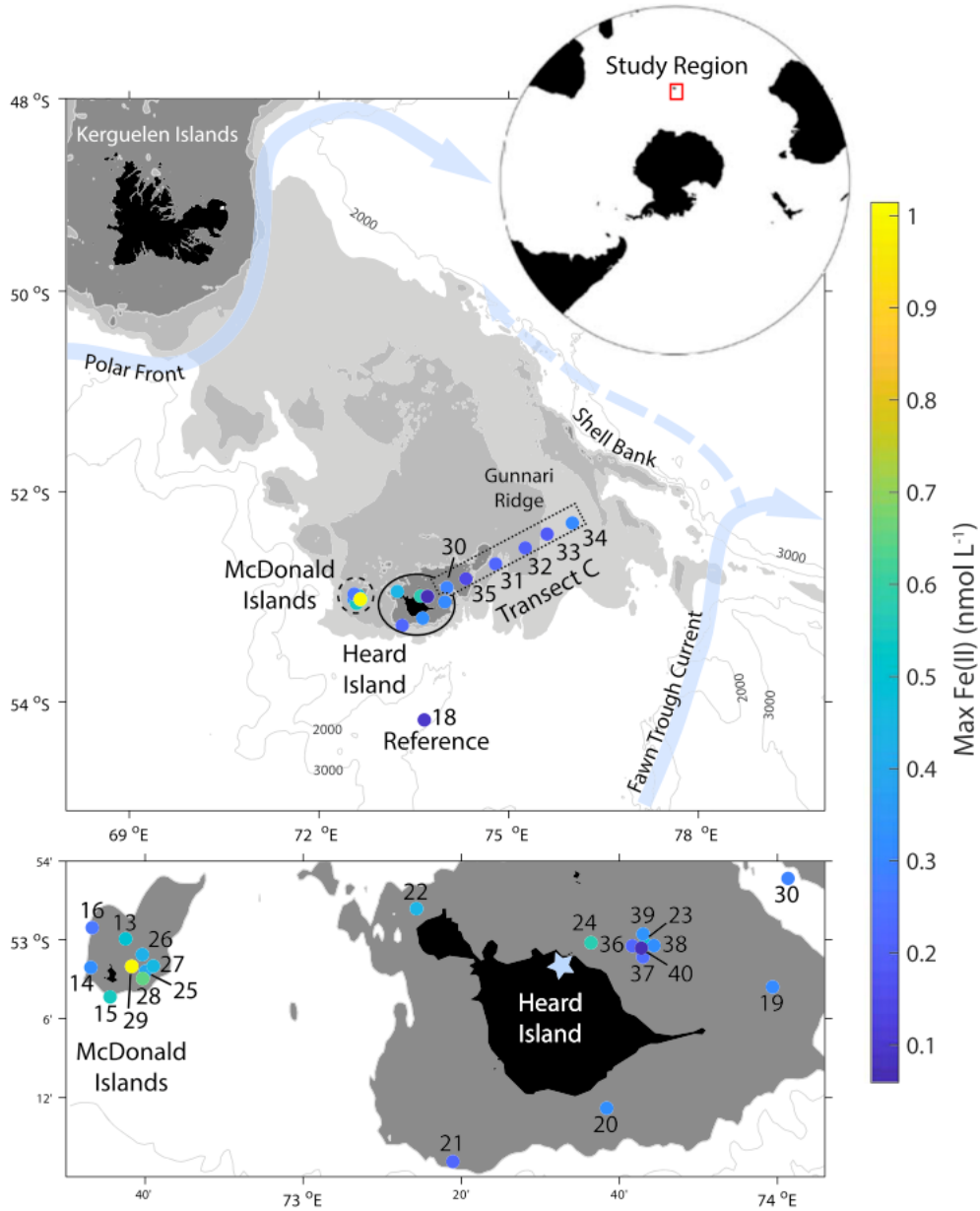
GEOTRACES SCIENTIFIC STEERING COMMITTEE
ANNUAL REPORT TO SCOR 2020/2021

June 2021

ANNEX – NATIONAL REPORTS

New GEOTRACES or GEOTRACES relevant scientific results



New research by Holmes et al. (2020) highlights results of Fe(II) measurements from GEOTRACES process study (GIpr05) around Heard and McDonald Islands on the Kerguelen Plateau in the Southern Indian Ocean. The authors report very high concentrations of Fe(II) in the vicinity of the islands (see figure above from the paper), amounting to nearly 30% of total dissolved Fe at some stations. Based on a negative correlation with salinity, elevated Fe(II) north of Heard Island is attributed to a sea-terminating glacier on the island. Elevated Fe(II) around McDonald Islands is attributed to shallow diffuse hydrothermalism. These multiple sources of Fe(II), and the implied slower oxidation kinetics, may be an important source of iron to support the large bloom that occurs in the broader Kerguelen Plateau

GEOTRACES or GEOTRACES relevant cruises

- GIpr10: SOLACE (Southern Ocean Large Areal Carbon Export) Voyage, IN2020_V08. Southern Ocean (~140E; 47S to 55S), 04 December 2020 – 15 January 2021
- GIpr08: SOTS (Southern Ocean Time Series) Voyage, IN2021_V02, 14 April 2021 – 28 April 2021

Outreach activities conducted

The SOLACE voyage (GIpr10) website has blogs and other information: https://aappartnership.org.au/solace/

Other GEOTRACES activities

- The first 230Th, REE and Nd isotopic composition data from Australia have been submitted to the IDP2021.
- Hydrochemistry data have been submitted for all Australian GEOTRACES voyages.

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

- Ellwood, M.J., Strzepek, R., Chen, X., Trull, T.W., Boyd, P.W. (2020). Some observations on the biogeochemical cycling of zinc in the Australian sector of the Southern Ocean: a dedication to Keith Hunter. Marine and Freshwater Research 71, 355-373.
- Holmes, T. M., Wuttig, K., Chase, Z., Schallenberg, C., van der Merwe, P., Townsend, A. T., & Bowie, A. R. (2020). Glacial and hydrothermal sources of dissolved iron (II) in Southern Ocean waters surrounding Heard and McDonald Islands. Journal of Geophysical Research: Oceans, 125(10), e2020JC016286. [4 ECRs]
- Ito, A., Perron, M.M.G., Proemse, B.C. et al. Evaluation of aerosol iron solubility over Australian coastal regions based on inverse modeling: implications of bushfires on bioaccessible iron concentrations in the Southern Hemisphere. Prog Earth Planet Sci 7, 42 (2020). https://doi.org/10.1186/s40645-020-00357-9 [4 ECRs]
- Latour, P., Wuttig, K., van Der Merwe, P., Strzepek, R. F., Gault-Ringold, M., Townsend, A. T., Corkill, M. & Bowie, A. R. (2021). Manganese biogeochemistry in the Southern Ocean, from Tasmania to Antarctica. Limnology and Oceanography. [5 ECRs]
- Menzel Barraqueta, J. L., Samanta, S., Achterberg, E. P., Bowie, A. R., Croot, P., Cloete, R., ... & Roychoudhury, A. N. (2020). A first global oceanic compilation of observational dissolved aluminum data with regional statistical data treatment. Frontiers in Marine Science, 7, 468. [2 ECRs]
- Sieber, M., Conway, T.M., de Souza, G.F., Hassler, C.S., Ellwood, M.J., Vance, D. (2021). Isotopic fingerprinting of biogeochemical processes and iron sources in the iron-limited surface Southern Ocean. Earth and Planetary Science Letters 567, 116967. [1 ECR]
- Yoshida, K., Seger, A., Karsh, K., Corkill, M., Heil, P., McMinn, A., & Suzuki, K. (2021). Low Fe availability for photosynthesis of sea-ice algae: Ex situ incubation of the ice diatom Fragilariopsis cylindrus in low-Fe sea ice using an ice tank. Frontiers in Marine Science, 8, 221 [2 ECRs]

Completed GEOTRACES PhD or Master theses

- Luis Duprat - Role of Sea Ice as a Biogeochemically Active Reservoir of Iron and Other Trace Metals. PhD submitted in December 2020. Supervisors D. Lannuzel and K. Meiners. The University of Tasmania.
- Cristina Genovese - Role of iron-binding organic ligands in the distribution of dissolved iron in Antarctic sea ice. PhD accepted in July 2020. Supervisors D. Lannuzel, K. Wuttig, A. Townsend, S. Moreau, The University of Tasmania.
- Christopher Traill - Lithogenic particle flux to the subantarctic Southern Ocean: a multi-tracer estimate using sediment trap samples. Masters thesis. Supervisors M Perron, Z. Chase and A. Bowie. The University of Tasmania.

GEOTRACES presentations in international conferences

- Dust and pyrogenic iron boost phytoplankton blooms in sub-Antarctic waters of the Tasman Sea. Joan Llort, Richard J. Matear, Pete G. Strutton, Andrew R. Bowie, and Zanna Chase; EGU 2020

Submitted by Zanna Chase (zanna.chase@utas.edu.au).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN BELGIUM

April 1st, 2019 to April 30th, 2021

New scientific results

- Dissolved Ba from the Canadian Arctic GEOTRACES cruise (collaboration with H. Thomas, Dalhousie University & Helmholtz-Zentrum Geesthacht).
- Reactive iron and sulfur geochemistry in the coastal Black Sea sediments

New projects and/or funding

- OCeANIC, nitrous Oxide and nitrogen Cycling in Antarctic sea Ice Covered zone, Belgium - China Research Cooperation, The role of the oceans in the climate system (CLIMocean).

New GEOTRACES publications

- Laura M. Whitmore, Alan M. Shiller, Tristan J. Horner, Yang Xiang, Maureen E. Auro, Dorothea Bauch, Frank Dehairs, Phoebe J. Lam, Jingxuan Li, Maria T. Maldonado, Chantal Mears, Robert Newton, Angelica Pasqualini, Hélène Planquette, Robert Rember, Helmuth Thomas, Strong margin influence on Arctic Ocean barium cycle revealed by Pan-Arctic Synthesis, JGR-Oceans, in review.
- Deman F., D. Fonseca-Batista, A. Roukaerts, M. I. García-Ibáñez, E. Le Roy, D. N. Thilakarathne, F. Dehairs, F. Fripiat, 2021. Nitrate isotopic composition along the GEOTRACES GA01 (GEOVIDE) section in the North Atlantic, Global Biogeochemical Cycles, 35, https://doi.org/10.1029/2020GB006887.
- Roukaerts A., F. Deman, F. Van der Linden, G. Carnat, A. Bratkic, S. Moreau, D. Lannuzel, F. Dehairs, B. Delille, J.-L. Tison, and F. Fripiat, 2021. The biogeochemical role of a microbial biofilm in sea ice: Antarctic landfast sea ice as a case study, Elementa, https://doi.org/10.1525/elementa.2020.00134.
- Lemaitre, N., H. Planquette, F. Dehairs, F. Planchon, G. Sarthou, M. Gallinari, S. Roig, C. Jeandel, M. Castrillejo, 2020. Particulate trace element export in the North Atlantic (GEOTRACES GA01 transect, GEOVIDE cruise), ACS Earth and Space Chemistry, https://doi=10.1021/acsearthspacechem.
- Mears C., H. Thomas, P. Henderson, M. Charette, H. MacIntyre, F. Dehairs and C. Monnin, 2020. Using 226Ra and 228Ra isotopes to unravel water mass distribution in the Canadian Arctic Archipelago, Biogeosciences, doi.org/10.5194/bg-2020-78, 2020.
- Van der Linden F., W. Champenois, J.-L. Tison, S. Moreau, G. Carnat, M. Kotovitch, F. Fripiat, F. Deman, A. Roukaerts, F. Dehairs, A. Lourenço, F. Vivier, T. Haskell, B. Delille, 2020. Sea ice CO2 dynamics across seasons: impact of processes at the interfaces, Journal of Geophysical Research – Oceans, 125, 6, doi.org/10.1029/2019JC015807.
- Fonseca-Batista D., X. Li, V. Riou, V. Michotey, F. Deman, F. Fripiat, S. Guasco, N. Brion, N. Lemaitre, M. Tonnard, M. Gallinari, H. Planquette, F. Planchon, G. Sarthou, M. Elskens, J. LaRoche, L. Chou and F. Dehairs, 2019. Evidence of high N2 fixation rates in the temperate Northeast Atlantic, Biogeosciences, 16, 999-1017, https://doi.org/10.5194/bg-16-999-2019.

Completed GEOTRACES PhD or Master theses

- Florian Deman: Sea ice primary production at the Pan-Antarctic scale and nutrient cycling in the Antarctic sea ice covered areas (sea ice and water column), Vrije Universiteit Brussel & Université de Liège, In progress.
- Audrey PLANTE, Marine benthic hypoxia and its consequences for sediment-water exchanges and early diagenesis. PhD thesis, Université libre de Bruxelles & Université de Liège, September 2020, 204pp.
- Naman AHMED BUTT, A study of iron sulfides in Black Sea sediments. Master's thesis, Université libre de Bruxelles, September 2020, 78pp.

Submitted by Frank Dehairs (fdehairs@vub.be) and Lei Chou (Lei.Chou@ulb.be).

Since the beginning of the COVID-19 pandemic in Brazil in march 2020, all universities and research centers have suspended activities. More than one year later, most research institutions are still closed since the severity of the pandemic has not significantly decreased. A few institutions are working in a reduced hours regime, with rotation of personal. In general, only graduate students approaching the conclusion of their work are allowed to work at university under restricted protocols. All cruises and field works have been postponed and it is yet to be determined when we return to normal activities.

New Scientific Results

- Anthropogenic Gd in coastal waters

Gadolinium-based contrast agents are worldly used for medical magnetic resonance imaging and are an emerging contaminant in natural waters. Based on this synoptic study and the conservative behavior of Gdanth, it was estimated a sewage-based source which accounts for 2200 pmol kg-1 and to an annual discharge of 25 kg of Gd to the ocean, suggesting that Gd is a tracer for water management and forensic purposes. To guide the application of this method to coastal waters impacted by metropolitan areas, it was proposed a conceptual model for Gdanth behavior within salinity gradients.

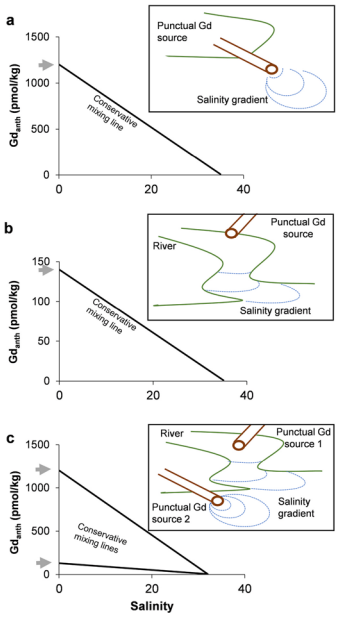


Figure 1: *Conceptual cases illustrating the conservative behavior of anthropogenic Gd during freshwater/seawater mixing: a) highly concentrated Gd_{anth} source scenario; b) diluted Gd_{anth} source scenario and; c) two distinct sources scenarios. Reference: da Costa et al., 2021.*

Other GEOTRACES Activities

- V. Hatje, Elizabeth Holland and Manmohan Sarin are the co-chairs of the new GESAMP working group 45 - Climate Change and Greenhouse Gas Related Impacts on Contaminants in the Ocean.
- V. Hatje is a Full Member of SCOR Working Group 145: Modelling Chemical Speciation in Seawater to Meet 21st Century Needs (MARCHEMSPEC).
- V. Hatje is serving as a member of the IAEA Standing Advisory Group on Nuclear Applications (SAGNA).
- V. Hatje is serving as a member of the SCOR Capacity Building Committee.

GEOTRACES-related articles

- Da Costa, A.R.B.; Rousseau, T.C.C.; Maia, P.D.; Amorin, A.M.; Sodré, F.F. Anthropogenic Gadolinium In Estuaries And Tropical Atlantic Coastal Waters From Fortaleza, Northeast Brazil. Applied Geochemistry, 127, 104908, 2021.
- De Freitas, T.O.P.; Pedreira, R.M.A.; Hatje, V. Distribution And Fractionation Of Rare Earth Elements In Sediments And Mangrove Soil Profiles Across An Estuarine Gradient. Chemosphere, V. 264, P. 128431, 2021.
- Hatje, V; Andrade, R.L.B.; Oliveira, C.C.; Polejack, A.; Gxaba, T. Pollutants In The South Atlantic Ocean: Sources, Knowledge Gaps And Perspectives For The Decade Of Ocean Science. Frontiers In Marine Science, V. 8, P. 644569, 2021.
- Miranda, D.A.; Benskin, J.P.; Awad, R.; Lepoint, G.; Leonel, J.; Hatje, V. Bioaccumulation Of Per- And Polyfluoroalkyl Substances (Pfass) In A Tropical Estuarine Food Web. Science Of The Total Environment, V. 754, P. 142146, 2021.
- Schettini, C.A.F.; Hatje, V. The Suspended Sediment And Metals Load From The Mariana's Tailing Dam Failure To The Coastal Sea. Integrated Environmental Assessment And Management, V. 16, P. 661-668, 2020.
- Barsanti, M.; Garcia-Tenorio, R.; Schirone, A.; Rozmaric, M.; Ruiz-Fernández, A.C.; Sanchez-Cabeza, J.A.; Delbono, I.; Conte, F.; De Oliveira Godoy, J.M.; Heijnis, H.; Eriksson, M.; Hatje, V.; Laissaoui, A.; Nguyen, H.Q.; Okuku, E.; Al-Rousan, Saber A.; Uddin, S.; Yii, M.W.; Osvath, I. Challenges And Limitations Of The 210pb Sediment Dating Method: Results From An Iaea Modelling Interlaboratory Comparison Exercise. Quaternary Geochronology, V. 59, P. 101093, 2020.
- Umbria-Salinas, K.; Valero, A.; Martins, S. E.; Wallner-Kersanach, M. Copper Ecological Risk Assessment Using Dgt Technique And Pnec: A Case Study In The Brazilian Coast. Journal Of Hazardous Materials, V. 403, P. 123918, 2021.
- Umbria-Salinas, K.; Valero, A.; Wallner-Kersanach, M.; Andrade, C. F.; Yabe, Mj Santos; Wasserman, J. C.; Kuroshima, K. N.; Zhang, Hao. Labile Metal Assessment In Water By Diffusive Gradients In Thin Films In Shipyards On The Brazilian Subtropical Coast. Science Of The Total Environment, V. 1, P. 145184, 2021.
- Poersch, L. H.; Bauer, W.; Wallner-Kersanach, M.; Wasielesky, W. Assessment Of Trace Metals, Total Organic Carbon And Total Nitrogen Of A Shrimp Farm System In Southern Brazil. Regional Studies In Marine Science, V. 1, P. 101452, 2020.
- Azar, E.; Pinango, A.; Wallner-Kersanach, M.; Kerr, R. Source Waters Contribution To The Tropical Atlantic Central Layer: New Insights On The Indo-Atlantic Exchanges. Deep-Sea Research Part I-Oceanographic Research Papers, V. 1, P. 103450, 2020.

- Dos Santos Vergilio, C.; Lacerda, D.; Da Silva Souza, T.; De Oliveira, B.C.V.; Fioresi, V. S.; De Souza, V.V.; Da Rocha Rodrigues, G.; De Araujo Moreira Barbosa, M. K.; Sartori, E.; Rangel, T.P.; De Almeida, D.Q. R.I; De Almeida, M.G.; Thompson, F.; De Rezende, C.E. Immediate And Long-Term Impacts Of One Of The Worst Mining Tailing Dam Failure Worldwide (Bento Rodrigues, Minas Gerais, Brazil). Science Of the Total Environment, V. 756, P. 143697-143709, 2021.

Submitted by Vanessa Hatje (vhatje@ufba.br).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CANADA

April 1st, 2019 to April 30th, 2021

During the last year Canadian principal investigators continue to work closely with US colleagues on Arctic GEOTRACES synthesis projects and a number of jointly authored manuscripts are planned, in progress or published at this point. The Canadian GEOTRACES community continues to support an ongoing process study making observations of bioactive trace elements and trace element- microbe interactions on time-series cruises completed along Line P in the northeast Pacific. The Canadian community is examining the impact of recent marine heatwaves on chemical and biological fields along Line P. Cullen is coordinating US colleagues to qualify the trace element sampling program for EXPORTS as a GEOTRACES compliant activity. The vast majority of data from GEOTRACES sections GN02 and GN03 were submitted and accepted into the IDP2021.

Our new, GEOTRACES relevant scientific results, publications and presentations are summarized below.

GEOTRACES or GEOTRACES relevant cruises

- Feiyue Wang (UManitoba) Participated in the GEOTRACES Intercalibration - TONGA project for mercury and methylmercury (led by Lars-Eric Heimbürger-Boavida, France).
- Jay Cullen (UVic), Maite Maldonado (UBC), Andrew Ross (DFO) Samples for trace elements and copper ligand measurement were collected using GEOTRACES protocols during Line P cruises 2020-08 (August 12-24, 2020) and 2021-001 (January 30 – February 18, 2021) as part of the Line P Iron Program, a GEOTRACES Process Study (GPpr07).

New projects and/or funding

- A new project that overlaps with Line P (stations P16, P20 and P26) and expands monitoring of copper ligands in the subarctic NE Pacific to a zone encompassing 38 stations has been approved for funding by the North Pacific Anadromous Fish Commission (NPAFC) and BC Salmon Restoration Initiative Fund (BC SRIF):
- Cullen, J.T., Peña, A., Ross, A.R.S. 2021-2023. Linking salmon survival to climate change through its impact on primary production via nutrient and metal ligand distributions in the North Pacific. International Year of the Salmon (IYS) 2022 Pan-Pacific Winter High Seas Expedition. NPAFC/BC SRIF ($69 K/yr).
- Funding from the new Fisheries and Oceans Canada (DFO) Competitive Science Research Fund (CSRF) to support sampling and analysis of trace metals and ligands along Line P (GEOTRACES Process Study GPpr07) has also been approved for the next 3 years:
- Ross, A.R.S., Peña, A., Christian, J. 2021-2024. Predicting marine productivity in a changing climate - linking phytoplankton biomass and ecology to ocean conditions and related changes in the availability of essential trace metals. DFO/CSRF ($43 K/yr).

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

- AMAP, 2021. AMAP Assessment 2021: Mercury in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway (in press).
- Beaupré-Laperrière A., Mucci A. and Thomas H. (2020) The recent state and variability of the carbonate system of the Canadian Arctic in the context of ocean acidification. Biogeosciences 17: 3923–3942. https://doi.org/10.5194/bg-17-3923-2020.
- Bundy, R.M., A. Tagliabue, N.J. Hawco, P.L. Morton, B.S. Twining, M. Hatta, A. Noble, M.R. Cape, S.G. John, J.T. Cullen and M.A. Saito. (2020). Elevated sources of cobalt in the Arctic Ocean. Biogeosciences. https://doi.org/10.5194/bg-2020-84
- Colombo, M., B. Rogalla, J. Li, S.E. Allen, K.J. Orians, M.T. Maldonado. Canadian Arctic Archipelago shelf-ocean interactions: a major iron source to Pacific-derived waters transiting to the Atlantic. Submitted to Global Biogeochemical Cycles June 2021
- Colombo, M., S.L. Jackson, J.T. Cullen and K.O. Orians. (2020). Dissolved iron and manganese in the Canadian Arctic Ocean: On the biogeochemical processes controlling their distributions. Geochimica et Cosmochimica Acta. 277: 150-174. https://doi.org/10.1016/j.gca.2020.03.012
- Colombo, M., J. Li, B. Rogalla, S.E. Allen, M.T. Maldonado. Particulate trace element distributions along the Canadian Arctic GEOTRACES section: shelf-water interactions, advective transport and contrasting biological production. Submitted to Geochimica et Cosmochimica Acta April 2021
- De Vera J., P. Chandan, P. Pinedo-González, S.G. John, S.L. Jackson, J.T. Cullen, M. Colombo, K.J. Orians, B.A. Bergquist. (In press) Anthropogenic lead pervasive in Canadian Arctic seawater. Proceedings of the National Academy of Sciences.
- Mears C., Thomas H., Henderson P.B., Charette M., Macintyre H., Dehairs F., Monnin C. and Mucci A. (2020) Using 226Ra and 228Ra isotopes to distinguish water mass distribution in the Canadian Arctic Archipelago. Biogeosciences 17: 4937-4959. https://doi.org/10.5194/bg-17-4937-2020
- Meyer, ACS; Grundle, D; Cullen, JT. (2021). Selective uptake of rare earth elements in marine systems as an indicator of and control on aerobic bacterial methanotrophy. Earth and Planetary Science Letters. 558, https://doi.org/10.1016/j.epsl.2021.116756
- Nixon, R.L. et al. (submitted). Evidence for the production of copper-complexing ligands by marine phytoplankton in the subarctic northeast Pacific.
- Sedwick, P., A. Bowie, T. Church, J.T. Cullen, R. Johnson, M.C. Lohan, C. Marsay, D. McGillicuddy, B. Sohst, A. Tagliabue and S. Ussher. (2020). Dissolved iron in the Bermuda region of the subtropical North Atlantic Ocean: Seasonal dynamics, mesoscale variability, and physicochemical speciation. Marine Chemistry. 219 https://doi.org/10.1016/j.marchem.2019.103748
- Shaked, Y., B.S. Twining, A. Tagliabue and M.T. Maldonado. Probing the bioavailability of dissolved iron to marine eukaryotic phytoplankton using in situ single cell iron quotas. Submitted to Global Biogeochemical Cycles. February 2021.
- Whitby, H., E. Bucciarelli, G. Sarthou, N. Cassar, C.L. Osburn, D.J. Janssen, J.T. Cullen, A. Gonzalez, M. Tonnard and H. Planquette. (2020) A call for refining the role of humic-like substances in the oceanic iron cycle. Scientific Reports. 10: 6144 https://doi.org/10.1038/s41598-020-62266-7
- Whitmore, L.M., A.M. Shiller, T. Horner, Y. Xiang, D. Bauch, F. Dehairs, P. Lam, J. Li, M.T. Maldonado, C. Mears, R. Newton, A. Pasqualini, H. Planquette, R. Rember, and H. Thomas. Barium Cycling in the Arctic Ocean: A Basin-wide Perspective Reveals Strong Shelf Influences. Submitted to JGR. April 2021

Completed GEOTRACES PhD or Master theses

- University of Victoria Biochemistry and Microbiology graduate student Richard L. Nixon, whose thesis research was supported by the Canadian Arctic GEOTRACES program (CCAR-NSERC Grant RPGCC 433848-2012), successfully defended his PhD thesis on June 11, 2020.
- Nixon, R.L. 2020. Origins, distribution, and ecological significance of marine microbial copper ligands (http://hdl.handle.net/1828/12085).

GEOTRACES presentations in international conferences

- Copper ligand concentrations in samples collected along Line P in 2016, 2017 and 2018 as part of GEOTRACES Process Study GPpr07 were featured in the following presentation:
- Ross, A.R.S., Nixon, R.L., George, J., Jackson, S.L., Cullen, J.T., Simpson, K.G, Robert, M. 2020. Temporal and spatial variations in copper ligand concentration along Line P. North Pacific Marine Science Organization (PICES) 2020 Virtual Annual Meeting, 13-29 October.
- Anderlini T., J-E. Tremblay, J.T. Cullen. Distributions of Dissolved Trace Metals in Surface Waters of Baffin Bay in the Canadian Arctic. ArcticNet ASM 2020, Dec. 3-7.
- Anderlini T., J-E. Tremblay, J.T. Cullen. Distributions of Dissolved Trace Metals in Surface Waters of Baffin Bay in the Canadian Arctic. Goldschmidt Virtual 2020, Jun. 21-26.
- Taves R., D.J. Janssen, M.A. Peña, A.R.S. Ross, W. Crawford, J.T. Cullen. Relationship between Surface Dissolved Iron Inventories and Net Community Production during a Marine Heatwave in the Subarctic Northeast Pacific. Goldschmidt Virtual 2020, Jun. 21-26.
- Bergquist B., J. De Vera, P. Chandan, P. Pinedo-Gonzalez, S. John, S.L. Jackson, J.T. Cullen, L. William, A. Steffen. Tracing the Sources of Lead in the Canadian Arctic from the Atmosphere to the Ocean. Goldschmidt Virtual 2020, Jun. 21-26.

Submitted by Dr. Jay T. Cullen (jcullen@uvic.ca).

New GEOTRACES or GEOTRACES relevant scientific results

- Surface and profile samples were collected from the western NPSG during the GPpr15 summer and winter cruises with an underway fish-towing system and a GEOTRACES standard rosette sampling system. The concentrations of dissolved Fe (dFe) were measured by a chemiluminescence-based FIA method onboard with solid phase extraction.

- The surface distribution of dFe in the western NPSG is shown in Figs. 2 and 3. Among all the surface samples, dFe varied from 0.10 to 0.36 nmol/L with higher concentrations in winter. The concentration of dFe was higher in the Kuroshio-affected area close to the Luzon Strait (0.2-0.3 nmol/L) and the area north of 20°N (0.2-0.36 nmol/L), whereas it was low between 126-140°E along the 20°N (~ 0.1 nmol/L).

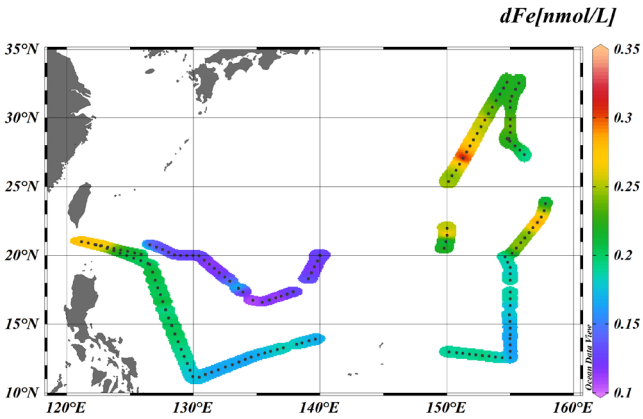


Figure 2: *Surface distribution of dFe in the western NPSG during GPpr15-summer cruise.*

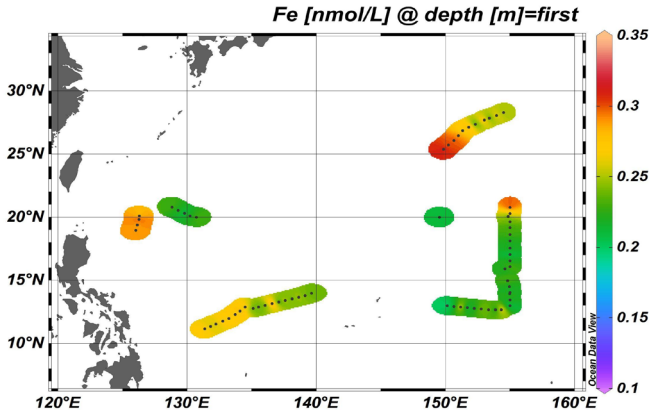


Figure 3. *Surface distribution of dFe in the western NPSG during GPpr15-winter cruise.*

- The vertical distribution of dFe in the western NPSG is shown in Figs. 4 and 5. In general, dFe showed a typical nutrient-type profile with a minimum concentration in the surface layer and maximum concentration in the intermediate waters. An enhanced dFe maximum was observed in the intermediate waters at Station M35 during summer, likely attributable

to the NPIW from the high latitude. Such dFe maximum also appeared in the intermediate waters at Stations K11a, K12a and K13a, which may be associated with the input from the island sediment and seamount sediment.

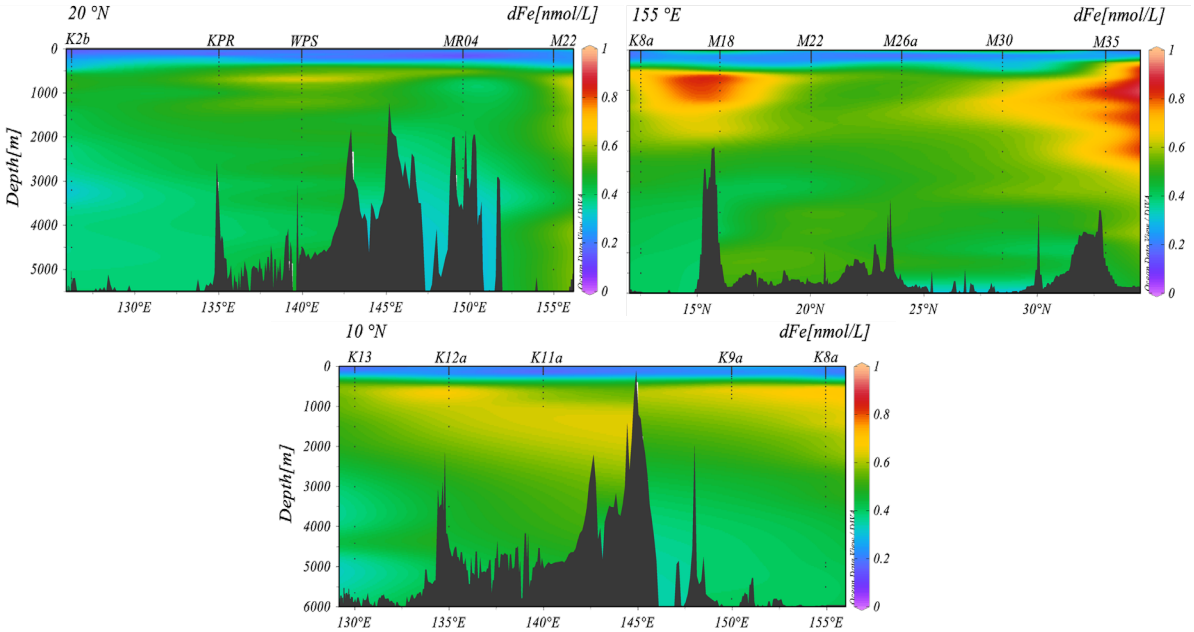


Figure 4: *Vertical distributions of dFe in the 20 °N, 155 °E and 10 °N sections observed in the western NPSG area during GPpr15-summer cruise.*

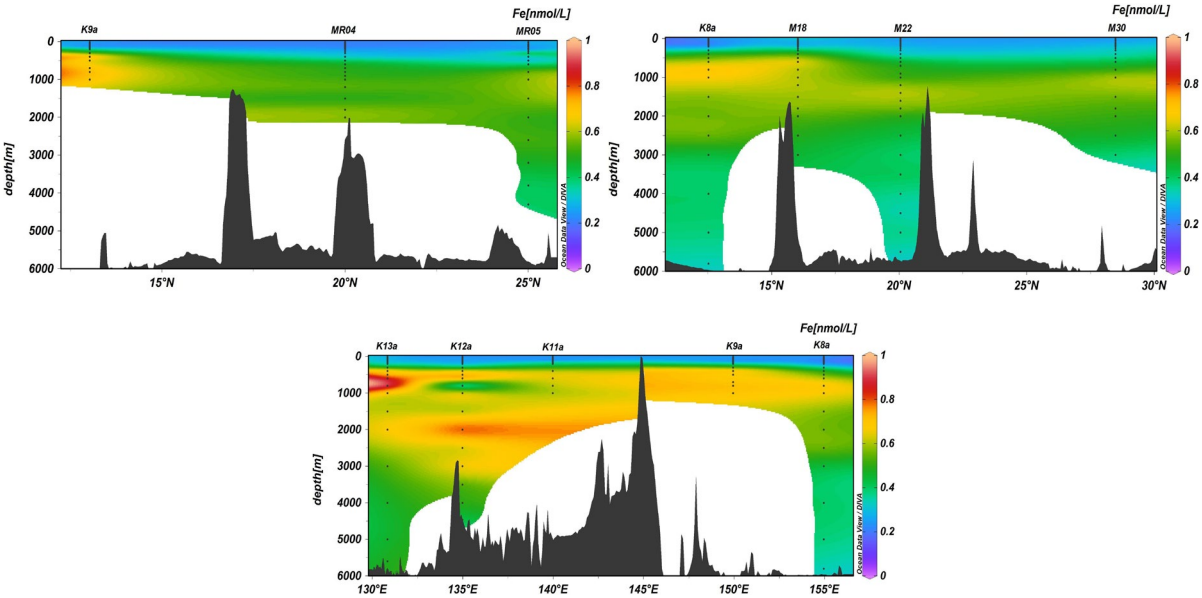


Figure 5: *Vertical distributions of dFe in the 150 °E, 155 °E and 10 °N sections observed in the western NPSG area during GPpr15-winter cruise.*

GEOTRACES or GEOTRACES relevant cruises

- GEOTRACES-GPpr15 summer cruise (Jul 3 to Aug 22, 2020; Chief Scienctists: Xin Liu, Weifang Chen, and Yongming Huang; R/V: Tan Kan Kee/Jiagen)

During the cruise, we conducted 20 clean CTD casts at 14 stations and collected trace metal clean surface waters from towed fish at 162 underway stations. Using in situ pump, we obtained 89 particle samples for trace metal concentration measurements at 9 stations. In addition, regular CTD casts at 17 stations were conducted for determining others physical (salinity, currents, turbulence, etc), chemical (DO, DIC, POC, macro-nutrients, etc), and biological (chlorophyll a, pigments, flow cytometry and molecular samples etc.) parameters (Fig. 6). We also did incubation experiments to quantify primary production, nitrogen fixation rate, bacterial production and respiration, zooplankton grazing rate, etc.

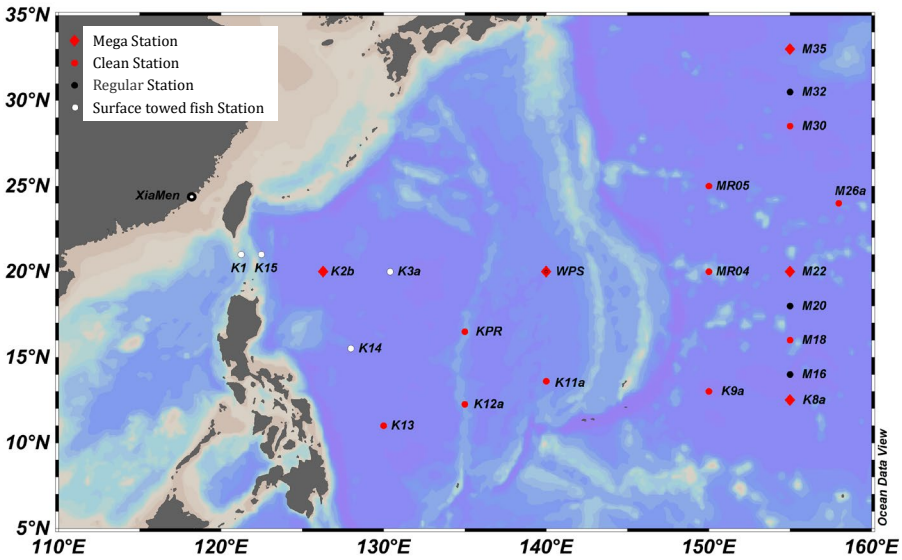


Figure 6: *Sampling stations of the GEOTRACES-GPpr15 summer cruise.*

- GEOTRACES-GPpr15 winter cruise (Dec 23, 2020 to Feb 7, 2021; Chief Scienctists: Zhimian Cao, Ruifeng Zhang, and Kuanbo Zhou; R/V: Tan Kan Kee/Jiagen)

  During the cruise, we conducted 14 clean CTD casts at 10 stations and collected trace metal clean surface waters from towed fish. Particle samples for trace metal concentration measurements were collected at 8 stations using in situ pump. In addition, regular CTD casts at 13 stations were conducted for determining others physical (salinity, currents, turbulence, etc), chemical (DO, DIC, POC, macro-nutrients, etc), and biological (chlorophyll a, pigments, flow cytometry and molecular samples etc.) parameters (Fig. 7). We also did incubation experiments to quantify primary production, nitrogen fixation rate, bacterial production and respiration, etc.

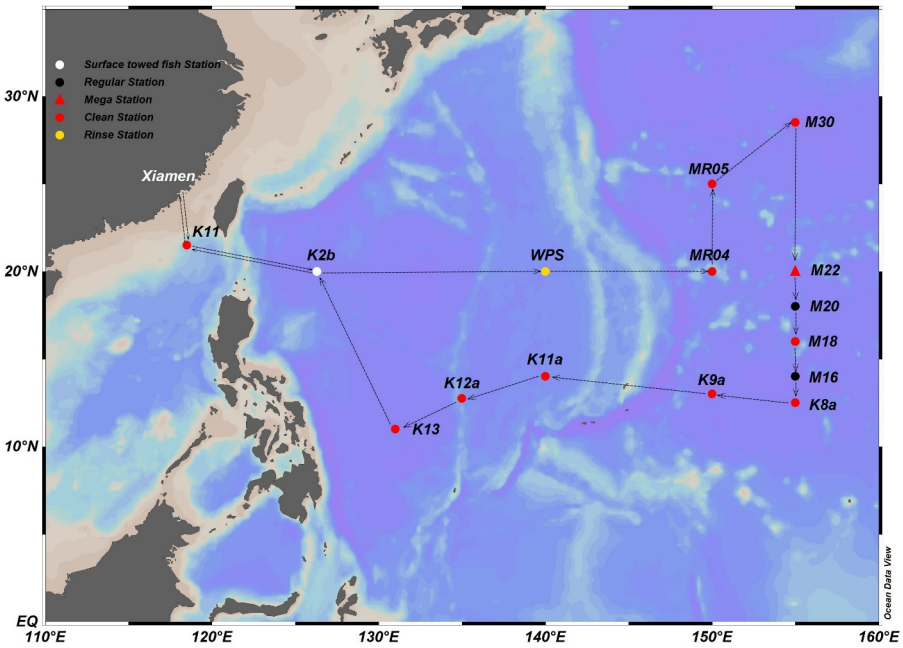


Figure 7: *Sampling stations of the GEOTRACES-GPpr15 winter cruise.*

New projects and/or funding

- NSFC-Excellent Young Scientist Fund: Marine biogeochemistry of Si and Ba isotopes and their role in the oceanic carbon cycling, ¥1.2M, 2021-2023, PI: Zhimian Cao
- NSFC-General Fund: The behaviour of Fe in hydrothermal fluid dilution process in the western Indian Ocean: using δ56Fe as a tracer, ¥560K, 2021-2024, PI: Li Li

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

- Cao Z., Li Y., Rao X., Yu Y., Hathorne E.C., Dai M., Frank M. (2020). Constraining barium isotope fractionation in the upper water column of the South China Sea. Geochimica et Cosmochimica Acta, 288, 120-137.
- Zhang Z., Cao Z., Grasse P., Dai M., Kuhnert H., Gledhill M., Chiessi C.M., Doering K., Frank M. (2020). Dissolved silicon isotope dynamics in large river estuaries. Geochimica et Cosmochimica Acta, 273, 367-382.
- Li L., Zhen X.T., Wang X.J., Ren Y.J., Hu L.M., Bai Y.Z., Liu J.H., Shi X.F. (2020) Benthic trace metal fluxes in a heavily contaminated bay in China: does the sediment become a source of metals to the water column? Environmental Pollution, 257, 113494.
- Li W., Sunda W.G., Lin W., Hong H., Shi D. (2020) The effect of cell size on cellular Zn and Cd and Zn-Cd-CO2 co-limitation of growth rate in marine diatoms. Limnology and Oceanography 65, 2896-2911.
- Liu, J., Yu, X., Chen, X., Du, J., Zhang, F. (2021) Utility of radium quartet for evaluating porewater-derived carbon to a saltmarsh nearshore water: Implications for blue carbon export. Science of The Total Environment, 764: 144238.
- Wang, J., Du, J., Qu, J., Bi, Q. (2021) Distribution of Pu isotopes and 210Pb in the Bohai Sea and Yellow Sea: Implications for provenance and transportation. Chemosphere, 263, 127896.

- Wang, J., Du, J., Zheng, J., Bi, Q., Ke, Y., Qu, J. (2021) Plutonium in Southern Yellow Sea sediments and its implications for the quantification of oceanic-derived mercury and zinc. Environmental Pollution, 266, 115262.
- Wang, X., Chen, X., Liu, J., Zhang, F., Li, L., Du, J. (2021) Radon traced seasonal variations of water mixing and accompanying nutrient and carbon transport in the Yellow-Bohai Sea. Science of The Total Environment, 784: 147161.
- Zhang, F., Wang, J., Bi., Q., Du, J. (2021) 90Sr in seawater of the East China Sea: Inventory, new potential source, and environmental implications. Science of the Total Environment, 764: 144266.

There are 5 ECRs involved in the publications above.

Submitted by Dalin Shi (dshi@xmu.edu.cn).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CHINA-TAIPEI

April 1st, 2019 to April 30th, 2021

New GEOTRACES or GEOTRACES relevant scientific results

Dr. Tung-Yuan Ho's group in Academia Sinica has been studying the trace metal phytoplankton interaction. Reich and coauthors studied the physiological responses of cultured symbiotic dinoflagellates when exposed to increasing temperatures (26 to 30°C) and different iron concentrations. The results show more iron is needed at higher temperature suggesting the importance of trace metals to the health of coral-algal mutualisms. This work was published on Journal of phycology, and was awarded the Harold C. Bold Award for outstanding graduate student presentation at the 2019 Phycological Society of America Annual Meeting (Fort Lauderdale, Florida).

Dr. Kuo-Fang Huang's group in Academia Sinica has been working on using trace element and isotopes to trace anthropogenic sources in aerosols. Wu and Huang analyzed PM10 samples in central Taiwan for water-soluble ion and trace metal concentrations as well as Pb isotope ratios. Their results suggested that Pb in PM_{10} was predominantly contributed by oil combustion and oil refineries during the local events. This study demonstrates the robustness of using a combination of Pb isotopic compositions and chemical characteristics in PM_{10} for source tracing in complex and heavily polluted areas. This work is published on Scientific Report.

Dr. George Burr's group at National Taiwan University has been studying iodine isotopes in marginal seas around Taiwan. They published a study of seawater 129I/127I time-series data from several coastal sites in Taiwan, in order to document how 129I/127I responds to known seasonal variations in the surface ocean currents that carry 129I to each of these sites. They also documented 129I/127I values from multiple surface ocean sites in the South China Sea (SCS), including a vertical profile from the South East Asia Time-Series Station that extends to a depth of 3,700 m. The 129I from both coastal Taiwan and surface waters of the SCS is >98% anthropogenic, primarily released to the environment as a byproduct of nuclear fuel reprocessing.

GEOTRACES or GEOTRACES relevant cruises

- All three new research vessels, the New Ocean Researcher I, II, and III, are now in operation.
- Abby Ren's group participated three cruises to the western Pacific east of Taiwan NORI-0001 (Dec. 2020), NORII (Nov. 2020), and NORIII-0015 (July 2020) for aerosol samples and seawater samples. The samples will be analyzed for nitrogen and oxygen isotopes on nitrate as well as nitrogen isotopes on total dissolved nitrogen.

New projects and/or funding

- Dr. Tung-Yuan Ho's research project on "Marine biogeochemical cycling of anthropogenic aerosol Fe" is funded by Ministry of Science and Technology from 2019/08-2022/07.
- Dr. Tung-Yuan Ho received Investigator Award by Academia Sinica from 2021 to 2025.
- Dr. Abby Ren's research project on "Past and Present Evolution of Global Ocean Nitrogen Cycle: Implications from Studies in the Western Tropical North Pacific and South China Sea" is funded by Ministry of Science and Technology till 2023/02.

