GEOTRACES SCIENTIFIC STEERING COMMITTEE
ANNUAL REPORT TO SCOR 2022/2023

July 2023

ANNEX – NATIONAL REPORTS

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN AUSTRALIA

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

- Dissolved Nd isotope and rare earth element data from the continental margin of East Antarctica published in Geochimica et Cosmochimica Acta investigated seawater and authigenic sedimentary phases for the use of Nd isotopes in paleoceanography see Creach'h et al 2023.
- New paper accepted in Elementa, entitled 'Seasonality of phytoplankton growth by iron and manganese in subantarctic waters' by Pauline Latour et al., on three separate shipboard bioassay experiments to evaluate the seasonality of iron (Fe) and manganese (Mn) co-limitation of subantarctic phytoplankton growth south of Tasmania.

GEOTRACES or GEOTRACES relevant cruises

- Southern Ocean Time Series 2021: Process study GIpr08 by Elizabeth Shadwick/Zanna Chase, Andrew Bowie (Th, Nd isotopes, [REE], TM aerosols). May 2022 full depth profiles were collected for Th, Nd and REEs.
- Process study GIpr11 to Cape Darnley, East Antarctica (CANYONS) to investigate Antarctic Bottom Water on the RV Investigator in January 2023 was interrupted again (cancelled in 2022 due to COVID19) by a medical evacuation. Unfortunately, only five out of 23 anticipated science days occurred prior to having to return to Australia for the medivac. Two short gravity (Kasten) cores and one long piston core were recovered, however, no surface sediment or dissolved trace metals for new proxy development were collected, and only 3 CTD casts out of a planned 13 were carried out. As such none of the voyage objectives were met and there is no discussion from the Marine National Facility on future opportunities to return to the region.

Upcoming voyages

- MISO voyage Jan-Mar 2024 along I9S line GEOTRACES section GS05 on the *RV Investigato*r. Bottle washing and prep continues in the lead up to this voyage.
- *RVS Nuyina* (Australia's new icebreaker) Jan-Mar 2025 voyage to the Denman Glacier/Shackleton Ice shelf will include trace metal water and water column particulate sampling and some sediment coring.

New projects and/or funding

- *RV Investigator* proposal for ship time in 2025/2026 summer seasons is currently in review for a voyage to the Antarctic margin lead by Dr Linda Armbrecht titled "Paleoecological and paleoclimate reconstruction of the Cook Ice Shelf: a genomic approach". If successful Dr Taryn Noble will apply for a GEOTRACES process study for trace metal and isotopes.
- Australian Research Council Discovery Project DP230100764 to Professor Andrew Bowie; Associate Professor Kerrie Swadling; Dr Lavenia Ratnarajah; Professor Alessandro Tagliabue on quantifying zooplankton iron content and examining its biogeochemical and ecological impact on Southern Ocean productivity.

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

- Creac'h, L., Noble, T. L., Chase, Z., Charlier, B. L. A., Townsend, A. T., Perez-Tribouillier, H., & Dietz, C. (2023). Unradiogenic reactive phase controls the εNd of authigenic phosphates in East Antarctic margin sediment. Geochimica et Cosmochimica Acta. https://doi.org/https://doi.org/10.1016/j.gca.2023.01.001
- Fourquez, M., Janssen, D. J., Conway, T. M., Cabanes, D., Ellwood, M. J., Sieber, M., Hassler, C. (2023). Chasing iron bioavailability in the Southern Ocean: Insights from Phaeocystis antarctica and iron speciation. Science Advances, 9(26). https://doi.org/10.1126/sciadv.adf9696
- Janssen, D. J., Gilliard, D., Rickli, J., Nasemann, P., Koschinsky, A., Hassler, C. S., … Jaccard, S. L. (2023). Chromium stable isotope distributions in the southwest Pacific Ocean and constraints on hydrothermal input from the Kermadec Arc. Geochimica et Cosmochimica Acta, 342, 31 – 44. https://doi.org/10.1016/j.gca.2022.12.010
- Lannuzel, D., Fourquez, M., de Jong, J., Tison, J. L., Delille, B., & Schoemann, V. (2023). First report on biological iron uptake in the Antarctic sea-ice environment. Polar Biology, 46(4), 339–355. https://doi.org/10.1007/s00300-023-03127-7
- Latour, P., Strzepek, R. F., Wuttig, K., Merwe, P., Sam, Eggins, … Bowie, A. R. (2022). Seasonality of phytoplankton growth limitation by iron and manganese in subantarctic waters.
- Smith, A. J. R., Nelson, T., Ratnarajah, L., Genovese, C., Westwood, K., Holmes, T. M., … Lannuzel, D. (2022). Identifying potential sources of iron-binding ligands in coastal Antarctic environments and the wider Southern Ocean. Frontiers in Marine Science, 9(August), 1–17. https://doi.org/10.3389/fmars.2022.948772
- Wang, H., Wang, W., Liu, M., Zhou, H., Ellwood, M. J., Butterfield, D. A., … Resing, J. A. (2022). Iron ligands and isotopes in hydrothermal plumes over backarc volcanoes in the Northeast Lau Basin, Southwest Pacific Ocean. Geochimica et Cosmochimica Acta, 336, 341–352. https://doi.org/10.1016/j.gca.2022.09.026

Completed GEOTRACES PhD or Master theses

- Christopher Nielson (Masters thesis University of Tasmania): "Atmospheric Fe fertilisation of oceans: characterisation of mineral dust sources in Australia" (supervised by Andrew Bowie)
- Lening Wang (Honours thesis University of Tasmania): "Characterizing the Dissolved Lithogenic Inputs to the Southwest Pacific Southern Ocean Using Rare Earth Elements" (supervised by Taryn Noble)
- Layla Creac'h (PhD thesis University of Tasmania): "Evaluation and application of palaeoceanographic proxies at the East Antarctic margin" (supervised by Taryn Noble and Zanna Chase)

GEOTRACES presentations in international conferences

- Fourquez MA, Stzrepek R, Ellwood M, Hassler C, Cabanes D, Eggins S, Pearce I, Deppeler S, Trull T, Boyd P & Bressac M. Responses of Microbial Residents to New Versus Regenerated Fe in a Cold-Core Eddy (Southern Ocean). Goldschmidt 2022

- Lemaitre N, Planquette H, Jeandel C, Ellwood M, Hassler C & Vance D Nickel and Zinc Cycling in the Southern Ocean: Insights from Isotopes. Goldschmidt 2022

Submitted by Taryn Noble (Taryn.Noble@utas.edu.au)

GEOTRACES or GEOTRACES relevant cruises

- Operação Antártica XLI – XVI GOAL CRUISE – PROVOCCAR & ECOPELAGOS CRUISE (24 February-11 March 2023). PI: Rodrigo Keer (FURG)

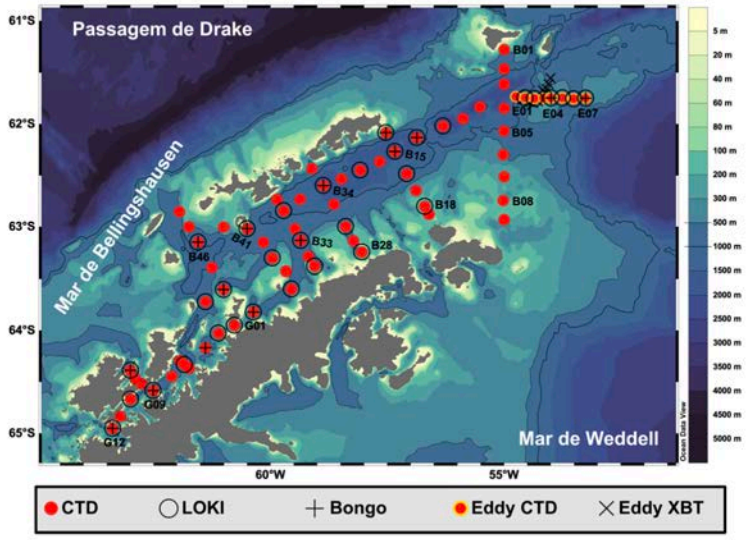


Figure BR-1. *Location of oceanographic stations, launches of eXpandable BathyThermograph (XBT) and trawls of Bongo and LOKI nets performed by GOAL during the 6th phase of OPERANTAR XLI.*

Water samples for Rare Earth Elements (REE) and Platinum (Pt) were collected between 2 and 7 depths along 34 vertical profiles of the water column using 12 L Niskin bottles.

New projects and/or funding

- Submitted Project to CNPq/MCTI/FNDCT 08/2023 – Brazilian Antarctic Program – PROANTAR, entitled: "Oceanographic Processes and Mesoscale Structures in Climate Hotspots: Synergies and Advances in Physical and Biogeochemical Monitoring around the Antarctic Peninsula (PRO-SAMBA Project)". Funding of 3 cruises in the North Antarctic Peninsula and analysis.

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

- SANTOS, ANA C. S. S.; SOUZA, LAÍS A.; ARAUJO, TAIANA G.; DE REZENDE, CARLOS EDUARDO ; Hatje, Vanessa . Fate and Trophic Transfer of Rare Earth Elements in a Tropical Estuarine Food Web. ENVIRONMENTAL SCIENCE & TECHNOLOGY, v. 57, p. 2404-2414, 2023.
- SENA, INGRID C.M.; SOUZA, LAÍS A.; PATIRE, VINICIUS F.; ARIAS-ORTIZ, ARIANE; CREED, JOEL C. ; CRUZ, IGOR ; Hatje, Vanessa . Environmental settings of seagrass meadows control rare earth element distribution and transfer from soil to plant compartments. SCIENCE OF THE TOTAL ENVIRONMENT, v. 1653, p. 157095, 2022.
- HATJE, V.; Sarin, M.; SANDER, S.; OMANOVIC, D.; RAMACHANDRAN, P.; VOELKER, C.; BARRA, R. O. ; TAGLIABUE, A. . Emergent interactive effects of climate

change and contaminants in coastal and ocean ecosystems. FRONTIERS IN MARINE SCIENCE, v. 1653, p. 111663, 2022.

GEOTRACES presentations in international conferences

- Plenary talk by V Hatje - Interactive effects of climate change and contaminants in marine ecosystems. XVI International Estuarine Biogeochemistry Symposium Šibenik, Croatia, 23-26 May 2023
- Poster by Andrade, RLB, V Hatje, C Jeandel. Neodymium isotopes across the Antarctic and South and Central Western Atlantic

Submitted by Vanessa Hatje (vhatje@ufba.br)

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CANADA

May 1st, 2022 to April 30th, 2023

Canadian PI's continue to work closely with US and European colleagues on Arctic GEOTRACES synthesis projects resulting in a number of jointly authored manuscripts. The Canadian GEOTRACES community continues to support the Canadian Line P Iron Programme (GPpr07) study making observations of bioactive trace elements and trace element- microbe interactions on time-series cruises completed along Line P in the northeast Pacific.

GEOTRACES or GEOTRACES relevant cruises

- Jean-Eric Tremblay (ULaval) and Jay Cullen (UVic) conducted trace element and isotope sampling in the Canadian Arctic as part of the ArcticNet supported NTRAIN program (https://arcticnet.ulaval.ca/project/nutrient-fluxes-and-living-marine-resources-in-the-inuit-nunangat/) in the eastern, central and western Arctic Ocean.
- 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 in 2021 and 2022 as part of the Line P Iron Program, a GEOTRACES Process Study (GPpr07). Samples for Fukushima derived radionuclides were collected in collaboration with John N. Smith (DFO).
- Erin Bertrand (Dalhousie) in collaboration with Rob Middag (NIOZ), found iron limitation in the Iceland basin and conducted incubation experiments to understand the interactions between changing Fe and temperature on phytoplankton physiology. There are interactive effects between Fe and temperature on phytoplankton community composition, nutrient drawdown and protein abundance patterns. https://www.nioz.nl/en/blog/metalgate-2021-cruise

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).

- Myers, P. (U. Alberta) and 7 others 2022-23 Ecosystems and Ocean Science Contribution Framework Open Call for Proposals. Understanding the bio-physical processes impacting the evolution of Tallurutiup Imanga and Pikialasorsuaq in a warming climate DFO $717,063

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

- Izett, R, Laura Castro de la Guardia, Melanie Chanona, Paul G. Myers, Stephanie Waterman, Philippe D. Tortell (2022). Impact of Vertical Mixing on Summertime Net Community Production in Canadian Arctic and Subarctic Waters: Insights From In Situ Measurements and Numerical Simulations. https://doi.org/10.1029/2021JC018215
- Jensen, J., J.T. Cullen, S.L. Jackson, L. Gerringa, D. Bauch, R. Middag, R.M. Sherrell, J. Fitzsimmons. (2022). A novel relationship between dissolved copper and nickel in the Arctic Ocean. Journal of Geophysical Research – Oceans. 127(5) https://doi.org/10.1029/2021JC018087
- Krisch, S., M.J. Hopwood, S. Roig, L.J.A. Gerringa, R. Middag, M.M. Rutgers van der Loeff, M.V. Petrova, P. Lodeiro, M. Colombo, J.T. Cullen, S.L. Jackson, L. Heimbürger-Boavida, E.P. Achterberg. (2022). Arctic-Atlantic exchange of iron, manganese, cobalt, nickel, copper and zinc with a focus on Fram Strait. Global Biogeochemical Cycles. 36(5) https://doi.org/10.1029/2021GB007191
- Kuang, C., S.W. Stevens, R. Pawlowicz, M.T. Maldonado, J.T. Cullen, R. Francois. (2022). Factors controlling the temporal variability and spatial distribution of dissolved cadmium in the coastal Salish Sea. Continental Shelf Research. 243, https://doi.org/10.1016/j.csr.2022.104761
- Taves, R., D.J. Janssen, M.A. Peña, A.R.S. Ross, K.G. Simpson, W.R. Crawford, J.T. Cullen. (2022). Relationship between surface dissolved iron inventories and net community production during a marine heatwave in the subarctic northeast Pacific. Environmental Science: Processes and Impacts. 24, 1460-1473. https://doi.org/10.1039/D2EM00021K
- Rogalla B, Colombo M, Allen S, Myers P, Orians K. (2023). Oceanic fingerprints of continental and glacial terrestrial runoff in Inuit Nunangat, the Canadian Arctic Archipelago. Journal Geophysical Research, Biogeosciences, e2022JG007072 doi:10.1029/2022JG007072
- Rogalla B, Allen S, Colombo M, Myers P, Orians K. (2022). Sediments in sea ice drive the Canada Basin surface Mn maximum: insights from an Arctic Mn ocean model.Global Biogeochemical Cycles. 36, e2022GB007320. doi:10.1029/2022GB007320
- Soetaert, G., R. C. Hamme, and E Raftery (2022) Renewal of seasonally anoxic Saanich Inlet is temporally and spatially dynamic, Frontiers in Marine Science, 9, 1001146, doi:10.3389/fmars.2022.1001146.
- Waugh, L.C., I.F. Ruiz, C. Kuang, J. Guo, J.T. Cullen, M.T. Maldonado. (2022). Seasonal dissolved copper speciation in the Strait of Georgia, British Columbia, Canada. Frontiers in Marine Science. 9:983763. https://doi.org/10.3389/fmars.2022.983763

Completed GEOTRACES PhD or Master theses

- Taves, R. (2022) The Distribution of Trace Metals and their Relationship to Net Community Production during Two Marine Heatwave Events in the Subarctic Northeast Pacific Ocean https://dspace.library.uvic.ca/bitstream/handle/1828/13910/Taves_Robyn_MSc_2022.pdf?sequence=1&isAllowed=y

GEOTRACES presentations in international conferences

- 2022 Anderlini, T., J-É. Tremblay, J.T. Cullen. Trace Metal Distributions in the Western Canadian Arctic. ArcticNet ASM 2022, Dec. 4-8, Toronto ON, Canada.
- 2022 Anderlini, T., J-É. Tremblay, J.T. Cullen. Spatial and Temporal Variability in the Distributions of Dissolved Trace Metals in Surface Waters of Baffin Bay in the Canadian Arctic. ArcticNet ASM 2022, Dec. 4-8, Toronto ON, Canada.
- 2022 Cullen, J.T. Second Knowledge Mobilization Workshop: Advancing the United Nations Sustainable Development Goals (SDGs) on Ocean Sustainability and Climate Action. The Chemical Institute of Canada – Environment Division. Nov. 23, virtual.
- 2022 Anderlini, T., G. Soetaert, J.T. Cullen. Rare Earth Element Distributions in Saanich Inlet and Surrounding British Columbian Waters. CSC 2022, Jun. 13-17, Calgary, AB, Canada.

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CHILE

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

A first assessment of the role of dissolved iron on coastal productivity of southern Chile: The nitrate and phosphate drawdown in low salinity (29) coastal waters of Patagonia can be enhanced by a 5 nM dissolved iron enrichment (by 13% and 28%, respectively) during the developing phase of a diatom bloom. The simultaneous enrichment in iron (5 nM) and silicic acid (5 µM) in these estuarine waters resulted in a similar macronutrient uptake enhancement, a 119% increment of the production of biogenic silica and a 2-fold rise in the abundance of *Pseudo-nitzschia spp* (a diatom capable to produce the neurotoxin domoic acid). Torres et al. (2023).

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

- Torres, R., Reid, B., Pizarro, G., Frangópulos, M., Alarcón, E., Márquez, M., Díaz-Rosas, F., Menschel, E., González, H.E., Moreno-Meynard, P., Montero, P., Pacheco, H., Pinto-Torres, M., Alarcón, C., Ibañez, R., Hawkings, J., 2023. Iron and silicic acid addition effects on early spring macronutrient drawdown and biogenic silica production of Patagonia estuarine waters. Progress In Oceanography, 214, 102982.

Submitted by Rodrigo Torres (rtorresaavedra@gmail.com).

New GEOTRACES or GEOTRACES relevant scientific results

- **UCYN-B dominates the diazotroph community in the western North Pacific**

  According to the observational results from GP09, GPpr15 summer and winter cruises, unicellular cyanobacteria UCYN-B was found to dominate the diazotroph community and drive variability in N_2 fixation rates in the western North Pacific. In contrast, we found *Trichodesmium* was only prevalent in regions near the western boundary of the North Pacific, and UCYN-A was dominant at the northern edge of the NPSG where N_2 fixation rates were relatively low. Therefore, UCYN-B is primarily responsible for both the high overall diazotroph abundance and N_2 fixation rates under conditions that characterize the under-sampled western North Pacific.

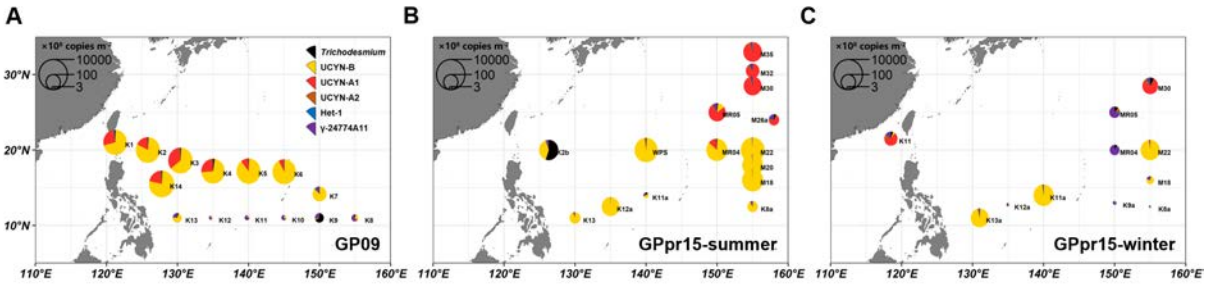


Figure CH-1. *Depth-integrated nifH gene abundance of six target diazotrophs in the western North Pacific in summer and winter. A. GP09. B. GPpr15 summer. C. GPpr15 winter.*

- **Mass Budget of Mercury (Hg) in the Seawater of Eastern China Marginal Seas: Importance of the Sediment-water Transport Processes**

  The Eastern China Marginal Seas (ECMS) have been facing a variety of environmental problems, including mercury (Hg) pollution. Although several previous studies have been focused on mass balance of Hg in the ECMS, the contribution of Hg transport at the sediment-water interface remains unclear. This study was aimed to access and quantify the importance of sediment-water transport processes in Hg cycling. Significantly positive correlations were observed between Hg concentrations in the overlying and bottom water and the diffusion rates of Hg from sediment to the water. Approximately 2-3 times higher of THg concentrations in the entire water column were observed in a winter cruise with strong waves which was supposed to strengthen the resuspension process. The mass budget of Hg in the ECMS further showed that diffusion and resuspension processes accounted for approximate 46%, 60%, and 16% of total input Hg in the BS, YS, and ECS, respectively. These results suggest that the sediment-water transport processes play an important role in Hg cycling in the ECMS. As an important 'pool' of Hg in the ECMS, the transport of Hg at the sediment-water interface may affect the long-term risk assessment of Hg in these systems.

- **Nonconservative behaviour of dissolved molybdenum and its potential role in nitrogen cycling**

  The dissolved Mo (dMo) concentrations and parameters related to Mo distribution and N cycling in surface and bottom seawaters of the Bohai (BS) and Yellow Seas (YS) were examined. The results showed that dMo concentrations ranged from 36.4 nmol L^{-1} to 125.0

nmol L^{-1}, most of which deviated significantly from the conservative line, indicating nonconservative behavior of Mo relative to salinity. Significant depletion up to 40-50 nmol L^{-1} of dMo mainly appeared in the BS, NYS and south of the SYS, suggesting the possible removal of dMo by biological utilization and particle adsorption. The similar spatial distribution of dMo and dMn concentrations suggested the possible scavenging by Mn oxide phases for Mo removal. The negative correlation between dMo and Chl-*a* concentrations in surface seawaters suggested that biological uptake was involved in dMo removal. The depleted dMo in most of sites corresponded with the higher nitrite concentrations, implying the possible involvement of nitrate reduction process.

- **Dynamic mobilization of redox sensitive elements Mo, U and V in seasonal hypoxic sediments off the Changjiang Estuary**

  The profiles of porewater and solid redox sensitive elements (RSEs) and their chemical speciation and diffusive fluxes at the sediment water interface (SWI) of five sites off the Changjiang Estuary in two seasons were measured. The results showed that porewater and solid RSEs displayed the corresponding profile variations. The porewater Mo and U concentrations generally decreased with depth, attributed to the reductive removal. Particularly, the removal of Mo may be mediated by the Fe–S phase, and the removal of U appears to be via the microbially-mediated reduction. Porewater V, U and Mo were removed successively with depth, corresponding to the peaks of dissolved nitrate, Fe^{2+} and acid volatile sulfur (AVS). However, porewater V increased again in the deep layers due to its complexation with dissolved organic matter. The upward shift of RSE peaks in porewater and transformation depths of their oxidation states based on the model from spring to summer reflected the occurrence of hypoxia in summer. The downward diffusive fluxes of RSEs at hypoxic site in summer indicated their hypoxia-induced enrichment. The Mo–U covariation suggested that the seasonal hypoxic sites off the Changjiang Estuary were more favorable for the accumulation of authigenic U.

- **Building a new biogeochemical model including iron cycle**

  We are developing a new biogeochemical model including iron cycle. The CoSiNE-Fe model has five phytoplankton groups including picoplankton, diatom, and three diazotrophs (unicellular cyanobacteria, *Trichodesmium*, diatom-diazotroph associations (DDA). The new Iron cycles including soluble Fe, colloidal Fe, strong ligand Fe, weak ligand Fe, strong ligand, and weak ligand, in which atmospheric depositions of Fe, N, P, and lithogenic particles, and parameterized Fe sources from sediments and hydrothermal vents are accounted. In addition, we introduce a new light attenuation scheme with a dual-band model and phytoplankton photoacclimation parameterization to the model. The CoSiNE-Fe model has been coupled with ROMS model for the Pacific Ocean to simulate interactions among physical, biological, and biogeochemical processes.

GEOTRACES or GEOTRACES relevant cruises

- 2022 Northwest Pacific Ocean Multidisciplinary Cruise, surficial and core samples were collected to analyze Hg species and isotopes during this cruise.
- 2022 Kuroshio Extension Cruise, profile samples were collected from the northern edge of NPSG and Kuroshio Extension area with a GEOTRACES standard rosette sampling system to analyse dissolved iron during this cruise.

New projects and/or funding

- Integrated Study on the Multiscale Material Cycling at the Sea-Air Interface in the West Pacific (Integrated Project of the NSFC Major Research Plan Program, 2023-2025, leading PI: Zhimian Cao)
- Impact of iron cycle on the carbon fixation and its future projection under climate change in the North Pacific Ocean (National key research and development program, 2023-2025, leading PI: Peng Xiu)

Other GEOTRACES activities

- The distribution of Ra isotopes (^{223}Ra, ^{224}Ra, ^{226}Ra and ^{228}Ra) in the Sanmen Bay and Dongshan Bay was investigated and used as tracers to determine submarine groundwater discharge carbon and nitrogen to the bays;
- The distribution of ^{210}Pb in the Qinzhou Bay and ^{210}Po, ^{210}Pb and ^{234}Th in the Taiwan Strait and East China Sea was investigated and used as tracers to evaluate the particle dynamics.

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

- Zhou, Z., Wang, H., Li, Y. (2023). Mercury stable isotopes in the ocean: Analytical methods, cycling, and application as tracers. *Science of the Total Environment*, 874, 162485.
- Chen, L., Liu, C., Yin, Y., Liu, G., Li, Y., Cai, Y. (2022). Mass Budget of Mercury (Hg) in the Seawater of Eastern China Marginal Seas: Importance of the Sediment-Water Transport Processes. *Environmental Science & Technology*, 56, (16), 11418-11428.
- Liu, J., Yu, X., Du, J. (2022). Tidally driven submarine groundwater discharge to a marine aquaculture embayment: Insights from radium and dissolved silicon. *Marine Pollution Bulletin*, 178, 113620.
- Yu, X., Liu, J., Chen, X., Huang, D., Yu, T., Peng, T., Du, J. (2022). Submarine groundwater-derived inorganic and organic nutrients vs. mariculture discharge and river contributions in a typical mariculture bay. *Journal of Hydrology*, 613, 128342.
- Zhong, Q., Li, L., Puigcorbé, V., Huang, D., Yu, T., Du, J. (2022). Contrasting behaviors of ^{210}Po, ^{210}Pb and ^{234}Th in the East China Sea during a severe red tide: Enhanced scavenging and promoted fractionation. *Acta Oceanologica Sinica*, 41(8), 5-21.
- Zhong, Q., Puigcorbé, V., Chen, X., Rodellas, V., Wang, X., Yu, T., Du, J. (2022). Unexpectedly high dissolved^{210}Pb in coastal groundwaters: Is submarine groundwater discharge important in coastal sea? *Chemical Geology*, 614, 121165.
- Zhong, Q., Guo, W., Wang, H., Ji, J., Lin, J., Du, J., Huang, D., Yu, T. (2023). ^{210}Po and ^{210}Pb as tracers for particle cycling in a shallow semi-enclosed bay of Taiwan Strait. *Deep Sea Research Part II: Topical Studies in Oceanography*, 207, 105228.
- Cao, A., Zhang, J., Zhang, H., Chen, Z., Cui, G., Liu, Z., Li, Y., Liu, Q. (2023). Dissolved rare earth elements in the Northwest Pacific: Sources, water mass tracing, and cross-shelf fluxes. *Frontiers in Marine Science*, 1135113.
- Kong, X., Zhang J., Li,Y., Otsuka, S., Liu, Q., He, Q. (2023). Selenium in the liver facilitates the biodilution of mercury in the muscle of *Planiliza haematocheilus* in the Jiaozhou Bay, China. *Ecotoxicology and Environmental Safety*, 258.

- Che, H., Zhang, J., Liu, Q. He, M. Zhao, Z. (2022). A driving factor for harmful algal blooms in the East China Sea coastal marine ecosystems — Implications of Kuroshio subsurface water invasion. *Marine Pollution Bulletin*, 181, 11387.
- Wang, X., Zhou, P., Yang, W., Chen, M., Cheng, H., Chen, G., Cai, Y. (2023). Enhanced mesopelagic particle export in the northern South China Sea derived from $^{210}Po/^{210}Pb$ disequilibrium. *Chemical Geology*, 634, 121582.

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

- Master thesis: Temporal and spatial distribution characteristics and ecological risks of heavy metals and total petroleum hydrocarbons in the Bohai Sea and its typical bay Laizhou Bay.
- Master thesis: Speciation and bioavailability of heavy metals in the sediment of Laizhou Bay and Jiaozhou Bay.
- PhD theses: Submarine groundwater discharge borne nutrients in the coastal aquaculture ecosystem and its environmental effects.
- PhD theses: A comparative study of submarine groundwater discharge and its-derived nutrients in typical bays under the influence of anthropological activities.
- Master theses: Carbon fluxes via submarine groundwater discharge in a typical coastal saltmarsh wetland-nearshore-estuary continuum.
- PhD thesis: Trophic dynamics and interactions of mercury and selenium in the food web of Jiaozhou Bay and assessment of their health risk exposure.
- Master thesis: Distribution characteristics and tracing of dissolved rare earth elements in the Northwest Pacific Subtropical Gyre during summer and winter.
- PhD thesis: On the particle dynamics in the tropical western North Pacific as elucidated by U-series nuclides: Dust deposition, Lateral transport and Boundary scavenging.

GEOTRACES presentations in international conferences

- Yanbin Li. Low system efficiency of producing methylmercury controls the current and future risk of mercury in China Coastal Seas. The Sixth Xiamen Symposium on Marine Environmental Sciences, January 12, 2023, Xiamen, China

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CHINA-TAIPEI

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

- Aerosol dissolvable metals are considered to be readily bioaccessible so that their input would influence the growth and composition of marine phytoplankton and affect elemental cycling globally. However, it is highly challenging to measure or estimate reliable deposition fluxes of aerosol dissolvable metals in the ocean partially due to the impacts of complicated processes involved in pre- and post-deposition of aerosols. Hsieh et al. (2023, Marine Chemistry) have collected lithogenic dust from major Chinese deserts and size-fractionated aerosols from the East China Sea (ECS) to study the variations of their dissolvable metals by using three operationally defined leaching protocols (ultrapure water, buffer, and Berger leaches). In addition to the extremely high solubilities observed for anthropogenic type elements, they found variations for solubilities of lithogenic type elements (Ti, Al, Fe) increase with increasing sizes by the three leaching treatments. Without knowing the size specific information (mass and solubility), their observations indicate that the deposition fluxes of lithogenic type elements would be significantly overestimated.
- The wind-driven meridional overturning circulation between the tropical and subtropical oceans is important for regulating decadal-scale temperature fluctuations in the Pacific Ocean and globally. An acceleration of the overturning circulation can act to reduce global surface temperature as ocean stores more heat. The equatorward low-latitude western boundary current represents a key component of the meridional circulation cell in the Pacific and a major source of water mass for the Equatorial Undercurrent, yet long-term observations of its transport are scarce. Chen et al. (2023, Nature Geoscience) demonstrate that the 15N/14N ratio recorded by Porites spp. corals in the western tropical South Pacific is sensitive to the exchanges of water masses driven by the western boundary transport. Using a 94-year coral record from the Solomon Sea, they report that the 15N/14N ratio declined as the global surface temperature rose. The record suggests that the South Pacific western boundary current has strengthened in the past century, and it may have contributed to the reported strengthening of the Equatorial Undercurrent. In addition, the 15N/14N record shows strong decadal variability, indicative of weaker equatorial Pacific upwelling and stronger western boundary transport when the eastern equatorial Pacific is in the warm stage of the Pacific Decadal Oscillation.

