ANNUAL REPORT ON GEOTRACES ACTIVITIES IN UNITED STATES

April 1st, 2020 to April 30th, 2021

The overriding feature of the last year has been the delay in U.S. GEOTRACES activities due to the COVID pandemic. This point will be made repeatedly in the report that follows.

New GEOTRACES or GEOTRACES relevant scientific results

With 49 peer-reviewed publications in the past year (see below) there are too many results to describe them all. Therefore, the approach this year is to begin by listing the 12 projects from U.S. GEOTRACES that were featured as GEOTRACES science highlights during the reporting period. See: < https://www.geotraces.org/category/science/newsflash/>. Following that we will report briefly on the status of the analysis of samples from GEOTRACES section GP15.

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

Highlight Date	**Lead P.I.**	**Synopsis**
4 May 2021	C. Hayes	Used core-top compositional measurements to estimate Th-normalized global fluxes of major sedimentary components.
19 Mar. 2021	B. Twining	Combined data from four GEOTRACES cruises to demonstrate luxury iron uptake by phytoplankton and related it taxa and environmental conditions.
3 Mar. 2021	T. Mellett	Studied the distributions of Fe- and Cu-binding ligands in the eastern Gulf of Mexico in relation to circulation and hydrography.
15 Jan. 2021	S. Roshan	Used neural networks (A.I.) and inverse methodology with GEOTRACES data to model the global biogeochemical cycle of copper.
13 Dec. 2020	F. Pavia	Interpreted the distributions of Pa and Th isotopes in the deep southwest Pacific to be related to isopycnal mixing transport to the Southern Ocean.
3 Dec. 2020	E. Black	Used GEOTRACES ^{234}Th and sediment trap data to constrain export fluxes on a global scale.
5 Nov. 2020	F. Pavia	Combined dissolved and particulate Th isotope data from a GEOTRACES process cruise in the South Pacific to demonstrate the importance of atmospheric dust fluxes to ocean productivity for the South Pacific.

2 Sep. 2020	D. Kadko	Has developed a new model for using the cosmogenic isotope ^{7}Be to constrain global, time-integrated aerosol fluxes of various TEIs to the sea surface.
22 Jul. 2020	L. Whitmore	Used dissolved Ga to characterize source waters (Atlantic vs. Pacific) in the Arctic, providing a powerful tool for deconvolving water mass structures for interpreting GEOTRACES TEI data.
10 Jun 2020	S. Roshan	Applied new scavenging parameterization to a model of the large-scale abyssal transport of hydrothermal iron in the South Pacific using GP16 data to explore its relative impact on surface global productivity.
5 May 2020	M. Charette	Gathered data on trace elements, radionuclides and dissolved organic matter to demonstrate that rivers and continental shelf sediments are significant sources of carbon and trace elements into parts of the Arctic Ocean via the Transpolar Drift.
4 May 2020	W. Jenkins	Combined GP15 ^{3}He, dFe, and dMn relationships with a regional model to estimate the absolute fluxes of those elements to the North Pacific from the Loihi Seamount.

We further note that the papers by Hayes, Black, Kadko, Charette, Jenkins and both papers by Roshan involve synthesis of multiple data sets to achieve products that exceed those that would be produced by individual investigators or by individual projects. We would also emphasize that Hayes, Mellett, Roshan, Pavia, Black and Whitmore are all **early-career investigators** whose work is being featured by GEOTRACES.

<u>Analysis of samples from GEOTRACES section GP15</u>, from Alaska to Tahiti, was delayed as most labs were fully or partially closed for a substantial portion of the calendar year 2020 due to the COVID pandemic. Sample analysis has now resumed and the strategy for completing this section is described below under "meetings." Here we highlight the contrasting biogeochemical regimes sampled along the GP15 transect. These contrasting regimes are best illustrated by the particulate organic carbon (POC) concentrations measured along the section, with high concentrations found in the Subarctic and at the equator whereas low concentrations were observed in the subtropical gyres to the north and south of the equator (Fig. 1). Much of the work that is still ongoing will relate the distributions of TEIs to the concentrations and fluxes of POC.