Outreach activities conducted

- Undergrad Research Program in Academia Sinica, 2020 Summer

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

- PC Wu, KF Huang (2021) Tracing local sources and long-range transport of PM 10 in central Taiwan by using chemical characteristics and Pb isotope ratios, Scientific reports 11 (1), 1-15 (number of ERCs: 2)
- SC Pai, YT Su, MC Lu, Y Chou, TY Ho (2021) Determination of Nitrate in Natural Waters by Vanadium Reduction and the Griess Assay: Reassessment and Optimization, ACS ES&T Water, https://doi.org/10.1021/acsestwater.1c00065 (number of ERCs: 3)
- HG Reich, WC Tu, IB Rodriguez, Y Chou, EF Keister, DW Kemp, OC LaJeunesse, T-Y Ho (2021) Iron availability modulates the response of endosymbiotic dinoflagellates to heat stress, Journal of phycology 57 (1), 3-13 (number of ERCs: 4)
- GS. Burr, H Matsuzaki, B-S Wang, H Kusuno, H Tokuyama, T Yamagata, T-L Yu, S-L Wang, C-C Chang, AJT Jull, C-H Lo (2020) Anthropogenic 129I in the South China Sea and coastal waters around Taiwan. Elementa: Science of the Anthropocene 2. 8 (1): 064. doi: https://doi.org/10.1525/elementa.2020.064 (number of ERCs: 4)

Submitted by Haojia Abby Ren (abbyren@ntu.edu.tw).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN COLOMBIA

April 1st, 2020 to April 30, 2021

New GEOTRACES or GEOTRACES relevant scientific results

- Technical report to environmental authorities about:
  - Parameters as total mercury and dissolved cadmium, copper, iron, nickel, and lead, to understand changes in marine environmental quality during seven weeks of COVID-19 isolation.
  - Parameters as total cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, vanadium, zinc and total mercury, to explain changes in water quality because a dark spot in a beach of Santa Marta, Colombia.
  - Parameters as total mercury, lead, cadmium, chromium, copper, zinc, iron, manganese, gamma-emitting radioactive isotopes of the ^{238}U chain, topics of interest to support the sustainable development of the offshore hydrocarbon sector.
  - Parameters as lead, cadmium, chromium, copper, nickel, zinc in suspended particulate material, sediments and organisms, in monitoring of environmental conditions and structural and functional changes in plant communities and fisheries resources during the rehabilitation of Ciénaga Grande de Santa Marta, an important coastal lake in the Colombian Caribbean.
- A research article: Vallejo Toro P.P., Ibarra-Gutierrez K.P., Bernal C.A., Espinosa-Díaz L.F. (2021). Accumulation Rates Using the ^{210}Pb Dating Method in a Sediment Core of the Cispatá Bay, a Marine Protected Area in the Southwestern Colombian Caribbean. Geol Earth Mar Sci. 3(2): 1-5. https://doi.org/10.31038/GEMS.2021322.

GEOTRACES or GEOTRACES relevant cruises

- Cruise in an off shore exploration block in the Colombian Caribbean where water and sediment samples were taken to measure key parameters such as micronutrients essential to life in the ocean and other related with anthropogenic pollution such as metals, and hydrocarbons.

New projects and/or funding

- Regional Cooperation Project with International Atomic Energy Agency "Strengthening capacities in marine and coastal environments through nuclear and isotopic techniques".
- National Project with Hydrocarbons National Agency, an environmental technical study in areas of interest in the Colombian Caribbean and Pacific to support the sustainable development of the offshore hydrocarbon sector phase 2021.

Submitted by Luisa Espinosa (luisa.espinosa@invemar.org.co).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CROATIA

April 1st, 2020 to April 30, 2021

New GEOTRACES or GEOTRACES relevant scientific results

The Croatian GEOTRACES activities were mainly related to: 1) application of improved electrochemical methods (in combination with ICPMS) for trace metals speciation and determination (mostly Zn, Cd, Pb, Cu, Fe, Ni, Co and its interaction with organic matter and sulfur species) in natural waters, including monitoring of the coastal and open waters of the Adriatic Sea; 2) mercury speciation and determination by CV- AAS in natural waters, including monitoring of the coastal and open waters of the Adriatic Sea; 3) development of new methods for ex- and in-situ determination of natural and anthropogenic radionuclides in the seawater (focus is on ^{89,90}Sr and ^{210}Pb); 4) update work on the automated system for voltammetric determination of trace metals in natural waters (e.g. seawater) named "Voltammetric AutoAnalyser (VoltAA)"; 5) development of electroanalytical method for determination and characterization of polysulfides in anoxic seawater conditions; 6) characterization of atmospheric precipitation (rain, aerosolos - PM2.5) regarding presence of major cations and anions, organic matter, sulfur species and trace metals; 7) measurements of activity concentration of ^{7}Be and ^{210}Pb in atmospheric precipitation (rain, aerosolos - PM2.5) in order to monitor dynamics of particle transport, metrological information, origin of air mass transfer and seasonal variation of aerosol deposition; 8) geochemical research in different environmental systems; 9) study of trace elements as indicators of environmental changes in marine lakes; 10) work on software for treatment and analysis of UV-Vis spectra (ASFit - UV/Vis CDOM spectra analysis) and fluorescence; 11) work on update of New "butterfly"-type water samplers (4.5 L and 12 L) - rope or rosette mounting.

New projects and/or funding

Current projects supported by the Croatian Ministry of Science, Education and Sport and Croatian Science Foundation (CSF):

- 2018-2022: MARine lake (Rogoznica) as a model for EcoSystem functioning in a changing environment (PI. I. Ciglenečki-Jušić)
- 2018-2022: Geochemistry and Records of Redox Indicators in Different Environmental Conditions: Towards a better understanding of redox conditions in the past (PI: E. Bura-Nakić)
- 2020-2024, CSF project: Marine (micro)plastic litter and pollutant metals interaction: a possible pathway from marine environment to human (METALPATH) (PI Vlado Cuculić)
- 2020-2024: SNSF/CSF: Understanding copper speciation and redox transformations in seawater

Other projects:

2020-2023: HAMAG-BICRO: "Application of artificial intelligence in advanced predictive technologies for online water quality control".

2020-2023: INTERREG CRO-ITA: InnovaMare - "Model of innovation ecosystem in the field of underwater robotics and sensors for control and monitoring purposes with a mission focused on the sustainability of the Adriatic Sea".

2020-2022: INTERREG ADRION : "SEAVIEWS - Sector Adaptive Virtual Early Warning System for marine pollution".

2020-2022: Partnership between scientists and fishermens - a network of town Ploče: Assessment of the physico-chemical and biological quality status of the fishery zone"

2020-2022: SKLEC China Open Research Fund: "Eco-environmental impacts of submarine groundwater discharge-derived nutrients, carbon and metal in oligotrophic karstic estuary of the Krka River (Adriatic Sea, Croatia)".

2020-2021: Providing a service of systematic testing of the state of transitional and coastal waters in the Adriatic Sea (Croatia).

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

- Lucija Knežević, Dario Omanović, Niko Bačić, Jelena Mandić and Elvira Bura-Nakić, Redox speciation of vanadium in estuarine waters using improved methodology based on anion exchange chromatography coupled to HR ICP-MS system, Molecules, 26 (2021) 2436.
- Saša Marcinek, Arnaud Chapoulie, Pascal Salaün, Scott Smith, Dario Omanović. Revised application of copper ion selective electrode (Cu-ISE) in marine waters: a new meta-calibration approach. Talanta, 226 (2021) 122170.
- Jasmin Pađan, Saša Marcinek, Ana-Marija Cindrić, Chiara Santinelli, Simona Retelletti Brogi, Olivier Radakovitch, Cédric Garnier and Dario Omanovic, Organic copper speciation by anodic stripping voltammetry (ASV) in estuarine waters with high dissolved organic matter, Frontiers in Chemistry, 8 (2021) 628749.
- Saša Marcinek, Chiara Santinelli, Ana-Marija Cindrić, Valtere Evangelista, Margherita Gonnelli, Nicolas Layglon, Stéphane Mounier, Véronique Lenoble and Dario Omanović. Dissolved organic matter dynamics in the pristine Krka River estuary (Croatia), Marine Chemistry, 225C (2020) 103848
- Bačić N, Mikac N, Lučić M, Sondi I. (2021) Occurrence and Distribution of Technology-Critical Elements in Recent Freshwater and Marine Pristine Lake Sediments in Croatia: A Case Study, Archives of Environmental Contamination and Toxicology, (), 1-15 DOI 10.1007/s00244-021-00863-x
- MF Turk, M Ivanić, J Dautović, N Bačić, N Mikac (2020) Simultaneous analysis of butyltins and total tin in sediments as a tool for the assessment of tributyltin behaviour, long-term persistence and historical contamination in the coastal environment. Chemosphere 258, 127307.
- D Berto, M Formalewicz, G Giorgi, F Rampazzo, C Gion, B Trabucco, M Giani, M. Lipizer, S Matijević, H. Keberi, C Zeri, O. Bajt, N Mikac D Jaoksimović, AF Aravantinou, M Poje, M Cara, L Manfra (2020) Challenges in harmonized assessment of heavy metals in the Adriatic and Ionian seas. Frontiers in Marine Science 7, 717, doi: 10.3389/fmars.2020.00717.
- Ciglenečki, I., Vilibić, I., Dautović, J., Vojvodić, V., Ćosović, B., Zemunik, P., Dunić, N., Mihanović, H., 2020. Dissolved organic carbon and surface active substances in the northern Adriatic Sea: long-term trends, variability and drivers. Sci. Tot. Environ. 730, 139104, doi:10.1016/j.scitotenv.2020.13910.
- Ciglenečki, I., Čanković, M., Kuzmić, M., Pagano, M., 2020. Accumulation of organic matter in a mesotidal Mediterranean lagoon (Boughrara, Tunisia). Estuar. Coast. Shelf Sci. 240, 106780.

Completed GEOTRACES PhD or Master theses

- Master Thesis, Iva Kostanjšek, Characterization of sedimentary environment and plastics in marine and beach sediment in Stupica Mala bay (Žirje island), University of Zagreb, 2021.
- Master Thesis, Renata Matekalo, Trace metals concentrations in seawater and on microplastic particles from Mala Martinska beach sediments near Šibenik, University of Zagreb, 2021.

GEOTRACES presentations in international conferences

- RISK 2020 Conference, Tbilisi, Gorgia, April 2020., Transport of Saharan Dust Over Mediterranean Basin -Ecological and Health Risks, Orlović-Leko, Ciglenečki, Dutour Sikirić, Mateša.
- 71. International Society of Electrochemistry meeting, Belgrade, Serbia, Electroanalytical characterization of polysulfides (Sx2-) in model solution and euxinic seawater conditions, S. Mateša, I.Ciglenečki
- EGU 2021-9040, Viena April 2021, Hypothesis on impact of winter conditions on annual organic production in the northern Adriatic, N. Supić, A. Budiša, I. Ciglenečki et al.
- EGU 2021-5793, Viena April 2021, Climatology of dust deposition in the Adriatic Sea and biological response of Rogoznica Lake (central Adriatic), B. Mifka, I. Ciglenečki, M. Telišman Prtenjak
- EGU 2021-12269, Viena April 2021, Radioactivity measurements in the atmosphere and water column of Rogoznica Lake (central Adriatic), I. Tucaković, S. Mateša, I. Coha, M. Marguš, M. Čanković, I. Ciglenečki.
- EGU 2021-9204, Viena April 2021, Post medieval cargo - contemporary problem source of mercury in pristine seawater environment (Gnalić, Biograd na Moru, Croatia), V. Cuculić, N. Cukrov, I. Radić Rossi, Ž. Kwokal
- EGU 2021, Viena April 2021, Correlation of microplastic type and metal association: Croatian coast case study (Žirje Island), H. Fajković, N. Cukrov, Ž. Kwokal, K. Pikelj, L. Huljek, I. Kostanjšek, V. Cuculić
- EGU 2021, Viena April 2021, Trace metals load on beached microplastics in the anthropogenically influenced estuarine environment - Croatian middle Adriatic, V. Cuculić, H. Fajković, Ž. Kwokal, R. Matekalo.
- MICRO 2020 International Conference, Plasto-tarball - a sinkhole for microplastic (Croatian coast case study), H. Fajković, V. Cuculić, N. Cukrov, Ž. Kwokal, K. Pikelj, L.; Huljek, S. Marinović; Baztan, Juan (ur.). Lanzarote: 333877

Submitted by Irena Ciglenečki-Jušić (irena@irb.hr).

New GEOTRACES or GEOTRACES relevant scientific results

- Residence time of particulate elements in the upper layer in the North Atlantic (GA01, GEOVIDE)

Combining elemental analyses on large (>53 µm) particles and ^{234}Th measurements, we determined downward export fluxes from the upper layers (40–110 m) of pTEs (Al, Cd, Co, Cu, Fe, Mn, Ni, P, Ti, V, Zn) and mineral phases (lithogenic, Fe- and Mn-oxides, calcium carbonate, and opal) (Lemaitre et al., 2020). The shortest residence times (dissolved + particulate) are generally observed where lithogenic particles control the pTE fluxes (as low as 2 days for Fe) whereas pTEs seem to be longer retained when the contribution of biogenic particles become greater (residence times up to 147 days for Fe).

- Surprising spread of lithogenic particles inferred by rare earth elements (REE) in the North Atlantic (GA01, GEOVIDE)

The first basin scale section of particulate REE concentrations was determined at epipelagic (ca. 0–200 m) and mesopelagic (ca. 200–1500 m) water depths across the North Atlantic Ocean using GEOVIDE samples (Lagarde et al., 2020). The results reveal the surprising westward spread of intermediate nepheloid layers identified by the percentage of lithogenic neodymium (Nd) (Fig. 8). This snapshot also enables us to highlight that absorption processes are dominant at the surface. Deeper, adsorption become predominant as shown by the holmium/yttrium (Ho/Y) and ytterbium/neodymium (Y/Nd) ratios and a progressive enrichment in cerium (Ce) in particles. In the deepest layers, the two ratios and the Ce positive anomaly are becoming constant, showing an equilibrium between adsorption and dissolution processes. This equilibrium is reached at a greater depth in the basin located east of the Labrador Sea. This difference likely reflects the contrasted surface productivity and export rates characterizing the areas: the Labrador Sea is marked by a strong bloom, high remineralization rates and thus low export. In this area, heavy REE concentrations (from terbium, Tb, to lutetium, Lu) show a sensitivity to biogenic silica (BSi) concentrations during the diatom bloom that is not observed for light REE concentrations (from lanthanum, La, to gadolinium, Gd).

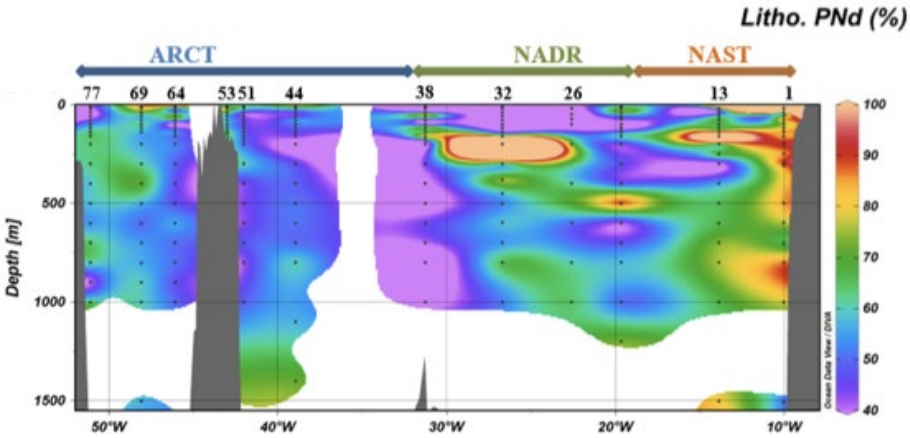


Figure 8: *Fraction of lithogenic particulate Nd along the GEOVIDE transect, in percent of the total particulate Nd concentrations, highlighting important lithogenic inputs at the Iberian margin (Lagarde et al., 2020)*

- <u>Processes controlling the dispersion and redox speciation of dissolved iron of hydrothermal origin at the Mid-Atlantic Ridge (GA13 and GAPr07)</u>

Until recently, the role of hydrothermal activity in the Fe cycle has been largely underestimated. In particular, the contribution of slowly spreading ridges remained poorly resolved. We combined observations, experiments and modelling, to deepen our knowledge of the iron (Fe) cycle in these environments (González-Santana et al, 2021). The concentrations and oxidation rates of iron(II) was determined around six hydrothermal sites along the Mid-Atlantic Ridge, in collaboration with the QUIMA group at the University of Las Palmas. This work was carried out as part of the FRidge campaign (GA13, PIs A. Tagliabue and M. Lohan, UK, 20/12/17-01/02/18) in the frame work of the David Gonzalez-Santa's PhD. Our results allowed us to extend the temperature range of previous Fe(II) oxidation rate (k') equations (Millero et al., 1987; Santana-Casiano et al., 2005; Santana-González et al., 2019) and to better constrain the rates in the deep ocean where the seawater temperature is below 2°C (Fig. 9). Furthermore, our results showed that organic matter and particles generally contribute to decrease the k' inducing a longer Fe (II) half-life.

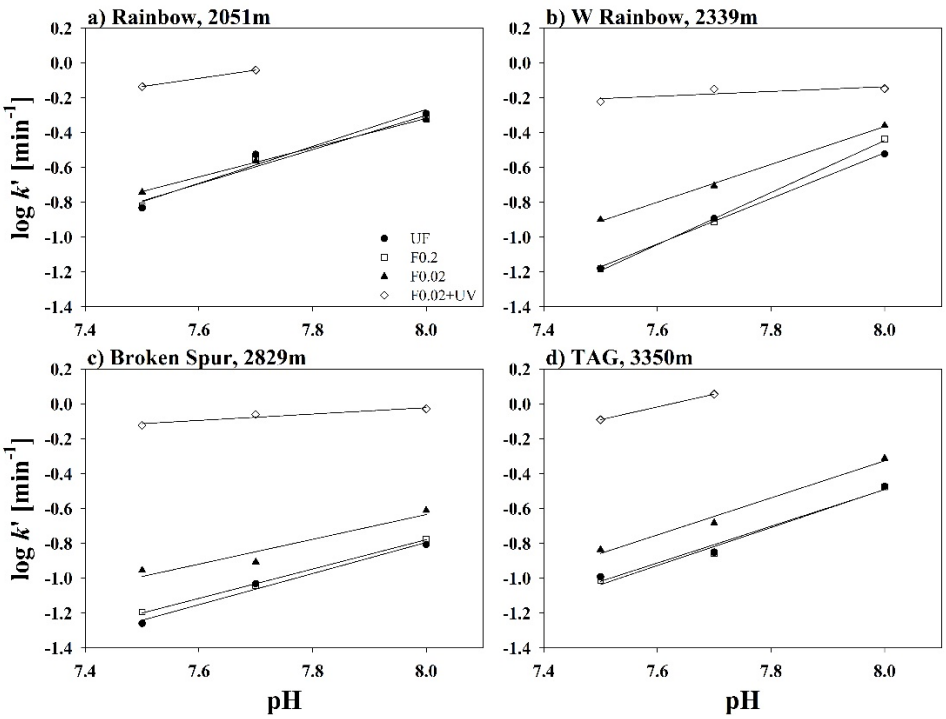


Figure 9: *Fe(II) oxidation rates at different pH values (7.5, 7.7 and 8), for unfiltered (UF, filled circles), 0.2 µm filtered (F0.2, open squares), 0.02 µm filtered (F0.02, filled triangles) and 0.02 µm filtered followed by UV irradiation (F0. 02+UV, open diamonds) at four different sites during the FRidge campaign a) Rainbow (Stn 16, 2051 m), b) West of Rainbow (Stn 13, 2339 m), c) Broken Spur (Stn 24, 2829 m) and d) TAG (Stn 35, 3350 m) (González-Santana et al, 2021).*

In the framework of the HERMINE mission (GAPr07, PIs Y. Fouquet, C. Cathalot and E. Pelleter, Ifremer, 15/05/17-30/06/17) and of David Gonzalez-Santa's PhD, we performed high spatial resolution analyses of dissolved dFe and manganese (dMn) samples (González-Santana et al., 2020). Our data combined with those of particulate iron and Al (Cheize et al., to be submitted) were used in a box model to study the effect of different processes such as dispersion/dilution, particle fall, aggregation/disaggregation (Fig. 10).

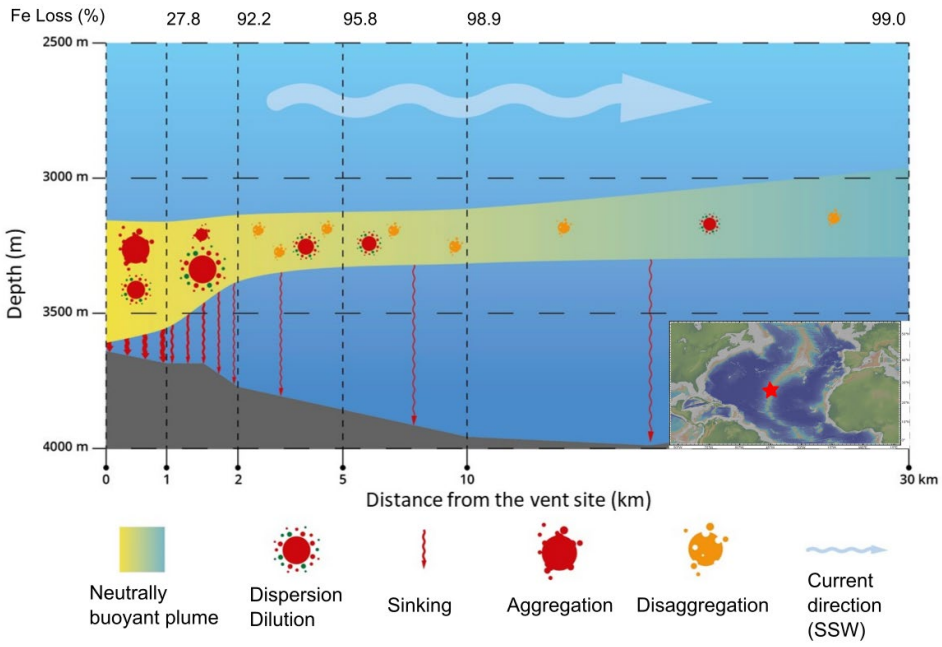


Figure 10: Schematic of the main processes taking place within the neutrally buoyant hydrothermal plume. The size of the symbol is representative of the importance of the process in relation to each section of the plume but is not to scale (from González-Santana et al., 2020).

The approach allowed defining the distances where the main reversible exchanges between dissolved and particulate phases start: while aggregation predominates within the first 2 km, disaggregation prevails beyond 2 km. In addition, the results reveal that the loss of Fe by sinking particles is due to particles with radii ranging from 2 to 20 µm, with decreasing sizes as the hydrothermal plume is transported away from the vent site. They also show that the dFe and dMn hydrothermal signal can still be seen 75 km from the TAG vent site, despite a rapid decrease in particle content in the first 2 km.

- <u>Major role of water transport to dissolved Al distribution in the subtropical North Atlantic (GApr08)</u>

New dissolved aluminum (dAl) data were obtained from the 2017 GEOTRACES process study GApr08 along 22°N in the subtropical North Atlantic Ocean (Artigue et al., 2021). To separate the component of the dAl signal derived from water mass transport from its biogeochemical component, we used a model considering advection in the surface and an optimum multi-parameter analysis below 200 m. The new result show that water mass transport plays a major role from the surface to the sea floor in this area (Fig. 11) even if the dAl distribution is usually considered to be dominated by atmospheric dust input and removal by particle scavenging. At the surface, advection and dust dissolution are equally important as dAl sources. Below 200 m, the water mass transport remains dominant. Dissolved/particle interactions act as a moderate dAl sink from 200 to 1000 m whereas they are a moderate dAl source from 1000 to 5500 m (grey shaded area in Fig. 11).

Overall, these results evidence that the effect of advection cannot be neglected in areas where a conjunction of significant horizontal dAl gradients and significant horizontal currents is found.

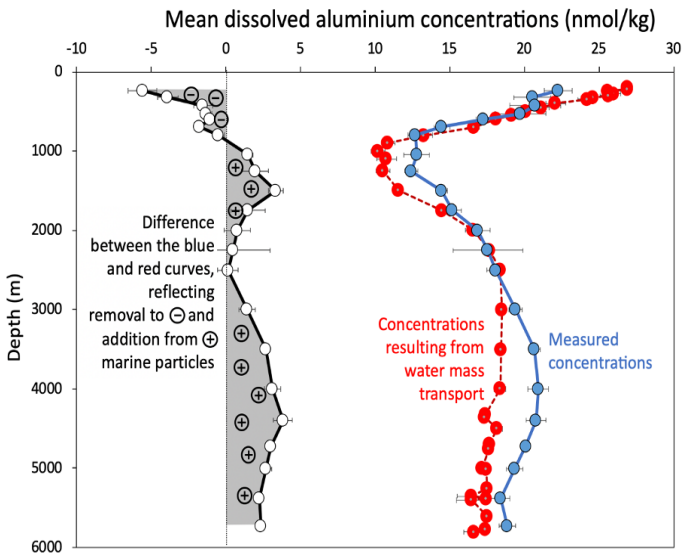


Figure 11: *Mean measured dissolved aluminum concentration (dAl) profile (blue dots), mean water mass transport dAl profile (red dots), and mean 'biogeochemical' dAl profile (difference between the blue and red curves, white dots) of the seven stations of GApr08 cruise. Error bars are standard errors from the 7-station mean. Modified from Artigue et al. (2021).*

- <u>Variable dissolution rates and fates of lithogenic tracers at the air-sea interface (PEACETIME)</u>

Lithogenic elements such as Al, Fe, REEs, thorium (^{232}Th and ^{230}Th, given as Th) and protactinium (Pa) are considered to be insoluble. The dissolution from Saharan dust reaching Mediterranean seawater was established by tank experiences included dust seeding under present and future climate conditions (+3 ◦C and −0.3 pH; Roy-Barman et al., 2021). The maximum dissolution was low for all seeding experiments: less than 0.3 % for Fe, 1 % for ^{232}Th and Al, about 2 %–5 % for REEs and less than 6 % for Pa (Fig. 12). Different behaviors were observed: dissolved Al increased until the end of the experiments, Fe did not dissolve significantly, and Th and light REEs were scavenged back on particles after a fast-initial release. The constant ^{230}Th/^{232}Th ratio during the scavenging phase suggests that there is little or no further dissolution after the initial Th release. Comparison of present and future conditions indicates that changes in temperature and/or pH influence the release of Th and REEs in seawater, leading to lower Th release and a higher light REE release under increased greenhouse conditions.

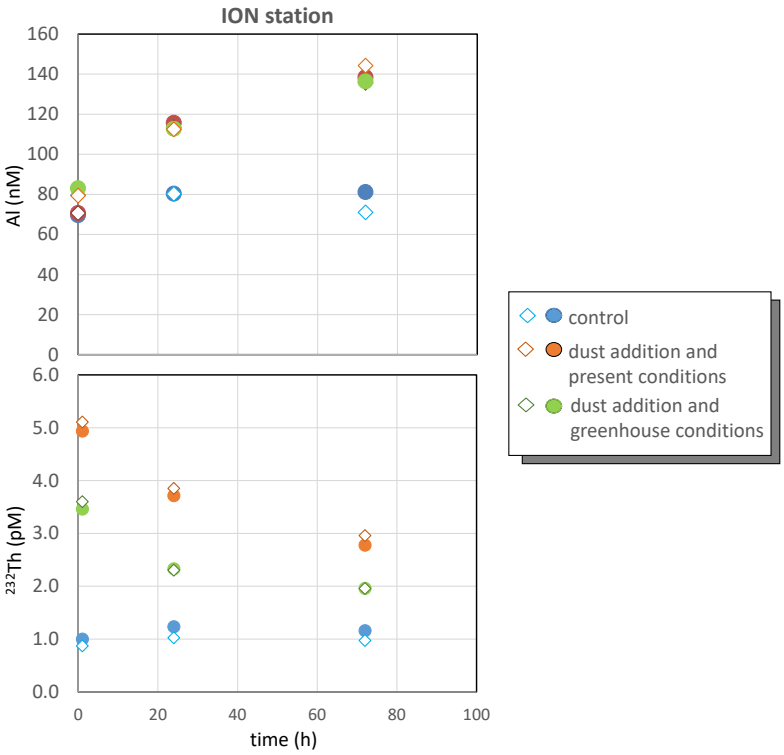


Figure 12: *Contrasted evolution of dissolved Al and dissolved ^{232}Th after dust deposition in Mediterranean seawater (Ionian Sea station) during tank experiments. No dust was added for the control experiments. Future climate conditions correspond to +3 ◦C and −0.3 pH unit compared to present conditions. The diamonds and circles indicate the results of different tanks (Roy-Barman et al., 2021).*

- New method of ^{227}Ac determination in seawater by isotope dilution and mass spectrometry

By diffusing from the deep sediments into the ocean, ^{227}Ac (half-life = 21.8 y) is a powerful tracer of vertical mixing in the deep ocean on decadal timescales. However, its use is limited by its very low concentration resulting in large volumes (hundreds of L) of seawater required for its analysis by nuclear spectroscopy. A new method of ^{227}Ac analysis has been developed by isotope dilution and MC-ICPMS (Levier et al., accepted). It significantly improves the measurement accuracy and reduces the sample size (10-30L). After spiking water samples with ^{225}Ac milked from a ^{229}Th solution, actinium isotopes are preconcentrated by manganese co-precipitation, purified by chromatographic methods and then measured by MC-ICPMS. ^{231}Pa (^{227}Ac progenitor) was also co-precipitated from the same water sample, recovered during the chromatography and analysed by MC-ICPMS. An internal quality control was carried out to validate the method by repeated measurements of 2L of surface seawater doped with a ^{227}Ac homemade standard solution and by duplicates of river water. Archived 10 L seawater samples from the Weddell Gyre collected during the Bonus GoodHope cruise, were also analysed, with ^{227}Ac concentration ranging from 4.2 ± 0.4 ag/kg to 10.9 ± 1.0 ag/kg (1 ag/kg= 10^{-18} g/kg = 0.161 dpm/m^3= 6.23 ag/k) in good agreement with previous measurement in the Weddell Gyre. The detection limit for 10 L seawater samples is ~ 0.8 ag/kg (Fig. 13).

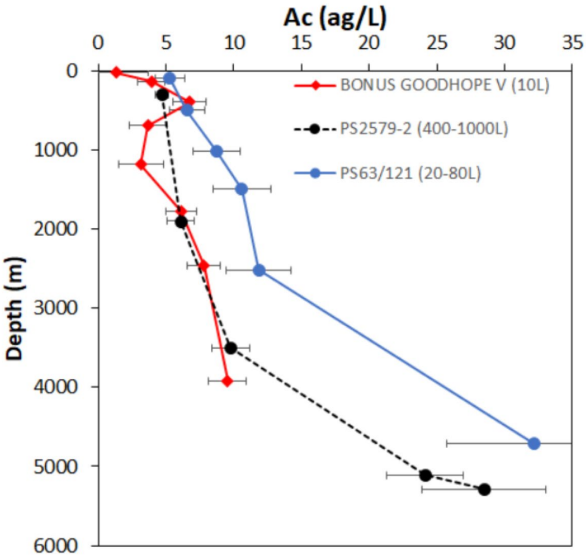


Figure 13: *Seawater ^{227}Ac profiles in the Weddell Gyre, at station Super V from Bonus GoodHope cruise, measured by mass spectrometry (red diamonds, Levier et al., accepted) and at station PS2579-2 (Geibert et al., 2002) (black dots) and PS63-121 measured by alpha-spectrometry (Geibert and Vöge, 2008) (blue dots). All uncertainties are expressed at 2σ_n. Levier et al., accepted.*

GEOTRACES or GEOTRACES relevant cruises

- SWINGS Cruise: PIs Catherine Jeandel (CNRS, LEGOS, Toulouse) and Hélène Planquette (CNRS, LEMAR, Brest)

SWINGS is a multidisciplinary 4-year project dedicated to elucidate trace element sources (sedimentary, atmospheric and hydrothermal), transformations and sinks (biogenic uptake, remineralization, particle fate, and export) along a section crossing key areas of the Southern Ocean containing the numerous fronts at the confluence between Indian and Atlantic Oceans (https://www.geotraces.org/follow-the-french-geotraces-swings-cruise/). It involves ca. 80 scientists (21 international laboratories, 7 countries[#]).

#SWINGS partners: CNRS_UPS_LEGOS (PI, Toulouse), CNRS_UBO_LEMAR (PI, Brest), AMU_MIO (Marseille), CNRS_UVSQ_LSCE (Saclay), CNRS_SU_LOCEAN (Paris), CNRS_SU_LOMIC (Banyuls), CNRS_UPS_GET (Toulouse), CNRS_SU_AD2M (Roscoff), CNRS_CECI (Toulouse), CSIR-SOCCO (Cape Town, South Africa), ULB_Bruxelles (Belgium), WU-SO (Washington Univ, USA), WHOI-MBC (Woods Hole, USA), FU-DEOAS (Florida State Univ, USA), Florida International University (USA), University of Southern

Mississippi (U.S.A), GEOMAR (Germany), PEO and ETH (Zurich, CH), University of Liverpool, University of Plymouth (UK), Universidad de Las Palmas de Gran Canaria (Spain)

The SWINGS cruise (R/V Marion-Dufresne, MD229, GEOTRACES section GS02) started from La Reunion on 11 January and ended at La Reunion 8 March 2021 (Fig. 14).

The strategy relies on the strong coupling between physical oceanography, biogeochemistry and modeling with special attention on the characterization of the physical, biological and chemical particle speciation in suspended and sinking particles.

A high spatial resolution sampling was realized for the dissolved and particulate phases (73 stations in total). Th and Pa isotopes will be analyzed to characterize the particle dynamics. Ra isotope will be measured for the quantification of land-ocean transfers while Nd isotopic composition will be used to trace the origin of the dissolved and particulate matter. These tracers will help identifying and characterizing hydrothermal source occurrences. Specific attention was paid to the ocean interfaces: atmospheric and land (Marion & Prince Edward, Crozet, Heard & Mc Donald, Kerguelen) contacts, and a segment of the South West Indian Ridge (possible active hydrothermal sites) were explored.

In addition to the characterization of phytoplankton biomass and community structure composition, we conducted dedicated biology experiments, such as nitrification, calcification or iron uptake experiments throughout the cruise. Prokaryotic community composition, metagenomics and metatranscriptomics analyses will be investigated.

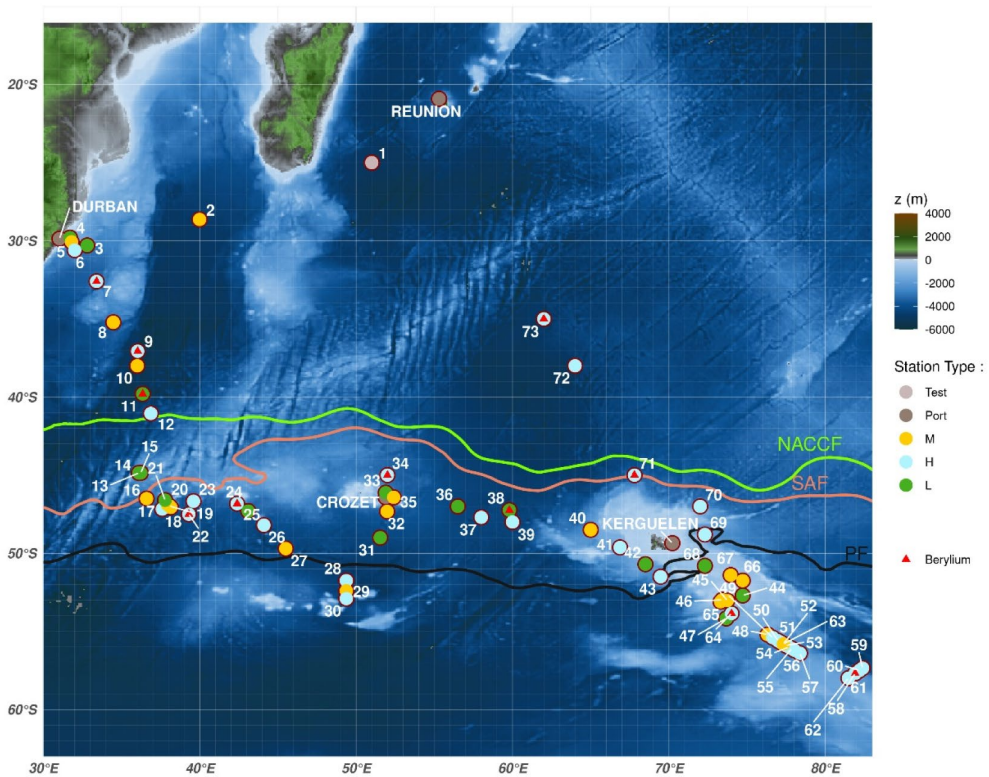


Figure 14: *Final map of the SWINGS cruise track, edited by Corentin Clerc and Sara Sergi. PF=Polar Front, SAF=SubAntarctic Front, NACCF=North Antarctic Circumpolar Current Front.*

The cruise track –at the Atlantic-Indian boundary- crossed up to 6 currents or fronts, among which the 3 majors are reported in Figure 7. These jets are major pathways of the general circulation, critical for chemical species transport: our navigation strategy was regularly adapted using the Scheduler for Oceanographic Samplings application in order to characterize these current dynamic (geostrophic calculation) as well as their trace element and isotope contents.

- TONGA-RECUP

One year after the TONGA cruise (DOI 10.17600/18000884) endorsed as a process study by GEOTRACES during which a fixed mooring has been deployed in the SW Pacific (20°42S / 177°52 W), the TONGA-RECUP cruise took place in oct-nov 2020 on the R/V Alis. All the samples were safely recovered: 11 months of exported material at 200 m (24 samples) and 1000 m (24 samples) are currently being analyzed for mass flux, carbon, LSi, BSi and metals. The fixed mooring line has also been instrumented below the 200 m-depth trap with 2 automatic sequential passive samplers (THOE) recently developed and patented by AEL (N. Caledonia) and Technicap (France). The chelating resins (DGT) chosen for this study binds the following elements: Al, Fe, Mn, Co, Ni, Cu, Zn, Cd, Sr, Ba, Pb and REE (Sampler 1), and, Hg and MMHg (Sampler 2).

GEOTRACES workshops and meetings organized

- First national workshop to prepare the French contribution to the international program BIOGEOSCAPES (Ocean metabolism and nutrient cycles on a changing planet, www.biogeoscapes.org) organized by videoconference on 7th and 8th December 2020.

Outreach activities conducted

- In relation to SWINGS

The SWINGS outreach activity is structured by 1) a documentary on the cruise. Videos and rushes will be finalized on land; 2) an online journal, eXploreur from the Toulouse University that was weekly edited (8 articles); 3) a daily web site, maintained in Toulouse, which received 28 articles from the cruise participants; 4) a special communication towards the schools, including an exchange with convicts.

The on-land edition of the web site (https://swings.geotraces.org/) and the journal eXploreur (https://exploreur.univ-toulouse.fr/) are two sources of information used by many actors like the CNRS, the IUEM at university of Bretagne Occidentale, the professors of schools and the journalists.

The list of articles and broadcasts, including a long article in the national newspaper "Le Monde" and a one-hour broadcast at the national public Radio is accessible https://www.geotraces.org/geotraces-french-swings-gs02-cruise-press-review/. Some examples of media coverage of GEOTRACES SWING GS02 cruise are listed below.

- EXPLOREUR journal (Université de Toulouse): Expedition SWINGS. This journal has followed the SWINGS expedition publishing one article per week: https://exploreur.univ-toulouse.fr/swings-expedition-english
- News, University of Liverpool, UK (25 February 2021): Studying iron cycling in the Southern Ocean

- Embassy of France in Australia (24 February 2021): Let's swing together on the Southern Ocean! Download the pdf version of this article.
- CNRS, News: Exploring the world's largest ocean current (26 January 2021): Exploring the world's largest ocean current
- News, Florida International University (21 April 2021: 52 days at sea — with someone else's research
- IPSL blog on the participation of LOCEAN lab at SWINGS GEOTRACES cruise: https://www.archives.ipsl.fr/Actualites/A-decouvrir/Carnet-de-campagne-SWINGS-South-West-Indian-Geotraces-Section

- In relation to TONGA
  - In the framework of the Mon Ocean et Moi project https://twitter.com/monoceanetmoi, the two BGC ARGO floats launched during TONGA have been adopted by students by 3 new schools (one in Vallon-Dore in New-Caledonia, one in Brest and one in Menton). http://www.monoceanetmoi.com/web/index.php/fr/adopt-a-float. This 'adoption' was the occasion to initiate the classrooms about ocean science in general and TONGA project in particular, and also to train the teacher during a specific session. Tweet about these activities can be found at https://twitter.com/tongaproject
  - The movie realized on board the TONGA expedition is available both in French https://www.youtube.com/watch?v=e5kAd0i6Dck and English https://www.youtube.com/watch?v=UeABf-cVR-k. Check it out!

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

- Artigue, L., Wyatt, N. J., Lacan, F., Mahaffey, C., and Lohan, M. C., 2021. The Importance of Water Mass Transport and Dissolved-Particle Interactions on the Aluminum Cycle in the Subtropical North Atlantic. Global Biogeochem. Cycles 35, e2020GB006569, https://doi.org/10.1029/2020GB006569.
- Artigue, L., Lacan, F., van Gennip, S., Lohan, M. C., Wyatt, N. J., Woodward, E. M. S., Mahaffey, C., Hopkins, J., and Drillet, Y., 2020. Water mass analysis along 22 °N in the subtropical North Atlantic for the JC150 cruise (GEOTRACES, GApr08). Deep Sea Research Part I: Oceanographic Research Papers 158, 103230, https://doi.org/10.1016/j.dsr.2020.103230.
- Behrens, M. K., Pahnke, K., Cravatte, S., Marin, F., and Jeandel, C., 2020. Rare earth element input and transport in the near-surface zonal current system of the Tropical Western Pacific. Earth and Planetary Science Letters 549, 116496, https://doi.org/10.1016/j.epsl.2020.116496.
- Bejannin, S., Tamborski, J. J., van Beek, P., Souhaut, M., Stieglitz, T., Radakovitch, O., Claude, C., Conan, P., Pujo-Pay, M., Crispi, O., Le Roy, E., and Estournel, C., 2020. Nutrient Fluxes Associated With Submarine Groundwater Discharge From Karstic Coastal Aquifers (Côte Bleue, French Mediterranean Coastline). Frontiers in Environmental Science 7 10.3389/fenvs.2019.00205.
- Black, E. E., Kienast, S. S., Lemaitre, N., Lam, P. J., Anderson, R. F., Planquette, H., Planchon, F., and Buesseler, K. O., 2020. Ironing Out Fe Residence Time in the Dynamic

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- Bressac, M., Wagener, T., Leblond, N., Tovar-Sánchez, A., Ridame, C., Albani, S., Guasco, S., Dufour, A., Jacquet, S., Dulac, F., Desboeufs, K., and Guieu, C., 2021. Subsurface iron accumulation and rapid aluminium removal in the Mediterranean following African dust deposition. Biogeosciences Discuss. 2021, 1-29, 10.5194/bg-2021-87.
- Diego-Feliu, M., Rodellas, V., Alorda-Kleinglass, A., Tamborski, J., van Beek, P., Heins, L., Bruach, J. M., Arnold, R., and Garcia-Orellana, J., 2020. Guidelines and Limits for the Quantification of Ra Isotopes and Related Radionuclides With the Radium Delayed Coincidence Counter (RaDeCC). Journal of Geophysical Research: Oceans 125, e2019JC015544, https://doi.org/10.1029/2019JC015544.
- Farmer, J. R., Hertzberg, J. E., Cardinal, D., Fietz, S., Hendry, K., Jaccard, S. L., Paytan, A., Rafter, P. A., Ren, H., Somes, C. J., Sutton, J. N., and GEOTRACES-PAGES Biological Productivity Working Group Members, 2021. Assessment of C, N and Si isotopes as tracers of past ocean nutrient and carbon cycling. Global Biogeochem. Cycles n/a, e2020GB006775, https://doi.org/10.1029/2020GB006775. (first author ECR)
- González-Santana, D., Planquette, H., Cheize, M., Whitby, H., Gourain, A., Holmes, T., Guyader, V., Cathalot, C., Pelleter, E., Fouquet, Y., and Sarthou, G., 2020. Processes Driving Iron and Manganese Dispersal From the TAG Hydrothermal Plume (Mid-Atlantic Ridge): Results From a GEOTRACES Process Study. Frontiers in Marine Science 7 10.3389/fmars.2020.00568.
- González-Santana, D., González-Dávila, M., Lohan, M. C., Artigue, L., Planquette, H., Sarthou, G., Tagliabue, A., and Santana-Casiano, J. M., 2021. Variability in iron (II) oxidation kinetics across diverse hydrothermal sites on the northern Mid Atlantic Ridge. Geochimica et Cosmochimica Acta 297, 143-157, https://doi.org/10.1016/j.gca.2021.01.013.
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- Lagarde, M., Lemaitre, N., Planquette, H., Grenier, M., Belhadj, M., Lherminier, P., and Jeandel, C., 2020. Particulate rare earth element behavior in the North Atlantic (GEOVIDE cruise). Biogeosciences 17, 5539-5561, 10.5194/bg-17-5539-2020.
- Lemaitre, N., Planquette, H., Dehairs, F., Planchon, F., Sarthou, G., Gallinari, M., Roig, S., Jeandel, C., and Castrillejo, M., 2020. Particulate Trace Element Export in the North Atlantic (GEOTRACES GA01 Transect, GEOVIDE Cruise). ACS Earth and Space Chemistry 4, 2185-2204, 10.1021/acsearthspacechem.0c00045.
- Levier M., Roy-Barman M., Colin C., Dapoigny A.: Determination of low level of actinium 227 in seawater and freshwater by isotope dilution and mass spectrometry. Marine Chemistry, Accepted. 2021.
- Pham, V. Q., Grenier, M., Cravatte, S., Michael, S., Jacquet, S., Belhadj, M., Nachez, Y., Germineaud, C., and Jeandel, C., 2019. Dissolved rare earth elements distribution in the Solomon Sea. Chem. Geol. 524, 11-36, https://doi.org/10.1016/j.chemgeo.2019.05.012.

- Robinson, S., Ivanovic, R., van de Flierdt, T., Blanchet, C. L., Tachikawa, K., Martin, E. E., Cook, C. P., Williams, T., Gregoire, L., Plancherel, Y., Jeandel, C., and Arsouze, T., 2021. Global continental and marine detrital εNd: An updated compilation for use in understanding marine Nd cycling. Chem. Geol. 567, 120119, https://doi.org/10.1016/j.chemgeo.2021.120119.
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- Silori, S., Sharma, D., Chowdhury, M., Biswas, H., Cardinal, D., and Mandeng-Yogo, M., 2021. Particulate organic matter dynamics and its isotopic signatures (δ13CPOC and δ15NPN) in relation to physical forcing in the central Arabian Sea during SW monsoon (2017–2018). Sci. Total Environ. 785,147326, https://doi.org/10.1016/j.scitotenv.2021.147326. (first and second authors ECR)
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- Tamborski, J., van Beek, P., Conan, P., Pujo-Pay, M., Odobel, C., Ghiglione, J.-F., Seidel, J.-L., Arfib, B., Diego-Feliu, M., Garcia-Orellana, J., Szafran, A., and Souhaut, M., 2020. Submarine karstic springs as a source of nutrients and bioactive trace metals for the oligotrophic Northwest Mediterranean Sea. Sci. Total Environ. 732, 139106, https://doi.org/10.1016/j.scitotenv.2020.139106.
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- van Horsten, N. R., Planquette, H., Sarthou, G., Ryan-Keogh, T. J., Mtshali, T. N., Roychoudhury, A., and Bucciarelli, E., 2021. Early winter barium excess in the Southern Indian Ocean as an annual remineralisation proxy (GEOTRACES GIPr07 cruise). Biogeosciences Discuss. 2021, 1-25, 10.5194/bg-2021-42.

