Award Number	Title	Principal Investigator	Co-PI Name(s)	PI Email Address	Abstract
2023178	Collaborative Research: **Management and Implementation of US GEOTRACES GP17 Section: Amundsen Sea Sector of the Antarctic Continental Margin (GP17-ANT)**	Peter Sedwick		psedwick@odu.edu	This project will support the management and implementation of a 60-day research cruise to the Amundsen Sea sector of the Antarctic continental margin to collect samples for measurements of a broad suite of trace elements and isotopes (“TEIs”), as part of the U.S. GEOTRACES program. GEOTRACES is a global effort in the field of Chemical Oceanography, the goal of which is to understand the distributions of trace elements and their isotopes in the ocean. Determining the distributions of these elements and isotopes will increase the understanding of processes that shape their distributions and also the processes that depend on these elements. Key TEIs include essential micronutrients such as iron and zinc; “tracers” such as aluminum, manganese, and isotopes of nitrogen, thorium and neodymium that can be used to investigate modern and ancient ocean processes; and elements such as lead that are indicative of human activities. In the Southern Ocean, the Antarctic continental margins are important as sources of micronutrient trace elements such as iron, which is required to support 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 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 melting rates of glacial ice shelves that border the region, driven by intrusions of warm Circumpolar Deep Water 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 the regional ecosystem. The cruise will comprise essential sampling operations (collection and shipboard processing) and ancillary measurements (hydrography, nutrients, algal pigments) in support of multiple, individual science projects, following the successful model of previous U.S. GEOTRACES cruises in the Atlantic, Pacific and Arctic ocean basins. The cruise will sample the ocean region between 100°W and 135°W, with stations ranging from 67°S in the Antarctic Circumpolar Current southward to the Amundsen Sea continental shelf, including stations adjacent to several rapidly melting ice shelves and in highly-productive shelf polynyas. Water column samples will be collected using conventional and trace-metal clean CTD-rosette systems, in-situ high-volume pumps, and a towed fish sampler or small boat, using established methods. Sampling time will also be provided for collection of sea ice, floating glacial ice, and seafloor sediments. To facilitate coordination with a complementary open-ocean cruise and ensure access to the study region to document the impact of biological processes, the cruise is planned for late austral summer (late January-late March). Beyond the disciplinary contributions, the proposed research will contribute knowledge concerning the cryosphere and its impacts on global sea level and ocean circulation, regional ecosystems and biological processes, ocean-atmosphere interactions, and past and future environmental change. The project will contribute to STEM education and outreach through the participation of an NSF-funded PolarTREC education professional, and a K-12 STEM program for students from underserved and underrepresented schools run by Rutgers University education specialists. To foster public engagement, the investigators will partner with the UCSC Science Communication Program to engage freelance science journalists to profile research in this spectacular and harsh Antarctic environment.This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2023363	see above	Robert Anderson		boba@ldeo.columbia.edu	see above
2023214	see above	Robert Sherrell		sherrell@marine.rutgers.edu	see above
2023230	see above	Phoebe Lam		pjlam@ucsc.edu	see above

2049577	Collaborative Research: **Southeast Pacific and Southern Ocean Seawater Isotopes determined from US GEOTRACES GP17-OCE and GP17-ANT samples**	Elisabeth Sikes		sikes@marine.rutgers.edu	The stable isotopic composition of the oxygen atom in seawater (d18O) is controlled by evaporation, precipitation, and riverine or glacial meltwater input. Most of the deep interior water masses in the ocean are formed or modified in the Southern Ocean and sink to fill the deep layers that circulate throughout the world's oceans. The d18O signatures in seawater can be used as tracers for these sub-surface water masses once they sink to depth. The Southern Ocean and South Pacific are critical locations for water mass formation and thus, for understanding global overturning circulation, carbon cycling and climate dynamics. However, data on the d18O of seawater, particularly in the sub-surface, is virtually nonexistent for the South Pacific and Southern Ocean. Moreover, our understanding of past temperature and oceanic processes based on the d18O signature in marine carbonates (e.g. corals and foraminifera) have relied on the assumption that variations in the oxygen isotopic composition of the sub-surface water masses are nominal through time, which can be directly tested on a wider basis using new technologies during this project. Investigators will conduct analyses of seawater d18O from samples collected from depth transects during the US GEOTRACES science expedition to the South Pacific (GP17-OCE) and the Amundsen Sea sector of the Antarctic continental margin (GP17-ANT). This ocean region is of particular significance because it is experiencing rapid environmental changes in the past few decades, including the fastest melting of ice shelves around the entire Antarctic. This project will support the development of diverse involvement in teaching and outreach efforts in a primarily undergraduate and Hispanic serving institution. The outreach activities will provide ample opportunities to engage students from underrepresented groups in both formal and informal settings. It is well-established from first principles that d18O and d2H of seawater have a positive relationship to salinity, but regional variations in the isotopic relationship of seawater to salinity are poorly constrained. Temperature reconstructions relying on d18O in calcite microfossils biologically precipitated in equilibrium with seawater and preserved in marine sediments are only quantitative if the seawater d18O (d18Osw) in which that carbonate was precipitated is known. Despite the reliance of these paleo-estimations on the d18O of modern seawater, surface measurements are few and far between and sub-surface data in the South Pacific and Southern Oceans is even more limited. Filling this fundamental gap in data to quantify the influence of precipitation, evaporation and glacial melt water on the d18O and d2H of interior seawater masses is globally relevant to our understanding of ocean circulation and broader climate dynamics. The development and improvement of new laser-based spectroscopy techniques such as off-axis integrated cavity output spectroscopy (OA-ICOS) and cavity ring-down spectroscopy, allows for seawater d18O and d2H analyses to be run quickly and cost effectively compared to traditional IRMS (Isotope Ratio Mass Spectrometry). A core aim of this project is to compare and contrast IRMS and OA-ICOS analyses to address accuracy, precision and offsets between methods. Obtaining d18Osw directly contributes to the GP17-OCE stated aims of characterizing near- and far-field trace element and isotope (TEI) inputs and to the GP17-ANT stated aims of quantifying gradients in TEI distributions and characterizing, glacial meltwater inputs in the Amundsen Sea and Southern Ocean. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2049664	see above	Amy Wagner		amy.wagner@csus.edu	see above
2219551	Collaborative Research: **U.S. GEOTRACE GP17-OCE and GP17-ANT: Characterizing iron-binding organic ligands in the Southern Ocean and implications for iron cycling in the global ocean**	Kristen Buck		kristenbuck@usf.edu	Iron is an essential element for life and plays an important role in defining how much atmospheric carbon dioxide is taken up into the ocean by phytoplankton. However, iron cycling is closely governed by the chemistry of seawater; nearly all iron in seawater is associated with various unknown organic compounds, called iron-binding ligands, which impact whether and how iron is utilized by organisms and the distribution of iron throughout the ocean. Detail understanding of the cycling of organic iron-binding ligands is necessary to understand iron cycling in the oceans and the connections between iron cycling and atmospheric carbon. The proposed research will be carried out as a part of US GEOTRACES expedition to test the hypothesis that the Southern Ocean is a globally significant source of iron-binding organic ligands, and that different sources of these organic molecules lead to different iron-ligand characteristics. The US GEOTRACES program is a large collaborative effort to sample ocean systems at high resolution for a suite of key trace elements and isotopes. The South Pacific and Southern Ocean regions targeted by the upcoming US GEOTRACES GP17 cruises are important locations of water mass formation and the subsequent transport of carbon and nutrients to the global ocean. Organic ligands produced in these regions thus have important implications for the stabilization, reactivity, and residence time of iron along the path of global water mass circulation and could impact the global oceanic inventory of dissolved iron. This project will measure the distribution of iron-binding organic ligands, and identify specific organic molecules that comprise these ligands, in field and experimental samples collected on upcoming US GEOTRACES cruises in the South Pacific (GP17-OCE) and Southern Ocean (GP17-ANT). These datasets will be utilized to conduct the first extensive intercalibration of the two most widely used approaches for characterizing iron-binding organic ligands, providing important insight into these datasets and how they can be synthesized to improve understanding of iron cycling in the oceans. All data from this project will be made publicly available. Project activities will provide educational and training opportunities for middle school, high school, undergraduate, and graduate students, and results will be shared with the public through the development of virtual reality modules and via local outreach events. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2219626	see above	Randelle Bundy		rbundy@uw.edu	see above