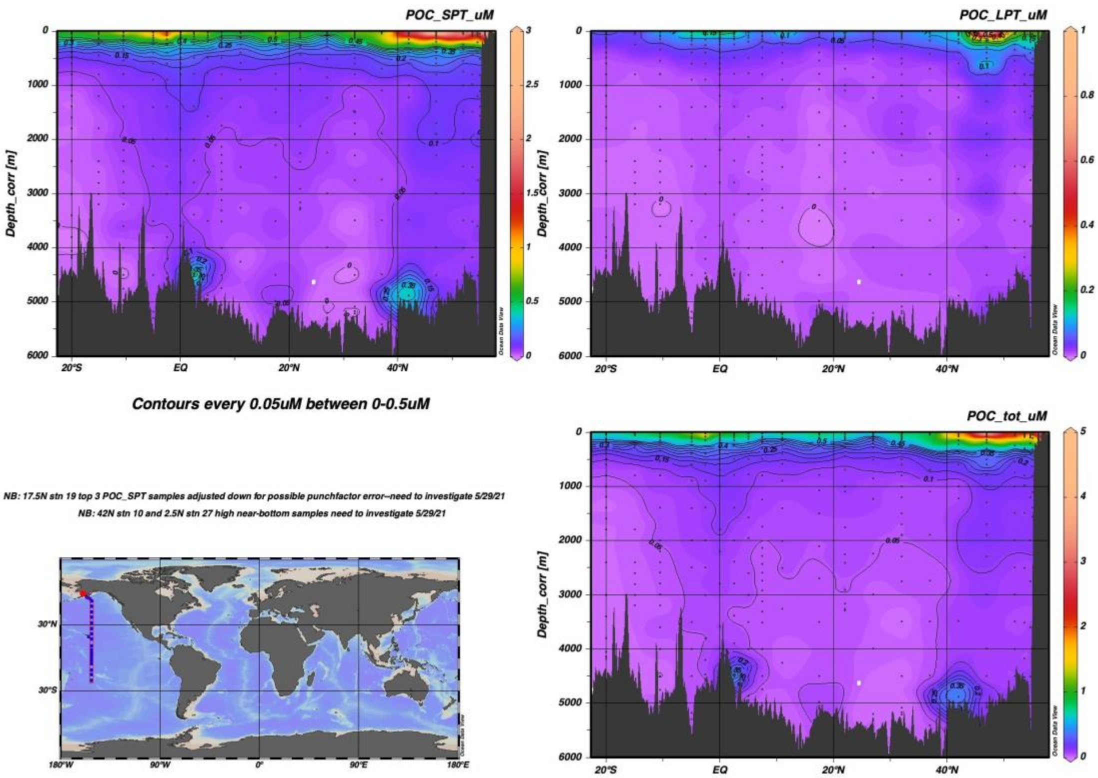

Figure 1: *Concentrations of POC in two size fractions of particles collected along the GP15 transact, shown in the lower left panel, together with the concentrations of total POC obtained by summing the concentrations of the two size factions, shown in the lower right panel. Figure courtesy of Phoebe Lam. Note the comment above the lower left panel regarding adjustments that have been made and results that are still in question.*

Another primary objective of GP15 was to document the abyssal distribution of hydrothermally sourced TEIs and to quantitatively relate those distributions to ^{3}He of hydrothermal origin. The latter TEI is conservative in the deep waters (i.e., does not react chemically or biologically) and is thus can be used as a dilution gauge for hydrothermal waters. Thus, correlating this isotope with other TEIs is useful for diagnosing nonconservative behavior. Second, since the global hydrothermal flux of this isotope has been quantified, it can, in some cases, be used as a *flux gauge* for other TEIs. The GP15 section was well situated to catch the large, mid-depth zonal plumes emanating from the East Pacific Rise at about 10°N and 15°S (see Fig. 2 below), but also the intermediate depth plume originating from the Loihi Seamount near 19°N. It is noteworthy that since the hydrothermally sourced He is isotopically distinct from atmosphere, and between different hydrothermal sources, the two He isotopes can be used to further understand the origins of the various TEI anomalies. Within the spirit of GEOTRACES collaboration, this data has been made available to all cruise participants to aid in their interpretation and will be shortly archived at BCO-DMO and made public available.

