

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN UNITED STATES

May 1st, 2017 to March 30th, 2018

U.S. GEOTRACES Meetings

The U.S. GEOTRACES Scientific Steering Committee (SSC) met on 21-22 June 2017 at the U.S. National Science Foundation (NSF), thereby facilitating interaction with NSF program officers who oversee support of U.S. GEOTRACES activities. The SSC reviewed progress on the two GEOTRACES sections completed most recently (GP16 in the eastern tropical South Pacific and GN01 in the western Arctic Ocean) and laid out plans for future US contributions to GEOTRACES. In particular, the SSC approved plans to complete the GEOTRACES GP17 section (Tahiti – Antarctica – Chile). The SSC also agreed to partner with the Ocean Carbon and Biogeochemistry program in a new initiative to assess community interest for a joint study of the biogeochemistry of the Gulf of Mexico. Additional information about this is provided below under Outreach.

Other meetings sponsored during the past year by U.S. GEOTRACES are associated with specific GEOTRACES sections, and are discussed below under Cruise-related Activities.

Cruise-related Activities

Eastern Tropical Pacific: A special issue of Marine Chemistry with results from GP16 was officially published in April, 2018 <https://www.sciencedirect.com/journal/marine-chemistry/vol/201/suppl/C?dgcid=raven_sd_via_email>. The title of the issue is “The U.S. GEOTRACES Eastern Tropical Pacific Transect (GP16)”. Jim Moffett of the University of Southern California served as the guest editor of the volume. A complete list of the 19 papers published in this volume is provided below. Meanwhile, additional papers describing results from the GP16 section continue to be submitted for publication, independently of the Marine Chemistry volume.

Arctic Ocean: U.S. investigators continue to analyze samples collected aboard the U.S. Coast Guard Cutter Healy (HLY1502, 9 August to 12 October, 2015, sailing out of and returning to Dutch Harbor, Alaska; Chief Scientist: David Kadko, Co-Chief Scientist: Bill Landing, Logistics Coordinator: Greg Cutter).

A total of 56 participants, representing each project involved in this section, gathered for a data workshop in Miami, Florida (23 to 26 October, 2017) to share and compare their findings. Several Arctic synthesis themes emerged from working group discussions during the workshop, including: 1) shelf-basin interaction that affects the distribution of trace elements and their isotopes (TEIs) in the halocline, 2) processes affecting TEI distributions in the seasonal ice zone, 3) residence times of TEIs in surface waters, and 4) sources of TEIs carried across the Arctic Ocean by the Transpolar Drift.

North Pacific Meridional Section Under the leadership of Greg Cutter (Chief Scientist) as well as Phoebe Lam and Karen Casciotti (co-Chief Scientists) US GEOTRACES will undertake Section GP15 (Alaska to Tahiti) later this year. Sailing aboard the R/V Roger Revelle, the cruise will depart Seattle on 18 September 2018 and conclude in Papeete Tahiti on 24 November, with a mid-cruise stop in Hilo Hawaii to permit offloading of samples, onloading of supplies and exchange of personnel. Altogether, 38 principal investigators representing 27 universities and

research institutions have been funded to participate in GP15. Their projects will cover the measurement of all GEOTRACES key TEIs. In addition, the cruise leaders are working with the BioGEOTRACES community to collect samples for as many BioGEOTRACES parameters as possible.

A workshop was held 8-9 March 2018 (Old Dominion University, Norfolk Virginia) to inform investigators about the cruise logistics and to negotiate allocation of shared samples (seawater and filtered particles). Altogether, more than 50 participants attended the meeting, representing each of the funded projects as well as the ship operators (Scripps Institution of Oceanography). Organizing and coordinating such a comprehensive program requires a tremendous effort on the part of the cruise leaders, who hold weekly teleconferences while working out the details of the cruise planning.

South Pacific Meridional Section: As noted above, U.S. GEOTRACES has initiated planning to undertake the GP17 section from Tahiti to Antarctica, completing the western Pacific meridional section. Discussion with program officers at NSF determined that the optimum time for the cruise will be roughly December 2021 to February 2022.

New Funding

Final decisions about which proposals will be funded to participate in GP15 were communicated to U.S. GEOTRACES PIs by NSF in late 2017.

A proposal requesting three years of continuing support for the U.S. GEOTRACES project office was submitted to NSF in February 2018. We anticipate that a decision will be received in June.

