GEOTRACES SCIENTIFIC STEERING COMMITTEE
ANNUAL REPORT TO SCOR 2020/2021

March 31st, 2020 to April 30th, 2021

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1. SCOR Scientific Steering Committee (SSC) for GEOTRACES

Co-Chairs
Karen Casciotti, USA
Maeve Lohan, UK

Members
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Zanna Chase, Australia
Jay T. Cullen, Canada
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Rodrigo Torres, Chile
Antonio Tovar-Sanchez, Spain

Ex-officio member
Andrew Bowie, Australia

The SSC membership (listed above) contains representatives of 15 different countries, with diverse expertises, including marine biogeochemistry of carbon and nutrients; trace elements and isotopes as proxies for past climate conditions; land-sea fluxes of trace elements/sediment-water interactions; trace element effects on organisms; internal cycles of the elements in the oceans; hydrothermal fluxes of trace elements; tracers of ocean circulation; tracers of contaminant transport; controls on distribution and speciation of trace elements; and ocean modelling.

2. Progress on implementation of the project

At the time this report is written, GEOTRACES is under the intensive period of preparing its third Intermediate Data Product, and this is being done on schedule despite the COVID-19 pandemic. Indeed, the current reporting period its marked by the pandemic; while several GEOTRACES activities had to be cancelled or postponed as described in the report that follows, GEOTRACES has proved resilience and it will release the data product in 2021 as planned.

2.1 Status of GEOTRACES field programme

Due to the COVID-19 pandemic several cruises scheduled during this reporting period (March 31th, 2020 to April 30th, 2021) were cancelled or postponed to a future date, so the number of cruises completed is lower than initially planned. Nevertheless, 5 GEOTRACES have been successfully completed. This includes 1 section cruise in the Southern Ocean (France) and 4 process studies (2 from China and 2 from Australia).

Overall, 125 cruises have been completed, corresponding to 32 GEOTRACES sections (with 43 cruises), 39 process studies (with 62 cruises) and 9 compliant data sets, as well as, 11 cruises completed as a GEOTRACES contribution to the International Polar Year (IPY).

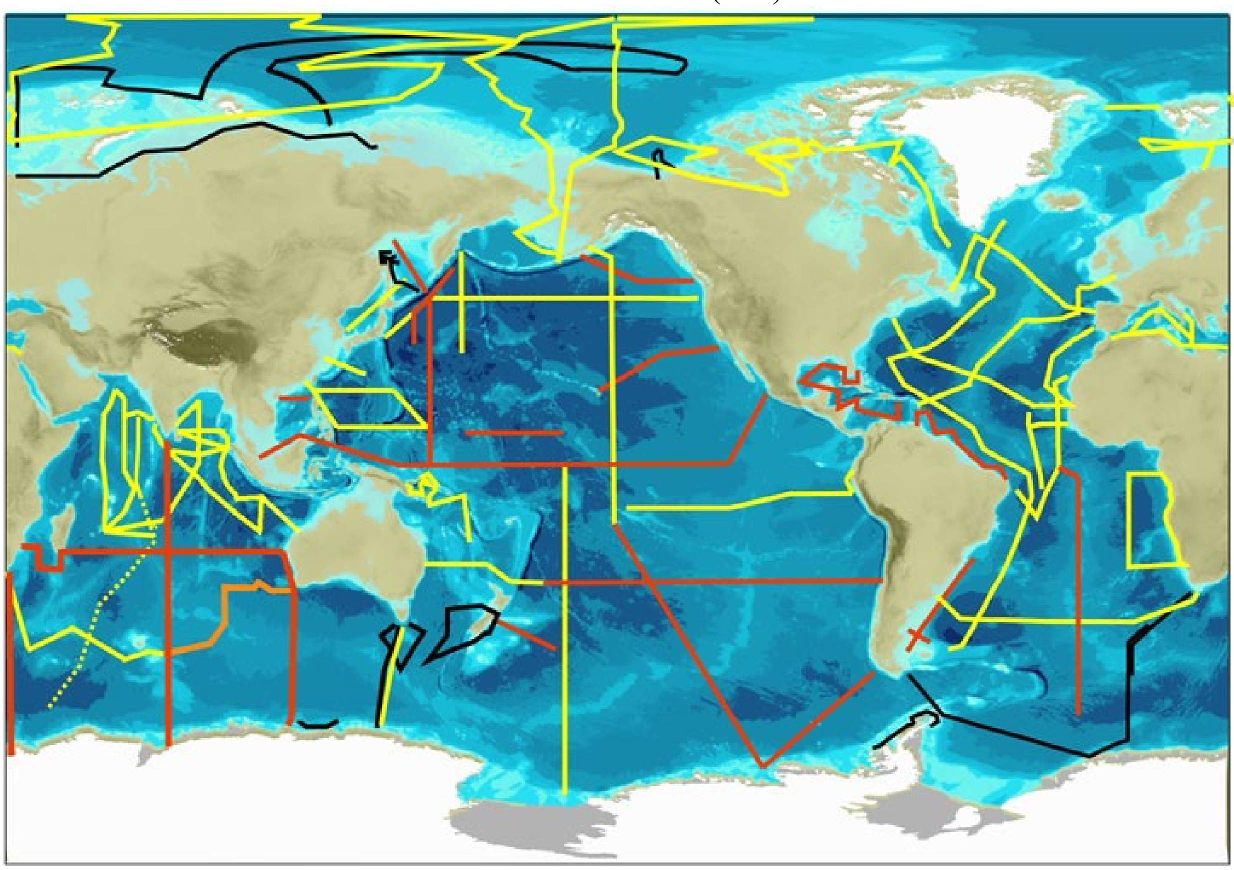


Figure 1: *Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as the GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey. In orange: Sections completed during the past year. In red: Planned Sections. An updated version of this map can be found on the GEOTRACES home page <http://www.geotraces.org>.*

2.2 GEOTRACES Intermediate Data Product

Forthcoming release of Intermediate Data Product 2021

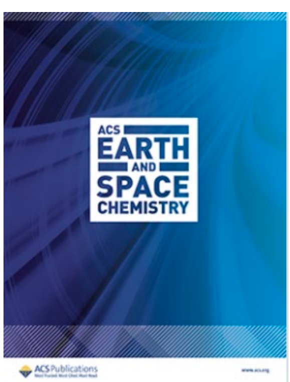
GEOTRACES will release the third Intermediate Data Product (IDP2021) in November 2021 alongside a series of science webinars designed to raise awareness of, and engagement with, the new data product across a broad audience.

To ensure timely release of the IDP2021, two deadlines for data submission were established: one deadline that guarantees data inclusion on April 1, 2020 (extended to May 15, 2020 due to the COVID-19 situation) and a final deadline in December 15, 2020. By the final deadline more than 2,760 datasets were registered in the on-line portal to register datasets for the IDP (DOoR, https://geotraces-portal.sedoo.fr/pi/). This portal continues to be open to accept submissions. Datasets received after the final deadline of December 15, 2020 will be processed for inclusion in a next IDP.

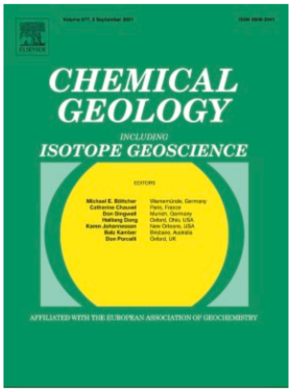
GEOTRACES INTERMEDIATE DATA PRODUCT 2021

2.3 GEOTRACES publications

During the reporting period, 118 new peer-reviewed papers have been published. This includes the publication of two special issues:



Marine Particle Chemistry: Influence on Biogeochemical Cycles and Particle Export
ACS Earth and Space Chemistry
Editors: Hilary G. Close, Phoebe J. Lam, and Brian N. Popp
https://pubs.acs.org/doi/10.1021/acsearthspacechem.1c00091#



Cycles of trace elements and isotopes in the ocean – GEOTRACES and beyond…
Chemical Geology
Editors: Tim M. Conway, Tristan Horner, Yves Plancherel, Aridane G. González
https://www.sciencedirect.com/journal/chemical-geology/special-issue/10VQ59LNSBP

This Special Issue is dedicated to the memory of Prof. Thomas M Church.