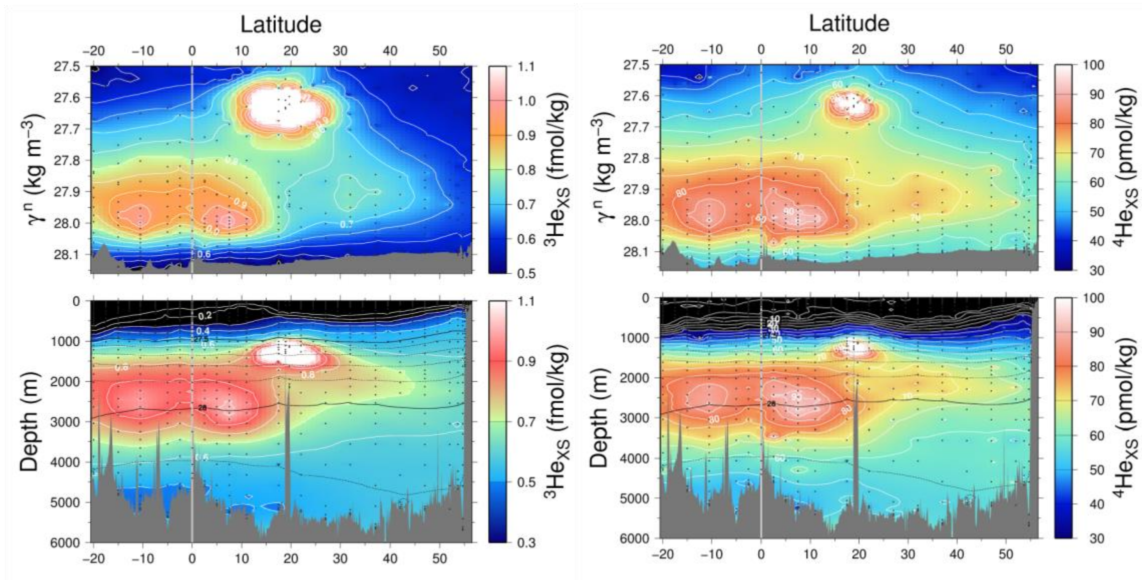

***Figure 2**: The deep meridional distributions of hydrothermally sourced (XS) helium isotopes. The less abundant ^{3}He is plotted on the left in fmol kg^{-1} as a function of depth (lower panel) and neutral density (upper panel). Note the color scales differ to show features better. The more abundant isotope ^{4}He is plotted on the right in pmol kg^{-1}, also as a function of depth (lower panel) and neutral density (upper panel). Note that although both isotopes show similar overall features, there are important subtle differences of value to understanding water mass origins.*

GEOTRACES or GEOTRACES relevant cruises

No U.S. GEOTRACES cruises were scheduled during the reporting period.

New projects and/or funding

Last year's report described U.S. GEOTRACES plans to complete section GP17 as a two-ship operation. Separate proposals were submitted for the management of each leg of GP17 (i.e., for each ship). We are pleased to report that both management proposals were funded, and individual investigator projects that would cover key for essential TEIs have already been recommended for funding as well. Some individual investigator proposals are currently under review and others will be submitted for the August 15 deadline of the NSF Chemical Oceanography program.

However, the schedule for the cruises has been delayed due to the COVID pandemic. The original schedule called for back-to-back cruises with a global class research vessel leaving Tahiti in November 2021 and arriving in Punta Arenas in January 2022. Gear would be immediately transferred to the RVIB Nathaniel B. Palmer and the second cruise would take place from January to March 2022. Currently, the best estimates are that the first cruise will sail from Tahiti in November 2022 while the second cruise will depart from Punta Arenas in November or December of 2023. These dates, though recommended, are still subject to change.