2049204	Collaborative Research: **U.S. GEOTRACES GP17-OCE and GP17-ANT: Thorium-230, Thorium-232 and Protactinium-231 as tracers of trace element supply and removal**	Robert Anderson	Martin Fleisher	boba@ldeo.columbia.edu	The goal of the international GEOTRACES program is to understand the distributions of trace chemical elements and their isotopes in the oceans. Many trace elements are essential for life and are thought to limit biological productivity throughout much of the ocean. This limitation, in turn, partly controls the ability of the ocean to support other marine life as well as the ocean's capacity to absorb carbon dioxide from the atmosphere. This project will provide constraints on the processes that supply and remove trace elements in the South Pacific Ocean and Amundsen Sea which are currently not well quantified. Naturally occurring radioactive isotopes such as thorium-230 and protactinium-231, which will be measured as a part of this work, can be utilized as proxies to provide critical information about the processes that supply iron and other micronutrient elements, as well as the rates of those processes. The isotope thorium-232 will also be utilized as a tracer of the supply of elements that are added to the ocean through the deposition of aerosol dust and from coastal sediments. These rates and fluxes can be used to improve our understanding of the micro-nutrient iron and the sinking fluxes of carbon which are both critical in the global carbon cycle. Outreach and broader impacts will be achieved through undergraduate and graduate teaching, community events such as the Ocean Sciences Bowl and other efforts through the international GEOTRACES program. This project will provide support for four collaborating labs (University of Southern Mississippi, University of Minnesota, Lamont-Doherty at Columbia University and CalTech) to undertake measurements on two US GEOTRACES cruises in the South Pacific, known as GP17 (GP17-OCE running from Tahiti south to the marginal sea ice zone and GP17-ANT focusing on the Amundsen margin). The PIs will measure dissolved and particulate concentrations of Th-230 and Pa-231. In addition, they will measure dissolved and particulate Th-232 concentrations and analyze a limited number of aerosol samples, aerosol leachates, colloidal size fractions and surface sediments for these radionuclides. They will be used to quantify trace element supply, including sedimentary inputs from the Amundsen Sea's glacial meltwater pump and atmospheric dust inputs in one of the world's lowest dust input regions. Additionally, the team will be able to quantify trace element removal, including sinking particulate fluxes for carbon, as well as trace elements, and scavenging characteristics of variable particle composition regimes. These goals also contribute to assessing Th and Pa as key palaeoceanographic proxies. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2048863	see above	Christopher Hayes		christopher.t.hayes@usm.edu	see above
2048542	see above	R. Lawrence Edwards		edwar001@umn.edu	see above
2151677	Collaborative Research: **US GEOTRACES GP-17- OCE and -ANT Sections: External sources, cycling and processes affecting mercury speciation in the South Pacific and Southern Oceans**	Carl Lamborg		clamborg@ucsc.edu	This project will evaluate the concentrations of mercury (Hg) in its various forms in the ocean and atmosphere to examine the factors that control its concentration and chemistry in remote regions of the ocean. The proposed work will examine mercury sources, primarily from the atmosphere, and how mercury is finally removed from ocean waters. Specifically, this study is focused on the South Pacific and Southern Ocean around Antarctica, regions that are remote from human activity and their associated Hg inputs to the biosphere. Human activity has substantially enhanced the amount of Hg in the biosphere and its levels in seafood consumed by humans, and therefore their potential exposure, but its impact in these remote regions is poorly constrained. The measurements will be made during two ocean expeditions that form part of the international GEOTRACES program. GEOTRACES aims to examine the concentrations and distributions of trace elements and their isotopes in the atmosphere, surface and deep oceans of the world. Mercury is a primarily a concern because of its ability to bioaccumulate in marine food chains, primarily in its organic form, methylmercury (MeHg). Elevated levels of MeHg in fish and other marine organisms is a concern for human and wildlife health due to exposure through seafood consumption, and the factors controlling this exposure are not well understood. The proposed work will support three graduate and several undergraduate students across the three participating institutions. During the two expeditions, the research team will collect high resolution data on the concentrations of the primary Hg forms in the atmosphere, the water column, and the sediments, to examine the sources of Hg to these regions and the processes that lead to the conversion of Hg to its more toxic and bioaccumulative form, MeHg. Dissolved and particulate forms of the various Hg species (gaseous elemental Hg, ionic Hg, MeHg and dimethylmercury) will be determined in the atmosphere and throughout the water column using high resolution sampling and novel techniques. Additionally, measurements of Hg stable isotopes in atmospheric and water samples will be used to identify sources (e.g., geogenic or anthropogenic inputs) and delivery mechanisms (e.g., dry or wet deposition, glacial melt) of Hg to these regions. This comprehensive project will leverage Hg speciation and Hg source tracking capabilities to assess the importance of human activity and climate change in altering the amount of Hg and MeHg in these ocean waters, and the resultant levels in marine organisms consumed by humans. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2152636	see above	Robert Mason	Sarah Janssen, Michael Tate	robert.mason@uconn.edu	see above
2152649	see above	Chad Hammerschmidt		chad.hammerschmidt@wright.edu	see above

2048510	Collaborative Research: **US GEOTRACES GP-17-ANT: Molecular speciation of trace element-ligand complexes in the Southern Ocean and Antarctic shelf**	Daniel Repeta		drepeta@whoi.edu	The supply of iron and other biologically essential trace elements to surface waters is a critical regulator of biological growth in the Southern Ocean. Sea ice volume and the physical dynamics of the Southern Ocean are currently experiencing rapid changes. An understanding of the corresponding changes in metal cycling is needed as these elements are essential for the growth of phytoplankton which plays an important role in modulating atmospheric CO2. One of the major knowledge gaps is understanding how soluble forms of these metals are generated and transported to the surface ocean. Many trace elements are insoluble in seawater and precipitate close to their sources unless they are bound to a dissolved organic molecule, or ligand, that keeps the metal in solution. Little is currently known about what these ligands are, where they come from, or how they affect the reactivity and fate of metals in the Southern Ocean. The study proposed here is designed to identify the organic ligands that bind to metals and determine the ligand sources and reactivity along the Antarctic continental margin. The proposed project will survey the molecular speciation of six biologically important trace elements (Fe, Cu, Zn. Ni, Co, Mn) along the US GEOTRACES cruise track along the Antarctic shelf in the Amundsen Sea in order to better understand trace element cycling across the region. The goal of the GEOTRACES expedition is to identify processes and quantify fluxes that control the distributions of trace elements and their isotopes to the Southern Ocean. As part of this effort, the investigators will assess biological ligand production as the ecosystem shifts from low productivity iron-starved conditions in the Antarctic Circumpolar Current to higher productivity along the upwelling continental margin, with a particular focus on assessing production within the Amundsen Sea polynya blooms and sinking organic matter remineralization zones. Second, changes in the accumulation, saturation, and composition of ligands in Circumpolar Deep Water will be measured as the water passes across the Antarctic shelf and receives inputs from sediments and glacial meltwaters. Finally, the role of sea ice on metal-ligand dynamics will be investigated. Metal ligands are a central parameter of numerical ocean models that predict and estimate metal distributions, and results from this project will provide those models with knowledge of the processes that supply ligands and affect ligand concentrations. Two graduate students and undergraduate interns will be supported and trained as part of this project. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2049280	see above	Rene Boiteau		rene.boiteau@oregonstate.edu	see above