Paleo-papers related to GETRACES issues

- Courtillat, M., Hallenberger, M., Bassetti, M.-A., Aubert, D., Jeandel, C., Reuning, L., Korpanty, C., Moissette, P., Mounic, S., and Saavedra-Pellitero, M., 2020. New Record of Dust Input and Provenance During Glacial Periods in Western Australia Shelf (IODP Expedition 356, Site U1461) from the Middle to Late Pleistocene. Atmosphere 11, 1251, https://www.mdpi.com/2073-4433/11/11/1251
- El Meknassi, S., Dera, G., De Rafélis, M., Brahmi, C., Lartaud, F., Hodel, F., Jeandel, C., Menjot, L., Mounic, S., Henry, M., Besson, P., and Chavagnac, V., 2020. Seawater 87Sr/86Sr ratios along continental margins: Patterns and processes in open and restricted shelf domains. Chem. Geol. 558, 119874, https://doi.org/10.1016/j.chemgeo.2020.119874.
- Hodel, F., Grespan, R., de Rafélis, M., Dera, G., Lezin, C., Nardin, E., Rouby, D., Aretz, M., Steinnman, M., Buatier, M., Lacan, F., Jeandel, C., and Chavagnac, V., 2021. Drake Passage gateway opening and Antarctic Circumpolar Current onset 31 Ma ago: The message of foraminifera and reconsideration of the Neodymium isotope record. Chem. Geol. 570, 120171, https://doi.org/10.1016/j.chemgeo.2021.120171.
- Tachikawa, K., Rapuc, W., Dubois-Dauphin, Q., Guihou, A., and Skonieczny, C., 2020. Reconstruction of ocean circulation based on neodymium isotopic composition: potential limitations and application to the Mid-Pleistocene transition. Oceanography 33, 80-87, https://doi.org/10.5670/oceanog.2020.205.

Completed GEOTRACES PhD or Master theses

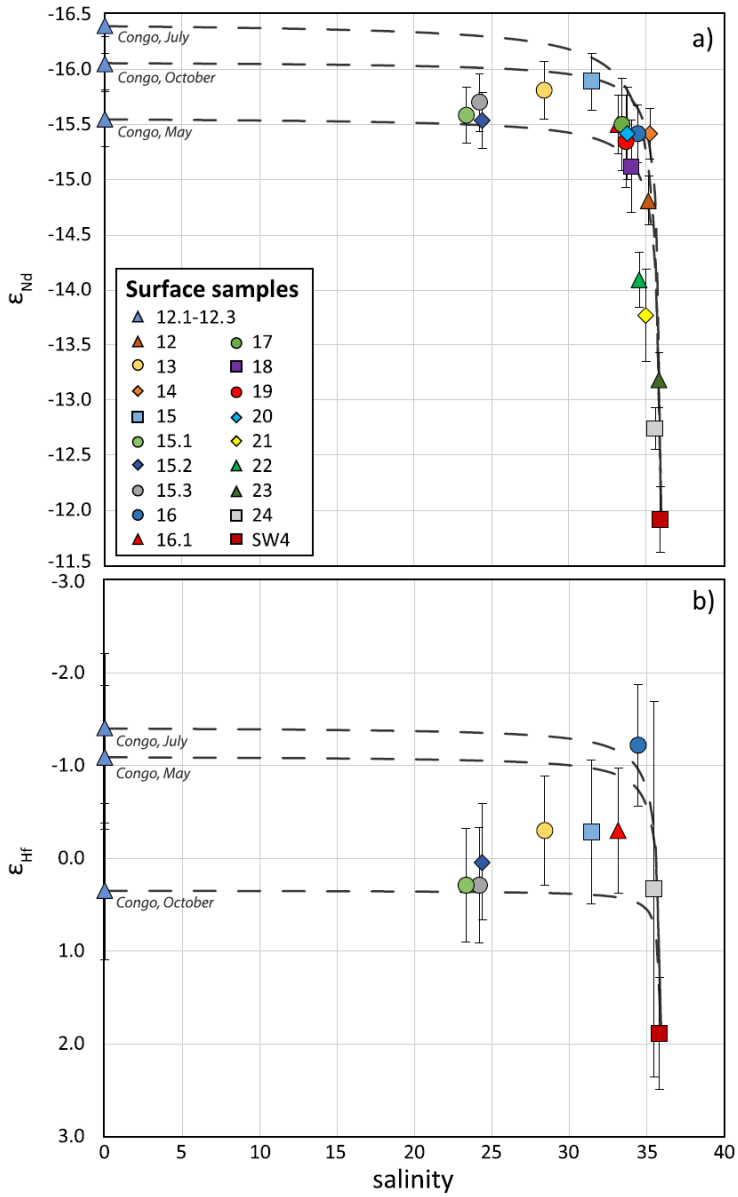
- Camille Akhoudas, 2020. A new look at the dynamics of the Southern Ocean and its interactions with the cryosphere revealed by an isotopic approach. Ph. D. thesis defended on 26th June 2020, Sorbonne Universite. Supervision by J.B. Sallée. http://theses.fr/s246342
- Lise Artigue, 2021. Ocean biogeochemical cycles: contributions of elemental and isotopic tracers, aluminium and iron coupled with a hydrodynamic approach. Ph. D. thesis defended on 3rd June 2020, Université de Toulouse. Supervision F. Lacan. https://tel.archives-ouvertes.fr/tel-03140152/document.
- Viet Pham, 2020. Tracing the lithogenic footprint in the Coral and Solomon Seas: contribution of rare earths and neodymium isotope composition. Ph. D. thesis defended on 24th June 2020, Université de Toulouse. Supervision C. Jeandel http://thesesups.ups-tlse.fr/4612/.
- David Gonzalez Santana, 2020. Impact of hydrothermal sources on biogeochemical cycles of trace metals. Ph. D. thesis defended on 11th December 2020, Université de Bretagne Occidentale. Supervision by G. Sarthou.
- Chengfan Yang, 2020. Li isotope study of Yangtze River sediments: new constraints on climate, weathering and carbon cycle relationships. Ph. D. thesis defended on 2nd December 2020, Sorbonne Universite., Paris and Tongji University, China. Supervision by Nathalie Vigier & Shouye Yang.

GEOTRACES presentations in international conferences

- Levier M, Roy-Barman M, Colin C and Dapoigny A. Seawater ^{227}Ac Analysis by ID-MC-ICPMS: A GEOTRACES Challenge. Virtual Goldschmidt, 2020. https://doi.org/10.46427/gold2020.1466
- Carla Geisen, Céline Ridame, Émilie Journet, Benoit Caron, Dominique Marie, Damien Cardinal, 2020. Impact of desert and volcanic aerosol deposition on phytoplankton in the South Indian Ocean and Southern Ocean. Communication at European Geosciences Union, April 2020.

Submitted by Kazuyo Tachikawa (kazuyo@cerege.fr).

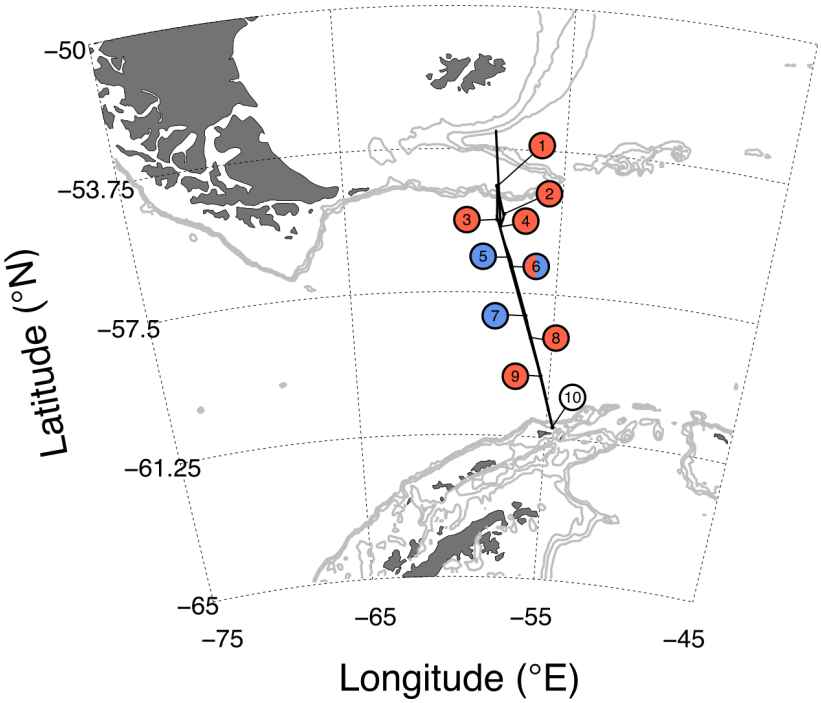
- Variability in the Arctic deep-sea due to increased particle flux at the margins (Valk et al.2020)
- Nd isotopes in the North Atlantic highlight the sensitive balance between vertical supply, horizontal supply and particulate removal (Stichel et al. 2020).



Mixing relationships between Nd and Hf isotopes and salinity of the Congo River and open ocean surface waters.

The paper presents the first combined dissolved neodymium (Nd) and hafnium (Hf) isotope and rare earth element (REE) concentration distributions following the Congo River plume along its flow path off the West African coast and along a connected offshore latitudinal section at 3°S.

Rahlf, P., Laukert, G., Hathorne, E.C., Vieira, L.H., and Frank, M. (2021) Dissolved neodymium and hafnium isotopes and rare earth elements in the Congo River Plume: Tracing and quantifying continental inputs into the southeast Atlantic. *Geochimica et Cosmochimica Acta* 294, 192-214.



Ten experiments were conducted through Drake Passage in the Southern Ocean to test for phytoplankton growth limitation by iron and/or manganese. Sites with a red label were found to be iron limited, whilst those with a blue label were found to be manganese limited; split red-blue label indicates iron-manganese co-limitation, whilst the white label indicates no nutrient was limiting.
Iron limited sites were generally found nearer to continental shelves (grey contours), where the supply of both iron and manganese is elevated but removal of iron compared to manganese is faster. In contrast, in the central part of Drake Passage, deep waters upwell to the surface that have been isolated from micronutrients inputs for long periods and are highly depleted in manganese.

Browning, T. J., Achterberg, E. P., Engel, A., & Mawji, E. (2021). Manganese co-limitation of phytoplankton growth and major nutrient drawdown in the Southern Ocean. Nature Communications, 12(1), 884. https://doi.org/10.1038/s41467-021-21122-6

GEOTRACES or GEOTRACES relevant cruises

- Research cruise Amazon-GEOTRACES 2 to the Amazon estuarine region approved (supposed to take place in 2022, will be applied for as GEOTRACES process study) as a follow-up research cruise to M147 (Amazon-GEOTRACES, GApr11 in Apr.-May 2018)
- Approval of Polarstern GEOTRACES cruise (section status planned) to the Central Arctic Ocean for 2024 ("ArcWatch-2")
- Award of cruise RainbowPlume as part of German Corona Cruise Proposal Round. Cruise will be sailed in period September 2 to October 5, 2021 (RV Meteor) and will investigate

plume geochemistry at Rainbow vent field (mid Atlantic Ridge). PIs Achterberg, Koschinsky, Browning, Frank. We will apply for GEOTRACES Process Study status.

- GP21 section cruise on FS Sonne in the South Pacific Ocean has been re-scheduled for February-April 2022 (Achterberg, Frank, Koschinsky).

New projects and/or funding

- The successor cruise of M147 (GApr11, AMAZON-GEOTRACES) that took place in spring 2018 in the high-discharge period in the Amazon estuary and plume to study trace-metal DOM processes and fluxes was approved and is planned for the end of 2022 in the dry, low-discharge period, but is not yet scheduled. Cruise applicants are Andrea Koschinsky, Thorsten Dittmar, Martin Frank and Martha Gledhill. This second cruise will also be applied for as a GEOTRACES process study.
- Continued work on development of an improved submersible pump system for all ocean depths ("Seafeather 10k") of AWI with company Fielax GmbH (Project funding contribution of the German Ministry for economy).
- Funding from AWI Innovation fund for the development of a clean laser cutting device for filters and other sample aliquots ("Cleancut")
- Funding contribution from EGU for Geotraces summer school 2021 (had to be postponed and funding was returned)
- GEOTRACES-relevant sampling opportunities on an earlier Polarstern cruise (ArcWatch-1)
- DFG Funding for Jan Scholten (Kiel Uni), Eric Achterberg & Aaron Beck (GEOMAR) and Walter Geibert (AWI) for two postdocs to conduct Ra, Th and He isotope work on upcoming GEOTRACES cruise(s).

GEOTRACES workshops and meetings organised

- M147 Amazon-GEOTRACES (process study GApr11) online workshop on the 27th November 2020 organized by Andrea Koschinsky, Jacobs University Bremen; with participants from several Brazilian universities, GEOMAR, University of Kiel, and University of Oldenburg. (13 early career researchers involved)
- Distribution and impacts of ocean nutrient limitation', ASLO Summer Meeting 2021 (T. Browning, E. Bertrand, A. Tagliabue, M. Moore)
- GEOTRACES S&I committee meetings were moved to an online format, happening twice a week since September 2020 in the virtual space.
- GEOTRACES summer School planned for summer 2021 had to be postponed to 2022 due to pandemic situation.
- Euromarine funded Foresight Workshop: BioGeoscapes in Europe.

  Date: 17th -19th Nov 2021.

  Location: Institut Ruđer Bošković, Zagreb, Croatia and on-line

  Aims: To capitalise on advances in trace element biogeochemistry, -omics disciplines and modelling approaches in marine science, the foundations of BioGeoSCAPES (a large-scale coordinated global microbial biogeochemistry program) are currently being laid at the international level.

The focus of this workshop will be to develop a community within Europe with an interest in the BioGeoSCAPES program and to develop ideas about how this program might be implemented across Europe:

The workshop will aim to combine assessment of the "State of the Art" with breakouts and discussions on the three following themes

-Trace element limitation, distribution, impact, significance

-Role of trace elements in microbial metabolisms

-Making complex interactions tractable

Spaces will be limited, but we do have some funding to support participants from ITC countries.

Please register your interest in attending the workshop by emailing: c.scape@geomar.de

Outreach activities conducted

- Press release for Southern Ocean Mn limitation paper. https://www.geomar.de/en/news/article/neuer-faktor-im-kohlenstoffkreislauf-des-suedozeans-nachgewiesen

Other GEOTRACES activities

- Intercalibration on dissolved V, Mo, U, Rb, Sr in seawater samples between Jacobs University Bremen and GEOMAR – in progress
- Sebastian Mieruch-Schnülle and Reiner Schlitzer from the Alfred Wegener Institute in Bremerhaven expanded the webODV online service for GEOTRACES and added the new "Data Exploration" tool that allows "ODV-like" interactive analysis and visualization of the GEOTRACES IDP data inside the users web browser. No data download or software installation are necessary. GEOTRACES webODV is available at https://geotraces.webodv.awi.de/.

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

- Hollister, A., Whitby, H., Seidel, M. Lodeiro, P. Gledhill, M. and Koschinsky, A. (in final revision): Dissolved concentrations and organic speciation of copper in the Amazon River estuary and mixing plume. Marine Chemistry
- Andrade, R.L.B., Hatje, V., Pedreira, R.M.A., Böning, P., Pahnke, K., 2020. REE fractionation and human Gd footprint along the continuum between Paraguaçu River to coastal South Atlantic Waters. Chem. Geol. 532, 1-11. doi: 10.1016/j.chemgeo.2019.119303.
- Behrens, M.K., Pahnke, K., Cravatte, S., Marin, F., Jeandel, C., 2020. Rare earth element input and transport in the near-surface zonal current system of the Tropical Western Pacific. Earth Planet. Sci. Lett. 549, 116496. doi: https://doi.org/10.1016/j.epsl.2020.116496.
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Benner, R., Bowman, K.L., Edwards, R.L., Gdaniec, S., Gerringa, L.J.A., González, A.G., Granskog, M., Haley, B., Hammerschmidt, C.R., Hansell, D.A., Henderson, P.B., Kadko, D.C., Kaiser, K., Laan, P., Lam, P.J., Lamborg, C.H., Levier, M., Li, X., Margolin, A.R., Measures, C., Middag, R., Millero, F.J., Moore, W.S., Paffrath, R., Planquette, H., Rabe, B., Reader, H., Rember, R., Rijkenberg, M.J.A., Roy-Barman, M., Rutgers van der Loeff, M., Saito, M., Schauer, U., Schlosser, P., Sherrell, R.M., Shiller, A.M., Slagter, H., Sonke, J.E., Stedmon, C., Woosley, R.J., Valk, O., van Ooijen, J., Zhang, R., 2020. The Transpolar Drift as a Source of Riverine and Shelf-Derived Trace Elements to the Central Arctic Ocean. Journal of Geophysical Research: Oceans 125, e2019JC015920. doi: 10.1029/2019JC015920.

- Geilert, S., Grasse, P., Doering, K., Wallmann, K., Ehlert, C., Scholz, F., Frank, M., Schmidt, M., Hensen, C., 2020. Impact of ambient conditions on the Si isotope fractionation in marine pore fluids during early diagenesis. Biogeosciences Discussions 2020, 1-39. doi: 10.5194/bg-2019-481.
- 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. Front. Mar. Sci. 7. doi: 10.3389/fmars.2020.00202.
- Paffrath, R., Laukert, G., Bauch, D., Rutgers van der Loeff, M., Pahnke, K., 2021. Separating individual contributions of major Siberian rivers in the Transpolar Drift of the Arctic Ocean. Sci. Rep. 11, 8216. doi: 10.1038/s41598-021-86948-y.
- Paffrath, R., Pahnke, K., Behrens, M.K., Reckhardt, A., Ehlert, C., Schnetger, B., Brumsack, H.-J., 2020. Rare Earth Element behavior in a sandy subterranean estuary of the southern North Sea. Front. Mar. Sci. 7. doi: 10.3389/fmars.2020.00424.
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- Valk, O., Rutgers van der Loeff, M. M., Geibert, W., Gdaniec, S., Moran, S. B., Lepore, K., et al. (2020). Decrease in 230Th in the Amundsen Basin since 2007: far-field effect of increased scavenging on the shelf? Ocean Sci., 16(1), 221-234. https://www.ocean-sci.net/16/221/2020/
- Dausmann, V., Frank, M. and Zieringer, M. (2020) Water mass mixing versus local weathering inputs along the Bay of Biscay: Evidence from dissolved hafnium and neodymium isotopes. Marine Chemistry 224, 1034844.
- Nasemann, P., Janssen, D.J., Rickli, J., Grasse, P., Frank, M., and Jaccard, S.L. (2020) Chromium reduction and associated stable isotope fractionation restricted to anoxic shelf waters in the Peruvian Oxygen Minimum Zone. Geochimica et Cosmochimica Acta 285, 207-224.
- Cao, Z., Li, Y., Rao, X., Yu, Y., Hathorne, E., Siebert, C., Dai, M., and Frank, M. (2020) Constraining barium isotope fractionation in the upper water column of the South China Sea. Geochimica et Cosmochimica Acta 288, 120-137.
- Rahlf, P., Laukert, G., Hathorne, E.C., Vieira, L.H., and Frank, M. (2021) Dissolved neodymium and hafnium isotopes and rare earth elements in the Congo River Plume: Tracing and quantifying continental inputs into the southeast Atlantic. Geochimica et Cosmochimica Acta 294, 192-214.
- Fuhr, M., Laukert, G., Yu, Y., Nürnberg, D., and Frank, M. (2021) Tracing water mass mixing from the Equatorial to the North Pacific Ocean with dissolved neodymium isotopes

and concentrations. Frontiers in Marine Science 7:603761, doi:10.3389/fmars.2020.603761.

- Patton, G.M., Francois, R., Weis, D., Hathorne, E., Gutjahr, M., Frank, M., and Gordon, K. (2021) An experimental investigation of the acquisition of Nd by authigenic phases of marine sediments. Geochimica et Cosmochimica Acta 301, 1-29.
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- Marsay, C. and Achterberg, E.P. (2021). Particulate iron and other trace elements in near-surface waters of the high latitude North Atlantic following the 2010 Eyjafjallajökull eruption. Marine Chemistry, https://doi.org/10.1016/j.marchem.2021.103959.
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- Wyatt, N. J., Milne, A., Achterberg, E. P., Browning, T. J., Bouman, H. A., Woodward, E. M. S., and Lohan, M. C. (2020). Seasonal cycling of zinc and cobalt in the Southeast Atlantic along the GEOTRACES GA10 section, Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-42.
- Hopwood, M.J., Carroll, D., Dunse, T., Hodson, A., Holding, J.M., Iriarte, J.L., Ribeiro, S., Achterberg, E.P., Cantoni, C., Carlson, D.F., Chierici, M., Clarke, J.S., Cozzi, S., Fransson, A., Juul-Pedersen, T., Winding, M.S., Meire, L. (2020). How does glacier discharge affect marine biogeochemistry and primary production in the Arctic? The Cryosphere, 14, 1347-1383, https://doi.org/10.5194/tc-14-1347-2020.
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- Plass, A., Schlosser, C. , Sommer, S., Dale, A. W. , Achterberg, E. P. and Scholz, F. (2020). The control of hydrogen sulfide on benthic iron and cadmium fluxes in the oxygen minimum zone off Peru. Biogeosciences, 17, 3685–3704, https://doi.org/10.5194/bg-17-3685-2020.
- Lodeiro, P., Rey-Castro, C., David, C., Achterberg, E.P., Puy, J., Gledhill, M. (2020). Acid-base properties of dissolved organic matter extracted from the marine environment. Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2020.138437.

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

- Paffrath, R. (2020). Terrestrial Input of Rare Earth Elements and Neodymium Isotopes to the Ocean and their Transport and Cycling - Case Studies from the Arctic Ocean and the Southern North Sea. University of Oldenburg.
- Rahlf, P. (2020) Tracing water masses and terrestrial inputs with radiogenic neodymium and hafnium isotopes and rare earth elements in the southeastern Atlantic Ocean. PhD thesis, University of Kiel, https://macau.uni-kiel.de/receive/macau_mods_00001033?lang=de

GEOTRACES presentations in international conferences

- Hollister A., De Carvalho LM, Gledhill M & Koschinsky A (2020): Distribution and Size Fractionation of Dissolved Cobalt and Nickel along the Amazon Estuary and Mixing Plume. Goldschmidt Conference 2020, https://doi.org/10.46427/gold2020.1051
- Ehlert, C., Liguori, B.T.P., Pahnke, K. The Influence of Water Mass Mixing and Particle Dissolution on the Silicon Cycle in the Central Arctic Ocean. Ocean Sciences, 2020.
- Behrens, M.K., Pahnke, K., Cravatte, S., Marin, F., Jeandel, C. Trace element sources and fluxes in the zonal current system of the tropical West Pacific: evidence from combined rare earth element, Nd isotope distributions and physical oceanographic observations. Ocean Science, 2020.
- Yu, Y., Siebert, C,. Fietzke, J., Goepfert, T., Hathorne, E., Cao, Z., Frank, M (2020) The impact of MC-ICP-MS plasma conditions on the accuracy and precision of stable isotope measurements evaluated for barium isotopes. Online Goldschmidt Conference, June 21-26, 2020.
- Francois, R., Patton, G., Weis, D., Hathorne, E., Gutjahr, M., Frank, M (2020) An Experimental Investigation of the Acquisition of Nd by Authigenic Phases in Marine Sediment, Online Goldschmidt Conference, June 21-26, 2020.
- Xu, A., Hathorne, E., Frank, M. (2020): Geochemical Behavior of Hafnium in the Amazon River Estuary and its Flux to the Atlantic. Online Goldschmidt Conference, June 21-26, 2020.
- Rahlf, P., Laukert, G., Hathorne, E.C., Frank, M. (2020) Congo River Influence on the Atlantic's Rare Earth Element and Nd/Hf Isotope Distributions. Online Goldschmidt Conference, June 21-26, 2020.
- Hathorne, E., Frank, M (2020) How Important is the Suspended Particulate Pool for Controlling Seawater Rare Earth Element Distributions? Online Goldschmidt Conference, June 21-26, 2020.

Submitted by Eric Achterberg (eachterberg@geomar.de).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN INDIA

April 1st, 2019 to March 31st, 2020

GEOTRACES activity is being pursued vigorously in India with new sampling and more measurements of trace elements and isotopes in the Indian Ocean with omics study. Seawater were sampled along both east and west coast of India and are currently being analysed to assess the impact of anthropogenic activity on budget of the trace elements and their fate in the coastal region.

Sampling in the Indian Ocean

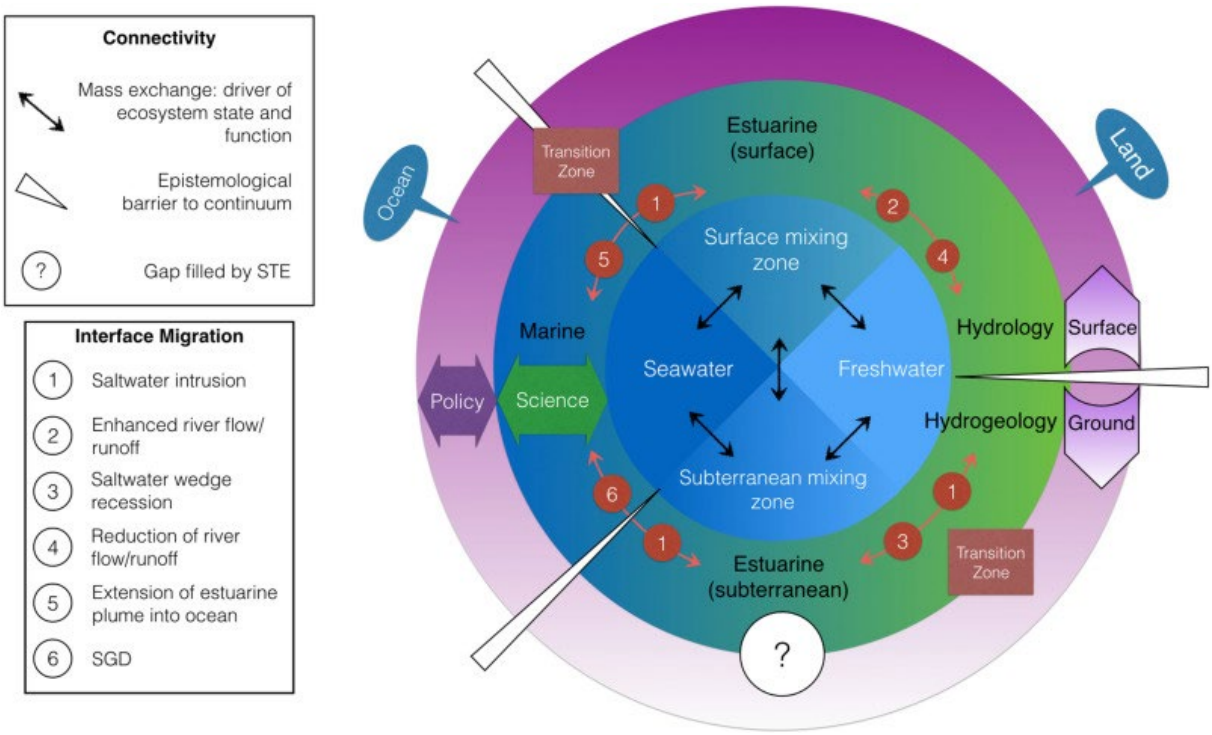
- Indian ocean was sampled onboard ORV Sindhu Sadhana from the mouth of the Ganga-Brahmaputra to 30 °S and 85 °E during March to June 2021. 28 researchers participated in the 90 days cruise to collect water, sediment, biological material, aerosol and rainwater samples for TEIs study to understand the sources, sinks, internal cycling and relation with biology.

Publications

- Singh Naman Deep, Chinni Venkatesh and Singh S. K., Dissolved aluminium cycling in the northern, equatorial and subtropical gyre region of the Indian Ocean, Geochim. Cosmochim. Acta, 268, 160-185, 2020.

Submitted by Vineet Goswami (vineetg@prl.res.in) and Sunil Kumar Singh (sunil@nio.org).

New GEOTRACES or GEOTRACES relevant scientific results



- Irish GEOTRACES scientist Carlos Rocha (TCD) was the lead author of a work examining the role and function of subterranean estuaries (STEs) in the context of coastal ecosystems and their associated submarine groundwater discharge (SGD) (Rocha et al, 2021).

GEOTRACES or GEOTRACES relevant cruises

- Irish expedition to the Greenland, Iceland and Norwegian (GIN) Seas during CIAAN CE20009 on the Celtic Explorer with Chief Scientist Dr. Audrey Morley (NUIG). Constraining the Impact of Arctic Amplification in the Nordic Sea: A biogeochemical approach (CIAAN) is an international, interdisciplinary and multi-themed oceanographic expedition aboard the R/V Celtic Explorer (Marine Institute Ireland) which took place between August-September 2020. CIAAN combined hydrographic surveying, modern biogeochemistry, plankton tows, planktonic foraminifera culturing and multi-core sediment sampling to fill an essential data gap in support of future paleoclimate investigations in polar regions.

New projects and/or funding

- The 2nd phase (2021-2026) of the Irish Centre for Research in Applied Geoscience (www.icrag-centre.org) was approved at the end of 2020. iCRAG2 began in January 2021 and there are GEOTRACES related projects on submarine groundwater discharge, the elemental composition of marine particles, thorium isotopes as flux tracers and elemental fluxes in the mesopelagic zone.

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

- Bennion, M., Morrison, L., Shelley, R., Graham, C., 2021. Trace elemental fingerprinting of shells and soft tissues can identify the time of blue mussel (Mytilus edulis) harvesting. Food Control 121, 107515.
- Ellwood, M.J., Boyd, P.W., Cornwall, C.E., Croot, P., Currie, K.I., Frew, R.D., Hurd, C.L., Law, C., Liss, P.S., McGraw, C.M., Mosley, L.M., Sander, S.G., Stirling, C., Zitoun, R., 2020. Keith Hunter's legacy to Marine Science in New Zealand. Marine and Freshwater Research 71, i-iii.
- Loughlin, C., Marques Mendes, A.R., Morrison, L., Morley, A., 2021. The role of oceanographic processes and sedimentological settings on the deposition of microplastics in marine sediment: Icelandic waters. Marine Pollution Bulletin 164, 111976.
- Lyons, W.B., Carey, A.E., Croot, P., Henry, T., Welch, S.A., Smith, D.F., Gardner, C.B., 2020. Current chemical denudation, silicate mineral weathering and erosion in Irish catchments: reflections on the tortoise and the hare. Irish Journal of Earth Sciences 38.
- Menzel Barraqueta, J.-L., Samanta, S., Achterberg, E.P., Bowie, A.R., Croot, P., Cloete, R., De Jongh, T., Gelado-Caballero, M.D., Klar, J.K., Middag, R., Loock, J.C., Remenyi, T.A., Wenzel, B., Roychoudhury, A.N., 2020. A First Global Oceanic Compilation of Observational Dissolved Aluminum Data With Regional Statistical Data Treatment. Frontiers in Marine Science 7.
- Ramon, D., Morick, D., Croot, P., Berzak, R., Scheinin, A., Tchernov, D., Davidovich, N., Britzi, M., 2021. A survey of arsenic, mercury, cadmium, and lead residues in seafood (fish, crustaceans, and cephalopods) from the south-eastern Mediterranean Sea. Journal of Food Science 86, 1153-1161.
- Rocha, C., Robinson, C.E., Santos, I.R., Waska, H., Michael, H.A., Bokuniewicz, H.J., 2021. A place for subterranean estuaries in the coastal zone. Estuarine, Coastal and Shelf Science 250, 107167.
- Savatier, M., Guerra, M.T., Murphy, J.E., Rocha, C., 2021. Radium isotope ratios as a tool to characterise nutrient dynamics in a variably stratified temperate fjord. Marine Chemistry 231, 103934.
- Van Dover, C.L., Colaço, A., Collins, P.C., Croot, P., Metaxas, A., Murton, B.J., Swaddling, A., Boschen-Rose, R.E., Carlsson, J., Cuyvers, L., Fukushima, T., Gartman, A., Kennedy, R., Kriete, C., Mestre, N.C., Molodtsova, T., Myhrvold, A., Pelleter, E., Popoola, S.O., Qian, P.Y., Sarrazin, J., Sharma, R., Suh, Y.J., Sylvan, J.B., Tao, C., Tomczak, M., Vermilye, J., 2020. Research is needed to inform environmental management of hydrothermally inactive and extinct polymetallic sulfide (PMS) deposits. Marine Policy 121, 104183.
- Xu, H., Croot, P., Zhang, C., 2021. Discovering hidden spatial patterns and their associations with controlling factors for potentially toxic elements in topsoil using hot spot analysis and K-means clustering analysis. Environment International 151, 106456.

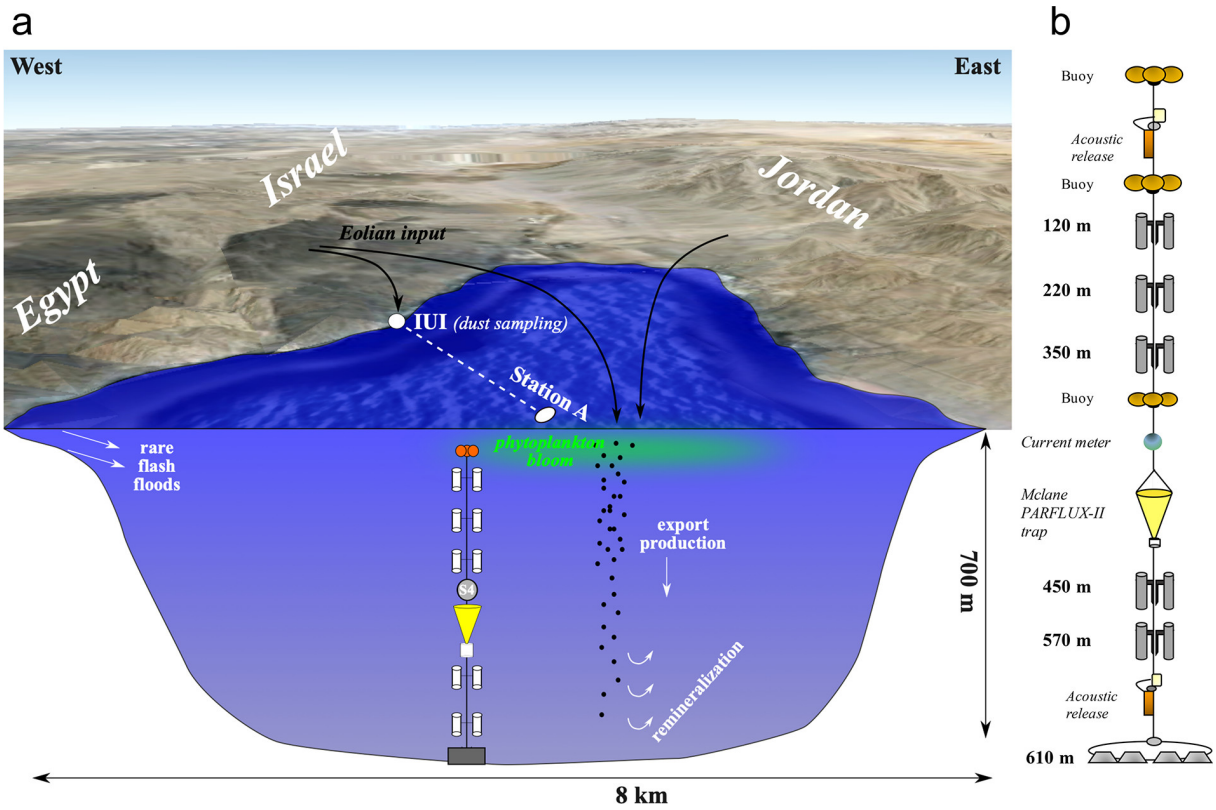
GEOTRACES presentations in international conferences

- T.L. Babila, A. Morley. PP018-0004 – Navigating the changing seas of international palaeoceanographic field research. AGU Fall Meeting (Online) 9 Dec 2020.

Submitted by Prof. Peter Croot (peter.croot@nuigalway.ie).

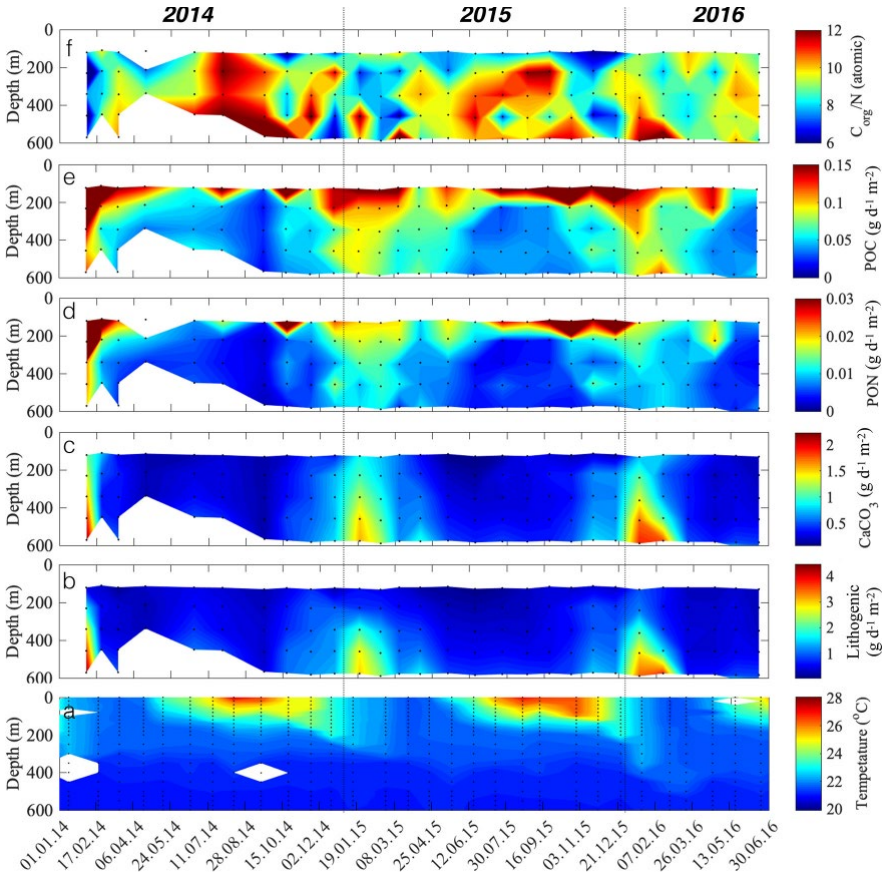
New GEOTRACES or GEOTRACES relevant scientific results

Marine particulate fluxes were studied between 2014 and 2017 in the oligotrophic Gulf of Aqaba (GOA), northern Red Sea. The results, described briefly below, were reported by Torfstein et al. (2020) in a special issue of *ACS Earth and Space Chemistry* devoted to "Marine Particle Chemistry: Influences on Biogeochemical Cycles and Particle Export". The study, which is part of the ***R**ed Sea **D**ust, **M**arine Particulates and **S**eawater **T**ime Series* (***REDMAST**, GIpr09*), includes a monthly –rotated bottom tethered mooring mounted with 5 sediment trap stations (KC Denmark Inc.) at approximately equal depth intervals between 120 and 570 m (water depth of ~610 m).



Schematic diagram of the study site at the Gulf of Aqaba. The sediment trap mooring is bottom-tethered at ~610 m water depth. The mooring included KC Denmark cylinder sediment trap stations deployed at depths of 120, 220, 350, 450, and 570 m (the mooring further included a McLane time series PARFLUX-II trap at 410 m, the results of which will be discussed elsewhere). An S4 current meter system was deployed at 380 m and recorded current velocity and direction during part of the time of the study. In addition, the National Monitoring Program (NMP) carries out monthly measurements of physical and chemical conditions at Station A. Fine eolian particles (dust) are delivered year round to the GOA, and an atmospheric dust trap is operated routinely at IUI, the logistical base for this study, as well as additional dust monitoring stations deployed by the Israel Ministry of Environmental Protection (MEP) along the coast of Eilat. Flash floods deliver terrestrial particles a few times a year during brief (<1 day) well-defined events.

The bulk particulate fluxes were determined for the entire period, with organic C and N, $CaCO_3$, and lithogenic fluxes determined for the first two and half years of the deployment. The results are evaluated in the context of monthly resolved records of seawater temperature, chlorophyll-a concentrations, and macro-nutrient concentrations, as well as hourly to weekly dust load records and rare fluvial events. The results are further compared to core-tops collected from varying water depths and are combined to produce a basin source-to-sink mass balance of particulate fluxes. The GOA undergoes strong seasonal changes expressed by surface water temperatures and water column stratification and mixing, which control the vertical and temporal distribution of nutrients and primary and export production.



***Time series in the GOA during 2014–2016**. (a) temperature (°C), (b) lithogenic flux (g m^{-2} d^{-1}), (c) $CaCO_3$ flux (g m^{-2} d^{-1}), (d) particulate organic nitrogen (PON) flux (g m^{-2} d^{-1}), (e) particulate organic carbon (POC) flux (g m^{-2} d^{-1}), and (f) Corg/N atomic ratios. Black dots mark the depths and times of sampling.*

Accordingly, the seasonal variability in particulate fluxes varies over a wide range, typically displaying peak bulk fluxes in bottom waters during the winter (~5–7 g m^{-2} d^{-1}) and minimum values in shallow waters during summer (<0.5 g m^{-2} d^{-1}). Organic C and N fluxes are the highest in shallow waters and display strong vertical attenuation that varies seasonally, a-priori reflecting enhanced remineralization in the warm shallow waters during summer. In contrast, particulate organic carbon and nitrogen fluxes are enhanced in bottom waters during winter, due to the combined effect of the increased presence of mineral ballasts and vertical water column mixing. The quantification of particulate fluxes in the GOA suggests that, while most of the bulk particulates are introduced into the basin via episodic fluvial events, with direct dust inputs contributing approximately an order of magnitude less material, the internal cycling of terrigenous material is complex, with a lag between the initial deposition of influxing material along shallow margins and seasonal reworking and transport of sediments to the deep seafloor. Nevertheless, the fluxes of terrigenous and organic particulates are largely independent of each other, with export production fluxes driven by water column mixing and nutrient availability in the photic zone. On a wider scale, the findings reported here relate to the role of dust deposition and hemipelagic sedimentation in the oceans and their impact on export production and particle cycling in coastal regions. Combined, the findings illuminate the factors impacting marine habitats and ecosystems, the cycling and sequestration of trace elements and anthropogenic components in the oceans, and facilitate better understanding of the interplay between solid and

dissolved phases in the oceans and reconstructing past oceanographic and climatic conditions from marine sediment cores.

GEOTRACES or GEOTRACES relevant cruises

- The National Monitoring Program of Israel's Mediterranean waters –Hydrographic and sedimentological cruises on board R.V. Bat Galim along E-W transects across the Israeli Mediterranean EEZ (Water – bi-annual; Sediments – annual).
- DeepLev Observatory – deep-sea mooring station in the eastern Levantine basin at 1500 m water depth, ~50 km offshore Haifa, Israel, aimed at enhancing synchronized measurements of physical and biogeochemical dynamics. The station carries an array of sediment traps and sensors that measure physical, chemical, and biological attributes along the water column. Two cruises with R.V. Bat Galim; mooring operations. (Joint study – IOLR; BIU; UH; HUJI; TAU).
- Seafloor Hydrocarbon Seeps in the southeastern Mediterranean Sea – till recently 3 cruises at the Palmachim area including water column and sediment sampling. R.V. Bat Galim.
- The National Monitoring Program (NMP) for the Gulf of Eilat/Aqaba operates out of the IUI (http://www.iui-eilat.ac.il/Research/NMPAbout.aspx). Activities include monthly cruises across the north Gulf of Eilat/Aqaba, during which physical, chemical and biological measurements are performed in depth profiles (at a water depth of 700 meters) together with spatial-surface coverage. The main-relevant parameters monitored are: Temperature, salinity, dissolved oxygen, pH, alkalinity, POC, NO_2, NO_3, $Si(OH)_4$, PO_4, Chl-a. The samples are collected with the IUI Research Vessel, which has a powder coated aluminium Rosette (SeaBird) with 12 niskin bottles (12 liters each), and a CTD (SeaBird electronics). These measurements have been performed continuously since the year 2000. Analyses are performed at the IUI labs.

Outreach activities conducted

- Yeala Shaked became involved in i-scientists, zoom meetings with secondary and high school students to discuss research, ocean biogeochemistry in a changing world etc. https://davidson.weizmann.ac.il/en/programs/iscientist

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

- Benaltabet T., Lapid G. and Torfstein A. (2020) Seawater Pb concentration and isotopic composition response to daily time scale dust storms in the Gulf of Aqaba, Red Sea. *Marine Chemistry 227*, 103895.
- Chernihovsky N., Almogi-Labin A., Kienast S.S. and Torfstein A. (2020) The daily resolved temperature dependence and structure of planktonic foraminifera blooms. *Scientific Reports 10*(1), 1-12.
- Costa et al. (2020) ^{230}Th normalization: New insights on an essential tool for quantifying sedimentary fluxes in the modern and Quaternary ocean. *Paleoceanography and Paleoclimatology* 35, 1-36.
- Rahav E., Paytan A., Mescioglu E., Bar-Zeev E., Mart F., Xian P. and Herut B. (2020). Bio-aerosols negatively affect Prochlorococcus in oligotrophic aerosol-rich marine regions. *Atmosphere.* 11(5), 540.
- Rahav E., Raveh O., Yanuka-Golub K., Belkin N., Astrahan P., Maayani M., Tsumi N.,

Kiro Y., Herut B., Silverman J. and Angel D.L. (2020). Nitrate enrichment Structures Phytoplankton Communities in the Shallow Eastern Mediterranean Coastal Waters. Front. Mar. Sci. 7:611497. doi: 10.3389/fmars.2020.611497.

- Shaked Y, Buck KN, Mellett T, and Maldonado MT. (2020) Insights into the bioavailability of oceanic dissolved Fe from phytoplankton uptake kinetics. *The ISME Journal doi.org/10.1038/s41396-020-0597-3*.
- Sisma-Ventura G., Kress N., Silverman J., Gertner Y., Ozer T., Biton E., Lazar A., Gertman I., Rahav E. and Herut B. (2021) Post-eastern Mediterranean Transient Oxygen Decline in the Deep Waters of the Southeast Mediterranean Sea Supports Weakening of Ventilation Rates. *Front. Mar. Sci.* 7:598686.
- Sisma-Ventura G., Herut B., Silverman J., Katz T., Rubin-Blum M. and Rahav E. (2021). P fluxes and prokaryotic cycling at benthic boundary layer in the deep southeastern Mediterranean Sea. *Journal of Geophysical Research: Biogeosciences,* 126, e2020JG006110.
- Titelboim D., Sadekov A., Blumenfeld M., Almogi-Labin A., Herut B., Halicz L., Benaltabet T., Torfstein A., Kuceara M. and Abramovich S. (2021) Monitoring of heavy metals in seawater using single chamber foraminiferal sclerochronology. Ecological Indicators 120, 106931.
- Torfstein A., Kienast S.S., Rivlin A., Isaacs S., Yarden B. and Shaked Y. (2020) Bulk and export production fluxes in the Gulf of Aqaba, northern Red Sea. *ACS Earth and Space Chemistry* 4(8), 1461-1479.