Presentation of results

Many presentations of U.S. GEOTRACES results were given at the 2017 Goldschmidt Conference in Paris France and at the 2018 Ocean Sciences meeting in Portland Oregon. The Goldschmidt GEOTRACES session spanned three oral sessions and included 35 oral presentations, of which a significant number were from US investigators, students, and postdocs. The editors of the journal Chemical Geology approached the lead convener (Tim Conway, University of South Florida) about putting together a special issue based on the exciting research presented during this session, which includes a mixture of synthesis and new research; several US investigators are contributing to this.

Synthesis

Two projects that grew out of the GEOTRACES synthesis workshop held at the Lamont-Doherty Earth Observatory, Palisades, New York, USA from 1-4 August, 2016, have advanced under the leadership of Christopher Hayes of the University of Southern Mississippi. The first combines inventories of selected key TEIs measured along the GA03 section together with the distributions of dissolved ^{230}Th and ^{232}Th to estimate the rate of supply of each TEI from dust, as well as its residence time in the water column. This paper has been submitted to Global Biogeochemical Cycles, reviewed, revised and resubmitted. We are awaiting a final decision on the manuscript. A second effort, also exploiting data from GA03, utilizes multiple radionuclide systems to calculate the sinking flux of particulate organic carbon as well as the particulate sinking fluxes of several key TEIs. In addition to providing estimates of sinking

fluxes throughout the water column, this synthesis activity is evaluating the strengths and limitations of each radionuclide system for estimating fluxes of particles and their constituents. A manuscript describing the results of this synthesis initiative is being written under the leadership of Chris Hayes and Erin Black.

Outreach and Capacity Building Activities

U.S. GEOTRACES co-organized and co-supported town hall meetings at the 2017 Goldschmidt Conference (Paris France) and at the 2018 Ocean Sciences meeting (Portland Oregon, USA) to inform the research community about the release of the latest GEOTRACES data product, IDP2017.

U.S. GEOTRACES investigators had a strong presence at the first GEOTRACES summer school in Brest France 20-26 August 2017, training the next generation of GEOTRACERS. US lecturers included Bob Anderson, Greg Cutter, Phoebe Lam, Kristen Buck and Paul Field, out of 17 total. Approximately 60 students from around the world, including the US, participated in the summer school.

U.S. GEOTRACES also co-organized a second town hall during the 2018 Ocean Sciences meeting to assess community interest in developing an interdisciplinary study of the biogeochemistry of the Gulf of Mexico. Our partner in organizing the town hall was the Ocean Carbon and Biogeochemistry program. The town hall was led by Alan Shiller (University of Southern Mississippi, and US GEOTRACES SSC member) and by Heather Benway (Executive Director of the OCB Project Office). In addition to representation by these two US programs, Juan-Carlos Herguera of the Ensenada Center for Scientific Research and Higher Education presented on the large ongoing Mexican research initiative in the Gulf of Mexico. The town hall demonstrated widespread interest in developing a future program in the Gulf of Mexico that may be expanded to include the Caribbean Sea. Alan Shiller is leading the long-term planning that will be needed to implement a project in the Gulf of Mexico. The project will incorporate research on TEIs of interest to GEOTRACES, but will not focus exclusively on TEIs. The possibility of developing this initiative as a GEOTRACES process study is being discussed.

In an effort to help build GEOTRACES capacity in East Asia, Bob Anderson (director of the U.S. GEOTRACES project office) participated in two meetings in the Republic of (South) Korea in late 2017. Anderson was invited to give a talk entitled “Indian Ocean GEOTRACES (Prospects for quantifying supply and removal of essential micronutrients in the Indian Ocean)” at the Korea Institute of Ocean Science and Technology International Seminar KIS 2017: New Observation and New Applications, 4-5 December 2017, Busan, Republic of Korea. While in Korea he also gave a keynote talk entitled “A GEOTRACES approach to identify sources of trace element nutrients in the Indian Ocean” at the workshop on strategic imperatives and implementation for Korea-US Indian Ocean Sciences (KUDOS) 2017, Seoul National University, 29 November – 1 December. Korea has recently acquired the NIOZTITAN clean sampling system for use aboard their new global class research vessel ISABU. Following a successful test of their system in the summer of 2017, Korean scientists are keen to begin developing an ambitious GEOTRACES program, with a focus on the Indian Ocean where they plan to use the ISABU over each of the next several years. During these meetings Anderson offered advice about the design and scientific goals of Korean GEOTRACES research.