In total, the GEOTRACES peer-reviewed paper database includes 1,471 publications.

Publicity documents: It is important to mention that in addition to the peer-reviewed publications, publicity articles to promote GEOTRACES are continuously published nationally and internationally. These publications are not included in the GEOTRACES publication database, but have a dedicated web page on the GEOTRACES site.

For complete information about GEOTRACES publications please check the following web pages:

- GEOTRACES peer-reviewed papers database: https://www.geotraces.org/geotraces-publications-database/
- GEOTRACES special issues: https://www.geotraces.org/category/scientific-publications/geotraces-special-issues/
- List of GEOTRACES promotional articles: https://www.geotraces.org/category/library/publicity/

2.4 GEOTRACES science highlights

The GEOTRACES International Project Office regularly generates science highlights of notable published articles, which are posted on the GEOTRACES website (https://www.geotraces.org/category/science/newsflash/). So far, about 246 highlights have been published. Among the numerous highlights published since last year's report, we selected the following seven:

Deep sea lithogenic weathering a source of iron colloids for the ocean

Homoky and co-workers (2021, see reference below) determined the isotope composition of dissolved iron (Fe) profiles in shallow surface sediments of the South Atlantic Uruguayan margin, from shelf-top to abyssal floor. They confirmed the presence of lithogenic iron isotope compositions in the oxidising zones of sediment porewaters, and further showed that these signatures are uniquely attributed to the presence of iron colloids (20-200nm). An isotopically constrained porewater mass-balance model is used to show that reductive dissolution and oxidation cannot fully account for the production of iron colloids, whereas non-reductive weathering of lithogenic phases and the production of nano-scale Fe organo-minerals can explain these data. An exchangeable inventory of dissolved iron in porewater is compiled for the ocean depths based on all the sites currently observed and suggests that sedimentary supply to the deep ocean interior will be dominated by organo-mineral iron colloids bearing lithogenic isotope signatures.

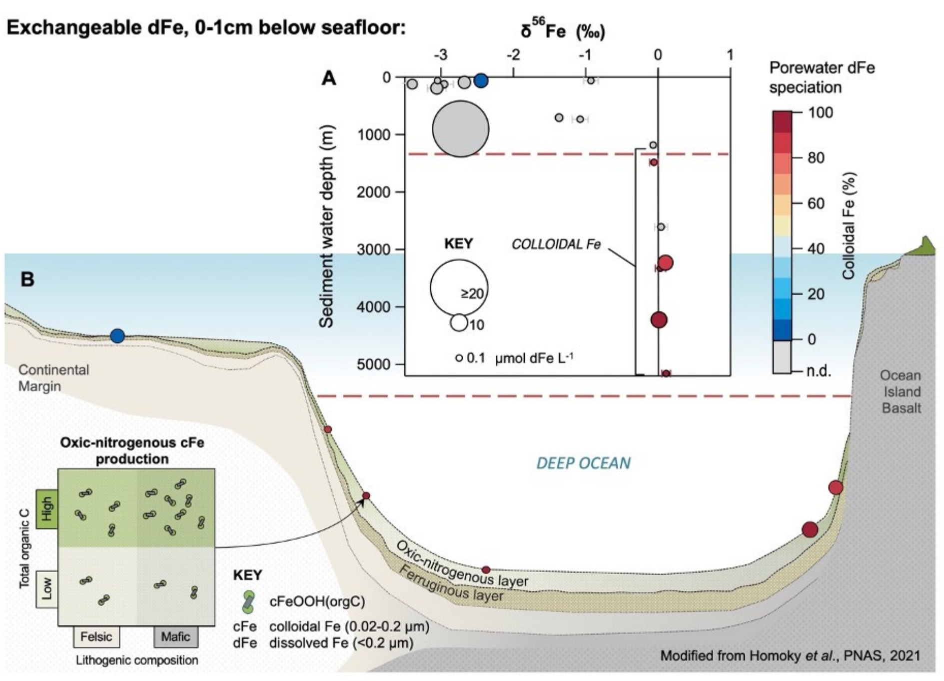


Figure 2 (modified from Homoky et al., PNAS, 2021): *Characterising the exchangeable source of dissolved iron in shallow porewaters beneath the open ocean. (A) Data markers correspond to measured surface (0-1 cmbsf) values compiled from sediments of the western South Atlantic (this study), the eastern South Atlantic, Cape margin1, the North Pacific, Oregon and California margins and Borderland Basins2,3, the North Atlantic, Celtic Sea4, and the Southern Ocean, Crozet Island abyss2. The measured surface inventory of porewater dFe is illustrated by the size of data symbols, and the relative abundance of colloidal iron in porewater is indicated by the colour scale – except for sites with symbols in grey, where dFe speciation was not determined (n.d.). (B) Illustrated summary of key factors attributed to colloidal Fe production, and the nature of its distribution so far observed. Additional data sources used in this figure: [1] Homoky et al. Nature Comms, 4, 2143 (2013); [2] Homoky et al. Geology 37, 751-754 (2009); [3] Severmann et al. Geochimica et Cosmochimica Acta 74, 3984-4004 (2010); [4] Klar et al. Biogeochemistry 135, 49–67 (2017).*

Reference:

W. B. Homoky, T.M. Conway, S.G. John, D. König, F. Deng., A. Tagliabue, and R.A. Mills. (2021) Iron colloids dominate sedimentary supply to the ocean interior. *Proc. Natl. Acad. Sci. U.S.A.* 118, e2016078118. Access the paper: https://doi.org/10.1073/pnas.2016078118

Time series thorium-230 data reveal scavenging intensification over the last 15 years in the Arctic Ocean

Since 2007, thorium-230 (^{230}Th) concentrations decreased significantly over the entire water column, particularly between 300 and 1,500 m in the Amundsen Basin, Arctic Ocean. As is often the case with ^{230}Th, this decrease could reflect either ventilation of ^{230}Th-depleted water or removal of this particle reactive tracer by scavenging intensification. Valk and co-workers (2020, see reference below) demonstrate that the later hypothesis is likely explaining ^{230}Th-depletion in intermediate layers of the Amundsen basin. They also hypothesize that the scavenging intensification occurs at the "source" and during the transport of these waters, along the Siberian shelves.