Completed GEOTRACES PhD or Master theses

- Natalie Chernihovsky, "High-resolution temporal dynamics of planktonic foraminifera in the Gulf of Aqaba", HUJI. Advisors: Adi Torfstein (HUJI), Ahuva Almogi-Labin (GSI).

GEOTRACES presentations in international conferences

- Benaltabet T., Lapid G. and Torfstein A. (2020) Seasonal seawater Al dynamics and response to short-term perturbations in the Gulf of Aqaba, northern Red Sea. Goldschmidt meeting.
- Kienast S.S., Torfstein A. and Riehl L. (2019) Constraining Remineralization of Sinking Organic Carbon in the Oligotrophic Ocean: A Case Study from the Gulf of Aqaba, AGU fall meeting.
- Kienast S.S. and Torfstein A. (2020) Sinking organic carbon in the Gulf of Aqaba: Implications for a warming ocean. Goldschmidt meeting.
- Lapid G., Benaltabet T. and Torfstein A. (2020) Dissolved ^{230}Th and ^{232}Th as tracers of particle fluxes in the Gulf of Aqaba, Red Sea. Goldschmidt meeting.
- Rahav E. (2020) Nitrate-enrichment structures phytoplankton communities in the shallow eastern Mediterranean coastal waters. Aquacosm meeting, Crete.
- Rahav E and Herut B. (2021) The hitchhikes guide to bacterial transport: the role of viable dust-borne microbes deposition into marine environments. Micro2021 meeting.
- Torfstein A., Kienast S.S., Tirosh O. and Yarden B. (2020) Major and trace element settling and burial fluxes in the Gulf of Aqaba, northern Red Sea. Goldschmidt meeting.
- Torfstein A. (2021) Bulk and export production fluxes in the Gulf of Aqaba, northern Red Sea. Ocean Carbon and Biogeochemistry in Tropical Seas, KAUST, Saudi Arabia.

Submitted by Adi Torfstein (adi.torf@mail.hujji.ac.il).

New GEOTRACES or GEOTRACES relevant scientific results

- Nishioka et al. (2020) reported the processes that determine the chemical properties of intermediate water and the uplift of Fe and nutrients to the main thermocline in the North Pacific, which eventually maintains surface biological productivity. In this study, comprehensive observations for investigating Fe and nutrients in the North Pacific and the Okhotsk Sea and the Bering Sea were carried out from 1998 to 2018, including GEOTRACES GP02 data. Nutrient-rich water is pooled in intermediate water (26.8 to 27.6 $\sigma\theta$) in the western subarctic area, especially in the Bering Sea basin. Increases of two to four orders in the upward turbulent fluxes of nutrients were observed around the marginal sea island chains, indicating that nutrients were uplifted to the surface and are returned to the subarctic intermediate nutrient pool as sinking particles through the biological production and microbial degradation of organic substances. This nutrient circulation coupled with the dissolved Fe in upper intermediate water (26.6 to 27.0 $\sigma\theta$) derived from the Okhotsk Sea evidently constructs an area that has one of the largest biological CO2 drawdowns in the world ocean. These results highlight the pivotal roles of the marginal seas and formation of intermediate water at the end of ocean conveyer belt.

Citation: Nishioka, J., H. Obata, H. Ogawa, K. Ono, Y. Yamashita, K. J. Lee, and I. Yasuda (2020), Subpolar marginal seas fuel the North Pacific through the intermediate water at the termination of the global ocean circulation, Proceedings of the National Academy of Sciences of the United States of America, 117, 12665-12673, doi:10.1073/pnas.2000658117.

GEOTRACES workshops and meetings organized

- PICES 2020 annual meeting topic session, "Atmospheric nutrient deposition and microbial community responses, and predictions for the future in the North Pacific Ocean", SOLAS-GEOTRACES relevant session, The session had 7 live presentations, 5 recorded oral presentations and 15 electronical poster presentations.
- Domestic GEOTRACES session was held during the fall meeting of The Oceanographic Society of Japan 2020 (November 29, 2020) online for pursuing scientific discussion on recent Japanese GEOTRACES studies. We had 9 oral presentations including those given by students.
- Domestic session entitled "Marine Geochemistry" related to GEOTRACES studies was held during the annual meeting of Geochemical Society of Japan 2020 (November 12 – 26, online). We had 16 presentations including those by 11 students.
- We had a national GEOTRACES symposium in March 23-24, 2021, for promoting scientific discussion on recent Japanese GEOTRACES studies (27 papers were presented). Seven students presented their original results. We also had a business meeting as a GEOTRACES sub-committee meeting under the national SCOR committee (Science Council of Japan) on March 23, 2021. These symposium and meeting were held online hosted by Atmosphere and Ocean Research Institute, the University of Tokyo.

Outreach activities conducted

- On August 17, we had a lecture meeting how to submit our data to IDP2021 for Japanese Geotracers. The lectures were given in Japanese by Dr. Yoshiko Kondo (a member of Standard and Intercalibration Committee) and Dr. Jun Nishioka (a member of Data Management Committee) online.
- The fourth workshop of the WESTPAC WG-06 "A framework for cooperative studies in the Western Pacific Marginal Seas: Energy and materials exchange between land and open ocean" was held on 6-7 October 2020 as a virtual meeting. Thirty experts from eight countries in East and Southeast Asia attended. During this workshop, all participants agreed to submit a proposal of new projects/programme in order for WESTPAC to expand its cooperative activities and contribute to the UN Decade for Ocean Sciences. After the workshop, a ten-year proposal titled "Healthy, Productive and Sustainable Asian Marginal Seas: Understanding changes in the marine environment in response to global climate change" was prepared, submitted and then approved at the 13th Intergovernmental Session of WESTPAC (27-29 April).

Other GEOTRACES activities

- The GEOTRACES Subcommittee of the SCOR Subcommittee of the Earth and Planetary Science Committee in Japan was held online on March 23, 2021. At the committee, recent activities of GEOTRACES-SSC, DMC, S&I meetings were reported by Dr. Hajime Obata (a member of SSC Committee), Dr. Jun Nishioka (a member of DMC Committee), and Dr. Yoshiko Kondo (a member of S&I Committee), respectively. In addition, a brief explanation about Japan GEOTRACES cruise (GP22) scheduled from May to August 2022 was given by Dr. H. Obata.

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

During the past year Japan GEOTRACES investigators published a total of 23 peer-reviewed journal articles. The underlined first author is the ECR.

- Escobar, M. T., N. Takahata, H. Obata, and Y. Sano (2021), Observation of the deep Indonesian Throughflow using helium isotopes. Journal of Oceanography, 77, 93-101.
- Fujiwara, Y., M. Tsujisaka, S. Takano, and Y. Sohrin (2020), Determination of the tungsten isotope composition in seawater: The first vertical profile from the western North Pacific Ocean. Chemical Geology 555, 119835, doi: https://doi.org/10.1016/j.chemgeo.2020.119835.
- Inoue, M., R. Takehara, S. Hanaki, H. Kameyama, J. Nishioka, and S. Nago (2020), Distribution of radiocesium and radium isotopes in the western Bering Sea in 2018, Marine Chemistry, 225, 103843, doi.org/10.1016/j.marchem.2020.103843.
- Kanna, N., S. Sugiyama, Y. Fukamachi, D. Nomura, and J. Nishioka (2020), Iron supply by subglacial discharge into a fiord near the front of a marine-terminating glacier in northwestern Greenland, Global Biogeochemical Cycles, doi.org/10.1029/2020GB006567.
- Kenyon, J., K. Buesseler, N. Casacuberta, M. Castrillejo, S. Otosaka, P. Masqué, J. Drysdale, S. Pike and V. Sanial (2020), Distribution and evolution of Fukushima Dai-ichi derived 137Cs, 90Sr, and 129I in surface seawater off the coast of Japan, Environmental Science & Technology, 54, 15066-15075.

- Kondo, Y., R. Bamba, H. Obata, J. Nishioka, and S. Takeda (2021), Size-fractionated natural organic Fe-binding ligands in the eastern and western subarctic Pacific, Scientific Reports, 11, 2053, doi.org/10.1038/s41598-021-81536-6.
- Liao, W.-H., S. Takano, S.-C. Yang, K. -F. Huang, Y. Sohrin, T. -Y. Ho (2020), Zn Isotope composition in the water column of the northwestern Pacific Ocean: The importance of external sources, Global Biogeochemical Cycles, 34, e2019GB006379, doi:10.1029/2019GB006379.
- Mashio, A. S., H. Obata, H. Fukuda, and H. Ogawa (2020), Spatiotemporal variations of platinum in seawater in Otsuchi Bay, Japan after the 2011 tsunami, Science of the Total Environment, 708, 134659; doi:10.1016/j.scitotenv.2019.134659.
- Mashio, A. S., T. Tanimura, H. Hasegawa, S. Takeda, and H. Obata (2021), Budgets and sources of dissolved platinum in the inland seas of Japan. Estuarine, Coastal and Shelf Science, 253, 107293.
- Misumi, K., J. Nishioka, H. Obata, D. Tsumune, T. Tsubono, M. C. Long, K. Lindsay, and J. K. Moore (2021), Slowly sinking particles underlie dissolved iron transport across the Pacific Ocean, Global Biogeochemical Cycles, 10.1029/2020GB006823.
- Miura, H., T. Ishimaru, Y. Ito, Y. Kurihara, S. Otosaka, A. Sakaguchi, K. Misumi, D. Tsumune, A. Kubo, S. Higaki, J. Kanda, and Y. Takahashi (2021), First isolation and analysis of caesium-bearing microparticles from marine samples in the Pacific coastal area near Fukushima Prefecture. Scientific Reports, 11, 5664.
- Nakaguchi, Y., Y. Ikeda, A. Sakamoto, L. Zheng, T. Minami, Y. Sohrin (2020), Distribution and stoichiometry of Al, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb in the East China Sea, Journal of Oceanography, https://doi.org/10.1007/s10872-020-00577-z.
- Nishioka, J., H. Obata, H. Ogawa, K. Ono, Y. Yamashita, K. J. Lee, and I. Yasuda (2020), Subpolar marginal seas fuel the North Pacific through the intermediate water at the termination of the global ocean circulation, Proceedings of the National Academy of Sciences of the United States of America, 117, 12665-12673, doi:10.1073/pnas.2000658117.
- Nishioka, J., H. Obata, T. Hirawake, Y. Kondo, Y. Yamashita, K. Misumi, and I. Yasuda (2021), A review: Iron and nutrients supply in the subarctic North Pacific and its impact to phytoplankton production, Journal of Oceanography, 10.1007/s10872-021-00606-5.
- Otosaka, S., S. Kambayashi, M. Fukuda, T. Tsuruta, T. Misonou, T. Suzuki, and T. Aono (2020), Behavior of radiocesium in sediments in Fukushima coastal waters: Verification of desorption potential through the pore water, Environmental Science and Technology 54, 13778-13785.
- Tanaka, T., D. Hasegawa, I. Yasuda, D. Yanagimoto, S. Fujio, H. Nakamura, R. Inoue, and J. Nishioka (2021), Enhanced vertical turbulent nitrate flux in the intermediate layer of the Kuroshio in the Tokara Strait, Jouranl of Oceanography, doi.org/10.1007/s10872-020-00581-3.
- Takano, S., W. -H. Liao, H. -A. Tian, K. -F. Huang, T. -Y. Ho, and Y. Sohrin (2020), Sources of particulate Ni and Cu in the water column of the northern South China Sea: Evidence from elemental and isotope ratios in aerosols and sinking particles. Marine Chemistry, 219, 103751. 10.1016/j.marchem.2020.103751.
- Tsujisaka, M., S. Nishida, S. Takano, M. Murayama, and Y. Sohrin (2020), Constraints on redox conditions in the Japan Sea in the last 47,000 years based on Mo and W as

palaeoceanographic proxies, Geochemical Journal, 54, 6, 351-363. 10.2343/geochemj.2.0606.
- Tomonaga Y., K. Yagasaki, J. Park, J. Ashi, S. Toyoda, N. Takahata, and Y. Sano (2020), Fluid dynamics along the Nankai Trough: He isotopes reveal direct seafloor mantle-fluid emission in the Kumano Basin (southwest Japan), ACS Earth and Space Chemistry, 4, 2105-2112, 10.1021/acsearthspacechem.0c00229.
- Yamashita, Y., T. Tosaka, R. Bamba, R. Kamezaki, S. Goto, J. Nishioka, I. Yasuda, T. Hirawake, J. Oida, H. Obata, and H. Ogawa (2021), Widespread distribution of allochthonous humic-like fluorescent dissolved organic matter in the intermediate water of the North Pacific, Progress in Oceanography, 191, doi.org/10.1016/j.pocean.2020.102510.
- Yamazaki, E., S. Taniyasu, X. Wang, N. Yamashita (2021), Per- and polyfluoroalkyl substances in surface water, gas, and particle in open ocean and coastal environment, Chemosphere, 272, 129869.
- Wiwit, K. -H. Wong, H. Fukuda, H. Ogawa, A. S. Mashio, Y. Kondo, J. Nishioka and H. Obata (2021), Wide range detection of Cu-binding organic ligands in seawater using reverse titration, Marine Chemistry, 230, 103927: doi.org/10.1016/j.marchem.2021.103927.
- Wong, K. -H., H. Obata, T. Kim, Y. Kondo, and J. Nishioka (2021), New insights into the biogeochemical cycling of copper in the subarctic Pacific: Distributions, size fractionation, and organic complexation, Limnology and Oceanography, 66, 1424-1439, https://doi.org/10.1002/lno.11695.

Completed GEOTRACES PhD or Master theses

- Ma Teresa Lumantas Escobar (2020), "Study of deep fluids near subduction zones using helium isotopes", PhD. Env. Thesis, The University of Tokyo.
- Akito Ichimura (2021), "Establishment of highly sensitive and accurate Pd analysis method in seawater using ID-ICP-MS", M. Eng. Thesis, Kanazawa University.
- Daiki Miura (2021), "Iron supply processes in the eastern south Pacific and Southern Ocean", M. Env. Thesis, Hokkaido University.
- Fumito Sakuragi (2021), "Investigation of composition and geochemical cycles of rare earth elements in Kuroshio Waters", M. Env. Thesis, The University of Tokyo.
- Siteng Zhu (2021), "Quantification of diapycnal/isopycnal mixing and material transport in the subtropical northwest Pacific using multiple chemical tracers: interaction between the Kuroshio and surrounding waters." M. Sci. Thesis, University of Toyama.
- Taiki Tanimura (2021), "The distributions and geochemical cycles of Pt in coastal area, Japan", M. Eng. Thesis, Kanazawa University.
- Yudai Sunahara (2021), "Distribution of organic Fe-binding ligands in the Pacific Ocean and East China Sea", M. F. Sc. Thesis, Nagasaki University.
- Yutaka Watanabe (2021), "The role of the southern Sea of Okhotsk on determine chemical properties of Coastal Oyashio water", M. Env. Thesis, Hokkaido University.

GEOTRACES presentations in international conferences

- Escobar M., N. Takahata, K. Shirai, T. Kagoshima, K. Tanaka, H. Obata, and Y. Sano (2020), Helium and CO2 fluxes in Wakamiko caldera, JpGU Meeting 2020, Online Poster, July 2020.
- Fukazawa, T., H. Obata, and K. Norisuye (2020), Development of a method for determination of dissolved Te species in open ocean water. Goldschmidt Conference 2020, Online, June 2020.
- Nishioka, J., H. Obata, and I. Yasuda (2020), Importance of intermediate water formation for supplying iron and macro-nutrient in the North Pacific, Goldschmidt Conference 2020, Online Talk (INVITED), June 2020.
- Norisuye, K. (2020), Distributions of Bi and Pb isotopes in the Sea of Japan, Goldschmidt Conference 2020, Online, June 2020.
- Snyder, G., N. Zhang, S. Bowden, Y. Kakizaki, N. Takahata, K. Tanaka, Y. Sano, and R. Matsumoto (2020), Are Japan Sea gas hydrate chimneys an analogue for potential microbial habitats on Mars and other planets? JpGU Meeting 2020, Online Poster, July 2020.
- Snyder G., A. Yatsuk, N. Takahata, R. Shakirov, Y. Kakizaki, H. Tomaru, K. Tanaka, A. Obzhirov, Y. Sano, and R. Matsumoto (2020), Seawater chemistry and helium isotopes in the Tatar Strait, Far Eastern Federal District, Russia, AGU Fall Meeting 2020, Online Oral, December 2020.
- Yamanaka, K., Y. Kondo, N. Fujita, Y. Sunahara, and H. Obata (2020), Fe redox status and its bioavailability in the East China Sea shelf break area, PICES 2020 Virtual Annual Meeting, Online Poster, October 2020.

Submitted by Yoshiko Kondo (yoshikondo@nagasaki-u.ac.jp).

GEOTRACES relevant scientific results

- The Baja California Peninsula could be an important source of dust and Fe to the Gulf of California during the warm months.

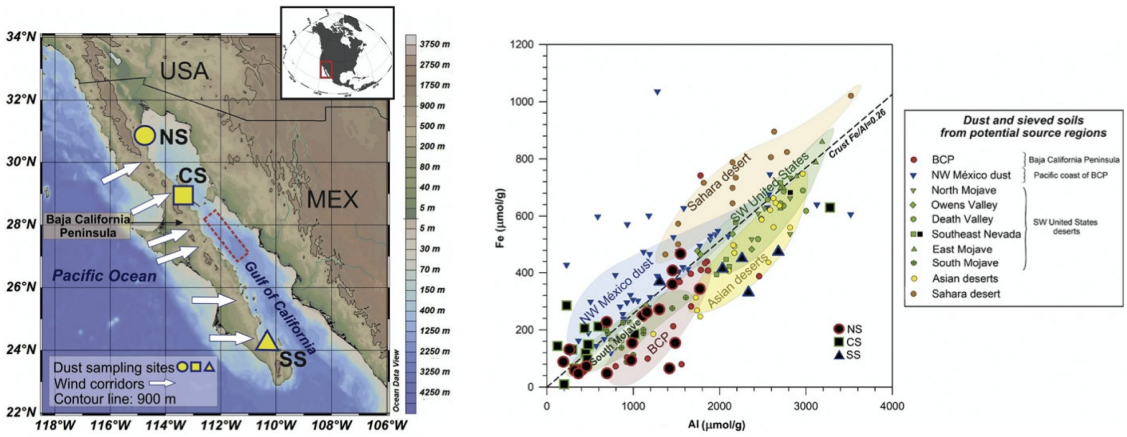


Figure 15: *Iron versus aluminum in dust samples collected at the west coast of the Gulf of California (GC). The shaded areas represent the typical metal composition (Fe and Al) of dust and/or sieved soils from the potential source regions.*

The seasonal and spatial variability of atmospheric mineral dust deposition and Fe fluxes along the west coast of the Gulf of California (GC) were measured. Meteorological data and dust samples, collected from June 2010 to October 2013 at three sites of the eastern side of Baja California Peninsula (BPC), evidenced an across-BCP wind component (W-E) during the warm season (May–September), suggesting that winds crossing the BCP from west to east were an important source of variability. Dust deposition at the northern and center sites were significantly higher during the warm season, revealing that the BCP could be an important source of dust and Fe to the GC during this season. An analysis of the total Fe concentration and Fe/Al ratios also suggest that the BCP and the Mojave Desert are potential sources of the dust arriving to the northern and central region of the GC. Total averages of dust and Fe fluxes were comparable to those reported for other marginal seas (e.g., Mediterranean, Aqaba) similarly influenced by inputs of mineral dust from the surrounding deserts. A comparison between fluxes show that atmospheric soluble Fe inputs are equivalent to between 6 ± 4% (cool season) and 71 ± 40% (warm season) of the dissolved Fe supplied by upwelling. Thereby, during the warm season, when the GC is warmer and strongly stratified, atmospheric deposition represents a significant source of soluble Fe. This supply of Fe would be enough to meet the requirements of N2-fixing primary producers that reside in the oligotrophic surface waters of the GC during summer.

- Mo_D in a hypersaline system showed a non-conservative behavior relative to salinity.

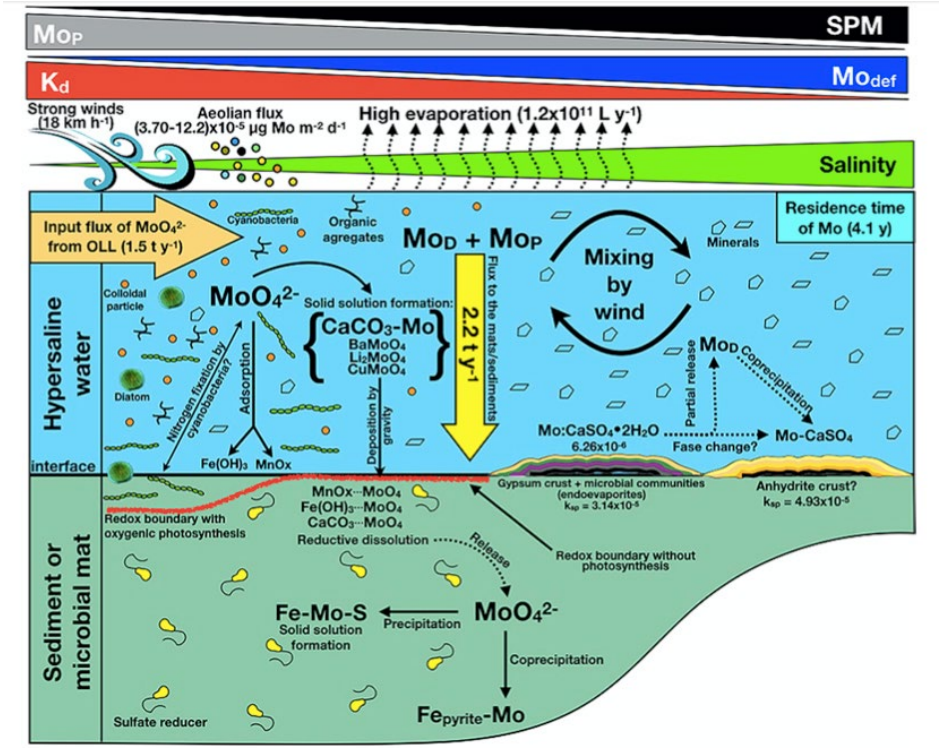


Figure 16: *Conceptual model of the potential Mo removal mechanisms from the hypersaline water column to the sediments and microbial mats examined in the study of Valdivieso-Ojeda et al. (2020) conducted on Ojo de Liebre Lagoon and evaporation ponds of the Guerrero Negro saltern, Baja California Peninsula, Mexico.*

Valdivieso-Ojeda, J.A., Huerta-Diaz, M.A., Delgadillo-Hinojosa, F. (2020). Non-conservative behavior of dissolved molybdenum in hypersaline waters of the Guerrero Negro saltern, Mexico. Applied Geochemistry, 115, 104565. doi: 10.1016/j.apgeochem.2020.104565

Trace metal distribution and speciation studies in hypersaline systems are scarce because of the difficulty in measuring low metal concentrations in high salinity waters. In this study dissolved molybdenum (Mo_D) was measured in samples collected in one of these systems. Mo_D concentrations were well below those predicted from simple seawater evaporation, indicating non-conservative behavior of Mo_D relative to salinity. The magnitude of the removal process was reflected in both the high calculated Mo_D fluxes toward the sediment/microbial mat (2.2 ton yr^{-1}), and the very short residence time of Mo_D (4.1 yr) in the water column of the evaporation ponds. These findings suggest that sediments/microbial mats and also gypsum from current hypersaline environments act as important, but as yet unquantified, Mo_D sinks. Removal of Mo_D in hypersaline environments may have been especially important during the geological past, when these environments were more prevalent and extensive, and thus capable of influencing the global Mo cycle as well as, indirectly, the nitrogen cycle.

Current projects

- Total and pyritic trace metals in sediments applied to the evaluation of paleoredox and paleoenvironmental conditions in marine systems. Project awarded to Universidad Autónoma de Baja California, Mexico. P.I. Dr. Miguel Angel Huerta Díaz (2015-2020).
- Atmospheric fluxes of bioactive metals and their solubility in the Gulf of California: a scene towards climate change. Multidisciplinary project financed by CONACyT (PI: Dr. Francisco Delgadillo Hinojosa; 2015-2020).
- Biological response of phytoplankton community to iron and vitamin B12 and their implication to the formation and presistence of Harmful Algal Blooms in Mexican coastal waters. Multidisciplinary project financed by CONACyT. PI: Dr. Mary Carmen Ruiz de la Torre (2017-2020).
- Mass balance of dissolved iron in Todos Santos Bay, Baja California: Biological responses of phytoplankton and biogeochemical implications. Project awarded by Universidad Autónoma de Baja California, Mexico. PI: Dr. Miguel Ángel Huerta Díaz (2018-2020).

GEOTRACES-relevant publications

- Celis-Hernández, O., Giron-Garcia, M.P., Ontiveros-Cuadras, J.F., Canales-Delgadillo, J.C., Pérez-Ceballos, R.Y., Ward, R.D., Acevedo-Gonzales, O., Armstrong-Altrin, J.S., Merino-Ibarra, M. (2020). Environmental risk of trace elements in mangrove ecosystems: An assessment of natural vs oil and urban inputs. Science of the Total Environment, 730, 138643. https://doi.org/10.1016/j.scitotenv.2020.138643
- Delgadillo-Hinojosa, F., Félix-Bermúdez, A., Torres-Delgado, E. V., Durazo, R., Camacho-Ibar, V., Mejía, A., Ruiz, M.C., Linacre, L. (2020). Impacts of the 2014-2015 warm-water anomalies on nutrients, chlorophyll-a and hydrographic conditions in the coastal zone of northern Baja California. Journal of Geophysical Research: Oceans, 125(12), e2020JC016473. https://doi.org/10.1029/2020JC016473
- Dótor-Almazán A., Gold-Bouchot G., Lamas-Cosío E., Huerta-Diaz M.A., Ceja-Moreno V., Oceguera-Vargas I., Zapata-Pérez O., Arcega-Cabrera F. (2020) Spatial and temporal distribution of trace metals in shallow marine sediments of the Yucatan Shelf, Gulf of Mexico. Bulletin of Environmental Contamination and Toxicology (in press). doi: 10.1007/s00128-021-03170-2.
- Félix-Bermúdez, A., Delgadillo-Hinojosa, F., Torres-Delgado, E. V., & Muñoz-Barbosa, A. (2020). Does sea surface temperature affect solubility of iron in mineral dust? The Gulf of California as a case study. Journal of Geophysical Research: Oceans, 125(9), e2019JC015999. https://doi.org/10.1029/2019JC015999
- García-Orozco, J, Huerta-Diaz, MA, Valdivieso-Ojeda, J, Delgadillo-Hinojosa, F, Mejía-Piña, KG, Árcega-Cabrera, F. (2020). A novel method to measure calcium carbonate with portable X-ray fluorescence instrumentation and its application to Gulf of Mexico surficial sediments. Sedimentary Geology, 105724. doi: 10.1016/j.sedgeo.2020.105724.
- González-De Zayas, R. Rossi, S., Hernández-Fernández, L., Velázquez-Ochoa, R. Soares, M., Merino-Ibarra, M. Castillo-Sandoval, F.S., Soto-Jiménez, M. (2020). Stable isotopes used to assess pollution impacts on coastal and marine ecosystems of Cuba and México.

Regional Studies in Marine Science, 39, 101413. https://doi.org/10.1016/j.rsma.2020.101413
- Muñoz-Barbosa, A, Delgadillo-Hinojosa, F, Torres-Delgado, EV, Félix-Bermúdez, A, Castro, R (2020). Bajacalifornian dust deposition and atmospheric input of iron to the Gulf of California during the summer. Marine Chemistry, 103850. https://doi.org/10.1016/j.marchem.2020.103850
- Ramos-de-la-Cruz, R., Pajares, S., Merino-Ibarra, M., Monreal-Gómez, M.A., Coria-Monter, E. (2021). Distribution of nitrogen-cycling genes in an oxygen-depleted cyclonic eddy in the Alfonso Basin, Gulf of California. Marine & Freshwater Research. https://doi.org/10.1071/MF20074
- Valdivieso-Ojeda, J.A., Huerta-Diaz, M.A., Delgadillo-Hinojosa, F. (2020). Non-conservative behavior of dissolved molybdenum in hypersaline waters of the Guerrero Negro saltern, Mexico. Applied Geochemistry, 115, 104565. doi: 10.1016/j.apgeochem.2020.104565
- Valdivieso-Ojeda, J.A., Huerta-Díaz, M.A., Delgadillo-Hinojosa, F., Otero, X.L., Arenas-Islas, D., García-Orozco, J. (2021). Sediment trace metal levels in the Ojo de Liebre Lagoonal Complex (Baja California, Mexico), a marine wildlife protected area. Marine Pollution Bulletin, 363: 341 –354. doi: 10.1016/j.marpolbul.2021.112097
- Valdivieso-Ojeda J.A., Huerta-Diaz M.A., Delgadillo-Hinojosa F., Otero X.L., Arenas-Islas D. and García-Orozco J. (2021) Sediment trace metal levels in the Ojo de Liebre Lagoonal Complex (Baja California, Mexico), a marine wildlife protected area. Marine Pollution Bulletin, 165, 112097. doi: 10.1016/j.marpolbul.2021.112097.

GEOTRACES PhD and Master theses

- Arenas Islas, Diana (2021) Determination of arsenic and mercury levels in sediments and microbial mats from hypersaline environments: Biogeochemical implications. Ph.D. thesis - Universidad Autónoma de Baja California. (In Spanish)
- Pérez Mendieta, R. (2021). Atmospheric flux of mineral dust and copper to the Gulf of California central region: spatial and temporal variability and implications. M.Sc. thesis - Universidad Autónoma de Baja California. (In Spanish)
- Cervantes Flores, Karla Roxana (2021). Degrees of trace metal pyritization in Gulf of Mexico deep sediments. M.Sc. thesis - Universidad Autónoma de Baja California. (In Spanish)

GEOTRACES presentations in international conferences

- Camacho-Ibar, V.F., Valencia, A., Hakspiel, C., Velasquez, J., Avila-López, C., Muñoz-Anderson, M., Lee, E. Inorganic nutrients in the deep-water region of the Gulf of Mexico: what have we learnt from a baseline study of the CIGoM project. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Cervantes, G., Hernández-Ayón, J.M., Zirino, A., Herzka, S.Z., Camacho-Ibar, V.F., Montes, I., Sudre, J., Delgado, J. A new characterization of the upper waters of the central Gulf of Mexico based on water mass hydrographic and biogeochemical characteristics. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Contreras-Pacheco, Y.V., Herguera, J.C., Herzka, S.Z., Bobadilla, D., Barradas, M.R., Quintanilla, G. Elemental and isotopic composition of particular organic carbon and

nitrogen in the Gulf of Mexico. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA

- Hakspiel, C., Camacho-Ibar, V., Valencia A. Mesoscale drives inorganic nutrient dynamics in two areas of the Mexican off-shore of the Gulf of Mexico. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Hernandez-Ayon, J.M., Delgado, J., Cervantes, G., Tanahara, S., Montes, I., Sudre, J., Herzka, S.Z., Camacho-Ibar, V.F. Increase of Caribbean water incursion into the Gulf of Mexico: The need in biogeochemistry studies of a new characterization of the upper waters of the central Gulf of Mexico. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Lee, E., Camacho-Ibar, V.F., Velasquez, J., Valencia, A. Effect of mesoscale eddies on the vertical distribution of dissolved inorganic nutrients in open waters of the Gulf of Mexico during a warm and a cold season. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Linacre, L., Lara-Lara, R., Mirabal-Gómez, U., Bazan-Guzmán, C. Pico-phytoplankton dynamics during contrasting seasonal conditions in two regions of Gulf of Mexico. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Valencia-Gasti, J.A., Camacho-Ibar, V.F., Hernández-Ayon, J.M., Barbero, L. Outflow of Gulf of Mexico waters below 600 m through the Western Yucatan Channel suggested by biogeochemical tracers and hydrography. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA
- Velasquez, J. Camacho-Ibar, V.F., Lee, E. Valencia, A., Trasviña-Castro, A. Control of mesoscale eddies on the vertical nitrate distribution and the nitracline shape and depth in open ocean waters of the Gulf of Mexico. Ocean Sciences meeting, 16-21 February 2020. San Diego, CA, USA

Contributors to the report

Miguel Angel Huerta-Díaz, Francisco Delgadillo-Hinojosa, Maria Lucila Lares

Submitted by Maria Lucila Lares (llares@cicese.mx).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN THE NETHERLANDS

April 1st, 2020 to April 30th, 2021

New GEOTRACES or GEOTRACES relevant scientific results

- Progress is being made with the interpretation and publication of results from cruises GA04N, ANA08B and PS117
- Sample analyses from cruise ANA08B and PS117, two GEOTRACES Process studies, is being finalised

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

- Ardiningsih, I., Seyitmuhammedov, K., Sander, S.G., Stirling, C.H., Reichart, G.J., Arrigo, K.R., Gerringa, L.J.A. and Middag, R., 2020. Sources of Fe-binding organic ligands in surface waters of the western Antarctic Peninsula. Biogeosciences Discussions, 2020: 1-25 (moderate revisions for final publication submitted.
- Ardiningsih, I., Zhu, K., Lodeiro, P., Gledhill, M., Reichart, G.-J., Achterberg, E.P., Middag, R. and Gerringa, L.J.A., 2021. Iron Speciation in Fram Strait and Over the Northeast Greenland Shelf: An Inter-Comparison Study of Voltammetric Methods. Frontiers in Marine Science, 7(1203).
- van Haren, H., Brussaard, C.P.D., Gerringa, L.J.A., van Manen, M.H., Middag, R. and Groenewegen, R., 2021. Diapycnal mixing across the photic zone of the NE Atlantic. Ocean Sci., 17(1): 301-318Gerringa, L.J.A., Alderkamp, A.-C., van Dijken, G., Laan, P., Middag, R., and Arrigo, K.R., 2020. Dissolved Trace Metals in the Ross Sea. Frontiers in Marine Science, 7(874).
- Neuholz, R., Kleint, C., Schnetger, B., Koschinsky, A., Laan, P., Middag, R., Sander, S., Thal, J., Türke, A., Walter, M., Zitoun, R., and Brumsack, H-J., 2020. Submarine Hydrothermal Discharge and Fluxes of Dissolved Fe and Mn, and He Isotopes at Brothers Volcano Based on Radium Isotopes. Minerals, 10(11):969.
- Menzel Barraqueta, J.-L., Samanta, S., Achterberg, E.P., Bowie, A.R., Croot, P., Cloete, R., De Jongh, T., Gelado-Caballero, M.D., Klar, J.K., Middag, R., Loock, J.C., Remenyi, T.A., Wenzel, B. and Roychoudhury, A.N., 2020. A First Global Oceanic Compilation of Observational Dissolved Aluminum Data With Regional Statistical Data Treatment. Frontiers in Marine Science, 7(468)
- Schine, C.M.S., Alderkamp, A-C., van Dijken, G., Gerringa, L.J.A., Sergi, S., Laan, P., van Haren, H., van de Poll, W., Arrigo, K.R., Massive Southern Ocean phytoplankton bloom fed by iron of possible hydrothermal origin. Nature communications [Paper #NCOMMS-20-07481C]
- Lenstra, W.K., Hermans, M., Seguret, M.J.M., Witbaard R., Severmann, S., Behrends, T. Slomp, C.P. (2020) Coastal hypoxia and eutrophication as key controls on benthic release and water column dynamics of iron and manganese. Limnology and Oceanography. 66, 807–826.
- Hermans, M., M. Astudillo Pascual, T. Behrends, W.K. Lenstra, D. J. Conley, C.P. Slomp. 2021. Coupled dynamics of iron, manganese and phosphorus in brackish coastal sediments populated by cable bacteria. Limnology and Oceanography. https://doi/10.1002/lno.11776

Completed GEOTRACES PhD or Master theses

- Ardiningsih, Indah, 2021. Organic Iron-binding ligands in the Arctic, Antarctic and subtropical Regions. PhD thesis, University of Utrecht, the Netherlands.
- Hermans, Martijn, 2020. Impact of cable bacteria and changes in bottom water oxygen on coastal sediment biogeochemistry. PhD thesis, Utrecht Studies in Earth Sciences, 210, Utrecht University, the Netherlands.

GEOTRACES presentations in international conferences

- Middag, R., Rolison, J.M., George, E., Gerringa, L.J.A., Stirling, C.H.. Basin scale distributions of nickel, zinc and cadmium in the Mediterranean Sea. Poster presentation at the 2021 NAC (Netherlands earth science meeting), 09-04-2021, online, Netherlands.
- Ardiningsih, I., Seyitmuhammedov, K., Sander, S. G., Stirling, C. H., Law, C., Reichart, Gert-Jan., Gerringa, L.J.A., Middag, R.. Organic Fe speciation in the Hauraki Gulf, New Zealand. Poster presentation at the 2021 NAC (Netherlands earth science meeting), 09-04-2021, online, Netherlands.
- Zitoun, R., Achterberg, E.P, Browning, T.J., Hoffmann, L.J., Kirsch, S., Sander, S. G., and Koschinsky, A.. The complex provenance of Cu-binding ligands in the South-East Atlantic. Oral presentation at the 2021 NAC (Netherlands earth science meeting), 09-04-2021, online, Netherlands
- Van Manen, M., Wille, F., Laan, P, Gerringa, L., Reichart G., Tian, H., and Middag, R.. Dissolved and Particulate iron and manganese in the Southern Ocean (Amundsen Sea). Poster presentation at the 2021 NAC (Netherlands earth science meeting), 09-04-2021, online, Netherlands.
- Van Manen, M., Ardiningsih, I., Gerringa, L., Reichart G., Tian, H,, and Middag, R.. Dissolved bio-essential metals in the Lazarev and Weddell Sea. Poster presentation and flash talk at SOOS Weddell Sea-Dronning Maud Land Working Group online workshop, 22-10-2020, online, Germany
- Tian, H., Wille, F., Laan, P., Reichart G., Van Manen, M., and Middag, R.. Biogeochemistry of zinc and cadmium in the Amundsen Sea, Antarctica. Oral presentation at the 2021 NAC (Netherlands earth science meeting), 09-04-2021, online, Netherlands.

Submitted on behalf of all Dutch GEOTRACES participants by Rob Middag (rob.middag@nioz.nl).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN NORWAY

April 1st, 2020 to March 31st, 2021

New GEOTRACES or GEOTRACES relevant scientific results

- See under Publications below

GEOTRACES or GEOTRACES relevant cruises

- Winter cruise in the Barents Sea (bio-essential and toxic element and DOC characterization) 19th Feb to 24th March 2021
- Spring cruise in the Barents Sea (bio-essential and toxic element and DOC characterization) 16th April – 20th May 2021

New Funded projects:

- Norwegian Institute for Water Research (NIVA) and Norwegian University of Science and Technology (NTNU). Bio-essential and toxic elements transformation and transport in the Arctic under pressure of Siberian Continental Shelf permafrost thawing (Funded by the Norwegian Research Council),
- NTNU. Building Capacity to Crosslink Coastal Pollution with Climate Change_BC5, in coastal waters of Ghana & Tanzania (toxic metals and organic pollutants, e-waste (funded by Norwegian Agency for Development Cooperation – Norad)

Other GEOTRACES activities

- The Biogeochemistry group at NTNU led by Dr. Ardelan have strengthened their trace element lab by adding a new DMA-80 and a Brooks Rand total Hg and MeHg determination instruments. They are also acquiring a new triple Quad ICP-MS to be housed in a newly built trace metal clean lab
- The department of chemistry has now hired a new laboratory technician to work on the ICP MS analysis. Kyyas Seyitmuhammedov, has recently obtained his PhD degree from Otago university, under the supervision of Claudine Sterling, Rob Middag and Malcolm Reid.

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

- *1.* Mathew KA, Ardelan MV, Gonzalez SV, Vadstein O, Veena S V, Leiknes Ø,. Olsen Y. (2021). Seasonal dynamics of carbon sequestration in coastal temperate Atlantic waters using molecular characterisation of dissolved organic matter. https://doi.org/10.1016/j.scitotenv.2021.146402.
- 2. Rios-Yunes, D, Santiago ARB, Mathew KA, Gonzalez SV, Ciesielski TM, Asimakopoulos AG; Ardelan MV. (2021) Potential effect of CO2 seepage at high pressure on the marine organic matter. Accepted- in International Journal of Greenhouse Gas Control. 106: 103276, https://doi.org/10.1016/j.ijggc.2021.103276
- 3. Bonnail, E. et al-, ... Ardelan, MV. (2021) Climate change mitigation effects: How do potential CO2 leaks from a sub-seabed storage site in the Norwegian Sea affect Astarte sp. bivalves? Chemosphere, 264, Part 2, 2021,128552,https://doi.org/10.1016/j.chemosphere.2020.128552.

- Hunnestad, A.V.; Vogel, A.I.M.; Armstrong, E.; Digernes, M.G.; Ardelan, M.V.; Hohmann-Marriott, M.F. (2020) From the ocean to the lab - assessing iron limitation in cyanobacteria: an interface paper. Microorganisms. https://doi.org/10.3390/microorganisms8121889.
- Hunnestad, A.V.; Vogel, A.I.M.; Digernes, M.G.; Ardelan, M.V.; Hohmann-Marriott, M.F. (2020). Iron Speciation and Physiological Analysis Indicate that Synechococcus sp. PCC 7002 Reduces Amorphous and Crystalline Iron Forms in Synthetic Seawater Medium. J. Mar. Sci. Eng. 8, 996. https://doi.org/10.3390/jmse8120996
- Borrero-Santiago, A.R., Netzer, R., Bonnail, E., Ribicic, D.; Koseto, D., Ardelan, M.V. (2020). Response of bacterial communities in Barents Sea sediments in case of a potential CO2 leakage from carbon reservoirs. Marine Environmental Research. 160: 105050, https://doi.org/10.1016/j.marenvres.2020.105050.

GEOTRACES presentations in international conferences

- Seasonal scavenging of inorganic mercury during transition to Arctic polar night. Stephen G. Kohler, Lars-Eric Heimburger-Boavida, Mariia V. Petrova, Murat V. Ardelan. Arctic Frontiers 2021 conference presentation.

Submitted by Nicolas Sanchez (nicolas.sanchez@ntnu.no).

New GEOTRACES or GEOTRACES relevant scientific results

- The monitoring of the trace metals (Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb) delivery via Vistula river, southern Baltic Sea. Samples are collected from the bridge in Kiezmark (Fig. 17).

- The monitoring of the seasonal changes of concentrations of the trace metals (Cr, Mn, Co, Ni, Cu, Zn, Cd, Pb) in the surface seawater, of the Gulf of Gdańsk, southern Baltic Sea. Samples are collected from the pier in Sopot (Fig. 17).

Figure 17: *Sampling sites.*

- The measurement of Fe and Mn return fluxes from the Baltic Depths (Gotland Deep, Gdańsk Deep, and Bornholm Deep) within the DiSeDOM project.

GEOTRACES or GEOTRACES relevant cruises

- 4 research cruises were organized in order to measure Fe and Mn return fluxes by r/v OCEANIA the property of the Institute of Oceanology Polish Academy of Sciences.

New projects and/or funding

- ArcticSGD - SUBMARINE GROUNDWATER DISCHARGE IN A CHANGING ARCTIC REGION: SCALE AND BIOGEOCHEMICAL IMPACT, 2020-2023, (Beata Szymczycha – Principal Investigator, The Institute of Oceanology Polish Academy of Sciences;). Arctic SGD is a Polish-Norwegian project which aims to investigate SGD (submarine groundwater discharge) around Svalbard and northern Norway. The knowledge gained from the study will provide baseline information on the environmental impact of SGD, which is crucial for predictions in a changing Arctic.

http://arcticsgd.iopan.pl/en/home

- ASSEMBLE PLUS project. Prof. Dr. Michael E. Böttcher, MSc. Catia Milene Ehlert and Dr. Beata Szymczycha working on the SGD in the Bay of Puck, southern Baltic Sea.

- DiSeDOM - Estimation of diffusion coefficient of dissolved organic matter from sediments to overlying waters through relationships between its optical and chromatographic characteristics and dissolved iron in Baltic Sea deeps, 2020-2023 (Piotr Kowalczuk – Principal Investigator, The Institute of Oceanology Polish Academy of Sciences).

GEOTRACES workshops and meetings organized

- ArcticSGD kick-off meeting (23.11.2020- 24.11.2020) (1 PhD- student).

Outreach activities conducted

- ArcticSGD newsletter https://mailchi.mp/049c4ba3301b/arcticsgd-project-newsletter-no01

Submitted by Beata Szymczycha (beat.sz@iopan.gda.pl).

New GEOTRACES relevant scientific results

Eurasian Arctic Shelf Seas

- River plumes in estuaries and deltas have very large synoptic and seasonal variability, which cannot be reconstructed from structure of bottom sediments due to their small accumulation velocity. However, the geochemical properties of bottom sediments can be indicative of variability of river plumes on inter-annual and decadal time scales. The large Ob and Yenisei buoyant plumes formed in the central part of the Kara Sea interact and mix in the area adjacent to the closely located Ob and Yenisei gulfs. Suspended sediments carried by these river plumes have different geochemical characteristics that can be used to detect Ob or Yenisei origin of bottom sediments. Using new geochemical methods we revealed dependence between spreading patterns of these plumes and spatial distribution and vertical structure of bottom sediments in the study area (Fig. 18). The mineral sedimentary material of the Ob origin found in the bottom sediments of the Yenisei Gulf also indicates the possibility of adding radioactive contamination from the Ob catchment area to the pollution of the Yenisei Gulf (Osadchiev et al., 2019).

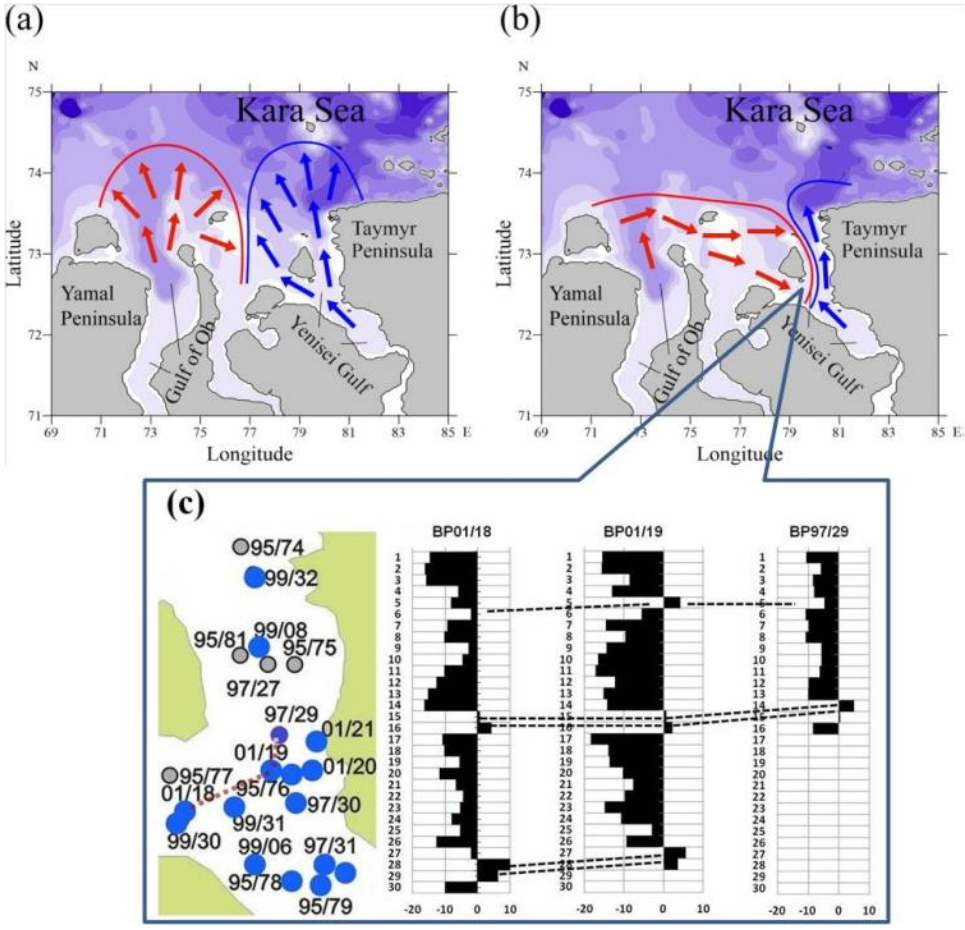


Figure 18: (a) & (b) – *the general patterns of the interaction between the Ob (red) and Yenisei (blue) plumes: northward spreading and offshore collision of the plumes (**a**); eastward intrusion of the Ob plume into the Yenisei Gulf and isolation of the Yenisei plume (**b**).* ***(c) –*** *sediment cores collected in the Yenisei Gulf area where clastic material from the Ob River was geochemically detected and depth/time correlation was established in bottom sediments.*

- Repeated core sampling of bottom sediments at key points of areas of increased radiocaesium activity in the Kara Sea and subsequent analysis of the distribution of radionuclides made it possible to establish positive trends in the change in the radiation state of the region's ecosystem. Almost complete degradation of the Ob Estuary radiocaesium contaminated zone and a rather significant degradation of the same Yenisei Gulf zone (initially the most polluted) were revealed (Miroshnikov et al., 2020a).

