in the next year. A proposal for work in the Gulf of Mexico is to be submitted in August 2024, and we anticipate that a proposal to work off the west coast of the US will be submitted to the US NSF in February, 2025. Additional information about these process studies is provided in the next section of this report.

GEOTRACES workshops and meetings organized

- The US GEOTRACES SSC met in person in Alexandria Virginia on 20 and 21 June 2023. At its previous meeting, with approval from the US NSF (which funds US GEOTRACES), the SSC decided that US GEOTRACES would undertake no more section cruises. The SSC reached this policy decision by concluding that the GEOTRACES global survey is nearly complete, and that it is time to transition into studies that are focused on specific processes that supply, cycle or remove TEIs in the ocean. US GEOTRACES also plans to pursue synthesis of GEOTRACES findings.
- US GEOTRACES is planning two process studies, one focusing on freshwater supply (rivers and submarine groundwater discharge) in the Gulf of Mexico and one that partners with physical oceanographers to work off the west coast of the US and test a hypothesis about the process(es) that mobilize Fe from continental margin sediments to create the large plumes of dissolved Fe emanating from continental margins that are observed in many GEOTRACES sections. Although neither process study has held in-person meetings, the investigators involved in the Gulf of Mexico study have held planning meetings via Zoom at approximately monthly intervals, while the west coast process study planning group has held Zoom meetings less frequently.
- Process studies in the Gulf of Mexico and off the west coast of the US were inspired by GEOTRACES sections GA05 and GP05, respectively, and are intended to replace these sections in the GEOTRACES global survey.

Outreach activities conducted (please list any outreach/educational material available that could be shared through the GEOTRACES web site) *(We are particularly interested in recordings from webinars from GEOTRACES research)*

- For the first time, US GEOTRACES attempted to create a virtual reality experience during GP17-OCE. Production of this virtual reality outreach product was under the direction of Christina Wiederwohl, at Texas A&M University, who presented a first look at the production during the 2023 Goldschmidt meeting in a presentation entitled “Reimagining oceanographic biogeochemistry: bringing the ocean to the community through virtual reality”. The project is not yet completed, but a progress report was presented by Jessica Fitzsimmons to the US GEOTRACES SSC on June 21, 2024.
- A journalist, Sophia Moutinho, sailing aboard GP17-ANT, followed multiple pathways to publicize GEOTRACES research objectives. Although both of the following occurred after 30 April 2024, they are reported here to accompany the write-up about GP17-ANT. First, Sophia Moutinho published in AGU’s EOS science news magazine about her experience on board the US GEOTRACES cruise in the Southern Ocean (EOS, Volume 105, No 6, June 2024). This article is described on the GEOTRACES web site at https://www.geotraces.org/us-geotraces-cruise-in-the-southern-ocean-makes-the-cover-of-eos-science-news-magazine/.
- More recently, a series of podcasts about GP17-ANT was prepared by Sophia Moutinho and produced by Rachel Feltman at Scientific American as a part of their "Science Quickly" standard podcast channel. It is a four-episode series under their special "Fascination." The first three episodes can be found at:
- https://www.scientificamerican.com/podcast/episode/could-iron-from-melting-glaciers-affect-global-climate/
- https://www.scientificamerican.com/podcast/episode/researchers-sample-antarctic-sea-ice-amid-rapid-melting/
- https://www.scientificamerican.com/podcast/episode/how-researchers-live-and-work-onboard-an-icebreaker-in-a-west-antarctic-sea/

The US GEOTRACES website hosts an updated publication database, information about completed and future cruises, submitted GEOTRACES Annual reports to SCOR, and information related to the annual SSC meetings. The web site <https://usgeotraces.ldeo.columbia.edu> also has pages to accommodate educational and outreach materials that can be used by the US GEOTRACES Community.

During the reporting period, US GEOTRACES published two issues of the seasonal US GEOTRACES Newsletter covering project updates, events, science highlights, featured publications, funding opportunities. The issues are distributed via the US GEOTRACES mailing list and is also available at the website (https://usgeotraces.ldeo.columbia.edu/content/newsletters).

Other GEOTRACES activities

- The US GEOTRACES project office continues to offer small amounts of funding (<$5k) to support travel and/or publication costs related to synthesis papers. During the reporting year the project office provided travel support for a synthesis group working on trace elements in the halocline of the Arctic Ocean (July, 2023). A manuscript from this group was submitted to a journal in August 2023. As of May 2024 the manuscript still had not been sent out for review, nor had the lead authors received a response to any of their three inquiries about the status of the manuscript. The lead authors are currently looking into alternative journals for publication.