2220305	Collaborative Research: **US GEOTRACES GP17-ANT: Answering key questions in marine particle trace element biogeochemistry in the Amundsen Sea**	Peter Morton		pmorton@fsu.edu	The goal of the international GEOTRACES program is to understand the distributions of trace chemical elements and their isotopes in the oceans. This project will generate a dataset of 40 trace elements on suspended particles and surface sediment samples collected on the GEOTRACES GP17-ANT cruise to the Amundsen Sea, West Antarctica. The Amundsen Sea hosts the most productive polynya per unit area in all of Antarctica, with biological carbon uptake ten times higher than the average for the Southern Ocean. Over the past 30 years, this region has become a primary locus of increased freshwater input, as the fastest melting glaciers in West Antarctica deliver huge and increasing volumes of freshwater to the Amundsen Sea. The major contribution of this region to global sea level rise is well documented, but the impact of accelerated additions of meltwater and associated chemical constituents on the biogeochemistry of the Antarctic shelf waters, and in particular on the cycling of trace elements, has not received comprehensive investigation. Hypotheses addressing four key components of the biogeochemical system in the Amundsen Sea will be tested, and results will closely mesh with complementary efforts proposed by other GP17-ANT investigators. The project will support a graduate student and several undergraduate interns, with a focus on broadening participation in STEM. The investigators will also work with established programs to create meaningful out-of-school science experiences for middle and high school students. The aim of the project is to quantify and interpret the distributions of particulate trace elements in approximately 500 samples covering a large swath of the Amundsen Sea shelf, including waters influenced by five major ice shelves, and in the adjacent iron-limited Southern Ocean waters bounded by 100°W and 135°W, and south of 67°S. The investigators will use size-fractionated sample collection, total acid digestion and weak acid leaching, and well-established mass spectrometric methods to determine concentrations and probe the physico-chemical state of the particulate trace elements. The team will use the new data to investigate the following issues: 1) the role of phytoplankton, with a focus on Phaeocystis and diatoms, dominant taxa on the Amundsen Sea shelf, in driving element cycling in the upper water column while experiencing variable degrees of iron stress; 2) the “meltwater pump” which generates vigorous and particle-rich outflow from ice shelf cavities; 3) the bottom nepheloid layer of resuspended sediments as a reaction zone that determines the composition of the sedimentary paleo-record and also modulates of chemical fluxes at the sediment-water boundary; and 4) the rare earth elements (REE), which the team proposes carry unique geochemical information about terrigenous particle provenance among the geologically diverse glacial drainage regions, and also includes a labile particulate fraction whose magnitude and inter-element ratios may serve as a relative index of element scavenging intensity that can be applied to predict regions of maximal scavenging for other particle-reactive elements. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2220306	see above	Robert Sherrell		sherrell@marine.rutgers.edu	see above

2123303	Collaborative Research: **US GEOTRACES GP17-ANT: Characterizing the composition, scavenging efficiency and bioavailability of size fractionated particles**	Phoebe Lam		pjlam@ucsc.edu	The Amundsen Sea adjacent to Antarctica has gained increasing attention because of rapid melting of glaciers that drain into it. While most of the scientific and media attention has focused on how melting glaciers will affect sea level rise, there are also important consequences for ocean chemistry and biology. Parts of the Amundsen Sea have the highest rates of photosynthesis of all open water regions surrounding Antarctica, and this may be because melting glaciers are supplying essential nutrients such as iron. A detailed understanding of how melting glaciers affect the supply and removal of nutrients including iron is necessary to predict the biological, chemical, and climate consequences of melting glaciers.This project aims to study this system by focusing on the role that marine particles play in the supply and removal of trace nutrient levels. Marine particles include all suspended, solid material in seawater that derive from biological, chemical, and geological processes. Some types of marine particles supply nutrients to seawater, whereas other types remove nutrients from seawater. The investigators will determine the concentrations and chemical compositions of marine particles in the Amundsen Sea in order to understand which types supply and which types remove nutrients from seawater. This work will clarify the essential role of particles in the supply and removal of nutrients in this quickly changing part of the world. This work will train undergraduate and graduate students from three public US institutions in the west coast (University of California, Santa Cruz), northeast (University of Rhode Island), and southeast (University of Georgia). This project will also support a journalist to participate in the cruise and pitch, report, and write stories from the expedition to communicate the results of this collaborative project to the public. The Amundsen Sea is a classic “warm Antarctic continental shelf”, where intrusions of warm Circumpolar Deep Water (CDW) onto the shelf have resulted in the highest glacial basal melt rates on the Antarctic Margin. The US GEOTRACES program has been funded for a 60-day research cruise in the Amundsen Sea to bring geochemical tools to study the biogeochemical consequences of this high melt. Particles are a key parameter for all GEOTRACES section cruises because of their importance in the supply, internal cycling, and removal of many trace elements and isotopes (TEIs). Previous cruises to the Amundsen Sea have suggested that particulate Fe, abundant in meltwater-influenced regions, may be helping to fuel the high NPP in the Amundsen. Particles also play an essential role in the removal of dissolved Fe and other particle-reactive TEIs via scavenging. Indeed, models have shown that scavenging by particles is by far the largest loss term for dissolved Fe (dFe), even larger than biological uptake when integrated over the entire water column. So far, particles have been represented only as particulate organic matter (POM). The inclusion of other particle types besides POM is likely important for scavenging: for example, Fe and Mn (oxyhydr)oxides have been shown to be 1-3 orders of magnitude more efficient at scavenging some TEIs compared to other particle types, including POM. Thus, the composition of particles, not just their concentration, is important for the scavenging removal of TEIs. To address this gap in the understanding of particle biogeochemistry in the Amundsen Sea, this project has the following three main goals: 1) To determine the distributions of major and minor phases (particulate organic carbon, opal, CaCO3, lithogenic particles, Fe oxyhydroxides, Mn oxides), and trace element and suspended particulate mass concentrations of size fractionated particles collected by in-situ filtration; 2) To determine the speciation and bioavailability of particulate Fe in the Amundsen Sea to assess its role as a source and sink of TEIs; 3) To examine the factors affecting the formation, reactivity, and stability of Mn oxides in the Amundsen Sea. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2123606	see above	Daniel Ohnemus		dan@uga.edu	see above
2049310	Collaborative Research: **US GEOTRACES GP17-ANT: Constraining the Neodymium (Nd) Isotope and Rare Earth Element Cycles near the Amundsen Sea Continental Margin**	Howard Scher		hscher@geol.sc.edu	Trace elements in seawater are relevant to climate and human society, because they can act as essential nutrients for marine ecosystems or useful chemical fingerprints for a variety of oceanographic processes. The international GEOTRACES program is intended to identify processes and quantify fluxes that control the distributions of key trace elements and their isotopes in the global ocean, and to establish how these distributions could respond to changing environments. Neodymium (Nd) isotopes and rare earth elements (REEs) are notable examples of such key elements because of their utility in tracing past and present ocean mixing and sources of trace elements to the ocean. In this project, investigators will participate in the US GEOTRACES science expedition GP17-ANT to the Amundsen Sea sector of the Antarctic continental margin, and analyze Nd isotope ratios and REE concentrations in samples collected from this expedition. This region of the ocean is of particular significance because it is experiencing rapid environmental changes in the past few decades, including the fastest melting of ice shelves around the entire Antarctic. Measurements from this project will advance our understanding of ocean processes that cause melting of local ice shelves, and also will shed new light on nutrient sources that sustain the unusually high biological productivity in the upper ocean of this region. This project will contribute to support the development of diverse involvement in Antarctic research, teaching and outreach efforts across career levels. The outreach activities will provide ample opportunities to engage K-12 students, students from underrepresented groups, and general public in discussions of ocean sciences and the Antarctic environment in both formal and informal settings. The US GEOTRACES GP17-ANT cruise to the Amundsen Sea provides an exceptional opportunity to study marine biogeochemical cycles of trace elements and their isotopes in relation to the Antarctic continental margin, fast iceshelf melting, productive polynyas, and water mass processes in an area especially susceptible to ongoing climate change. This project will study sources and processes that regulate the distribution of Nd isotopes and REEs in seawater in this region. Specific sources and processes that will be studied, and quantified where possible, include: (1) water mass transport and mixing; (2) slope exchange; (3) aerosols; (4) sea ice; (5) subglacial meltwaters; (6) sediments and shelf exchange; (7) particle interactions. Nd isotope and REE concentration analyses will be conducted on a suite of carefully selected seawater, particulate, sediment, aerosol, and sea ice samples to constrain the nature and relative significance of these different controls, providing a comprehensive understanding of Nd isotope and REE cycling in the Antarctic margin. These results will not only provide critical constraints on water mass processes and lithogenic inputs that are directly relevant to understand all other trace element biogeochemical cycles in this region, but also improve the utility of Nd isotopes and REE patterns as useful tracers for studies of modern and ancient oceans.This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2049554	see above	Xinyuan Zheng		zhengxy@umn.edu	see above