- Insoluble particles in the snowpack of the Kara Sea catchment area (the Western Siberia) were studied at 36 sites on a 2800 km submeridional profile from the city of Barnaul to Salekhard along the Ob River and its tributaries in February 2020 (Fig. 19). Snow samples were collected over the full depth of the snow core, from the surface of the snow cover to the boundary with soil, except for the lower 1–2 cm. After the filtration of melted snow through a 0.45 µm-membrane, the particle composition was studied using a scanning electron microscope with an Energy microprobe. In the background areas, the concentration of insoluble particles in the snow was below 2 mg/L. Significantly higher particle concentrations were encountered near cities and hydrocarbon production areas. Particulate matter in snow mainly consists of biogenic and lithogenic particles mixed with anthropogenic particles (ash and black carbon aggregates). The proportion of anthropogenic particles increases near cities and areas of active hydrocarbon production (Shevchenko et al., 2020).

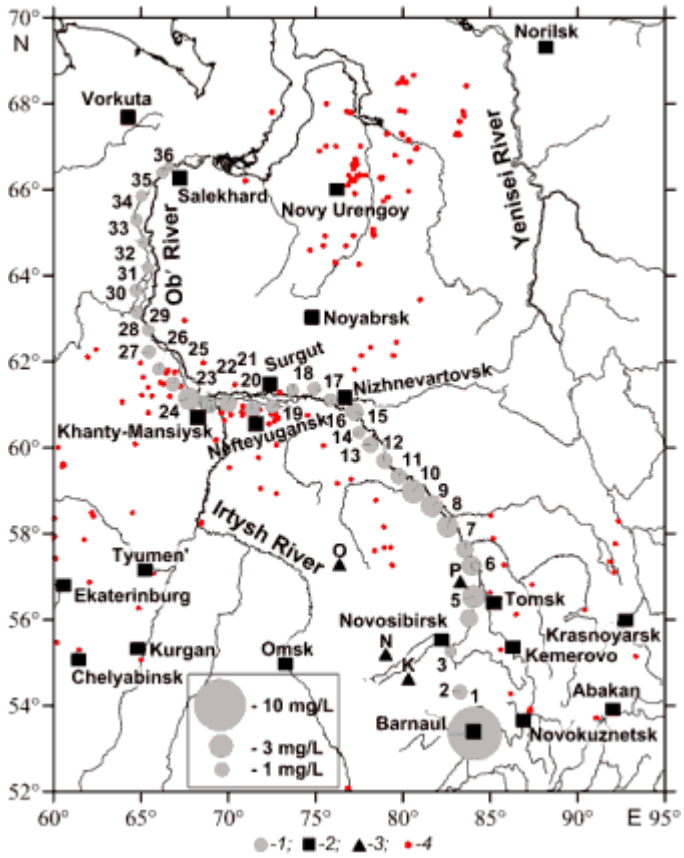


Figure 19: *Concentration of insoluble particles in the snowpack of the Kara Sea catchment area (the Western Siberia, Russia) along the Ob River and its tributaries in February 2020 [Shevchenko et al., 2020]: 1—positions of the sampling sites (sizes of circles reflect the concentrations of particulate matter); 2—large cities; 3—sites of snowpack studies in (Ermolov et al., 2020); 4—the positions of gas flaring taken from https://firms.modaps.eosdis.nasa.gov/download/.*

- The concentrations of the artificial radinuclides and sedimentation rates were determined in the recent sediments of the Bear Island Trough, the Cambridge Strait (Franz Josef Land), and Russkaya Gavan' Bay (Novaya Zemlya Archipelago), Barents Sea (Fig. 20). The concentration of ^{137}Cs in sediments is low and does not exceed 10 Bq/kg, that corresponds to the regional background values. The highest activity levels were found near the Franz Josef Land. Moreover, the samples contain appreciable amounts of ^{241}Am, up to 2.6 Bq/kg. The highest sedimentation rates (> 4 mm/year) were found in Russkaya Gavan' Bay (st. 5424, the Novaya

Zemlya Archipelago), slightly lower ones (2.5 mm/year), in the Cambridge Strait (st. 5454, the Franz Josef Land). In the western part of the Barents Sea (st. 5432), the Bear Island Trough, the much lower sedimentation rate was detected (1.3 mm/year) (Demina et al., 2020).

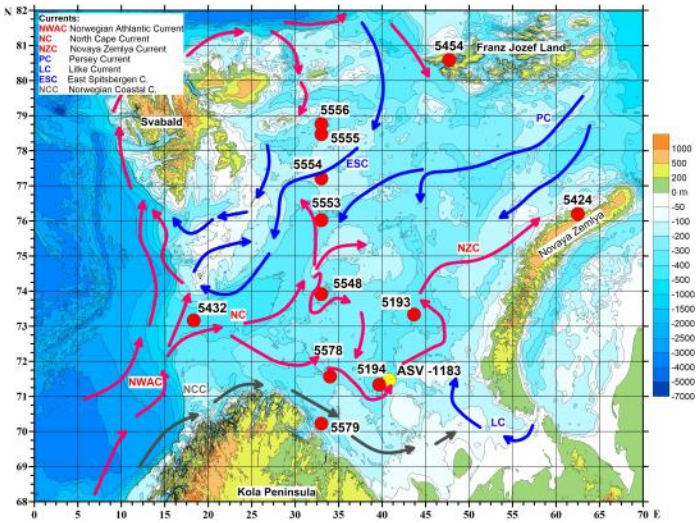


Figure 20: *Scheme of location of studied sediment cores and directions of surface currents in the Barents Sea. Red and blue arrows mean relatively warm and cold currents respectively.*

- Elemental and mineral proxies were tested for recognizing recent change in the environmental conditions in the Barents Sea. Three cores of the recent sediments (age did not exceed 140 years, length to 33 cm) were studied (Demina et al., 2020). Along with the mean sedimentation rates, these sediments differ in grain-size and mineral composition, as well as elemental contents. These characteristics are obviously related to different sediment source: the basaltic province associated with trap magmatism of the Franz Josef Land, and the sedimentary rocks of the Novaya Zemlya Archipelago, while sediments from the Bear Island Trough are deposited under unstable conditions of bottom currents bearing sedimentary material from both the Atlantic and Arctic oceans. The most intense sediment deposition in the Russkaya Gavan' Bay is reflected in the highest sedimentation rates, leading to weak particle differentiation. As a result, throughout the core of the Russkaya Gavan' Bay, mineral composition, as well as values of Si/Al, Mn/Fe, P/Al, and Ti/K ratios are lowered and almost invariable (Fig. 21), accompanied by elevated values of the quartz-feldspar Q/Fps ratio (1.05–1.79).

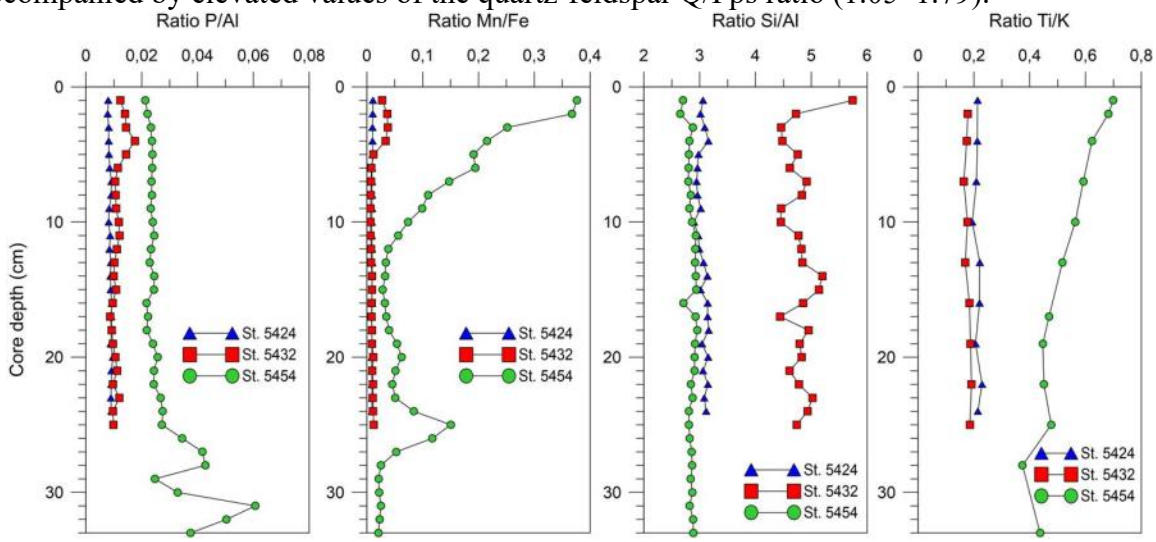


Figure 21: *Comparison of selected elemental ratios in sediment cores collected in the Barents Sea: st. 5424, the Russkaya Gavan' Bay, Novaya Zemlya Archipelago; st. 5432, the Bear Island Trough, and st. 5454, the Cambridge Strait, Franz Josef Land Archipelago.*

The sediments of the Bear Island Trough with the low sedimentation rate and strongly elevated coarse-grained fraction, in contrast, are characteristic by the much higher Si/Al indices, showing rhythmic variation, along with the weak change in Mn/Fe, P/Al, and Ti/K ratios down the core. Unlike these, in the Cambridge Strait, the low value of Q/Fps (0.4–1.2), along with the lowered Si/Al and strongly elevated Mn/Fe, P/Al, and Ti/K ratios, indicate an insignificant supply of the clastic material and enlarged contribution of the weathered basaltic rocks. Besides, the downcore distribution pattern of Mn/Fe, P/Al, and Ti/K ratios differs from that in the Bear Island Trough and Russkaya Gavan' Bay. For this reason, these three ratios have been proposed as good proxies for detecting the differences in the short-term change in sedimentation environment (Demina et al., 2020).

- In the East Siberian Sea the γ-spectrometric analysis found that the existed specific activity of artificial cesium-137 in sediments is two orders of magnitude below the acceptable level and reflects the influence of global fallout from the atmosphere only. Sediments are not contaminated with heavy metals either. The data obtained can be considered as initial background values for subsequent monitoring of the ecological state of the East Siberian Sea (Miroshnikov et al., 2020b).

- Sources of surface bottom sediments in the eastern part of the East Siberian Sea were reconstructed based on geochemical data. Studies were carried out along the profile stretching 550 km from Billings Point towards the underwater Mendeleev Ridge (Fig. 22). It was found that the studied set of samples for the values of Cr/Th, Th/Co, La/Sc, as well as Eu/Eu* and $(Eu/Sm)_N$, consists of two groups. On the diagrams $(La/Yb)_N$–Eu/Eu* and $(La/Yb)_N$–(Eu/Sm)N, the obtained data points are located in the overlap zone.

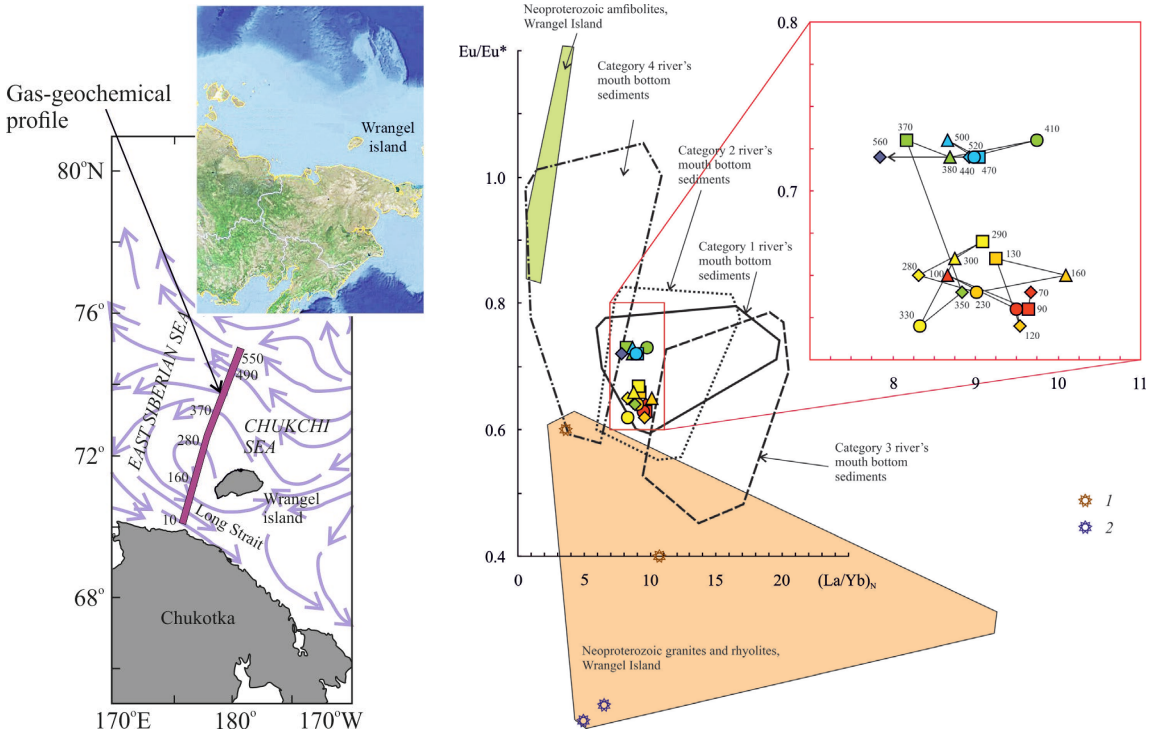


***Figure 22**. The studied transect location (left). The arrows show the surface water circulation. Distribution of data points of sediment samples collected along the transect on the $(La/Yb)_N$–Eu/Eu* diagram (right): 1 – muscovite granites; 2 – rhyolites.*

The distribution of the data points of bottom sediments on these diagrams, as well as on the $(La/Yb)_N$–Th diagram, differs from the distribution of data points of the Neoproterozoic amphibolites, granitoids, and rhyolites of Wrangel Island. Therefore, the latter, most likely, could not be sources of thin aluminosiliciclastics. The samples of the first group are quite close

to the surface sediments of the East Siberian Sea in terms of Eu/Eu* and $(Eu/Sm)_N$ values and a number of other parameters. On the contrary, the samples of the second group are closer to the bottom sediments of the Chukchi Sea. Apparently, the bottom sediments northwest of Wrangel Island were formed under the influence of currents carrying clastic material from the Chukchi Sea. To the west of Wrangel Island, the composition of the sediments is controlled mainly by material coming from the western and central regions of the East Siberian Sea (Maslov, 2021).

- The intensive annual blooms of *Emiliania huxleyi* found every summer in the southern Barents Sea (data of 2014–2018). The blooms were recorded in the upper mixed layer in July and August every year, during which they spread to cover large areas and were associated with Atlantic water. The transformation of Atlantic water in the Barents Sea in the *E. huxleyi* bloom areas is associated with a decrease in dissolved inorganic nitrogen (DIN) concentrations in surface waters. In contrast, the Si and P concentrations remain unchanged. These blooms typically occur in the presence of water column stratification, low Si and DIN concentrations, and relatively high P concentrations, and DIN:P ratio significantly below the Redfield ratio. The results of our study most greatly support hypothesis that *E. huxleyi* is a good competitor at low DIN concentrations since these conditions limit diatom growth. The seasonal thermoclines are essential for decreasing DIN flux to the upper mixed layer. The absence of diatoms and the presence of large cell mixotroph dinoflagellates create a simple community with a high rate of nutrients turnover (Silkin et al., 2020).

Far Eastern seas

- The radium quartet ^{224}Ra, ^{223}Ra, ^{228}Ra ^{226}Ra with half-lives of 3.6 and 11.5 days, 5.7 and 1600 years, respectively, was used to identify the sources of water discharge at the biogeochemical test site "Estuary of the Razdolnaya River", Amur Bay, Sea of Japan (Semkin et al., 2021). Dissolved radium isotopes determined using a delayed coincidence system (RaDeCC, USA). In the winter season (Fig. 23), a high activity of the radium quartet was discovered at a distance of more than 15 km from the mouth bar upstream. This is caused by groundwater discharge (GWD). The activity of radionuclides in the GWD area was as follows: ^{224}Ra − 66.32 ± 0.60 dpm $100L^{-1}$, ^{223}Ra − 2.85 ± 0.17 dpm $100L^{-1}$, ^{226}Ra − 61.12 ± 2.69 dpm $100L^{-1}$, ^{228}Ra − 159.15 ± 0.13 dpm $100L^{-1}$. Also GWD accompanied by the temperature anomaly and thawing of ice in the river/sea mixing zone area. The composition

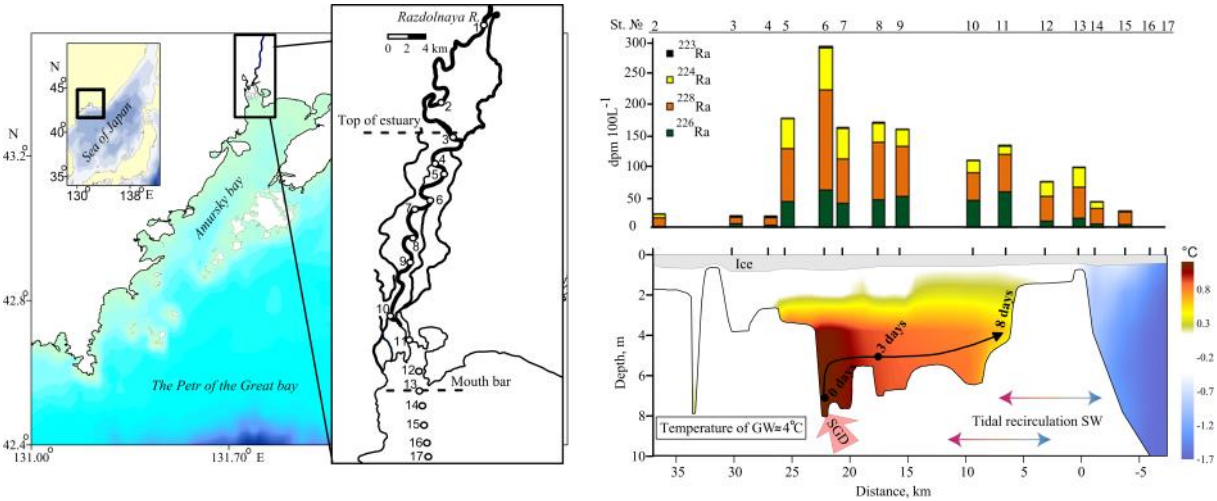


***Figure 23**: Layout and numbers of stations in the winter season. Activity of radium isotopes, water temperature and age (days) calculated for radium in the longitudinal profile of the Razdolnaya River Estuary, Amur Bay, the northwestern part of the Sea of Japan.*

of stable isotopes $\delta^{18}O$ and δD in the discharge zone is subject to the sea water/river water ratio. It is considered that the main reason for GWD is that recirculated sea water has penetrated into the upper aquifer during the winter runoff low period and further discharged into the deepest section line of the estuary.

In the summer (Fig. 24), the high activity of radionuclides was in the area of the mouth bar. The activity of ^{224}Ra, ^{223}Ra, ^{228}Ra increased by 4, 17, and 139 times, respectively, in the area compared with their activity in river water. The ^{228}Ra maximum is associated with desorption from particulate matter carried by the river. The maximum ^{224}Ra (65.41±0.68 dpm 100 L^{-1}), and high activity of ^{223}Ra observed in near-bottom waters with a low concentration of particulate matter. The enrichment of the bottom water layer with ^{224}Ra isotopes, in the area of the estuarine seashore, is associated with bioirregation and bioturbation. Thus, in summer, desorption from river particulate matter in the area of the mouth bar was the source of the dissolved isotopes ^{228}Ra. The exchange of pore waters with near-bottom waters caused an extremum of ^{224}Ra and an increase activity of ^{223}Ra (Semkin et al., 2021).

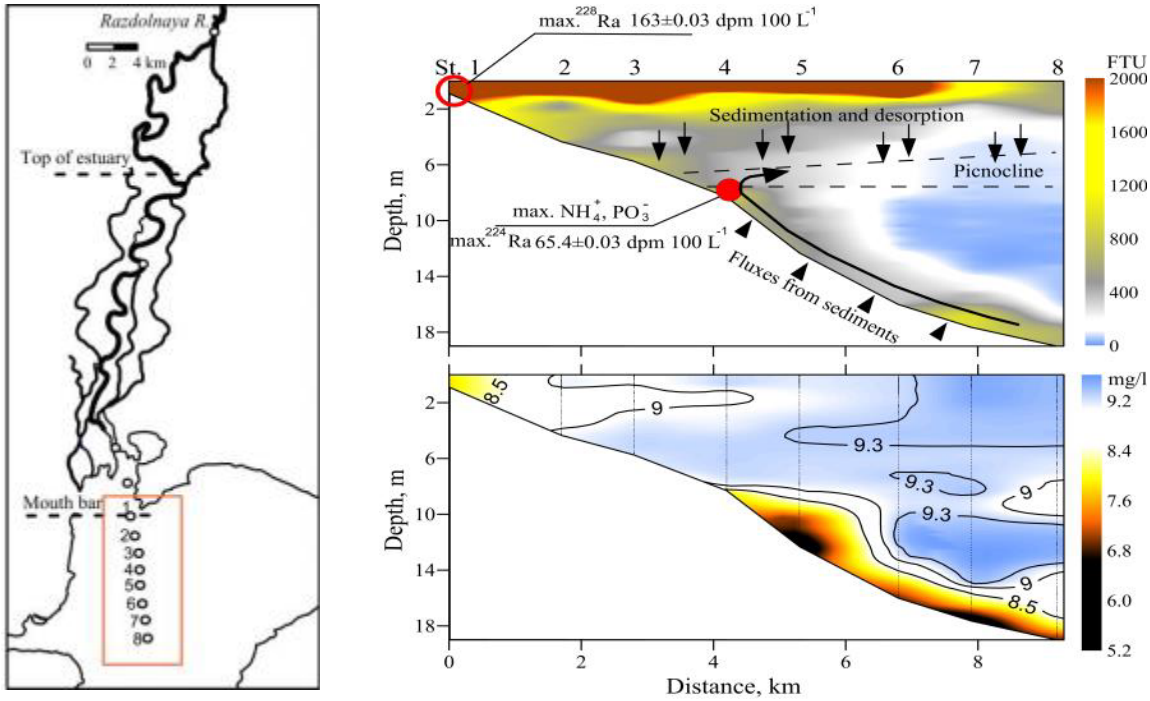


Figure 24: *Layout and numbers of stations in the flood regime of the Razdolnaya River Estuary, Amur Bay, the northwestern part of the Sea of Japan. Distribution of turbidity, oxygen concentration, and location of extremums of radium isotopes at the estuarine seashore.*

Atlantic Ocean

- Paleoceanographic and geochemical record for the last ~250 kyr of the sediment core from the southwestern Lofoten Basin (Norwegian Sea) is carried out using X-ray fluorescence spectrometer Geotek core logging system (Fig. 25). We revealed four global cooling stages (MIS 2, 4, 6, 8) and four warming stages (MIS 1, 3, 5, 7). The IRD grains marked the iceberg influence during the stages MIS 2–4 and MIS 6 that corresponded to the magnetic susceptibility data. Si/Al ratio used as a proxy for biogenic production and changes in the composition of aluminosilicate. The Si/Al ratio marks changes in the grain size composition with maxima corresponding to the increasing of sandy fraction content. In the Vedde ash interlayer (12.6 kyr), the increase of Si/Al and Sr/Ti ratios does not depend on the coarse-grained fraction of sediment. Ca/Ti ratio record shows higher values matching each interglacial stage in the Loften Basin sediments. The highest values of Ca/Ti ratio belong to the end of cooling stage MIS 4 and warming stages MIS 5–5e and correspond to the maximum of the total plankton and benthic foraminifer's concentrations. Therefore, the elemental ratios along with grain size and micropaleontological data show at least tree hiatus during the last 250 kyr sedimentation in the Lofoten Basin. The iceberg sedimentation in this area continued until the 10.4 kyr with a reduction during the MIS 5–5e stage while the biogenic carbonate production has peaked (Novichkova et al., *in preparation*).

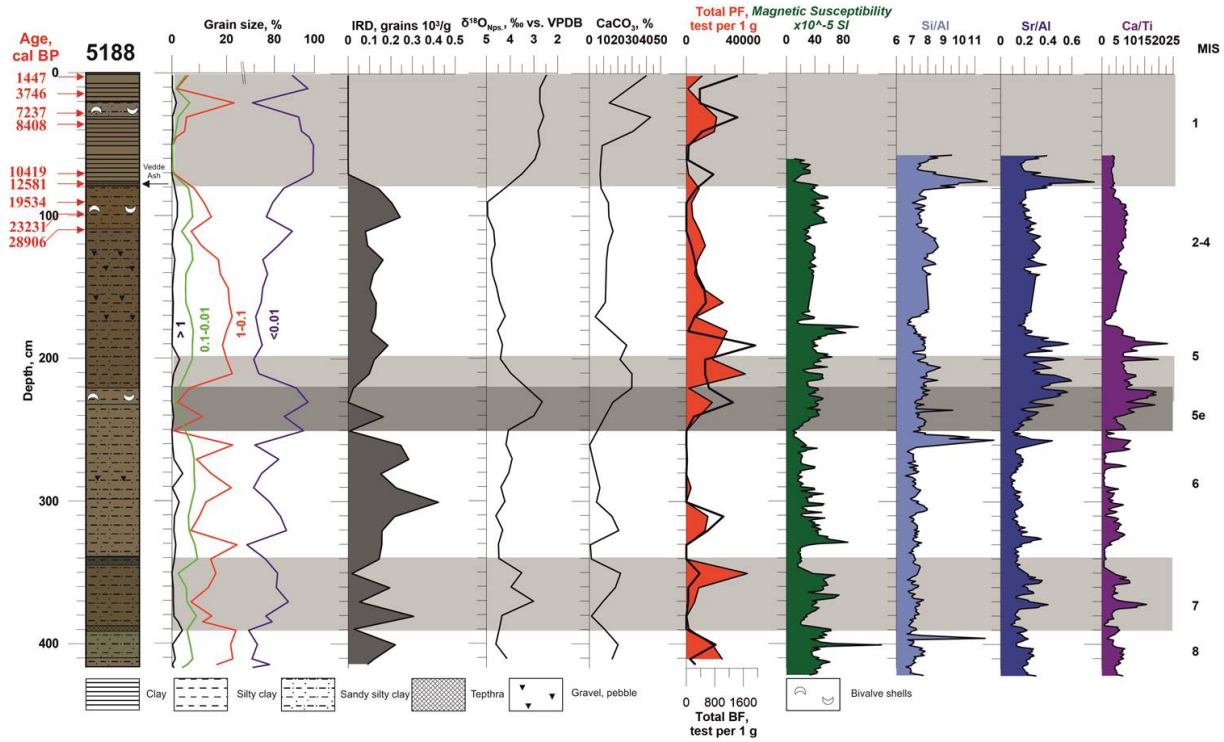


Figure 25: *The downcore distribution of grain size, IRD content, oxygen isotope values, calcium carbonate, and organic carbon content, as well as, total abundances of the planktic and benthic foraminifera, magnetic susceptibility, and Si/Al, Sr/Al, Ca/Ti ratios, Lofoten Basin, Norwegian Sea.*

GEOTRACES relevant cruises

- From July 31 to August 26, 2020, multidisciplinary studies of the European Arctic were carried out during cruise 80 of the RV *Akademik Mstislav Keldysh* (PhD Alexey Klyuvitkin is a cruise leader) (Fig. 26). The cruise was funded by State Tasks of the Shirshov Institute of Oceanology, Russian Academy of Sciences (IO RAS). The studies were performed in the Norwegian and Barents seas, and Nansen Basin (Klyuvitkin et al., 2021). Some of the preliminary results: (i) in the sea-ice edge zone of the deep-water region of the high Arctic (Nansen basin, 83 °N), in the summer of 2020, a bloom of the large-cell centric diatom *Porosira glacialis* was found with an abnormally high biomass (Pautova et al., *submitted*). The bloom was close to the surface (5–10 m) at the halocline separating the nutrient-rich Atlantic waters from the nutrient-poor Arctic waters. The presence of this Atlantic diatom, in a complex hydrographic structure formed by the interaction of warm Atlantic and cold Arctic water masses, provides clear evidence of atlantification of high Arctic ecology. (ii) New areas of possible methane seepage with a pronounced atmospheric response have been investigated in the Russian part of the Barents Sea. *(iii)* Expansion of *coccolithophore bloom* in the southern Barents Sea was investigated and their role in biological carbon pump was studied.

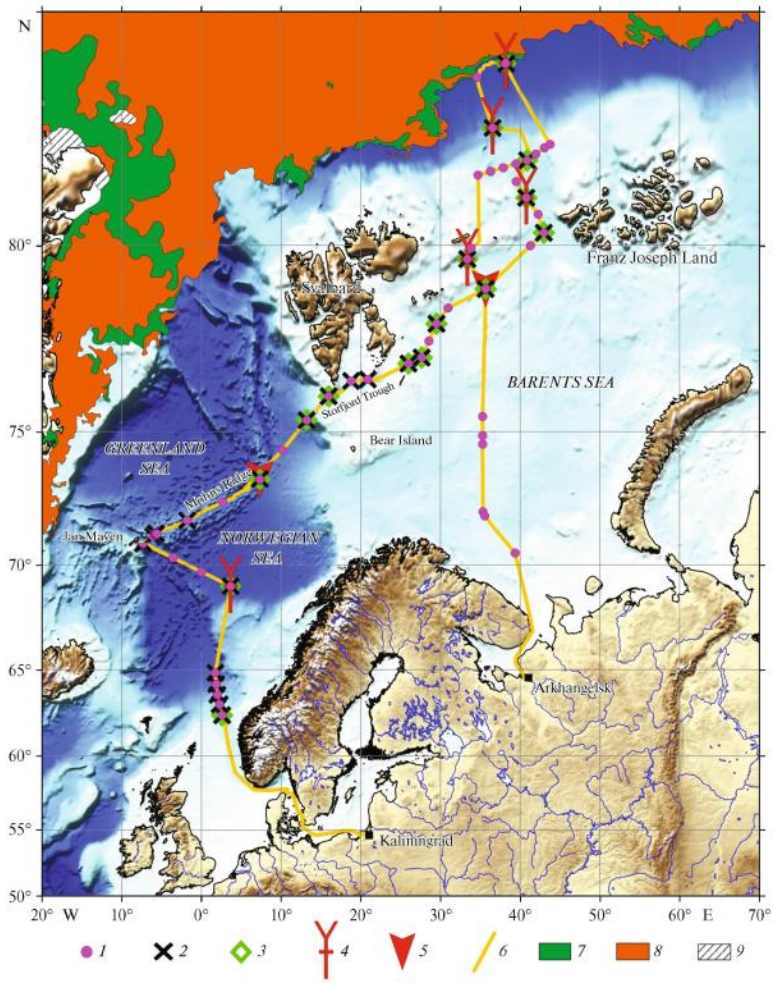


Figure 26: *Expedition route and works performed during cruise, July–August 2020. Image of the ice cover is composited over August 16–18, 2020, provided by State Research Center "Arctic and Antarctic Research Institute": http://www.aari.ru/odata/_d0015.ph. 1 – stations; 2 – grab sampling of bottom sediments; 3 – multicorer sampling of bottom sediments; 4 – gravity corer sampling of bottom sediments; 5 – recovering/ /deployment of sediment traps; 6 – route of vessel; 7 – ice concentration, 1–6 points; 8 – ice concentration, 7–10 points; 9 – fast ice.*

New projects and/or funding

- "Response of the estuarine ecosystem of the transboundary Razdolnaya River (Primorsky Region of the Russian Federation) to the discharge of groundwater of the upper aquifer", *Grant of the President of the Russian Federation* (no. MK-153.2020.5). Pavel Yu. Semkin is project leader, early career researcher, Department Ocean Geochemistry and Ecology, V.I. Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russia. URL: https://www.minobrnauki.gov.ru/grants/?ELEMENT_ID=9468

New GEOTRACES-relevant publications (published or in press)

- Agafonova, E., Polyakova, Y., & Novichkova, Y. (2020). The diatom response to Postglacial environments in the White Sea, the European Arctic. Marine Micropaleontology, 161. https://doi.org/10.1016/j.marmicro.2020.101927 1 ECR involved in the publication
- Budko, D. F., Demina, L. L., & Lisitzin, A. P. (2021). The heavy metal partitioning in the particle flux of the subarctic White Sea (Northwestern Russia). Estuarine, Coastal and Shelf Science, 249. https://doi.org/10.1016/j.ecss.2020.107063 1 ECR involved in the publication
- Demina, L. L., Dara, O., Aliev, R., Alekseeva, T., Budko, D., Novichkova, E., … Bulokhov, A. (2020). Elemental and mineral composition of the barents sea recent and late pleistocene−holocene sediments: A correlation with environmental conditions. Minerals, 10(7). https://doi.org/10.3390/min10070593 2 ECRs involved in the publication

- Drits, A.V., Klyuvitkin, A.A., Kravchishina, M.D., Karmanov, V.A., Novigatsky, A.N. (2020). Fluxes of sedimentary matter in the Lofoten Basin of the Norwegian Sea: seasonal dynamics and the role of zooplankton. Oceanology, 60(4), 501–517, https://link.springer.com/article/10.1134/S0001437020040074 1 ECR involved in the publication
- Golobokova, L. P., Khodzher, T. V., Izosimova, O. N., Zenkova, P. N., Pochyufarov, A. O., Khuriganowa, O. I., … Shevchenko, V. P. (2020). Chemical Composition of Atmospheric Aerosol in the Arctic Region and Adjoining Seas along the Routes of Marine Expeditions in 2018–2019. Atmospheric and Oceanic Optics, 33(5), 480–489. https://doi.org/10.1134/S1024856020050085 1 ECR involved in the publication
- Klyuvitkin, A. A., Kravchishina, M. D., & Boev, A. G. (2021). Particle Fluxes in Hydrothermal Vent Fields of the Southern Part of the Mohns Ridge. Doklady Earth Sciences, 497(1), 200–205. https://doi.org/10.1134/S1028334X21030053
- Klyuvitkin, A. A., Politova, N. V., Novigatsky, A. N., & Kravchishina, M. D. (2021). Studies of the European Arctic on Cruise 80 of the R/V Akademik Mstislav Keldysh. Oceanology, 61(1), 139–141. https://doi.org/10.1134/S0001437021010094
- Klyuvitkin, A.A., Kravchishina, M.D., Nemirovskaya, I.A., Baranov, B.V., Kochenkova, A.I., Lisitzin, A.P. (2020). Studies of sediment systems of the European Arctic during the 75th cruise of the Research Vessel Akademik Mstislav Keldysh. Oceanology, 60(3), 421–423. https://link.springer.com/article/10.1134/S0001437020030030 1 ECR involved in the publication
- Kopeikin, V. M., Shevchenko, V. P., Malafeev, G. V., Novigatsky, A. N., Pankratova, N. V., Ya Ponomareva, T., … Yu Churakova, E. (2020). The black carbon content variations in the Arctic region during 2011 - 2018. In IOP Conference Series: Earth and Environmental Science (Vol. 606). IOP Publishing Ltd. https://doi.org/10.1088/1755-1315/606/1/012024
- Lokhov, A. S., Kravchishina, M. D., Klyuvitkin, A. A., & Kochenkova, A. I. (2020). In situ Measurements of the Characteristics of Suspended Particles in the Barents Sea by the LISST-Deep Laser Diffractometer. Oceanology, 60(5), 650–663. https://doi.org/10.1134/S0001437020050148 2 ECRs involved in the publication
- Maslov A.V. (2021). Sources of Bottom Sediments in the East part of Eastern Siberian Sea (Reconstruction on Geochemical Data). Oceanology, in press.
- Miroshnikov, A. Y., Flint, M. V., Asadulin, E. E., & Komarov, V. B. (2020a). Radiation-Geochemical Stability of Bottom Sediments in the Ob and Yenisei Estuaries and Adjacent Shoal Area of the Kara Sea. Oceanology, 60(6), 817–830. https://doi.org/10.1134/S0001437020060065 2 ECRs involved in the publication
- Miroshnikov, A. Y., Flint, M. V., Asadulin, E. E., Kravchishina, M. D., Luksha, V. L., Usacheva, A. A., … Komarov, V. B. (2020b). Ecological State and Mineral-Geochemical Characteristics of the Bottom Sediments of the East Siberian Sea. Oceanology, 60(4), 518–531. https://doi.org/10.1134/S0001437020040141 2 ECRs involved in the publication
- Nemirovskaya, I. A. (2020). Natural and Anthropogenic Hydrocarbons in Seawater and Bottom Sediments of the Black Sea. https://doi.org/10.1007/698_2020_476
- Nemirovskaya, I. A., & Shevchenko, V. P. (2020). Organic compounds and suspended particulate matter in snow of high latitude areas (arctic and antarctic). Atmosphere, 11(9). https://doi.org/10.3390/atmos11090928

- Novigatsky, A. N., Lisitzin, A. P., & Klyuvitkin, A. A. (2020). Dispersed Sedimentary Matter in the Marine Cryosystem: Snow–Drifting Ice–Icewater of the Arctic and Antarctic. Oceanology, 60(5), 643–649. https://doi.org/10.1134/S0001437020050185
- Novigatsky, A. N., Lisitzin, A. P., & Klyuvitkin, A. A. (2020). Dispersed Sedimentary Matter in the Marine Cryosystem: Snow–Drifting Ice–Icewater of the Arctic and Antarctic. Oceanology, 60(5), 643–649. https://doi.org/10.1134/S0001437020050185
- Novigatsky, A. N., Lisitzin, A. P., Shevchenko, V. P., Klyuvitkin, A. A., Kravchishina, M. D., & Politova, N. V. (2020). Sedimentogenesis in the White Sea: Vertical Fluxes of Suspended Particulate Matter and Absolute Masses of Bottom Sediments. Oceanology, 60(3), 372–383. https://doi.org/10.1134/S0001437020030078
- Osadchiev, A. A., Asadulin, E. E., Miroshnikov, A. Y., Zavialov, I. B., Dubinina, E. O., & Belyakova, P. A. (2019). Bottom Sediments Reveal Inter-Annual Variability of Interaction between the Ob and Yenisei Plumes in the Kara Sea. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-019-55242-3 1 ECR involved in the publication
- Sakerin, S. M., Zenkova, P. N., Kabanov, D. M., Kalashnikova, D. A., Lisitzin, A. P., Makarov, V. I., … Shevchenko, V. P. (2020). Results of Studying Physicochemical Characteristics of Atmospheric Aerosol in the 71st Cruise of RV Akademik Mstislav Keldysh. Atmospheric and Oceanic Optics, 33(5), 470–479. https://doi.org/10.1134/S1024856020050164
- Semkin, P.Yu., Tishchenko, P.Ya., Charkin, A.N. et al. (2021). Discharge of salt groundwater in the Estuary of the Razdol'naya River (Amur Bay) in February 2020. Water Resources, 48(3), 345–350. https://link.springer.com/article/10.1134/S009780782103012X 1 ECR involved in the publication
- Semkin, P.Yu., Tishchenko, P.Ya., Charkin, A.N. et al. (2021). Isotopic, hydrological and hydrochemical indicators of submarine groundwater discharge in the Estuary of Razdolnaya river (Amursky Bay, Sea of Japan) in the ice covered period. Geoecology, 3, 29–43. 1 ECR involved in the publication
- Shevchenko, V. P., Vorobyev, S. N., Krickov, I. V., Boev, A. G., Lim, A. G., Novigatsky, A. N., … Pokrovsky, O. S. (2020). Insoluble particles in the snowpack of the ob river basin (Western Siberia) a 2800 km submeridional profile. Atmosphere, 11(11). https://doi.org/10.3390/atmos11111184 1 ECR involved in the publication
- Silkin, V., Pautova, L., Giordano, M., Kravchishina, M., & Artemiev, V. (2020). Interannual variability of Emiliania huxleyi blooms in the Barents Sea: In situ data 2014–2018. Marine Pollution Bulletin, 158. https://doi.org/10.1016/j.marpolbul.2020.111392
- Silkin, V., Pautova, L., Kravchishina, M., Artemiev, V., & Chultsova, A. (2020). Dataset of theEmiliania huxleyi abundance and phytoplankton composition in the Barents Sea in summer 2014–2018. Data in Brief, 32. https://doi.org/10.1016/j.dib.2020.106251

Completed GEOTRACES-relevant Master theses

- Irina Migdisova (Geochemistry Department of the Geological Faculty, Lomonosov Moscow State University), Master degree thesis "Variability of Elemental Composition of Sedimentary Matter in the Sedimentation System of the Lofoten Basin, Norwegian Sea". PhD Dina Starodymova (participant of the International Summer School GEOTRACES–Spain, Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow) is a supervisor.

The elemental composition of settling particles collected by sediment traps and surface bottom sediments sampled using multicorer is studied in the Master thesis. Sediment traps were deployed at the depth of 3050 m in the Lofoten Basin from August 2018 to May 2019. Major and trace element composition is studied by AAS and ICP-MS (Agilent 7500 instrument). The aim of the work was to study the vertical fluxes and seasonal (monthly) variability of major and trace elements content in sedimentary matter, as well as to assess changes in the composition of sediments in the water/bottom interface. Studied sedimentary matter appears to be enriched in Ni, Ba, Pb, Mo, Zn, Cu, Cd, Mn, Sr. The enrichment of matter decreases with increasing depth as it is diluted with lithogenic matter (Fig. 27).

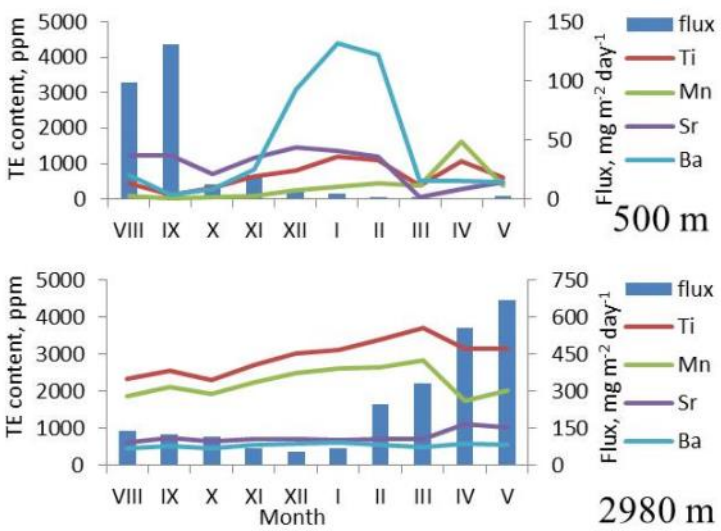


Figure 27: *Variations of trace metal concentrations in sedimentary matter collected in the upper (500 m) and near bottom (2980 m) water layers.*

The material of the near-bottom layer is more homogeneous, while the particle composition of the upper water layer depends on biological cycles. Cu, Zn, Ag, Cd, Pb enrich the near bottom sedimentary matter in comparison with bottom sediments. The REE content in sedimentary matter increases with depth what reflects an increase in the lithogenic material content, and the negative cerium anomaly becomes less pronounced (Migdisova, 2021).

GEOTRACES-relevant presentations in international conferences

- The 2nd International Electronic Conference on Mineral Science, 16–30 November, 2020. **Session D**: Mineral Geochemistry and Geochronology. Presentation by Demina L.L., Gablina I.F., Dara O.M., Budko D.F., Solomatina A.S., Gorkova N.V., Smirnova T.V. "Geochemical fractions of heavy metals in bottom sediments of the Pobeda hydrothermal field, Mid-Atlantic Ridge (17º07′–17º08′ N)". Abstract sciforum-037518. https://sciforum.net/dashboard/author/submissions/ea970e4e03030b70d774d849f95eadf2.
- Joint Workshop "Multi-disciplinary Approaches for Studying the Water and Sediments in the Oceans", Shirshov Institute of Oceanology, RAS–Institute of Ocean Research, PKU, 8 June, 2020. ZOOM at 10:30 (Moscow) = 15:30 (Beijing): presentation by Kravchishina M.D. "Particulate matter as a main source and proxy of sedimentation processes"; presentation by Klyuvitkin A.A. "Vertical and lateral fluxes of sedimentary matter".

- EGU General Assembly 2020, 4–8 May, Online: presentation by Elena Kudryavtseva "Variability in planktonic community caused by sub-mesoscale eddies and spatial features of the Baltic Sea coast" (D670 EGU2020-21523).
  https://meetingorganizer.copernicus.org/EGU2020/EGU2020-21523.html

Submitted by Marina Kravchishina (kravchishina@ocean.ru).

New GEOTRACES or GEOTRACES relevant scientific results

Also this year most of the research was oriented into the study of stable isotopes of light and heavier isotopes such as mercury (Hg) in marine ecosystems.

- In collaboration with the Institute Nazionale di Oceanografia e Geofisica Sperimentale – OGS Trieste, Italy a mesocosmos experiment was performed in order to decode how different sources (natural, anthropogenic) of CO2 influence biological systems (phytoplankton) using stable carbon isotopes. The experiments prove that phytoplankton isotopic composition quickly responds to changes in the δ13C of the medium, making this approach a promising and low-impact tool for detecting CO2 submarine leakages from carbon capture sites (CCS).