The proposed cruise track for each ship is shown below in Figure 3, with recognition that the cruise track and station locations may be altered after all of the individual projects have been funded and the funded investigators have had a chance to meet and present their specific needs.

The final station locations of each cruise will be set to accommodate the needs of individual projects as well as possible, keeping in mind that some compromises must be made. Station locations off the coast of Antarctica will also depend on the ice conditions encountered as the ship approaches those stations.

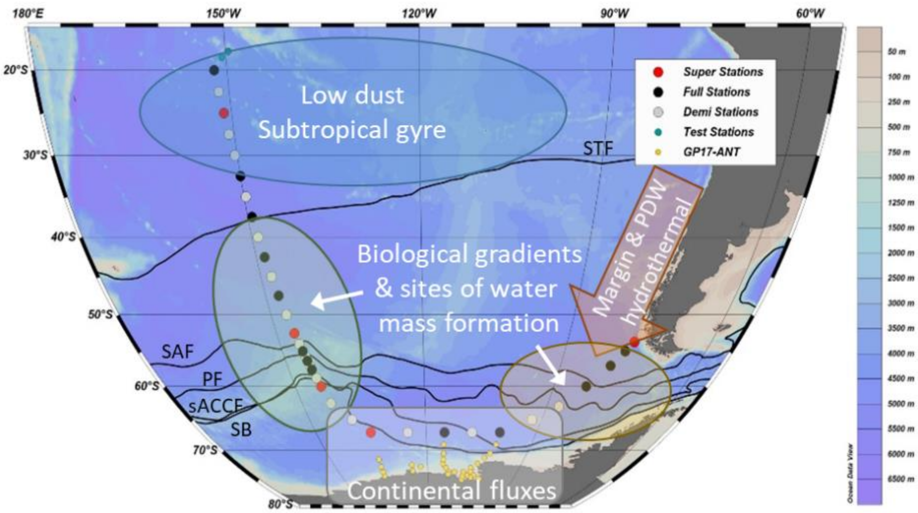

Figure 3: *Station locations for the proposed two-ship operation constituting GEOTRACES section GP17. The legend shows the different types of stations to be sampled from the global class research vessel. In yellow near the coast of Antarctica are the proposed stations for the icebreaker. The principal oceanographic features targeted for study are also indicated. The transits to and from the Amundsen Sea on the icebreaker are not shown in this map.*

Principal investigators for the voyage from Tahiti to Antarctica and then to Chile are Ben Twining (chief scientist), Jessica Fitzsimmons, and Greg Cutter. Principal investigators for the cruise into the Amundsen Sea are Pete Sedwick (chief scientist), Phoebe Lam, and Rob Sherrell.

GEOTRACES workshops and meetings organized

The first two meetings described below were included in last year's report even though they took place during the current reporting period. In order to be complete, here we repeat the information from last year's report.

The largest workshop sponsored by US GEOTRACES in the past year was the planning workshop for GP17 on 6-8 May of 2020; this was held remotely due to the travel and shelter in place restrictions imposed due to the pandemic. Altogether approximately 100 participants attended the cruise-planning workshop, which served to inform prospective investigators of the scientific goals and of the anticipated logistics of a two-ship operation. During the first day, representatives from the US NSF described the current situation associated with the pandemic and the resulting uncertainty in both funding and ship scheduling. In addition, eight plenary presentations described the principal oceanographic features of the region that provide motivation for a GEOTRACES study there. During the second day, approximately 48 interested investigators gave five-minute advocacy talks in which each speaker presented a rationale for including specific chemical parameters in the study while also indicating the logistical needs for each type of study (e.g., volume of water and number of berths required). The last day was devoted to breakout sessions to assess the sampling needs for the various shipboard sampling systems as well as to coordinate common interests related to each of the major scientific themes that are part of GP17. Each of the cruise leaders took part in leading discussion, hosting breakout rooms, and moderating the question and answer periods in plenary. For a remote meeting of its size, it was remarkably interactive and effective. Many participants remarked on the success of the meeting, and the Zoom recordings comprise a valuable record of plenary talks, advocacy talks, and discussions for future proposals.