GEOTRACES or GEOTRACES relevant cruises

- On-going cruise in the Western Subtropical North Pacific, July 07 to August 05, 2023
- Scheduled NORI cruise to the Western Subtropical North Pacific, March 2024 (18 days)
- Scheduled Legend cruise to the Western Philippian Sea, August 2024 (15 days)

New projects and/or funding

- Grant Title: Anthropogenic aerosol trace metal marine biogeochemistry, funded by Academia Sinica (2021/01-2025/12, 5M NTD per year)

- Grant Title: Aerosol Fe biogeochemical cycling in the Northwestern Pacific Ocean (II): phase transformation and field validation, funding source: MOST (2022/08-2025/07, 2M NTD per year)

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

- Hsieh, Chih-Chiang, Chen-Feng You, and Tung-Yuan Ho. "The solubility and deposition flux of East Asian aerosol metals in the East China Sea: The effects of aeolian transport processes." Marine Chemistry (2023): 104268.
- Chen, WH., Ren, H., Chiang, J.C.H. et al. Increased tropical South Pacific western boundary current transport over the past century. Nat. Geosci.(2023). https://doi.org/10.1038/s41561-023-01212-4
- Chen, T.-Y., Chen, C.-L., Chen, Y.-C., Chou, C. C.-K., Ren, H., and Hung, H.-M.: Source apportionment and evolution of N-containing aerosols at a rural cloud forest in Taiwan by isotope analysis, Atmos. Chem. Phys., 22, 13001–13012, https://doi.org/10.5194/acp-22-13001-2022, 2022.
- Ekka, S. V., Liang, Y. H., Huang, K. F., Huang, J. C., & Lee, D. C. (2023). Riverine molybdenum isotopic fractionation in small mountainous rivers of Taiwan: The effect of chemical weathering and lithology. Chemical Geology, 620, 121349.
- Liao, W. H., Planquette, H., Moriceau, B., Lambert, C., de Gesincourt, F. D., Laurenceau-Cornec, E., ... & Gorgues, T. (2023). The effect of temperature on the release of silicon, iron and manganese into seawater from resuspended sediment particles. Geochimica et Cosmochimica Acta, 351, 1-13.

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN COLOMBIA

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

- Parameters as Pb, Cd, Cr, Cu, Ni, Hg, Zn suspended particulate material, sediments and Hg in 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".
- 220 records reported by INVEMAR to the data portal for SDG 14 indicator 14.3.1. https://oa.iode.org/data

GEOTRACES or GEOTRACES relevant cruises

- Parameters as Cd, Pb, Cu, Zn, Cr, Ni, Fe, Hg, micronutrients, hydrocarbons and carbonate system variables were analyzed in the cruise CHO-OFF 5 area, located in the Colombian Pacific Basin (CPC), in the marine areas off the departments of Cauca and Valle del Cauca. In addition, the historical reconstruction of Cu, Cr, Hg, Fe, Zn and Mn metals in a sediment core was performed.
- Parameters as Cd, Pb, Cu, Zn, Cr, Ni, Fe, Hg, micronutrients, hydrocarbons and carbonate system variables were analyzed in the cruise Baja Guajira area, located in the Colombian Caribbean. In addition, sediment cores were collected for historical reconstruction of Cu, Cr, Hg, Fe, Zn and Mn metals.

New projects and/or funding

- 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 2022.

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CROATIA

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

The Croatian GEOTRACES activities were related to:

- interaction of trace metals with marine microplastics
- investigation of cobalt (II) complexes with naturally present ligands, relevant to understanding the speciation of cobalt, especially in aquatic but also in atmospheric and terrestrial environments and various organisms
- application of improved electrochemical methods (in combination with ICPMS) for determination of number of trace metals, their speciation, fractionation and interaction with organic matter and sulphur species in natural waters, including monitoring of the coastal and open waters of the Adriatic Sea;
- mercury speciation and determination by CV-AAS in natural waters, including monitoring of the coastal and open waters of the Adriatic Sea;
- study of geochemistry of redox proxies and redox transformations in seawater under a range of critical environmental conditions (Cu, V, Re, Mo and U);
- study of geochemistry of technology critical elements (Li, Nb, Sc, Ga, Y, La, Sb, Ge, Te and W) in marine sediments;
- geochemical research and biological response in different environmental systems (coastal and open sea, marine lakes, anchialine caves, submarine groundwater discharge);
- development of new methods for ex- and in-situ determination of natural and anthropogenic radionuclides (focus is on $^{86/87}$Sr, ^{89,90}Sr and ^{210}Pb);
- development of electroanalytical method for determination and characterization of polysulfides in anoxic seawater conditions;
- study of interactions between surface water chemistry, phytoplankton, atmospheric chemistry, and climate;
- characterization of atmospheric precipitation (rain, aerosols - PM2.5) regarding presence of major cations and anions, organic matter, sulphur species and trace metals;
- measurements of activity concentration of ^{7}Be and ^{210}Pb in atmospheric precipitation (rain, aerosols - PM2.5) in order to monitor dynamics of particle transport, metrological information, origin of air mass transfer and seasonal variation of aerosol deposition;
- work on advanced technologies for water quality control/monitoring and prediction purposes.

New projects and/or funding

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

- 2018-2022: Biochemical REsponses of oligotrophic Adriatic surface ecosystems to atmospheric Deposition Inputs (BiREADI) (PI. Sanja Frka)

- 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 (PI: E. Bura-Nakić)

Other projects:

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

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". (PI. M. Mlakar)

2020-2022: INTERREG ADRION: "SEAVIEWS - Sector Adaptive Virtual Early Warning System for marine pollution". (AP. D. Omanović)

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)". (PI. N. Cukrov)

Other GEOTRACES activities

- D. Omanović is a member of the GESAMP working group 45 - Climate Change and Greenhouse Gas Related Impacts on Contaminants in the Ocean.

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

- Lucija Knežević and Elvira Bura-Nakić, Investigation of thiol compounds (L-cysteine, thioacetic acid and ethanethiol) with V(V) and V(IV) using combined spectroscopy and chromatography, *Journal of Inorganic Biochemistry*, 242 (2023) 112158
- Saša Marcinek, Josep Galceran, Irena Ciglenečki and Dario Omanović, A new tool for the determination of humic substances in natural waters: Pulsed voltammetry approach, *Talanta* 259 (2023) 124547
- Niki Simonović, Iva Dominović, Marija Marguš, Antonija Matek, Zrinka Ljubešić and Irena Ciglenečki: Dynamics of organic matter in the changing environment of a stratified marine lake over two decades, Science of The Total Environment, 865 (2023) 161076
- Marija Marguš, Marijan Ahel, Milan Čanković, Zrinka Ljubešić, Senka Terzić, Vedranka Hodak Kobasić, Irena Ciglenečki: Phytoplankton pigment dynamics in marine lake fluctuating between stratified and holomictic euxinic conditions, *Marine Pollution Bulletin*, 191 (2023) 114931

- Krešimir Maldini, Neven Cukrov, Kristina Pikelj, Natalija Matić and Marina Mlakar, Geochemistry of metals and organic matter in water and sediments of the karst river Cetina, Croatia, *Water*, 15 (2023) 1429
- Irena Ciglenečki, Palma Orlović-Leko, Kristijan Vidović, Niki Simonović, Marija Marguš, Jelena Dautović, Sarah Mateša and Ivo Galić: The possibilities of voltammetry in the study reactivity of dissolved organic carbon (DOC) in natural waters, *Journal of Solid State Electrochemistry* (2023) 1-13.
- Vlatka Filipović Marijić, Maria Angels Subirana, Dirk Schaumlöffel, Josip Barišić, Etienne Gontier, Nesrete Krasnići, Tatjana Mijošek, Jesús S. Hernández-Orts, Tomáš Scholz and Marijana Erk: First insight in element localisation in different body parts of the acanthocephalan Dentitruncus truttae using TEM and NanoSIMS, *Science of the total environment*, 887 (2023) 164010
- Petra Burić, Ivana Čarapar, Dijana Pavičić-Hamer, Ines Kovači, Lara Jurković, Maja Dutour Sikiri, Darija Domazet Jurašin, Nevenka Mikac, Niko Bačić and Daniel Mark Lyons: Particle Size Modulates Silver Nanoparticle Toxicity during Embryogenesis of Urchins Arbacia lixula and Paracentrotus lividus, *International Journal of Molecular Sciences*, 24 (2023) 745
- Nevenka Mikac, Martina Furdek Turk, Dragana Petrović, Miljan Bigović, Sladjana Krivokapić: First assessment of butyltins (BuTs) contamination of the Montenegrin coast (Southeast Adriatic): Tributyltin (TBT) poses a threat to the marine ecosystem, *Marine Pollution Bulletin* 185 (2023) 114270
- Damir Kapetanović, Irena Vardić Smrzlić, Snježana Kazazić, Dario Omanović, Neven Cukrov, Ana-Marija Cindrić, Ana Rapljenović, Lorena Perić, Karla Orlić, Tatjana Mijošek, Zuzana Redžović, Ana Gavrilović, Tena Radočaj and Vlatka Filipović Marijić, A preliminary study of the cultivable microbiota on the plastic litter collected by commercial fishing trawlers in the south-eastern Adriatic Sea, with emphasis on Vibrio, *Marine Pollution Bulletin* 187 (2023) 114592
- Ana Vrdoljak Tomaš, Danijela Šantić, Mladen Šolić, Sanda Skejić, Andrea Milinković, Ana Cvitešić Kušan, Blaženka Gašparović, Stefanija Šestanović and Sanja Frka, How do open coastal fire episodes' impact sea surface microlayer neuston communities?, *Science of The Total Environment*, 861 (2023) 10593
- Lucija Knežević, Emanuele Zanda, Elvira Bura-Nakić, Montserrat Filella and Vladimir Sladkov, Vanadium(IV) and vanadium(V) complexation by succinic acid studied by affinity capillary electrophoresis. Simultaneous injection of two analytes in equilibrium studies, *Journal of Chromatography A*, 1695 (2023) 463941
- Abra Penezić, Xinke Wang, Sebastien Perrier, Christian George and Sanja Frka, Interfacial photochemistry of marine diatom lipids: Abiotic production of volatile organic compounds and new particle formation, *Chemosphere*, 313 (2023) 137510
- Sergio Stefanni, Luca Mirimin, David Stanković, Damianos Chatzievangelou, Lucia Bongiorni, Simone Marini, Maria Vittoria Modica, Elisabetta Manea, Federico Bonofiglio, Joaquin del Rio Fernandez, Neven Cukrov, Ana Gavrilović, Fabio C. De Leo and Jacopo Aguzzi: Framing Cutting-Edge Integrative Deep-Sea Biodiversity Monitoring via Environmental DNA and Optoacoustic Augmented Infrastructures, *Frontiers in Marine Science*, 8 (2022) 797140
- Ante Šiljeg, Ivan Marić, Fran Domazetović, Neven Cukrov, Marin Lovrić and Lovre Panđa: Bathymetric Survey of the St. Anthony Channel (Croatia) Using Multibeam Echosounders

(MBES)-A New Methodological Semi-Automatic Approach of Point Cloud Post-Processing, *Journal of Marine Science and Engineering*, 10 (2022) 101

- Jinlong Wang, Mark Baskaran, Neven Cukrov and Jinzhou Du: Geochemical mobility of ^{137}Cs in marine environments based on laboratory and field studies, *Chemical Geology*, 614 (2022) 121179
- Abra Penezić, Violetta Drozdowska, Tihana Novak and Blaženka Gašparović: Distribution and characterization of organic matter within the sea surface microlayer in the Gulf of Gdańsk, *Oceanologia*, 64 (2022) 631-650
- Andrea Milinković, Abra Penezić, Ana Cvitešić Kušan, Valentina Gluščić, Silva Žužul, Sanda Skejić, Danijela Šantić, Ranka Godec, Gordana Pehnec, Dario Omanović, Anja Engel and Sanja Frka, Variabilities of biochemical properties of the sea surface microlayer: Insights to the atmospheric deposition impacts, *Science of The Total Environment* 838 (2022) 156440
- Sanja Frka, Martin Šala, Helena Brodnik, Bogdan Štefane, Ana Kroflič and Irena Grgić, Seasonal variability of nitroaromatic compounds in ambient aerosols: Mass size distribution, possible sources and contribution to water-soluble brown carbon light absorption, *Chemosphere*, 299 (2022) 134381
- Marija Parać, Vlado Cuculić, Nuša Cukrov, Sunčana Geček, Marin Lovrić and Neven Cukrov, Microplastic Distribution through the Salinity Gradient in a Stratified Estuary, *Water*, 14 (2022) 3255
- Mišić Radić, T., Vukosav, P., Čačković, A. and Dulebo, A.: Insights into the morphology and surface properties of microalgae at the nanoscale by atomic force microscopy (AFM): A review, *Water*, 15 (2023) 1983
- Vukosav, P., Pašalić, L., Bakarić, D., Domazet Jurašin, D. and Mišić Radić, T.: Interaction of Silica Nanoparticles with Microalgal Extracellular Polymers, *Water*, 15 (2023) 159-159
- Mišić Radić, T., Vukosav, P., Komazec, B., Formosa-Dague, C., Domazet Jurašin, D., Peharec Štefanić, P., Čačković, A., Juraić, K. and Ivošević DeNardis, N.: Nanoplastic-induced nanostructural, nanomechanical, and antioxidant response of marine diatom *Cylindrotheca Closterium*, *Water*, 14 (2022) 2163
- Hana Fajković, Neven Cukrov, Stanislav Frančišković-Bilinski, Laura Huljek, Iva Kostanjšek, Željko Kwokal, Renata Matekalo, Kristina Pikelj and Vlado Cuculić, Correlation of metals and degraded marine (micro)plastic litter in geologically similar coastal areas with different anthropogenic characteristics, *Marine pollution bulletin*, 183 (2022), 114041
- Ivanka Lovrenčić Mikelić, Neven Cukrov, Višnja Oreščanin, Krunoslav Škaro and Delko Barišić: ^{137}Cs Sediment profiles as a tracer of marine sedimentation processes in a semi-enclosed bay affected by anthropogenic releases-example of Kaštela Bay (Adriatic Sea, Croatia), *Water*, 14 (2022) 2655
- Anđela Bačinić, Petra Vukosav, Ivana Kero and Marina Mlakar, Study on the Surface Interactions of Co(II) with Phospholipids from the Marine Environment, *Journal of Marine Science and Engineering*, 10 (2022) 1261

Completed GEOTRACES PhD or Master theses

- Doctoral Thesis: Lucija Knežević, Biogeochemical cycling of vanadium(+IV and +V) in aquatic systems and sediments, University of Zagreb, May 2023.
- Doctoral Thesis: Anđela Bačinić, Electochemical characterisation of Co(II) complexes with organic ligands from seawater, University of Zagreb, December 2022. (URL: https://www.bib.irb.hr/1277006)

GEOTRACES presentations in international conferences

- *5th International Symposium on Anchialine Ecosystems*, Kona, Hawai, USA, November 2022: Anchialine caves of the Krka River estuary, Croatia; Cukrov N., Bishop R., Cuculić V., Cukrov M., Cukrov N., Geček S., Jalžić B., Klanjšček T., Kwokal Ž., Omanović D. et al.
- *ECSA 59 Using the best scientific knowledge for the sustainable management of estuaries and coastal seas*, San Sebastian, Spain, September 2022: Beached marine plastic litter as a carrier of abiotic and biotic phases in the coastal Adriatic Sea; Rapljenović A., Fajković H., Kapetanović D., Lakuš I., Pikelj K., Stančec V., Cuculić V.
- *3rd European NECTAR Conference*, Ljubljana, Slovenija, August 2022: Vanadium(IV) and vanadium(V) complexation with succinic acid by affinity capillary electrophoresis; Knežević L., Zanda E., Bura-Nakić E., Sladkov V.
- *Goldschmidt 2022*, July 2022: Dynamics of trace elements and dissolved organic matter in estuarine surface microlayer; Marcinek S., Cindrić A.M., Omanović. D.
- *11th ISE Satellite Student Regional Symposium on Electrochemistry*, Zagreb, Croatia, July 2022: Modification of electroanalytical method for analysis of metal amounts from marine plastic surfaces; Rapljenović A., Cuculić V.
- *EGU General Assembly 2022*, Vienna, Austria, May 2022: Rhenium geochemistry in hypoxic and euxinic marine lakes of the Eastern Adriatic Sea; Živković I.; Knežević L., Omanović D., Jagodić Hudobivnik M., Rovan L., Bura-Nakić E.
- *EGU General Assembly 2022*, Vienna, Austria, May 2022: Preliminary studies on V(III) determination in the form of picnolate complex using HR ICP-MS; Knežević L., Mandić J., Živković I., Omanović D., Bura-Nakić E.
- *EGU General Assembly 2022*, Vienna, Austria, May 2022: Insights to the short-term atmospheric deposition impacts on the biology and chemistry of the sea surface microlayer in the Adriatic Sea coastal region; Milinković A., Penezić A, Cvitešić Kušan A., Bakija Alempijević S., Gluščić V., Žužul S., Jakovljević I., Skejić S., Šantić D., Godec R. et al.
- *EGU General Assembly 2022*, Vienna, Austria, May 2022: Comparison of the trace metals mass fractions adsorbed on the beached plastic litter: different ubiquitous items of everyday use; Rapljenović A. and Cuculić V.
- *7th Croatian Congress of Microbiology with International Participation*, Sveti Martin na Muri, Croatia, May 2022: Diversity and antibiotic resistance of bacteria associated to marine plastic litter collected by commercial fishing trawlers in the southern Adriatic Sea, Croatia; Kapetanović D., Vardić Smrzlić I., Kazazić S., Perić L., Orlić K., Filipović Marijić V., Mijošek T., Redžović Z., Cukrov N., Cindrić A. M., Rapljenović A., Gavrilović A. and Radočaj T.

- *8th Croatian Meeting of Chemists and Chemical Engineers*, Rovinj, Croatia, March 2023: An attempt to quantitatively analyse submillimetre microplastics by DSC; Pucić I., Rapljenović A., Kwokal Ž., Cuculić V.
- *28th Croatian Meeting of Chemists and Chemical Engineers*, Rovinj, Croatia, March 2023: Trace metal adsorption on plastic pellets and fibers in the marine and estuarine environment; Viskić M., Rapljenović A., Cukrov N., Cuculić V.
- *Regional Meeting & Conference of the International Society of Electrochemistry*, Prague, Czech republic, August 2022: Complexation of membrane phospholipids with metal ions in themarine environment; Bačinić A., Matijević T., Kero I., Mlakar M.
- *8th hybrid SOLAS Open Science Conference*, Kaapstad, Južnoafrička Republika, September 2022: Variabilities of biochemical properties of the sea surface microlayer: insights to the atmospheric deposition impacts; Milinković A., Penezić A, Cvitešić Kušan A., Gluščić V., Žužul S., Skejić S., Šantić D., Godec R., Pehnec G., Omanović D. et al.
- *8th hybrid SOLAS Open Science Conference*, Kaapstad, Južnoafrička Republika, September 2022: Impacts of biomass burning versus anthropogenic aerosol deposition on the surface layers in the central Adriatic Sea: A mesocosm study; Milinković A., Penezić A, Bakija Alempijević S., Cvitešić Kušan A., Skejić S., Šantić D., Lehners C., Striebel M., Niggemann J., Žužul S. et al.
- *11th International Aerosol Conference (IAC 2022)*, Atena, Grčka, September 2022: Variability of black carbon aerosol concentrations and sources at the Central Adriatic coastal zone: light-absorption observation and source-oriented modelling; Milinković A., Gregorič A., Džaja Grgičin V., Vidič S., Penezić A., Cvitešić Kušan A., Bakija Alempijević S., Kasper- Giebl Anne., Frka S.

Submitted by Saša Marcinek (smarcin@irb.hr)

New GEOTRACES or GEOTRACES relevant scientific results

- The unaccounted dissolved iron (II) sink: insights from dFe(II) concentrations in the deep Atlantic Ocean.

Hydrothermal vent sites found along mid-ocean ridges are sources of numerous reduced chemical species and trace elements. To establish dissolved iron (II) (dFe(II)) variability along the Mid Atlantic Ridge (between 39.5°N and 26°N, GA13 UK GEOTRACES section), dFe(II) concentrations were measured above six hydrothermal vent sites, as well as at stations with no active hydrothermal activity. The dFe(II) concentrations ranged from 0.00 to 0.12 nmol L^{-1} (detection limit = 0.02 ± 0.02 nmol L−1) in non-hydrothermally affected regions to values as high as 12.8 nmol L^{-1} within hydrothermal plumes. Iron (II) in seawater is oxidised over a period of minutes to hours, which is on average two times faster than the time required to collect the sample from the deep ocean and its analysis in the onboard laboratory. A multiparametric equation was used to estimate the original dFe(II) concentration in the deep ocean. The in-situ temperature, pH, salinity and delay between sample collection and its analysis were considered. The results showed that dFe(II) plays a more significant role in the iron pool than previously accounted for, constituting a fraction >20 % of the dissolved iron pool, in contrast to <10 % of the iron pool formerly reported. This discrepancy is caused by Fe(II) loss during sampling when between 35 and 90 % of the dFe(II) gets oxidised. In-situ dFe(II) concentrations are therefore significantly higher than values reported in sedimentary and hydrothermal settings where Fe is added to the ocean in its reduced form. Consequently, the high dynamism of dFe(II) in hydrothermal environments masks the magnitude of dFe(II) sourced within the deep ocean (González Santana et al., 2023, Science of the Total Environment).

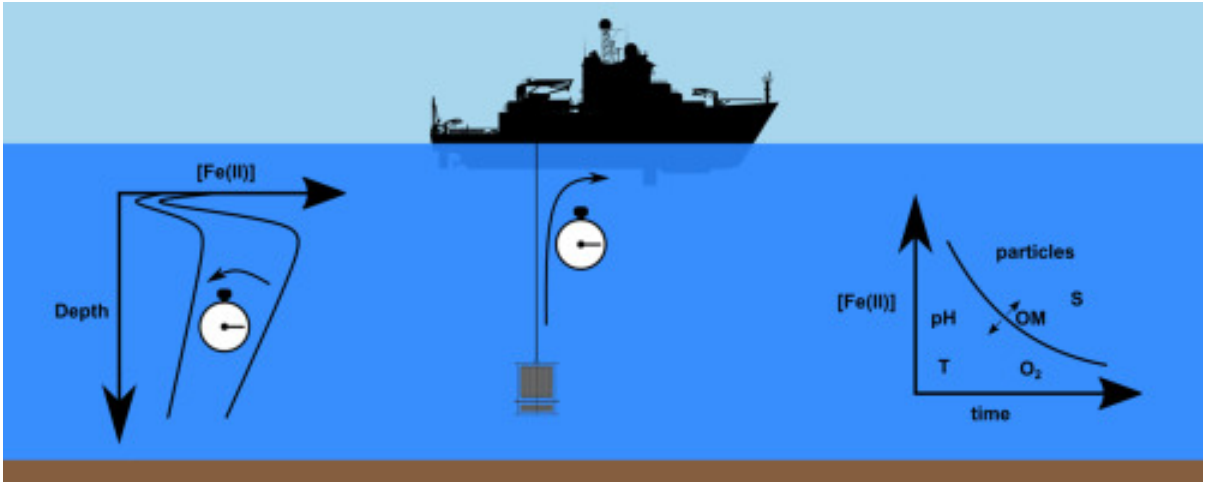


Figure FR-1: *Sources and physicochemical conditions which modulate the dFe(II) profile. Over the whole water column, the oxidation of Fe(II) is a limiting factor, with measured dFe(II) concentrations only accounting for 10 to 65 % of the computed original Fe(II) concentrations. The factors involved in the oxidation vary with ocean depths: high seawater temperature above 15 °C, high pH and highly oxic waters in the surface layer; in the central waters, where the minimum oxygen zone is produced as a result of organic matter remineralization, the conditions allow for a slower oxidation rate, where measured dFe(II) concentrations increase; in the deep ocean, hydrothermal activity acts as a source of Fe(II), whose concentrations will depend on the vent site, the distance from the vent to the sampling point and the oxidation rate (González-Santana et al., 2023).*

- Natural iron fertilization by shallow hydrothermal sources fuels diazotroph blooms in the ocean

The objective of the TONGA project and campaign (GEOTRACES GPpr14) was to study the control of ocean productivity and carbon sequestration by micronutrients of shallow hydrothermal origin. It was shown that along the west to east zonal transect, total chlorophyll-a (Chla) and particulate organic nitrogen stocks peaked in the naturally Fe-fertilized waters. N_2 fixation rates and *Trichodesmium* abundances increased by a factor of 10 and 90, respectively in these Fe-fertilized waters compared to adjacent waters. Carbon sequestration efficiency by hydrothermal Fe is much higher than those from artificial mesoscale Fe-addition experiments and in the range of values measured in well-recognized shelf driven natural fertilizations occurring in the Southern Ocean around Kerguelen and Crozet Islands, confirming that natural Fe fertilizations are more efficient. It is necessary to pay attention in future studies to the timescale of delivery of this newly-recognized mode of Fe supply through shallow hydrothermalism, especially in biogeochemical models (Bonnet, Guieu et al., 2023, Science).

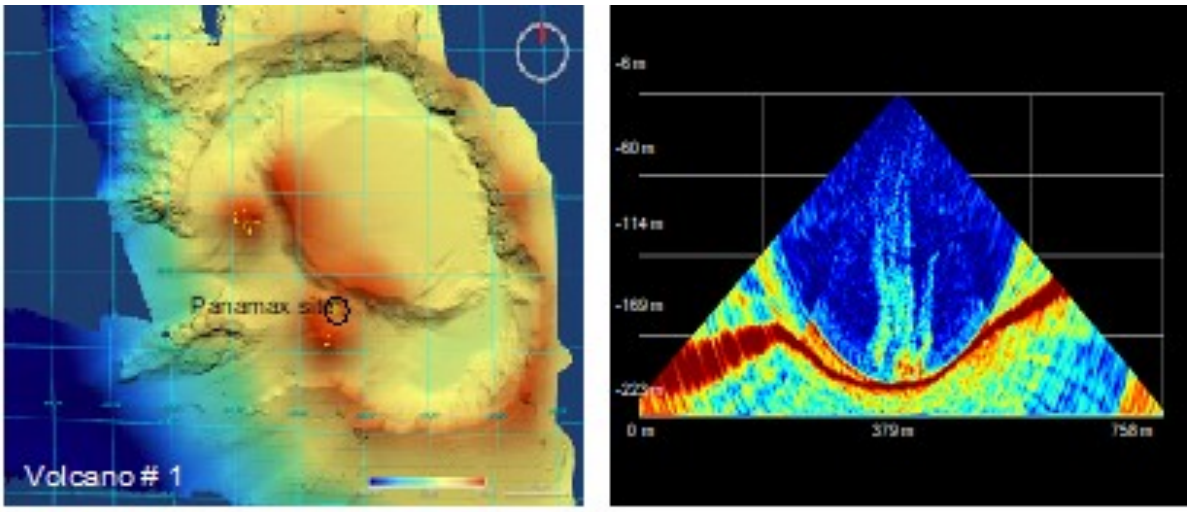


Figure FR-2: *Bathymetry of one of the explored volcanoes performed during TONGA (left). Multibeam echo sounder image showing hydrothermal gas and fluid emissions from the seafloor (~ 200 m) rising up to ~10 m below the surface (right) (Bonnet, Guieu et al., 2023).*

- Influence of shallow hydrothermal fluid release on the functioning of phytoplankton communities

The mechanisms behind iron fertilization by shallow hydrothermal sources was explored in details through novel trace metal clean mixing experiments in minicosms. Hydrothermal fluids had an initial toxic effect and some phytoplankton detoxified the environment through the production of ligands, making the toxic metals in the fluids less available; after this initial period, a strong stimulation of primary production was observed with N_2 fixation and increase in carbon export rates, in line with in-situ observations (Tilliette et al., 2023).

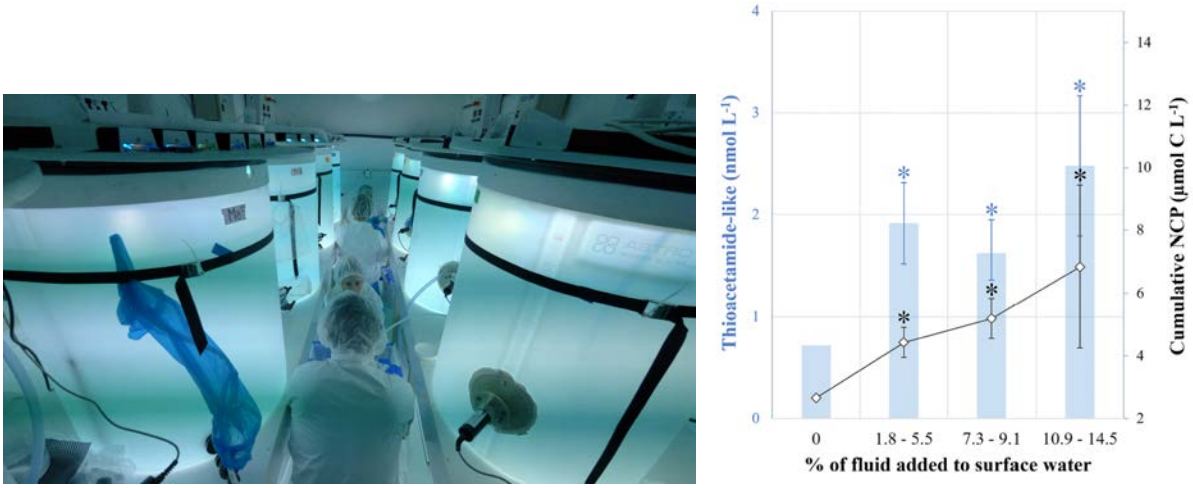


Figure FR-3: *(Left) The sampling team during the mixing experiment, inside the clean container, on-board R/V Atalante. (Right) Summary diagram. (1) in blue, the ratio of thioacetamide-like compound concentrations measured 12 h after the mixing versus at the end of the experiment (D0.5:D9) and, (2) in black, the ratio of cumulative 13C-net community production rates measured at the end versus at the start of experiment (D9:D0.5). Treatments were grouped: no addition (0, control), low (+1.8-5.5%), medium (+7.3-9.1%) and high (+10.9-14.5%) fluid addition. Asterisks represent the significance of each group relative to control (unpaired Student test, $p < 0.01$) (Tilliette et al., 2023).*

- Solid-solution distribution of the cosmogenic beryllium-7 in the water column

The cosmogenic radionuclide ^{7}Be has been applied as a tracer of dynamical processes in the upper ocean and of atmospheric deposition of trace elements at the sea surface. These applications usually assume that ^{7}Be is entirely in the dissolved form, and that scavenging and downward export of ^{7}Be by settling particles can be neglected. This work questions the validity and limits of this hypothesis. The ^{7}Be activity in suspended particles collected in and below the mixed layer in oceanic regions as different as the Mediterranean Sea, the Southern Ocean and the subpolar Atlantic (section GEOVIDE/GEOTRACES-GA01). While the particulate ^{7}Be ($^{7}Be_{p}$) activity generally monotonically decreases with depth below the mixed layer, they reveal that, at least in some oceanic regions, the removal of ^{7}Be by marine particles may be significant. The $^{7}Be_{p}$ fraction ranges from 2% to 32% of the total activity ($^{7}Be_{tot}$) along the GEOVIDE section in the North Atlantic. In the Labrador Sea, the comparison of the $^{7}Be_{p}$ inventories with the dry ^{7}Be deposition fluxes estimated from aerosol samples collected during GEOVIDE suggest that a significant portion of $^{7}Be_{p}$ may be removed by sinking particles. Future research should focus on quantifying the downward export of $^{7}Be_{p}$ to deep waters, and on assessing its temporal and spatial variability. For this objective, both seawater and particulate samples should be collected at the same locations, at the same depths, and at the same time (Grenier et al., 2023).