Publications (GEOTRACES, GEOTRACES Compliant and GEOTRACES-related)

During the past year US GEOTRACES investigators published a total of 38 peer-reviewed journal articles, including papers published by lead authors in other nations for which U.S. GEOTRACES investigators serve as co-authors.

Special issue Marine Chemistry: The U.S. GEOTRACES Eastern Tropical Pacific Transect (GP16) – 19 Publications

- Black, E.E., Buesseler, K.O., Pike, S.M. and Lam, P.J. (2018) ^{234}Th as a tracer of particulate export and remineralization in the southeastern tropical Pacific. *Marine Chemistry* 201, 35-50.
- Buck, K.N., Sedwick, P.N., Sohst, B. and Carlson, C.A. (2018) Organic complexation of iron in the eastern tropical South Pacific: Results from US GEOTRACES Eastern Pacific Zonal Transect (GEOTRACES cruise GP16). *Marine Chemistry* 201, 229-241.
- Cutter, G.A., Moffett, J.G., Nielsdóttir, M.C. and Sanial, V. (2018) Multiple oxidation state trace elements in suboxic waters off Peru: In situ redox processes and advective/diffusive horizontal transport. *Marine Chemistry* 201, 77-89.
- Hawco, N.J., Lam, P.J., Lee, J.-M., Ohnemus, D.C., Noble, A.E., Wyatt, N.J., Lohan, M.C. and Saito, M.A. (2018) Cobalt scavenging in the mesopelagic ocean and its influence on global mass balance: Synthesizing water column and sedimentary fluxes. *Marine Chemistry* 201, 151-166.
- Ho, P., Lee, J.-M., Heller, M.I., Lam, P.J. and Shiller, A.M. (2018) The distribution of dissolved and particulate Mo and V along the U.S. GEOTRACES East Pacific Zonal Transect (GP16): The roles of oxides and biogenic particles in their distributions in the oxygen deficient zone and the hydrothermal plume. *Marine Chemistry* 201, 242-255.
- Hoffman, C.L., Nicholas, S.L., Ohnemus, D.C., Fitzsimmons, J.N., Sherrell, R.M., German, C.R., Heller, M.I., Lee, J.-m., Lam, P.J. and Toner, B.M. (2018) Near-field iron and carbon chemistry of non-buoyant hydrothermal plume particles, Southern East Pacific Rise 15°S. *Marine Chemistry* 201, 183-197.
- Jenkins, W.J., Lott, D.E., German, C.R., Cahill, K.L., Goudreau, J. and Longworth, B. (2018) The deep distributions of helium isotopes, radiocarbon, and noble gases along the U.S. GEOTRACES East Pacific Zonal Transect (GP16). *Marine Chemistry* 201, 167-182.
- John, S.G., Helgoe, J. and Townsend, E. (2018a) Biogeochemical cycling of Zn and Cd and their stable isotopes in the Eastern Tropical South Pacific. *Marine Chemistry* 201, 256-262.
- John, S.G., Helgoe, J., Townsend, E., Weber, T., DeVries, T., Tagliabue, A., Moore, K., Lam, P., Marsay, C.M. and Till, C. (2018b) Biogeochemical cycling of Fe and Fe stable isotopes in the Eastern Tropical South Pacific. *Marine Chemistry* 201, 66-76.
- Kipp, L.E., Sanial, V., Henderson, P.B., van Beek, P., Reyss, J.-L., Hammond, D.E., Moore, W.S. and Charette, M.A. (2018) Radium isotopes as tracers of hydrothermal inputs and neutrally buoyant plume dynamics in the deep ocean. *Marine Chemistry* 201, 51-65.
- Lam, P.J., Lee, J.-M., Heller, M.I., Mehic, S., Xiang, Y. and Bates, N.R. (2018) Sizefractionated distributions of suspended particle concentration and major phase

composition from the U.S. GEOTRACES Eastern Pacific Zonal Transect (GP16). *Marine Chemistry* 201, 90-107.