In 2020 the US GEOTRACES SSC attended the planning workshop for the GP17 expedition rather than having a stand-alone meeting at NSF as was done in previous years. At the request of NSF program officers, and following the precedent started with GP15, the SSC held a virtual meeting on 12 May to set priorities for essential parameters that must be measured on GP17, in addition to the key parameters listed in Table 2 of the GEOTRACES science plan, with the goal of achieving the scientific objectives of the section. The prioritized list of essential parameters was purposefully kept to a minimum in order to allow greater flexibility in funding decisions by the NSF proposal review process. The list of essential parameters has been used, and will continue to be used, by NSF in its review and evaluation of proposals for individual TEI projects.

An in-person data workshop for GP15 was originally planned for July 2020. These plans were canceled because of the pandemic and a virtual data workshop, with 86 registered participants, was held on October 15 of 2020. Although some exciting results were presented during this workshop, many of the projects had completed less than half of their planned sample analyses due to delays related to shutdowns of laboratory facilities caused by the pandemic. Consequently, GP15 investigators are holding a quasi-biweekly on-line seminar series in which new results are presented and discussed. This seminar series is proving to be a great opportunity for each investigator to see the results from their colleagues. The long-range plan is that the regular seminar series will come to an end in late June 2021, after which GP15 investigators will assemble working groups to pursue synthesis of topics or problems that have been identified in individual data sets. It is anticipated that these synthesis projects will be reported on next year.

Early career presence: Some of the events held in the reporting period were so large that it is impossible to determine retroactively, as requested, the number of early career investigators that participated. Also, the SCOR definition of **early career investigators** has not been conveyed to us. The American Geophysical Union defines early career as anyone within 10 years of their PhD, and this is the definition that we use.

Outreach activities conducted

Outreach activities during the past year were impeded by the pandemic. Despite these restrictions, several outreach activities are noted here.

GN01: Katlin Bowman lead a webinar entitled "Breaking the Ice Ceiling: Arctic Ocean Mercury Biogeochemistry" on 15 March 2021 as part of the webinar series "Breaking the Ice Ceiling" organized by a coalition of institutions including The Arctic Institute, Women in Polar Sciences, and Women of the Arctic. The Breaking the Ice Ceiling webinar series aims to illuminate polar research by those who identify as women and to foster discussion on systemic change in polar sciences (Indigenous, natural, and social sciences) to advance diversity, equity, and inclusion.

GP15: In September 2020 Greg Cutter gave an invited talk entitled "Water: what makes Earth the blue planet " to the Christopher Newport University's Life Long Learning Society of which half the content was GP15-related.

GP15: University of California at Santa Cruz undergraduate Sophie Rojas, who is a biology major/STEM education minor, worked with Phoebe Lam and the UCSC Cal Teach director, Gretchen Andreasen, to develop a high school curriculum about the biological carbon pump based partly on POC data from GP15.

The curriculum has 11 learning segments, and includes modules on the biological, chemical, and physical processes that affect the biological pump, an experiment (using coffee grounds) to explore the link between particle size and sinking speed, map and graph reading skills, graphing software skill building, and synthesis activities.

The curriculum went through a third round of review from a focus group of four middle and high school teachers from Santa Cruz County, and was ready to deploy for the 2020-2021 school year. Several of the teachers expressed an interest in trying the curriculum with their students, but because of COVID, it wasn't deployed. We hope to revive it when the pandemic situation gets closer to normal.