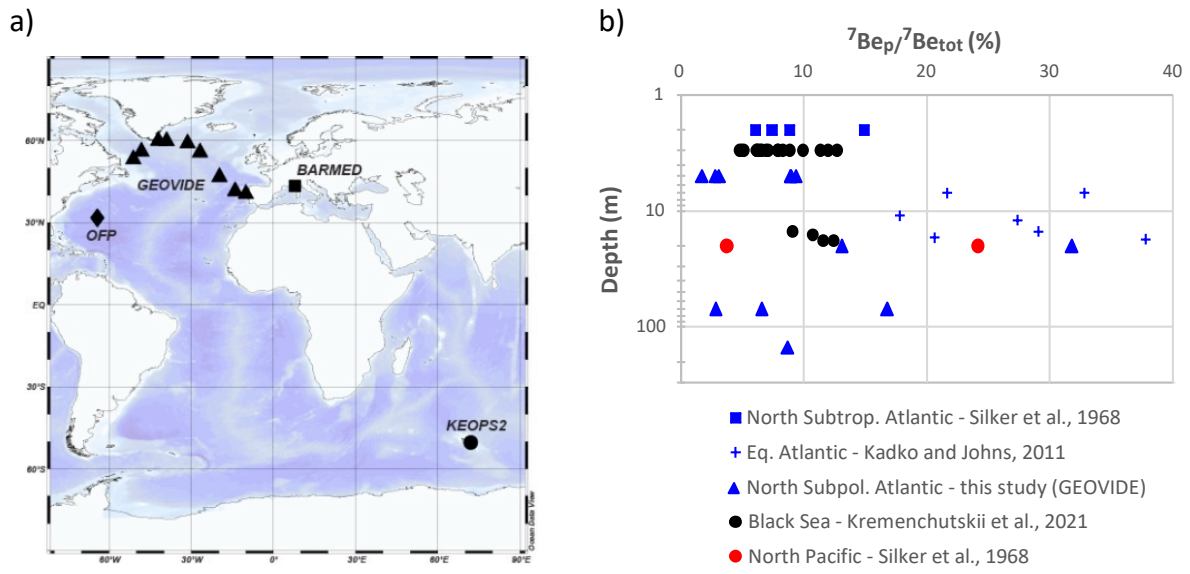


Figure FR-4: *a) Sampling stations: OFP (Sargasso Sea), BARMED (Mediterranean Sea), KEOPS2 (Southern Ocean), and GEOVIDE/GA01 (North Atlantic). b) Compilation of estimates of the $^{7}Be_p/^{7}Be_{tot}$ activity ratio in the open ocean (in %, linear scale) as a function of depth (in m, log scale). The particulate ^{7}Be fraction of the GEOVIDE samples accounts for 2-9% of the total ^{7}Be activity at a water depth of 5 m (n = 6) and 13-32% at 20 m (n = 2). These ranges are consistent with the existing published data (Grenier et al., 2023).*

GEOTRACES or GEOTRACES relevant cruises

- In 2023: 2 cruises were conducted at the DYFAMED station in the framework of the BE-7-FLUX project (LEFE-INSU; PIs: Pieter van Beek and Mélanie Grenier) in March and April/May to study the vertical distributions of dissolved and particulate 7Be. 7Be has been used as a tracer to study vertical mixing in the upper water column and to quantify TE atmospheric fluxes.

New projects and/or funding

- **ANR AWESOME-SWINGS**: A Water mass analysis and Exploration of linkS betweenmarine Organisms and trace MEtals along the South West INdian GEOTRACES Section. Principal Investigator: Hélène Planquette (LEMAR, Plouzané), Co-PI: Catherine Jeandel (LEGOS, Toulouse). 48 months, **481 380 €.**
- **BE-7-FLUX** (LEFE-INSU 2022-23; PIs: Pieter van Beek and Mélanie Grenier): Toward a better understanding of the 7Be cycle in the ocean.
- **IsoMargin** (EU-MSCA 2022-2024; PIs: Nolwenn Lemaitre and François Lacan): Isotopes of micronutrients to trace margin sediment fluxes

GEOTRACES workshops and meetings organized

- Hosting the S&I committee in LEMAR, Plouzané, 7-9 September, 2022

Outreach activities conducted

- ***N. Lemaitre in March 2023.*** Presentation of the research profession to students of a primary school (Blagnac) as part of the International Days of Women and Girls in Science (2h).
- ***N. Lemaitre in May 2022.*** Article in the online journal 'Connected Oceans': Nolwenn Lemaitre, Winner of a European Fellowship
- ***N. Lemaitre in May 2022.*** Phone conference with a visual impaired audience (Les Chemins Buissonniers)
- ***N. Lemaitre in March 2022.*** Online TV report (TV Trégor): Dans le sillage de Nolwenn Lemaître
- ***M. Lagarde in February 2023.*** Presentation of research careers and oceanographic cruises to high school students, lycée Berthelot, Toulouse

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

** marks the results highlighted in this report*

- Blain, S., Planquette, H., Obernosterer, I., Gueneugues, A., 2022. Contrasted export dynamics of 15 trace elements explained by their attribution to lithogenic and biogenic vectors in the Southern Ocean. *Global Biogeochemical Cycles, 36(5), e2022GB007371,* http://dx.doi.org/10.1029/2022GB007371.
- *Bonnet, S., Guieu, C., Taillandier, V., Boulart, C., Bouruet-Aubertot, P., Gazeau, F., Scalabrin, C., Bressac, M., Knapp, A. N., Cuypers, Y., González-Santana, D., Forrer, H. J., Grisoni, J.-M., Grosso, O., Habasque, J., Jardin-Camps, M., Leblond, N., Le Moigne, F. A. C., Lebourges-Dhaussy, A., Lory, C., Nunige, S., Pulido-Villena, E., Rizzo, A. L., Sarthou, G., and Tilliette, C., 2023. Natural iron fertilization by shallow hydrothermal sources fuels diazotroph blooms in the ocean. *Science* **380**, 812-817, 10.1126/science.abq4654.
- Dulaquais, G. Fourrier, P., Guieu, C., Mahieu, L., Riso, R., Salaun, P., Tilliette, C. and Whitby, H. (Accepted) The role of humic-type ligands in the bioavailability and stabilization of dissolved iron in the Western Tropical South Pacific Ocea. *Accepted for publication in Frontiers in Marine Science, Marine Biogeochemistry.*
- Fourrier, P., Dulaquais, G., Guigue, C., Giamarchi, P., Sarthou, G., Whitby, H., & Riso, R., 2022. Characterization of the vertical size distribution, composition and chemical properties of dissolved organic matter in the (ultra) oligotrophic Pacific Ocean through a multi-detection approach. *Marine Chemistry*, *240*, 104068. https://doi.org/10.1016/j.marenvres.2022.105754. P. Fourrier was a PhD student at LEMAR
- Fourrier, P., Dulaquais, G., & Riso, R., 2022. Influence of the conservation mode of seawater for dissolved organic carbon analysis. *Marine Environmental Research*, *181*, 105754. P. Fourrier was a PhD student at LEMAR
- *González Santana, D., Lough, A.J., Planquette, H., Sarthou, G., Tagliabue, A., Lohan, M.C., 2023. The unaccounted dissolved iron (II) sink: insights from dFe(II) concentrations in the deep Atlantic Ocean. *Science of the total environment, 862, 16117,* https://doi.org/10.1016/j.scitotenv.2022.161179. D. González Santana was a PhD student at LEMAR.
- *Grenier M., van Beek P., Lerner P., Sanial V., Souhaut M., Lagarde M., Marchal O., Reyss J.L., 2023. New insights on the ^{7}Be cycle in the ocean. *Deep-Sea Research I*, 194 doi.org/10.1016/j.dsr.2023.103967
- Le Roy E., van Beek P., Lacan F., Souhaut M., Sanial V., Charette M., Henderson P., Deng F., 2023. The distribution of 227Ac along the GA01 section in the North Atlantic. *Marine Chemistry* 248, pp.104207. ⟨10.1016/j.marchem.2023.104207⟩. ⟨hal-03959500⟩.

- Lemaitre N., Du J., de Souza G., Archer C., Vance D., 2022. The essential bioactive role of nickel in the oceans: Evidence from nickel isotopes. *Earth and Planetary Science Letters*, 584, 117513. https://doi.org/10.1016/j.epsl.2022.117513.
- Liang, Z., McCabe, K., Fawcett, S.E., Forrer, H.J., Jeandel, C., Marconi, D**.,** Planquette, H., Saito, M.A., Sohm, J.A., Thomas, R.K., Letscher, R.T., and Knapp, A.N. A global ocean dissolved organic phosphorus (DOP) concentration database (DOPv2021). *Scientific Data, Nature 9* (1), 772. https://doi.org/10.1038/s41597-022-01873-7
- Liao W.-H., Planquette H., Moriceau, B., Lambert, C., Desprez de Gesincourt, F., Laurenceau-Cornec, E., Bucciarelli, E., Sarthou, G., Gorgues, T. The effect of temperature on the non-reductive iron dissolution from resuspended sediments: mechanisms and Fe isotope fractionation. *Geochimica et Cosmochimica Acta,* https://doi.org/10.1016/j.gca.2023.04.014 W.-H. Liao was a Postdoc at LEMAR at the time.
- *Tilliette, C., Gazeau, F., Portlock, G., Benavides, M., Bonnet, S., Guigue, C., Leblond, N., Lory, C., Marie, D., Montanes, M., Pulido-Villena, E., Sarthou, G., Tedetti, M., Vorrath, M.-E., Whitby, H., and Guieu, C., 2023. Influence of shallow hydrothermal fluid release on the functioning of phytoplankton communities. *Frontiers in Marine Science* **10**, https://www.frontiersin.org/articles/10.3389/fmars.2023.1082077. C. Tilliette was a PhD student at LOV.

Completed GEOTRACES PhD or Master theses

- Pierre FOURRIER**.** Biogéochimie de la Matière Organique Dissoute dans l'Océan Pacifique. Biogeochemistry of dissolved organic matter in the Pacific Ocean. https://www.theses.fr/2022BRES0082

GEOTRACES presentations in international conferences

Goldschmidt, Hawaii, 2022:

- Baudet, C., Planquette, H., Bucciarelli, E., Sarthou, G., Pelleter, E., Gayet, N., Germain Y., Jeandel, C. Trace metal distributions in the South West Indian Ocean (SWINGS cruise): a focus on iron and manganese. C. Baudet is a PhD student at LEMAR

- Belhadj Senini, M., Jeandel, C., Lagarde, M., Planquette H., Baudet C. Dissolved and particulate REE distributions in the tropical and subtropical Indian Ocean (SWINGS cruise).

- Cloete, R., Loock, J., van Horsten, N., Samanta, S., Mtshali, T., Fietz, S., Planquette H., Roychoudhury A. Winter Copper and Nickel distributions from the Indian sector of the Southern Ocean. R. Cloete is now a postdoc at LEMAR.

- Lagarde, M., Pham, V., Belhadj, M., Lherminier, P., and Jeandel, C.: Rare Earth Element partition coefficients in the North Atlantic (GEOVIDE cruise, GEOTRACES GA01).

- Lemaitre, N., Planquette, H., Jeandel, C., Ellwood, M., Hassler C., Vance, D. Nickel and zinc cycling in the Southern Ocean: insights from isotopes.

- Léon, M., van Beek, P., Sanial, V., Souhaut, M. Jeandel C., Planquette H. Radium isotopes to emphasize a hydrothermal plume in the South West Indian Ridge region.

Challenger society, 2022:

- Mahieu, L., Whitby, H., Dulaquais, G., Tilliette, C., Bressac, M., Arnone, V., González-Santana, D., Sarthou, G., Planquette, H., Guieu, C., Bonnet, S., Salaün, P. Iron-binding ligands in the Western South Tropical Pacific. GPpr14 – TONGA cruise 2019

- Goddard-Dwyer M., Ryan-Keogh T., Hamelin B., Liao W., González-Santana D., Baudet C., Vorrath M., Lemaitre N., LoMonaco C., Barut G., Fin J., Mignon C., Vivier F., Kestenare E., Eldin G., Clerc C., Izard L., Sergi S., Planquette H., Jeandel C., Tagliabue A., Whitby H. Biogeochemical Cycling of Iron Binding Humic Ligands in the South-West Indian Sector of the Southern Ocean.

12th International Symposium Geochemistry of the Earth's Surface 2022:

- Lemaitre, N., Ellwood, M., Hassler, C., Jeandel, C., Planquette, H., Vance, D. Nickel and zinc cycling in the Southern Ocean: insights from isotopes.

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN GERMANY

May 1st, 2022 to April 30th, 2023

GEOTRACES or GEOTRACES relevant cruises

- GP11 section cruise 'Cycling of trace elements and their isotopes in the Equatorial Pacific Ocean and consequences for ocean productivity'on *FS Sonne* (SO298) in the Equatorial Pacific Ocean (Guayaquil_Ecuador – Townsville_Australia) has been sailed in the period April 14 – June 2 2023 PIs Achterberg, Frank, Koschinsky, and important involvement by Scholten, Walter Geibert, S Galer, W Abouchami.
- *R/V Sonne* cruise SO290, Nouméa-Nouméa, took place in April/May 2022 (chief scientist Katharina Pahnke, co-chief scientist Frank Lamy). The water column in the southern Tasman Sea was sampled for dissolved Nd isotopes and REE, nutrients and dissolved stable O, C, H and Si isotopes. Surface sediment and long sediment cores were collected from intermediate to deep depths for paleoceanographic reconstructions.
- GEOTRACES Process study GApr17 'Island Impact' *RV Polarstern* cruises PS133/1 and PS133/2 South Georgia and the adjoining Antarctic Circumpolar Current, took place from Oct 1 to Dec 19, 2022
- Heincke training cruise HE603 scheduled for 12 July-15 July 2022 (GEOTRACES Summer School, Geibert/Benthien/Cutter/Middag) started but was aborted after one day due to pandemic

Upcoming:

- Arcwatch-2 (=Transarc3) FS Polarstern expedition PS143 to the Central Arctic Ocean August-September 2024, main applicant Geibert, Chief Scientist Rabe
- GI07 section cruise on FS Sonne (SO308) in the South Indian Ocean is scheduled for the period November- December 2024. PIs Achterberg, Frank, Koschinsky, and important involvement by Walter Geibert, S Galer, W Abouchami.

New projects and/or funding

- European Research Council Starting Grant funding for Dr Tom Browning for project Oceanglow
- Funding of one Postdoc for 26 months within project Cycling of trace elements and their isotopes in the Equatorial Pacific Ocean and consequences for ocean productivity', related to research cruise SO298

GEOTRACES workshops and meetings organised

- GEOTRACES Summer School at AWI Bremerhaven, led by W. Geibert, C. Hanfland, E. Le Roy. 10-15 July 2022, funded by Volkswagen Stiftung with additional travel support by US GEOTRACES and SCOR. 50 participants, 14 lecturers.
- GApr11: research cruise M147 (2018) related workshop. M147 Amazon-GEOTRACES workshop held as a hybrid-meeting at Constructor University (formerly known as Jacobs University), 27 participants of Germany, Brazil, England, France, and Switzerland

Outreach activities conducted

- Press release for Equatorial Pacific GEOTRACES cruise GP11. https://www.geomar.de/en/news/article/measuring-plankton-growth-across-the-pacific-ocean
- The alumni of a German pupil/student award for artificial intelligence ("Bundeswettbewerb KI") were invited to the Alfred Wegener Institute on 20 and 21st of April 2023 and introduced to marine sciences and GEOTRACES data resources by Walter Geibert and Sebastian Mieruch-Schnülle: https://www.instagram.com/p/CrQyZ9fgdbU/?hl=en
- Training videos (Cleanroom and ICP-MS), developed in conjuction with the GEOTRACES summer school at AWI Bremerhaven, funded by Volkswagen Stiftung, were continued and are in the final cutting stage.

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

- Al-Hashem, A.A., Beck, A.J., Krisch, S., Menzel Barraqueta1, J.L., Steffens, T., Achterberg, E.P. (2022). Particulate Trace Metal Sources, Cycling and Distributions on the Southwest African Shelf. Global Biogeochemical Cycles, 36 (11). e2022GB007453. DOI 10.1029/2022GB007453.
- Browning, T.J., Liu, X., Zhang, R., Wen, Z., Liu, J., Zhou, Y., Xu, F., Cai, Y., Zhou, K., Cao, Z., Zhu, Y., Shi, D., Achterberg, E.P. and Dai, M. (2022), Nutrient co-limitation in the subtropical Northwest Pacific. Limnol Oceanogr, 7: 52-61. https://doi.org/10.1002/lol2.10205
- Camoying, M., Thoms, S., Geuer, J. K., Koch, B. P., Bischof, K., Trimborn, S. 2022 In contrast to diatoms, cryptophytes are susceptible to iron limitation, but not to ocean acidification. Physiol Plant 174(1), e13614, doi:10.1111/ppl.1361.
- Chen, X. G., Rusiecka, D., Gledhill, M. , Milne, A., Annett, A. L., Birchill, A. J., Lohan, M. C., Ussher, S., Woodward, E. M. S. and Achterberg, E. P. (2023) Ocean circulation and biological processes drive seasonal variations of dissolved Al, Cd, Ni, Cu, and Zn on the Northeast Atlantic continental margin. Marine Chemistry . Art.Nr. 104246. DOI 10.1016/j.marchem.2023.104246.
- Chen, X. G., Rusiecka, D., Gledhill, M. , Milne, A., Annett, A. L., Beck, A. J. , Birchill, A. J., Lohan, M. C., Ussher, S. and Achterberg, E. P. (2023) Physical and biogeochemical controls on seasonal iron, manganese, and cobalt distributions in Northeast Atlantic shelf seas. Geochimica et Cosmochimica Acta, 348 . pp. 278-295. DOI 10.1016/j.gca.2023.03.023.
- Chen, X. G., Krisch, S. , Al-Hashem, A., Hopwood, M. J. , Rutgers van der Loeff, M. M., Huhn, O., Lodeiro, P. , Steffens, T. and Achterberg, E. P. (2022) Dissolved, labile and total particulate trace metal dynamics on the northeast Greenland Shelf. Global Biogeochemical Cycles, 36 (11). e2022GB007528. DOI 10.1029/2022GB007528.
- Fourquez, M., Cabanes, D., Janssen, D., Conway, T., Jaccard, S., Sieber, M., Ellwood, M., Trimborn, S., Hassler, C. Chasing iron bioavailability in the Southern Ocean: Insights from Phaeocystis antarctica and iron speciation. Science Advances, in press
- Gledhill, M., Zhu, K., Rusciecka, D., Achterberg, E.P. (2022). Competitive Interactions Between Microbial Siderophores and Humic like Binding Sites in European Shelf Sea Waters. Frontiers in Marine Science, section Marine Biogeochemistry, 9, 855009.

- Gledhill, M. , Hollister, A., Seidel, M., Zhu, K., Achterberg, E. P. , Dittmar, T. and Koschinsky, A. (2022) Trace metal stoichiometry of dissolved organic matter in the Amazon plume. Science Advances, 8 (31). Art.Nr. eabm2249. DOI 10.1126/sciadv.abm2249.
- Gosnell, K.J., Beck, A.J., Müller, P., Keßler, A. and Achterberg, E.P. (2022). Effects of salinity and temperature on seawater dissolution rate of initial detonation agent mercury fulminate. Marine Pollution Bulletin, 185(Pt A), pp.114311-114311.
- Hunt, H. R., Summers, B. A., Sieber, M., Krisch, S. , Al-Hashem, A., Hopwood, M., Achterberg, E. P. and Conway, T. M. (2022) Distinguishing the influence of sediments, the Congo River, and water-mass mixing on the distribution of iron and its isotopes in the Southeast Atlantic Ocean. Marine Chemistry, 247 . Art.Nr. 104181. DOI 10.1016/j.marchem.2022.104181.
- Janssen, D.J., Gilliard, D., Rickli, J., Nasemann, P., Koschinsky, A., Hassler, C.S, Bowie, A.R., Ellwood, M.J., Kleint, C., Jaccard, S.L. (2023) Chromium stable isotope distributions in the southwest Pacific Ocean and constraints on hydrothermal input from the Kermadec Arc. Geochimica et Cosmochimica Acta 342, 31-44. https://doi.org/10.1016/j.gca.2022.12.010.
- Krisch, S. , Huhn, O., Al-Hashem, A., Hopwood, M. J. , Lodeiro, P. and Achterberg, E. P. (2022) Quantifying Ice-Sheet Derived Lead (Pb) Fluxes to the Ocean; A Case Study at Nioghalvfjerdsbræ. Open Access Geophysical Research Letters, 49 (21). e2022GL100296. DOI 10.1029/2022GL100296.
- Krisch, S., Hopwood, M. J., Roig, S., Gerringa, L. J., Middag, R., Rutgers van der Loeff, M. M., et al. (2022). Arctic – Atlantic exchange of the dissolved micronutrients Iron, Manganese, Cobalt, Nickel, Copper and Zinc with a focus on Fram Strait. Global Biogeochemical Cycles, 36, e2021GB007191. https://doi.org/10.1029/2021GB007191
- Liu, T, Krisch, S., Xie, R.C., Hopwood, M.J., Dengler, M. and Achterberg, E.P. (2022). Sediment release in the Benguela Upwelling System dominates trace metal input to shelf and eastern South Atlantic Ocean. Global Biogeochemical Cycles, e2022GB007466.
- Liu, F., Gledhill, M. , Tan, Q. G., Zhu, K., Zhang, Q., Salaün, P., Tagliabue, A., Zhang, Y., Weiss, D., Achterberg, E. P. and Korchev, Y. (2022) Phycosphere pH of unicellular nano- and micro- phytoplankton cells and consequences for iron speciation. The ISME Journal, 16 . pp. 2329-2336. DOI 10.1038/s41396-022-01280-1.
- Pausch, F., Koch, F., Hassler, C., Bracher, A., Bischof, K., Trimborn, S. 2022 Responses of a natural phytoplankton community from the Drake Passage to two predicted climate change scenarios. Front Mar Sci Glob Change 9: 759501. doi:10.3389/fmars.2022.759501.
- Schmidt, K., Paul, S. A., Achterberg, E. P. (2022). Assessing the availability of trace metals and rare earth elements in deep ocean waters of the Clarion-Clipperton Zone, NE Pacific: Application of an in situ DGT passive sampling method. TrAC Trends in Analytical Chemistry, 116657.
- Schneider, A.B., Velasquez, I., Paul, S.A.L., Krause, C.H., Koschinsky, A. (2022). Mixing and partially non-conservative behavior of molybdenum, uranium and vanadium along the salinity gradients of the Amazon and Pará estuaries and associated plume. Marine Chemistry 247, 104182. https://doi.org/10.1016/j.marchem.2022.104182.
- Steiner, Z. , Rae, J. W. B., Berelson, W. M., Adkins, J. F., Hou, Y., Dong, S., Lampronti, G. I., Liu, X., Achterberg, E. P. , Subhas, A. V. and Turchyn, A. V. (2022) Authigenic formation

of clay minerals in the abyssal North Pacific. Global Biogeochemical Cycles, 36 (11). e2021GB007270. DOI 10.1029/2021GB007270.

- Sutorius, M., Mori, C., Greskowiak, J., Boettcher, L., Bunse, C., Dittmar, T., Dlugosch, L., Hintz, N.H., Simon, M., Striebel, M., Pahnke, K., 2022. Rare earth element behaviour in seawater under the influence of organic matter cycling during a phytoplankton spring bloom – A mesocosm study. Front. Mar. Sci. 9. doi: 10.3389/fmars.2022.895723.
- Ukotije-Ikwut, P. R., Steiner, Z. , Gledhill, M. , Müller, M., Oakes, J. M., Sukri, R. S., Jiang, S. and Achterberg, E. P. (2023) The distribution and behaviour of Fe, Al, Si, Mn, Cu and Ni in ombrotrophic tropical peat draining blackwater estuaries on Borneo Island. Open Access Frontiers in Marine Science, 9 . Art.Nr. 1075155. DOI 10.3389/fmars.2022.1075155.
- Zhu, K., Achterberg, E. P. , Bates, N. R., Gerringa, L. J. A., Middag, R., Hopwood, M. J. and Gledhill, M. (2023) Influence of changes in pH and temperature on the distribution of apparent iron solubility in the oceans. Global Biogeochemical Cycles, 37 (5). e2022GB007617. DOI 10.1029/2022GB007617.

Completed GEOTRACES PhD or Master theses

- PhD thesis: Trace Metal Biogeochemical Cycling and Fluxes in the eastern South Atlantic (Te Liu, 2023.04; related to cruise GA08)
- Jenna Balaguer (2022): Iron manganese co-limitation – a potential driver of Southern Ocean phytoplankton ecology. University Bremen. https://doi.org/10.26092/elib/1980

GEOTRACES presentations in international conferences

- Liu, Te: Shelf sediments in the Benguela Upwelling System as a major source of trace metals to the shelf and eastern South Atlantic Ocean. Sixth Xiamen Symposium on Marine Environmental Sciences (XMAS-VI, January 2023)
- Tessele SR., I., Carvalho, L., Koschinsky, A.: Distribution of chromium and thallium species along the Amazon and Pará estuaries and mixing plume. Goldschmidt conference 2022
- Kurahashi, E., Poehle, S., Koschinsky, A.: Determination of vanadium redox species V(IV) and V(V) in the South-East Atlantic Ocean using chelating resin and Inductively-coupled Plasma Mass Spectrometry. Goldschmidt conference 2022
- Fröhberg, N., Klose, L., Koschinsky, A.: Organic complexation of Ni in the hydrothermal plume of the Rainbow vent field. Goldschmidt conference 2022
- Schneider, A.B., Koschinsky, A., Krause, C.H., Gledhill, M., Carvalho, L.: Distribution of dissolved and soluble Ti along the salinity gradients in the Pará and Amazon estuaries and plume. Goldschmidt conference 2022
- Stichel, T., Freitag, J. Henkel, S. Geibert, W. and Kasten, S.: Marine Ice: A sleeping iron giant in the Southern Ocean? Goldschmidt conference 2022

[the list of conference contributions is not exhaustive]

With contributions by Eric Achterberg, Walter Geibert (walter.geibert@awi.de), Andrea Koschinsky, Katharina Pahnke, Sandra Pöhle, Scarlett Trimborn.

New GEOTRACES or GEOTRACES relevant scientific results

- Biogeochemical cycling of micronutrients in the Arabian Sea

The Indian Ocean is unique in terms of its geographical position, physicochemical conditions, and the existence of numerous sources and sinks of micronutrients. The biogeochemical cycling of the micronutrients in the Indian Ocean has received little attention. The current study demonstrates the sources, sinks, and internal cycling of the micronutrients, as well as their influence on the ecological distribution in the Indian Ocean.

To determine the distribution of micronutrients such as Fe, Ni, Cd, Co, Cu etc. in the Indian Ocean and to identify the sources, sinks and internal cycling of these micronutrients in the Indian Ocean, seawater from the Arabian Sea has been analysed.

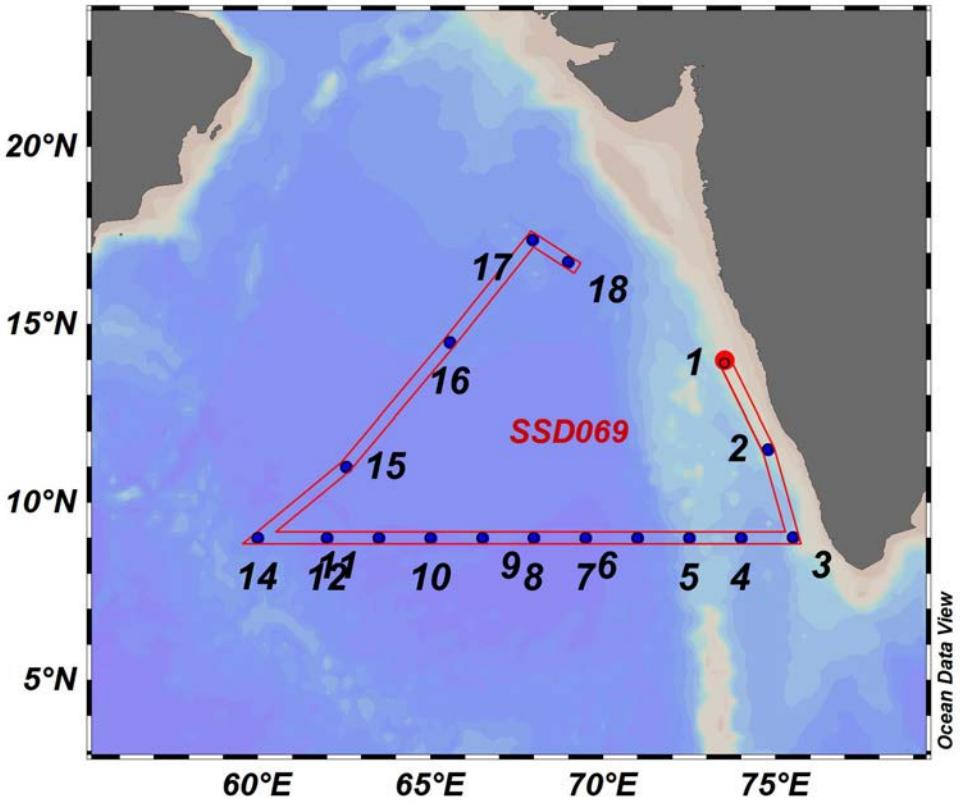


Figure IN-1: *Study area showing the stations of the water sampling along the cruise track of GI10 in the Arabian Sea from Jan to Feb 2020.*

Iron:

The present study shows the dissolved Fe (dFe) concentration in the surface waters from 0.1-0.5 nM, which gradually increases with depth up to 1nM. A slightly high concentration is observed in the surface waters of the south-eastern Arabian Sea, which is due to the inflow of the Bay of Bengal Low Saline Water (BBLSW) transported by the East India Coastal Current (EICC). Pronounced supply of dFe is observed (~3nM) in the coastal sub-surface water of the Eastern Arabian Sea due to the lateral advection of Fe from the reducing shelf margin. Towards

the south-western Arabian Sea, a relatively higher concentration of dFe (~2nM) marked in deep and intermediate waters, which reaches up to ~200-300 meters signify hydrothermal input, could be sourced from the active hydrothermal vents over the Carlsberg Ridge. This large supply of dFe up to such height in the water column may reach the surface due to the strong upwelling (during SW monsoon) and can be bio-available, hence increases the productivity. The release of dFe (1 to 1.8 nM) to the water column in the Oxygen Minimum Zone of the Arabian Sea acts as another valuable source. Distinctive physicochemical processes in different depths of the water column add to or remove dFe working as a source or sink in the marine realm, controlling its biogeochemical cycle.