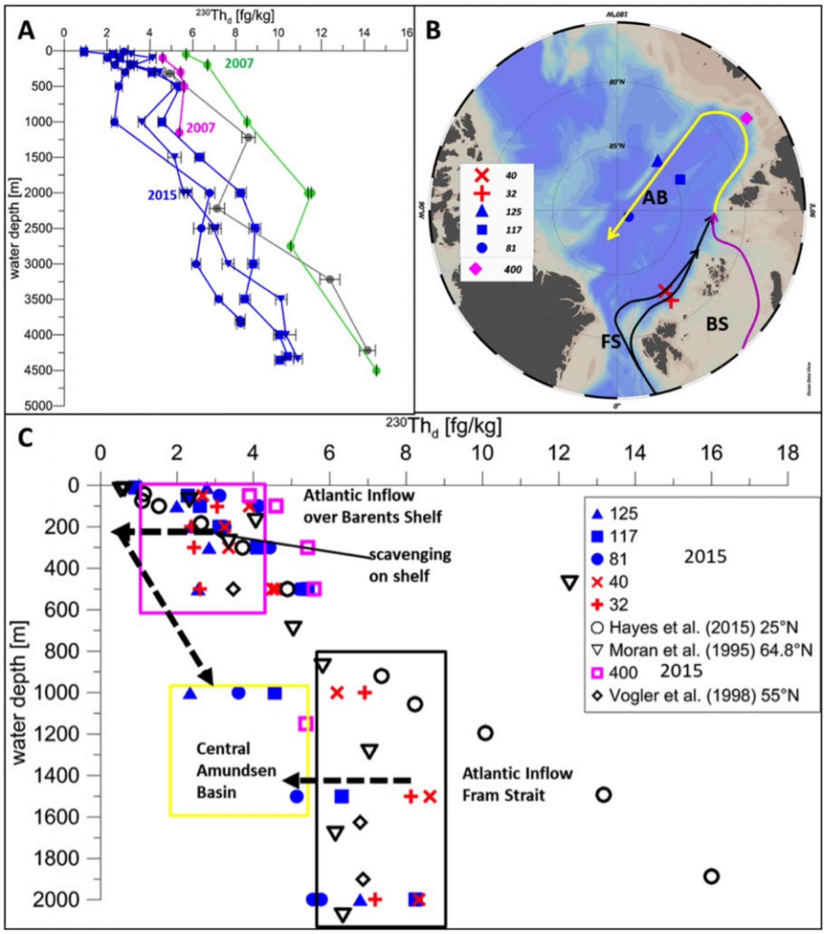


Figure 3 (from Valk et al., 2020): *(A) Dissolved 230Th profiles from the Amundsen Basin (AB) of the Arctic Ocean, collected in 1991 (grey) [2], 2007 (green) and 2015 (blue). The pink profile is a station from the basin margin collected in 2007. Concentrations of dissolved ^{230}Th decreased in the central Amundsen Basin after 2007. The hypothesised reason for this temporal development is that ^{230}Th, a particle reactive isotope, was removed from inflowing Atlantic waters at the slopes of the Eurasian Basin (black arrows) and in the Barents Sea (BS) (purple arrow) by scavenging onto sinking particles. These areas experience notable increases of particle fluxes, due to climate warming.*

(B) Atlantic Waters, entering the Arctic Ocean, flow through these areas and loose a significant part of their dissolved ^{230}Th content by scavenging onto particles. As these waters progress on their way following the Arctic Ocean circulation (yellow arrow), the ^{230}Th removal process continues. Station 400 from 2007 (pink profile in A and pink diamond in the map) showed already in 2007 low ^{230}Th concentrations, comparable to 2015 in the central Amundsen Basin. The conclusion was that a change observed in the central AB in 2015 was already affecting areas upstream.

(C) This process is illustrated as the development of ^{230}Th concentrations from the North Atlantic [3] over the Norwegian Seas [4, 5] and along the margins of the Eurasian Basin [6] towards the central Amundsen Basin. As the Barents Sea Inflow water sinks to greater depths it mixes with ambient waters and causes, together with the Fram Strait (FS) Inflow, a depletion of dissolved ^{230}Th in the Amundsen Basin.

References:

1. Valk, O., Rutgers van der Loeff, M. M., Geibert, W., Gdaniec, S., Moran, S. B., Lepore, K., Edwards, RL., Lu, Y., Puigcorbé, V., Casacuberta, N., Paffrath, R., Smethie, W. Roy-Barman, M. (2020). Decrease in 230Th in the Amundsen Basin since 2007: far-field effect of increased scavenging on the shelf? Ocean Science, 16(1), 221–234. DOI: https://doi.org/10.5194/os-16-221-2020

2. Scholten, J.C., M.M. Rutgers van der Loeff, and A. Michel, Distribution of 230Th and 231Pa in the water column in relation to the ventilation of the deep Arctic basins. Deep-Sea Research II, 1995. 42: p. 1519-1531.

3. Hayes, C.T., et al., 230Th and 231Pa on GEOTRACES GA03, the U.S. GEOTRACES North Atlantic transect, and implications for modern and paleoceanographic chemical fluxes. Deep-Sea Research Part II: Topical Studies in Oceanography, 2015. 116: p. 29-41.

4. Vogler, S., et al., 230Th in the eastern North Atlantic: the importance of water mass ventilation in the balance of230Th. Earth and Planetary Science Letters, 1998. 156(1–2): p. 61-74.

5. Moran, S.B., et al., High precision 230Th and 232Th in the Norwegian Sea and Denmark by thermal ionization mass spectrometry. Geophysical Research Letters, 1995. 22(19): p. 2589-2592.

6. Gdaniec, S., et al., 231Pa and 230Th in the Arctic Ocean: Implications for boundary scavenging and 231Pa-230Th fractionation in the Eurasian Basin. Chemical Geology, 2020. 532: p. 119380.

When GEOTRACES-based synthesis efforts improve global iron-cycling understanding

Authors of a recent paper published in Global Biogeochemical Cycles conducted a detailed study of the residence times of total and dissolved iron (Fe) in the upper layers (0-250m) of the global ocean. Using historical (1987-2007) and recent GEOTRACES data, they compiled an impressive data set comprising dissolved, filtered and trap-collected particulate Fe spanning different biogeochemical oceanographic provinces. They also used indirect isotopic approaches to calculate Fe export from the surface layers (e.g., based on thorium-234-uranium-238 disequilibrium). The study revealed that upper ocean residence times of total Fe consistently fell between 10 and 100 days, despite a broad range of total Fe inventories and ocean biogeochemical settings. Conversely, dissolved Fe residences times were longer and more variable, cycling on sub annual to annual time scales. In addition to these detailed insights on upper ocean Fe cycling, these new data sets will help constrain the rate constant for total Fe export, an important term for exploring links between ocean Fe cycling and the global carbon cycle in ocean biogeochemical models.