2123333	Collaborative Research: **US GEOTRACES GP17-ANT: Dissolved concentrations, isotopes, and colloids of the bioactive trace metals**	Jessica Fitzsimmons		jessfitz@tamu.edu	The goal of the international GEOTRACES program is to understand the distributions of trace chemical elements and their isotopes (TEIs) in the oceans. Many trace metals such as iron are essential for life and thus considered nutrients for phytoplankton growth, with trace metal cycling being especially important for influencing carbon cycling in the iron-limited Southern Ocean, where episodic supply of iron from a range of different external sources is important. The primary goal of this project is to measure the dissolved concentrations, size partitioning, and dissolved isotope signature of Fe on a transect of water-column stations throughout the Amundsen Sea and surrounding region of the Antarctic Margin, as part of the GP17-ANT Expedition. The secondary goal of this project is to analyze the concentrations and size partitioning of the trace metals manganese, zinc, copper, cadmium, nickel, and lead in all water-column samples, measure the isotope ratios of zinc, cadmium, nickel, and copper in a subset of water column samples, and measure the Fe isotopic signature of aerosols, porewaters, and particles. Observations from this project will be incorporated into regional and global biogeochemistry models to assess TEI cycling within the Amundsen Sea and implications for the wider Southern Ocean. This project spans three institutions, four graduate students, undergraduate students, and will provide ultrafiltered samples and data to other PIs as service. The US GEOTRACES GP17 ANT expedition, planned for austral summer 2023/2024 aims to determine the distribution and cycling of trace elements and their isotopes in the Amundsen Sea Sector (100-135°W) of the Antarctic Margin. The cruise will follow the Amundsen Sea 'conveyor belt' by sampling waters coming from the Antarctic Circumpolar Current onto the continental shelf, including near the Dotson and Pine Island ice shelves, the productive Amundsen Sea Polynya (ASP), and outflowing waters. Episodic addition of dissolved Fe and other TEIs from dust, ice-shelves, melting ice, and sediments drive seasonal primary productivity and carbon export over the Antarctic shelf and offshore into Southern Ocean. Seasonal coastal polynyas such as the highly productive ASP thus act as key levers on global carbon cycling. However, field observations of TEIs in such regions remain scarce, and biogeochemical cycling processes are poorly captured in models of ocean biogeochemistry. The investigators will use their combined analytical toolbox, in collaboration with the diagnostic chemical tracers and regional models of other funded groups to address four main objectives: 1) What is the relative importance of different sources in supplying Fe and other TEIs to the ASP? 2) What is the physiochemical speciation of this Fe, and its potential for transport? 3) How do biological uptake, scavenging and regeneration in the ASP influence TEI distributions, stoichiometry, and nutrient limitation? 4) What is the flux and signature of TEIs transported offshore to the ACC and Southern Ocean? This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2123354	see above	Timothy Conway		tmconway@usf.edu	see above
2123491	see above	Seth John		sethjohn@usc.edu	see above
2124172	Collaborative Research: **US GEOTRACES GP17-ANT: Iron redox cycling in the Amundsen Sea in the water column and shelf sediments**	Silke Severmann		silke@marine.rutgers.edu	The Amundsen Sea is one of the most rapidly changing areas along the Antarctic coast, with some of the fastest rates of glacial melting on the continent. There is great interest in the role of iron in controlling primary production and carbon and nutrient cycling within the Amundsen Sea, and it is probably an important source of iron to offshore waters of the Southern Ocean, which are rich in nutrients but iron limited. The work is part of the US GEOTRACES GP17-ANT cruise to the Amundsen Sea, a multi-investigator study of trace elements and isotope cycling. This work will study how iron is mobilized from sediments at the seafloor of the Amundsen basin. Such mobilization is influenced by two factors directly linked to climate change. Glacial melting increases ice-free areas known as polynyas, which experience large blooms of phytoplankton. Organic matter from these blooms eventually reaches the seafloor, creating low-oxygen conditions that accelerate iron transport into the overlying waters. Moreover, accelerated melting of glaciers will increase the transport of this iron to the surface via the buoyant "meltwater pump" along the glacier/ocean interface. These processes create feedbacks between climate and biological productivity that must be understood to develop models with a useful predictive capability. The broader impacts include partnering with University of Southern California Joint Educational Project and a PolarTREC teacher to create curriculum based on GEOTRACES Antarctic Expedition, which will be disseminated to 15 elementary school in Los Angeles area and develop online data exploration modules to encourage data-based learning in oceanography classes. This collaborative project will investigate iron redox cycling between sediments and water column of the Amundsen Sea and exchange with the Southern Ocean by determining iron (II) concentrations and redox kinetics in the water column as well as fluxes of iron and other elements from the seafloor to the water column from porewater measurements. A major objective of the US GEOTRACES GP17-ANT cruise is to study the exchange of iron between the Amundsen Sea and the Southern Ocean. The proposed work is essential to identifying the sources of iron and controls on source fluxes as well as internal transformations that will determine its fate. The data product from the project will be integrated with the results of other investigators in a synthesis effort after the cruise, including dissolved and particulate iron and related metals like manganese, as well as important tracers of sediment sources like radium isotopes. Iron(II) oxidizes very slowly in these cold waters, and kinetics will be combined with iron(II) bottom water concentrations and benthic fluxes to evaluate the importance of the slow oxidation kinetics on iron transport away from the benthic boundary layer. Benthic-derived iodine (denoted as "excess iodine"), will be utilized as an important semi-conservative tracer of iron inputs. Iodine is a useful comparative element because both iron and iodine accumulate in sediments under oxidizing conditions and are released under reducing conditions. Iodine is of interest in its own right because Antarctic Shelf waters are a massive source of reactive iodine species to the atmosphere. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2124188	see above	James Moffett		jmoffett@usc.edu	see above

2148921	Collaborative Research: **US GEOTRACES GP17-ANT: Nitrogen isotope dynamics on the Amundsen Sea continental margin**	Daniel Sigman		sigman@princeton.edu	The continental shelf of Antarctica is a dynamic and often biologically productive polar environment, with global importance for ocean circulation, nutrient and carbon cycling. Due to its high latitude location and the impacts of the proximal Antarctic ice sheet, the Antarctic continental shelf stands to change quickly under ongoing global warming. Yet the natural state of the Antarctic continental shelf is poorly known, and previous research suggests that this environment has changed through time, which would also signal how it may change in the future. This study will investigate the operation of the nitrogen cycle on the Antarctic continental shelf, using the natural isotopes of nitrogen. Nitrogen is a critical nutrient for life, limits biological productivity in many environments, and provides a holistic view of the balance between biological growth and decomposition in ocean waters. The nitrogen isotope measurements, combined with the other measurements of the U.S. GEOTRACES GP17-ANT expedition, will determine the major sources and sinks of biological productivity on a segment of the Antarctic continental shelf – the Amundsen Sea shelf – that may be particularly susceptible to change as Antarctic ice sheet melting accelerates. The measurements will also provide key baseline information to support the reconstruction of past changes using sediment cores and other archives. The project will train graduate and undergraduate students and support one early career postdoctoral researcher. The U.S. GEOTRACES GP17-ANT expedition will provide the opportunity to generate complementary data sets of trace elements and isotopes on the Amundsen Sea shelf, an Antarctic margin environment characterized by abundant sea ice, melting ice shelves, and highly productive polynyas. For all stations of GP17-ANT, full depth profiles of the nitrogen and oxygen isotope ratios of nitrate will be measured, along with nitrogen isotope ratios of total dissolved nitrogen at a few representative stations to provide insight into nitrogen sources and cycling in the water column. Moreover, suspended particle nitrogen isotope ratios will be measured from the GEOTRACES high-volume pump samples from deeper depths than standard methods allow, to investigate regeneration and ground-truth the application of deep-sea coral nitrogen isotope ratios as a paleo-proxy. Lastly, from surface sediment samples, bulk sediment and diatom-bound nitrogen isotope ratios will be measured, providing ground-truthing for ongoing paleo-oceanographic reconstructions using longer sediment cores. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2148926	see above	Xingchen Wang		xingchen.wang@bc.edu	see above