Nickel:

The concentration of dNi in the Arabian Sea varies from 1.9-2.7nM in the surface waters to 10.2-11nM in the deeper waters. In the coastal waters the dNi concentration varies from 2.2nM-5nM. We have collected water samples throughout the water column depth in 8 stations in the zonal transect of 90N (90N,740E-90N,620E). The concentration of dNi in this transect in the surface waters ranges from 2.2-2.4nM, in the intermediate waters (100m-1000m) ranges from 2.3nM to a maximum of~ 7nM at depth of 1000m. Deeper waters (>1000m) have a range of 6.8nM to ~10nM of dNi. Three stations from SSD069 (station 16-18) were done in the perennial oxygen minimum zone of the Arabian Sea. The concentration of the dNi in the surface waters varies 2-2.4nM whereas in depth the concentration reaches up to a maximum of 11nM. dNi concentration values in the deeper waters are seen to be little bit higher in the northern and the perennial OMZ regions than the southern part (9ºN transect). Although earlier report conceived the theory of the role of water masses and their mixing of them controls the distribution of dNi in the water column, however in the context of the Indian Ocean, it seen the overpowering role of the OMZ and remineralisation. In the Northern Indian Ocean, the role of OMZ in the intermediate waters depletes dNi wrt Phosphate. The depletion in Ni in the OMZ waters of the Arabian Sea is found to be maximum at SSD069 station 17 and 18 at depth 150 m and 300m of value around 300 pmol/L.

Copper:

Biogeochemical cycling and internal circulation play a major role in the distribution of Cu. Reversible scavenging and subsequent sedimentary input are the major processes associated with the Cu distribution. Besides, association of Cu with the Fe-Mn oxy-hydroxides is critical which is not a major source in the open ocean waters but can be a significant source in the continental margins. Though a debate on the hydrothermal vents whether a source or sink, but in our studies we have not seen any significant signature of dCu in the vent areas. In the Arabian Sea along the cruise SSD069 coastal waters shows a high concentration of dCu of 2-2.5nM may be due to the sources from the continents and gradually decreases further towards the open ocean. The profile shows a gradual increase in the concentration with depth unlike other elements of nutrient type. At station 5 a higher signal is seen. And in the OMZ areas the minimum values of dCu persisted up to a greater depth which may be the effect of the change in redox condition in the water column.

Cobalt:

Cobalt may act as a primary or secondary limiting nutrient. The requirement of this micro-nutrient in the marine phytoplankton is due to the presence in vitamin B_{12} (Cobalamin) and its crucial role as a potential co-factor of Carbonic Anhydrase and Alkaline Phosphatase. In the Arabian Sea the surface concentration remains low except near the coastal areas as probable

sources are the continental margin, riverine input and the atmospheric dust. However, with progressing towards the open ocean surface concentration gradually decreases. As the dCo shows a hybrid type of profile in the water column with scavenging in the surface and then enriching in the intermediate waters. Although the enrichment of dCo in this zone is even more up to 0.11nM in the perennial OMZ.

Cadmium:

The biogeochemical cycling of dCd is mainly dominated by the biological uptake of the phytoplankton in the photic zone and the regeneration of the particulate Cd which governs the shape of the vertical profile of dCd in ocean, however, water-mass circulation also plays an important role in the distribution of dCd in ocean waters. It has been recently argued that the precipitation of Cd in the form of sulphides also affects its biogeochemical cycling in the Oxygen Deficient Zone (ODZ) and is not restricted to the euxinic basins. Though recent studies reveal the CdS precipitation in the North Atlantic and South Pacific but not in North Pacific. However, in the Northern Indian Ocean it is supposed to be precipitated from the water column but we observed a range of positive and negative Cd anomaly with respect to the phosphate in the OMZ waters of the Arabian Sea. The dCd in the Arabian Sea ranges from 0.01nM to 0.98nM. Recent studies on the sulphide precipitation of metals is observed in the ODZs. The Northern Indian Ocean although experiences the process still its dynamic nature makes some variations in the precipitation of different metals. In case of dNi, the Arabian Sea experiences a depletion with respect to the phosphate but in dCd it is not the case. Arabian Sea experiences an enrichment even in the layers of OMZ. The high productivity of Arabian Sea, its uptake and subsequent regeneration might have overpowered the CdS precipitation process. Also, the intrusion of the Red Sea water and Persian Gulf Water in the water depth of 200m- 800m night have influence it. Further isotopic studies in the dissolved and particulate phases will exactly describe the dominance of the processes in the water column in various part of the Indian Ocean though this CdS precipitation seems to be a regional scale process.

- Link of the short-term temporal trends of Sr and Nd isotopic composition of aeolian dust over the Arabian Sea with the source emissions

Aeolian transport of continental dust from the Middle East and South Asia to the Arabian Sea (AS) is an important route for delivering key trace metals and nutrients. Despite being surrounded by several deserts, it is not clear which dust source is most likely contributing to mineral aerosols over this marine basin in winter. Substantial information on dust source emissions and transport pathways over the AS is, thus, needed for better constraining the biogeochemical effects in the sunlit surface waters.
Here, we investigated the Sr and Nd isotopic composition ($^{87}Sr/^{86}Sr$ and $\varepsilon_{Nd}(0)$), respectively: characteristic of source material) of dust samples collected over the AS during a GEOTRACES-India expedition (GI-10: 13 January-10 February 2020).

Both tracers, $^{87}Sr/^{86}Sr$ (0.70957–0.72495) and $\varepsilon_{Nd}(0)$ (−24.0 to −9.3), showed pronounced spatial variability. These proxies were further tagged with their source profiles of surrounding land masses based on the origin of air mass back trajectories (AMBTs). We also encountered two dust storms (DS), one on 27 January 2020 ($^{87}Sr/^{86}Sr$: 0.70957; $\varepsilon_{Nd}(0)$: −9.3) and the second one on 10 February 2020 ($^{87}Sr/^{86}Sr$: 0.71474, $\varepsilon_{Nd}(0)$:-12.5), which showed distinct isotopic signatures. AMBTs and satellite imagery together revealed that DS1 is from the Arabian Peninsula and DS2 is from Iran and/or the Indo-Gangetic Plain. Notably, the Sr and Nd isotope composition of DS1 is further consistent with other dust samples collected over the

pelagic waters, suggesting the impact of dust outbreaks from the Arabian Peninsula during winter season. Such documentation based on the $^{87}Sr/^{86}Sr$ and $\varepsilon_{Nd}(0)$ over the Arabian Sea, hitherto, is lacking in literature and, thus, highlights the need for more measurements.

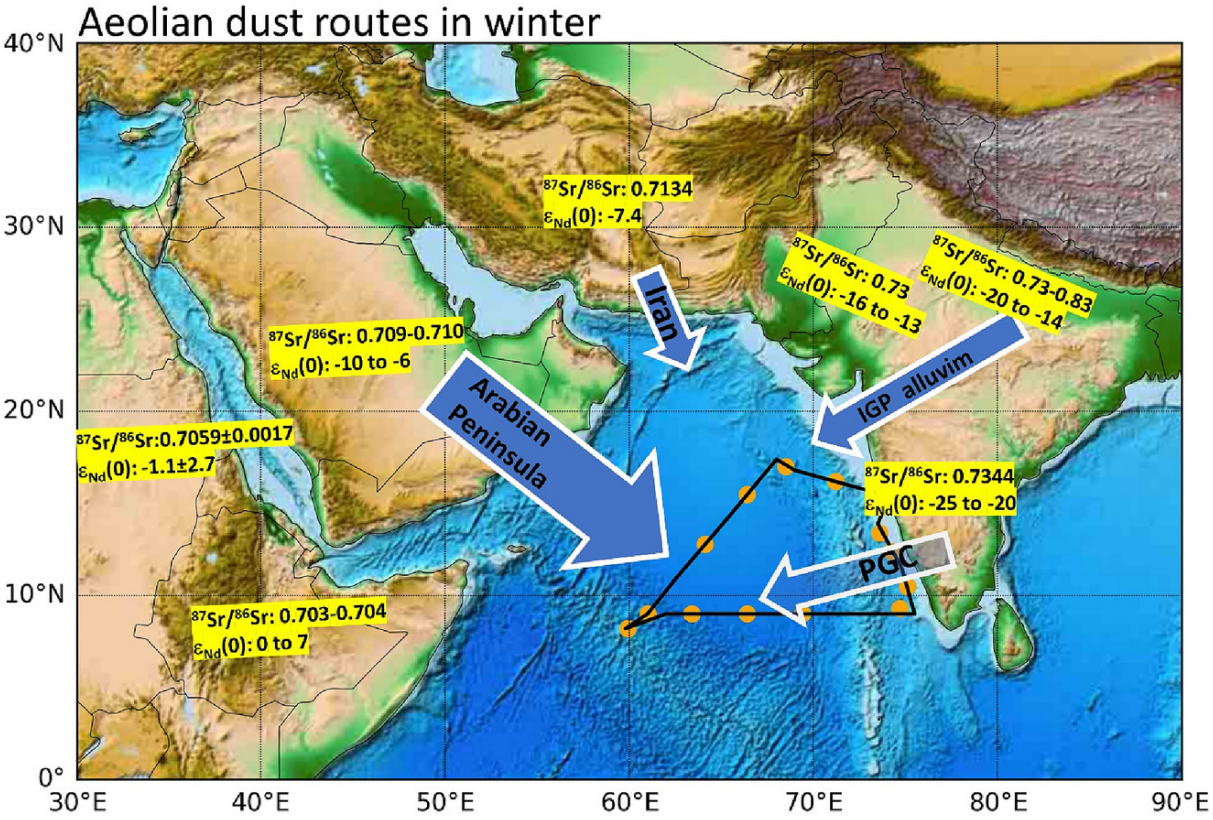


Figure IN-2: *Study area in the Arabian Sea showing aerosol dust pathways in the winter season, with characteristic radiogenic isotopic composition ($^{87}Sr/^{86}Sr$, ε_{Nd}) of source regions.*

- Biogeochemical cycling of dissolved manganese in the Arabian Sea

Manganese (Mn) acts as a bio-essential trace metal and its availability in seawater may impact the productivity and diversity of marine phytoplankton (Coale, 1991; Raven, 1990; Sunda, 2012). Particulate authigenic Mn oxides and oxyhydroxides formed in the ocean water column may act as important sink for other bio-essential trace metals (e.g., Co, Zn, Ni, etc.) and, therefore, the Mn redox cycling in seawater can impact the bio-availability of these micro-nutrients. We measured dissolved Mn (dMn) in the water column along the GEOTRACES-India transects, GI-05 and GI-10 (Figure IN-1), to understand the control of diverse biogeochemical processes, including atmospheric dust deposition, biological cycling, water mass mixing, redox changes in the sediment and water column, on dMn distribution in the coastal and open Arabian Sea regions. The study presents important implications for the Mn and other trace nutrient bio-availability in the AS euphotic waters.

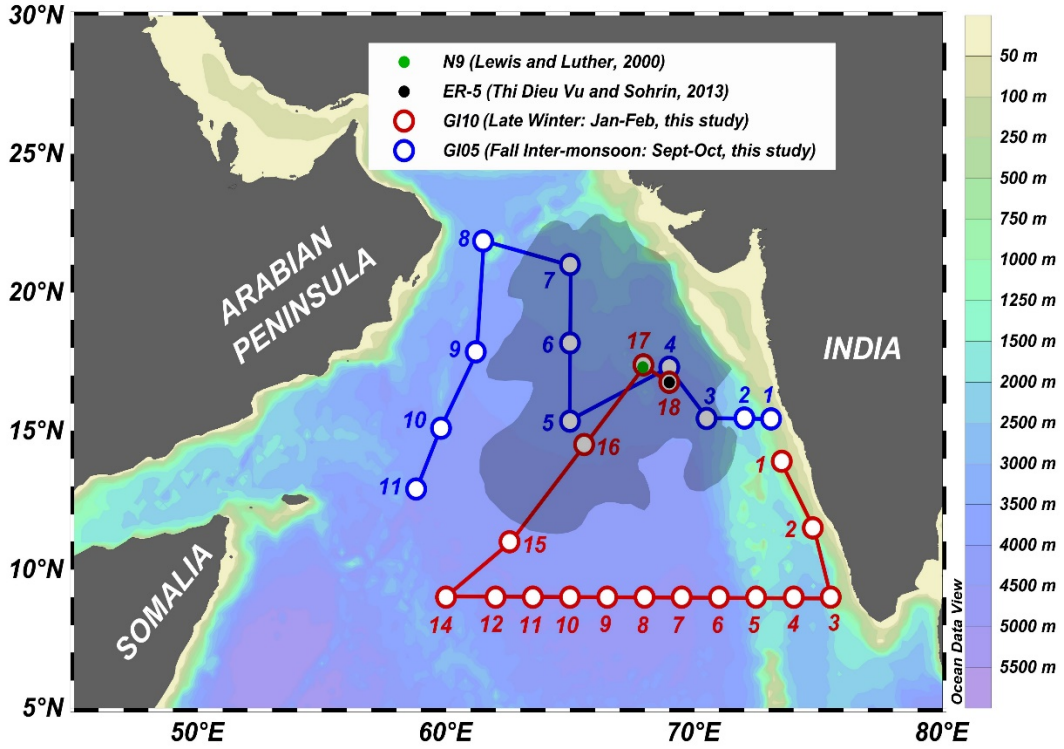


Figure IN-3: *Sampling locations along the GI05 (blue circles) and GI10 (red circles) cruise transects where vertical dMn profiles are measured. The shaded area represents the AS denitrification zone identified by Naqvi (1991), where* $[NO_2^-] > 1\mu M$ *at the secondary nitrite maximum depth. Crossover stations from earlier studies, ER-5 (black circle) and N9 (green circle), are also marked.*

A strong east-west concentration gradient was observed in the surface dMn distribution in the AS (Figure IN-2). Higher dMn input from atmospheric dust deposition and, presumably, from riverine discharge and/or shelf sediments resulted in increased dMn levels (1.6–5.7 nmol kg^{-1}) in the surface waters of the eastern AS. While, strong removal of dMn via Mn-oxidation and scavenging led to relatively lower dMn levels (1.3–2.2 nmol kg^{-1}) in the surface waters of the open western AS.

A mass-balance of dMn in the euphotic waters of different open AS regions was done considering the input (atmospheric deposition), removal (bio-assimilation, and Mn-oxidation and scavenging) and internal redistribution (water mass mixing) of dMn (Figure IN-3). Significant contribution (14–99%) from atmospheric Mn deposition to the total estimated dMn input flux is estimated. In terms of removal, Mn-oxidation and particle scavenging are found to be the predominant processes, contributing 61–99% of the total estimated output fluxes. Removal via Mn bio-assimilation and subsequent export plays a secondary role. Water mass mixing (via lateral and vertical advection-eddy diffusion) is found to predominantly contribute (~70–80% of the total input flux) to the dMn inventory in the euphotic zone of the coastal regions of the western AS.

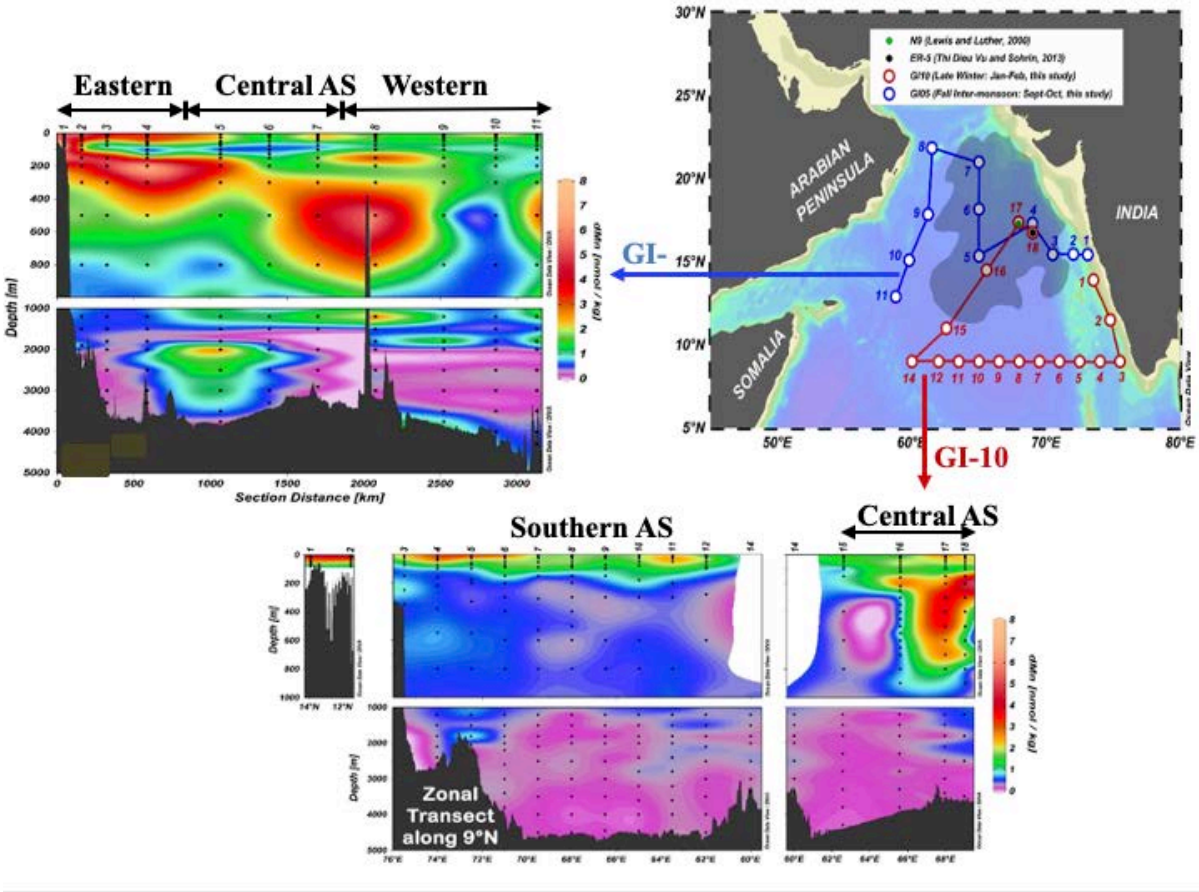


Figure IN-4: *Dissolved Mn distribution along the GI05 (top left) and GI-10 (bottom) cruise transects.*

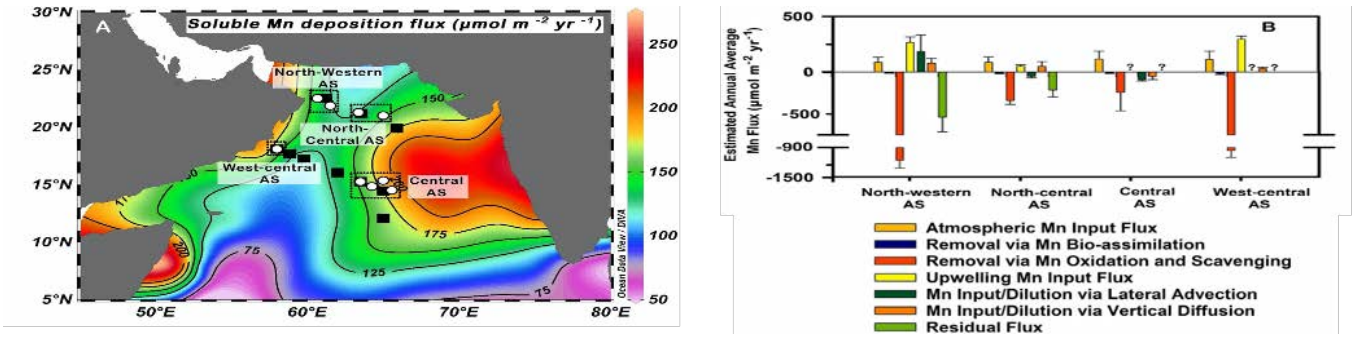


Figure IN-5: *(A) Estimated soluble Mn deposition flux from atmospheric dust deposition. (B) Mass-balance of dMn in the euphotic waters (upper 100m) of different AS regions.*

Dissolved Mn and secondary nitrite maxima are observed to be correlated in the upper thermocline water in the denitrification zone of the (DNZ) eastern and central AS (Figures IN 4A and 4B), indicating an important role of *in situ* reductive dissolution of Mn oxides and oxyhydroxides. However, the strength of dMn maximum increases from the central AS coast to the eastern AS, suggesting additional dMn input from the reducing shelf and slope sediments of the western Indian margin to the open AS through lateral advection.

Outside the DNZ, in the north-central and western AS, dMn maxima is observed to show a relative shift to the lower thermocline waters (~500 m, Figure IN-4C). This shift is attributed to the change in source region of the dMn input to the western and north-central AS, from the reducing margins of the north (Pakistan Margin) and north-western AS (Oman Margin), where core of the oxygen minima intersects the margin sediments at depth range of 400–600 m.

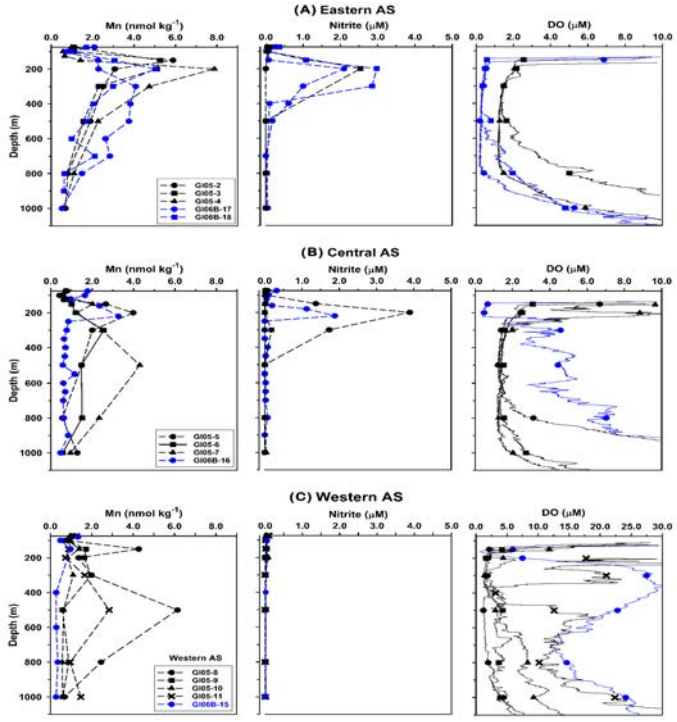


Figure IN-6: *Vertical profiles of dMn, dissolved nitrite and oxygen in the (A) eastern, (B) central and (C) western AS regions.*

- Impact of weathering, lithology and fluvial transport on δ^{98}Mo in a tropical river (Narmada)

Stable molybdenum (Mo) isotopes (δ^{98}Mo) were measured in the waters from the Narmada River to understand the impact of various processes on the Mo supply to the ocean. Results show that the Mo isotopic composition (δ^{98}Mo; relative to NIST SRM-3134 = 0.25‰) of the Narmada river water vary significantly, from 0.30 to 0.92‰, considerably heavier than the crustal components. The measured δ^{98}Mo in the Narmada river water show significant control of continental weathering, soil organic matter cycling, secondary mineral formation, and surface-ground water interactions.

GEOTRACES or GEOTRACES relevant cruises

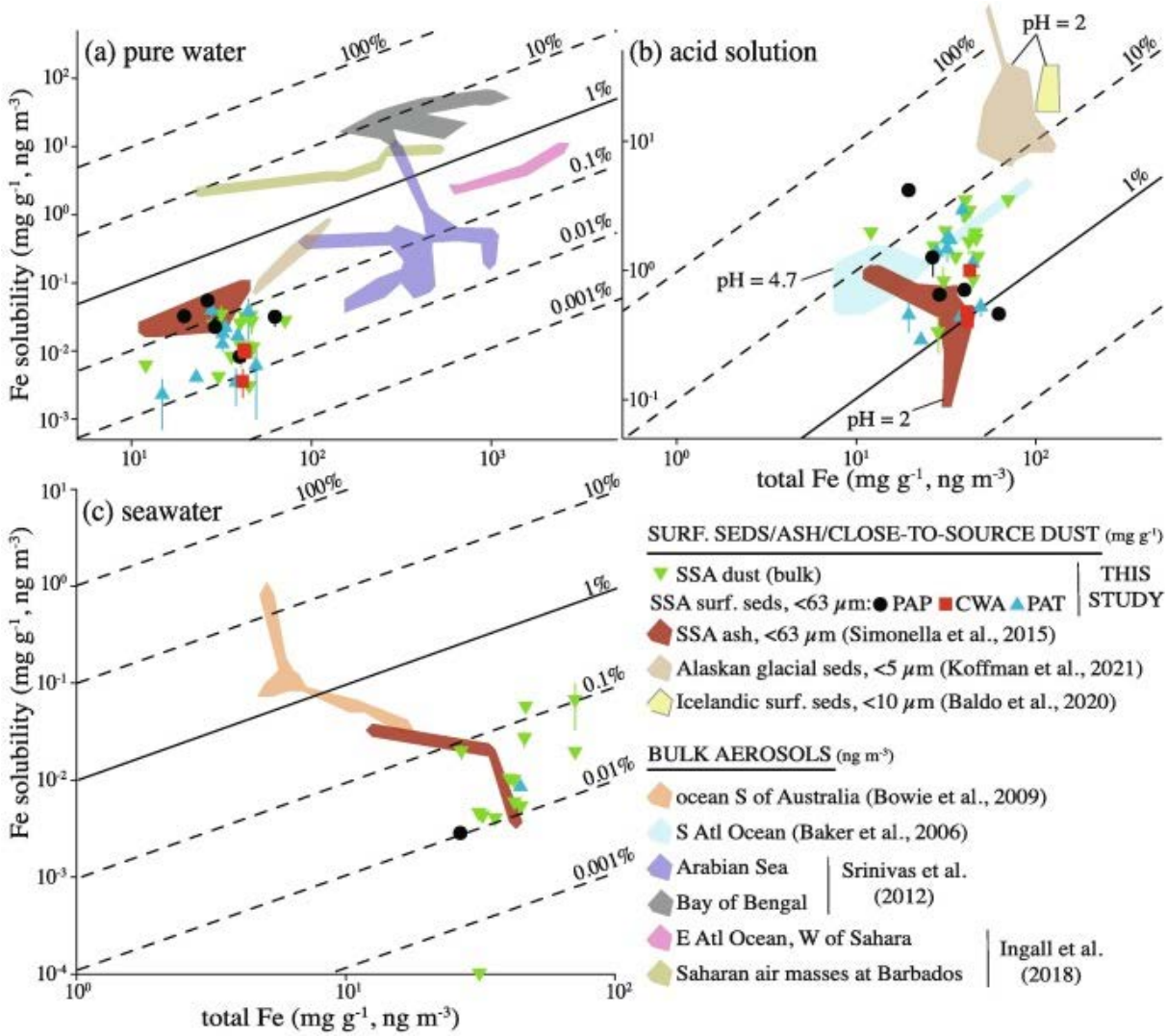
- There was no new sample collection done through the last year. However, various water and sediment/particulate samples are being analysed currently for their trace element and isotopic composition and other key parameters.

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

- Naman Deep Singh, Sunil Kumar Singh, Nirmalya Malla, Venkatesh Chinni, Biogeochemical cycling of dissolved manganese in the Arabian Sea, Geochimica et Cosmochimica Acta, Volume 343, 2023, Pages 396-415, ISSN 0016-7037, https://doi.org/10.1016/j.gca.2022.12.030.
- Karri Damodararao, Sunil Kumar Singh, Substantial submarine groundwater discharge in the estuaries of the east coast of India and its impact on marine strontium budget, Geochimica et Cosmochimica Acta, Volume 324, 2022, Pages 66-85, ISSN 0016-7037, https://doi.org/10.1016/j.gca.2022.03.002.
- Rakesh K. Tiwari, Tarun K. Dalai, Saumik Samanta, Waliur Rahaman, Sunil K. Singh, Tristan J. Horner, Geochemistry of uranium in the Ganga (Hooghly) River estuary, India: The role of processes in the water column and below the sediment-water interface, Marine Chemistry, Volume 247, 2022, 104173, ISSN 0304-4203, https://doi.org/10.1016/j.marchem.2022.104173.
- Naman Deep Singh, Sunil Kumar Singh, Distribution and cycling of dissolved aluminium in the Arabian Sea and the Western Equatorial Indian Ocean, Marine Chemistry, Volume 243, 2022, 104122, ISSN 0304-4203, https://doi.org/10.1016/j.marchem.2022.104122.
- Vineet Goswami, Sunil K. Singh, Ravi Bhushan, Vinai K. Rai, Spatial distribution of Mo and δ98Mo in waters of the northern Indian Ocean: Role of suboxia and particle-water interactions on lighter Mo in the Bay of Bengal, Geochimica et Cosmochimica Acta, Volume 324, 2022, Pages 174-193, ISSN 0016-7037, https://doi.org/10.1016/j.gca.2022.03.010

Submitted by Vineet Goswami (vineetg@prl.res.in).

New GEOTRACES or GEOTRACES relevant scientific results



Simonella et al. Low source-inherited iron solubility limits fertilization potential of South American dust. Geochimica et Cosmochimica Acta 335, 272-283. (2022).

Where atmospheric processing is weak due to low anthropogenic emissions, fertilization of iron-limited oceans by non-volcanic mineral dust aerosols strongly depends on iron solubility at the sources. Southern South America (SSA) is a pristine environment and the main dust supplier to the southern oceans, the most sensitive to iron fertilization. Thus, the present-day lack of SSA dust fertilization of the southern oceans is hypothesized to reflect low source-inherited iron bioavailability. However, a dearth of geochemical studies on SSA dust prevents testing this hypothesis. To remedy this, we conducted the first systematic sampling of SSA dust sources. Iron leaching experiments showed fractional solubilities of close-to-source dust (bulk) and dust-emitting surface sediments (<63 µm) in pure water (0.05 ± 0.05%), seawater (0.03 ± 0.04%) and 1% nitric acid (5 ± 6%) that imply a low mass-normalized fertilization potential of SSA dust compared to dust from other regions. Based on grain size, size-resolved mineralogy, elemental chemistry and iron speciation determinations, we found that variability

in labile iron is enhanced by high clay contents, small grain size and higher proportions of paramagnetic versus non-paramagnetic iron, irrespective of oxidation state. The independence of the most labile, water-soluble iron on grain size and its strong negative correlation to the Chemical Index of Alteration may imply that we currently underestimate the role of coarse glaciogenic dust as a supplier of bioavailable iron during drier-than-present ice ages when continental chemical weathering was reduced, and during which enhanced supply of dust-borne bioavailable iron to the southern oceans is observed.