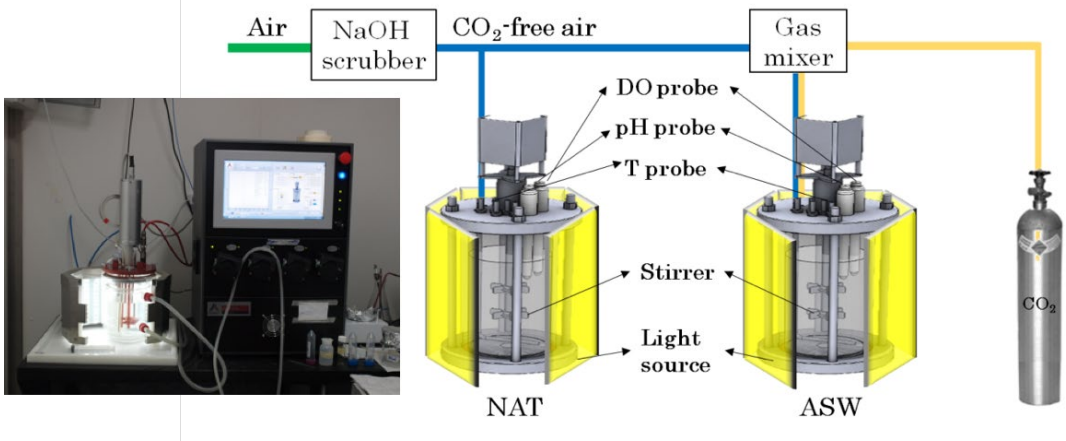


Figure 28: *Schematic description of photobioreactors used for the three T. rotula culture experiments. NAT: natural seawater medium; ASW: artificial seawater medium. During algal growth, only CO_2-free air was used (on:off cycle: 10:50 min) in both media. Note that $CO_{2(g)}$ from cylinder was only supplied during ASW medium preparation. Dissolved oxygen (DO; % sat), temperature (T; °C) and pHNBS were recorded by on-line probes. Light:dark regime: 14:10 h; continuous gentle stirring. Photobioreactor outline modified from Kbiotech®.*

- In order to collect evidences of the possible occurrence of anaerobic oxidation of methane (AOM) at the sediment-water interface and infer the entity of the associated methane flux, the analyses of bulk sulphide minerals δ34S, total organic carbon and redox-sensitive elements were combined. The research was performed in the drift area of Kveithola trough, a glacially-carved depression located in north-western Barents Sea, where active fluid escapes have been recently recognised. According to the negative values of δ34S within the extracted solid sulphur phases (up to −49.1‰ for pyritic sulphur), organoclastic sulphate reduction and/or disproportionation of sulphur intermediates result to be the only active processes in the near-surface sediments of the study area. However, moderate to strong enrichments of Mo detected in the relatively organic carbon-poor intervals of both the two cores suggests that the sulphidic conditions favouring Mo enrichments have been produced by AOM. Therefore, we can infer that the Kveithola trough experienced high methane

fluxes that occasionally moved upward the sulphate-methane transition zone, inducing intense AOM in proximity of its sediment-water interface.

The research conducted in the Gulf of Trieste, N Adriatic is a part of the joint collaboration between National Institute of Oceanography and Experimental Geophysics (OGS) in Italy, Jožef Stefan Institute (JSI), Ljubljana, Slovenia and the Institute of Hydrobiology, the Chinese Academy of Sciences (IHB-CAS). The main objective of this study is to investigate the effects of allochthonous nutrients inputs and the sediment-water interaction on the nutrient availability for primary producers. All results from 5 sampling campaign are colleceted in the report: Giani, M., Cabrini, M., Bazzaro, M., Cataletto, B., Cerino, F., Cibic, T., Cociancich E., De Vittor C., France, J., Fornasaro, D., Franzo A., Krajnc B., Kralj M., Ogrinc N., Relitti F., Urbini L. Mechanisms of red tides and hypoxia as ecological marine disasters and technologies for its early warning and emergency security along the sea of 'Belt and Road' countries; Testing and Analyzing, Report, December 2020.

Here only the summary of research is presented. Overall in the water column there is a P limitation due to the reduced input of river borne P. This P limitation reduced the phytoplankton biomass that in the most recent year is again increasing both in the Gulf of Trieste (and in the western Northern Adriatic Sea. The offshore waters are more strongly affected by seasonal oxygen depletion with respect to the coastal waters, this is due to the confinement of bottom waters in the deeper part of the Gulf of Trieste not easily affected, during the stratified period, by the mixing induced by wind.

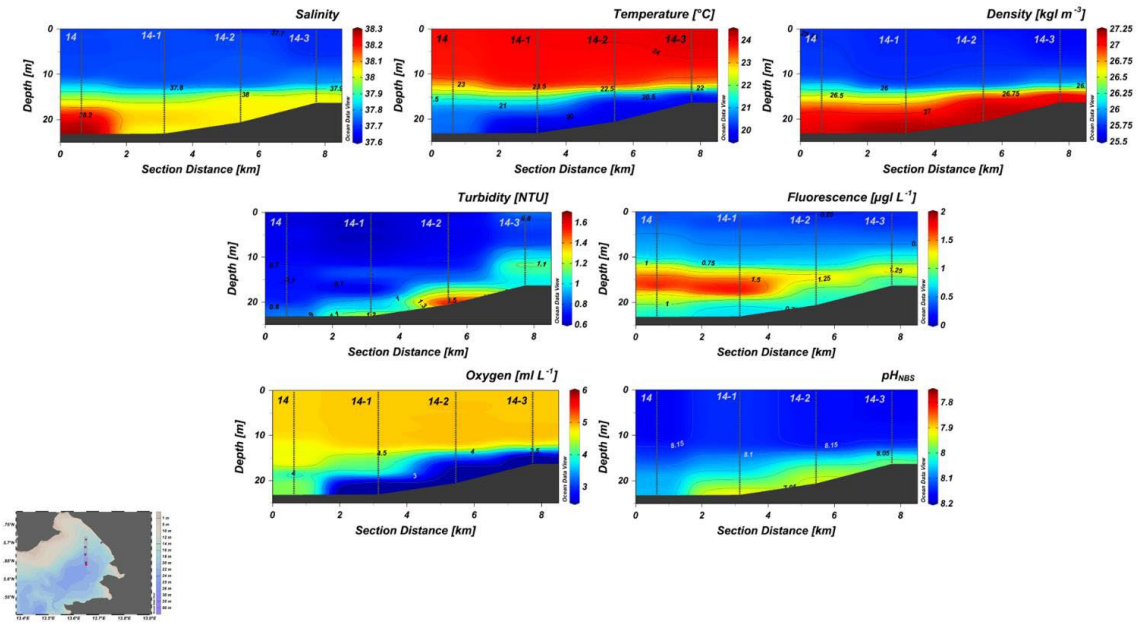


Figure 29: *September 2019. Water column physical and chemical characterisation (temperature, salinity, density, turbidity, fluorescence, dissolved oxygen, pH) along a transect from off-shore towards the coast.*

The regenerated nutrients in bottom waters in the deeper station are not available for the phytoplankton growth in the whole water column till the late autumn/winter mixing induced by cooling and the heat loss that drives the dense water formation. The most elevated oxygen depletion was registered in the bottom offshore waters in September 2018. During 2019 the lowest oxygen concentrations were encountered in June 2019 but then a

reoxygenation occurred due to wind induced mixing. Therefore in late summer/autumn 2019 there was not a seasonal marked oxygen depletion. The inorganic DIN/PO4 ratio in the study period resulted smaller than in the previous period (1999-2010). This could be due to the increase of riverine discharges whose mean value varied from 86 m3 s-1 in the period 1999-2010 to 129 m3 s-1 in 2019: The overall trend of DIN/PO4 ratio in the Gulf of Trieste shows anyway a positive slope (1992-2018). The Gulf of Trieste is characterised by the overall prevalence of dissolved organic matter over inorganic constituents, and by an excess of carbon and nitrogen over phosphorus in all compartments, as demonstrated by C:P ratios higher than Redfield.

The stoichiometric ratios of the dissolved organic matter in the water overlying the sediment are quite similar for the DOC/DON and DOC/DOP but show an increase for the DON/DOP both at the coastal and offshore stations with respect to the 1999-2010 period. A marked increase of the incidence of DOP contribution to TDP is evident particularly in the offshore stations where the highest DIN/PO4 ratio is observed. This could indicate a more intense remineralisation of a fraction of the organic bound P and/or a higher diffusion of inorganic P from the sediments pore waters in the coastal station. The sediment oxygen consumption resulted, in 2018-19, 3-5 fold lower than at the beginning of 1990s and this is potentially attributable to a lower primary production and organic matter sedimentation in bottom waters caused by the reduction of riverine P discharge and to the consequent P limitation. Also the benthic primary production seem reduced with respect to previous measurements. Our result show that DOM degradation in the water column is strongly affected by seasonal warming. However although if the warming counteracts the O2 reduced consumption for OC oxidation by increasing deoxygenation and hetrotrophic respiration still it does not cause hypoxia or anoxia as in the past.

The stoichiometric ratio of the benthic fluxes show that inorganic nitrogen (mainly as ammonium) and phosphates are regenerated in a proportion near or higher than the Redfield ratio (median values: 17 and 28 at coastal and offshore station respectively) whereas silicates are regenerated in a much higher proportion as the Si(OH)4/PO4 median values range from 49 to 55, at coastal and offshore station respectively. It seems that a higher fraction of P remains trapped in the sediment with respect to N and Si, particularly at the offshore station. This can be due to the fact that in oxic condition phosphates are bound to iron oxides or can precipitate as authigenic carbonate fluorapatite whereas only in anoxic condition the release of P from sediments is favoured.

However as in the sediments, alkaline phosphatase showed a significant correlation with temperature the remineralization of P from organic matter could be enhanced in future due to warming.

Outreach activities conducted

- HORVAT, Milena. Deep ocean sediments, geochemistry and chemical contaminants in relation to project: Sargasso Sea European Eel Research Project Virtual Workshop, 5th May 2020: webinar.

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

- PETRANICH, Elisa, CROSERA, Matteo, PAVONI, Elena, FAGANELI, Jadran, COVELLI, Stefano. Behaviour of metal(loid)s at the sediment-water interface in an aquaculture lagoon environment (Grado Lagoon, Northern Adriatic Sea, Italy). Applied sciences. 2021, iss. 5, [article] 2350, 1-16. ISSN 2076-3417. https://www.mdpi.com/2076-3417/11/5/2350, DOI: 10.3390/app11052350.
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- BAJT, Oliver. From plastics to microplastics and organisms. FEBS open bio. 2021, [1-28]. https://febs.onlinelibrary.wiley.com/doi/epdf/10.1002/2211-5463.13120, https://febs.onlinelibrary.wiley.com/doi/10.1002/2211-5463.13120, DOI: 10.1002/2211-5463.13120.
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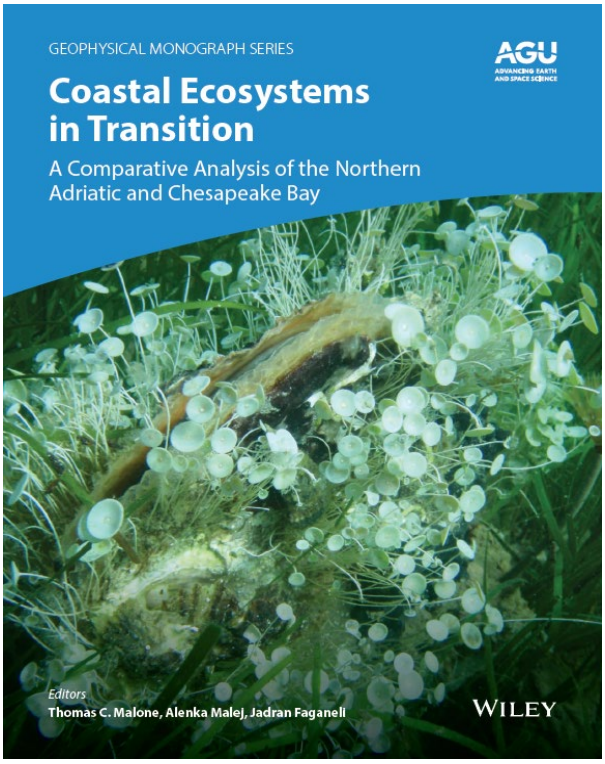

New book

Coastal Ecosystems in Transition: A Comparative Analysis of the Northern Adriatic and Chesapeake Bay

Editor(s): Thomas C. Malone, Alenka Malej, Jadran Faganeli

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Relevant chapters:

TESTA, Jeremy M., FAGANELI, Jadran, GIANI, Michele, BRUSH, Mark J., DE VITTOR, Cinzia, BOYNTON, Walter R., COVELLI, Stefano, WOODLAND, Ryan J., KOVAČ, Nives, KEMP, W. Michael. Advances in our understanding of pelagic-benthic coupling. In: MALONE, Thomas C. (ed.), MALEJ, Alenka (ed.), FAGANELI, Jadran (ed.). Coastal ecosystems in transition : a comparative analysis of the northern Adriatic and Chesapeake Bay. 1st ed. Hoboken: American Geophysical Union: Wiley, 2021. Str. 147-175. Geophysical monograph series. ISBN 978-1-119-54362-6.

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MALEJ, Alenka, FAGANELI, Jadran, MALONE, Thomas C. Ecosystem-based management of multiple pressures : summary and conclusions. In: MALONE, Thomas C. (ed.), MALEJ, Alenka (ed.), FAGANELI, Jadran (ed.). *Coastal ecosystems in transition : a comparative analysis of the northern Adriatic and Chesapeake Bay*. 1st ed. Hoboken: American Geophysical Union: Wiley, 2021. Str. 229-232. Geophysical monograph series. ISBN 978-1-119-54362-6. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/9781119543626.ch11,
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- OGRINC, Nives. Stable isotopes in interdisciplinary research. In: PINTAR, Albin (ed.), et al. Zbornik povzetkov = Book of abstracts: Slovenski kemijski dnevi 2020 = 26th Annual Meeting of the Slovenian Chemical Society: 16.-18. september 2020, Portorož, Portorose, Slovenija. Ljubljana: Slovensko kemijsko društvo, 2020. Str. 25. ISBN 978-961-93849-7-8.
- TURK, Valentina, BEDNARŠEK, Nina, FAGANELI, Jadran, GASPAROVIĆ, Blaženka, GIANI, Michele, GUERRA, Roberta, KOVAČ, Nives, MALEJ, Alenka, KRAJNC, Bor, MELAKU CANU, Donata, OGRINC, Nives. Carbonate system and acidification of the Adriatic Sea. In: EGU General Assembly 2020: Online: 4-8 May 2020. [S. l.]: European Geosciences Union, 2020. 1 str.
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atmospheric CO2: Bor Krajnc, Samo Tamše, and Nives Ogrinc. In: EGU General Assembly 2020: Online: 4-8 May 2020. European Geosciences Union, 2020. 1 str. https://meetingorganizer.copernicus.org/EGU2020/EGU2020-18746.html.

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Submitted by Nives Ogrinc (nives.ogrinc@ijs.si).

New GEOTRACES or GEOTRACES relevant scientific results

- **New approaches to quantify the strength of iron stress:** It is not possible to directly infer iron stress from observed concentrations. Manipulation experiments of natural communities provide insight regarding the role of iron addition, while proteomic techniques quantify cellular responses to *in situ* resource stresses. However, these existing methods cannot be easily applied at broad spatial and temporal scales across the Southern Ocean that are required to assess trends in ecosystem status linked to climate drivers. A novel approach is the *in vivo* quantification of the degree of non-photochemical quenching in relation to available light (α_{NPQ}), which quantifies the strength of iron stress [Ryan-Keogh & Thomalla, 2020, Ryan-Keogh & Smith Jr., 2021]. A particular strength of this novel iron stress proxy is that it can be applied to any ocean with coincident measurements of fluorescence, photosynthetically active radiation and backscatter or beam attenuation, providing the opportunity to deliver a long term time series by taking advantage of historical measurements. The robustness of α_{NPQ} as a proxy for Fe stress is supported by its ability to reproduce known gradients in Southern Ocean iron limitation, from both natural and artificial Fe fertilization. With confidence in the ability of α_{NPQ} to quantify Fe stress, we used a data set of 44 BGC-Argo floats and 163 cruises comprising a total of 5683 profiles spanning 25 years, to produce the first long term (1996 - 2021) *in situ* assessment of Fe stress in the Southern Ocean. We find a significant positive linear trend in α_{NPQ} indicative of a progressive increase in Fe stress (5.6% yr^{-1}) in the Southern Ocean. *(by Dr Tommy Ryan-Keogh)*

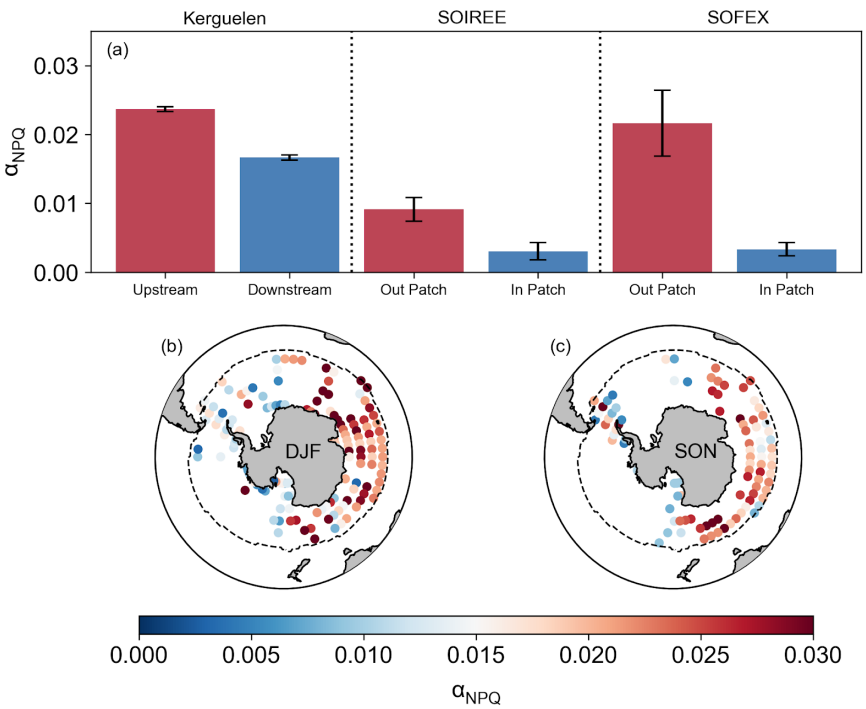


Figure 30: *Robustness of α_{NPQ} as a proxy for iron stress demonstrated through natural and artificial Fe gradients and seasonal Fe depletion. (a) Mean α_{NPQ} ± standard errors from BGC-Argo profiles upstream and downstream of the Kerguelen plateau and from ship-based profiles in and out of Fe-fertilized patches during SOIREE and SOFEX. Maps of α_{NPQ} based on combined BGC-Argo and ship-based profiles (1996 - 2021) for (b) Summer (DJF: December, January and - February) and (c) Spring (SON: September, October and - November) gridded to 5° × 5°. The dashed line represents the spatial extent of the Southern Ocean defined as the subpolar and ice biomes from Fay & McKinley (2014)*

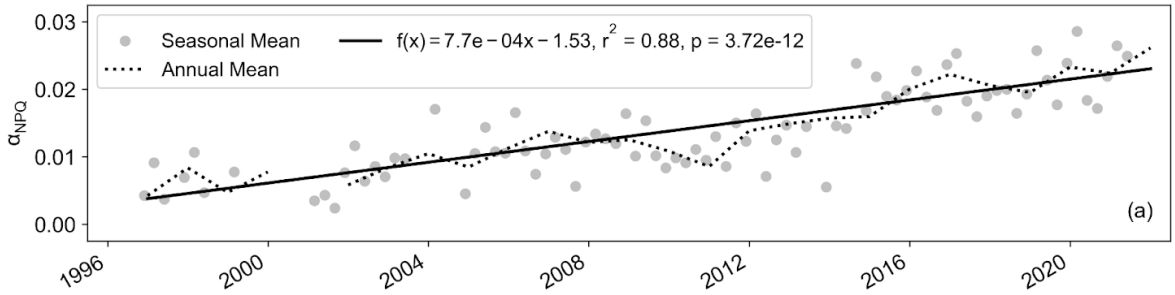


Figure 31: *Significant long-term trend in Southern Ocean iron stress. Displayed is the seasonal and annual means, with an Ordinary Least Squares regression on the annual mean, of α_{NPQ} determined from the combined BGC-Argo and ship-based dataset (1996 -2021)*

- **Winter distributions of dissolved cadmium (dCd) and particulate cadmium (pCd)**: measured for the first time in the Indian sector of the Southern Ocean thereby contributing a unique spatial and seasonal dataset. Seven depth profiles, between 41°S and 58°S, were collected along the 30°E longitude during the 2017 austral winter to investigate the biogeochemical cycling of cadmium during a period characterised by contrasting upper water column dynamics compared to summer. Our results support an important role for biological uptake during winter months albeit weaker compared to summer. Distinct, biologically driven changes in cadmium cycling across the transect were observed. For example, surface ratios of pCd to phosphorus (P; pCd:P) increased from 0.37 to 1.07 mmol mol^{-1} between the subtropical zone (STZ) and the Antarctic zone (AAZ) reflecting increased Cd requirements for diatoms at higher latitudes which, in turn, was driven by a complex relationship between the availability of dCd and dissolved iron (dFe), zinc (dZn) and manganese (dMn). Vertical profiles (Fig. 32) of pCd:P displayed near-surface maxima consistent with 1) P occurring in two phases with different labilities and the lability of Cd being somewhere in-between and 2) increasing dCd to phosphate (PO_4; dCd:PO_4) ratios with depth at each station. North of the Antarctic Polar Front (APF), a secondary, deeper pCd:P maximum may reflect an advective signal associated with northward subducting Antarctic Intermediate Water (AAIW). The strong southward increase in surface dCd and dCd:PO_4, from approximately 10 to 700 pmol kg^{-1} and 40 to 400 µmol mol^{-1} respectively, reflected the net effect of preferential uptake and regeneration of diatoms with high Cd content and the upwelling of Cd enriched water masses in the AAZ. Furthermore, distinct dCd versus PO_4 relationships were observed in each of the intermediate and deep water masses suggesting that dCd and PO_4 distributions at depth are largely the result of physical water mass mixing. *(by Dr Ryan Cloete)*

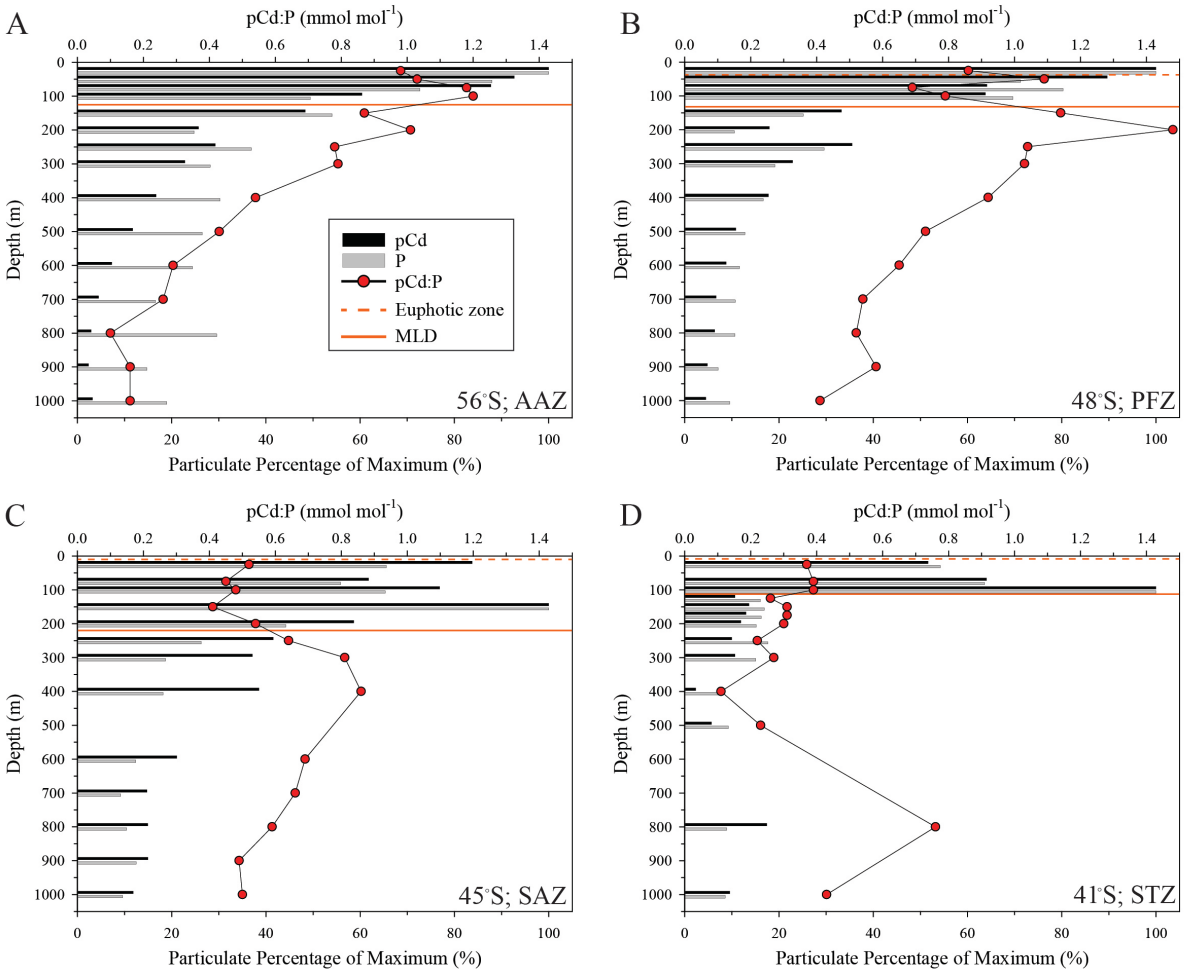


Figure 12: *Particulate cadmium (black bars) and P (grey bars) normalised to profile maximum values (bottom axis) for the upper 1000 m in A) the AAZ, B) the PFZ, C) the SAZ and D) the STZ. The red dots are the absolute pCd:P ratios at each depth (top axis). Dashed horizontal lines represents the bottom of the euphotic zone at each station. Solid horizontal line represents the bottom of the MLD at each station. No euphotic zone data for 56°S (AAZ) due to PAR sensor failure.*

- **Winter biogenic silica and diatom distributions in the Indian Southern Ocean:** Diatoms are a major contributor to Southern Ocean particulate organic carbon (POC) production and export, and exert a strong control on Antarctic surface and Subantarctic thermocline nutrient concentrations, thus influencing the low-latitude nutrient supply. We investigated the distribution of nanophytoplankton (≥3 µm) and their associated biogeochemical environments along 30°E across the Indian Southern Ocean in July 2017 (Weir et al., 2020). Mixed layer-integrated biogenic silica (bSi) decreased 12-fold from the southern AZ to the STZ, resulting in a strong south-north gradient in bSi-per-chl- and bSi-per-POC (Fig. 33). We attribute this to a high abundance of heavily-silicified diatom species (e.g., *Fragilariopsis* spp., which dominated the AZ diatom community) and a limited contribution of other phytoplankton to chlorophyll-a and POC to the south. While mixed-layer $Si(OH)_4$ concentrations decreased more than NO_3^- across the PF, likely due to preferential $Si(OH)_4$ consumption by iron-limited diatoms, our data imply a lower ratio of $Si(OH)_4$ to NO_3^- uptake compared to summer. This suggests that iron limitation may be less severe in the AZ in winter, at least in the west Indian sector. We conclude that AZ diatoms impact the low-latitude nutrient supply and are potentially important for carbon export in winter, despite the lower productivity of the Southern Ocean during this season. *(by Dr Susanne Fietz)*

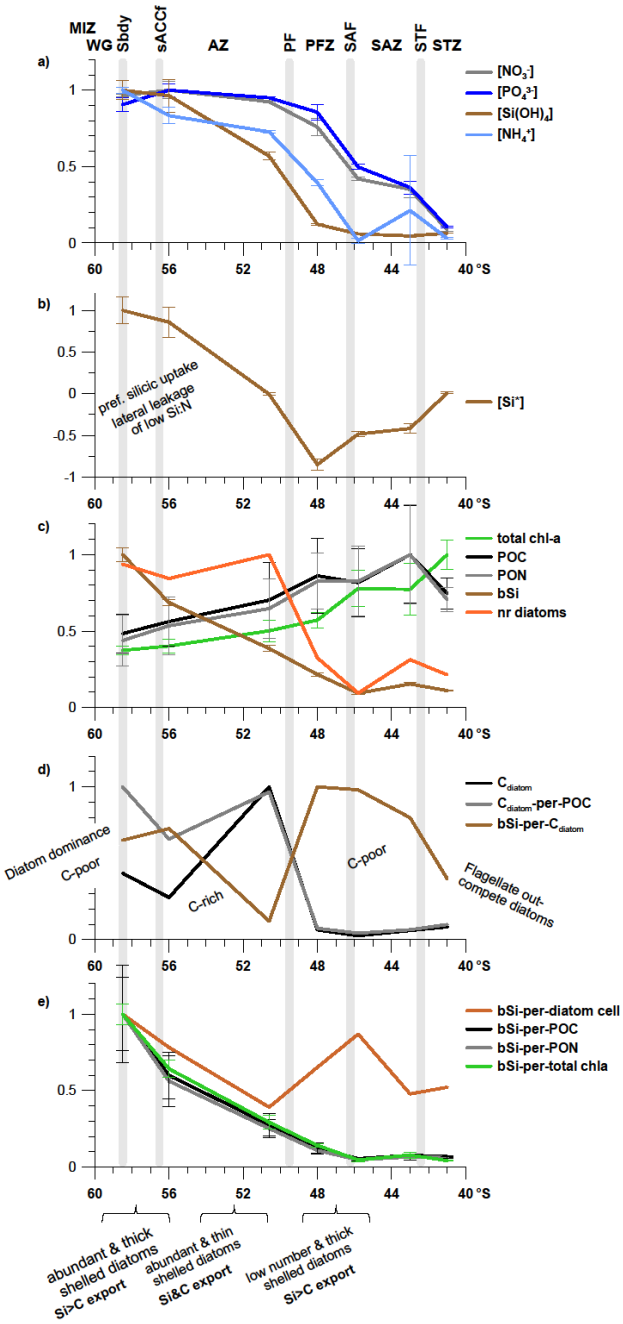


Figure 33: *Mixed-layer (ML) normalised to maximum value (i.e., all y-axes are scaled from 0 to 1) as a function of latitude (°S). Grey vertical lines indicates the approx. positions of the Sbdy, sACCf, PF, SAF and STF at the time of sampling. a) Average ML macronutrient concentrations (µM), b) average ML Si* concentration (µM), c) average upper 150 m concentrations of total chl-a (µg/L), POC, PON, and bSi (µmol/L) along with the number (nr) of diatoms (cells/mL) at the surface (~10 m), d) estimated C_{diatom} (µmol/L), contribution of C_{diatom} to total POC (%), bSi-to-C_{diatom} ratio (mol/mol) at the surface (~10 m), e) bSi-to-total chl-a ratio (mol/g), bSi-to-POC ratio (mol/mol), bSi-to-PON ratio (mol/mol), and bSi-per-diatom cell (pmol/cell). Error bars denote the coefficient of variation of averages.(from Weir et al., 2020, DSR I).*

GEOTRACES or GEOTRACES relevant cruises

- Dr T. Ryan-Keogh (CSIR) and Heather Forrer (UCT/FSU; Image 1) participated on the French Geotraces SWINGS cruise, looking at the effects of iron addition on photophysiology, nitrogen uptake and primary production. The cruise ran from the 10th Jan 2021 until 8th March 2021, where we departed Reunion Island and sailed via all sub-Antarctic Islands from Marion to Heard. We conducted 33 short-term iron addition experiments, 12 iron and nitrogen uptake experiments along with several other experiments measuring natural rates of primary production, nitrogen uptake and nitrification. Additionally, two international PhD students were part of Dr T. Ryan-Keogh team, 1 from University of Plymouth (Isobel Turnbull), who was studying siderophore production, and 1 student from University of Liverpool (Millie Goddard-Dwyer), who was studying microbial ligand and DOM production.

  The team managed to conduct for the first-time short-term iron addition experiments to quantify the land mass effects of all sub-Antarctic islands in the Indian sector of the Southern Ocean. They found low levels of iron stress (low Δ(Fv/Fm)) in close proximity to the islands, which increased as they moved further away from the islands (high Δ(Fv/Fm)) (Fig 34). Co-incident with these experiments is high resolution measurements of iron speciation, from the soluble, colloidal, dissolved and particulate fractions of iron. By linking measurements of photophysiology alongside measurements of the iron fractions, we hope to begin to answer questions on what constitutes bioavailable iron. Furthermore, the team made significant progress in quantifying and characterising nitrogen cycling in this region with a particular focus on understanding how iron directly impacts uptake. This work particularly focuses on Kerguelen to determine whether nitrogen cycling in this region is dominated by nitrification.

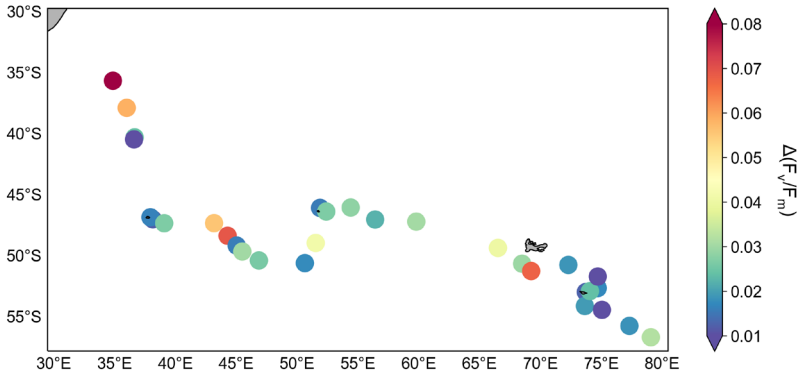


Figure 34: *(above) Results of short-term iron addition experiments from the SWINGS cruise. Δ(Fv/Fm) is calculated as the difference between the iron addition treatment Fv/Fm and control treatment Fv/Fm after 24 hours.*

Image 1 (right) Miss Heather Forrer filtering samples for primary production during the SWINGS cruise.

New projects and/or funding

- Dr T. Ryan-Keogh (Early Career Researcher), National Research Foundation of South Africa (NRF; 2021-2023): "Seasonal iron speciation in the Southern Ocean, from open ocean environments to naturally fertilised sub-Antarctic Islands"

Ongoing/extended projects and/or funding

- Fietz S (2018-2020+2021) South African National Antarctic Programme (SNA170506229934) Shifts in phytoplankton and microbial community composition and functional diversity related to trace metal cycling; R914,000
- Fietz S, Lloyd J, Makhalanyane T (2018-2020+2021) South African bilateral programme, SA-Mexico (MESA170607237905) Exploiting microbes for remediation of pollution in oceans; R2,284,200
- Roychoudhury AN (2018-2020+2021) Distribution and Speciation of Bioactive Trace Elements in Southern Ocean, NRF SANAP, R1,820,000

Contributions to intl. partner projects:

- Mackey B, Roychoudhury AN, Vichi M, Findlay, K (2019 – 2022) Humpback whales in changing climate, Donor funding AUD 4,019,503

New GEOTRACES or GEOTRACES-relevant publications

SA Early Career Researcher-led publications:

- Ryan-Keogh T.J. and Thomalla, S. J., 2020. Deriving a proxy for iron limitation from chlorophyll fluorescence on buoyancy gliders. Frontiers in Marine Science, 7: 275, doi: 10.3389/fmars.2020.00275.
- Ryan-Keogh T.J. and Smith Jr., W. O., 2020 Temporal patterns of iron limitation in the Ross Sea as determined from chlorophyll fluorescence. Journal of Marine Systems, 215, doi: 10.1016/j.jmarsys.2020.103500.
- Weir I, Fawcett S, Smith S, Walker D, Bornmann T, Fietz S., 2020.Winter biogenic silica and diatom distributions in the Indian Sector of the Southern Ocean. Deep Sea Research Part I, 103421. https://doi.org/10.1016/j.dsr.2020.103421
- Ogundare MO, Fransson A, Chierici M, Joubert WR and Roychoudhury AN (2021) Variability of Sea-Air Carbon Dioxide Flux in Autumn Across the Weddell Gyre and Offshore Dronning Maud Land in the Southern Ocean. Front. Mar. Sci. 7:614263. doi: 10.3389/fmars.2020.614263
- Cloete R, Loock JC, van Horsten N, Fietz S, Mtshali TN, Planquette H, Roychoudhury AN. Winter biogeochemical cycling of dissolved and particulate cadmium in the Indian sector of the Southern Ocean (GEOTRACES GIpr07 transect). Frontiers in Marine Sciences (2021, in review, endorsed by 2 reviewers)
- Cloete R, et al. Winter dissolved and particulate zinc in the Indian Sector of the Southern Ocean: Distribution and relation to major nutrients (GEOTRACES GIpr07 transect). Marine Chemistry (2021, in revision)
- Samanta S, Menzel Barraqueta JL, de Bie J, Meynecke J-O, Roychoudhury A. Dissolved Pb and Pb isotope data in the global ocean basins: distribution and synthesis. Marine Chemistry (2021, in revision)

SA-contributions to international partner publications:

- Kauko HM, Hattermann T, Ryan-Keogh T, Singh A, et al. (2021) Phenology and Environmental Control of Phytoplankton Blooms in the Kong Håkon VII Hav in the Southern Ocean. March 2021. Front. Mar. Sci. 8:623856. doi: 10.3389/fmars.2021.623856
- Farmer J, Hertzberg J, Cardinal D, Fietz S, Hendry K, Jaccard S, Paytan A, Rafter P, Ren H, Somes C, Sutton J. (2021) Assessment of C, N and Si isotopes as tracers of past ocean nutrient and carbon cycling. Global Biogeochemical Cycles, accepted. e2020GB006775 doi: 10.1029/2020GB006775
- Shalileh F, Lloyd JR, Fietz S, Zahiri HS, Emameh RZ. Identification of novel cadmium-binding zeta carbonic anhydrase subfamilies from marine prokaryotic and eukaryotic microorganisms (in review)

Completed GEOTRACES PhD or Master theses

PhD:

- Dr Jean Loock (04/2021): Austral Summer and Winter Trace Metal Distributions in the Southern Ocean and Antarctic Seasonal Sea Ice
- Dr Ryan Cloete (12/2020): On the distribution and biogeochemical cycling of bioactive trace metals in the Southern Ocean

MSc:

- Ms Raya Stavreva (12/2020): Constraining the suitability of barium as an indicator of paleoproductivity in different aquatic environments; https://scholar.sun.ac.za/handle/10019.1/109374
- Ms Zandria Jordaan (12/2020): Testing potential drivers for carbon isotopic signature of particulate organic carbon in the Southern Ocean; https://scholar.sun.ac.za/handle/10019.1/109335

GEOTRACES presentations at international conferences

- Samanta S, Menzel Barraqueta JL, Cloete R, Loock J, de Jongh T, Roychoudhury A. Sources and cycling of dissolved rare earth elements in the Southern Ocean: linkages to the nutrient dynamics. Goldschmidt2020. https://doi.org/10.46427/gold2020.2271
- Menzel Barraqueta J-L, Samanta S, Loock JC, Cloete R, Viljoen JJ, Mahieu L, Krisch S, Kaukurauee K, Bernhard W, Fietz S & Roychoudhury A. Winter and Spring Trace Metals at the Antarctic Marginal Sea Ice Interfaces. Goldschmidt2020. https://doi.org/10.46427/gold2020.1781
- Singh A., M. Ardelan, S. Fietz, A. Fransson, N. Sanchez, S. J. Thomalla and T. J. Ryan-Keogh. On the response of phytoplankton to iron addition in the Weddell Sea and along the Dronning Maud Land ice edge during austral autumn. p. 159. In: Ocean, Weather and Climate: Science to the Service of Society. Proceedings of the Nansen-Tutu Centre 10th Anniversary Symposium, 10-12 March 2020, Cape Town, South Africa. Editors – M Rouault, JA Johannessen, A Samuelsen and B Backeberg. ISBN: 978-1-77634-359-1, 2021. https://86bba567-88e7-4f82-90ca0152e7cb926c.filesusr.com/ugd/92b3c9_f7293264dff143539d67d12fe8d130e5.pdf

Outreach activities

- Stellenbosch TracEx Team
  - Blogs: https://southernoceanfe.wordpress.com/ https://tracexsite.wordpress.com/
  - Facebook page: https://www.facebook.com/Environmental-Geochemistry-at-Stellenbosch-University-135430226505633/
  - Twitter account: https://twitter.com/TracexS

Submitted by Susanne Fietz (sfietz@sun.ac.za).

New GEOTRACES or GEOTRACES relevant scientific results

- H.J Seo and G. Kim (2020, GCA) reported the distributions of rare earth elements (REEs) were measured at 14 stations from 0 to 3365 m (n = 176) in the entire East Sea for the first time. The East Sea has its own deep-convection system, which operates on a time scale that is approximately one tenth that of the global ocean; it is also a downwind region of Asian dust (below figure).

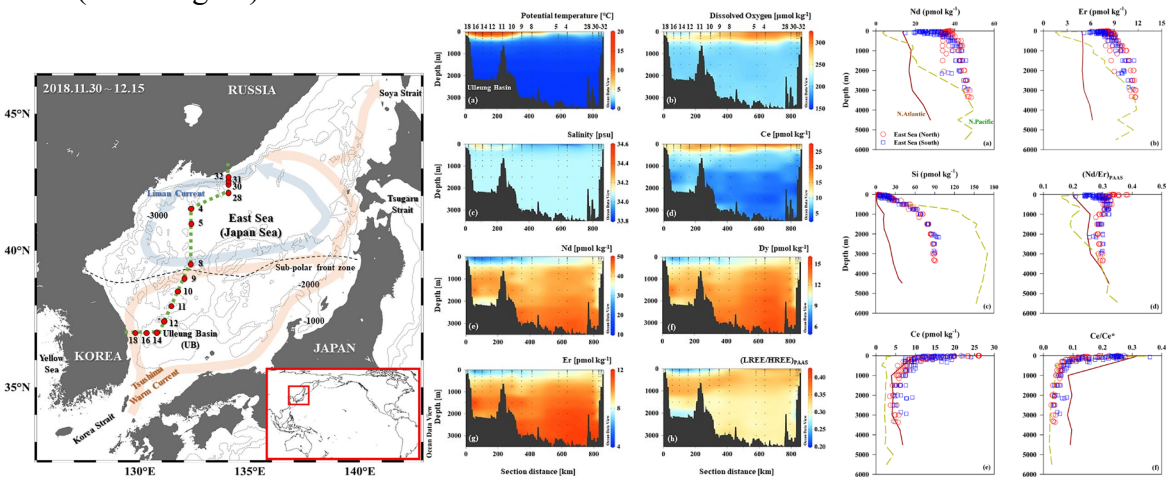


Figure 35: *Map showing the current patterns of the surface waters in the East (Japan) Sea and locations of sampling stations (left figure). Vertical distributions of (a) potential temperature, (b) dissolved oxygen, (c) salinity, (d) Ce, (e) Nd, (f) Dy, (g) Er and (h) PAAS normalized LREE/HREE in the East Sea (Center). Vertical distributions of (a) Nd, (b) Er, (c) Si, (d) (Nd/Er)PAAS, (e) Ce, and (f) Ce/Ce* in the East Sea.*

- In this study, in the deep layer below 750 m, large increases of heavy-REEs (HREEs) relative to light-REEs (LREEs), opposite to the re-mineralization trend, were observed suggesting that LREEs were preferentially re-scavenged by sinking particles. In addition, the boundary scavenging of REEs was also observed for all REEs in the bottom layer of the East Sea (Seo and Kim, 2020, https://doi.org/10.1016/j.gca.2020.07.016). They also trace the water mass and physical mixing patterns of Tsushima Warm Water (TWW) in the upper ocean using the REE ratio (LREE/HREE).

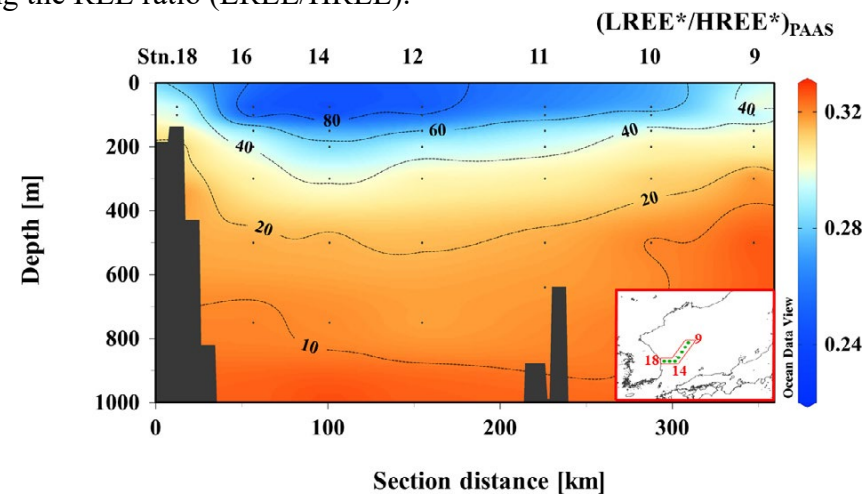
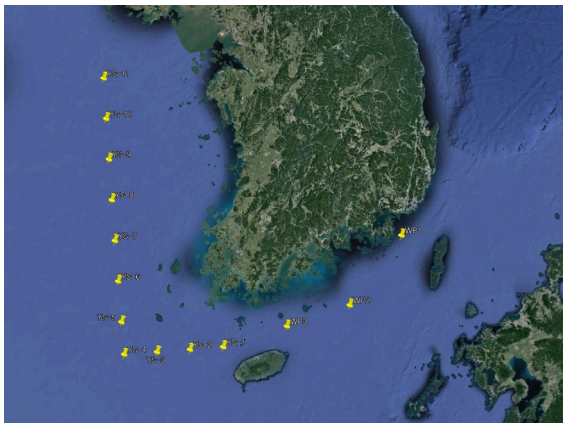


Figure 36: *Distributions of PAAS-normalized LREE/HREE ratios corrected for re-mineralization using AOU in the southern part of the East Sea (0–1000 m). Mixing ratio (%) contours are shown as a dashed black.*

GEOTRACES or GEOTRACES relevant cruises

- The research cruise in 2020 for section study in western Indian Ocean (68E and 65E including the Seychelles-Chagos Thermocline Ridge (SCTR) region) in 2020 using R/V Isabu (of Korea institute of Ocean Science and Technology, KIOST), were cancelled due to the Covid-19 situation, and postponed/re-scheduled later after 2021. The Korean communities are still watching the vaccination situation and the international situation for next Korean-GEOTRACES cruises.
- Instead, the domestic research activities and cruises are continuing steadily. Recently, in March 2021, trace element-clean seawater sampking were conducted in South Sea and Yellow sea cruises by R/V Isabu, KIOST. The details of sampling location are as below.



	Lat.	**Lon.**	**Note**
YS-1	33.6000	126.0000	Ultra Clean CTD (UCC),
YS-2	33.6000	125.5000	UCC, CTD
YS-3	33.6000		UCC, CTD
YS-4	33.6000	124.5000	UCC, CTD
YS-5	34.0000	124.5000	UCC, CTD
YS-6	34.5000	124.5000	UCC, CTD
YS-7	35.0000	124.5000	UCC, CTD
YS-8	35.5000	124.5000	UCC, CTD
YS-9	36.0000	124.5000	UCC, CTD
YS-10	36.5000	124.5000	UCC, CTD
YS-11	37.0000	124.5000	UCC, CTD

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

- Seo, H., & Kim, G. (2020). Rare earth elements in the East Sea (Japan Sea): Distributions, behaviors, and applications. Geochimica et Cosmochimica Acta, 286, 19-28. https://doi.org/10.1016/j.gca.2020.07.016

Submitted by Dr. Intae Kim, KIOST (ikim@kiost.ac.kr).