2148091	Collaborative Research: **US GEOTRACES GP17-ANT: Tracing Inputs and Transport of Aluminum, Manganese, and Iron from the Amundsen Sea Sector of the Antarctic Continental Margin**	Joseph Resing		resing@uw.edu	The international GEOTRACES program seeks to understand the distributions of trace elements and their isotopes in the oceans. As part of this effort, the US GEOTRACES program will undertake the GP17-ANT research cruise in November 2023-January 2024, with a focus on the distribution of trace elements and isotopes in the Amundsen Sea sector of the Southern Ocean. Biological production in the Southern Ocean plays an important role in regulating atmospheric carbon dioxide via biological uptake and the associated transfer of organic matter into the ocean interior. Most of this ocean region has abundant major nutrients (nitrogen, phosphorous and silicon) required for phytoplankton growth, but is deficient in the essential micronutrient iron. This means that phytoplankton growth during the summer growing season is regulated by iron. Other trace elements, such as manganese and cobalt, may also hold importance in this context. Hence, there is a compelling need to constrain the sources of these micronutrient trace elements to Southern Ocean surface waters. Chief among these sources are sediments, glaciers and sea ice on the Antarctic continental margins. This project seeks to advance understanding of the sources and transport of the micronutrients iron and manganese in the Amundsen Sea sector of the Southern Ocean, as part of the upcoming GEOTRACES GP17-ANT research expedition. The Amundsen Sea is a highly productive section of the Antarctic continental margin that is bordered by some of Antarctica's most rapidly melting glacial ice shelves, and is thought to provide an important source of dissolved iron to the adjacent, iron-deficient surface waters of the Antarctic Circumpolar Current. As such, the measurements of trace elements and isotopes during this expedition will provide a critically important benchmark to assess the impacts of major changes that are anticipated for this marine environment during the coming decades, such as inputs of the micronutrient iron that are associated with increased glacial melting. The project involves two US laboratories, and will support the research of a graduate student and an undergraduate student. The project also includes the participation of a K-12 STEM education specialist who will develop educational outreach materials targeting elementary and middle school students and science teachers. In this project, the concentrations of trace elements that serve as micronutrients (dissolved iron and manganese) and tracers of inputs from continental dust and seafloor sediments (dissolved aluminum and manganese) will be measured in seawater samples collected during GP17-ANT. In addition, shipboard experiments will be performed to assess the potential for suspended particles and surface sediments to contribute these dissolved trace elements to surface seawater. This work, together with measurements of other trace elements and isotopes made by collaborators, will assess the sources, transport and chemical transformations of micronutrients in this sector of the Antarctic continental margin, and hence the trajectories of these micronutrient inputs in response to future environmental changes. The chemical analyses of dissolved aluminum, manganese and iron will be performed at sea, in near real-time, thus providing data to inform the cruise sampling strategy and guide the analyses of other investigators. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2148166	see above	Peter Sedwick		psedwick@odu.edu	see above

2045408	Collaborative Research: **US GEOTRACES GP17-OCE and GP17-ANT: Export and remineralization rates of bioactive and particle reactive trace elements using thorium-234**	Ken Buesseler		kbuesseler@whoi.edu	The overarching goal of the international GEOTRACES Program is 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 environmental conditions.” These trace elements exist at exceeding low concentrations in the ocean, yet play a key role in the growth and distribution of marine organisms, in particular marine phytoplankton. In addition, many trace elements are important to study as pollutants, such as copper and lead, which at high levels can be harmful to marine life. Thus, studies of the trace metal sources and sinks are needed. To meet this goal, the project is designed to measure how quickly these trace elements are cycled through marine food webs, in particular as they are transported by marine snow, i.e. slowly settling marine particles that carry these trace elements and carbon to the deep sea. The work will be conducted aboard two upcoming US GEOTRACES expeditions to the South Pacific, Southern Ocean, and Amundsen Sea. The project will provide training for two postdoctoral investigators, one focused on sample analysis and one on the modeling. To carry out this study, this proposal will use the naturally occurring particle reactive radionuclide Thorium-234 (234Th, half-life = 24.1 d) to quantify variability in trace elements and isotopes scavenging, residence times, and particle export from the surface ocean and their attenuation into the deep sea. This project will sample across extreme biogeographical and trace elemental gradients that range from the clear waters of the low dust, low productivity South Pacific (GP17-OCE) to the “greenest” high productivity Amundsen Sea and its polynyas in the Southern Ocean (GP17-ANT). Assessing these spatial and vertical gradients requires 234Th sampling at every station (n=66 casts x 13 depths) and measuring the TEI/234Th ratio on particles (n=43 x 8 depths x 2 size classes). There results of this project will lead to an increased understanding of how the trace elements are modified by removal and regeneration associated with scavenging on to, and remineralization off of, sinking particles. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2046790	see above	Claudia Benitez-Nelson		cbnelson@geol.sc.edu	see above
2046807	see above	Laure Resplandy		laurer@princeton.edu	see above
2147761	Collaborative Research: **US GEOTRACES GP17-OCE and GP17-ANT: Pb Isotopes**	Franco Marcantonio		marcantonio@geo.tamu.edu	Although most of the chemical element lead (Pb) found in the ocean is derived from human emissions to the atmosphere, natural sources of Pb may be important in remote locations such as the Southern Ocean. Natural sources of Pb are derived from the Earth’s crust and are delivered to the ocean by glacial erosion and aerosol inputs. Lead is produced by radioactive decay and has three stable isotopes that are derived from the decay of uranium and thorium. Thus, distinct lead isotope ratios are seen in deposits from source rocks of different ages. These isotope ratios make it possible to distinguish whether pollutant lead in the ocean is derived from American, Australian, European, and Chinese sources. Isotope measurements of Pb provide information about temporal changes in the global transport of pollutants by atmospheric aerosols and the distribution of contaminants and other elements by ocean circulation and particulate transport. In this project, water samples will be collected from the South Pacific sector of the Southern Ocean to help establish the origins of anthropogenic lead in this ocean region, distinguish it from natural lead from the Antarctic continent, and understand the dispersal of Pb by ocean circulation. The project will support one graduate student and one early career postdoctoral scholar. The proposed work will be carried out as part of the GEOTRACES trace element and isotope sampling expedition to the South Pacific and Pacific sector of the Southern Ocean. The measurement of Pb isotopes during these expeditions will provide the ability to trace the source, fate, and transport of other particle-reactive metals in the ocean. Water column, sediment core top and aerosol samples will be analyzed for the full suite of Pb isotopes (204, 206, 207, 208) to provide insights into the extent of anthropogenic Pb contamination in the water column, the relative contribution of different lead isotopes from the South American continent, significance of hydrothermal Pb input from Pacific-Antarctic Ridge and whether sediment Pb isotopes reflect variation in the atmospheric circulation pattern. This work will allow evaluation of various anthropogenic and natural processes that determine the global distributions and processes of Pb. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2148916	see above	Edward Boyle		eaboyle@mit.edu	see above