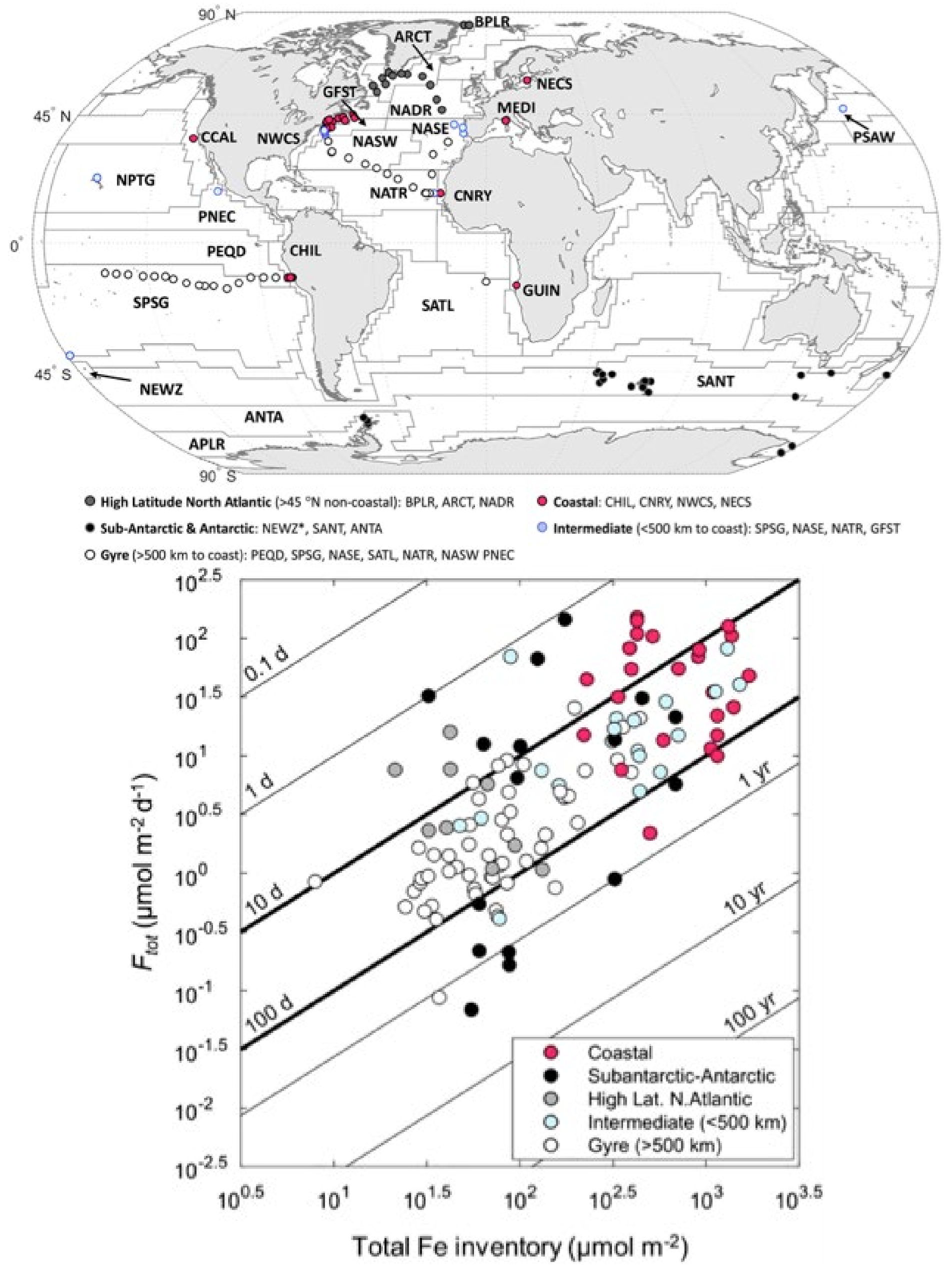


Figure 4 (from Black et al, 2020): *In-situ iron concentration and export (Ftot) estimates from numerous GEOTRACES efforts were combined with prior study results to constrain the residence time of iron in the upper ocean (diagonal lines, lower panel). Broad patterns in iron residence times emerged when contrasting coastal and open regions (pink vs. white), as well as with high and low latitude zones (black vs. white). Despite clear regional differences, however, the majority of residence times for total iron fell into a small range between 10 and 100 days.*

Joint Science Highlight with [US-Ocean Carbon & Biogeochemistry (US-OCB).](https://www.us-ocb.org)

Reference:

Black, E. E., Kienast, S. S., Lemaitre, N., Lam, P. J., Anderson, R. F., Planquette, H., Planchon, F., Buesseler, K. O. (2020). Ironing Out Fe Residence Time in the Dynamic Upper Ocean. Global Biogeochemical Cycles, 34(9). DOI: https://doi.org/10.1029/2020GB006592

Surface water trace element and isotope data challenge dust flux models

Using measurements of dissolved and particulate thorium-230 (^{230}Th) and thorium-232 (^{232}Th) along a section across the South Pacific (GEOTRACES process study GPpr09), Pavia and collaborators (2020, see reference below) estimated the dust flux over this remote area. Although the calculated dust input rates stand among the lowest ever determined, they are 1–2 orders of magnitude higher than those estimated by global dust models. Using published dissolved iron (Fe) data, Fe/^{232}Th ratios and solubility of these tracers in aerosols, the authors also estimated the dust-borne Fe flux over the South Pacific Gyre (SPG). They reveal that in contrast to previous studies, atmospheric deposition and not the physical transport, is the most important process supplying Fe to phytoplankton at the surface of the SPG.

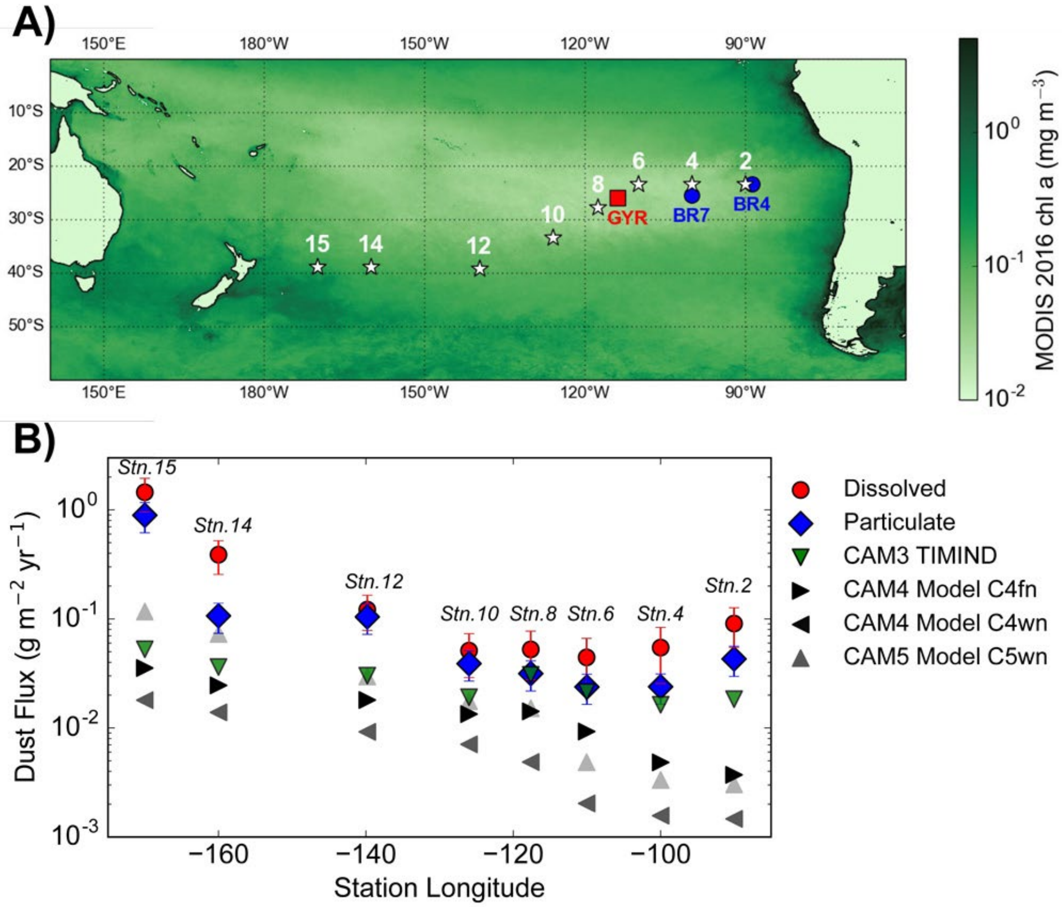


Figure 5: *Study area and dust flux results from Pavia et al. 2020. Panel A) shows the locations of the sampling stations in this study as stars, with the sampling locations of previous studies that measured dissolved iron shown as either dots or squares. The colormap shows MODIS satellite estimates of chlorophyll a concentrations at the sea surface. Panel B) shows the dust flux estimates from dissolved (red circles) and particulate (blue diamonds) thorium isotope based methods measured in this study, while the dust flux estimates from global atmospheric models are shown as triangles.*

Reference:

Pavia, F. J., Anderson, R. F., Winckler, G., & Fleisher, M. Q. (2020). Atmospheric Dust Inputs, Iron Cycling, and Biogeochemical Connections in the South Pacific Ocean From Thorium Isotopes. Global Biogeochemical Cycles, 34(9). DOI: https://doi.org/10.1029/2020GB006562

Precise estimate of the mercury export from the Arctic to the Atlantic Ocean

The Fram Strait is the only deep connection between the Arctic and Atlantic Oceans. Several mercury (Hg) mass balance studies hinted a net export from the Arctic to the Atlantic Ocean. However, in the absence of observations at Fram Strait these estimates had to be based on many assumptions. Using new observations acquired during the 2015 GEOTRACES (section GN04) TransArcII cruise to the Barents Sea Opening and the 2016 GEOTRACES (section GN05) GRIFF cruise, to the Fram Strait and Northeast Greenland Shelf, a refined arctic Hg budget was established. The Hg concentrations in the East Greenland Current (EGS 1.29 ± 0.43 pM) were higher, compared to the West Spitsbergen Current (WSC 0.80 ± 0.26 pM), resulting in a northward flow of 43±9 Mg y−1 and a southward flow of 54±13 Mg y−1 at Fram Strait. The updated arctic Hg mass balance shows that the Arctic Ocean exports about 18 Mg y−1 Hg to the Atlantic Ocean, 40% of which is in the form of methylmercury.