Geotraces related articles

- González-Santana, D., González-Dávila, M., Lohan, M.C., Artigue, L., Planquette, H., Sarthou, G., Tagliabue, A., Santana-Casiano, J.M. 2021.Variability in iron (II) oxidation kinetics across diverse hydrothermal sites on the northern Mid Atlantic Ridge. Geochimica et Cosmochimica Acta, 297,143-157. https://doi.org/10.1016/j.gca.2021.01.013
- Puigcorbé, V., Ruiz-González, C., Masqué, P. and Gasol, J.M. (2020). Sampling device-dependance of prokaryotic community structure on marine particles: higher diversity recovered by in situ pumps than by oceanographic bottles. Frontiers in Microbiology, 11:1645. https://doi.org/10.3389/fmicb.020.01645.
- Puigcorbé, V., Masqué, P. and Le Moigne, F.A.C. (2020). Global database of oceanic particulate organic carbon to 234Th ratios: Improving estimates of the biological carbon pump. Earth System Science Data, 12, 1267-1285. https://doi.org/10.5194/essd-12-1267-2020.
- Tesán-Onrubia, J.A., Petrova, M.V., Puigcorbé, V., Black, E.E., Valk, O., Dufour, A., Hamelin, B., Buesseler, K.O., Masqué, P., Le Moigne, F.A.C., Sonke, J.E., Rutgers van der Loeff, M., Heimbürger-Boavida, L.-E. (2020). Mercury export flux in the Arctic Ocean estimated from 234Th:238U disequilibria. ACS Earth and Space Chemistry, 4,5, 795-801. https://dx.doi.org/10.1021/acsearthspacechem.0c00055.
- Kenyon, J., Buesseler, K., Casacuberta, N., Castrillejo, M., Otosaka, S., Masqué, P., Drysdale, J., Pike, S. and Sanial, V. (2020). Evolution of concentrations of 137Cs, 90Sr, and 129I in surface ocean waters derived from the Fukushima Dai-ichi nuclear accident. Environmental Science and Technology, 54, 23, 15066-15075. https://doi.org/10.1021/acs.est.0c05321.
- Álvarez-Vázquez, M.A., Álvarez-Iglesias, P., de Uña-Álvarez, E., Quintana, B., Caetano, M., Prego, R., 2020. Industrial dynamics of trace elements, historical record in estuarine sediments of the Anthropocene (Ria of Ferrol, NW Iberian Peninsula). Marine Chemistry, 223: 103825.
- Martinez-Ruiz, F., Paytan, A., Gonzalez-Muñoz, M.T., Jroundi, F., Abad, M.M., Lam, P.J., Horner, T.J., Kastner, M. Barite Precipitation on Suspended Organic Matter in the Mesopelagic Zone (2020) Frontiers in Earth Science, 8, art. no. 567714.
- Charette, M. A., Kipp, L. E., Jensen, L. T., Dabrowski, J. S., Whitmore, L. M., Fitzsimmons, J. N., ... & Zhang, R. (2020). The Transpolar Drift as a Source of Riverine and Shelf-Derived Trace Elements to the Central Arctic Ocean. Journal of Geophysical Research: Oceans, 125(5), e2019JC015920.
- Whitby, H., Planquette, H., Cassar, N., Bucciarelli, E., Osburn, C. L., Janssen, D. J., ... & Sarthou, G. (2020). A call for refining the role of humic-like substances in the oceanic iron cycle. Scientific reports, 10(1), 1-12.
- Albuquerque R, Bode A, González-Gordillo JI, Duarte CM, Queiroga H (2021) Trophic structure of neuston across tropical and subtropical oceanic provinces assessed with stable isotopes. Frontiers in Marine Science 7, 606088 https://doi.org/10.3389/fmars.2020.606088

- Álvarez M, Fajar NM, Carter BR, Guallart EF, Pérez FF, Woosley RJ, Murata A (2020a) Global Ocean Spectrophotometric pH Assessment: Consistent Inconsistencies. Environmental Science & Technology 54:10977-10988 https://doi.org/10.1021/acs.est.9b06932
- Belgacem M, Chiggiato J, Borghini M, Pavoni B, Cerrati G, Acri F, Cozzi S, Ribotti A, Álvarez M, Lauvset SK, Schroeder K (2020) Dissolved inorganic nutrients in the western Mediterranean Sea (2004-2017). Earth System Science Data 12:1985-2011, https://doi.org/10.5194/essd-12-1985-2020
- Bode A, Álvarez M, García García LM, Louro MA, Nieto-Cid M, Ruíz-Villarreal M, Varela MM (2020a) Climate and local hydrography underlie recent regime shifts in plankton communities off Galicia (NW Spain). Oceans 1:181-197. https://doi.org/10.3390/oceans1040014
- Bode A, Lamas AF, Mompeán C (2020) Effects of upwelling intensity on nitrogen and carbon fluxes through the planktonic food web off A Coruña (Galicia, NW Spain) assessed with stable isotopes. Diversity 12, https://doi.org/10.3390/d12040121
- Espinosa-Leal L, Bode A, Escribano R (2020) Zonal and depth patterns in the trophic and community structure of hyperiid amphipods in the Southeast Pacific. Deep Sea Research, https://doi.org/10.1016/j.dsr.2020.103402
- Hainbucher D, Álvarez M, Astray Uceda B, Bachi G, Cardin V, Celentano P, Chaikakis S, Chavez Montero MM, Civitarese G, Fajar NM, Fripiat F, Gerke L, Gogou A, Fernández Guallart E, Gülk B, Hassoun AER, Lange N, Rochner A, Santinelli C, Steinhoff T, Tanhua T, Urbini L, Velaoras D, Wolf F, Welsch A (2020) Variability and trends in physical and biogeochemical parameters of the mediterranean sea during a cruise with RV Maria S. Merian in March 2018, Earth System Science Data Discussions, https://doi.org/10.5194/essd-2020-82
- Hernández-León S, Koppelmann R, Fraile-Nuez E, Bode A, Mompeán C, Irigoien X, Olivar P, Echevarría F, Fernández de Puelles ML, González-Gordillo I, Cózar A, Acuña JL, Agustí S, Duarte CM (2020) Large deep-sea zooplankton biomass mirrors primary production in the global ocean. Nature Communications, 11: 6048 https://doi.org/10.1038/s41467-020-19875-7
- Olsen A, Lange N, Key RM, Tanhua T, Bittig HC, Kozyr A, Álvarez M, Azetsu-Scott K, Becker S, Brown PJ, Carter BR, Cotrim da Cunha L, Feely RA, van Heuven S, Hoppema M, Ishii M, Jeansson E, Jutterström S, Landa CS, Lauvset SK, Michaelis P, Murata A, Pérez FF, Pfeil R, Schirnick C, Steinfeldt R, Suzuki T, Tilbrook B, Velo A, Wanninkhof R, Woosley RJ (2020) An updated version of the global interior ocean biogeochemical data product, GLODAPv2.2020, Earth Syst. Sci. Data, 12, 3653–3678, https://doi.org/10.5194/essd-12-3653-2020
- Torres R, Artioli Y, Kitidis V, Ciavatta S, Ruiz-Villarreal M, Shutler J, Polimene L, Martinez V, Widdicombe C, Woodward EMS, Smyth T, Fishwick J, Tilstone GH (2020) Sensitivity of modeled CO2 air–sea flux in a coastal environment to surface temperature gradients, surfactants, and satellite data assimilation. Remote Sensing, 12: 2038. https://doi.org/10.3390/rs12122038
- Varela MM, Rodríguez-Ramos T, Guerrero-Feijoo E, Nieto-Cid M (2020) Changes in activity and community composition shape bacterial responses to size-fractionated marine DOM. Frontiers in Microbiology 11:586148. https://doi.org/10.3389/fmicb.2020.586148

- Ceballos Romero, Elena, Buesseler, Ken, Villa Alfageme, M., 2021. Revisiting 50 years of 234Th data: a comprehensive global oceanic compilation. PANGAEA. https://doi.org//10.1594/PANGAEA.918125
- Laglera L.M., Tovar-Sánchez A., Sukekava C.F., Naik H., Naqvi S.W.A., Wolf-Gladrow D.A. Iron organic speciation during the LOHAFEX experiment: Iron ligands release under biomass control by copepod grazing. Journal of Marine Systems, 207. 103151, 2020. https://doi.org/10.1016/j.jmarsys.2019.02.002

Meetings

- Martinez-Ruiz, F., Paytan, A., Gonzalez-Muñoz, M.T., Jroundi, F., Abad M.M., Lam, P., Horner, T., Kastner, M. Role of Exopolymers in Pelagic Barite Precipitation in the Ocean. GOLDSCHMIDT 2020, Virtual, June 21-26, 2020 (https://goldschmidt.info/2020/).
- Álvarez M, Kozyr A, Velo A, Lange N, Tanhua T, Acerbi R, Guallart EF et al. (2020b) Towards a public and internally consistent data product containing CARbon, transient tracers and ancillary data In the Mediterranen Sea, CARIMED. 8-10 September, GOA-ON Ocean Acidification week, on line event, MedSea Hub. Oral presentation.
- García-Ibáñez MI, Guallart EF, Fajar NM, Barbero L, Cai WJ, Wanninkhof R, Takeshita Y, Pierrot D, Pérez FF, Álvarez M (2020) Gaining insights into ocean CO2 system inconsistencies from discrete fCO2 measurements. 8-10 September, GOA-ON Ocean Acidification week, on line event, North East Atlantic Hub. Oral presentation.
- Guallart EF, García-Ibáñez MI, Santiago-Domenech R, Hassoun AER, Fajar NM, Pérez FF, Easley R, Álvarez M (2020) Spectrophotometric measurement of [CO32-] in seawater: dealing with inconsistencies. 8-10 September, GOA-ON Ocean Acidification week, on line event, North East Atlantic Hub. Oral presentation.
- Jerusalén-Lleó E, Nieto-Cid M, Álvarez-Salgado XA (2020) Solid phase extraction of ocean DOM with PPL cartridges: efficiency and selectivity. SIQUIMAR: XX Seminario Ibérico de Química Marina, Vigo 1-3 July. Oral presentation.

GEOTRACES related projects

- Effects of ocean acidification, temperature and organic matter on Fe(II) persistence in the Atlantic Ocean. Ministerio de Economía y Competitividad. CTM2017-83476-P (2018-2021) IP: J. Magdalena Santana Casiano, Melchor González Dávila
- Marine productivity oscillations in the Mediterranean: new perspectives on climate change impacts and role of deoxygenation and eolian dust input. PID2019-104624RB-I00 (01/06/2020-31/05/2023) PI: Francisca Martinez-Ruiz. Budget: 157.300€
- Interrelationships among marine primery production and climate variability: new perspectives and insights from Barium biogeochemistry and the global carbon cycle. Junta de Andalucia P18-RT-3804 (01/01/2020-31/12/2022) PI: Francisca Martinez-Ruiz. Budget: 108.292€
- H2020 - MSCA-IF. Global Fellowship (University of Sevilla-WHOI).“IMaging Ocean Sinkers for evaluating carbon export fluxes (IMOS). From: 01/09/2022 to: 31/08/25. 245 732 €.

Outreach activities conducted **(EPB authors in bold)**

- Olsen A, Lange N, Key RM, Tanhua T, Bittig H, Kozyr A, **Álvarez M,** Azetsu-Scott K, Becker S, Brown PJ, Carter BR, Cotrim da Cunha L, Feely RA, van Heuven S, Hoppema M, Ishii M, Jeansson E, Jutterström S, Landa CS, Lauvset SK, Michaelis P, Murata A, Pérez FF, Pfeil R, Schirnick C, Steinfeldt R, Suzuki T, Tilbrook B, Velo A, Wanninkhof R, Woosley RJ (2020) GLODAPv2.2020: A data product of internally consistent ocean biogeochemical observations. Poster. https://www.nodc.noaa.gov/ocads/oceans/GLODAPv2_2020/

PhD Thesis

- Nieves Torres Crespo. The barium biogeochemical cycle in the Mediterranean: bacterial barite precipitation and implication for paleoproductivity reconstructions. University of Granada. April 2021

Cruises

- IFADO cruise (B/O Sarmiento de Gamboa). 10-23 July 2020. NE Atlantic (Cape Finisterre section). Chief Scientist: M. Ruíz-Villarreal.

Other activities

- Bode A, Olivar MP, Hernández-León S (2021) Natural abundance of stable isotopes in micronekton fish species from the BATHYPELAGIC cruise (North Atlantic, June 2018): carbon and nitrogen values in bulk tissues and nitrogen values in amino acids. PANGAEA https://doi.org/10.1594/PANGAEA.930111
- Bode A, Álvarez M, García L, Louro MÁ, Nieto-Cid M, Ruiz-Villarreal M, Varela MM (2020) Time series of hydrographic, biogeochemical and plankton variables for a shelf station off A Coruña (NW Spain): 1990-2018. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.919087
- Bode A, Lamas AF, Mompeán C (2020) Monthly data of stable carbon and nitrogen isotopes in seston, sedimented particles, and plankton size-fractions for a shelf station off A Coruña (NW Spain): 2010-2011. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.911575
- Bode A, Mompeán C (2020) Stable isotope data of mesozooplankton for depth layers along the Malaspina-2010 expedition. PANGAEA https://doi.pangaea.de/10.1594/PANGAEA.919314

Contributors to the report

Pere Masqué, J. Magdalena Santana-Casiano, Melchor González-Dávila, Ricardo Prego, Francisca Martínez-Ruiz, Aridane González, María Villa, Antonio Bode, Marta Álvarez, Marta Varela, Elisa Fernández, Manuel Ruiz, Mar Nieto-Cid, Mercedes de la Paz, Tamara Rodríguez Luz García, Pilar Díaz, Gelines Louro, Martinho MA., Antonio Tovar-Sánchez

Submitted by Antonio Tovar-Sánchez (a.tovar@csic.es).

New GEOTRACES or GEOTRACES-relevant scientific results

- This was a productive period for Swiss GEOTRACES-relevant research, with a total of 16 publications from Switzerland-affiliated authors (13 first-author papers; see list below).
- Perhaps the most significant Swiss contribution is represented by the first trace metal biogeochemistry publications from the **Antarctic Circumnavigation Expedition** carried out by the **Swiss Polar Institute** in early 2017 (https://spi-ace-expedition.ch/). With high spatial resolution in the shallow subsurface, the circumpolar Southern Ocean data allow a detailed analysis of the behaviour of a suite of trace metals relative to macronutrients (**Janssen et al., 2020**), as well as characterising the stable isotope systematics of the biologically-active trace metals chromium (**Rickli et al., 2019**), cadmium (**Sieber et al., 2019**) and zinc (**Sieber et al., 2020**). The circumpolar sampling of all Southern Ocean zones and co-analysis of cadmium, zinc and their isotopes allowed Sieber et al. (2020) to explain how (a) the extent of biological drawdown in the surface Southern Ocean and (b) its associated isotope fractionation combine to explain the observation that upper-ocean water masses exported from the Southern Ocean (SAMW, AAIW) bear isotopically-fractionated signals for Cd, but not for Zn (see Fig. below).

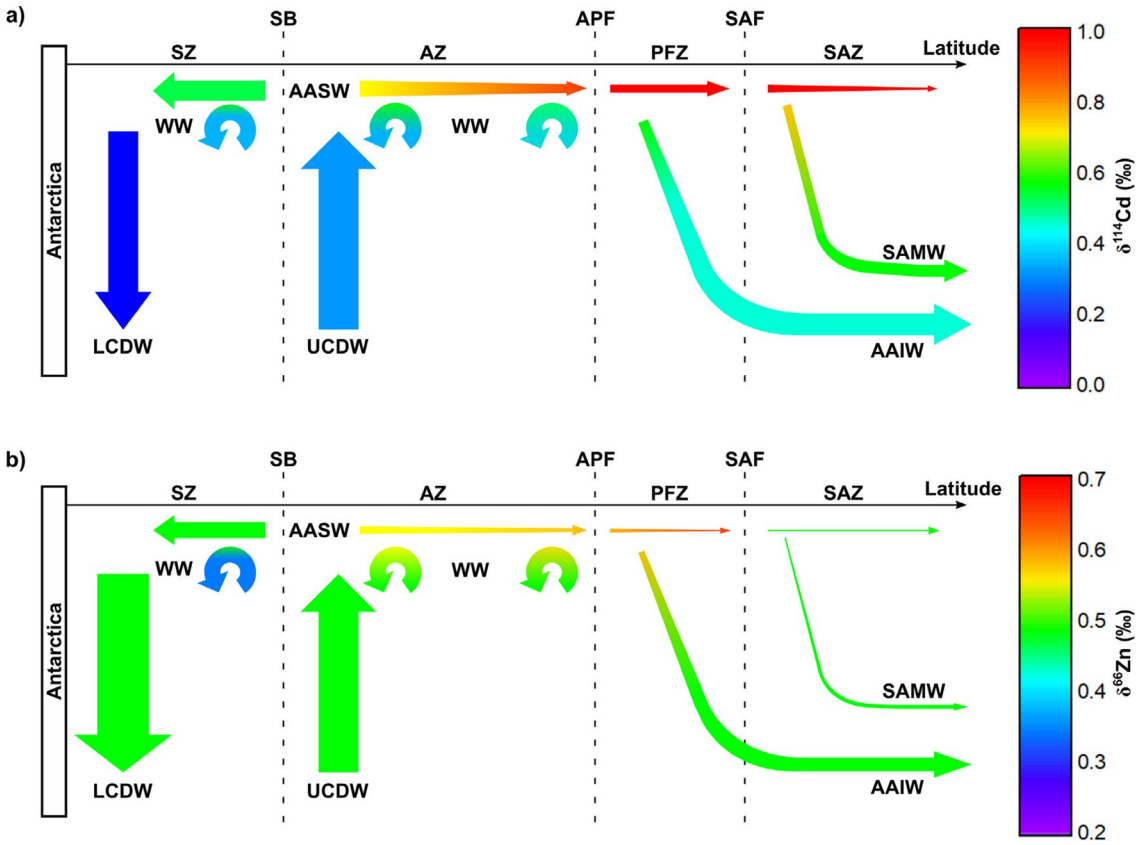


Figure 37 *(From Sieber et al. (2020): Schematic cycling of (a) Cd and (b) Zn in the upper Southern Ocean. Arrows represent the meridional circulation across the Southern Ocean fronts (dashed lines; SAF: Subantarctic Front; APF: Antarctic Polar Front; SB: Southern Boundary). Arrow thickness represents observed dissolved Cd (range: ~0 to 1 nmol/kg) and Zn concentrations (range: ~0 to 7.5 nmol/kg). Colours indicate dissolved isotope signatures of water masses (SAMW: Subantarctic Mode Water; AAIW: Antarctic Intermediate Water; AASW: Antarctic Surface Water; WW: Winter Water; UCDW/LCDW: Upper/Lower Circumpolar Deep Water).*

New projects and/or funding

- 01.04.2019–31.09.2022: "Using trace metal isotopes to understand ocean biogeochemistry: ancient and modern", Swiss National Science Foundation project funding to Prof. Derek Vance, ETH Zurich.
- 01.01.2020–31.12.2021: "The critical role of sedimentary trace element fluxes in ocean biogeochemistry", ETH Fellowship to Dr. Jianghui Du, ETH Zurich (Group of D. Vance).

New GEOTRACES or GEOTRACES-relevant publications

*Researchers at Swiss institutions in **bold**.*

- Bayon, G., **N. Lemaitre**, J.-A. Barrat, X. Wang, D. Feng, S. Duperron (2020). Microbial utilization of rare earth elements at cold seeps related to aerobic methane oxidation. *Chemical Geology*, Article 119832.
- **Du, J.**, B. A. Haley, A. C. Mix (2020). Evolution of the Global Overturning Circulation since the Last Glacial Maximum based on marine authigenic neodymium isotopes. *Quaternary Science Reviews*, Article 106396.
- Little, S. H., **C. Archer**, J. McManus, J. Najorka, A. V. Wegorzewski, **D. Vance** (2020). Towards balancing the oceanic Ni budget, *Earth and Planetary Science Letters*, Article 116461.
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Completed GEOTRACES PhD or Master theses

- Matthias Sieber, Ph.D. thesis, ETH Zurich: "The role of the Southern Ocean in the global biogeochemical cycling of cadmium and zinc and their isotopes".
  Supervisors: Prof. D. Vance, Dr. T. Conway, Dr. G. de Souza.
  https://www.research-collection.ethz.ch/handle/20.500.11850/348367

GEOTRACES presentations in international conferences

- **Chatterjee, A.**, **E. R. Ciscato**, S. H. Little, S. Severmann, J. McManus, **D. Vance** (2019). "The output of nickel from the ocean to reducing sediments" , Goldschmidt2019, Barcelona, Spain. *Poster presentation.*
- **de Souza, G. F.**, **M. Sieber**, T. M. Conway, **D. Vance** (2019). "Biogeochemical behaviour of Cd and Zn in eastern-boundary OMZs", Goldschmidt2019, Barcelona, Spain. *Oral presentation.*
- **Eisenring, C. E.**, **G. F. de Souza**, S. P. Khatiwala, **D. Vance** (2019). "Influence of seasonal variability on Zn cycling in OGCMs with different spatial resolutions", Goldschmidt2019, Barcelona, Spain. *Poster presentation.*
- **He, Z.**, **M. O. Clarkson**, M. Andersen, **C. Archer**, F. Huang, **D. Vance** (2019). "Understanding molybdenum and uranium isotope systematics in continental margin sediments", Goldschmidt2019, Barcelona, Spain. *Poster presentation.*
- **Janssen, D. J.**, J. Rickli, P. Quay, A. White, S. L. Jaccard (2019). "Biological control of δ^{53}Cr in the surface ocean", Goldschmidt2019, Barcelona, Spain. *Oral presentation*.
- **Janssen, D. J.**, M. Sieber, M. J. Ellwood, T. M. Conway, P. M. Barrett, C. S. Hassler, S. L. Jaccard (2020). "Significant biological uptake of trace metals in the Mertz Glacier Polynya", Ocean Sciences Meeting 2020, San Diego, USA. *Oral presentation.*
- **Lemaitre, N.**, H. Planquette, F. Dehairs, F. Planchon, G. Sarthou, P. Lherminier, **D. Vance** (2019). "Trace element cycling in the North Atlantic", Goldschmidt2019, Barcelona, Spain. *Keynote oral presentation.*
- **Nasemann, P.**, J. Rickli, P. Grasse, M. Frank, S. L. Jaccard (2019). "Cr reduction and associated isotope fractionation restricted to anoxic shelf waters in the Peruvian Oxygen Minimum Zone", Goldschmidt2019, Barcelona, Spain. *Poster presentation.*
- **Rickli, J.**, D. J. Janssen, C. Hassler, M. J. Ellwood, S. L. Jaccard (2019). "Chromium biogeochemistry and stable isotope distribution in the Southern Ocean", Goldschmidt2019, Barcelona, Spain. *Oral presentation.*
- **Sieber, M.**, T. M. Conway, **G. F. de Souza**, M. J. Ellwood, **D. Vance** (2019). "Iron cycling in the upper Southern Ocean: insights from Fe isotopes", Goldschmidt2019, Barcelona, Spain. *Oral presentation.*
- **Sun, M.**, **C. Archer**, **D. Vance**, Y. Shen (2019). "Improved ion-exchange procedures for multiple transition metal isotope proxy studies", Goldschmidt2019, Barcelona, Spain. *Poster presentation.*

Submitted by Gregory de Souza (desouza@erdw.ethz.ch).

New GEOTRACES or GEOTRACES relevant scientific results

Nutrients, trace element in Western and Eastern Mediterranean Sea surface sediment: Environmental variability and anthropoghenic footprint

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[1]National Institute of Marine Sciences and Technologies, Marine science laboratory, Tunisia
[2]Royal Netherlands Institute for Sea Research, NIOZ, Netherlands

ABSTRACT. During GEOTRACES MedBlack Sea cruise, our work was focused on physicochemical parameters measurements, water sampling and short core sediment sampling. Trace elements necessitate trace metal clean CTD system sampling. Analysis are assessing nutrient, trace element (Fe, Pb, Cd, Zn, Co, Mo, Cu and Ni) and trace element fractionation, carried out on sediment in eastern and western surface sediment. The X-ray diffraction is applied on the clay fraction. Results salinity section plot shows some clearly recognizable water masses. Clay minerals assemblages have distinctive sources and their dispersal reflects different agents of transport in the eastern Mediterranean Sea. Nutrients show more oligotrophic condition in eastern area. The most important sources of dissolved silicate in the Mediterranean Sea come from the continental fluvial system and from groundwater discharges. Electronic microscopy shows dominance of diatoms, which play an important role in organic matter export to the deep sea. Trace element fractionation differentiates five fractions the forth first fractions constitute bioavailable fraction that is compared to deep water (near sediment water interface). This comparison shows at first the impotence of surface sediment as potential pump of trace element to the water column and the deep influence of continental discharges on surface sediment trace element acumulation and the deep water mainly for Fe, Cu and Co.

Keywords: Bioavailability. Mediterranean Sea. Nutrients. Surface sediment. Trace element.

Submitted by Zaaboub Noureddine (nouri.zaaboub@gmail.com).

New GEOTRACES or GEOTRACES relevant scientific results

- The new results of the Black Sea and Marmara Sea DeepRedox project Cruise (funded by TUBIRAK) held winter of 2020 is given below.

The Black Sea and Sea of Marmara are the two ideal oceanographic study sites to understand the shelf to deep-sea redox gradient, biogeochemical processes, trace metal cycling, burial, and transport. The Black Sea contains one of the world's largest permanent anoxic deep seawater and oxic/anoxic interface of the shelf to basin-wide. Besides, the Sea of Marmara is recently deoxygenated due to climate forcing, anthropogenic artifacts, and eutrophication. The critical deoxygenation of the Sea of Marmara represents the oxygen minimum zone (OMZ) extending the 1000m depth. More to that, the Sea of Marmara is recently under the impact of thick mucilage among its surface and deep seawaters that could intensify organic matter burial, deoxygenation, or presence of the sulfidic deep waters. Therefore, these study sites are the primary concern of the national activities to understand the redox gradient of seawater, nutrients, and redox-related trace metal cycles.

In that regard, seawater and sediment core samples were obtained from 90 and 9 stations, respectively in the Sea of Marmara and the Black Sea (Fig. 38). More to that, nano gold/amalgam sensör attached to Analytical Instrument Systems (AIS ISEA X) brand and model situ system was applied to measure real-time in situ oxygen and hydrogen sulfide if available. The core samples were collected about 50-60 cm in height without disturbance of the sediment-water interface. Each core was sectioned, sliced and porewater extracted from the solid phase and

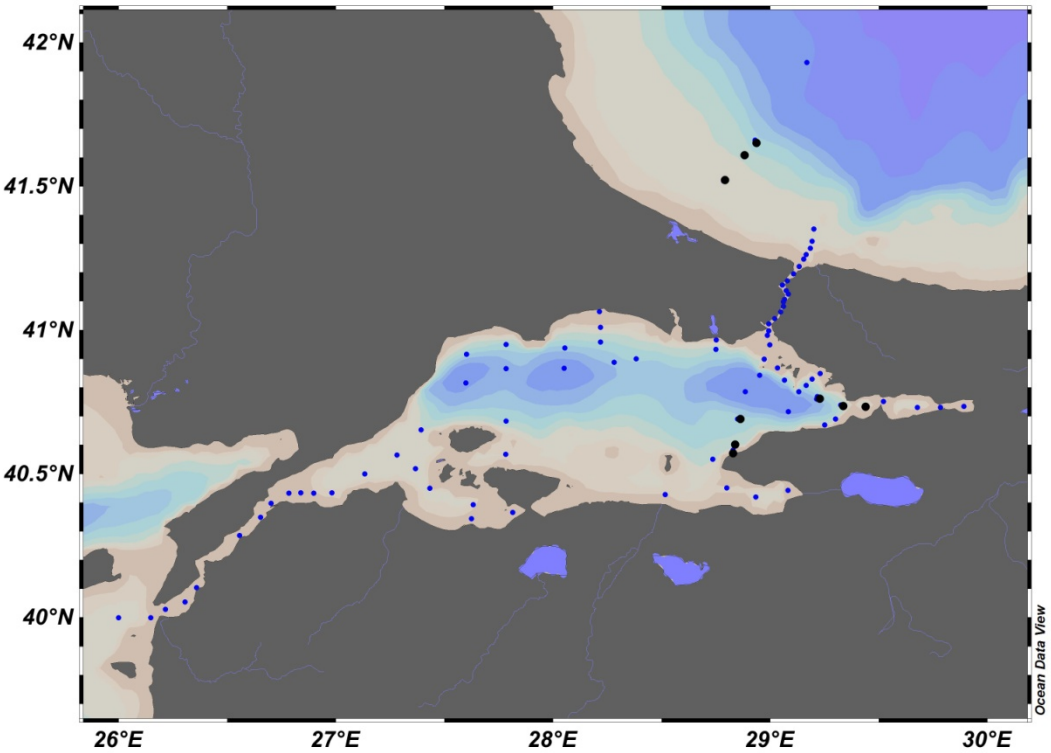


Figure 38: *The stations of the winter cruise in the Black Sea and the Sea of Marmara; blue dots represent only sampling of seawater; black dots represent sampling of core and seawater.*

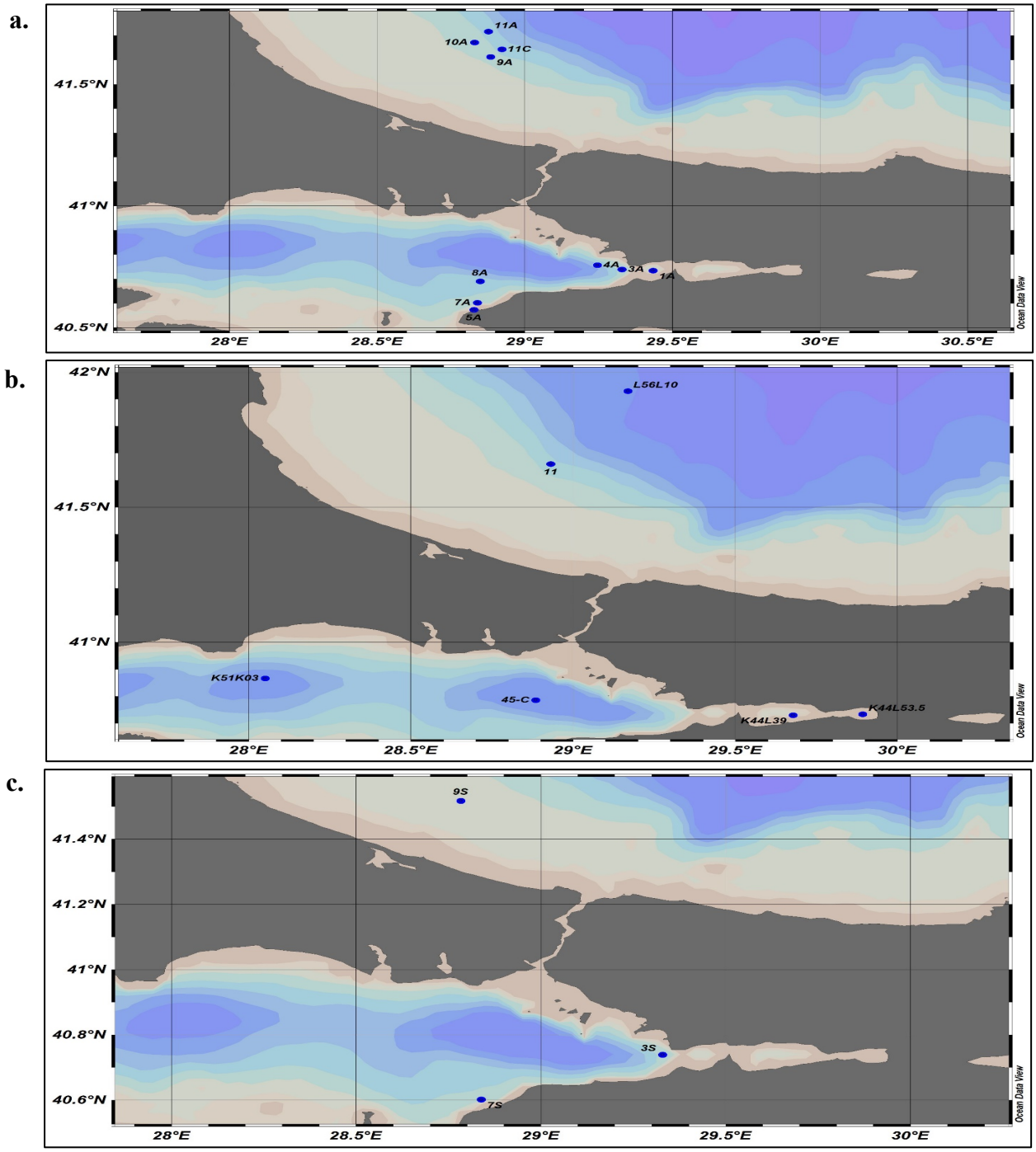


Figure 39: *The core samples collected at stations of winter cruise 2020, a. Fe and dFe of the porewater were measured at 9 stations , b. Fe of the seawater were measured at 6 stations, c. Fe size fractionation of porewater were held at 3 stations*

frozen for laboratory analyses. The total iron, dissolved iron (dFe), and dissolved were measured onboard. Iron size fractionation and seawater iron measurement were held at the selected stations on board. The collected seawater, porewater, and solid samples were subsampled for hydrogen sulfide, trace metals, nutrients, and other major ions (Cl, SO4, Li, Na, K, Mg, Ca) on the campus. Also, the core samples were collected separately for microbial analysis under sterile conditions and frozen immediately.

The porewater Fe and dFe were measured at 9 stations, whereas Fe seawater measurement and Fe size fractionation were held at 6 and 3 stations, respectively (Fig. 39). The porewater subsamples for Fe were spiked with HCl immediately after extraction. The porewater Fe and dFe were measured by the liquid-core waveguide spectrophotometry and Ferrozine method

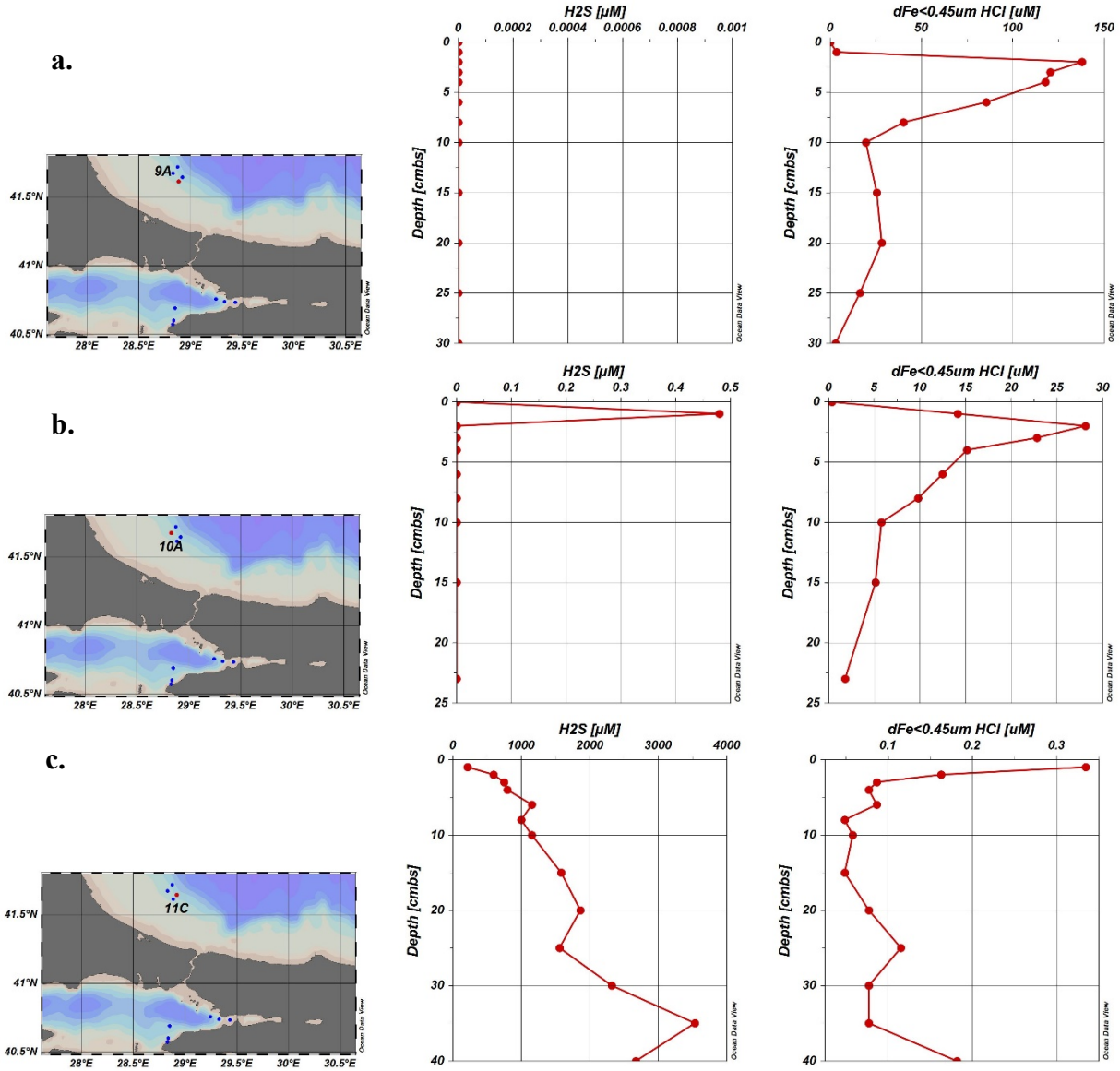


Figure 40: *The Black Sea oxic shelf to deep sulfidic sediment transition, H_2S(µM) and dFe (µM) concentrations a. in the oxic station, b. suboxic station, c. sulfidic station.*

with 50cm optical path length capillary cuvette. All of the subsampling and analysis for Fe detection were practiced with pre-acid cleaned glassware and apparatus and ultra-pure chemicals under trace metal-free conditions on board. The detection limit was 18nM for onboard the liquid core waveguide spectrophotometric analysis. The calibration curve had R2 = 0.9983. Fe size fractionation of porewater was syringe filtered with 0.45 µM nylon membrane, 0.20 µM polycarbonate membrane, and 0.02 µM Anodisc membrane. Each filtrate was subsampled then spiked with HCl and HNO3, separately. The results display the oxic to sulfidic transition from shelf to deep seafloor of the Black Sea and deoxygenation of the Sea of Marmara. The dFe of the oxic Black Sea shelf sediment is times more than the sulfidic basin sediment (Fig. 40).

The deoxygenation of the Sea of Marmara is confirmed with the findings of this study. More to that, the H_2S measured at the sediment-water interface at 2 µM level displays the oxygen minimum zone transition in the İzmit inlet located the eastern Sea of Marmara (Fig. 41).

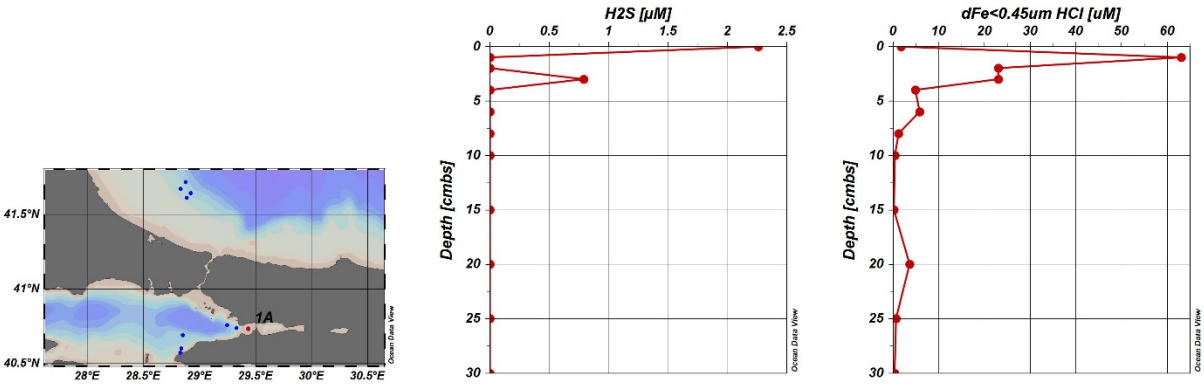


Figure 41: *The H_2S (µM) and dFe (µM) distribution through the sediment column from the İzmit inlet of Sea of Marmara.*

The main findings of the study are the high dissolved iron concentration and fluctuation in the oxic shelf sediment compared to sulfidic sediment. The iron compounds mainly in the dissolved form of the total iron fraction in the sediment, which highlights the importance of the nano-sized iron compounds. The size fractionation of the Fe compounds is mostly linked to its diffusion rate of vertical transition and the surface adsorption capacity of other trace metals and phosphorus. Hence, the high dissolved fraction of iron in the oxic shelf could create nanoparticle accumulation of Fe and Fe-derived microbial life.

GEOTRACES or GEOTRACES relevant cruises

- Black Sea and Marmara Sea Redox Cruise held winter and summer of 2020 with R/V Bilim-2. Fe in the sediment core measured on board with Ferrozine method at nanomolar level.

New projects and/or funding

- EU H2020 BRIDGE-BS consortium project, coordinated by METU IMS has been launched. The project aims to advance Black Sea marine science and innovation with a specific work package dedicated to develop novel observing systems for the Black Sea.

Outreach activities conducted

- 1st summary report of the DEEPREDOX project, 2020.

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

- Akcay, İ., Tugrul, S., Yucel, M. (2021). Benthic nutrient fluxes across a productive shelf adjacent to an oligotrophic basin: case of the Northeastern Mediterranean Sea. https://doi.org/10.31223/X5390F.

Submitted by Dr. Mustafa Yucel (myucel@ims.metu.edu.tr).

New scientific results

- **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.

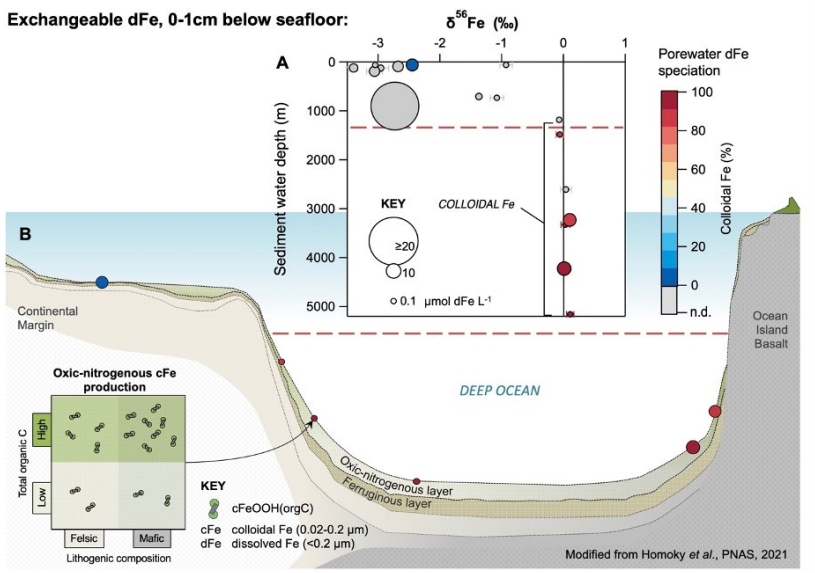


Figure 42: *Characterising the exchangeable source of dissolved iron in shallow porewaters beneath the open ocean. (A) Data markers correspond to measured surface (0-1 cmbsf) values compiled from sediments of the western South Atlantic (this study), the eastern South Atlantic, Cape margin[1], the North Pacific, Oregon and California margins and Borderland Basins[2,3], the North Atlantic, Celtic Sea[4], and the Southern Ocean, Crozet Island abyss[2]. 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).*

Homoky et al. (2021), PNAS.

- **An unknown source of reactor radionuclides in the Baltic Sea**

The combinations of multi-isotope fingerprints from uranium and iodine isotope indicates a source of reactor ^{236}U in the Baltic Sea in addition to inputs from the two European reprocessing plants and global fallout. This additional reactor ^{236}U may come from unreported discharges from Swedish nuclear research facilities as supported by high ^{236}U levels in sediment nearby Studsvik, or from accidental leakages of spent nuclear fuel disposed on the Baltic seafloor.

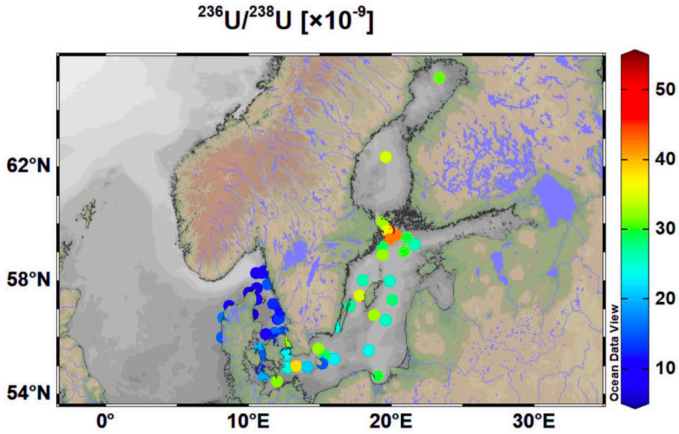
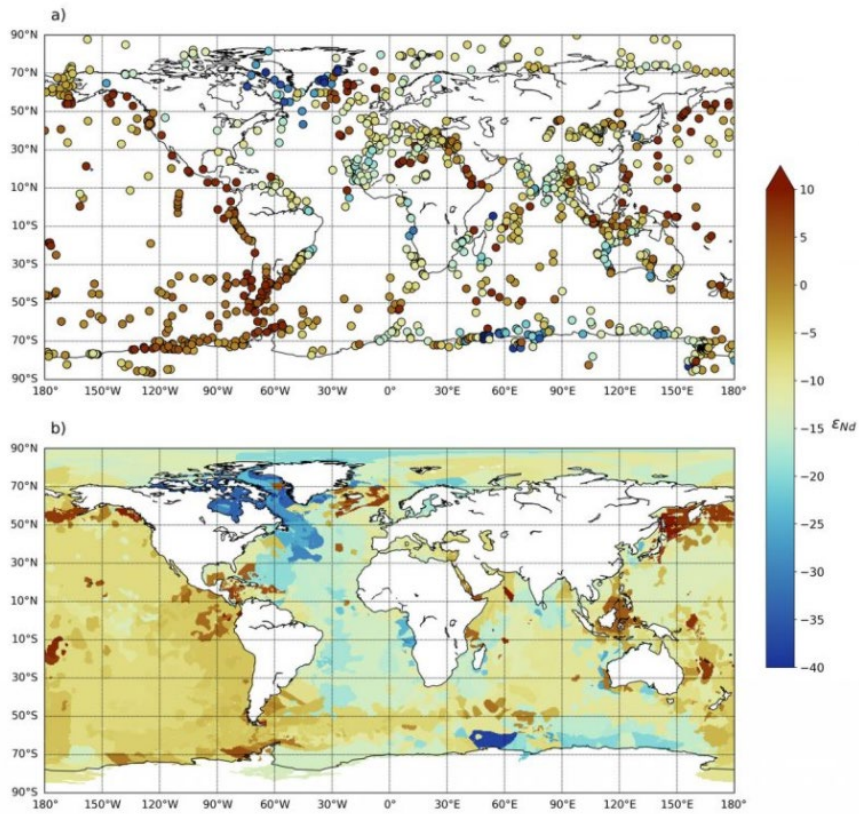


Figure 43: *$^{236}U/^{238}U$ increases in the Baltic, demonstrating addition of reactor ^{236}U.*

Qiao et al. (2021), Nature Comms.