- Lee, J.-M., Heller, M.I. and Lam, P.J. (2018) Size distribution of particulate trace elements in the U.S. GEOTRACES Eastern Pacific Zonal Transect (GP16). *Marine Chemistry* 201, 108-123.
- Marsay, C.M., Lam, P.J., Heller, M.I., Lee, J.-M. and John, S.G. (2018) Distribution and isotopic signature of ligand-leachable particulate iron along the GEOTRACES GP16 East Pacific Zonal Transect. *Marine Chemistry* 201, 198-211.
- Moffett, J.W. and German, C.R. (2018) The U.S. GEOTRACES Eastern Tropical Pacific Transect (GP16). *Marine Chemistry* 201, 1-5.
- Ohnemus, D.C., Lam, P.J. and Twining, B.S. (2018) Optical observation of particles and responses to particle composition in the GEOTRACES GP16 section. *Marine Chemistry* 201, 124-136.
- Pavia, F., Anderson, R.F., Vivancos, S., Fleisher, M., Lam, P., Lu, Y., Cheng, H., Zhang, P. and Lawrence Edwards, R. (2018) Intense hydrothermal scavenging of ^{230}Th and ^{231}Pa in the deep Southeast Pacific. *Marine Chemistry* 201, 212-228.
- Peters, B.D., Jenkins, W.J., Swift, J.H., German, C.R., Moffett, J.W., Cutter, G.A., Brzezinski, M.A. and Casciotti, K.L. (2018a) Water mass analysis of the 2013 US GEOTRACES eastern Pacific zonal transect (GP16). *Marine Chemistry* 201, 6-19.
- Peters, B.D., Lam, P.J. and Casciotti, K.L. (2018b) Nitrogen and oxygen isotope measurements of nitrate along the US GEOTRACES Eastern Pacific Zonal Transect (GP16) yield insights into nitrate supply, remineralization, and water mass transport. *Marine Chemistry* 201, 137-150.
- Sanial, V., Kipp, L.E., Henderson, P.B., van Beek, P., Reyss, J.L., Hammond, D.E., Hawco, N.J., Saito, M.A., Resing, J.A., Sedwick, P., Moore, W.S. and Charette, M.A. (2018) Radium-228 as a tracer of dissolved trace element inputs from the Peruvian continental margin. *Marine Chemistry* 201, 20-34.

Journal articles: (19 publications)

- Crusius, J., Schroth Andrew, W., Resing Joseph, A., Cullen, J. and Campbell Robert, W. (2017) Seasonal and spatial variabilities in northern Gulf of Alaska surface water iron concentrations driven by shelf sediment resuspension, glacial meltwater, a Yakutat eddy, and dust. *Global Biogeochemical Cycles* 31, 942-960.
- Gardner, W.D., Mishonov, A.V. and Richardson, M.J. (2018a) Decadal Comparisons of Particulate Matter in Repeat Transects in the Atlantic, Pacific, and Indian Ocean Basins. *Geophysical Research Letters*.
- Gardner, W.D., Richardson, M.J. and Mishonov, A.V. (2018b) Global assessment of benthic nepheloid layers and linkage with upper ocean dynamics. *Earth and Planetary Science Letters* 482, 126-134.
- Haley, B.A., Du, J., Abbott, A.N. and McManus, J. (2017) The impact of benthic processes on rare earth element and neodymium isotope distributions in the oceans. *Frontiers in Marine Science* 4, 426.