GP15: Stanford graduate student Rian Lawrence, working with Karen Casciotti, was responsible for the following three outreach projects:

1) She worked with the Stanford Earth Communications Team to make a graphic explaining chemical oceanography to the general public. This was shared on Stanford Earth's social media (Facebook, Instagram and Twitter). A link to the tweet with her graphic is below: https://twitter.com/StanfordEarth/status/1304170287831883777?s=20
2) Rian was on a panel organized by Pertenecer/YouBelong and the Stanford Earth Graduate Student Advisory Committee to speak with ~30 students in an Antioch High School Environmental Science class on January 7th. She spoke about her journey that led her to work with GP15 data in the Casciotti Lab and spoke briefly about her research.
3) From March 24th to 25th, Rian spoke with a total of four environmental science classes of ~25 students per class at Utah County Academy of Sciences (a specialized, magnet public high school). Again, she spoke about her journey that led her to work with GP15 data in the Casciotti Lab and spoke briefly about her research.

Other GEOTRACES activities

Nothing to report.

New GEOTRACES or GEOTRACES-relevant publications (published or in press)

A list of 49 US GEOTRACES peer-reviewed publications is appended at the end of this report.

To the best of our knowledge none of these publications acknowledge SCOR support.

The number of publications and the number of authors is so large that it is impossible to track all of the early career investigators involved in these publications.

Completed GEOTRACES PhD or Master theses

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

GEOTRACES presentations in international conferences

The number of US GEOTRACES presentations at international meetings and conferences is too large to track.

Submitted by Bob Anderson and Bill Jenkins (boba@ldeo.columbia.edu, wjenkins@whoi.edu).

Publication appendix follows.

2019-2020 US GEOTRACES and GEOTRACES-related Publications and other products

Peer reviewed publications = 49

- Black, E. E., S. S. Kienast, N. Lemaitre, P. J. Lam, R. F. Anderson, H. Planquette, F. Planchon, and K. O. Buesseler (2020), Ironing Out Fe Residence Time in the Dynamic Upper Ocean, Global Biogeochemical Cycles, 34(9), e2020GB006592, doi:10.1029/2020GB006592.
- Bolt, C., A. Aguilar-Islas, and R. Rember (2020), Particulate Trace Metals in Arctic Snow, Sea Ice, and Underlying Surface Waters during the 2015 US Western Arctic GEOTRACES Cruise GN01, ACS Earth and Space Chemistry, 4(12), 2444-2460, doi:10.1021/acsearthspacechem.0c00208.
- Boyle, E. A., C. Zurbrick, J.-M. Lee, R. Till, C. P. Till, J. Zhang, and A. R. Flegal (2020), Lead and lead isotopes in the U.S. GEOTRACES East Pacific zonal transect (GEOTRACES GP16), Marine Chemistry, 227, 103892, doi: 10.1016/j.marchem.2020.103892.
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- Fan, S. Y., Y. Gao, R. M. Sherrell, S. Yu, and K. X. Bu (2021), Concentrations, particle size distributions, and dry deposition fluxes of aerosol trace elements over the Antarctic Peninsula in austral summer, Atmospheric Chemistry and Physics, 21(3), 2105-2124, doi:10.5194/acp-21-2105-2021.
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- Hawco, N. J., M. M. McIlvin, R. M. Bundy, A. Tagliabue, T. J. Goepfert, D. M. Moran, L. Valentin-Alvarado, G. R. DiTullio, and M. A. Saito (2020), Minimal cobalt metabolism in the marine cyanobacterium Prochlorococcus, Proceedings of the National Academy of Sciences, 117(27), 15740, doi:10.1073/pnas.2001393117.
- Hayes, C. T., K. M. Costa, R. F. Anderson, E. Calvo, Z. Chase, L. L. Demina, J.-C. Dutay, C. R. German, L.-E. Heimbürger-Boavida, S. L. Jaccard, A. Jacobel, K. E. Kohfeld, M. D. Kravchishina, J. Lippold, F. Mekik, L. Missiaen, F. J. Pavia, A. Paytan, R. Pedrosa-Pamies, M. V. Petrova, S. Rahman, L. F. Robinson, M. Roy-Barman, A. Sanchez-Vidal, A. Shiller, A. Tagliabue, A. C. Tessin, M. van Hulten, and J. Zhang (2021), Global Ocean Sediment Composition and Burial Flux in the Deep Sea, Global Biogeochemical Cycles, 35(4), e2020GB006769, doi:10.1029/2020GB006769.
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