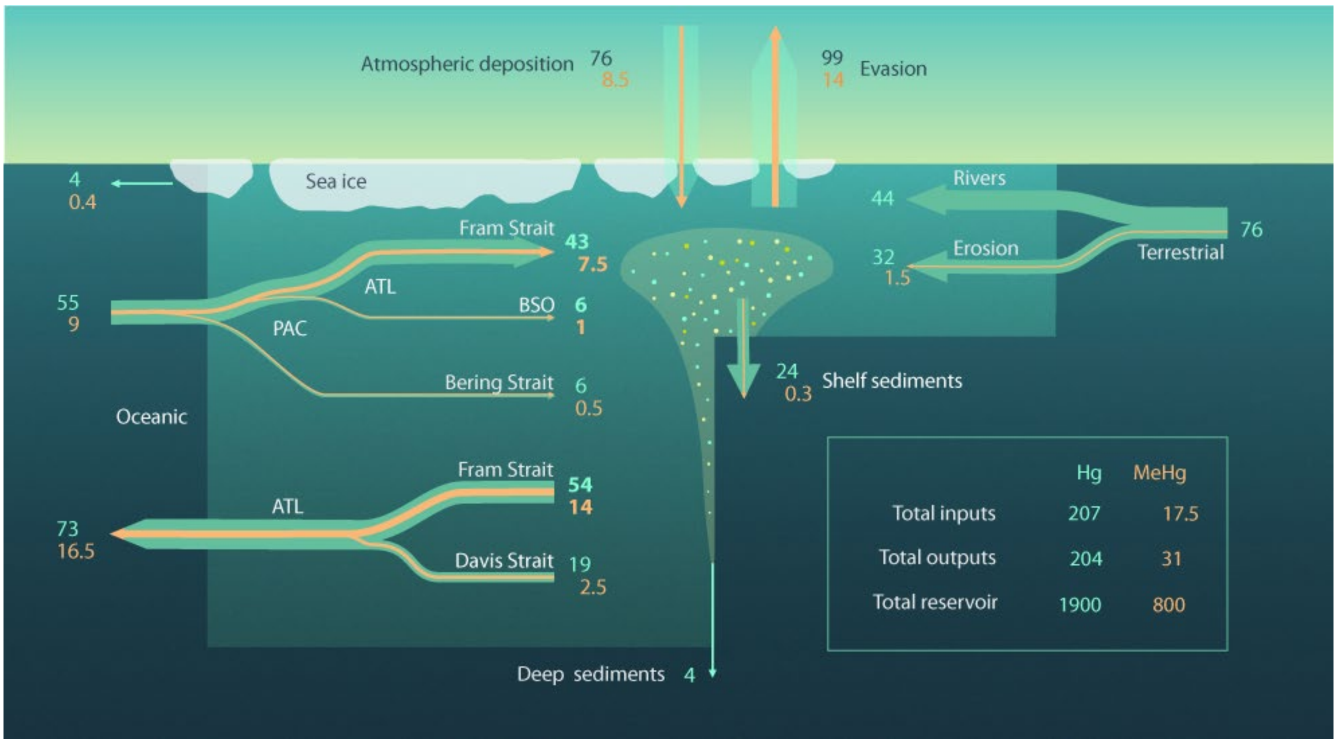


Figure 6: *Updated Arctic Mercury Budget. Using the new numbers at Fram Strait (bold) and those of previous studies an updated Arctic mercury and methylmercury budget is developed. Fluxes in Mg/y and reservoirs in Mg.*

Reference:

Petrova, M. V.; Krisch, S.; Lodeiro, P.; Valk, O.; Dufour, A.; Rijkenberg, M. J. A.; Achterberg, E. P.; Rabe, B.; van der Loeff, M. R.; Hamelin, B.; Sonke, J.E., Garnier, C.; Heimbürger-Boavida, L.E. Mercury Species Export from the Arctic to the Atlantic Ocean. *Mar. Chem.* 2020, 103855. DOI: https://doi.org/10.1016/j.marchem.2020.103855

Silicon isotopes reveal the different Arctic endmembers contributing to the deep water formed in the North Atlantic Ocean

Combining a multiparametric analysis, biogenic and dissolved silicon (Si) isotope data (^{30}Si-bSiO$_2$ and δ^{30}Si-DSi, respectively) in the Arctic Ocean, Liguori and co-workers (2020, see reference below) could unravel the influence of water masses on the δ30Si-DSi distribution within the Arctic Ocean. Any deviation of the δ^{30}Si-DSi signature from pure mixing was attributed to the contribution of biogenic particle dissolution. This is particularly true for the Dense Arctic Atlantic Waters which are dominating from 200 to 500 m water depth and are marked by the highest δ^{30}Si-DSi, indicating a strong lateral influence of waters from the shelves, especially the Barents Sea shelf, due to its high productivity. Contrastingly, the deepest waters are not influenced by the dissolution of sinking bSiO$_2$, probably due to the low concentration of bSiO$_2$. The authors could thus establish that the Arctic Ocean potentially presents several isotopically different endmembers that contribute to the deep water formed in the North Atlantic Ocean.

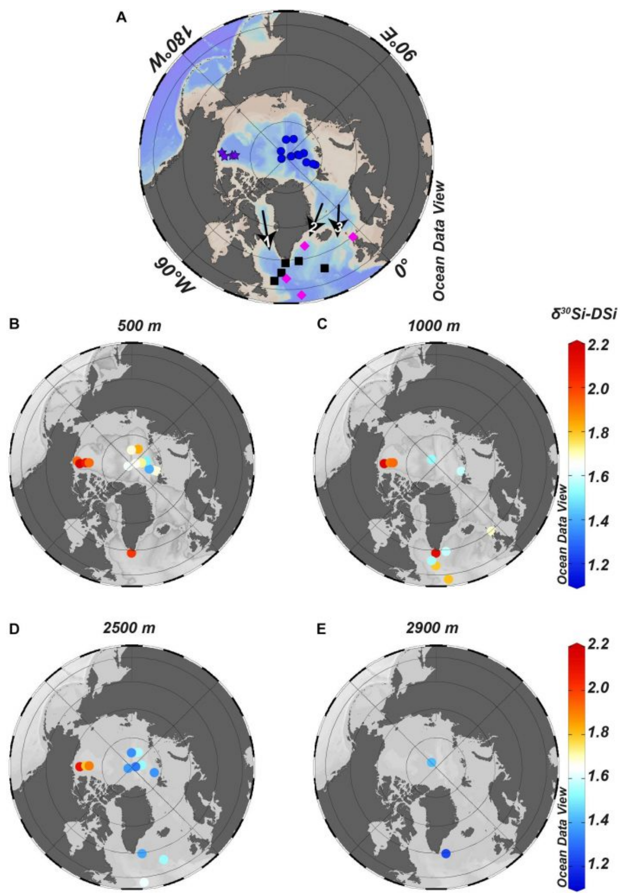


Figure 7: Isosurface plots for δ^{30}Si-DSi for different water depths in the Arctic Ocean. (A) Blue dots – this study, purple stars – Varela et al. (2016), pink diamonds – de Souza et al. (2012) and black squares – Sutton et al. (2018b). Black arrows mark the outflowing waters: 1 – Labrador Sea Water, 2 – Denmark Strait Overflow Water, and 3 – Iceland Scotland Overflow Water. Waters from the Canadian Arctic Ocean leaving predominantly through the shallow Canadian Archipelago and the Labrador Sea contribute higher δ^{30}Si-DSi (Varela et al., 2016) to the Labrador Sea Water (1) and therefore to North Atlantic Deep Water (NADW). In contrast, waters from the Central Arctic Ocean/Eurasian Basin leaving through the much deeper Fram Strait contribute lower δ^{30}Si-DSi to the Denmark Strait Overflow Water (2) and Iceland Scotland Overflow Water (3) and their respective precursor water masses revealing that the Arctic Ocean export different endmember signals contributing to the NADW.