GEOTRACES or GEOTRACES relevant cruises

- PS132 – Prof. Peter Croot was chief teacher on the *P.S. Polarstern* (30 Aug – 29 Sep, 2022, 30 days at sea, Bremerhaven to Cape Town). NoSoAT POGO Training expedition (including introducing students to SOLAS and GEOTRACES related work in the Open Ocean) .

New projects and/or funding

- A new SEAL AA500 nutrient analyzer funded in the 2nd phase of the Irish Centre for research in Applied Geoscience (iCRAG2) was installed at the University of Galway in October 2022 and is now available to Irish researchers on a cost share basis.

GEOTRACES workshops and meetings organized

- There were no GEOTRACES specific workshops run in Ireland during the reporting period.

Outreach activities conducted

- There were no specific GEOTRACES outreach activities conducted during the reporting period.

Other GEOTRACES activities

- Prof. Croot is a member of the Chemical Speciation Group – Joint Committee on the Properties of Seawater (2023-present).
- Prof. Croot attended the United Nations Ocean Conference, held in Lisbon, Portugal (27 June -1 July, 2022).
- Prof. Croot attended the GESAMP WG38 International Workshop – Potential role of atmospheric deposition in driving ocean productivity in the Southwest Indian Ocean. Gqeberha, South Africa. October 4-7, 2022.
- Prof. Croot is an associate member of SCOR Working Group 167 - Reducing Uncertainty in Soluble aerosol Trace Element Deposition (RUSTED) (2022 – present).

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

- Boswell, Z., Verga, J.U., Mackle, J., Guerrero-Vazquez, K., Thomas, O.P., J., C., Wolf, B.J., Choo, Y.M., Croot, P., Hamann, M.T., Hardiman, G., 2023. In-Silico Approaches for the Screening and Discovery of Broad-Spectrum Marine Natural Product Antiviral Agents Against Coronaviruses. . Infect Drug Resist. 16, 2321-2338.

- Calvo-Martin, E., Teira, E., Álvarez-Salgado, X.A., Rocha, C., Jiang, S., Justel-Díez, M., Ibánhez, J.S.P., 2022. On the hidden diversity and niche specialization of the microbial realm of subterranean estuaries. Environmental Microbiology 24, 5859-5881.
- Ibánhez, J.S.P., Álvarez-Salgado, X.A., Rocha, C., 2023. Radon prevalence in domestic water in the Ría de Vigo coastal basin (NW Iberian Peninsula). Environmental Science and Pollution Research 30, 69927-69940.
- Rocha, C., Jiang, S., Ibánhez, J.S.P., Yang, Q., Mazi, K., Koussis, A.D., 2022. The effects of subterranean estuary dynamics on nutrient resource ratio availability to microphytobenthos in a coastal lagoon. Science of The Total Environment 851, 157522.
- Simonella, L.E., Cosentino, N.J., Montes, M.L., Croot, P.L., Palomeque, M.E., Gaiero, D.M., 2022. Low source-inherited iron solubility limits fertilization potential of South American dust. Geochimica et Cosmochimica Acta 335, 272-283.
- Xu, H., Croot, P., Zhang, C., 2022. Exploration of the spatially varying relationships between lead and aluminium concentrations in the topsoil of northern half of Ireland using Geographically Weighted Pearson Correlation Coefficient. Geoderma 409, 115640.

Completed GEOTRACES PhD or Master theses

- No GEOTRACES related PhD or Master theses were completed during the reporting period.

GEOTRACES presentations in international conferences

- Prof. Croot presented on shipboard training activities (including those related to GEOTRACES) at the GESAMP WG38 International Workshop – Potential role of atmospheric deposition in driving ocean productivity in the Southwest Indian Ocean. Gqeberha, South Africa. October 4-7, 2022.

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

New GEOTRACES or GEOTRACES relevant scientific results

- Dissolved aluminium dynamics in the Red Sea (Benaltabet et al., 2022): Dissolved aluminium (Al) is a primary tracer for evaluating atmospheric deposition fluxes and terrigenous inputs to the open ocean. However, the impact of short-term environmental perturbations such as dust storms, sediment resuspension and rainfall events on the oceanic water column is poorly constrained due to the typically low temporal resolution sampling in open ocean settings. The Gulf of Aqaba (GOA), northern Red Sea, is a highly accessible deep oligotrophic water body featuring exceptionally high atmospheric deposition fluxes delivered by dust storms, which constitutes as the main terrigenous input to the GOA surface water. Benaltabet et al. (2022) present a time series of dissolved Al and silicate (Si) concentration profiles sampled during 2017 and 2018, with a particular focus on daily time scale dust storms, episodes of sediment resuspension and rain events. We evaluate the results in conjunction with high temporal resolution measurements of airborne aerosols and sediment trap -based water column sinking particulate fluxes.

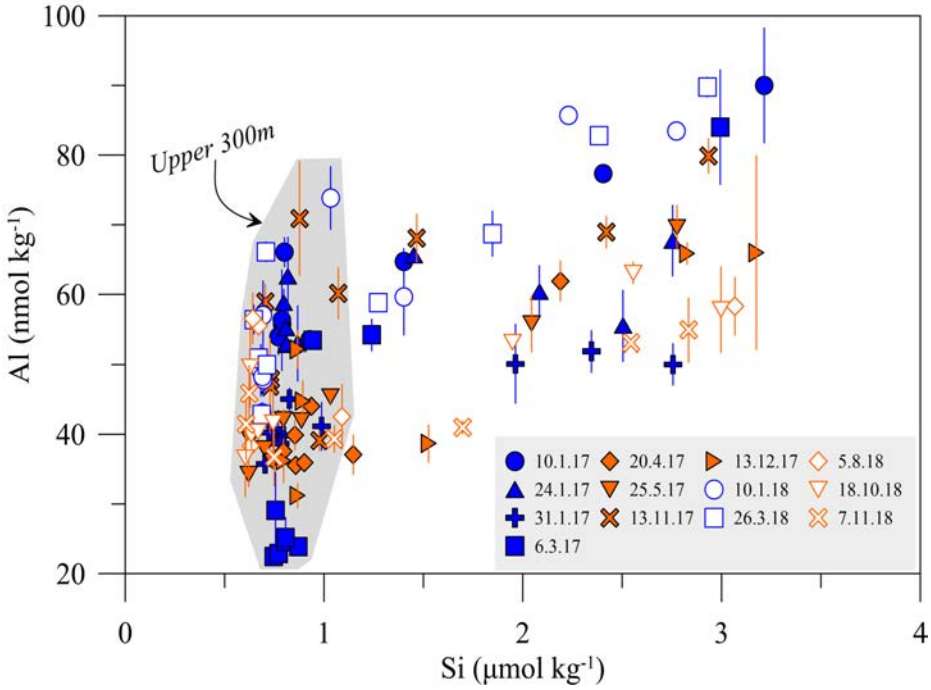


Figure ISR-1. *Dissolved Al and Si relationship in the deep profiles sampled in Station A, GOA during 2017 (full symbols) and 2018 (empty symbols). January – March and April – December profiles are marked by blue and orange symbols, respectively. The grey field represents the decoupling of Al and Si concentrations in the upper water column (300 m) while in the deep water column, Al and Si are correlated. Note the change in slope and correlation between 10.1.17 and 24.1.17, driven by Al scavenging onto resuspended sediments.*

Dissolved Al and Si concentrations range between 22 and 91 nmol kg^{-1} and 0.6 and 3.2 µmol kg^{-1}, respectively, and are correlated at depth and decoupled in the upper water column. Counter intuitively, mixed layer Al (Al_{ML}) inventories decrease with increasing aerosol loads, with dust storms promoting intense Al scavenging, abruptly driving down Al_{ML} by up to 14%. Similarly, a sediment resuspension event induced a decrease of 34% in the Al water column inventory. By contrast, wet deposition may enhance the soluble Al flux from mineral

dust by a factor of 13. Post dust storm Al_{ML} change rates increase linearly with increasing theoretical dissolution rates. Accordingly, low seawater particle density driven by low magnitude dust storms and deep mixing depths will result in scavenging favoring conditions. Atmospheric deposition flux estimates (36.1 ± 0.4 g m^{-2} $year^{-1}$) calculated using long-term average Al_{ML} and mixed layer depths agree with independent flux estimations. Conversely, fluxes calculated using discrete profiles yielded a wide range of values (8 - 93 g m^{-2} $year^{-1}$). The combined results demonstrate that atmospheric deposition in the oceans acts as a long-term source for Al while concomitantly serving as a short-term sink through scavenging. The in-situ rates and insights presented here may be used to understand and quantify the true impact of abrupt environmental events on water column chemical compositions.

Reference: Benaltabet, T., Lapid, G. and Torfstein, A., 2022. Dissolved aluminium dynamics in response to dust storms, wet deposition, and sediment resuspension in the Gulf of Aqaba, northern Red Sea. *Geochimica et Cosmochimica Acta*, *335*, pp.137-154.

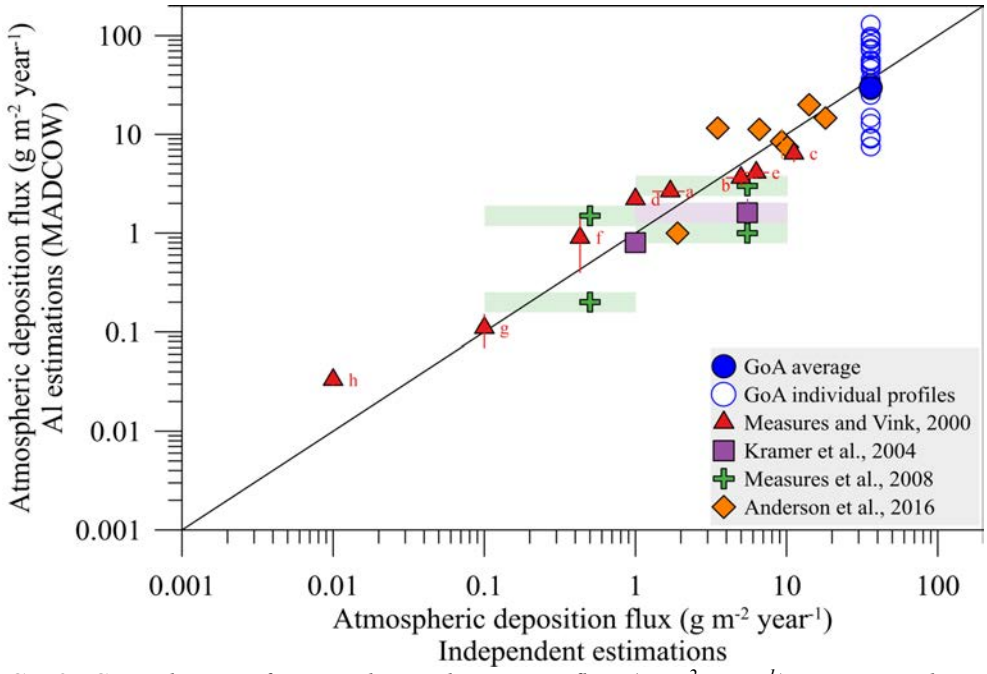


Figure ISR-2. *Compilation of atmospheric deposition flux (g m^{-2} $year^{-1}$) estimates derived from dissolved mixed layer Al measurements (MADCOW model) against independent flux estimates obtained by other means for the GOA and other oceanic regions (black line represent 1:1 ratio). A full blue circle represents the flux calculated using average Al_{ML} and 5-year average MLD while flux estimates calculated from individual profiles are depicted by empty blue circles. Al derived flux estimates from Measures and Vink (2000) (red triangles) were calculated for the (a) Sargasso Sea, (b) Caribbean region, (c) Gulf of Guinea, (d, e) Western Equatorial Atlantic 5°S and 5°N, (f) Hawaii, (g) New Zealand, and (h) Pacific Ocean – 63°S. These were compared to modelled (Duce et al., 1991; Prospero, 1996), sediment trap (Honjo, 1982; Jickells et al., 1998) and direct atmospheric deposition (Uematsu et al., 1985) flux estimates. Kramer et al. (2004) (purple squares) and Measures et al. (2008) (green crosses) compared Al derived atmospheric deposition flux estimates in the Subtropical North Atlantic and across 50°N - 5°S in the Atlantic Ocean, respectively, to average flux estimates from Duce et al. (1991), the range of which is represented by horizontal colored bars. Anderson et al. (2016) (orange diamonds) compared Al derived atmospheric deposition fluxes in the Eastern Tropical North Atlantic (after Measures et al. (2015)) to modelled flux estimates from Mahowald et al. (2005).*

- Airborne prokaryotic microorganisms in the eastern Mediterranean (Rahav et al., 2022): Dust particles play a fundamental role in transporting airborne prokaryotes across the oceans and land. Despite the harsh atmospheric conditions, a considerable fraction of the airborne prokaryotic microorganisms survive the journey and remain viable upon deposition, and can affect the receiving environment. We assessed the potential viability proxy for airborne prokaryotic cells at the Southeastern Mediterranean coast in 22 events, representing marine and terrestrial air-mass trajectories and a significant dust storm event. An agglomerative hierarchical clustering (AHC) analysis showed that marine-origin samples significantly differ from aerosols of a dominant terrestrial trajectory. In the marine-origin aerosols a significant negative correlation was calculated between Pb/Al or Cu/Al and the relative potential viability of airborne prokaryotes, while in the terrestrial-origin aerosols a less clear trend was observed. Fe or Al (proxy for mineral dust particles) were positively correlated in both marine ($p<0.05$) and terrestrial-origin aerosols, noting the limited number of observations. The negative effect of Cu/Al and Pb/Al was attributed to the potential toxicity of these anthropogenic trace metals. The positive relationships between the relative viability proxy and Fe or Al concentrations in air, as proxies for mineral dust content may be linked to the release of some associated nutrients or the positive role of the particle's micro-environment. This suggest that airborne prokaryotes may benefit from a particle–associated lifestyle through attachment to particles, especially under humid (marine) conditions. Reference: Rahav, E., Paytan, A. and Herut, B., 2022. Relative viability proxy of airborne prokaryotic microorganisms at the Southeastern Mediterranean coastal Sea. *Frontiers in Environmental Science*, *10*, p.900977.

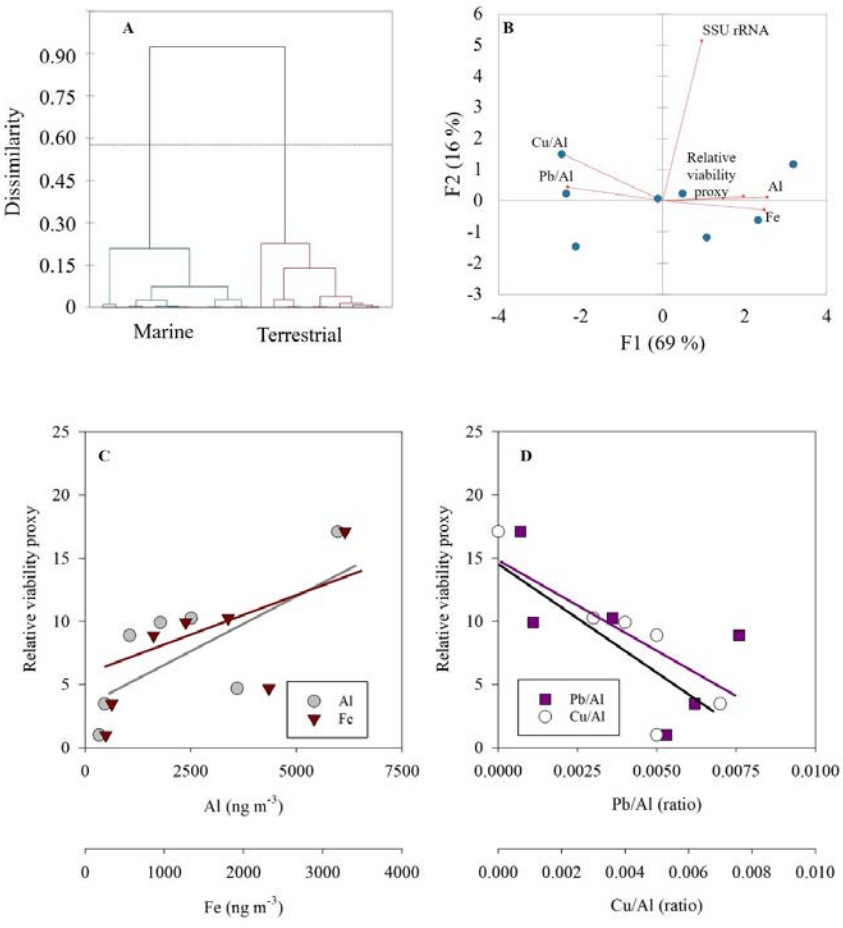


Figure ISR-3.

(A) An agglomerative hierarchical clustering (AHC) dendrogram showing the dissimilarities (Euclidean distance) between aerosols with marine (green) and terrestrial (red) origin; (B) Principle component analysis (PCA) of the marine-origin trajectories; (C+D) The relationship between the relative potentially viable airborne prokaryotes and Al (grey), Fe (dark red), Pb/Al (dark pink) and Cu/Al (white) in marine-origin aerosols (corresponds to panel B).

- Eastern Mediterranean seawater mixing times based on Radium transects (Yishai Weinstein group, Bar-Ilan University): The recent increase in offshore and coastal development (e.g. gas production rigs, seawater desalinization plants) greatly threaten the very fragile, highly oligotrophic ecosystem of the Levantine Basin, eastern Mediterranean Sea. The reported project targets the exchange of surface water between coastal and the offshore. Four cross-shore transects were conducted to 130 km offshore Israel (distributed evenly from northern to southern Israel) in June and August 2021, and two of them were repeated in April 2022. Samples (250L) were run onboard through Mn-coated fibers, and measured for the Ra quartet (RaDeCC, emanation system and Lucas Cells, Gamma spectrometry) as well as for ^{228}Th and ^{227}Ac (RaDeCC). Some of the 2021 results are presented in the figure below. We note that all measured activities were corrected to Ra adsorption efficiency, which was determined using secondary fibers. While ^{226}Ra does not show any significant change along the transects (as anticipated) and ^{228}Ra decreases along the shelf but then stays constant to 130 km (see figure), ^{223}Ra shows a sharp decline along the narrow shelf (15-25 km) and then a gradual decline of 20-50% to 130 km (see figure). This suggests mixing times of up to 11 days (rates of >10km d^{-1}) between shelf break and 130 km offshore, which will be elaborated on in future reports.

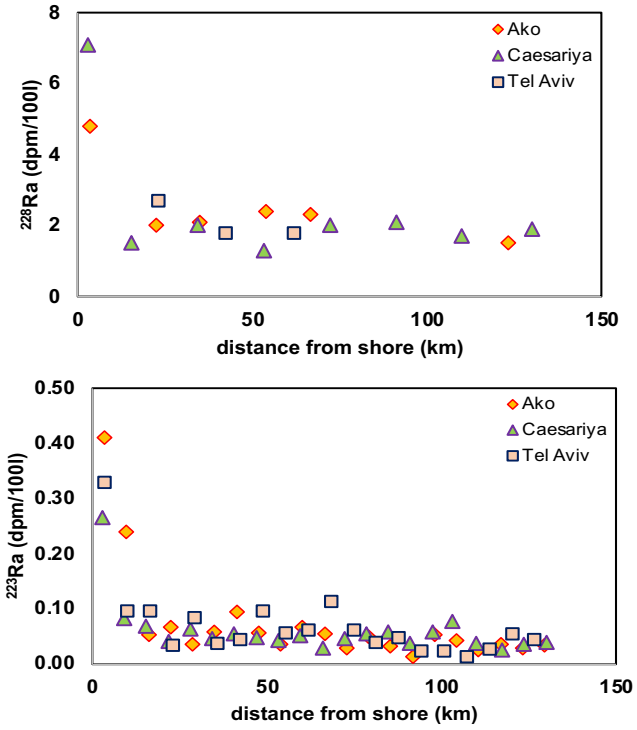


Figure ISR-4. *Radium transects offshore Israel. Akko is located in northern Israel, Caesariya and Tel Aviv are in central Israel.*

Water column profiles of ^{228}Ra (100-200L per sample) were conducted offshore northern and central Israel at distances between 35 km (slope base) and 130 km. ^{228}Ra profiles are presented in the figure below. All profiles, except for one, show high activities in surface water (2.5-3.9 dpm 100L^{-1}), then a decline to 0.5-1.5 dpm 100L^{-1} at 280-500 m, which persists down to deep water (1300 m). Apparently, the low values at depth could be supported by ^{232}Th on suspended particulate matter (to be further studied in the future), therefore excess ^{228}Ra at depth is assumingly close to zero. It is suggested that the high activities in surface water indicate recent mixing with coastal water (see above), while the water deeper than 280 m is relatively old (>30 years, i.e. 5 half-lives of ^{228}Ra). This should be further studied in terms of the different water bodies of the eastern Mediterranean Sea (e.g. surface water, Levantine Intermediate water and Levantine Deep Water). Also, future profiles should focus on higher resolution of water depth at 280-500 m.

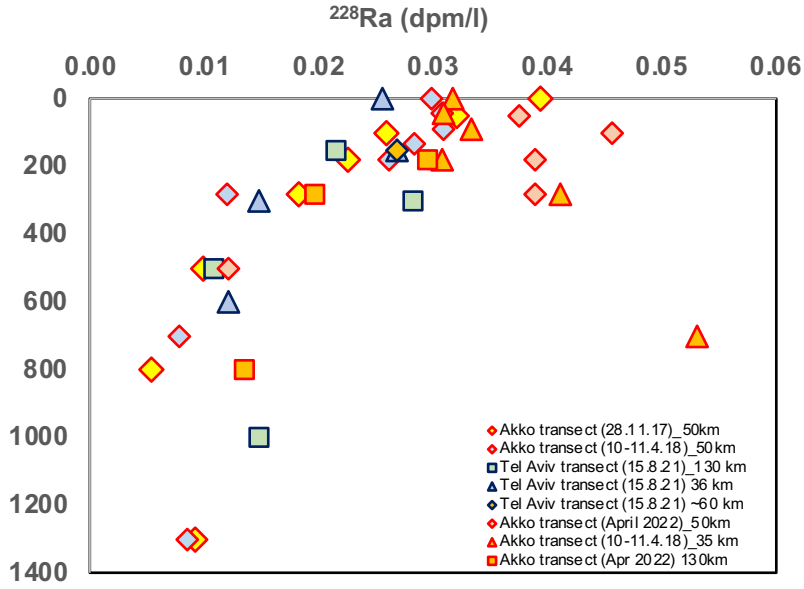


Figure ISR-5. *^{228}Ra depth profiles 35-130 km from shore, offshore northern and central Israel (Akko and Tel Aviv, respectively).*

GEOTRACES or GEOTRACES relevant cruises

- 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.
- 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 (nutrients, alkalinity, pH, DO, Chl-a, pico-phytoplancton, PP, BP); Sediments – annual).
- Marine particulate fluxes are studied in the oligotrophic Gulf of Aqaba (GOA), northern Red Sea as part of the ***Red*** *Sea* ***Dust,*** *Marine Particulates and* ***S****eawater* ***T****ime Series* (***REDMAST,*** *GIpr09*). This 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).
- Focused field campaigns:
  - April 2022, Week long observational sampling in the Gulf of Aqaba, The Interuniversity Institute for Marine Sciences in Eilat, Israel. *Tracking host-virus interactions during a diatom bloom*. In collaboration with Dr. Miguel Frada (HUJI) and Prof. Assaf Vardi (WIS),
  - *Particulate, organic, trace element, and silicon cycling during deep resuspension events* in the Gulf of Aqaba (January 2023, Adi Torfstein, Chana Kranzler, Eyal Wurgaft).
  - Gulf of Naples, Stazione Zoologica Anton Dohrn, Italy: three week field campaign (May 2022, Chana Kranzler), *Diatom virus infection of natural communities* (DaVINCI), Incubation experiments and observational sampling in the Gulf. In collaboration with Prof Kay Bidle and Dr. Kimberlee Thamatrakoln (Rutgers University).

New projects and/or funding

- 2021-2025 Israel Science Foundation (ISF) research grant (Yeala Shaked): *Dust as a source of Phosphorus to Trichodesmium - a globally important marine N_2-fixer*.
- 2022-2026 United States – Israel Binational Science Foundation (BSF) research grant (Yeala Shaked with Rene Boiteau): *Ocean Fertilization by Dust – Studying how marine microorganisms 'mine' nutrients from dust*.
- 2022-2025 Israel Science Foundation (ISF) research grant (Eyal Rahav and Barak Herut): *Assessing the survival and diversity of airborne bacteria in response to different anthropogenic and natural aerosols upon interaction with seawater*.
- 2022 Award - European Research Council (ERC) Starting Grant (Chana Kranzler): *Host-virus interactions in marine diatoms across environmental and ecophysiological gradients.*

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

- Benaltabet, T., Lapid, G. and Torfstein, A., 2022. Dissolved aluminium dynamics in response to dust storms, wet deposition, and sediment resuspension in the Gulf of Aqaba, northern Red Sea. *Geochimica et Cosmochimica Acta*, *335*, pp.137-154.
- Eichner, M., Inomura, K., Karlusich, J.J.P. and Shaked, Y., 2023. Better together? Lessons on sociality from Trichodesmium. *Trends in Microbiology*.
- Herut, B., Rubin-Blum, M., Sisma-Ventura, G., Jacobson, Y., Bialik, O.M., Ozer, T., Lawal, M.A., Giladi, A., Kanari, M., Antler, G. and Makovsky, Y., 2022. Discovery and chemical composition of the eastmost deep-sea anoxic brine pools in the Eastern Mediterranean Sea. *Frontiers in Marine Science*, *9*, p.1040681.
- Keuter, S., Koplovitz, G., Torfstein, A. and Frada, M.J., 2023. Two-year seasonality (2017, 2018), export and long-term changes in coccolithophore communities in the subtropical ecosystem of the Gulf of Aqaba, Red Sea. *Deep Sea Research Part I: Oceanographic Research Papers*, *191*, p.103919.
- Kienast, S.S. and Torfstein, A., 2022. Evaluation of biological carbon pump metrics in the subtropical gulf of Aqaba, northern Red Sea. *Global Biogeochemical Cycles*, *36*(10), p.e2022GB007452.
- Koedooder, C., Zhang, F., Wang, S., Basu, S., Haley, S.T., Tolic, N., Nicora, C.D., del Rio, T.G., Dyhrman, S.T., Gledhill, M. and Boiteau, R.M., 2023. Taxonomic distribution of metabolic functions underpins nutrient cycling in Trichodesmium consortia. *bioRxiv*, pp.2023-03.
- Ozer, T., Rahav, E., Gertman, I., Sisma-Ventura, G., Silverman, J. and Herut, B., 2022. Relationship between thermohaline and biochemical patterns in the levantine upper and intermediate water masses, Southeastern Mediterranean Sea (2013–2021). *Frontiers in Marine Science*, *9*, p.958924.
- Qiu, G.W., Koedooder, C., Qiu, B.S., Shaked, Y. and Keren, N., 2022. Iron transport in cyanobacteria–from molecules to communities. *Trends in microbiology*, *30*(3), pp.229-240.
- Rahav, E., Paytan, A. and Herut, B., 2022. Relative viability proxy of airborne prokaryotic microorganisms at the Southeastern Mediterranean coastal Sea. *Frontiers in Environmental Science*, *10*, p.900977.
- Shaked, Y., de Beer, D., Wang, S., Zhang, F., Visser, A.N., Eichner, M. and Basu, S., 2023. Co-acquisition of mineral-bound iron and phosphorus by natural Trichodesmium colonies. *Limnology and Oceanography*, *68*(5), pp.1064-1077.
- Wang, S., Koedooder, C., Zhang, F., Kessler, N., Eichner, M., Shi, D. and Shaked, Y., 2022. Colonies of the marine cyanobacterium Trichodesmium optimize dust utilization by selective collection and retention of nutrient-rich particles. *Iscience*, *25*(1).

- The National Monitoring Program of Israel's Mediterranean waters, Scientific Reports:
  - Herut B., Ozer T., Biton E., Lazar A., Silverman J., Sisma-Ventura G., Goldman R., Gertman I. (2023). The National Monitoring Program of Israel's Mediterranean waters – Scientific Report on Climate Change and Hydrography for 2022, Israel Oceanographic and Limnological Research, IOLR Report H25/2023.
  - Herut B., Segal Y., Silverman J., Gertner Y., Rahav E., Guy Sisma-Ventura G., Tibor G. (2023). The National Monitoring Program of Israel's Mediterranean waters – Scientific Report on Marine Pollution for 2020, Israel Oceanographic and Limnological Research, IOLR Report H26/2023.
  - Rahav E., Herut B., Rubin-Blum M., Guy-Haim T., Gordon N., Lubinevsky H., Katav-Naim S., Stern N., Rilov G., Paz G. Rinkevich B. (2023). The National Monitoring Program of Israel's Mediterranean waters – Scientific Report on Biodiversity for 2022; Israel Oceanographic and Limnological Research, IOLR Report H27/2023.