- **Updated compilation of the global continental and marine lithogenic neodymium isotopic measurements**

The work proposed by Robinson and co-workers (2021, see reference below) was more than expected! Using an up-to-date compilation of published terrestrial and marine sedimentary Nd isotopic measurements, they constructed a high resolution, gridded, global maps that characterise the Nd-isotopic signature (εNd) of the continental margins and seafloor sediment. This a considerable improvement of Nd-source identification compared to the seminal work of Jeandel et al. (2007, see reference below). Among others, Robinson's study provides a refined map of



the seafloor sediment εNd, based on measurements from pore waters and deep seafloor detrital samples. Such better characterisation of global εNd distributions at the entire sediment-ocean interface, together with a refined description of the εNd signature of the fields surrounding the northern North Atlantic Ocean, is a rich resource for further modelling.

Figure 44: *These maps display the location and εNd of the samples assembled in the updated compilation of over 5000 published terrestrial and marine sedimentary Nd isotopic measurements presented here, (a). From this database, we construct high resolution, gridded, global maps that characterise the Nd-isotopic signature of all continental margins and seafloor sediment, e.g. (b). These maps are especially designed for investigating marine Nd cycling, particularly to aid in constraining the magnitude and εNd from sediment-water interaction and how this influences the distribution of marine εNd. Thus, the new compilation and gridded datasets offer a concrete way forward to improve the application of Nd isotopes as a useful tracer of ocean circulation.*

Robinson et al. (2021), Chem. Geol.

- **Co-occurrence of Fe and P stress in natural populations of the marine diazotroph Trichodesmium**

Trichodesmium's (cynaobacteria that fixes nitrogen) colonial lifestyle likely produces challenges for dissolved Fe and P acquisition, which must be compensated for by production of multiple nutrient transport systems, such as for particulate iron and organic phosphorous, at a considerable cost. Metaproteomic observations and accompanying nutrient uptake model demonstrate that Fe and P co-stress is the norm rather than the exception.

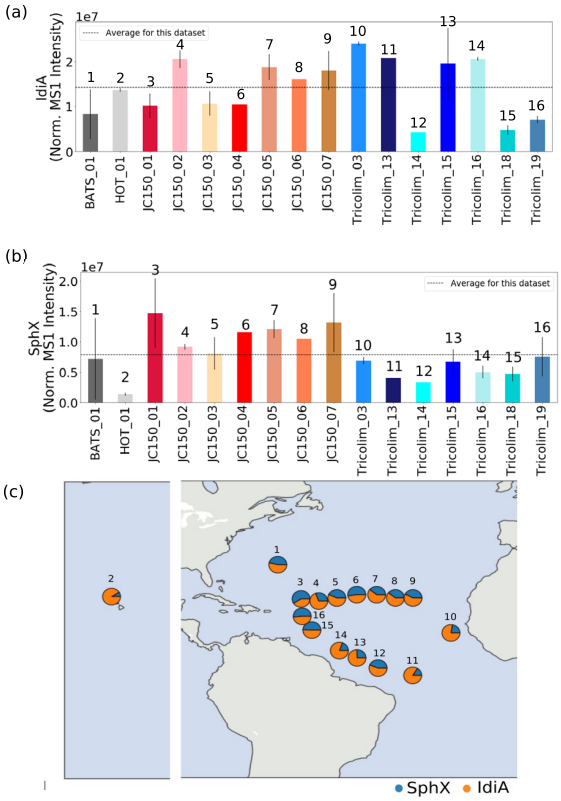


Figure 45: *(A) Relative abundance of iron stress protein IdiA (A) and phosphate stress protein SphX (B). IdiA and SphX were among the most abundant proteins in the entire dataset. Error bars are one standard deviation on the mean when multiple samples were available. Dashed lines represent average values across the dataset. (C) Relative abundance of IdiA (orange) and SphX (blue) overlaid on the sampling locations.*
Held et al. (2020), Biogeosciences.

- **Tropical Pacific fisheries affected by uncertainty in phytoplankton iron uptake.**

Tagliabue et al. (2020), Global Change Biol.

GEOTRACES or GEOTRACES relevant cruises

- PhD student Isobel Turnbull (U Plymouth) participated in the French GEOTRACES cruise SWINGS (GS02).

New projects and/or funding

- Gideon Henderson (U Oxford) and Alex Baker (UEA) won funding for their project 'Atmospheric fluxes of mineral dust-derived soluble trace elements to the ocean using thorium isotopes (ThorMap)'. NERC standard grant (2021-2023). Involves the measurement of a range of GEOTRACES water and aerosol samples.

Outreach activities conducted

- Jade Hatton published an article in the ECO magazine about sensors. http://digital.ecomagazine.com/publication/frame.php?i=674747&p=&pn=&ver=html5&view=articleBrowser&article_id=3771619

Other GEOTRACES activities

- Maeve Lohan (NOCS, co-chair) and Tina van de Flierdt (Imperial College London, committee member) attended bi-weekly virtual Standards & Intercalibration (S&I) meetings from summer 2020 to spring 2021.
- Maeve Lohan (NOCS, S&I co-chair) and Alessandro Tagliabue (University of Liverpool, DMC co-chair) attended four virtual DMC meetings.
- Maeve Lohan (NOCS), Tina van de Flierdt (Imperial College London) and Alessandro Tagliabue (University of Liverpool) attended the virtual annual SSC meeting.

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

- Archer, C., Vance, D., Milne, A., Lohan, M.C. (2020), The oceanic biogeochemistry of nickel and its isotopes: New data from the South Atlantic and the Southern Ocean biogeochemical divide. Earth and Planetary Science Letters, 535, 116118, https://doi.org/10.1016/j.epsl.2020.116118.
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- Cassarino, L., Hendry, K. R., Henley, S. F., MacDonald, E., Arndt, S., Freitas, F. S., Pike, J., Firing, Y. L. (2020), Sedimentary nutrient supply in productive hotspots off the West Antarctic Peninsula revealed by silicon isotopes. Global Biogeochemical Cycles, e2019GB006486, https://doi.org/10.1029/2019GB006486.
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Completed GEOTRACES and GEOTRACES relevant PhD or Master theses

- PhD – Arthur Gourain. '*Copper biogeochemical cycle and the organic complexation of dissolved copper in the North Atlantic*.' University of Liverpool.
- PhD – Korinna Kunde. '*Coupling Macro and micro biogeochemistry: Distribution and speciation of iron and other bioactive trace metals required for phosphorus acquisition in the sub-tropical North Atlantic*.' University of Southampton.
- PhD – Shaun Rigby. '*Copper biogeochemical cycle and the organic complexation of dissolved copper in the North Atlantic*.' University of Liverpool.
- PhD – Wenhao Wang. '*Biogeochemical cycling of iron and chromium in the North Atlantic Ocean: Insights from stable iron and chromium isotopes*.' University of Southampton.
- MSc – Oliver Flanagan. 'Biogeochemical controls on particulate bioactive trace metals along the Western Antarctic Peninsula Shelf.' University of Southampton.
- MSc – Magali Roberts. '*Seasonality and physico-chemical speciation of iron in nepheloid layers and creation of an optical method to estimate the concentration of particulate iron*'. University of Plymouth (exchange student from the University of Bretagne Occidentale Brest).

SELECTED GEOTRACES presentations in international conferences

- **Virtual Goldschmidt Conference, 21-26 June 2020**
  - Susan Little chaired Theme 13: *Chemistry of the Oceans and the Atmosphere: now and through time*.
  - Wang, W., Goring-Harford, H., Kunde, K., Lohan, M., Connelly, D., James, R. (2020), '*Biogeochemical Cycling of Chromium and Chromium Isotopes in the Sub-Tropical North Atlantic Ocean*.'

Submitted by Tina van de Flierdt (tina.vandeflierdt@imperial.ac.uk).

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 US 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 US 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.

Analysis of samples from GEOTRACES section GP15, 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. 46). Much of the work that is still ongoing will relate the distributions of TEIs to the concentrations and fluxes of POC.

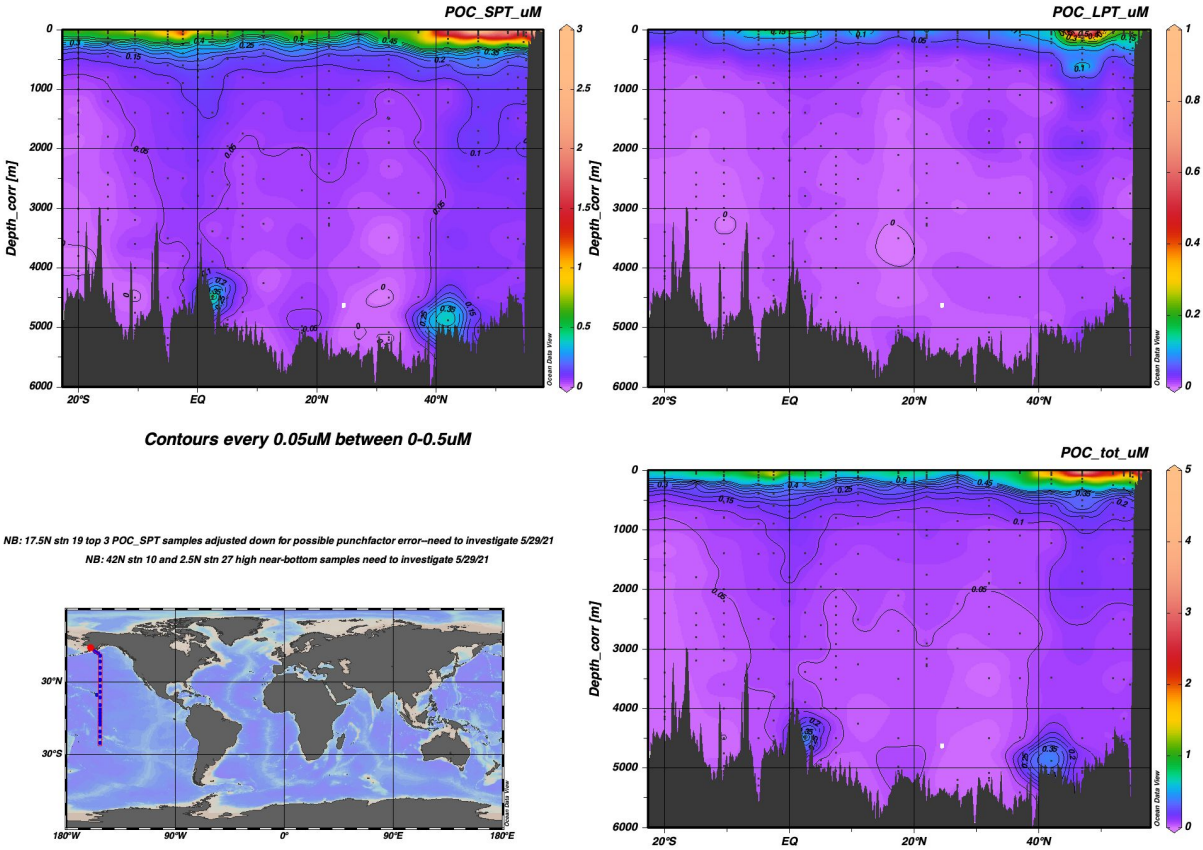

Figure 46: *Concentrations of POC in two size fractions of particles collected along the GP15 transact, shown in the lower left panel, together with the concentrations of total POC obtained by summing the concentrations of the two size factions, shown in the lower right panel. Figure courtesy of Phoebe 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. 47 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.

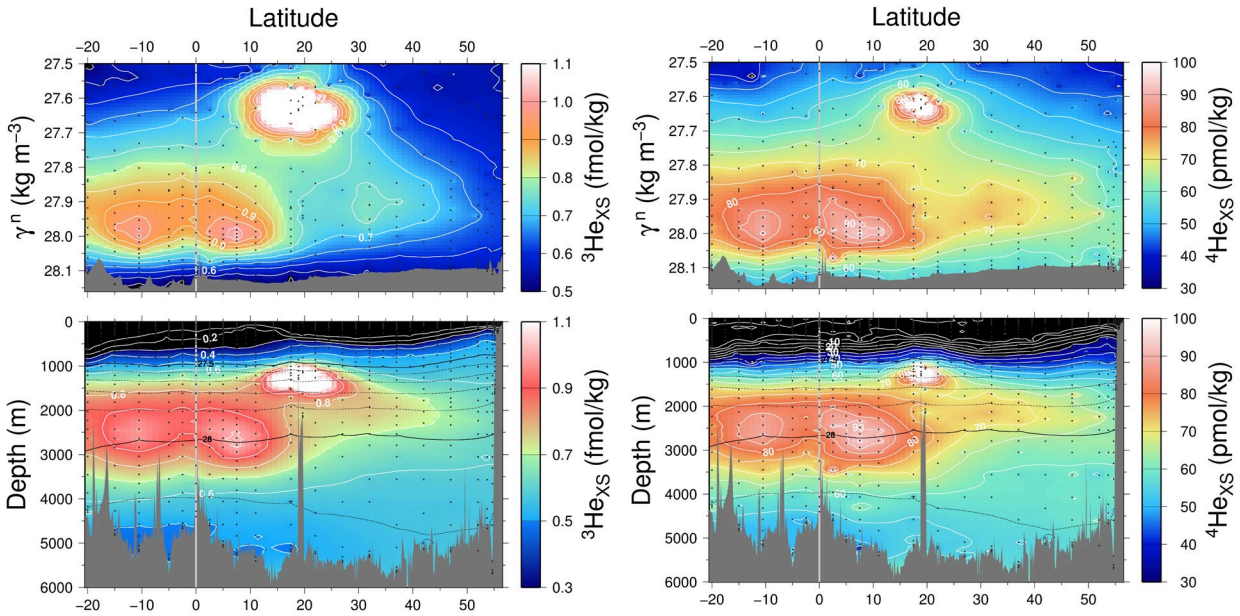

Figure 47*: The deep meridional distributions of hydrothermally sourced (XS) helium isotopes. The less abundant ^{3}He is plotted on the left in fmol kg^{-1} as a function of depth (lower panel) and neutral density (upper panel). Note the color scales differ to show features better. The more abundant 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 US GEOTRACES cruises were scheduled during the reporting period.

New projects and/or funding

Last year's report described US 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 48, 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.

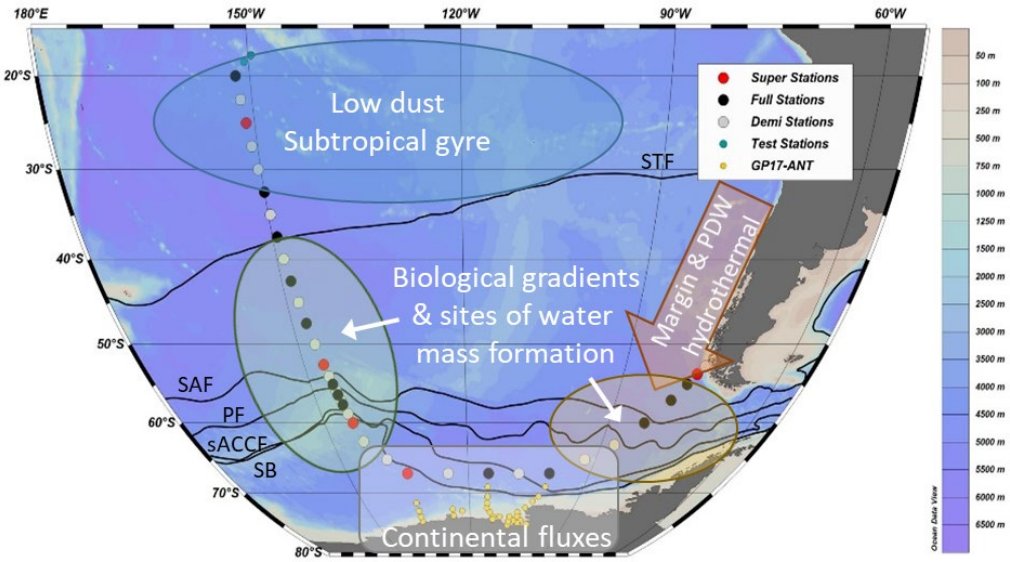

Figure 48: *Station locations for the proposed two-ship operation constituting GEOTRACES section GP17. The legend shows the different types of stations to be sampled from the global class research vessel. In yellow near the coast of Antarctica are the proposed stations for the icebreaker. The principal 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 break-out 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 CalTeach 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:https://doi.org/10.1016/j.marchem.2020.103892.
- Bundy, R. M., A. Tagliabue, N. J. Hawco, P. L. Morton, B. S. Twining, M. Hatta, A. E. Noble, M. R. Cape, S. G. John, J. T. Cullen, and M. A. Saito (2020), Elevated sources of cobalt in the Arctic Ocean, Biogeosciences, 17(19), 4745-4767, doi:10.5194/bg-17-4745-2020.
- Deng, J., Y. Gao, J. Zhu, L. Li, S. Yu, K. Kawamura, and P. Fu (2021), Molecular markers for fungal spores and biogenic SOA over the Antarctic Peninsula: Field measurements and modeling results, Science of The Total Environment, 762, 143089, doi:https://doi.org/10.1016/j.scitotenv.2020.143089.
- 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.
- Gao, Y., S. Yu, R. M. Sherrell, S. Fan, K. Bu, and J. R. Anderson (2020), Particle-Size Distributions and Solubility of Aerosol Iron Over the Antarctic Peninsula During Austral Summer, Journal of Geophysical Research: Atmospheres, 125(11), e2019JD032082, doi:10.1029/2019JD032082.
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Other Products (e.g., compiled data sets)

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1. Sallie W. Chisholm GROUP (Massachusetts Institute of Technology, Boston, MA, USA)
Jed Fuhrman (University of Southern California)
Paul M. Berube (Massachusetts Institute of Technology)
Jesse McNichol (University of Southern California)

Paul Berube, Jesse McNichol and Reiner Schlitzer identified ways in which to best integrate the chemical data sets in GEOTRACES with the 'omics data generated from samples obtained on US GEOTRACES sections. These methods leverage alternative data portals, such as the Simons Collaborative Marine Atlas Project (CMAP) (Ashkezari et al., 2021). CMAP was built with the intent of making oceanographic data (biological, chemical, or physical) more easily accessible to diverse users and intercomparable by having each measurement indexed by explicit space/time coordinates. For example, an investigator interested in complementary measurements taken near one of the BioGEOTRACES transects could input the latitude / longitude / depth / time information from the cruise path to CMAP and retrieve any other data sources matching those spatiotemporal coordinates. This process is referred to as "co-localization" by the developers of CMAP. In addition, CMAP also provides a central repository for these data, making it easier for non-domain experts to download and exploit datasets across traditional disciplinary boundaries.

We are getting closer to integrate/include the GEOTRACES data in portals such as CMAP, now that the GEOTRACES data use policy has been modified. It seems that the new GEOTRACES data use policy will satisfy the requirements of CMAP to have GEOTRACES data stored directly in their databases. This would allow users to co-localize GEOTRACES chemical data with other forms of data in CMAP such as biogeochemical model output or satellite products using the "co-localization" approach described above. We have encouraged the developers of CMAP (Ashkezari and Armbrust, University of Washington; Ashkezari et al., 2021) to reach out to the GEOTRACES Data Management Committee to initiate direct conversations on how to improve cross-platform access to diverse GEOTRACES data sets, including the BioGEOTRACES 'omics data.

There are several original papers that document the BioGEOTRACES data sets currently under discussion (Berube et al., 2018; Biller et al., 2018; Pachiadaki et al., 2019; McNichol et al., 2021). All of these data sets are derived from samples obtained by the Chisholm Laboratory (MIT) on the GA02, GA03, GA10, and GP13 sections. These include metagenomic data (Biller et al., 2018), 16S/18S rRNA gene amplicon sequences to facilitate high resolution taxonomy (McNichol et al., 2021), and single cell genomes (Berube et al., 2018; Pachiadaki et al., 2019). One single cell genomics data set is focused on cyanobacterial genomes (Berube et al., 2018). The other single cell genomics data set (Pachiadaki et al., 2019) – generated by the Stepanauskas group at the Bigelow Laboratory for Ocean Sciences, in collaboration with the Chisholm group at MIT – aimed to capture a wide breadth of the microbial diversity in the epipelagic zone of both the Pacific and Atlantic basins. Multiple downstream papers have resulted from further analysis of these data sets (Becker et al., 2019; Berube et al., 2019; Acker et al., 2020; Hackl et al., 2020; among others). Additionally, a newly released data set compilation (Martiny group at UC-Irvine) combines metagenomic data from BioGEOTRACES, Tara Oceans, and Bio-GO-SHIP (Larkin et al., 2021).

The generation of additional datasets for the GP15 section are planned, but have been delayed due to the COVID-19 health emergency. These data sets include 16S/18S amplicons and cyanobacterial 16S-23S rRNA gene internal transcribed spacer sequence amplicons (generated by Paul Berube and Dreux Chappell for GP15). Jed Fuhrman and Jesse McNichol are also currently working up data for GA02 and GA10, in addition to the published data for GA03 and GP13 (McNichol et al., 2021).

And here are some highlights about how we are incorporating BioGEOTRACES 'omics data in the GEOTRACES IDP 2021:

1. To make the "discovery" process easier for users with less experience in the analysis of 'omics data, the 'omics data will be a variable of choice in the IDP2021. So, for example in the WebODV "Required variables" we could add a box that says "Omics" and then you click there and see the three choices of data: metagenomics, single cell genomics, and amplicon sequence data (with the appropriate parameter names, of course!)

2. All the omics data comes from the regular rosette. The metadata associated with the 'omics samples were submitted to GEOTRACES. In addition, each 'omics sample will be linked to all the trace metal data depth profile associated with that station.

3. When bioinformaticians download all the GEOTRACES data associated with the station where that specific 'omics sample was collected, there will be no interpolation of the data. The users can delete whatever data they do not want and they can interpolate the data to their liking. In addition, CMAP (Ashkezari et al., 2021) has co-localization tools that can facilitate combined analysis of physical, chemical, and biological data and the developers are also working on various interpolation tools. So, with all these data they can do some nice data analyses between the 'omics and the GEOTRACES data for a given station.

4. In essence, the excel sheet with the 'omics data was submitted to GDAC and it contained 3 tabs. Tab #1: the GEOTRACES bottle numbers and the three columns with their NCBI accession numbers; Tab#2 metadata associated with their bottles (these was downloaded from the IDP2017, and in essence are the regular rosette data; Tab # 3 are the DOI associated with these OMICS data. The parameter names for the three OMIC data types are:
   Metagenomes: NCBI_Metagenome_BioSample_Accession
   Single cell genomes: NCBI_Single-Cell-Genome_BioProject_ Accession
   Amplicon data: NCBI_16S-18S-rRNA-gene_BioSample_Accession

5. To deal with the issue of multiple single cell genomes per bottle (we are actually dealing with 100's of single cell genomes per bottle, and both eukaryotic and prokaryotic), we decided that we will reference the Project accession number instead of the single cell genome. If people go to that BioProject in NCBI, they will see all the associated single cell genomes. Please note that there is more than one number listed sometimes, as there are more than one BioProject associated with these single cell genomes. We separated the projects by a semicolon.

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2. Ben Twining GROUP (Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA)

Since July 2020, we have submitted both of the manuscripts referred to in last year's report: Twining et al. (2021, L&O Letters, 6: 96-106) summarized phytoplankton metal quota data from a GEOTRACES section cruise (GP16) and two GEOTRACES-compliant cruises (GeoMICS and IRNBRU).

Shaked et al. (2021, Global Biogeochemical Cycles, in revision) uses a global phytoplankton metal quota dataset, along with global modeling output, to calculate cellular Fe uptake rates across low-Fe surface waters in the global ocean.

All of these data have been submitted to US BCO-DMO data repository.

Recently-collected phytoplankton metal quota data from a GEOTRACES-compliant cruise to the Southern Ocean (IN2018_V02; Philip Boyd, chief scientist) are supporting a submitted manuscript (Hawco, Tagliabue and Twining, 2021, in review) on Mn limitation in the global ocean and a manuscript in preparation examining global variability in metal quotas of picoeukaryotes.

3. Mak Saito GROUP (Woods Hole Oceanographic Institution, MA, USA)

Graduate student Riss Kellogg published a GEOMICS Expedition (original Biogeotraces pilot cruise by US NSF) with dissolved metal sections and laboratory studies showing unusual efficiency of Co use in Northeast Pacific Diatoms where dCo can become more abundant than dZn: Kellogg, M.M., McIlvin, M.R., Vedamati, J., Twining, B.S., Moffett, J.W., Marchetti, A., Moran, D.M. and Saito, M.A., 2020. Efficient zinc/cobalt inter-replacement in northeast Pacific diatoms and relationship to high surface dissolved Co: Zn ratios. Limnology and Oceanography, 65(11), pp.2557-2582. https://doi.org/10.1002/lno.11471

Natalie Cohen from dissolved the Saito group (now at Skidaway) also submitted a paper on dissolved Fe, Mn, Zn, Cu, Cd, and Ni full depth ocean sections and hydrothermal inputs and microbial proteins within the plume on the Tonga ridge from Metzyme and submitted them to BCO-DMO and the GEOTRACES IDP. https://bg.copernicus.org/preprints/bg-2021-96/

Natalie Cohen from the Saito group (now at Skidaway) published a paper on dinoflagellates, nutrient and micronutrient stresses and shifts from phototrophy/mixotrophy to heterotrophy with depth on the Metzyme GEOTRACES compliant section. https://www.nature.com/articles/s41564-020-00814-7

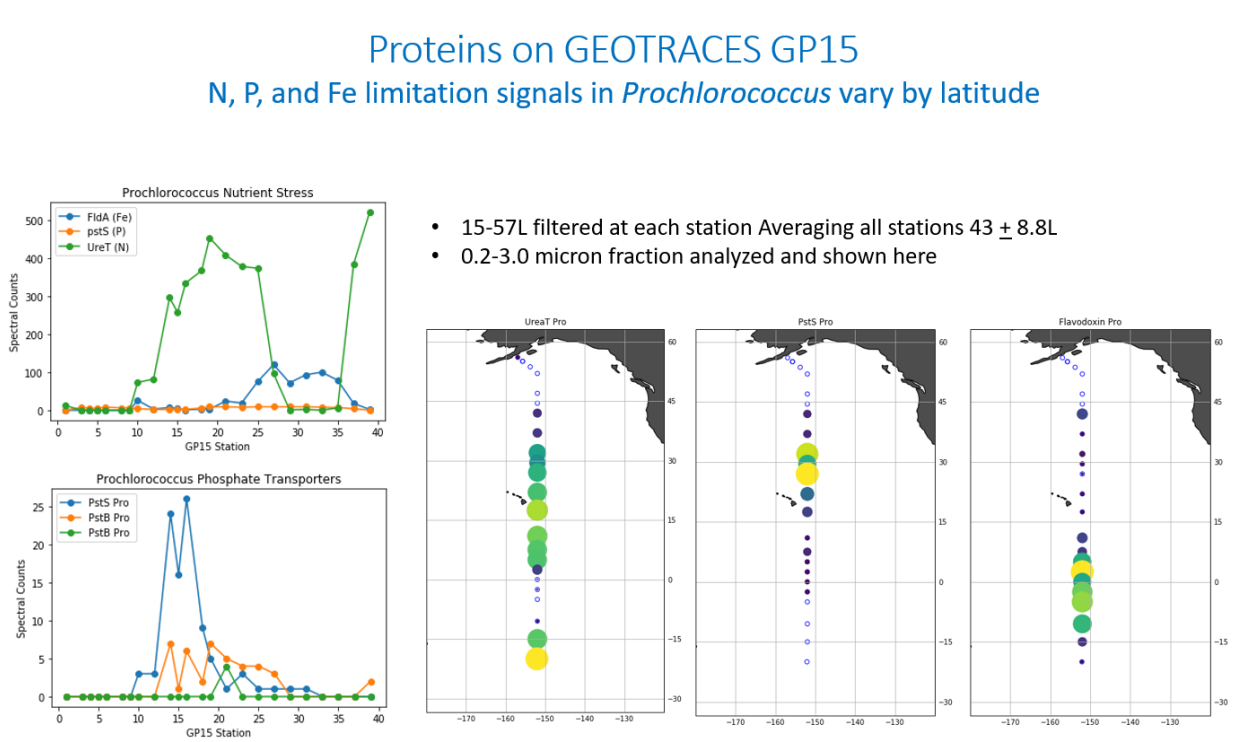
Metaproteomic intercomparison project supported by OCB, led by Saito and McIlvin, is ongoing. BATS protein filter samples have been distributed to 10 labs, 9 have submitted data, a hybrid data workshop is being planned for September of 2021. https://www.us-ocb.org/intercomparison-and-intercalibration-metaproteomics/

The Ocean Protein Portal (www.oceanproteinportal.org) received renewed NSF funding to develop Version 2.0 for enhanced capabilities and sustainability in 2020. Two manuscripts describing the Ocean Protein Portal were published in 2020:

Saito, M.A., Saunders, J.K., Chagnon, M., Gaylord, D.A., Shepherd, A., Held, N.A., Dupont, C., Symmonds, N., York, A., Charron, M. and Kinkade, D.B., 2020. Development of an Ocean Protein Portal for Interactive Discovery and Education. Journal of Proteome Research. https://pubs.acs.org/doi/abs/10.1021/acs.jproteome.0c00382

Saunders, J.K., Gaylord, D.A., Held, N.A., Symmonds, N., Dupont, C.L., Shepherd, A., Kinkade, D.B. and Saito, M.A., 2020. METATRYP v 2.0: Metaproteomic Least Common Ancestor Analysis for Taxonomic Inference Using Specialized Sequence Assemblies—Standalone Software and Web Servers for Marine Microorganisms and Coronaviruses. Journal of Proteome Research, 19(11), pp.4718-4729. https://pubs.acs.org/doi/abs/10.1021/acs.jproteome.0c00385

Surface protein transect from US GEOTRACES track GP15 have been completed, showing Fe, N, P stresses occurring along the transect, which can be compared other cruise data. The results were shared at a US GEOTRACES GP15 seminar. The data will be uploaded to the Ocean Protein Portal when QC is complete for public access. A python Jupyter notebook version of the data is available as well upon request and will be submitted to BCO-DMO. See figure below.



Rates from Omics and the discovery of the most abundant metalloenzyme in the mesopelagic study published in 2020 in Nature Geosciences: Saito, M.A., McIlvin, M.R., Moran, D.M., Santoro, A.E., Dupont, C.L., Rafter, P.A., Saunders, J.K., Kaul, D., Lamborg, C.H., Westley, M. and Valois, F., 2020. Abundant nitrite-oxidizing metalloenzymes in the mesopelagic zone of the tropical Pacific Ocean. Nature Geoscience, 13(5), pp.355-362. https://www.nature.com/articles/s41561-020-0565-6

Postdoc Mike Mazzotta published a study of iron use within metalloproteins of marine heterotrophic bacteria combined with a metaproteomic section of iron siderophore transport system. Mazzotta, M.G., McIlvin, M.R. and Saito, M.A., 2020. Characterization of the Fe metalloproteome of a ubiquitous marine heterotroph, Pseudoalteromonas (BB2-AT2): multiple

bacterioferritin copies enable significant Fe storage. Metallomics, 12(5), pp.654-667. https://doi.org/10.1039/d0mt00034e

Field studies of co-limitation of Trichodesmium in the North Atlantic Ocean using metaproteomics. Held, N.A., Webb, E.A., McIlvin, M.M., Hutchins, D.A., Cohen, N.R., Moran, D.M., Kunde, K., Lohan, M.C., Mahaffey, C., Woodward, E.M.S. and Saito, M.A., 2020. Co-occurrence of Fe and P stress in natural populations of the marine diazotroph Trichodesmium. Biogeosciences, 17(9), pp.2537-2551. https://bg.copernicus.org/articles/17/2537/2020/

Clio: a vehicle for BioGeotraces sampling

First manuscript describing BATS science validation and Bermuda-Woods Hole section described: Breier, J.A., Jakuba, M.V., Saito, M.A., Dick, G.J., Grim, S.L., Chan, E.W., McIlvin, M.R., Moran, D.M., Alanis, B.A., Allen, A.E. and Dupont, C.L., 2020. Revealing ocean-scale biochemical structure with a deep-diving vertical profiling autonomous vehicle. Science Robotics, 5(48). https://robotics.sciencemag.org/content/5/48/eabc7104.abstract

- Awaiting scheduling for Clio expedition in the Pacific OMZ (delayed due to COVID)
- Short Atlantic Continental shelf Clio expedition planned for November 2021, could follow up on the study of nepheloid layers characterized during the GEOTRACES North Atlantic expeditions. Clio will conduct high-resolution sampling near the seafloor.

4. Julie LaRoche GROUP (Dalhousie University, Halifax, NS, Canada)

Abstracts submitted to the Ocean Sciences meeting in Feb 2020:
Here it is pasted below

Diazotrophs distribution and N_2 fixation drivers in the northern North Atlantic Ocean FONSECA-BATISTA, Debany, DEMAN, Florian, DESPREZ DE GESINCOURT, Floriane, PLANQUETTE, Hélène, SARTHOU, Géraldine, DEHAIRS, Frank and LAROCHE, Julie

The biological conversion of dissolved dinitrogen (N_2) gas by bacterioplankton referred to as diazotrophs, constitutes the major source of nitrogen (N) to the global ocean. Marine primary production (i.e., biological fixation of atmospheric carbon dioxide, CO_2 dissolved in the ocean) is mostly limited by the availability of dissolved inorganic nitrogen (e.g., nitrate, ammonium) in the global ocean. Surveys of the nitrogenase reductase-encoding gene (nifH), used as a diazotroph phylogenetic marker, complemented by metagenomic assembly and binning approaches have revealed that the ability of marine microbial communities to fix gaseous N_2 is widely distributed in the surface ocean. While there is some molecular marker evidence for the presence of diazotrophs in high latitude regions mostly shelf areas, concurrent N_2 fixation observations are still too scarce and scattered to determine their biogeochemical importance. During the cross-Atlantic GEOVIDE expedition from Lisbon, Portugal to St. John's, Newfoundland, Canada (GEOTRACES GA01, May-June 2014), we carried out rates measurements of N_2 fixation and primary production, surveyed the nifH gene distribution and abundance of predominant diazotroph groups, to be gauged against key environmental variables monitored during or at the time of our sampling such as seawater trace metals concentrations, climatological nutrient data and remotely sensed atmospheric depositions. We aim at gaining a better understanding of the factors regulating diazotrophic

activity in this temperate to sub-polar basin, while highlighting the important role played in those regions by non-photosynthetic diazotrophs, i.e. unicellular diazotrophic cyanobacterium of group A (UCYN-A) and non-cyanobacterial diazotrophs (i.e. Proteobacteria, Firmicutes, and Archaea).

AND

Inferring the metabolic diversity and ecological function of non-photosynthetic diazotrophs in the context of their associated microbial communities along a latitudinal transect in the Canadian Arctic Gateway LAROCHE, Julie, ROBICHEAU, Brent, TOLMAN, Jennifer, DESAI, Dhwani, FONSECA BATISTA, Debany, MALDONADO, Maria T.

Diazotrophs are a group of microorganisms with the ability to fix N2 gas into ammonia, thereby contributing to new fixed nitrogen (N) to the oceanic N inventory. Although diazotrophs are taxonomically and metabolically diverse, they have been broadly separated into photosynthetic and non-photosynthetic groups. Classically, the role of photosynthetic diazotroph is well established in the oligotrophic ocean, where fixed N chronically limits primary productivity. The photosynthetic diazotrophs contribute to primary production by escaping N-limitation. Marine environments at high latitude however are dominated by non-photosynthetic diazotrophs whose function in the planktonic community remains uncharacterized. Several well-studied diazotrophs show a broad metabolic diversity, and the genome sequence of recently isolated marine diazotrophs suggest that they can utilize a broad range of compounds. Here we combine several approaches ranging from satellite imagery to (meta)genomics to explore their potential metabolic diversity and functional role in the microbial communities of the Labrador Sea (LS)and the Baffin Bay (BB), the Canadian Arctic Gateway (CAG). DNA samples were collected at multiple depths during the first leg (July10-August 10, 2015) of the Canadian Arctic Geotraces (GN02) summer campaign from Quebec city to Kugluktuk on board the CCGS Amundsen. Highly multiplexed amplicon sequencing the nifH gene, a marker gene for diazotrophy, indicated that diazotrophic microbial community of the CAG waters are highly different from that observed in the Canadian Arctic Archipelago (CAA). The suite of chemical and biological parameters from the Geotraces transect, metagenomic analysis of the microbial communities along the latitudinal transect from 55N to 73N, as well as the genomes of recently isolated strains, will be used to infer the functional role of diazotrophs within the microbial communities. In particular, we have focused on the Pseudomonas stutzeri, a dominant and widely distributed gammaproteobacterium within the Canadian Arctic gateway.

In addition, there are 2 papers submitted that include some molecular data from the French Geovide cruise.

Louropoulou et al. 2019 https://www.frontiersin.org/articles/10.3389/fmicb.2019.01566/full

Fonseca-Batista et al. 2019 https://www.biogeosciences.net/16/999/2019/

The data submitted for the IDP2021 includes:

GA03 (USA) Southern North Atlantic transect (KN204 and KN199)

- DNA samples/nifH qPCR
- Published (Ratten et al. 2015 Deep-Sea Research special issue)

GN01 (Canada) Canadian Arctic cruise

- DNA samples/flow cytometry/16S rRNA, 18S rRNA, nifH genes amplicon sequencing. qPCR for some diazotrophs
- Manuscripts in prep
    - Li, Maldonado et al. Microbial community structure in the particulate Mn maximum
    - Robicheau et al. Diazotrophs and phytoplankton community structure in the Canadian Arctic Ocean

Submitted by Maite Maldonado (mmaldonado@eos.ubc.ca).

ANNUAL REPORT ON BIOGEOSCAPES ACTIVITIES

April 1st, 2020 to April 30th, 2021

BioGeoSCAPES Newsletter #3
December 1st, 2020
https://www.biogeoscapes.org

We hope you and your loved ones are all staying healthy, happy and relatively sane in these difficult times. As we learn to cope with challenges caused by the pandemic, we are continuing to make some progress on BioGeoSCAPES-related activities. We would like to keep you informed of events from around the globe that are maintaining the momentum behind a BioGeoSCAPES future program.

Some highlights of the most recent, ongoing and upcoming activities include:

- Intercomparison of Ocean Metaproteomic Initiative, ongoing; funded by the US Ocean Carbon Biogeochemistry (OCB) program. This first ocean metaproteome intercomparison effort is underway, with samples collected from the Bermuda Atlantic Timeseries Station and distributed to participating laboratories in February 2020. Initial deadlines were delayed due to COVID laboratory shutdowns, but were recently restarted and data submissions are underway. A workshop (virtual or in person depending on the public health landscape) to discuss results is planned for summer of 2021. A more complete description of intercomparison activities and the upcoming workshop is available here: (https://www.us-ocb.org/intercomparison-and-intercalibration-metaproteomics/)

- Manuscripts describing the recently launched Ocean Protein Portal have recently been published in the Journal of Proteome Research (https://pubs.acs.org/doi/pdf/10.1021/acs.jproteome.0c00382 and https://pubs.acs.org/doi/10.1021/acs.jproteome.0c00385)

- The US Ocean Carbon Biogeochemistry (OCB) Ocean Nucleic Acids 'omics Intercalibration and Standardization Workshop was held at the University of North Carolina in Chapel Hill on January 9-11, 2020. Thirty-two participants from across the US along with guests from Canada and France met to discuss the development of an intercalibration and standardization (I&S) effort for nucleic acid 'omics approaches (e.g., amplicon sequencing, metagenomics and metatranscriptomics) to facilitate the formation of large international co-ordinated field programs such as BioGeoSCAPES. A workshop report is currently being synthesized that will include a recommendation of proposed 'omic I&S activities for the oceanographic community. A more complete description of the workshop is available here (https://www.us-ocb.org/ocean-nucleic-acids-omics-workshop/)

- China recently finished their GEOTRACES Process Study GPpr15, Carbon-FE (Carbon Fixation and Export in the oligotrophic ocean) cruise on RV Tan Kah KEE of Xiamen University. In total 36 scientists from Xiamen University, Ocean University of China and Shanghai Jiaotong University participated in the 51-day cruise (July 3 - August 22, 2020) to the western North Pacific, which included sampling and experiments to study spatial distribution, nutrient limitation and contribution to export production of nitrogen fixation in the region (for further details contact Dalin Shi; dshi@xmu.edu.cn).

- In South Africa, discussions with the Department of Science and Innovation have been initiated to support BioGeoSCAPES activities (for further details contact Thulani Makhalanyane; thulani.makhalanyane@up.ac.za).

- In Australia, a small group of scientists have met regularly, along with colleagues overseas, to discuss how to integrate molecular, physiological, and biogeochemical approaches in future BioGeoSCAPES campaigns. This working group is writing a manuscript to be submitted in early 2021. The intent of this paper is to foster dialogue on how BioGeoSCAPES can combine these disciplines to realise the most impactful science (for further details contact Robert Strzepek; robert.strzepek@utas.edu.au).

- In Europe, Martha Gledhill (GEOMAR Helmholtz Centre for Ocean Research) and Sandi Orlic (Institut Ruđer Bošković, Zagreb, Croatia) received funding from Euromarine for a pan-European workshop to further foster BioGeoSCAPES collaborations and to support their COST application. The workshop will be scheduled sometime in 2021 (for further details contact Martha Gledhill; mgledhill@geomar.de).

- In Italy: 1) scientists at the Stazione Zoologica Anton Dohrn (Napoli, Italy) are organizing an Italian working group, together with ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Giovanna Armiento). A meeting is planned for early 2021; 2) Italian scientists have completed a 1-year pilot phase of the local augmented observatory NEREA (Naples Ecological REsearch for Augmented Observatories, which consider physics, chemistry (including trace elements) and biology (microscopy and advanced genomics). EU funding is in place for a 3-year continued operation of this activity, which will constitute the initial core of the Italian contribution to BioGeoSCAPES; and 3) A series of cruises, which included trace elements sampling, were conducted in the Tyrrhenian Sea by ENEA (for further details contact Daniele Iudicone; iudicone@szn.it)

- In the United Kingdom, a small group of scientists met in January 2020 to discuss how to begin organising the BioGeoSCAPES community. A mailing list was set up (email: UKBiogeoscapes@gmail.com) and Alessandro Tagliabue (University of Liverpool), Thomas Mock (University of East Anglia), Julie Robidart (National Oceanography Centre) and Patricia Sanchez-Baracaldo (University of Bristol) successfully applied to the Royal Society for a two day discussion meeting around 'marine microbes in a changing climate' to be held sometime in 2022.

- A new large scale project that will characterize the Atlantic Ocean microbiome (www.atlanteco.eu) is taking shape. The EU-funded AtlantECO project (2020-2024, 36 partners, 11M Euros) aims to develop and apply a novel, unifying framework that provides knowledge-based resources for a better understanding and management of the Atlantic Ocean and its ecosystem services. The project focuses on three pillars of research: microbiomes, microplastic and the plastisphere, and seascape connectivity. It will develop and disseminate in the oceanographic community the use of advanced approaches (-omics, optics, sensors). Flagship cruises will sample the microbiome and microplastics combining these tools with a full characterization of the environment, including trace elements. The aim is to reach an all Atlantic assessment of the microbiome status and functioning. This program seeks to align their research goals with those of a BioGeoSCAPES program.

- The 1st France BioGeoSCAPES Planning Workshop was planned for May 4-7, 2020 in Toulouse, but due to COVID, it has been rescheduled to a virtual meeting on December 7-8, 2020. Organizers: Catherine Jeandel, Ingrid Obernoster (ingrid.obernosterer@obs-banyuls.fr) and Damien Cardinal.

- A US BioGeoSCAPES Planning Workshop entitled "Laying the foundation for a potential future BioGeoSCAPES program: Assessing needs and capabilities for studying controls on ocean metabolism through integrated omics and biogeochemistry" is being organized by Ben Twining, Mak Saito, Alyson Santoro, Adrian Marchetti, and Naomi Levine. The workshop was scheduled for the fall of 2020, but has been rescheduled due to the pandemic. The proposed new dates for the workshop are mid to late 2021, depending on the public health situation. A more complete description of the workshop is available here: https://www.us-ocb.org/ocb-scoping-workshop-laying-the-foundation-for-a-potential-future-biogeoscapes-program/

- A couple of BioGeoSCAPES Sessions at the ASLO 2021 Aquatic Sciences Meeting in Palma de Mallorca, Spain (June 22-27) have been proposed, including "Distribution and impacts of ocean nutrient limitation" convened by Tom Browning, Erin Bertrand, Mark Moore, and Al Tagliabue. The approved sessions will be published in the meeting webpage (https://www.aslo.org/palma-2021/) at the end of 2020 and will be listed in our next newsletter in spring 2021.

- The engineering and science trials of the autonomous underwater vehicle Clio, designed for basin-scale sampling of 'omics and biogeochemistry, have been completed and described in this publication (https://robotics.sciencemag.org/content/5/48/eabc7104), and Clio's potential role in BioGeoSCAPES is portrayed in this Inner Workings article in PNAS (https://www.pnas.org/content/117/43/26544).

We would also like to take the opportunity to encourage you to organize your own national meeting to continue gauging interest and brainstorming your national scientific goals. During these national meetings we would like to suggest discussing/addressing the following questions:

1) What science questions do we see as the most important within the broad scope of BioGeoSCAPES on a 10 year timeframe?
2) How would your nation best contribute to BioGeoSCAPES efforts – e.g. fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics?
3) Are there any impediments within your nation that the international program could seek to mitigate via training or collaboration?
4) What productive strategies can you undertake to secure funding for a BioGeoSCAPES program in your nation?
The answers to these questions by each nation will be invaluable in guiding the write up of the international BioGeoSCAPES science plan in the next couple of years. We will also like to start populating the website with 2-page National Scoping Documents summarizing the Planning Workshop outcomes, using the answers to these 4 questions as a starting template.

BioGeoSCAPES related science is being promoted on social media through the Twitter account "@BioGeoSCAPES". If you have any highlights for the Twitter feed, please share them with us.

Thanks for showing interest in BioGeoSCAPES!

Sincerely,
Adrian Marchetti, Mak Saito, Alessandro Tagliabue, and Maite Maldonado.

For those who are new to this initiative, here is a bit of history

BioGeoSCAPES is the concept for a potential future interdisciplinary global-scale microbial biogeochemistry program that arose out of a small international working group in late 2018 (see the meeting report here<https://drive.google.com/file/d/1EjIE4Fz2edd_hmusaaio-JHQQaDazGYn/view>) and various prior related activities. BioGeoSCAPES is at an early stage of the organizing process, when those interested are gauging and aiming to build international community support, as well as discussing potential science objectives and parameters.

Upcoming plans include organizing national meetings to continue gauging interest and brainstorming scientific goals. In addition, initial intercalibration efforts are being encouraged for potential parameter such as the recently organized metagenomic and metaproteomic intercalibration projects. Future sessions at international meetings are also being organized, such as at the ASLO 2021 Aquatic Sciences Meeting in Palma de Mallorca, Spain (June 22-27).

In parallel, we would like to find a way to facilitate the inclusion of more nations and researchers in BioGeoSCAPES activities. To help with this we have begun a list of ambassadors and shared it here https://docs.google.com/spreadsheets/d/1lwYWRNgrVM_zfIcD0uksyRf_JohBgEkAgnEHDd6trrs/edit#gid=0

If you would like to get involved in BioGeoSCAPES activities, please contact your country's representative listed at the link above, or one of us. If your country is not listed and you wish to be added as a representative, please contact us (Mak, Al, Adrian or Maite).