References:

Liguori, B. T. P., Ehlert, C., & Pahnke, K. (2020). The Influence of Water Mass Mixing and Particle Dissolution on the Silicon Cycle in the Central Arctic Ocean. *Frontiers in Marine Science*, *7*. DOI: https://doi.org/10.3389/fmars.2020.00202

de Souza, G. F., Reynolds, B. C., Rickli, J., Frank, M., Saito, M. A., Gerringa, L. J., et al. (2012). Southern Ocean control of silicon stable isotope distribution in the deep Atlantic Ocean. Glob. Biogeochem. Cycles 9, 4199-4213. DOI: https://doi.org/10.5194/bg-9-4199-2012

Sutton, J. N., Souza, G. F. D., Garcia-Ibiliez, M. I., and De La Rocha, C. L. (2018b). The silicon stable isotope distribution along the GEOVIDE section (GEOTRACES GA-01) of the North Atlantic Ocean. Biogeosciences 15, 5663–5676. DOI: https://doi.org/10.5194/bg-15-5663-2018

Varela, D. E., Brzezinski, M. A., Beucher, C. P., Jones, J. L., Giesbrecht, K. E., Lansard, B., et al. (2016). Heavy silicon isotopic composition of silicic acid and biogenic silica in Arctic waters over the Beaufort shelf and the Canada Basin. Glob. Biogeochem. Cycles 30, 804–824. DOI: https://doi.org/10.1002/2015gb005277

3. Activities

3.1 GEOTRACES intercalibration activities

The S&I Committee is currently composed of Ana Aguilar-Islas, Karen Casciotti, Tina van de Flierdt, Walter Geibert, Lars-Eric Heimbürger-Boavida, Yoshiko Kondo, Maeve Lohan, Hélène Planquette, Peter Sedwick and Alyson Santoro. Maeve Lohan and Walter Geibert serve as co-chairs. The committee could not meet in person during this period due to COVID-19 pandemic regulations. Instead, a schedule of virtual meetings was set up, which was challenging because the members are distributed in time zones from Japan to Alaska, and the frequency of meetings needed to be very high. From 10th September 2021, meetings took place twice a week most weeks, for 1.5-2 hours, in order to evaluate the intercalibration submissions with guaranteed consideration for IDP2021.

The focus for the past reporting period was fully on the preparation of the upcoming intermediate data product (IDP2021), and on implementing improvements of the S&I report submission procedure in close dialogue with and support from the IPO in Toulouse and the software developers of the DoOR, as well as with GDAC.

With the new functionalities offered by the DoOR system, it is possible to track individual criteria for intercalibration and reporting back to the submitting PIs is simplified. Supported by the well-structured parameter names, unique identifiers, and the portal software, PIs now select the parameters to be submitted and intercalibrated themselves. This has proven to be a very useful way of handling submissions.

As a result, the S&I committee has approved 1,560 parameters from 30 x section cruises in the reporting period (GA01, GA02, GA04, GA06, GA08, GA10, GA13, GP02, GP03, GP06, GP09, GP12, GP15, GP16, GP18, GP19, GI01, GI03, GI04, GI05, GI06, GN01, GN02, GN03, GN04, GN05, & GS02, GIPY01, GIPY04, GIPY06), 7 x process studies (GPpr01, GPpr07, GPpr08, GPpr09, GPpr11, GApr08, GIpr01), 7 x compliant cruises (ACE 1, ACE 2, ACE 3, PS1718, Cassiopee (GPc05) KH05-2, GPc03). The data above were included in more than 150 individual submissions (out of a total of 245 submissions- prisonizations were applied depending of guaranteed inclusion deadlines and a hierarchy of Section > Process study > Compliant data.

The excellent and immediate support the S&I committee has obtained from the IPO and the software developers was essential and greatly appreciated. Questions regarding use of the software or individual datasets were handled very rapidly, and the transition to the data tracking system has proven to be extremely useful. GDAC has responded just as quickly and helpfully, which ensured an efficient and smooth handling of the submissions.

As a result, the guaranteed inclusion for submission at a given deadline could be delivered in most cases, in spite of a very large number of submissions and a challenging situation regrading meetings.

The co-chairs also met with the DMC virtually 3 times during this period to aid with data management issues for IDP 2021.

Next Meeting:
The date for the next meeting of the S&I committee is currently not set as the duration of the travel restrictions due to the COVID-19 is unclear. We are continuing to meet monthly to finish off any remaining data queries for IDP 2021.

3.2 Data management for GEOTRACES

The British Oceanography Data Centre (BODC) hosts the GEOTRACES Data Assembly Centre (GDAC). Dr Mohamed Adjou, the lead GEOTRACES Data Manager, is based at Liverpool BODC Head office, and works in active collaboration with Donna Cockwell based at the Southampton BODC office. GDAC benefits from additional BODC expertise when work cases require it.

GDAC is responsible for the entirety of the GEOTRACES data activities. This takes into account the following components:

- interaction between principal investigators (PIs) and national data centres in order to encourage regular and timely data/ metadata submissions;
- maintaining and modifying GDAC web pages to include updated ocean basin maps (http://www.bodc.ac.uk/geotraces/cruises/section_maps/) and upcoming cruises on the programme page (http://www.bodc.ac.uk/geotraces/cruises/programme/);
- liaising with the Data Management Committee and Standards and Intercalibration Committee to answer issues/questions relating to GEOTRACES;
- input of metadata and data into the BODC database and compilation of documentation to include originator's methodology
- collation of data and metadata for the future IDP;
- answering requests from GEOTRACES community and assisting on IDP download.

The main GDAC tasks over the last year were:

<u>IDP2021 data reception, archiving and processing:</u> As agreed with the GEOTRACES DMC, over the last year, the main working focus of GDAC was the collation of data and metadata from different individual data submitters (i.e. GEOTRACES PIs or data contributors) or directly from national marine data centres (i.e. BCO-DMO, CYBER-LEFE, JAMSTEC, NIOZ and SKLMES). Data and metadata review was performed systematically before the data processing and requests were sent to the data PIs for complementary information when required.
In total as of May 1st 2021, over ~1100 new datasets were archived and processed at GDAC for potential inclusion in IDP2021.

<u>DOoR portal information review and assistance to PIs:</u> DOoR portal developed by SEDOO is undeniably an excellent platform, where data information is transparently displayed to the PIs who register their data and to the other GEOTRACES involved parties: GDAC, S&I committee and DMC. The steps of data registration in DOoR are self-explanatory; however, GDAC provided help by responding to questions from individual PIs who required assistance during datasets registration and submission. In some cases, review of registered datasets required interaction with GDAC, S&I and SEDOO with a close coordination with Elena Masferrer (GEOTRACES International Project Office, IPO).

<u>Cooperation with the IPO:</u> The IPO is also in regular contact with GDAC in order to have an up-to-date cruise inventory as displayed on the GDAC website. IPO is also assisting GDAC by sending reminders to project participants to respect the deadlines of time-scheduled tasks.

<u>DMC meeting series:</u> Over the last year, series of virtual DMC meetings were scheduled to respond, among other things, to the potential impact of the pandemic on the preparation of the IDP2021. GDAC participation was fundamental to providing update on IDP2021 data processing progress and contributing actively to discussions on increasing data quality checks.

Summary of GEOTRACES cruises, which have taken place in the period April 2020-Mai 2021:

Cruise	Chief scientist(s)	GEOTRACES scientist(s)	Type	Period	Location
IN2021_V02 (GIpr08)	E. Shadwick	Z. Chase	Process Study	2021-04-18 — 2021-05-02	Southern Ocean (East Indian sector)
MD229 (GS02)	C. Jeandel H. Planquette	C. Jeandel, H. Planquette	Section Cruise	2021-01-13 — 2021-03-08	South West Indian Ocean.
KK2007 (GPpr15)	Z. Cao, R. Zhang, K. Zhou	M. Dai	Process Study	2020-12-23 — 2021-02-13	North West Pacific
IN2020_08 GIpr10	P. Boyd	M. Ellwood, P. Boyd	Process Study	2020-12-03 — 2021-01-16	South West Indian Ocean
KK2003 (GPpr15)	X. Liu,	M. Dai	Process Study	2020-07-03 — 2020-08-23	North West Pacific

	W. Chen, Y. Huang				

In summary
Receiving, archiving and processing GEOTRACES datasets at GDAC was the most notable task this year in GDAC work, in order to prepare the IDP2021. Reviewing data and metadata is central in GDAC work and the aim is to increase the quality standards through transparent actions involving the PIs feedback during dataset submission and post-processing.

3.3 GEOTRACES International Project Office

The GEOTRACES International Project Office (IPO) is based at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS) in Toulouse, France. The IPO is staffed by Elena Masferrer Dodas, the IPO Executive Officer. She works under the scientific supervision of Catherine Jeandel (CNRS, LEGOS, France).