GEOTRACES presentations in international conferences

- Benaltabet T., Lapid G., Alkalay R., Weinstein Y., Steffens T., Achterberg E.P. and Torfstein A. (2023) Dissolved trace metals, rare earth elements and Pb isotopes in the eastern Mediterranean Sea. Goldschmidt meeting.
- Benaltabet T., Lapid G. and Torfstein A. (2023) Dissolved trace metal dynamics in response to dust storms and sediment resuspension in the Gulf of Aqaba, northern Red Sea. Israel Geological Society Annual Meeting.
- Benaltabet T., Lapid G. and Torfstein A. (2022) Dissolved aluminium in the Gulf of Aqaba, northern Red Sea: On the short- and long- term effects of daily time scale dust storms, wet deposition and sediment resuspension. Goldschmidt meeting.
- Benaltabet T., Lapid G. and Torfstein A. (2022) Dissolved aluminium dynamics in response to dust storms, wet deposition, and sediment resuspension in the Gulf of Aqaba, northern Red Sea. Israel Association for Aquatic Sciences meeting.
- Edvardson G., Torfstein A. and Wurgaft E. (2022) Heterogeneous reactions and their effect on dissolved inorganic carbon and total alkalinity. Israel Association for Aquatic Sciences meeting.
- Hoober L., Titelboim D., Abramovich S., Herut B., Teutsch N., Benaltabet T. and Torfstein A. (2022) Establishing baseline assessment levels for monitoring coastal heavy metals using foraminiferal shells: A case study from the Southeastern Mediterranean. Goldschmidt meeting.
- Hoober L., Titelboim D., Abramovich S., Herut B., Teutsch N., Benaltabet T. and Torfstein A. (2022) Establishing baseline assessment levels for monitoring coastal heavy metals using foraminiferal shells: A case study from the Southeastern Mediterranean. Israel Association for Aquatic Sciences meeting.
- Kranzler C. (2023) Viral infection dynamics in marine diatoms across environmental and ecophysiological gradients, Ilanit, Federation of the Israel Societies of Experimental Biology.
- Kranzler C. (2022) Biogeochemical consequences of host-virus interactions in marine diatoms, Israel Association for Aquatic Sciences meeting.
- Kranzler C. (2022) Diatom host-virus interactions and biogeochemical consequences in the ocean, The Israeli Society for Microbiology Annual Meeting (ISM).
- Krekova V., Abramovich S., Herut B. and Torfstein A. (2023) Foraminiferal shell geochemistry as a new tool for monitoring heavy metal contamination along the

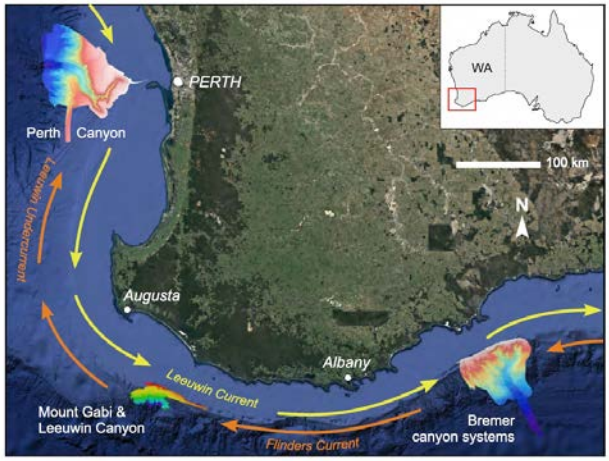
Mediterranean Coast of Israel. Israel Geological Society Annual Meeting. (Winner of best poster competition)

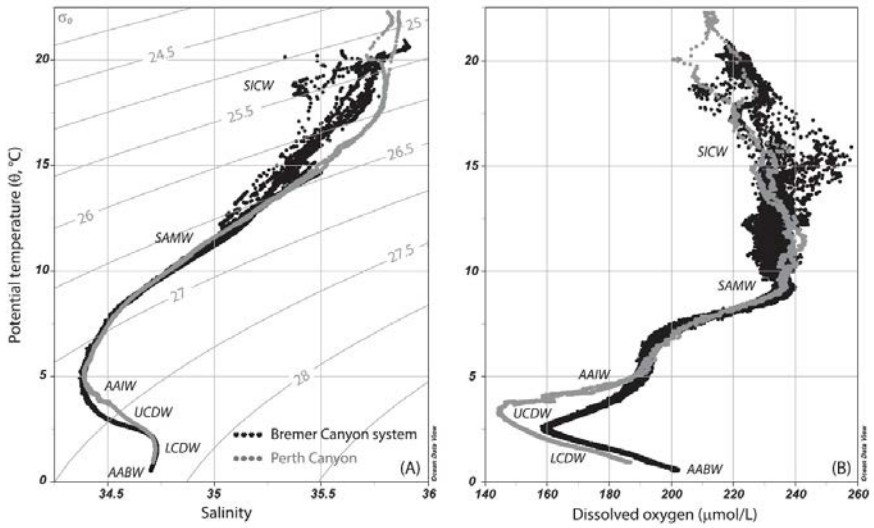
- Kienast S.S. and Torfstein A. (2023) Evaluation of biological carbon pump metrics in the subtropical Gulf of Aqaba, northern Red Sea. ASLO meeting.
- Lapid G. and Torfstein A. (2022) The ($^{234}U/^{238}U$) compositions and trace element concentrations of sequential leachates of atmospheric dust collected in the northern Red Sea between 2009-2019. Goldschmidt meeting.
- Lapid G., Benaltabet T., Alkalay R., Steffens T., Achterberg E.P., Weinstein Y. and Torfstein A. (2022) Dissolved trace metals and Pb and Th isotope dynamics between the continental shelf and the deep and warm ultraoligotrophic eastern Mediterranean. Israel Association for Aquatic Sciences meeting.
- Levy N., Torfstein A., Schiebel R., Chernihovsky N., Jochum K.P., Weis U., Stoll B., and Haug G.H. (2023) Temperature calibration for enriched Mg-calcite planktic Foraminifera shells from the Gulf of Aqaba. Israel Geological Society Annual Meeting.
- Levy N., Torfstein A., Schiebel R., Chernihovsky N., Jochum K.P., Weis U., Stoll B., and Haug G.H. (2022) Temperature calibration for high Mg-calcite planktic Foraminifera shells from the Gulf of Aqaba. GeoMinKöln meeting.
- Torfstein A., Benaltabet T., Lapid G., Alkalay R., Steffens T., Achterberg E.P. and Weinstein Y. (2022) Dissolved trace metals and Pb and Th isotope dynamics between the continental shelf and the deep and warm ultraoligotrophic eastern Mediterranean. Goldschmidt meeting.

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

New GEOTRACES or GEOTRACES relevant scientific results

- A new study reporting some of key physico-chemical seawater parameters (T, salinity, dissolved oxygen, TA, DIC, pH, dissolved inorganic nutrients, Ba concentration) of the major water masses flowing along the Bremer and Perth canyons in the southwestern Australia has been recently published in Progress in Oceanography (Trotter et al., 2022). The CTD-Rosette data were acquired during the cruise FK200126, from January 26th to February 26th 2020 aboard R/V *Falkor* (now *Gaia Blu*), the former research vessel of the Schmidt Ocean Institute that was donated to CNR (Italy) in March 2022. The major water masses identified were SICW (South Indian Central Water), SAMW (Subantarctic Mode Water), low salinity AAIW (Antarctic Intermediate Water), low oxygen UCDW (Upper Circumpolar Deep Water), LCDW (Lower Circumpolar Deep Water) and AABW (Antarctic Bottom Water). The AAIW, UCDW and LCDW in the Perth Canyon have distinctly lower dissolved oxygen concentrations than the Bremer canyon systems (DO minimum ~145 µmol/L at 1320 m vs ~160 µmol/L at 1650 m), where the low-oxygen UCDW (defined by the DO minimum) shoals and becomes warmer as it flows northward into the SE Indian Ocean. The dissolved inorganic nutrients (DIC, N-NOx, P-PO4, Si-SO3, Ba) measured across our SW Australian sites are very consistent, although, concentrations in the more northern Perth Canyon are slightly higher (or at the upper range) than in the Bremer canyon systems. This is likely due to the progressive aging of these water masses as they leave their Southern Ocean source and flow northwards.





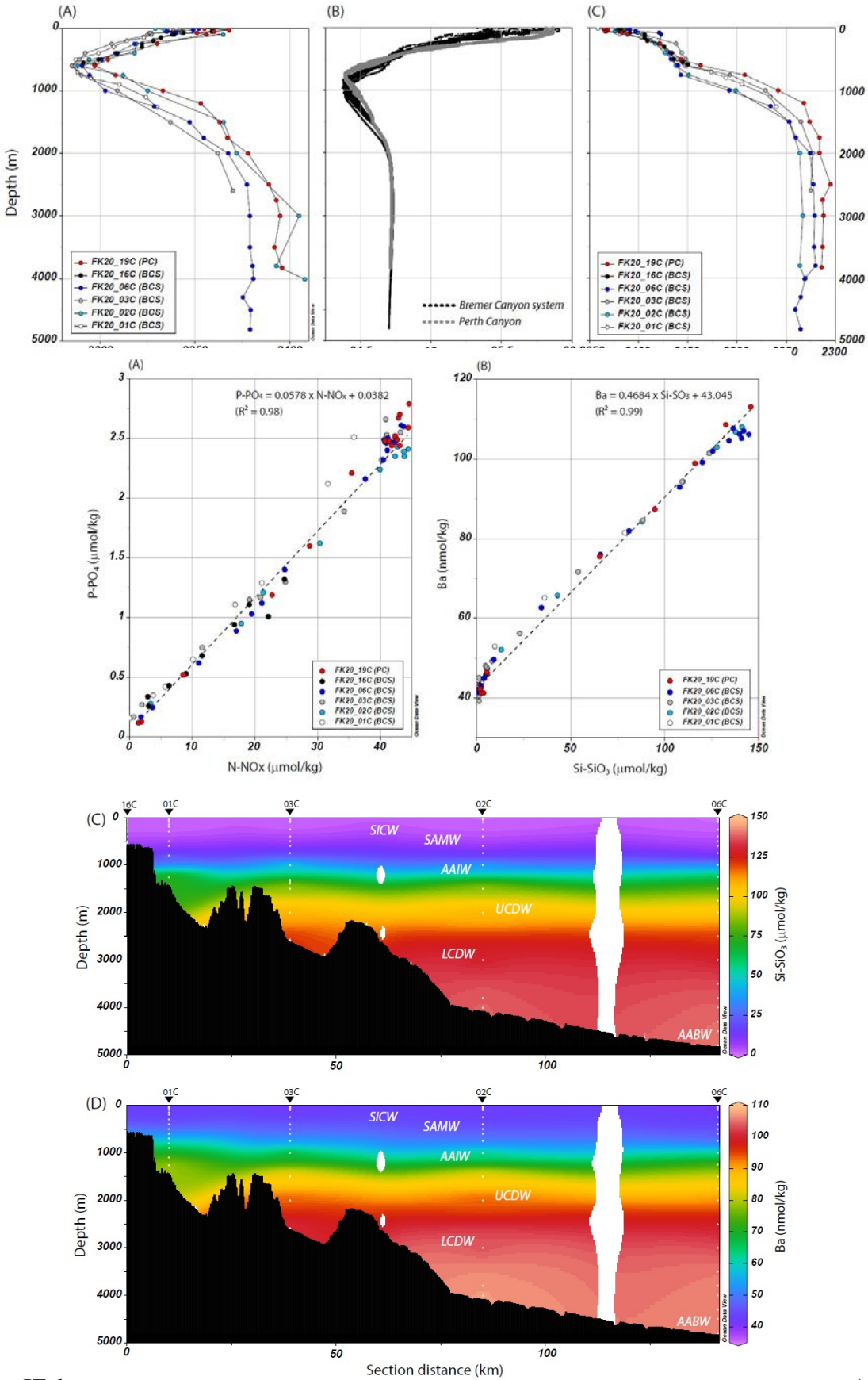


Figure IT-1. *Trotter J., Taviani M., Foglini F., Sadekov A., Skrzypek G., Mazzoli C., Remia A., Santodomingo N., Castellan G., McCulloch M., Pattiaratchi C., Montagna P. (2022). Unveiling deep-sea habitats of the Southern Ocean-facing submarine canyons of southwestern Australia. Progress in Oceanography, 209, 102904.*

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

- Trotter J., Taviani M., Foglini F., Sadekov A., Skrzypek G., Mazzoli C., Remia A., Santodomingo N., Castellan G., McCulloch M., Pattiaratchi C., Montagna P. (2022). Unveiling deep-sea habitats of the Southern Ocean-facing submarine canyons of southwestern Australia. Progress in Oceanography, 209, 102904.

Submitted by Paolo Montagna (paolo.montagna@cnr.it)

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN JAPAN

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

Takano et al. (2022) reported the evolution of concentrations and isotope ratios of dissolved nickel (Ni), copper (Cu), and zinc (Zn) from the North Equatorial Current in the western North Pacific to the Kuroshio in the East China Sea, where the inputs of anthropogenic and lithogenic materials through riverine and aeolian pathways are relatively high. The seawater samples were obtained during the GEOTRACES GP06 cruise. The concentrations and isotope ratios for Ni, Cu, and Zn in the deep water of the East China Sea were similar to those of the western North Pacific. The concentrations of Ni, Cu, and Zn in the Changjiang diluted water were significantly higher than those in the surface water of the western North Pacific, suggesting the riverine input. In the Changjiang diluted water, isotope ratios of Ni were lower than the surface water (<150 m) of the western North Pacific. The distribution of concentrations and isotope ratios for dissolved Ni fit with simple mixing among the three endmembers; Changjiang diluted water, Kuroshio surface water, and deep water in the western North Pacific. A mixing model using isotope ratios and concentrations for Ni quantitatively evaluates the sources of dissolved Ni in the East China Sea. The ranges of isotope ratios of Cu and Zn in the Changjiang diluted water were similar to those in the surface water of the Okinawa Trough, but lower than those in the oceanic region, such as the central Pacific. Compared with published data from the global ocean, dissolved Ni, Cu, and Zn in the surface water of this study area were isotopically lighter than in the pelagic regions, indicating that isotopically light Ni, Cu, and Zn are supplied from the continents.

Citation: Takano, S., W.-H. Liao, T.-Y. Ho, Y. Sohrin (2022), Isotopic evolution of dissolved Ni, Cu, and Zn along the Kuroshio through the East China Sea. Marine Chemistry, 243, 104135.

GEOTRACES workshops and meetings organized

- We had a national GEOTRACES symposium on March 9-10, 2023, for promoting scientific discussion on recent Japanese GEOTRACES studies (20 papers were presented). Six 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 10, 2023. These symposium and meeting were held in person and partially online hosted by Atmosphere and Ocean Research Institute, the University of Tokyo.
- The domestic session entitled “Marine Geochemistry” related to GEOTRACES studies was held during the annual meeting of Geochemical Society of Japan 2022 (September 7 – 9, online and in person at Kochi University). We had 12 presentations including those by 5 students.

Cruise

One GEOTRACES-section cruise in the western Pacific (GP22) was conducted as KH-22-7 by R/V Hakuho-Maru (June 30 – September 1, 2022; PI: Hajime Obata).

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

During the past year, Japan GEOTRACES investigators published a total of 26 peer-reviewed journal articles. The underlined first author is the ECR.

- Alam, M., M. Tripti, G. P. Gurumurthy, Y. Sohrin, M. Tsujisaka, A. D. Singh, S. Takano, K. Verma (2022), Palaeoredox reconstruction in the eastern Arabian Sea since the late Miocene: Insights from trace elements and stable isotopes of molybdenum (δ98/95Mo) and tungsten (δ186/184W) at IODP Site U1457 of Laxmi Basin. Paleogeography, Palaeoclimatology, Palaeoecology 587, 110790.
- Alam, M. M. Tripti, G. P. Gurumurthy, A. Mohammad, Y. Sohrin, A. D. Singh, T. Radhakrishna, D. K. Pandey, K. Verma (2023), Hydroclimatic conditions and sediment provenance in the northeastern Arabian Sea since the late Miocene: insights from geochemical and environmental magnetic records at IODP Site U1457 of the Laxmi Basin. Geological Magazine 160, 813-829.
- Honda, M., M. Martschini, O. Marchhart, A. Priller, P. Steier, R. Golser, T. K. Sato, K. Tsukada, A. Sakaguchi (2022), Novel ^{90}Sr analysis of environmental samples by Ion-Laser InterAction Mass Spectrometry, Analytical Methods, 28, 2725-2796.
- Horikawa, K., T. Kodaira, J. Zhang, H. Obata (2023), Salinity–oxygen isotope relationship during an El Niño (2014–2015) in the southwestern Pacific and comparisons with GEOSECS data (La Niña, 1973–1974). Marine Chemistry, 249, 104222. https://doi.org/10.1016/j.marchem.2023.104222
- Ikenoue, T., M. Yamada, N. Ishii, N. Kudo, Y. Shirotani, Y. Ishida, M. Kusakabe (2022), Cesium-137 and 137Cs/133Cs atom ratios in marine zooplankton off the east coast of Japan during 2012–2020 following the Fukushima Dai-ichi nuclear power plant accident. Environmental Pollution, 311, 119962. DOI:10.1016/j.envpol.2022.119962.
- Ikhsani, I. Y., K. H. Wong, H. Ogawa, H. Obata, 2023. Dissolved trace metals (Fe, Mn, Pb, Cd, Cu, and Zn) in the eastern Indian Ocean. Marine Chemistry, 248, 104208: doi.org/10.1016/j.marchem.2023.104208.
- Kanna, N., S. Sugiyama, T. Ando, Y. Wang, Y. Sakuragi, T. Hazumi, et al. (2022), Meltwater discharge from marine-terminating glaciers drives biogeochemical conditions in a Greenlandic Fjord. Global Biogeochemical Cycles, 36(11), e2022GB007411.
- Kuwae, M., B. P. Finney, Z. Shi, A. Sakaguchi, N. Tsugeki, T. Omori, T. Agusa, Y. Suzuki, Y. Yokoyama, H. Hinata, Y. Hatada, J. Inoue, K. Matsuoka, M. Shimada, H. Takahara, S. Takahashi, D. Ueno, A. Amano, J. Tsutsumi, M. Yamamoto, K. Takemura, K. Yamada, K. Ikehara, T. Haraguchi, S. Tims, M. Froehlich, L. K. Fifield, T. Aze, K. Sasa, T. Takahashi, M. Matsumura, Y. Tani, P. R. Leavitt, H. Doi, T. Irino, K. Moriya, A. Hayashida, K. Hirose, H. Suzuki, Y. Saito (2023), Beppu Bay, Japan, as a candidate global boundary stratotype section and point for the Anthropocene series, The Anthropocene Review, 10, 49-86.
- Mashio, A. S., A. Ichimura, H. Yamagishi, K. H. Wong, H. Obata, H. Hasegawa (2022), Determination of the sub-picomolar concentration of dissolved palladium in open ocean seawater. Marine Chemistry, 243, 104124: doi.org/10.1016/j.marchem.2022.104124.
- Matsuoka, K., T. Tatsuyama, S. Takano, Y. Sohrin (2023), Distribution of stable isotopes of Mo and W from a river to the ocean: signatures of anthropogenic pollution. Frontiers in Marine Science, 10.
- Nakaguchi, Y., A. Sakamoto, T. Asatani, T. Minami, K. Shitashima, L. Zheng, Y. Sohrin (2022), Distribution and stoichiometry of Al, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb in the Seas of Japan and Okhotsk. Marine Chemistry, 241, 104108.
- Otosaka S., H. Jeon, Y. Hou, T. Watanabe, T. Aze, Y. Miyairi, Y. Yokoyama, H. Ogawa (2022), A safer preprocessing system for analyzing dissolved organic radiocarbon in

seawater. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 527, 1-6.

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- Sakata, K., M. Kurisu, Y. Takeichi, A. Sakaguchi, H. Tanimoto, Y. Tamenori, A. Matsuki, Y. Takahashi (2022), Iron (Fe) speciation in size-fractionated aerosol particles in the Pacific Ocean: The role of organic complexation of Fe with humic-like substances in controlling Fe solubility. Atmospheric Chemistry and Physics, 22, 9461–9482, https://doi.org/10.5194/acp-22-9461-2022
- Sieber, M., N. T. Lanning, X. Bian, S. -C. Yang, S. Takano, Y. Sohrin, T. S. Weber, J. N. Fitzsimmons, S. G. John, T. M. Conway (2023), The Importance of reversible scavenging for the marine Zn cycle evidenced by the distribution of zinc and its isotopes in the Pacific Ocean. Journal of Geophysical Research: Oceans, 128, e2022JC019419.
- Sukigara, C., S. Otosaka, N. Horimoto-Miyazaki, Y. Mino (2022), Temporal variation of particulate organic carbon flux at the mouth of Tokyo Bay. Journal of Oceanography, 79, 1-11.
- Takahashi, H., A. Sakaguchi, K. Hain, A. Wiederin, M. Kuwae, P., Steier, Y. Takaku, S. Yamasaki, K. Sueki (2023), Reconstructing the chronology of the natural and anthropogenic uranium isotopic signals in a marine sediment core from Beppu Bay, Japan, Heliyon, 9, E14153.
- Takano, S., W.-H. Liao, T.-Y. Ho, Y. Sohrin (2022), Isotopic evolution of dissolved Ni, Cu, and Zn along the Kuroshio through the East China Sea. Marine Chemistry, 243, 104135.
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- Wang, Y., R. Bi, J. Zhang, J. Gao, S. Takeda, Y. Kondo, F. Chen, G. Jin, J. P. Sachs, M. Zhao (2022), Phytoplankton distributions in the Kuroshio-Oyashio region of the Northwest Pacific Ocean: Implications for marine ecology and carbon cycle. Frontiers in Marine Science, 9, doi: 10.3389/fmars.2022.865142.
- Wong, K. H., J. Xu, Y. Kondo, S. Takeda, A. S. Mashio, H. Hasegawa, H. Obata (2022), Very strong but exchangeable organic ligand of cobalt in the marginal sea. Limnology and Oceanography, 67 (6), 1299-1312, doi: 10.1002/lno.12078.
- Yamada, M., J. Zheng (2022), Enhanced boundary scavenging of ^{241}Am on the continental margin of the East China Sea. Journal of Environmental Radioactivity, 255, 107044. doi:10.1016/j.jenrad.2022.107044.
- Yamada, M., S. Oikawa (2022), ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{137}Cs, and ^{210}Pb in seafloor sediments in the western North Pacific Ocean and the Sea of Japan: distributions, sources and budgets. Journal of Radioanalytical and Nuclear Chemistry, 331(6), 2689-2703. doi:10.1007/s10967-022-08332-y.
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- Zheng, L., T. Minami, S. Takano, Y. Sohrin (2022), Distributions of aluminum, manganese, cobalt, and lead in the western South Pacific: Interplay between the South and North Pacific. Geochimica et Cosmochimica Acta, 338, 105-120.

Completed GEOTRACES PhD or Master theses

- Eita Toyoshima (2023), Distributions and biogeochemical cycles of dissolved Mn, Fe, Cu, Zn and Pb in the eastern South Pacific, M. S. (Environmental Studies), The University of Tokyo.
- Haruka Yamagishi (2023), Establish of Pd analysis method and clarification of vertical distribution in coastal seawater. M. S. (Engineering), Kanazawa University.
- Hayato Kuriyama (2023), Studies on the distribution and origins of Pb stable isotopes in the Sea of Japan and East China Sea. M. S. (Science), Graduate School of Science and Technology, Niigata University.
- Hideo Kanamura (2023), Development and application of isotope ratio analysis of Fe, Ni, Cu, Zn, Cd, and Pb in seawater, M. Sc., Kyoto University.
- Kanako Itoh (2023), Elucidation of elution conditions of platinum from sediments to seawater. M. S. (Engineering), Kanazawa University.
- Kohei Matsuoka (2023), Distribution of stable isotope ratios of dissolved molybdenum and tungsten from a river to the ocean, M. Sc., Kyoto University.
- Kota Isobe (2023), Development of analytical method for palladium, platinum, and gold in environmental water, M. Sc., Kyoto University.
- Li Ziwei (2023), The distribution and behavior of platinum in macroalgae., M. S. (Engineering), Kanazawa University.
- Momoka Imai (2023), Impact of sea ice meltwater on biogeochemical condition in the southern Sea of Okhotsk, M. S. (Environment), Hokkaido University.
- Tsukasa Nakamura (2023), Development of electrochemical methods for selective accumulation and determination of iodide in watersphere. M. S. (Environmental Sciences), Tsukuba University.
- Yuka Shiokawa (2023), Investigation of conditions for sequential extraction of platinum in sediments. M. S. (Engineering), Kanazawa University.
- Yo Nitta (2023), Analytical conditions and behavior of organic complex platinum in coastal seawater. M. S. (Engineering), Kanazawa University.
- Yukiko Kawakami (2023), Dynamics of dissolved vitamin B_{12} in the western North Pacific and adjacent area, M. S. (Fisheries), Nagasaki University.
- Zhou Jiakai (2023), Accumulation of Iron in Sea Ice during Ice Formation, M. S. (Environment), Hokkaido University.

GEOTRACES presentations in international conferences

- Alam, M. et al. (2022), Reconstruction of the late Miocene redox condition in the eastern Arabian Sea at IODP Site U1457 of Laxmi Basin using stable isotopes of molybdenum and tungsten. Goldschmidt 2022, Jul. 16, 2022, Honolulu, USA.
- Imai, M., A. Murayama, K. Ono, Y. Yamashita, K. Suzuki, T. Nakamura, K. I. Ohshima, H. Mitsudera, J. Nishioka (2023), Impact of sea ice meltwater on biogeochemical condition in the southern Sea of Okhotsk, The 37th International Symposium on the Okhotsk Sea & Polar Oceans, Feb. 22, 2023, Monbetsu, Japan.
- Matsuoka, K., Y. Sohrin, S. Takano (2022), Analysis of distribution and sources of Mo and W in the hydrosphere based on concentration and isotope ratios, Goldschmidt 2022, Jul. 14, 2022, Honolulu, USA.
- Otosaka, S. et al. (2023), Origin and transport of dissolved organic matter in the northwestern margin of the North Pacific inferred from radiocarbon signatures. International Conference on Aquatic Science & Technology (i-CoAST) 2023, Jeju, Korea.

- Sakaguchi, A. (2022), Actinide trace amount measurements and the application of such measurements to environmental studies, South Pacific Environmental Radioactivity Association Conference, Nov. 28-30, 2022, Christchurch, NZ. (Key Note speech)
- Sohrin, Y., L. Zheng, C.-Y. Chan (2022), Distinct distributions of aluminum, manganese, cobalt, and lead in the Pacific Ocean. 8th International Symposium on Metallomics, Jul. 12, 2022, Kanazawa, Japan.
- Zhang, Z., T. Nakamura, J. Nishioka (2023), Seasonal mixed-layer dissolved iron variation in the Western Subarctic Gyre, The 37th International Symposium on the Okhotsk Sea & Polar Oceans, Feb. 22, 2023, Monbetsu, Japan.
- Zhou Jiakai (2023), Accumulation of Iron in Sea Ice during Ice Formation, The 37th International Symposium on the Okhotsk Sea & Polar Oceans, Feb. 22, 2023, Monbetsu, Japan.

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

New GEOTRACES or GEOTRACES relevant scientific result

- Nutrient-like profiles of Ni in the Gulf of México resemble those from the Atlantic Ocean, but they showed high spatial variability within the first 1000 m, which was associated with the impact of mesoscale eddies (Félix-Bermúdez et al., 2023).

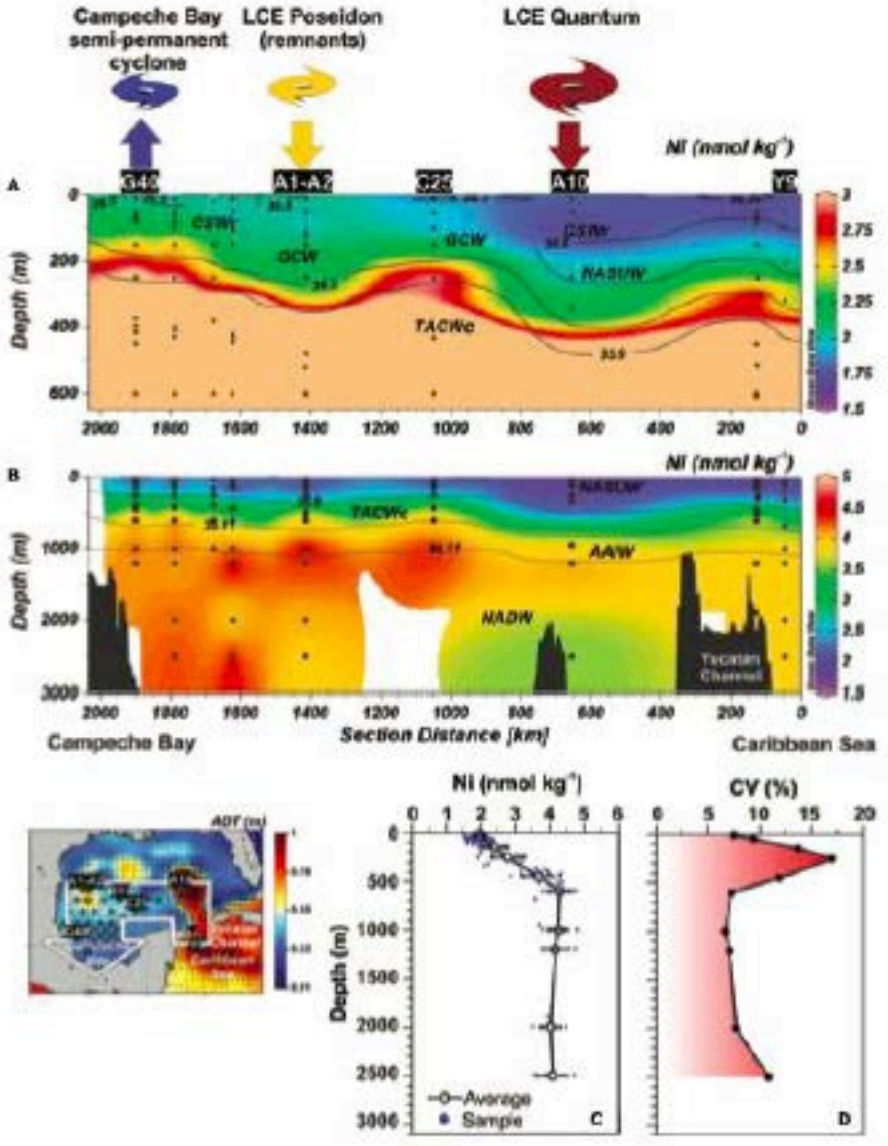

FIGURE 4
Sectional distribution of dissolved Ni along a transect that begins in the Caribbean Sea and ends in the Gulf of Mexico in the Campeche Bay area during the XIXIMI-6 cruise: (A) from 0 to 600 m depth and (B) from 0 to 3500 m depth. (C) Average vertical profile (± standard error) and (D) coefficient of variation (CV) of dissolved Ni for depths 10, 50, 150, 250, 450, 500, 1000, 1200, 2000, and 2500 m. The average profile was constructed using the dissolved Ni concentrations measured in the 22 stations sampled during the XIXIMI-6 cruise. The locations of the sampling stations marked in (A) are shown on the map. The big white arrow shown on the map indicates the direction and extent of the transect. To highlight the spatial differences in the Ni concentration in both shallow and deep waters, the range of Ni concentrations represented by the color scale is different for (A, B). The black solid contours in (A, B) indicate the isohaline boundaries of water masses based on the classification proposed by Pontes et al. (2018). LCE, Loop Current eddy; ADT, absolute dynamic topography; CV, coefficient of variation; CSW, Caribbean Surface Water remnant; GCW, Gulf Common Water; NASUW, North Atlantic Subtropical Underwater; TACWc, Tropical Atlantic Central Water core; AAIW, Antarctic Intermediate Water; and NADW, North Atlantic Deep Water.