2148473	Collaborative Research: **US GEOTRACES GP17-OCE and GP17-ANT: Properties and processes impacting other trace element and isotope cycles using noble gas and stable isotope tracers**	Brice Loose		bloose@uri.edu	The goal of the international GEOTRACES program is to understand the distributions of trace chemical elements and their isotopes in the oceans. This project will undertake measurements of noble gas concentrations, helium and oxygen isotope abundances, and tritium on two upcoming U.S. GEOTRACES expeditions to the South Pacific, Southern Ocean, and Amundsen Sea. The noble gas and isotope tracers will be used to determine the contributions of hydrothermal venting, glacial meltwater, and sea ice formation to the water masses of the region. Glacial melt and sea ice production are considered important drivers of trace element cycling on the Antarctic continental shelf. These processes also help establish the properties of Southern Ocean-sourced deep water. Upwelling of deep-sourced hydrothermal water could deliver limiting micronutrients such as iron to the surface waters of the Southern Ocean, driving enhanced primary productivity. Deeper-lying hydrothermal plumes may export fluxes of hydrothermal trace elements and isotopes (TEIs) through the Drake Passage. The project will support a graduate student, teacher professional development, and public outreach. During the GEOTRACES GP17-OCE expedition, the team will measure helium-3, helium concentration, and neon concentration. On the GP17-ANT expedition, they will measure the concentrations of all five noble gases, helium-3, the stable isotope composition of water, and tritium. Specific aims include (1) to study pathways for hydrothermal inputs throughout the South Pacific, (2) to quantify other hydrothermally-sourced TEI fluxes and scavenging rates, (3) to quantify the inputs of snow and sea ice melt in relation to iron and other TEIs in the Amundsen Sea, (4) trace the ice shelf pump mechanism in the Amundsen Sea, and examine the spread of northward spread of meltwater and TEIs from the ice-covered marginal seas to the open Southern Ocean. In addition, since there is evidence that not all the hydrothermal inputs to the Southern Ocean have been discovered, the expeditions have the potential to expand knowledge of where additional hydrothermal systems, important to the biogeochemistry of the water column, are located. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2148620	see above	Jennifer Middleton	Gisela Winckler	jennym@ldeo.columbia.edu	see above
2148626	see above	Chris German	William Jenkins	cgerman@whoi.edu	see above
2048858	**US GEOTRACES GP17-ANT: Quantifying the Properties of Atmospheric Trace Elements and Their Fluxes to the Amundsen Sea**	Yuan Gao		yuangaoh@newark.rutgers.edu	The goal of the international GEOTRACES program is to understand the distributions of many chemical elements and their isotopes in the oceans. The National Science Foundation is supporting a U.S. GEOTRACES sampling expedition in the Southern Ocean and Amundsen Sea. This three-year project, for the first time, measures the atmospheric properties of trace elements and their fluxes to the Amundsen Sea as part of the US GEOTRACES GP17-ANT section. This project will focus on the measurement of trace elements in atmospheric aerosols, which are an important source of trace elements to many areas of the oceans. In addition, the investigators will determine the sources of dust and aerosol particles, and quantify the amounts of trace metals delivered to the surface ocean, where they provide essential nutrients to phytoplankton blooms. The new observational data from this project can be used to support both atmospheric and ocean models for coupled air-sea interaction simulations and projections, promoting interdisciplinary sciences. This project will make significant broader impacts by involving female and minority students in research at both the doctoral and undergraduate levels. The lead investigator will incorporate the results from this project into her teachings to promote classroom learning with examples of real-world research, and she will actively participate in the GEOTRACES outreach program to contribute to its education activities. The primary goal of this project is to quantify the key properties of atmospheric trace elements and their fluxes to the Amundsen Sea. The ultimate goal is to advance the knowledge of the atmosphere-ocean-ice interactions for improved understanding of the Earth climate system. The working objectives of this project are: (1) To determine aerosol composition and mineralogy and to explore the sources of dust and target trace elements, including Fe, Al, Ca, Cd, Co, Cu, K, Mn, Na Ni, P, Pb, Ti, V, and Zn; (2) To measure particle-size distributions of aerosol trace elements, aerosol Fe fractional solubility and speciation, organic/inorganic ligands including oxalate and ammonium, and marine biogenic tracers including methanesulfonate and non-sea-salt sulfate and to understand better trace element solubility and processes affecting them; (3) To quantify total atmospheric fluxes of trace elements by both dry deposition and wet deposition processes, contributing to understanding trace element distributions in seawater. Aerosol samples collected on the GP17-ANT cruise will be analyzed for concentrations, composition and mineralogy by utilizing inductively coupled plasma mass spectrometry (ICPMS), synchrotron-based X-ray absorption spectroscopy (XAS) and scanning electron microscopy (SEM). Air mass back trajectory-based cluster analyses will be performed for different air mass provinces impacting the study region. Iron solubility and speciation in aerosol samples will be measured using UV/VIS spectrophotometry and synchrotron-based XAS. Ion chromatography will be utilized to determine water-soluble organic and inorganic species of marine origins. Trace elements in size-segregated aerosols and precipitation will be measured. Atmospheric deposition models will be used to calculate the deposition fluxes to the Amundsen Sea. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

2049305	US GEOTRACES GP17-OCE and GP17-ANT: **Atmospheric Deposition and Aerosol Fractional Solubility in Remote Ocean Regions**	Clifton Buck	Christopher Marsay	Clifton.Buck@skio.uga.edu	Trace Elements are defined by their low concentrations in the open ocean and their addition and removal rates are key uncertainties in our understanding of ocean chemistry. In spite of their scarcity, trace elements can play an outsized role in determining where living things thrive in the open ocean. Near the coasts, these elements may be found in abundance because of features like rivers which bring source material from the continents to the ocean. Far from land, however, trace elements are scarce. The most significant source of these elements to the open ocean may come from dust and other particles falling onto the surface water either directly, or within rain droplets. An improved understanding of this process will further knowledge of element cycling in the ocean, including the carbon cycle. This project will sample the atmosphere of the South Pacific Ocean and the Pacific sector of the Southern Ocean around Antarctica. Input from the atmosphere to these waters is not well known and the research results will provide much needed information to the scientific community. This project will support an early career researcher as well as a graduate student. The deposition and subsequent dissolution of aerosols in surface waters remains a critical research area in the oceanographic community. Much of the ocean remains poorly sampled and improvements in flux estimates, chemical characterization, and fractional solubility estimates are necessary to improve the understanding of this important trace element source. This project will include a cruise in the South Pacific Ocean and one in the Amundsen Sea sector of the Southern Ocean, both as part of the GEOTRACES program. The cruise tracks will cover regions which lie downwind of dust producing regions of Australia and where atmospheric deposition could play a role in dictating distributions of trace elements in the water column. The flux of aerosols across the air-sea interface is a key research area within GEOTRACES and the broader oceanographic community. Flux from the atmosphere to the ocean is highly episodic making the capture of this important term difficult in the open ocean. Flux rates will be determined by the use of the cosmogenic isotope 7Be, providing a rate estimate for time scales longer than the cruise period. Aerosol trace element fractional solubility remains poorly constrained and is one of the reasons that biogeochemical models show poor agreement for marine trace element distributions. Aerosol dissolution will be tested in several solution of varying chemistry to provide a range of solubility estimates which are representative of conditions in precipitation, surface seawater, and in more aggressive environments which provide a high-end solubility estimate. Calculated terms like residence time are also poorly constrained due to this uncertainty. This project will address these questions by capturing bulk and size-fractionated aerosol samples as well as samples of precipitation. The study will advance understanding of dust and soluble aerosol trace element flux from the atmosphere to the ocean and provide contextual data for complimentary studies associated with these GEOTRACES section cruises. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2048774	**US GEOTRACES GP17-OCE and GP17-ANT: Cobalt Biogeochemical Cycling and Phytoplankton Protein Biomarkers in the Pacific and Southern Oceans**	Mak Saito		msaito@whoi.edu	Dissolved metals have an important role as micronutrients that influence marine photosynthesis and the overall carbon cycle. Of these metals, cobalt is one of the scarcest elements. Cobalt has an unusual behavior in the environment in that it is strongly influenced by both nutrient uptake processes in the upper water column and scavenging removal processes in the mid-water and deep ocean. There is also growing evidence of cobalt's importance within marine biological processes where different chemical forms of cobalt have been observed to influence primary productivity. In addition, protein biomolecules bind most metals within organisms, and the study of proteins within marine microbes can provide useful information about how microbes respond to environmental influences. In this proposal, the investigator will study the biogeochemistry of cobalt and selected proteins across the South Pacific and Southern Oceans as part of the GEOTRACES GP17-OCE and GP17-ANT expeditions. GEOTRACES is a global program that studies the distribution of trace elements and isotopes. The project will support a graduate student and a postdoctoral researcher. The distributions of dissolved and labile cobalt will be determined across the South Pacific and the Southern Ocean on these two expeditions. Moreover, microbial proteins representative of nutrient and micronutrient stresses will be measured across surface transects to compare to the distributions of metals. The Southern Ocean and Antarctica coastal regions are of interest for cobalt research because vitamin B12, which contains a cobalt atom, has been observed to influence phytoplankton growth in Antarctic polynyas due strong seasonal demand and increased glacial iron inputs. Recent data suggests that this increased B12 use by the biota may be shifting the Co biogeochemical cycle in multiple ways, and this project will explore these dynamics and compare it with historical data. Cobalt will be measured using cathodic stripping voltammetry after ultraviolet radiation to remove metal-binding ligands. Proteins will be measured by metaproteomic methods that use nanospray liquid chromatography high resolution mass spectrometry and metatranscriptomic databases. Metaproteomic results will be incorporated into the Ocean Protein Portal for broader use in research and education. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

2148468	**US GEOTRACES GP17-OCE and GP17-ANT: Inorganic Carbon Cycling in the South Pacific and Southern Oceans by Direct Measurement**	Ryan Woosley		rwoosley@mit.edu	The oceans help to slow climate change by absorbing about a quarter of the carbon dioxide (CO2) produced by burning of fossil fuels and other human activities. The Pacific and Southern Oceans are known to take up and store significant amounts of anthropogenic CO2, but many questions regarding the amount, variability, and biogeochemical and ecological impacts remain unanswered. This research will focus on answering some of those questions in two areas of the Pacific by analyzing samples for total CO2, total alkalinity, and pH on two GEOTRACES cruises, GP17-OCE and GP17-ANT. The project will support several undergraduate student researchers and create educational modules on ocean acidification for general public and K-12 students. On the GP17-OCE expedition in the south Pacific, sub-decadal scale variability in the uptake of CO2 and resulting decrease in pH (termed ocean acidification) will be examined by comparing data collected on this expedition with data from prior occupations of the line in 1991, 2005 and 2014. An extended multilinear regression technique will be used to separate natural variability from human induced changes. The second expedition, GP17-ANT, covers the Amundsen Sea, an area with few prior carbon measurements. This sea is perennially ice-covered with several seasonal polynyas (areas of open water surrounded by sea ice) and exhibits complex water circulation making the contribution to the global carbon cycle uncertain. The data collected from this expedition will examine several hypotheses regarding how carbon is taken up, mixed, and recirculated in the region, how glacial ice melt, sea ice, and biological productivity influence the carbon cycle, and provide baseline measurements against future data to determine changes in the carbon cycle of the region over time. Both expeditions will leverage the myriad of other parameters being measured, particularly trace metals such as iron and zinc, to examine how cycling of carbon and trace metals are interlinked through pH. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2049151	**US GEOTRACES GP17-OCE and GP17-ANT: Mapping zinc speciation in the Southern Ocean overturning circulation to test the zinc scavenging hypothesis**	Nicholas Hawco		hawco@hawaii.edu	The Southern Ocean plays a significant role in the global carbon cycle because deep ocean waters rich in CO2 are brought into the surface layer and can exchange with the atmosphere. The growth of phytoplankton counteracts this carbon source by fixing CO2 into biomass, which can sink back to the deep sea. While the Southern Ocean is rich in macronutrients that support phytoplankton growth, key micronutrients such as iron, manganese and zinc are at very low abundance. Of these metals, only iron has been found to limit phytoplankton productivity on a large scale, but few observations of Zn and Mn have been made. This proposal seeks to map bioavailable Zn concentrations across an oceanographic transect from the South Pacific Ocean to the Amundsen Sea. At low abundance, Zn scarcity can limit phytoplankton, but Zn can also affect the uptake of other scarce metals, especially Mn. Measurements made as part of this project will determine the extent of limiting and toxic levels of Zn in this critical but undersampled region of the oceans. Such constraints are necessary for modelling changes to the oceanic Zn cycle – and its effect on phytoplankton activity – under past and future climate scenarios. As part of the GEOTRACES GP17 OCE and ANT expeditions, parameters governing the reactivity of Zn will be measured in high vertical and latitudinal resolution across a transect extending several thousand kilometers and crossing formation regions of globally important water masses. Voltammetry techniques will be used to determine the concentrations of free zinc (Zn') and Zn-binding organic ligands dissolved in seawater for hundreds of samples. Together with other investigators in the GEOTRACES program, these measurements will constrain the reactivity of Zn' in the deep ocean and define empirical relationships between Zn' and phytoplankton metal uptake. This is essential for understanding the global distribution of Zn and other micronutrients in the oceans and their potential to affect primary production. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

2049272	**US GEOTRACES GP17-OCE and GP17-ANT: Particulate and biogenic trace elements in the South Pacific and Southern Ocean**	Benjamin Twining		btwining@bigelow.org	The goal of the international GEOTRACES program is to understand the distributions of trace chemical elements and their isotopes in the oceans. Many trace metals, such as iron, manganese and zinc, are essential for life and serve as nutrients for phytoplankton. However, regions of the Pacific and Southern Oceans have very low concentrations of iron and manganese, in particular, limiting the growth of phytoplankton at times. This project will improve understanding of the uptake and removal of micronutrient metals by phytoplankton in these regions. This project will accomplish three main objectives: 1) measure the concentrations of phosphorus and eleven trace metals in particles collected from the upper region of the South Pacific and Southern Oceans during a cruise from Tahiti to Chile; 2) measure a subset of these elements, along with carbon, sulfur and silicon, directly in phytoplankton cells collected from these waters; and 3) measure the same elements in phytoplankton collected from coastal Antarctic waters on a subsequent, companion cruise into the Amundsen Sea. Two undergraduate student interns will be involved in the project, along with a postdoctoral scholar. The scientific results and research experience will be shared with additional undergraduates through two classes, and the project will be brought to the broader public through a virtual reality game and associated activities produced during the project and introduced through libraries and institutional outreach events. The U.S. GEOTRACES GP17-OCE expedition, planned for late 2022, aims to determine the distribution of trace elements and isotopes along a transect spanning regions of global importance to nutrient and carbon cycling, crossing the South Pacific Gyre, the iron-limited waters of the Antarctic Circumpolar Current, Pacific Deep Waters with hydrothermal inputs, and waters near the Chilean margin. The South Pacific Gyre and Pacific sector of the Southern Ocean are climate-critical regions for the transfer of heat, carbon, and nutrients within the global ocean, and they are a region where phytoplankton growth is typically limited by low concentrations of iron (Fe) in the surface ocean. The researchers will use inductively-coupled plasma mass spectrometry and synchrotron x-ray fluorescence microscopy to address three primary research questions focused on the internal biogeochemical cycling of trace elements in this region: 1) How do trace element contents of dominant phytoplankton taxa respond to environmental macronutrient and trace element gradients? 2) How does the trace element composition of the various particulate matter fractions (lithogenic, authigenic, biogenic) vary across the section? 3) How does the composition and stoichiometry of particulate material influence trace element cycling and trace element:nutrient stoichiometry of the surrounding water masses? This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.