The IPO is responsible for:

- assisting the Scientific Steering Committee (SSC) in implementing the GEOTRACES Science Plan and implementation plans of the programme;
- organising and staffing meetings of the SSC, working groups and task teams;
- liaising with the sponsors and other relevant organisations;
- seeking and managing programme finances;
- representing the project at international meetings;
- maintaining the project website and Facebook and Twitter pages;
- maintaining the project mailing lists;
- preparing GEOTRACES science highlights and the bimonthly GEOTRACES eNewsletter;
- maintaining the GEOTRACES publications database and the GEOTRACES Scientists Analytical Expertise Database;
- assisting the GDAC in securing information about upcoming cruises; and
- interacting with GEOTRACES national committees and groups, as well as other international projects.

This year, we want to highlight the following activities:

- <u>On-line GEOTRACES DOoR portal</u>

  The IPO has continued to manage the development of the GEOTRACES Data for Oceanic Research (DoOR) on-line portal providing new interfaces to facilitate the work for the PIs and those who work behind the scenes to assemble the data product. The technical work is assured by François André (development) and Arnaud Mière (maintenance), of the SEDOO Data Centre in Toulouse, France. The team has been meeting weekly or bi-weekly during the reporting period.

Main developments done during the reporting period include:

- Release of an improved version of the GEOTRACES DOoR (version 2 in July 2020);
- Development of a new interface to manage the GEOTRACES parameter names;
- Roll over into DOoR of GEOTRACES IDP2014 and IDP2017 metadata (barcode assignation to all these data);
- Improve the GDAC Interface to allow upload of proof check files for PI to check their data before is being included in the IDP;
- Development of a new interface to manage the IDP GEOTRACES reference system (currently working on it).

In addition, the IPO and the SEDOO have assisted GDAC, S&I and PDC in improving their interfaces to facilitate their job, reviewing registered datasets and creating new parameters when needed.

- GEOTRACES endorsed as Ocean Decade Action

A proposal coordinated by the National Science Foundation was submitted to the United Nations' call to be endorsed as Ocean Decade Action. Note: At the time this report is finalized GEOTRACES has been notified is one of the first selected Ocean Decade Actions.

- Outreach

Several materials to promote GEOTRACES to non-scientific audiences are currently being prepared. The materials will be presented alongside the IDP2021.

- Some statistics

29 new highlights published (246 in total)
6 eNewsletters published, including one special issue (bimonthly 45 in total)
118 new peer-reviewed papers included in the GEOTRACES Publication Database (1,471 in total)
205 new articles published on the GEOTRACES website
1,874 followers and 701 followers in Facebook
189 new subscribers on the GEOTRACES mailing list

Featured outreach activity: *Following GEOTRACES SWINGS Expedition Live!*

From 13 January to 8 March 2021, it has been possible to follow the GEOTRACES SWINGS expedition in the Southern Ocean live, thanks to the *Exploreur Journal* from the University of Toulouse that published one article per week. The articles were intended for the general audience and provided information about the science and the daily life on board the cruise along with short interviews of the members of the expedition. All these materials have been translated from French to English by the IPO and broadcasted widely through GEOTRACES media. As a result, several other articles and materials based on this work are being prepared and will be broadcasted by other media.

List of articles published:

Swings #1: “Trace metals”, the oceanographers’ holy grail

Swings #2: The ocean’s role in climate change revealed thanks to marine particles

Swings #3: Hydrothermal sources, discovering deep-sea geysers

Swings #4: Between sky and sea, a story of dust

Swings #5 : Bacteria, the cradle of ocean breathing

Swings #6 : The ocean, the primary regulator of the climate

Swings #7: Tracking CO2 in the ocean

Read them here: https://exploreur.univ-toulouse.fr/swings-expedition-english

Figure 8: *The research vessel Marion Dufresne in the often difficult sailing conditions as here in the Roaring Forties. © Laurent Godard.*

In this context, SWINGS is a multidisciplinary 4-year project dedicated to elucidate trace element sources, transformations and sinks along a section crossing key areas of the Southern Ocean. Major French contribution to the international GEOTRACES programme SWINGS involves 80 scientists (19 international laboratories, 6 countries). The major piece of this ambitious project is the oceanographic cruise “SWINGS” (South Indian Ocean GEOTRACES Section GS02) to which 48 researchers participated.

Want to learn more? Follow the GEOTRACES cruise blog:
https://swings.geotraces.org/en/category/diary/

3.4 GEOTRACES summer school

In light of the COVID-19 pandemic, the "GEOTRACES Summer School: Introducing Polar Parameters" initially scheduled to take place from 11th to 16th July 2021 in Bremerhaven, Germany, was postponed to boreal summer 2022 (dates to be announced). This was a precautionary measure to ensure the safety of all participants.

Building on the two successful previous summer schools in Brest and Cadiz, the 3rd GEOTRACES Summer School will offer training possibilities for ~50 students, with a combination of hands-on training, lectures and 1:1 science discussions with 12 renowned experts in the field.

Participants will be trained in sampling marine trace elements onboard *RV Heincke*, sample processing, data validation, visualisation and a perspective on modelling with such data.

Figure 9: *2019 Sampling training during the 2019 GEOTRACES Summer School in Cadiz. ©miguelgomez*

<u>3.5 Special sessions at international conferences featuring GEOTRACES findings</u>

Several GEOTRACES special sessions were held or are planned in major international conferences including:

Virtual Goldschmidt 2020, 21-26 June 2020
For further information: https://goldschmidt.info/2020/

GEOTRACES session:

*14m: Biogeochemical Cycling of Trace Elements and their Isotopes in the Oceans (GEOTRACES)
Conveners: Tim Conway, Mariko Hatta, Nick Hawco
Keynote: Brandy Toner
Invited Speakers: Jun Nishioka, Sam Wilson

Forthcoming:

Virtual 2021 ASLO meeting, 22-26 June 2021
For further information: https://www.aslo.org/2021-virtual-meeting/

Plenary Talk:

*Trace metals as agents and tracers in the ocean and climate system
Plenary speaker: Katharina Pahnke

GEOTRACES sessions:

*SS63: Towards a mechanistic understanding of metal-microbe interactions in the Oceans
Co-conveners: Martha Gledhill, Yeala Shaked, Ingrid Obernosterer.

*SS03: Distribution and impacts of ocean nutrient limitation
Co-conveners: Thomas Browning, Mark Moore, Erin Bertrand and Alessandro Tagliabue

Virtual Goldschmidt 2021, 4-9 July 2021
For further information: https://2021.goldschmidt.info/

GEOTRACES session:

*13a. Marine biogeochemistry: Particle fluxes and dissolved trace element cycling from source to sink
Co-conveners:
Adi Torfstein, Phoebe Lam, William B Homoky, Erin Black, Amber Annett, Christopher T Hayes

Keynote speaker:
Claudia Benitez-Nelson, University of South Carolina

AGU Fall Meeting 2021, 13-17 December 2021, New Orleans, LA, and on-line.
For further information: https://www.agu.org/Fall-Meeting

GEOTRACES session:

*PP024. Refinement of paleo-proxies in the GEOTRACES era
Co-conveners: Christopher Hayes, Kazuyo Tachikawa, Kassandra Costa and Jesse R Farmer

3.6 Capacity building

Sampling Systems It is a goal of GEOTRACES that every nation carrying out oceanographic research should have access to a trace metal-clean sampling system. GEOTRACES offers guidance based on past experience in the design and construction of sampling systems, as well as advice in operating these systems as shared facilities. In this sense, a document including "Recommendations for nations developing a trace metal-clean sampling system" prepared by Greg Cutter (Old Dominion University, past S&I co-chair) is available on the GEOTRACES web site. This document will summarise the lessons learned during past guidance experiences and it will be of great resource for other countries wishing to develop trace metal-clean sampling. This document along with other materials is available on the GEOTRACES Capacity Building web page https://www.geotraces.org/geotraces-capacity-building-activities/

An updated status of trace metal-clean sampling systems to support GEOTRACES research is provided in the table below (in blue new additions since last reporting period). Scientists interested in developing one of these systems for their own use are encouraged to contact the GEOTRACES IPO or any member of the SSC, who will arrange for contact with an appropriate person to provide technical information about the design, construction and cost of a system.