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

- Amezcua, F., Ruelas-Inzunza, J., Coiraton, C., Spanopoulos-Zarco, P., Páez-Osuna, F., 2022. A Global Review of Cadmium, Mercury, and Selenium in Sharks: Geographical Patterns, Baseline Levels and Human Health Implications. Reviews of Environmental Contamination and Toxicology 260, 4. https://doi.org/10.1007/s44169-021-00006-2
- Celis-Hernández, O., Ontiveros-Cuadras, J.F., Ward, R.D., Girón-García, M.P., Pérez-Ceballos, R.Y., Canales-Delgadillo, J.C., Acevedo-Granados, I.V., Santiago-Pérez, S., Armstrong-Altrin, J.S., Merino-Ibarra, M., 2022. Biogeochemical behaviour of cadmium in sediments and potential biological impact on mangroves under anthropogenic influence: A baseline survey from a protected nature reserve. Marine Pollution Bulletin, 185 (A), 114260. https://doi.org/10.1016/j.marpolbul.2022.114260
- De La Peña-Lastra, S., Pérez-Alberti, A., Ferreira, T.O. Huerta-Díaz, M.A., Otero, S.L., 2022. Global deposition of potentially toxic metals via faecal material in seabird colonies. Scientific Reports 12, 22392. https://doi.org/10.1038/s41598-022-26905-5
- Félix-Bermúdez, A., Delgadillo-Hinojosa, F., Lares Reyes M. L., Torres-Delgado E. V., Huerta-Díaz, M. A., Tovar-Sánchez A., Camacho-Ibar V. F., 2023. Spatial variability of dissolved nickel is enhanced by mesoscale dynamics in the Gulf of Mexico. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2022.1036331
- Fernández-Robledo A., Lares M. L., Schramm-Urrutia Y., 2022. Trace metal concentrations in California sea lions from rookeries exposed to different levels of coastal urbanization in Baja California, Mexico. Marine Pollution Bulletin. https://doi.org/10.1016/j.marpolbul.2022.114163
- García-Orozco, J. Huerta-Diaz, M.A. Mejia-Piña, K.G., Delgadillo-Hinojosa, F., Jacob Alberto Valdivieso-Ojeda, J.A., Árcega-Cabrera, F., 2022. Pyrite and reactive iron fluxes in deep (> 966 m) sediments of the Gulf of Mexico, Chemical Geology, 612, 121148, https://doi.org/10.1016/j.chemgeo.2022.121148.
- Hakspiel-Segura C., Delgadillo Hinojosa F., Lares Reyes M. L., Torres-Delgado E. V., Félix-Bermúdez A., Segovia-Zavala J. A., Camacho-Ibar V., Muñoz-Barbosa A., Millán-Núñez E., 2022. Nitrogen limitation prevents the effects of iron or dust additions on biological carbon fixation in the Gulf of California. Journal of Experimental Marine Biology and Ecology. https://doi.org/10.1016/j.jembe.2022.151866
- Martínez-Ayala, J.C., Galván-Magaña, F., Tripp-Valdez, A., Marmolejo-Rodríguez, A.J., Piñón-Gimate, A., Huerta-Diaz, M.A., Sánchez-González, A., 2022. Heavy metal concentrations in the Pacific sharpnose shark Rhizoprionodon longurio from the Santa Rosalia mining zone, Baja California Sur, Mexico. Marine Pollution Bulletin, 182, 114018. https://doi.org/10.1016/j.marpolbul.2022.114018
- Mejia-Piña, K.G., Valdivieso-Ojeda, J.A., Huerta-Diaz, M.A., Chavez-Jimenez, M. Xosé Luis Otero, X.L., Fernández-Díaz, V.Z., Arreguín-Rodríguez, G.J., 2023. Geochemical footprint of dredged material discharges and sediment health status in Todos Santos Bay, Mexico. Regional Studies in Marine Science, 62, 102962. https://doi.org/10.1016/j.rsma.2023.102962
- Ontiveros-Cuadras, J.F., Ruiz-Fernández, A.C., Pérez-Bernal, L.H., Santiago-Pérez, S., González y González, S., Ávila, E., Cardoso-Mohedano, J.G., Sanchez-Cabeza, J.-A., 2022. Accumulation and fluxes of potentially toxic elements in a large coastal lagoon (southern

Gulf of Mexico) from 210Pb sediment chronologies. Marine Pollution Bulletin, 181, 113839. https://doi.org/10.1016/j.marpolbul.2022.113839

- Vega-Barba, C., Páez-Osuna, F., Galván-Magaña, F., Baró-Camarasa, I., Aguilar-Palomino, B., Galván-Piña, V.H., Marmolejo-Rodríguez, A.J., 2022. Trace elements in the silky shark Carcharhinus falciformis in the Central Pacific Mexican Shelf. Marine Pollution Bulletin, 185(A), 114263. https://doi.org/10.1016/j.marpolbul.2022.114263

Completed GEOTRACES PhD or Master theses

- García Orozco J. (2023) Geoquímica de elementos traza redox-sensibles (Fe, Mo y V) en fracciones reactivas y totales, y sus flujos en diferentes ambientes sedimentarios modernos. PhD thesis, UABC (Universidad Autónoma de Baja California), 254 p.
- Gutiérrez, R. A. (2022). Variación espacial y estacional del manganeso disuelto en la Bahía Todos Santos (verano 2008 – primavera 2009). MS thesis, UABC (Universidad Autónoma de Baja California)

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN THE NETHERLANDS

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

- • Progress is being made with the interpretation and publication of results from cruises ANA08B, PS117 and MetalGate (64PE474)

GEOTRACES or GEOTRACES relevant cruises

- 64PE517; North Sea-Atlantic Exchange (NoSE) expedition aboard *RV Pelagia* to the Norwegian Trench, including trace metal measurements from May 26th till June 14th 2023 from Texel (Netherlands) to Texel (Netherlands)

New projects and/or funding

- NWO XL proposal. The role of the North Sea in the Atlantic Ocean biogeochemical system: North Sea-Atlantic Exchange (NoSE). P.I. Dr F. Mienis. A.I.'s: Dr. M.P. Humphreys, Prof. Dr. R. Middag, Prof. Dr. P.M.J. Herman, Dr. ir. B.C. van Prooijen, Dr. P. Kraal, Dr. F. Sangiorgi, Dr. R. Hennekam, Dr. M.T.J. van der Meer, Prof. Dr. S. Schouten, Prof. Dr. R. Bintanja, Dr. Ir. J. van der Molen, Prof. Dr. K. Soetaert.
- Polair Programma Polaire Strategische Kansen 2022. East Antarctic Ice Sheet Expedition aboard FS Polarstern; a strategic opportunity. PI Rob Middag.

GEOTRACES workshops and meetings organized

- Netherlands BioGeoSCAPES scoping workshop for the International BioGeoSCAPES community at the University of Amsterdam on 22 February 2023

Outreach activities conducted

- Sporenmetalen, de oceaan en een veranderende wereld: de kracht van de allerkleinsten. Inaurgual lecture by R. Middag, University of Groningen Press
- Lecture on trace metals and limitation 'Plankton Overleg Nederland' meeting 23/03/2023
- Interview Radio 1 'vroege vogels', 'Oceaanleven kan niet zonder metalen' 30/10/2022

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

- Zhu, K., Achterberg, E.P., Bates, N.R., Gerringa, L.J.A., Middag, R., Hopwood, M.J. and Gledhill, M., 2023. Influence of Changes in pH and Temperature on the Distribution of Apparent Iron Solubility in the Oceans. Global Biogeochemical Cycles, 37(5): e2022GB007617
- Olivelli, A., Murphy, K., Bridgestock, L., Wilson, D.J., Rijkenberg, M., Middag, R., Weiss, D.J., van de Flierdt, T. and Rehkämper, M., 2023. Decline of anthropogenic lead in South Atlantic Ocean surface waters from 1990 to 2011: New constraints from concentration and isotope data. Marine Pollution Bulletin, 189: 114798

- Tian, H.-A., van Manen, M., Wille, F., Jung, J., Lee, S., Kim, T.-W., Aoki, S., Eich, C., Brussaard, C.P.D., Reichart, G.-J., Conway, T.M. and Middag, R., 2023. The biogeochemistry of zinc and cadmium in the Amundsen Sea, coastal Antarctica. Marine Chemistry, 249: 104223
- Eich, C., Biggs, T.E.G., van de Poll, W.H., van Manen, M., Tian, H.-A., Jung, J., Lee, Y., Middag, R. and Brussaard, C.P.D., 2022. Ecological Importance of Viral Lysis as a Loss Factor of Phytoplankton in the Amundsen Sea. Microorganisms, 10(10): 1967
- van Manen, M., Aoki, S., Brussaard, C.P.D., Conway, T.M., Eich, C., Gerringa, L.J.A., Jung, J., Kim, T.-W., Lee, S., Lee, Y., Reichart, G.-J., Tian, H.-A., Wille, F. and Middag, R., 2022. The role of the Dotson Ice Shelf and Circumpolar Deep Water as driver and source of dissolved and particulate iron and manganese in the Amundsen Sea polynya, Southern Ocean. Marine Chemistry, 246: 104161
- Eich, C., Biggs, T.E.G., van de Poll, W.H., van Manen, M., Tian, H.-A., Jung, J., Lee, Y., Middag, R. and Brussaard, C.P.D., 2022. Ecological Importance of Viral Lysis as a Loss Factor of Phytoplankton in the Amundsen Sea. Microorganisms, 10(10): 1967.
- Kipp, M.A., Li, H., Ellwood, M.J., John, S.G., Middag, R., Adkins, J.F. and Tissot, F.L.H., 2022. 238U, 235U and 234U in seawater and deep-sea corals: A high-precision reappraisal. Geochimica et Cosmochimica Acta, 336: 231-248
- Jensen, L.T., Cullen, J.T., Jackson, S.L., Gerringa, L.J.A., Bauch, D., Middag, R., Sherrell, R.M. and Fitzsimmons, J.N., 2022. A Refinement of the Processes Controlling Dissolved Copper and Nickel Biogeochemistry: Insights From the Pan-Arctic. Journal of Geophysical Research: Oceans, 127(5): e2021JC018087

GEOTRACES presentations in international conferences

- Lena Beckley, Loay Jabre, Jennifer Tolman, Rachel Sipler, Willem van de Poll, Julie LaRoche, Rob Middag, Erin Bertrand. Interactive effects of temperature and iron on High Latitude North Atlantic phytoplankton communities and primary production. Oral presentation at the Canadian Meteorological and Oceanographic Society 57th Congress, May 28th-June 1st 2023, Saint John's (NL), Canada.
- B. Rabe, M. Janout, Lars-Eric Heimbürger, Rob Middag, Ellen Damm, Sinhue Torres Valde, Kirstin Schulz. Upper ocean turbulence and vertical mass fluxes from in-situ observations in the central Arctic Ocean 2015. Arctic and Subarctic Ocean Fluxes (ASOF) workshop 2023, Universidad de las Palmas de Gran Canaria (Spain), 10-12 May 2023.
- Duncan Dale, Marcus Christl, Andreas Macrander, Sólveig Ólafsdóttir, Rob Middag, and Núria Casacuberta. Treasure from trash: Using nuclear waste to trace ocean circulation around Iceland. EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-12097
- Middag, R. The importance of marine (microbial) life and biogeochemical cycles for a healthy and habitable planet Invited oral presentation at the United Nations workshop in support of the Regular Process for Global Reporting and Assessment of the State of the Marine Environment meeting, The Hague, the Netherlands, 28-30 November 2022.
- Middag, R., Ardiningsih, I., Bertrand, E.M., Brussaard, C.P.D., Eich, Jabre, L., McCain, J., van Manen, M., Tian, H.-A. Effects of Iron and Temperature on Antarctic Phytoplankton. Poster presentation at the Royal Society Meeting 'Marine microbes in a changing climate', Whittlebury Park, UK, 13 September 2022.
- Middag, R. Trace element limitation – distribution, impact and significance. Euromarine Foresight Workshop on Biogescapes, Zagreb, Croatia, 16th-17th June 2022.

- Hung-An Tian, Mathijs van Manen, Zach B. Bunnell, Jinyoung Jung, Sang Hoon Lee, Tae-Wan Kim, Gert-Jan Reichart, Tim M. Conway, Rob Middag. Dissolved Fe isotopic compositions in the Amundsen Sea Polynya, Antarctica: insights for external Fe sources and biogeochemical processes. Poster presentation at the 2022 NWO National Polar Symposium, The Hague, the Netherlands, 19th May. 2022

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN NORWAY

May 1st, 2022 to April 30th, 2023

Outreach activities conducted

- *Popular article:* Climate change may lead to more toxic mercury in the Arctic https://partner.sciencenorway.no/arctic-ocean-barents-sea-biology/climate-change-may-lead-to-more-toxic-mercury-in-the-arctic/2066235

Other GEOTRACES activities

- Building Capacity to Crosslink Coastal Pollution with Climate Change (BC5) Project, (funded by Norad - Norwegian Agency for Development Cooperation), focusing on pollution from e-waste and plastic pollution, had both Ghana and Tanzania field works (December 2022 – February 2023) to collect trace elements including Hg and MeHg 2022-2023

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

- *Kohler et al., 2022.* Arctic Ocean's wintertime mercury concentrations limited by seasonal loss on the shelf. https://doi.org/10.1038/s41561-022-00986-3
- *Dietz et al., 2022.* A risk assessment review of mercury exposure in Arctic marine and terrestrial mammals https://doi.org/10.1016/j.scitotenv.2022.154445
- *Kohler et al., 2022.* Distribution pattern of mercury in northern Barents Sea and Eurasian Basin surface sediment. https://doi.org/10.1016/j.marpolbul.2022.114272
- *Moreau et al., 2023.* Wind-driven upwelling of iron sustains dense blooms and food webs in the eastern Weddell Gyre https://doi.org/10.1038/s41467-023-36992-1

Completed GEOTRACES PhD or Master theses

- Laura M Kull MSc thesis (August 2022). Total Mercury Distribution in the Barents Sea and the Arctic Ocean Surface Sediments https://hdl.handle.net/11250/3028517

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

New GEOTRACES relevant scientific results

- The increasing influence of Atlantic inflows in the Arctic Ocean in recent decades has had a potential impact on regional biogeochemical cycles of major and trace elements. The warm and salty Atlantic water, entering the Eurasian Basin through the Norwegian Sea margin and the Barents Sea, affects particle transport, sink, phyto-, and zooplankton community structure and could have far-reaching consequences for the marine ecosystems. This study discusses the elemental composition of suspended particulate matter and fluffy-layer suspended matter (FLSM) derived from samples collected in the Barents Sea and northern Norwegian Sea in August 2017 (**Figure RU-1**). The mosaic distribution of SPM elemental composition is mainly determined by two factors: (i) The essential spatial variability of biological processes (primary production, abundance, and phytoplankton composition) and (ii) differences in the input of terrigenous sedimentary matter to the sea area from drainage sources (weak river runoff, melting of archipelago glaciers, etc.). The distribution of lithogenic, bioessential, and redox-sensitive groups of elements in the particulate matter was studied at full-depth profiles. Marine cycling of strontium in the Barents Sea is shown to be significantly affected by increasing coccolithophorid bloom, which is associated with Atlantic water. Mn, Cu, Cd, and Ba significantly enrich the suspended particulate matter of the benthic nepheloid layer relative to the fluffy layer particulate matter within the benthic boundary layer [Starodymova et al., 2023].

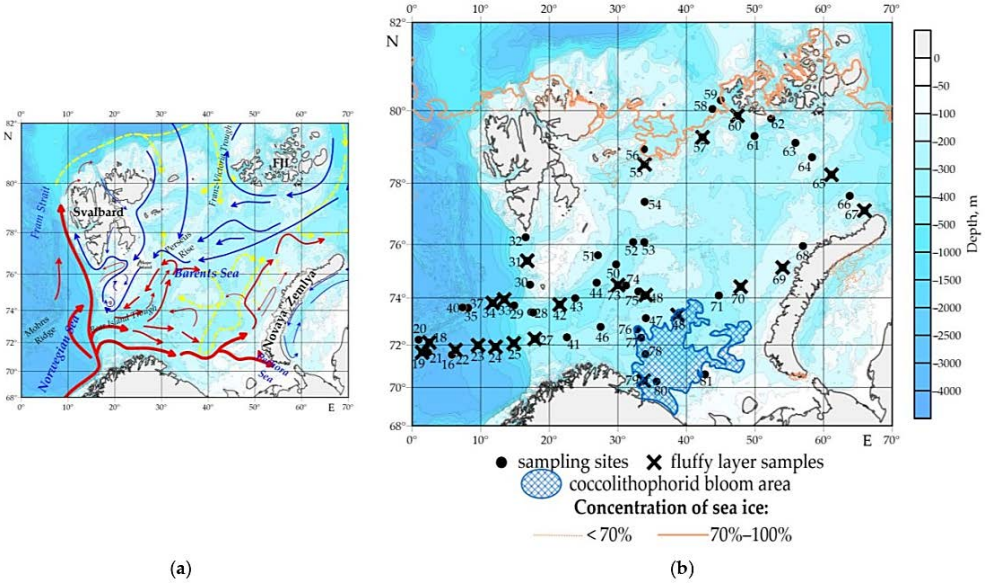

Figure RU-1. *(**a**) Water circulation scheme after [Loeng, 1991; Pisarev, 2021]: red arrows—warm currents; blue arrows – cold currents; dashed yellow arrows – subsurface currents. (**b**) Map of SPM and FLSM sampling stations, July–August 2017. Station numbers are omitted in the first two digits. The area of coccolithophorid blooms (>1.5 10^6 cells/l) derived from MODIS-Aqua data; images are composites over August 2017 [Kopelevich et al., 2020]; sea ice conditions from satellite imagery on August 8, 2017 [http://old.aari.ru/odata/]. Bathymetric data based on IB-CAO bathymetry [Jakobsson et al., 2020].*

- The study investigated vertical particle fluxes and associated environmental parameters in the southern part of the Kara Sea in September 2022 on the basis of a 5-day deployment of two moored Automatic Deep-Sea Sedimentation Observatories (ADOS) with sediment traps and CTD, currents and hydrooptical profilers (**Figure RU-2**). A significant heterogeneity (up to two orders of magnitude) in the spatial distribution of the total particle fluxes and the main components of the sedimentary matter was revealed based on data of two moorings

deployed at the same sea depth of 100 m in the area of the Yamal shelf [Klyuvitkin et al., *in press*].

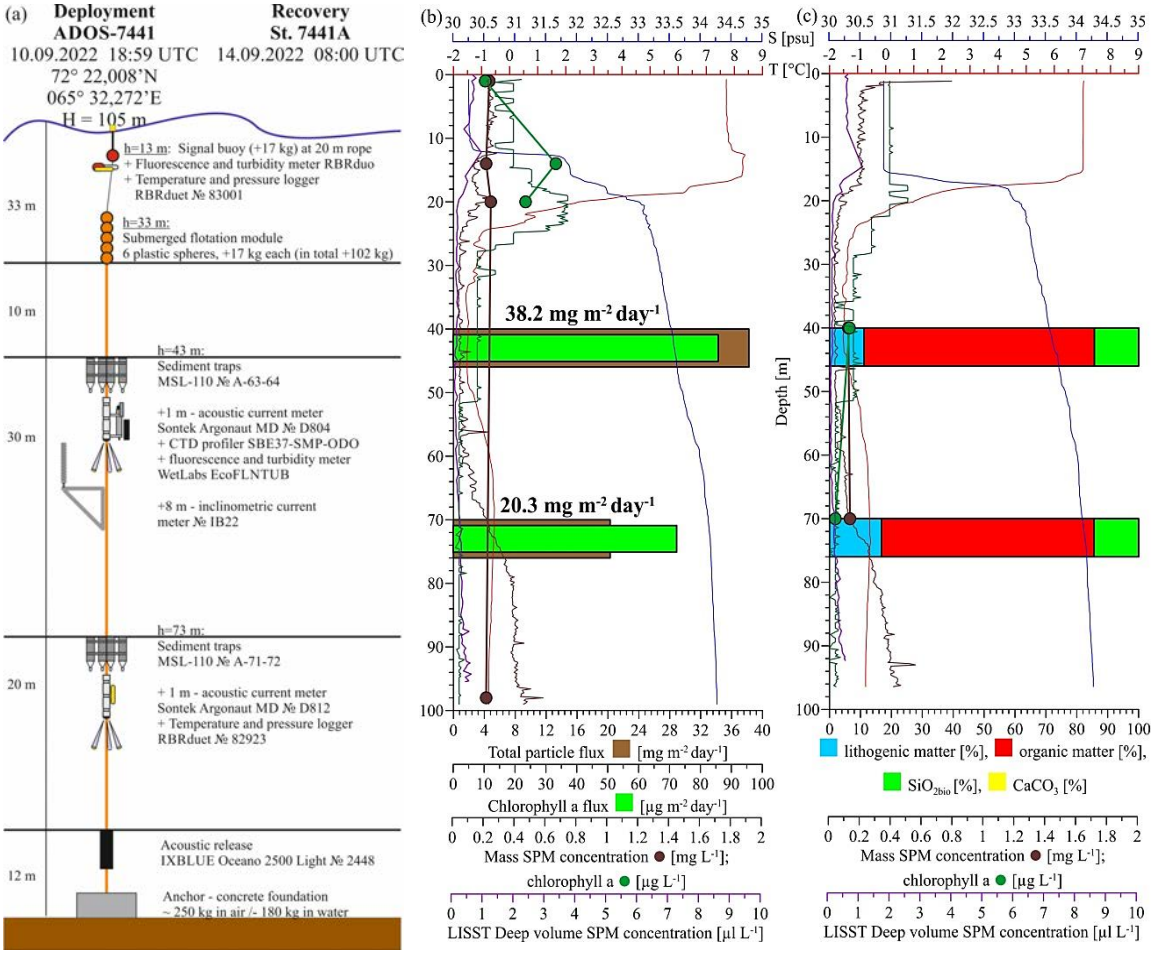

***Figure RU-2**. Example of ADOS-7441 deployed in the Kara Sea in September 2022: scheme (a) and total particle flux and Chl-a flux (b) and flux composition (c) with main environmental features vertical distribution: temperature, salinity, suspended particulate matter and Chl-a concentration before deployment (b) and after recovery of ADOS-7441 (c).*

- Mercury (Hg) concentrations in lichens and mosses can be used as surrogates for atmospheric Hg deposition to continental surfaces. Hg concentrations (n = 334) and isotopic composition (n = 67) of epiphytic tree lichens and terricolous lichens and mosses from remote locations across the Eurasian Arctic and sub-Arctic (50º to 72° N, 30º to 180° E) were studied [Sonke et al., 2023]. The total Hg (THg) concentrations ranged from 13 to 7700 ng·g^{-1}. Epiphytic tree lichens had significantly higher median THg levels (243 ng ·g^{-1}) than terricolous lichens (35 ng·g^{-1}) and mosses (74 ng·g^{-1}) (**Figure RU-3**). THg is substantially higher in both tree lichens and terricolous lichens near the Arctic Ocean shore and up to 300 km inland. The combined δ^{202}Hg, Δ^{199}Hg, and Δ^{200}Hg signatures suggest that the elevated coastal Hg levels are delivered by marine air masses rich in gaseous and particulate-oxidized Hg^{II} forms, such as $HgBr_2$. Similar to other vegetation Hg isotope studies, inland terricolous lichen and moss Δ^{200}Hg are near zero, indicating a dominant (63%) atmospheric Hg^0 origin followed by Hg^{II} wet and dry deposition. Inland tree lichens carry a more positive Δ^{200}Hg of 0.15‰, similar to the atmospheric Hg^{II} end-member, suggesting that they preferentially accumulate Hg^{II} wet and dry deposition compared to colocated terricolous lichens. Mosses from the European sub-Arctic show a low δ^{202}Hg of −3.1‰, which we speculate to result from regional soil Hg^0 emissions that are recaptured by mosses. Overall, the Hg isotope

variability of mosses and lichens reveals latitudinal gradients in Hg deposition pathways and identifies preferential Hg^0 or Hg^{II} uptake [Sonke et al., 2023].

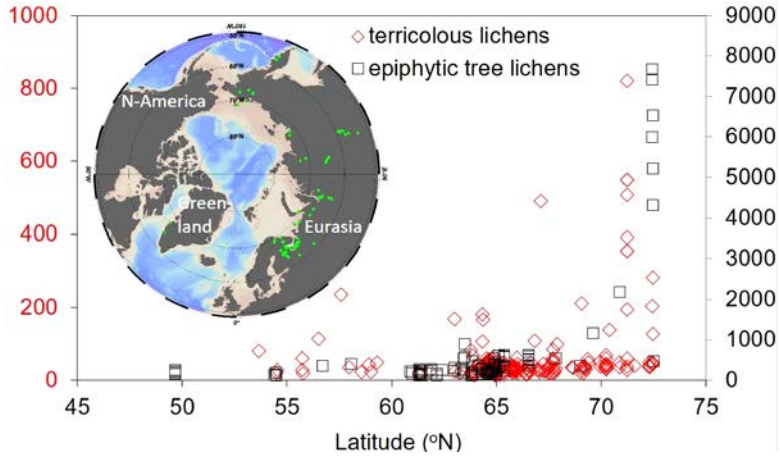

***Figure RU-3**. The plot demonstrates that Eurasian lichen Hg ($ng \cdot g^{-1}$) increases with latitude.*

- Distribution of trace elements was studied in the methane seep ecosystem's components of the Koryak slope, the Bering Sea (**Figure RU-4**). Concentrations of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Zr, Mo, Cd, Ba, W, Pb, U were determined in seawater, benthic organisms, and surface layer of bottom sediments. Along with this, analysis of dissolved methane in water, as well as the total organic and inorganic carbon in organisms and sediments has been performed [Demina et al., 2022].

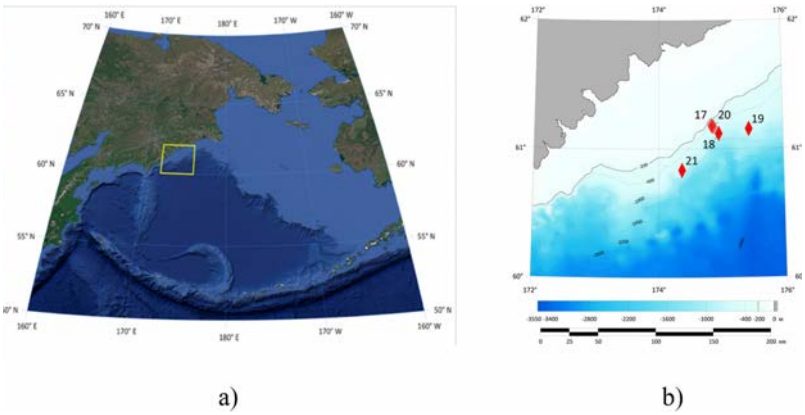

***Figure RU-4.** Study area, the Koryak Slope, the Western Bering Sea (a), and sampling sites (b) in cruise 82nd RV Akademik M.A. Lavrentyev, 2018.*

Methane-saturated emanations from the Koryak slope serve a source of many trace elements: the near-bottom water layer is enriched in trace elements (5 to 1000 times) compared to the ocean water (**Figure RU-5**). Diffuse methane flows from reduced sediments contribute to the benthic diffuse flux of dissolved elements into seawater, providing the high concentration in near-bottom water. The data we have obtained could contribute to future quantitative analysis of the impact of methane seepage processes on the global-scale budget of the trace elements.

One of the biogeochemical features of seep ecosystems is an accumulation of trace elements by benthic organisms, particularly by gills of the pliocardiinae symbiotrophic clam *Calyptogena pacifica*. Gills of *C. pacifica* are significantly enriched in many trace elements, especially in Fe, Zn, and Cd (up to n 10^2 μg/g dry wt.), as well as the other chalcophile metals such as Co, Mo, Ni, Pb. The soft tissues of organisms, enriched in TOC (to 52 % dry wt.) are a target not only for essential elements Fe, Cu, Zn, Co, Ni, Cr, and Mo but also for potentially toxic As, Cd, Pb, U, and W. The lithophile elements such as Ti, Mn, and Ba showed a predominant accumulation in the clam shells.

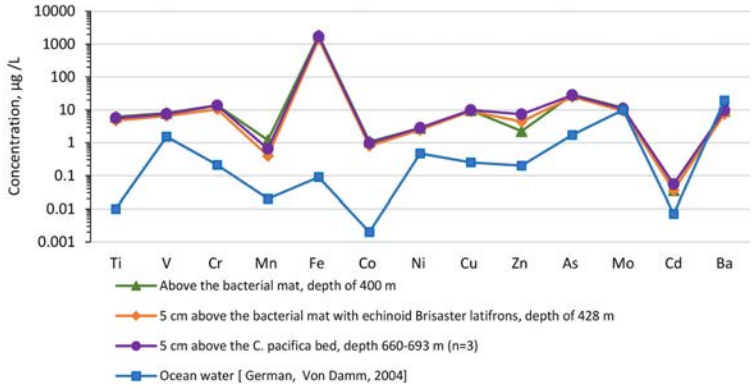

Figure RU-5. *The trace element distribution in the biotope water of methane seep areas at the Koryak slope, compared to the ocean water (German, Von Damm, 2004).*

Estimation of the trace element Enrichment Factor in methane seep surface sediments relative to the upper continental crust has revealed depletion in most elements that may be caused, along with the reduced conditions, by the intensive element uptake by organisms. Our data suggest that methane seeps are biogeochemically important areas where the concentration and dispersion processes of trace elements coexist [Demina et al., 2022].

- Study of the current level and origin of hydrocarbons (HC): aliphatic – AHC and polycyclic aromatic – PAH (September 2021, May and September 2022) in suspended particulate matter in surface water layer and in bottom sediments of the coastal areas of the Caucasian sector of the Black Sea has established a decrease in concentrations in surface waters. HC accumulation occurs in finely dispersed sediments. The Kerch Strait is one of the most polluted water areas of the Black Sea where AHC and PAH content in sediments reached 200 µg/g and 320 ng/g, respectively. It is shown that natural processes (productivity of the water area, fluid flows from the sedimentary strata) have a great influence on the HC values [Nemirovskaya et al., 2022].
- AMK 5188, 5189, 5190, 5191 and 5536 cores were sampled during the 2015-2016 IO RAS expeditions in the Norwegian Sea (**Figure RU-6**). Major and trace element contents are derived from XRF core scanner analyses. The distribution of the Ti/Ca ratio as one of the main stratigraphic proxies (**Figure RU-7**) has shown that its highest values for the North Atlantic correlate with glacial events (MIS 8, 6 and 4). The minimum Ti/Ca values associated with biogenic calcite input are typical for MIS 7, 5 and 1. Our data correlate well with results for the Greenland Sea and the southern Norwegian Sea (Sabine et al., 2022) and can be used for the integrated stratigraphy of the Norwegian-Greenland Basin [Novichkova et al., *in press*].

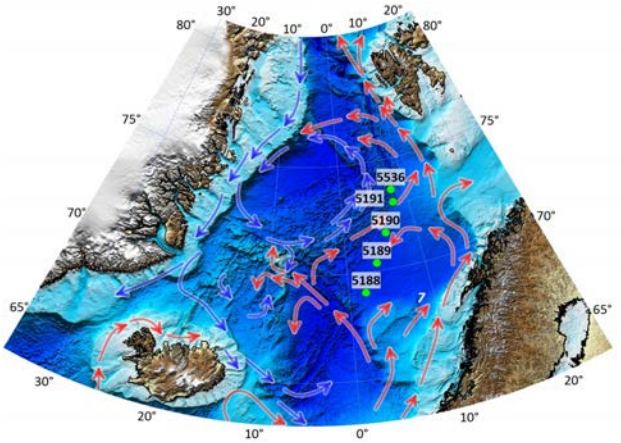

Figure RU-6. *Overview map of main North Atlantic surface (red arrows) and bottom (blue arrows) currents [Blindheim, Rey, 2004] and location of studied cores.*

***Figure RU-7**. Ti/Ca ratio stratigraphy along a south-north profile of the Norwegian Sea. The interglacial MIS 1, 3, 5, 7 shown as shadow [Novichkova et al., in press].*

- The distribution of particulate organic carbon in the seas of the Russian Arctic is characterized by circumcontinental and vertical zonalities. They The latter are expressed in decreasing concentrations and fluxes (mgC/m^2/day) of suspended organic carbon in the transition from the near-continental to pelagic regions of the Arctic Ocean, as well as from the surface photic layer to the near-bottom layer by two orders of magnitude, which is confirmed by instrumental data of sedimentation traps and correlates with the zonality of bioproduction processes (**Figure RU-8**).