- Hein, J.R., Konstantinova, N., Mikesell, M., Mizell, K., Fitzsimmons, J.N., Lam, P.J., Jensen, L.T., Xiang, Y., Gartman, A., Cherkashov, G., Hutchinson, D.R. and Till, C.P. (2017) Arctic Deep Water Ferromanganese-Oxide Deposits Reflect the Unique Characteristics of the Arctic Ocean. *Geochemistry, Geophysics, Geosystems* 18, 37713800.
- Heller, M.I., Lam, P.J., Moffett, J.W., Till, C.P., Lee, J.-M., Toner, B.M. and Marcus, M.A. (2017) Accumulation of Fe oxyhydroxides in the Peruvian oxygen deficient zone implies non-oxygen dependent Fe oxidation. *Geochimica et Cosmochimica Acta* 211, 174-193.
- Kipp, L.E., Charette, M.A., Moore, W.S., Henderson, P.B. and Rigor, I.G. (2018) Increased fluxes of shelf-derived materials to the central Arctic Ocean. *Science Advances* 4, 10.1126/sciadv.aao1302.
- Lerner, P., Marchal, O., Lam, P.J., Buesseler, K. and Charette, M. (2017) Kinetics of thorium and particle cycling along the U.S. GEOTRACES North Atlantic Transect. *Deep Sea Research Part I: Oceanographic Research Papers* 125, 106-128.
- Lupton, J.E. and Jenkins, W.J. (2017) Evolution of the south Pacific helium plume over the past three decades. *Geochemistry, Geophysics, Geosystems* 18, 1810-1823. • Marconi, D., Sigman Daniel, M., Casciotti Karen, L., Campbell Ethan, C., Alexandra Weigand, M., Fawcett Sarah, E., Knapp Angela, N., Rafter Patrick, A., Ward Bess, B. and Haug Gerald, H. (2017) Tropical dominance of N₂ fixation in the North Atlantic Ocean. *Global Biogeochemical Cycles* 31, 1608-1623.
- Mukherjee, P., Glamoclija, M. and Gao, Y. (2018) Insignificant impact of freezing and compaction on iron solubility in natural snow. *Journal of Atmospheric Chemistry*, 10.1007/s10874-10018-19375-10872.
- Noble, A.E., Ohnemus, D.C., Hawco, N.J., Lam, P.J. and Saito, M.A. (2017) Coastal sources, sinks and strong organic complexation of dissolved cobalt within the US North Atlantic GEOTRACES transect GA03. *Biogeosciences* 14, 2715-2739.
- Saito, M.A., Noble, A.E., Hawco, N., Twining, B.S., Ohnemus, D.C., John, S.G., Lam, P., Conway, T.M., Johnson, R., Moran, D. and McIlvin, M. (2017) The acceleration of dissolved cobalt's ecological stoichiometry due to biological uptake, remineralization, and scavenging in the Atlantic Ocean. *Biogeosciences* 14, 4637-4662.
- Schroth, A.W., Crusius, J., Gassó, S., Moy, C.M., Buck, N.J., Resing, J.A. and Campbell, R.W. (2017) Atmospheric deposition of glacial iron in the Gulf of Alaska impacted by the position of the Aleutian Low. *Geophysical Research Letters* 44, 5053-5061.
- Shelley, R.U., Roca-Martí, M., Castrillejo, M., Masqué, P., Landing, W.M., Planquette, H. and Sarthou, G. (2017) Quantification of trace element atmospheric deposition fluxes to the Atlantic Ocean (>40°N; GEOVIDE, GEOTRACES GA01) during spring 2014. *Deep Sea Research Part I: Oceanographic Research Papers* 119, 34-49.
- Shiller, A.M., Chan, E.W., Joung, D.J., Redmond, M.C. and Kessler, J.D. (2017) Light rare earth element depletion during Deepwater Horizon blowout methanotrophy. *Sci Rep* 7, 10389.
- Tang, Y., Stewart, G., Lam, P.J., Rigaud, S. and Church, T. (2017) The influence of particle concentration and composition on the fractionation of ²¹⁰Po and ²¹⁰Pb along the North Atlantic GEOTRACES transect GA03. *Deep Sea Research Part I: Oceanographic Research Papers* 128, 42-54.

- Till, C.P., Shelley, R.U., Landing, W.M. and Bruland, K.W. (2017) Dissolved scandium, yttrium, and lanthanum in the surface waters of the North Atlantic: Potential use as an indicator of scavenging intensity. *Journal of Geophysical Research: Oceans* 122, 66846697.
- Woosley, R.J., Millero, F.J. and Takahashi, T. (2017) Internal consistency of the inorganic carbon system in the Arctic Ocean. *Limnology and Oceanography: Methods* 15, 887-896.

Although not yet officially published, we draw attention to the following paper online that will be of interest to GEOTRACES investigators working in the North Atlantic Ocean.

Holzer, M., Smethie, W. M., & Ting, Y.-H. (2018). Ventilation of the subtropical North Atlantic: Locations and times of last ventilation estimated using tracer constraints from GEOTRACES section GA03. *Journal of Geophysical Research: Oceans*, 123. <https://doi.org/10.1002/2017JC013698>

Dissertations

- Black, E.E. 2018. PhD. An investigation of basin-scale controls on upper ocean export and remineralization, MIT-WHOI Joint Program, Woods Hole, MA.
- Wambaugh, Z. 2017. M.S. in Ocean and Earth Sciences. Thesis Title: Selenium distribution and cycling in the eastern equatorial Pacific Ocean. Old Dominion University.
- McQuiggan, K. A. 2018. M.S. in Ocean and Earth Sciences. Thesis Title: Biogeochemical cycling of selenium in the western Arctic Ocean. Old Dominion University.
- Mukherjee, P. 2018. P.D. Thesis title: Investigation of chemical and physical processes on Arctic aerosols through a combined approach of field and laboratory studies. Rutgers University.

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