Nation	Status	System/ Carousel	Bottles	Depth
Australia (Australia National University)	Complete	Powder coated aluminium, autonomous 1018 intelligent rosette system (General Oceanics)	12 x 10-L Teflon-lined Niskin-1010X (General Oceanics)	6000 m; 6 mm Dynex rope
Australia (Marine National Facility)	Complete	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Australia (Marine National Facility)	Complete (backup system)	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Brazil	Complete	GEOTRACES WATER SAMPLER - 24-bottle	24 X 12-L GO-Flo	3000 m; Kevlar cable

		sampler for use with modem equipped 911plus CTD		
Canada	Complete	Powder coated aluminium with titanium CTD housing, Seabird Rosette	24 X 12-L GO-Flo	5000 m conducting Vectran
China - Beijing	Complete	Seabird Rosette. Powder coated aluminium with titanium pressure housings and fittings	24 x 12-L OTE GO-Flo; 24 X 12-L Teflon-lined Niskin-X	8000 m; conducting Kevlar
China - Taipei	Complete	Teflon coated rosette	Multi- size GO-Flo	3000 m; Kevlar line
France	Complete	Powder coated aluminium with titanium pressure housing for CTD	24 X 12-L GO-Flo	8000 m; conducting Kevlar
Germany (GEOMAR)	Complete	Two titanium rosette frames (built by KUM, Kiel) with titanium pressure housings and fittings	27 x 12-L OTE GO-Flo and 27 x 12-L OTE Niskin	8000 m; conducting Kevlar
Germany (Polarstern)	Partly available (completion expected 2022)	Titanium frame with 911 plus CTD; all sensors with titanium housing	24 x 12-L OTE GO-Flo	8000 m; conducting Vectran cable
India	Complete	Powder coated aluminum with titanium pressure housings and fittings	24 X 12-L Niskin-X	8000 m; conducting Kevlar
Israel	Complete	Powder coated aluminium, SeaBird Rosette	12 X 12-L Niskin; 8 X 12-L GO-Flo (Teflon coated)	2000 m, steel conducting cable
Italy	Complete	Go-Flo bottles on Kevlar line	5 x 20-L Go-Flos	Kevlar
Japan	Complete	Powder coated aluminium	12-L Niskin-X	7000 m; Vectran conducting Cable
Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean polypropylene	10000 m; conducting Kevlar* **There is only one cable for the two systems*

Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean PVDF	10000 m; conducting Kevlar* **There is only one cable for the two systems*
New Zealand	Complete	Powder coated aluminium	13 X 5-L Teflon-lined Niskin-X; 13 X 5GO-Flo	4000 m; 8 mm Kevlar line
Norway	In development	Standard 12 positions CTD Rosette GO	5-L Niskin-X	
Poland	Complete* (although the steel cable)	Powder coated aluminum, SeaBird Rosette	8x 10L GoFlo	3000m, steel conducting cable
Poland	Complete	Single bottle	10l G-FLO X Teflon coated	300m Kevlar
Republic of Korea	Complete	Titanium frame PRISTINE	24 × 12L PVDF	10,000 m; conducting Kevlar
Russia	Complete* (although the steel cable)	Powder coated aluminium, SeaBird Rosette SBE9p occupied CTD SBE 9+	24 × 12-L Niskin bottles	4000 m, steel conducting cable
Russia	In development (by 2022– 2024)	Powder coated aluminium, SeaBird Rosette and all titanium housings and fittings	GO-FLO, Niskin-X, 24 × 12-L	10000 m, conducting Kevlar
South Africa	Complete	Powder coated aluminium, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
South Korea	Complete	Titanium frame	24 × 12L PVDF	10,000 m; conducting Kevlar
UK	Complete	2 x Titanium frame, Ti pressure housings	24 10-L OTE 24 10-L OTE	2 x 8000m conducting Kevlar
USA - CLIVAR	Complete	Sea-Bird GEOTRACES Powder-coated aluminium	12 X 12-L GO-FLO	1500 m; conducting Vectran cable
USA - GEOTRACE	Complete	Seabird GEOTRACES Powder-coated	24 X 12-L GO-FLO	7000 m conducting Vectran cable

S		aluminium with titanium pressure housings and fittings		
USA- University of Alaska Fairbanks	Complete	Sea-Bird GEOTRACES Powder-coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	No Kevlar line available yet.
USA – University of South Florida	Complete	Sea-Bird GEOTRACES Powder-coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 12-L OTE Niskin-X	3000 m 0.25” Amsteel wire
USA- Old Dominion University	Complete	Sea-Bird GEOTRACES Rosette. SBE-19plusV2 CTD unit. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	2000 m 0.5-inch Kevlar wire
USA – Polar Programs	Complete	Sea-Bird GEOTRACES Powder-coated aluminium with titanium pressure housings and fittings	12 X 12-L Niskin-X	3500 m; conducting Vectran cable
USA – Scripps Institution of Oceanograph y	Complete	Sea-Bird painted aluminium with stainless pressure housing (standard system). Fires at pre-programmable depths	12 X 10-L Niskin-X 12 X 5-L Niskin-X	2000 m Amsteel cable and 2000 m Space-Lay coated metal cable
USA – Woods Hole Oceanograph ic Institution	Complete	Sea-Bird painted aluminium with stainless pressure housing (standard system). Fires at pre-programmable depths	12 X 8-L Niskin-X	4000 m Amsteel cable

4. Plans for the coming year

Release of Intermediate Data Product 2021

Major GEOTRACES effort will be devoted to the release of the third GEOTRACES IDP in November 2021 and to the promotion of it through a series of science webinars (1 webinar per week from November to December 2021) as well as other events to be decided during the GEOTRACES SSC meeting in September 2021.

In addition, GEOTRACES will continue to advance the implementation of the field work programme with cruises already planned by the Netherlands, US, Japan, Germany, and Canada. At the same time, GEOTRACES will continue to collect and process data registered through the GEOTRACES DOoR portal. Indeed, PI are encouraged to provide data as soon as available on a continuous manner to facilitate processing of data for the next data product.

Capacity building through the GEOTRACES Summer School

GEOTRACES plans to hold its third summer school, which was postponed due to the COVID-19 pandemics, in boreal summer 2022 in Bremerhaven, Germany, organised by Walter Geibert (AWI-Bremerhaven). See section 3.4 for further details.

Scientific workshops

The synthesis workshop on sensitivity to trace elements and isotopes cycles to global change which was initially planned for 2021 at Hanse-Wissenschaftskolleg Institute for Advanced Study (HWK) in Delmenhorst, Germany, had to be postponed to boreal summer 2023. This workshop will be driven by Walter Geibert, and it will combine new knowledge gained from GEOTRACES with the latest models of TEIs. This workshop will continue GEOTRACES synthesis efforts initiated by the suite of three synthesis workshops (in 2015, 2016 and 2018, http://www.geotraces.org/science/synthesis-of-results). It should also continue the efforts in bringing together the observational and modelling communities fostered by the three Data-Model Synergy Workshops that GEOTRACES organised in 2007, 2009 and 2011. In any case, the synthesis will continue to respond to the expectation that GEOTRACES results benefit other oceanographic disciplines.

BioGeoSCAPES effort

GEOTRACES investigators continue to provide advice and recommendations, as appropriate, to help launch this new programme. A complete report on the activities completed by the BioGeoSCAPES is available in the annex of this report.

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Written and compiled by:
Elena Masferrer Dodas (GEOTRACES IPO Executive Officer)

Catherine Jeandel (GEOTRACES IPO Science Director)
Maeve Lohan and Karen Casciotti (Co-Chairs GEOTRACES SSC)
Walter Geibert (Co-Chair of the GEOTRACES S&I Committee)
Alessandro Tagliabue and Bill Landing (Co-Chairs of the GEOTRACES DMC Committee)
Mohamed Adjou (GEOTRACES Data Manager)

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