New GEOTRACES or GEOTRACES-relevant publications (published or in press) *(If possible, please identify those publications acknowledging SCOR funding)*

- A list of publications is appended at the end of this report
- In addition, although the final publication dates will be in the 2024-2025 reporting period, most of the work for two special publications was done during the 2023-2024 reporting period, so they will be mentioned briefly here and reported on in greater detail next year.
    - A special issue of Oceanography Magazine, celebrating 20 years of GEOTRACES, (https://doi.org/10.5670/oceanog.2024.415 ;https://usgeotraces.ldeo.columbia.edu/news/twenty-years-geotraces) has been compiled by guest editors Tim M. Conway, Jessica N. Fitzsimmons, Rob Middag , Taryn L. Noble and Hélène Planquette. Conway and Fitzsimmons are members of the US GEOTRACES community, and the cost of the special issue was covered by the US NSF through the grant under which the US GEOTRACES project office operates.
    - Articles are still being published as part of the Special (virtual) Issue of the U.S. GEOTRACES Pacific Meridional Transect (GEOTRACES Section GP15) (https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1944-9224.GP15).

Completed GEOTRACES PhD or Master theses (please include the URL link to the pdf file of the thesis, if available)

- A list of dissertations is included in the list of publications appended at the end of this report.

GEOTRACES presentations in international conferences

- The number of US GEOTRACES presentations at international meetings and conferences is too large to track. However, we do note four special sessions at the recent Ocean Sciences Meeting (February, 2024, New Orleans, Louisiana USA) that were organized by US GEOTRACES investigators:

  1) Geochemical tracers of ocean processes
  Lauren Kipp, Christopher Hayes, Erin Black, and Thomas S Weber.

  2) Biogeochemical Cycling in the Caribbean Sea, the Gulf of Mexico and Beyond
  Tim Conway, Angela Knapp, Juan Carlos Herguera, and Jessica Fitzsimmons.

3) Speciation and Bioavailability of Trace Metals in the Marine Environment
Kristen Buck, Ana Aguilar-Islas, Randelle Bundy, Maeve Lohan, and Machakalai Rajesh Kumar.

4) Heading South: Contrasting Biogeochemical Cycling of Trace Elements and Isotopes from Tropical to Southern Ocean Waters
Gregory Cutter, Jessica Fitzsimmons, Benjamin Twining and Isuri Kapuge.

Submitted 6 July 2024 by:

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2023-2024 US GEOTRACES and GEOTRACES-related Publications
References 1 May 2023 – 30 April 2024 plus papers missed in previous reports

32 Publications, 6 PhD Dissertations, 5 Masters theses

Related Publications include:

1) US GEOTRACES PIs publishing results that support the GEOTRACES mission but the results are not from GEOTRACES cruises,
2) Papers that use data from US GEOTRACES cruises but do not include US GEOTRACES PIs as co-authors, and
3) Papers describing international collaboration on which US GEOTRACES PIs appear as co-authors.

Peer-reviewed Journal Publications

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Dissertations, including those not listed in previous years

PhD

Amaral, V. J. (2023), Cycling and export of particulate organic carbon in the ocean, PhD thesis, University of California Santa Cruz

Buckley, N. R. (2024), Hydrogen Sulfide as a Strong Ligand Affecting Trace Metal Cycling in the Pacific and Southern Oceans, PhD thesis, Old Dominion University.

Lanning, N. T. (2023), The Biogeochemical Cycling of Dissolved Iron, Manganese, and Lead in the Equatorial & North Pacific Oceans, PhD thesis, Texas A&M University.

Liang, H. (2023), Investigating the global ocean biogeochemical cycling of alkalinity, barium, and copper using data-constrained inverse models, PhD thesis, University of Southern California.

Moore, L. E. (2023), The Impact of Organic Ligand Complexation on the Stabilization and Transport of Dissolved Iron, PhD thesis, University of Washington.

Starr, L. (2022), Hg and Hg methylation along the freshwater to marine continuum, PhD thesis, Wright State University.

Masters

Crawford, C. M. (2023), Labile Dissolved Nickel Concentrations in the North Pacific, MS thesis, University of South Florida, Tampa, Florida USA.

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