2048067	**US GEOTRACES GP17-OCE and GP17-ANT: Sources and Rates of Trace Element and Isotope Cycling Derived from the Radium Quartet**	Matthew Charette		mcharette@whoi.edu	The goal of the GEOTRACES program is to “identify processes and quantify fluxes that control the distribution of trace elements and isotopes (TEIs) in the ocean and to establish the sensitivity of these distributions to changing environmental conditions”. This ambitious objective requires coordinated seagoing field work for collection of samples to measure many elements simultaneously across the earth’s major ocean basins. However, these comprehensive global concentration maps for trace elements cannot be properly interpreted without concurrent measurement of radioactive tracers like radium isotopes that can provide time scales of their ocean input. In this project, the investigators will measure the abundance and distribution of radium isotopes in the Southern Ocean between the southern tip of South America and Antarctica, including a detailed characterization of the Antarctic coastal marine environment. The project will support a postdoctoral research associate and involve two undergraduate student researchers in post-cruise analyses. The main motivation of the proposed research is to utilize the quartet of radium (Ra) isotopes (224Ra, 223Ra, 228Ra, 226Ra) to enable source identification and flux quantification of TEIs during the forthcoming US GEOTRACES GP17-OCE and GP17-ANT expeditions. Measurement of Ra isotopes will allow the team to address several key questions related to ocean margin and benthic boundary processes and their role in supplying and transporting TEIs to marine ecosystems including: (1) What are the rates of lateral transport of TEIs from the Antarctic and Patagonian continental margins out to and including the high nutrient low chlorophyll (HNLC) Southern Ocean? (2) What are the TEI fluxes associated with Antarctic glacial meltwater? and (3) What are the time scales of TEI transport associated with Pacific-Antarctic Ridge neutrally buoyant hydrothermal plumes? Boundary inputs are considered to be the dominant source of many key TEIs to the ocean including iron, however, TEI concentrations must be coupled with input and transport rates to determine their effect on marine biogeochemical cycles. The wide range of Ra isotope half-lives (3.66 days to 1600 years) allow for the quantification of TEI transport processes on time scales relevant to ocean mixing processes. The proposed coupled Ra-TEI measurements will allow the full value of the distribution of numerous TEIs as measured by GEOTRACES PIs to be realized. This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

2123942	**Autonomous Ocean Carbon Observer Development and Calibration**	James Bishop		jkbishop@berkeley.edu	The very fast and dynamic ocean biological carbon pump (OBCP) plays a fundamental role in the global carbon cycle and in setting concentrations of atmospheric carbon dioxide. Photosynthetic organisms that that fuel the OCBP live and die on a week to week basis, and the resulting sinking (or export) of organic and inorganic carbon particles from the surface layer and consumption losses of these particles in deeper waters are similarly variable. Simply stated, the OCBP is poorly understood due to dependence on short- term, and seasonally and spatially limited ship observations; thus model estimates of its strength and future trajectory are highly uncertain. To address this gap, the investigators will engineer and sea-test two robotic Lagrangian Ocean Carbon Observer (OCO) floats capable of 8 month to multi-year missions, yet able to resolve flux processes on hourly to daily time scales and relay data in real time via satellite telemetry while operating anywhere in the ocean. The development of the OCO enables the identification of specific pathways and controls on the vertical transfer of particulate organic and inorganic carbon (POC and PIC) from the surface ocean to subsurface waters. The project logically follows on from the investigator's development and successful deployment of robotic Lagrangian Carbon Explorer (CE) and Carbon Flux Explorer (CFE) floats, which measure optically POC and PIC concentration and flux variability to depths of 1000 m. A unique capability of the CFE is that it is able to measure the sinking flux of carbon carried by different sizes and classes of particles. The project will merge CFE and CE capabilities to create the OCO. The team will contribute to the development of a STEM workforce by engaging UC Berkeley undergraduates and one graduate student in all phases (development, laboratory, seagoing, and interpretive) of the project and in the class room. Specifically, CFEs and two new Ocean Carbon Observers (OCOs) that simultaneously measure both particle flux and concentration profiles will be constructed and test-deployed at sea in January 2023. During the times that these autonomous instruments drift at target depths within the upper kilometer (interrupted by transit to the surface for location and real time bidirectional telemetry), they will autonomously quantify the inherent optical properties and size distributions of sinking material captured. Bishop et al. (2016; Biogeosciences 13, 3019-3129, doi:10.5194/bg-13-3109) describe CFE capabilities and methodology for rendering raw OSR imagery to rigorously defined inherent optical measures of particle loading -- attenuance and cross-polarized photon yield. Bourne et al. (2019; Biogeosciences, 16, 1249-1264; doi:10.5194/bg-16-1249-2019) show that attenuance is strongly correlated ($r^2 > 0.86$) with POC and PN sampled at 150 m by sampler-equipped CFEs "(CFE-Cal floats)" over a broad range of particle flux and particle size distributions. Planned further deployment of the CFE-Cal floats to sample sinking material to depths of at least 500 m will enable validation of our calibration of the attenuance proxy and to enable a first calibration of the PIC optical flux proxy. Bourne et al. (2021; Biogeosciences, 18, 3053–3086, doi:10.5194/bg-18-3053-2021) demonstrate the unique capability of CFEs to resolve and quantify the vertical flux carried by different particle size classes in the mesopelagic; furthermore, they describe prototype algorithms that will lead to flux size-distribution analysis in real time on the CFEs. The project will enable fully autonomous long-term deployments of CFE and OCO systems in the global ocean. The involvement a commercial float vendor (MRV Systems) and sensor manufacturer (Seabird Scientific) may lead to a commercialization pathway for the OCO.
2242222	**US GEOTRACES GP17-ANT: Dissolved Ga, Ba, and V as interface, process, and circulation tracers in the Amundsen Sea**	Laura Whitmore		lmwhitmore@alaska.edu	A decline in the presence of sea ice and glaciers in and around the Amundsen Sea may result in large-scale biogeochemical changes within the Amundsen Sea and neighboring Ross Sea and Southern Ocean. It is imperative that we understand the current state of supply, redistribution, and export of salt, heat, and bioactive elements in the Amundsen Sea because of its connectivity to regions where deep, intermediate, and mode waters are formed and distributed. The Amundsen Sea shelf is characterized by warm upwelling, sea ice formation and melt, highly productive polynyas, and rapidly melting terminating glaciers – potentially affecting stability of the West Antarctic Ice Sheet. These compounding features make it difficult to track any one process with a single tracer. Indeed, efforts to deconvolve water masses in the Amundsen Sea have, in some cases, over-determined the system to reduce uncertainty. Outside of circulation, tracing the impact of non-conservative processes such as particle scavenging, sedimentary fluxes, or productivity-associated uptake and export require similar scrutiny: they require multiple tracers to quantify the effect of each process on seawater geochemical signals. Herein, I propose that Ga, Ba, and V can be used with respect to each other and to essential element (e.g., Fe and other micronutrients) distributions to better understand Amundsen Sea biogeochemistry.