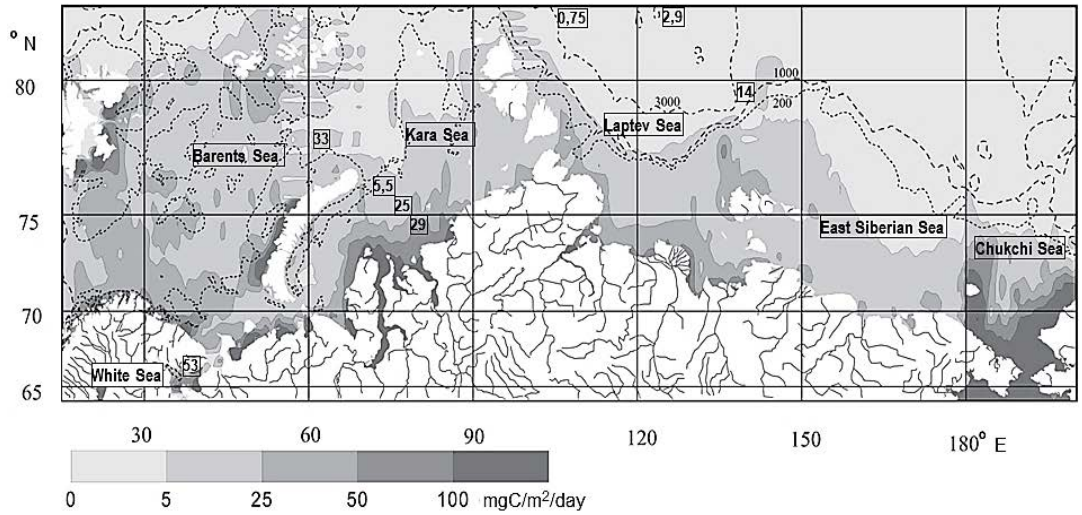

***Figure RU-8**. Schematic map of the calculated primary production average annual flux of organic carbon (mgC/m^2/day) to the bottom in the Arctic seas of Russia [Vetrov, Romankevich, 2019] in comparison with the mean annual instrumental data of sedimentation traps installed in the bottom horizon, the figures show: White Sea 53 mgC/m^2/day [Novigatsky et al., 2020]; Barents Sea 33 mgC/m^2/day [Agafonova et al., 2023]; Kara Sea 5.5 mgC/m^2/day [Drits et al., 2021], 25 and 29 mgC/m^2/day [Gaye et al., 2007]; Laptev Sea 0.75 mgC/m^2/day [Nöthig et al., 2020], 2.9 mgC/m^2/day [Fahl et al., 2009], 14 mgC/m^2/day [Lalande et al., 2007].*

However, the rarity and relatively large uncertainty of annual organic carbon fluxes obtained by the sediment trap method makes it difficult to estimate them accurately. Additional observations of suspended organic carbon fluxes over a broader range of environmental regimes are needed to thoroughly evaluate and validate the calculated primary production model results and to better understand the processes controlling the flux of suspended organic carbon to depth in the ocean [Novigatsky et al., *in press*].

- Mineralogical, geochemical, and isotopic studies of the Fe–Mn crust collected in the Jan Mayen vent field area have been carried out for the first time. The crust (about 3 cm thick) has a distinct microstratified structure, sharp contact with the underlying volcanic substrate, and colloform Fe and Mn oxyhydroxides at its bottom. The crust is composed mainly of Mn oxyhydroxides: birnessite and buserite with an impurity of volcanic glass. As follows from the layer-by-layer study of the crust, the Mn content increases by 3–10 times from bottom to top, whereas Fe and REE decrease in the same direction. The samples are marked by a positive Eu anomaly (Eu/Eu_{NASC} 1.08–1.41). Ce/Ce_{NASC} is 0.89 ± 0.05. $^{87}Sr/^{86}Sr$ in the crust's lower and middle layers is within 0.70621–0.70713, while εNd reaches 5.6–6.2. These parameters are 0.70740 and –0.1, respectively, in the uppermost layer of the crust. The REE composition, positive Eu anomaly, high εNd values, and low $^{87}Sr/^{86}Sr$ ratios in the crust are indicative of the fact that the ore material mainly originated from hydrothermal solutions (**Figure RU-9**). Changes in the Sr and Nd isotope characteristics and REE composition in the crust layers are due to a decrease in the hydrothermal material contribution as the crust grew at a high crust deposition velocity in the Jan Mayen vent field area [Kravchishina et al., 2022].

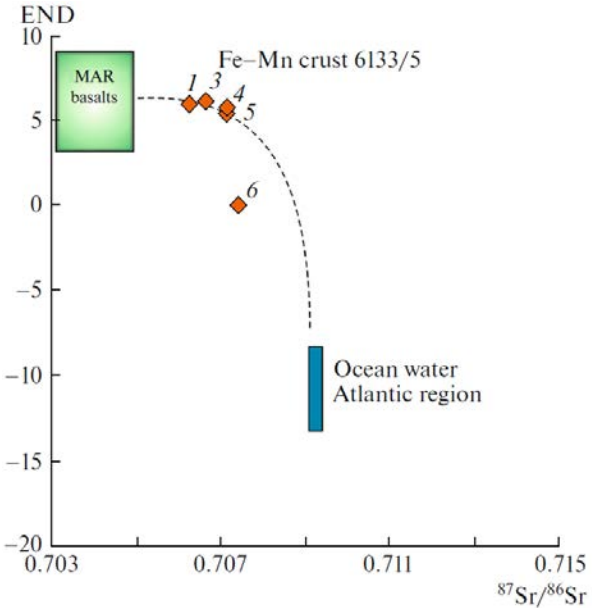

***Figure RU-9**. Sr and Nd isotopic composition in several layers of the Fe–Mn crust 6133/5. The dotted line indicates the mixing of the average isotopic compositions of MAR oceanic basalts and seawater after [Faure, 1986; Kuznetsov et al., 2012].*

GEOTRACES relevant cruises

- A unique climate experiment was carried out to study the composition of air and characteristics of the underlying surface in the Russian sector of the Arctic and Siberia. Synchronized research on board the R/V *Akademik Mstislav Keldysh* and the unique scientific facility the *Tu-134 Optik* flying laboratory were carried out in the South Kara Sea from September 5 to 18, 2022 (**Figure RU-10**). The cruise leader is Dr. Kravchishina M.D. The airborne and spaceborne optical satellite algorithms were validated to retrieve the sea surface characteristics during the cruise. For the first time on the Arctic shelf, data on methane concentration in the natural troposphere–near-surface atmosphere over sea–water

column–bottom sediments system was obtained. Greenhouse gases fluxes were estimated simultaneously from the shelf area and adjacent land. Related research on recent and ancient sedimentation conditions and processes was carried out in the South Kara sedimentary basin, where huge oil and natural gas reserves are located.

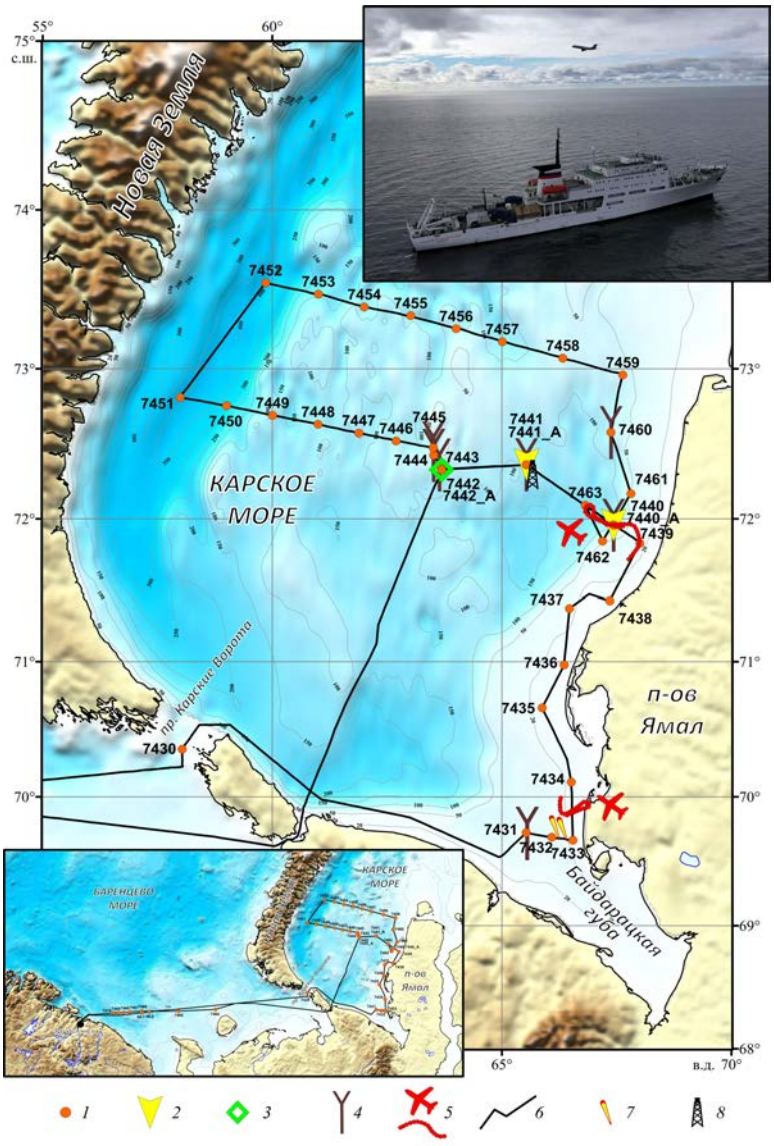

***Figure RU-10**. Map of marine expeditionary research in South Kara Sea, September 08–15, 2022: (1) integrated stations (set of optical, hydro-optical, hydrological, hydrochemical, hydrobiological, microbiological, and sedimentological measurements and lithological and geochemical works for sampling upper undisturbed sediment layer using a multicorer); (2) integrated mooring stations with deployment and raising of automatic deep-sea sedimentation observatories; (3) mooring station with inclinometers; (4) integrated stations with samplings of long sediment cores using large-diameter gravity corer; (5) research polygons for direct overflight measurements with flight path of Tu-134 Optik; (6) vessel's route with continuous en route measurements (gas-chemical, optical, and hydro-optical); (7) gas flares according to echo-sounding profiling data; (8) Leningradskoe gas condensate field.*
Bathymetry is based on data from [Miroshnikov et al., 2021]. Insets: (bottom) entire route of vessel; (top) photo of synchronous works aboard RV Akademik Mstislav Keldysh and Tu-134 Optik flying laboratory.

The climate experiment consisted of a set of measurements in situ in the water column and the nearsurface atmospheric layer continuously along the vessel's entire route of (2275.4 nautical miles) and works at 44 oceanographic stations with the participation of the flying laboratory and satellite remote sensing of sea surface characteristics. The aircraft made direct passes over the ship at an altitude of ~90–200 m above the sea surface on September 9 and 10, 2022, to validate airborne algorithms for retrieving the characteristics of the underlying surface (suspended particulate matter, chlorophyll, dissolved OM, etc.) and measuring the composition of air and aerosols in the atmosphere and troposphere over the sea [Kravchishina et al., 2023].

New projects and/or funding

- Prolongation of the grant of Russian Science Foundation "The role of hydrothermal and thermogenic processes in recent sedimentation in the subpolar North Atlantic and Arctic Oceans", no. 20-17-00157, 2020–2024. Dr. Marina Kravchishina is a project leader. URL: https://rscf.ru/project/20-17-00157/ The main purpose of the grant is to investigate the combined role of hot (hydrothermal) and cold (methane seepage) fluids in recent sedimentation processes in the Arctic (Mohns Ridge and Eurasian Arctic shelf).

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

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

- Evgenia Berezhnaya completed PhD thesis “Geochemistry of platinum-group elements in ocean ferromanganese ores”, Shirshov Institute of Oceanology, Russian Academy of Sciences. Scientific advisor is Dr. Alexander Dubinin (IO RAS).

GEOTRACES presentations in international conferences

- Kravchishina V.D., Kusnetsov A.B., Starodymova D.P., Dara O.M., Chebotareva V.A., Klyuvitkin A.A., Baranov B.V., Lein A.Yu. Genesis of ferromanganese crusts in the Jan Mayen hydrothermal vent field area, Mohn’s Ridge. 10th International Conference on Mineral Resources of the World's Oceans. June 2023. г. FSBI "VNIIOkeangeologia", Angliyskiy prospect, 1, St. Petersburg, Russia.
- Starodymova D.P., Kravchishina M.D., Novichkova E.A., Slomnyuk S.V., Migdisova I.A., Iakimova K.V. Lithogeochemical signatures of volcanic and hydrothermal processes in the sedimentary cover of the Mohn’s Ridge (Norwegian-Greenland Basin). 10th International Conference on Mineral Resources of the World's Oceans. June 2023. г. FSBI "VNIIOkeangeologia", Angliyskiy prospect, 1, St. Petersburg, Russia.

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

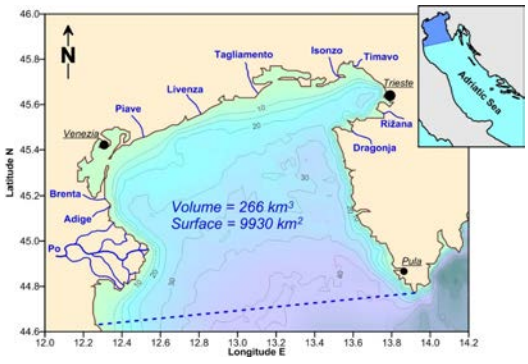
New GEOTRACES or GEOTRACES relevant scientific results

The results of two relevant topics can be considerd:

- Several research studies related to mercury (Hg) speciation and behavior in various marine environments, with a particular focus on the South Atlantic Ocean (as a part of GEOTRACES program) and the northern Adriatic Sea were performed. In the South Atlantic Ocean, the authors investigated Hg speciation and observed a linear correlation between dissolved gaseous mercury (DGM) and dissolved inorganic carbon (DIC), suggesting DGM production through organic matter remineralization. In the northern Adriatic Sea, two sites were compared for DGM production and gaseous mercury (Hg^0) fluxes, with the highly Hg-impacted site showing substantial DGM production, while the less impacted site exhibited lower DGM levels. The presence of Hg^0 fluxes at both sites suggested that factors like water turbulence and mixing conditions influenced Hg evasion more than DGM concentrations alone. The wet deposition of Hg from the atmosphere to the Central Adriatic Sea was studied, and a correlation was found between normalized wet deposition of total mercury (THg) and the THg gradient in surface seawater, accounting for wind-induced seawater mixing. Finally, continuous DGM measurements were conducted in the Gulf of Trieste, a contaminated area, showing good agreement between continuous and discrete methods. The correlation of DGM concentrations with environmental parameters suggested transport from a polluted area as the probable source of high DGM events. The computed annual Hg^0 flux across the water-air interface was lower than reported in other studies, emphasizing the importance of spatial and temporal coverage in understanding Hg evasion and DGM variability in polluted coastal regions. Overall, these studies contribute to the understanding of Hg behavior in marine environments and its potential implications for the biogeochemical cycling of mercury and the environment's overall health.

- Four different research studies focusing on various aspects of ocean changes and their impact on marine ecosystems include:

  Impact of Ocean Warming and Acidification on Pteropods: This study examined the impact of ocean warming and acidification (OWA) on Limacina helicina, a globally distributed pteropod species, in the California Current Ecosystem. Through a comprehensive approach using field data, experimental incubations, and global distribution analysis, the study found increased mortality of pteropods under OWA conditions. The findings emphasized the need to consider multiple stressors in understanding species distributions and highlighted the significant threat OWA poses to pteropod habitats.



Northern Adriatic Sea (NAd) and rivers considered in the study

River Inputs and the Carbonate System in the Northern Adriatic Sea: The second study investigated the role of riverine discharges on the carbonate system in the shallow northern Adriatic Sea. Data from major rivers flowing into the area were analyzed, showing how river discharges can alter the carbonate chemistry and influence biological processes. Anthropogenic disturbances were suggested to potentially modify these natural processes, underscoring the importance of studying the effects of river inputs on the marine carbonate system.

Sediment Accumulation and Carbon Uptake in the Black Sea and Adriatic Sea: The third study examined the long-term accumulation rates of organic and inorganic carbon in sediments of the Black Sea and Adriatic Sea. The study proposed that increased atmospheric carbon dioxide (CO_2) has enabled more efficient photosynthesis in phytoplankton, leading to higher organic carbon accumulation in sediments (CO_2 fertilization). Additionally, the increase in sea temperatures decreased calcite solubility, contributing to increased inorganic carbon accumulation. The findings emphasized the role of coastal sediments in carbon uptake and their potential impact on regulating Earth's climate.

Characterization of Colloidal Organic Matter from Phytoplankton Exudates: The fourth study focused on isolating colloidal organic matter (COM) from phytoplankton exudates in the Gulf of Trieste. The COM analysis revealed that the phytoplankton COM was primarily composed of polysaccharides, with minor contributions from proteins and lipids. This study highlighted the significance of phytoplankton-derived COM in the marine COM pool, particularly in the polysaccharide fraction.

Overall, the studies provide valuable insights into the complex interactions between environmental stressors, species distributions, carbon uptake, and marine ecosystems' responses to global changes. They underscore the urgent need for comprehensive research to understand and mitigate the impacts of ongoing global change on the world's oceans.

New projects and/or funding

- National project J1-2468: Biomarkers of sub-cellular stress in the Northern Adriatic under global environmental change (coordinator: N. Bednaršek)

GEOTRACES workshops and meetings organized

15th Internationa Symposium on the Interactions between Sediment and Water: June 13-15 2022, Piran, Slovenia

National Institute of Biology and Jožef Stefan Institute organized 15th International Symposium on the Interactions between Sediment and Water from 13 to 15 June 2022 in Piran, Slovenia. The Gulf of Trieste in the northern Adriatic Sea has been the subject of intensive marine biogeochemical investigations, including sediments, over the last fifty years making it a scientifically relevant site for an IASWS meeting. The symposium consists of six sessions that have been organized around ten themes which integrate the following topics:

- Biogenic Influences on Sediment-water Interactions from the Micro to Macro Scale
- Sediment-associated Nutrient and Contaminant Processes
- Source, Fate and Effect of Sediments in Freshwater and Marine Ecosystems
- Assessing and/or Restoring Disturbed Catchments
- Extreme environments
- Special session: GMOS-Train

The program consisted with six invited speakers and 30 oral and 12 poster presentations. The symposium also continues its tradition of strong international representation, with authors of accepted abstracts from 11 countries from around the world. The book of abstract have been published on USB key:

FAGANELI, Jadran (urednik), OGRINC, Nives (urednik). *15th International Symposium on the Interactions Between Sediments and Water : Piran, Slovenia, June 12-15, 2022 : book of abstracts*. Piran: National Institute of Biology, Marine Biological Station,; Ljubljana: Jožef Stefan Institute, 2022. 1 USB ključ, ilustr. ISBN 978-961-7144-16-1.

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

- GIANI, Michele, OGRINC, Nives, TAMŠE, Samo, COZZI, Stefano. Elevated river inputs of the total alkalinity and dissolved inorganic carbon in the Northern Adriatic Sea. Water. 2023, vol. 15, no 5, str. 894-1-894-22. ISSN 2073-4441. DOI: 10.3390/w15050894.
- VRANA, Ivna, BAKIJA ALEMPIJEVIĆ, Saranda, NOVOSEL, Nives, IVOŠEVIĆ DENARDIS, Nadica, ŽIGON, Dušan, OGRINC, Nives, GASPAROVIĆ, Blaženka. Hyposalinity induces significant polar lipid remodeling in the marine microalga Dunaliella tertiolecta (Chlorophyceae). Journal of applied phycology. 2022, vol. 34, str. 1457–1470. ISSN 1573-5176. DOI: 10.1007/s10811-022-02745-8.
- FLOREANI, Federico, BARAGO, Nicolò, KLUN, Katja, FAGANELI, Jadran, COVELLI, Stefano. Dissolved gaseous mercury production and sea-air gaseous exchange in impacted coastal environments of the northern Adriatic Sea. Environmental pollution. [Print ed.]. Sept. 2023, vol. 332, [art.] 121926, [1]-16 str., ilustr., zvd. ISSN 0269-7491. https://doi.org/10.1016/j.envpol.2023.121926, DOI: 10.1016/j.envpol.2023.121926.
- KLUN, Katja, ŠKET, Primož, BERAN, Alfred, FALNOGA, Ingrid, FAGANELI, Jadran. Composition of colloidal organic matter in phytoplankton exudates. Water. 2023, vol. 15, iss. 1, str. 1-10, ilustr. ISSN 2073-4441. https://doi.org/10.3390/w15010111, DOI: 10.3390/w15010111.
- BEDNARŠEK, Nina, CARTER, Brendan, MCCABE, Ryan M., FEELY, Richard Alan, HOWARD, Evan M., CHAVEZ, Francisco P., ELLIOTT, Meredith, FISHER, Jennifer L., JAHNCKE, Jaime, SIEGRIST, Zach. Pelagic calcifiers face increased mortality and habitat loss with warming and ocean acidification. Ecological applications. 18 May 2022, vol. 32, iss. 7, str. 1-15, ilustr. ISSN 1939-5582. https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.2674, DOI: 10.1002/eap.2674.
- ŽIVKOVIĆ, Igor, GAČNIK, Jan, JOZIĆ, Slaven, KOTNIK, Jože, ŠOLIĆ, Mladen, HORVAT, Milena. A simplified approach to modeling the dispersion of mercury from precipitation to surface waters—The Bay of Kaštela case study. Journal of marine science and engineering. 2022, vol. 10, no. 4, str. 539-1-539-13. ISSN 2077-1312. DOI: 10.3390/jmse10040539.
- KOTNIK, Jože, ŽAGAR, Dušan, NOVAK, Gorazd, LIČER, Matjaž, HORVAT, Milena. Dissolved gaseous mercury (DGM) in the gulf of Trieste, Northern Adriatic Sea. Journal of marine science and engineering. 2022, vol. 10, no. 5, str. 587-1-587-18, ilustr. ISSN 2077-1312. DOI: 10.3390/jmse10050587.
- VINKOVIĆ, Andrija, HORVAT, Milena, NEČEMER, Marijan, JAĆIMOVIĆ, Radojko, KLANJŠČEK, Tin, et al. Could atmospheric carbon be driving sedimentation?. Journal of soils and sediments : protection, risk assessment and remediation. 2022, vol. 22, no. 11, str. 2912-2928. ISSN 1439-0108. DOI: 10.1007/s11368-022-03282-0.
- ŽIVKOVIĆ, Igor, BRATKIČ, Arne, KOTNIK, Jože, BEGU, Ermira, FAJON, Vesna, HORVAT, Milena, et al. Enhanced mercury reduction in the South Atlantic Ocean during carbon remineralization. Marine pollution bulletin. 2022, vol. 178, str. 1-113644-10-113664. ISSN 0025-326X. DOI: 10.1016/j.marpolbul.2022.113644. Acknowledging GEOTRACES funding

GEOTRACES presentations in international conferences

Invited lecture:

- ŽIVKOVIĆ, Igor, KOTNIK, Jože, BEGU, Ermira, FAJON, Vesna, HORVAT, Milena, et al. Mercury reduction in the South Atlantic Ocean during carbon remineralization. V: FAGANELI, Jadran (ur.), OGRINC, Nives (ur.). 15th International Symposium on the Interactions Between Sediments and Water : Piran, Slovenia, June 12-15, 2022 : book of abstracts. Piran: National Institute of Biology, Marine Biological Station,; Ljubljana: Jožef Stefan Institute, 2022. Str. 41. ISBN 978-961-7144-16-1.
- ŽIVKOVIĆ, Igor, GAČNIK, Jan, JOZIĆ, Slaven, KOTNIK, Jože, ŠOLIĆ, Mladen, HORVAT, Milena. Normalized wet deposition of total mercury reflects concentration gradient in surface seawater. V: Goldschmidt 2022: Honolulu, Hawai'i, USA and online,10-15 July 2022. Honolulu: https://conf.goldschmidt.info/goldschmidt/2022/meetingapp.cgi/Paper/11806.

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

New GEOTRACES or GEOTRACES relevant scientific results

In 2022/2023, GEOTRACES South Africa has developed representation in diverse fields, such as iron stress in the Southern Ocean, iron's role in the nitrogen cycle, carbon export, metal-phytoplankton and metal-microbial dynamics, and metals as contaminants. The following highlights illustrate some of these efforts:

Ryan-Keogh T.J. et al. (2023) reports an increase in irradiance-normalized non-photochemical quenching (NPQ) between 1996 and 2021 in the Southern Ocean (Figure SA-1), linked to an increase in iron stress and reduced net primary production. In turn, such change in the primary productivity led to changes in the Southern Ocean carbon cycle and has implications for climate change.

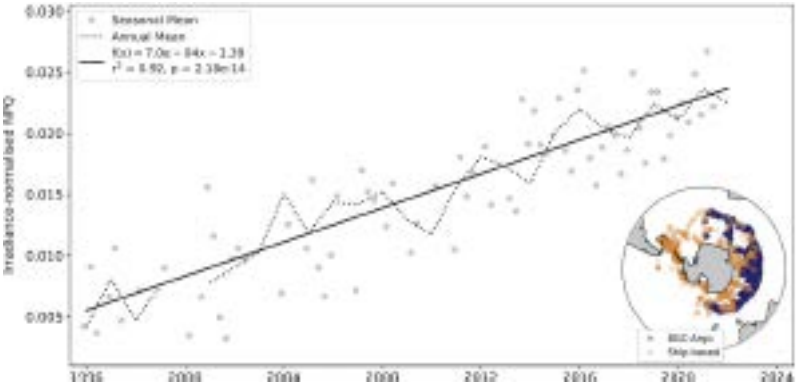


Figure SA-1. *Distribution and trend of irradiance-normalized non-photochemical quenching (NPQ). (source: Ryan-Keogh et al. 2023)*

Singh et al. (2022, 2023) further investigated the drivers of Southern Ocean photophysiology. Singh et al's results highlight the complex interplay drivers and responses, and that environmental drivers may act antagonistically. They exemplify that some of the low Fv/Fm results could be linked to iron stress, but photosynthesis in other areas was unlikely to be (solely) driven by iron limitation. They showed that occasionally, the phytoplankton photophysiology shows no significant response to iron addition (Figure SA-2), indicating that distinct times and areas of the Southern Ocean have ambient iron concentrations sufficient to fulfil the cellular requirements.

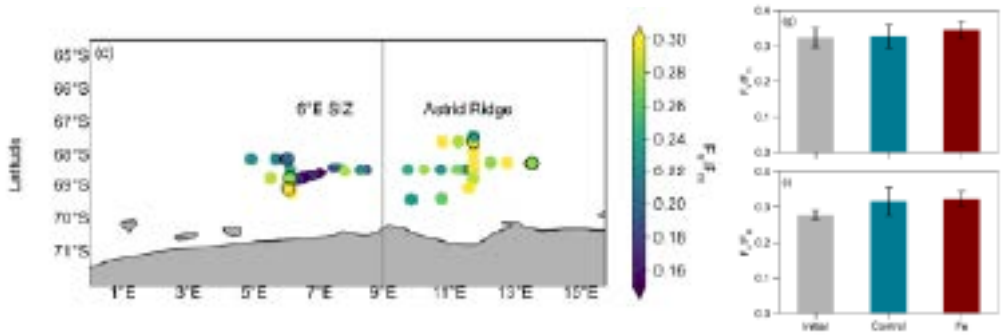


Figure SA-2. *(a) in-situ conditions of the study region (here: Fv/Fm) and (b) mean Fv/Fm from the initial, control and the Fe treatments in incubation experimentsconducted in the Sea-Ice Zone (source: Singh et al. 2023)*

Mdutyana, M., et al. (2022a, b) observed that nitrite oxidation may be limited by dissolved iron in the Southern Ocean surface waters, implying that iron availability affects nitrification and ammonium and nitrite distributions in the Southern Ocean (Figure SA-3). Mdutyana, M., et al. further conducted kinetics experiments across the Southern Ocean to investigate the controls of ammonium uptake and oxidation. They observed that the maximum rate decreased poleward, and was apparently controlled mainly by light in winter and temperature in summer. However, it appears that iron availability may (co-)limit the maximum ammonium oxidation rate (Figure SA-4).

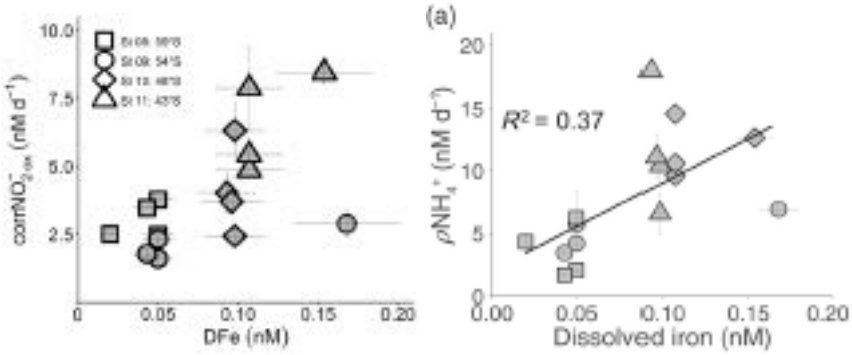


Figure SA-3. *Nitrite oxidation rates vs. dissolved iron concentrations (for details see source: Mdutyana et al. 2022a)*

Figure SA-4. *Rates of NH4+ uptake vs. dissolved iron concentrations (for details see source: Mdutyana et al. 2022b)*

Castillo et al. (2022) and Dithugoe et al. (2023) elucidated the seasonal variability in the impact of the Southern Ocean microbial communities on ecosystem functions and the biological carbon pump. Castillo et al. (2022) provide a comprehensive overview of microbial community compositions across the Southern Ocean (Figure SA-5). They observed abundant bacteria involved in recycling photosynthetically derived organic matter, an important asset to control carbon flux to higher trophic levels when light and iron availability favour primary production in spring and summer. In contrast, winter, chemolithoautotrophs contribute to prokaryotic production in Antarctic waters. This seasonal distinction improves our understanding of the microbiotas' role as mediators of primary productivity and carbon sequestration. In addition, Dithugoe et al. (2023) analyzed microbial metagenomes linked to suspended and sinking marine particles from the Sub-Antarctic Southern Ocean Time Series (Figure SA-6). Both, suspended and sinking particle-pools were dominated by bacteria with the potential to degrade organic carbon (Figure SA-6). They thus carry potential for mediating particulate organic matter export.

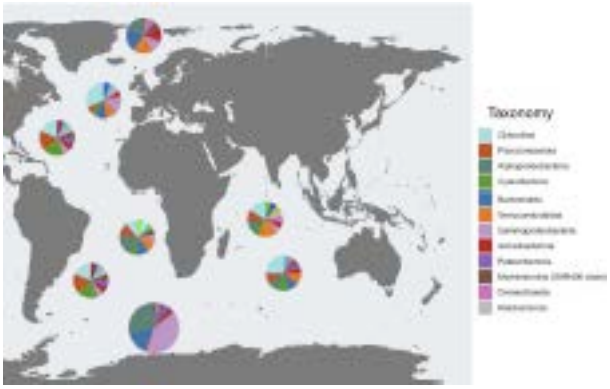


Figure SA-5. *Southern Ocean prokaryotic composition (modified from Castillo et al. 2022)*

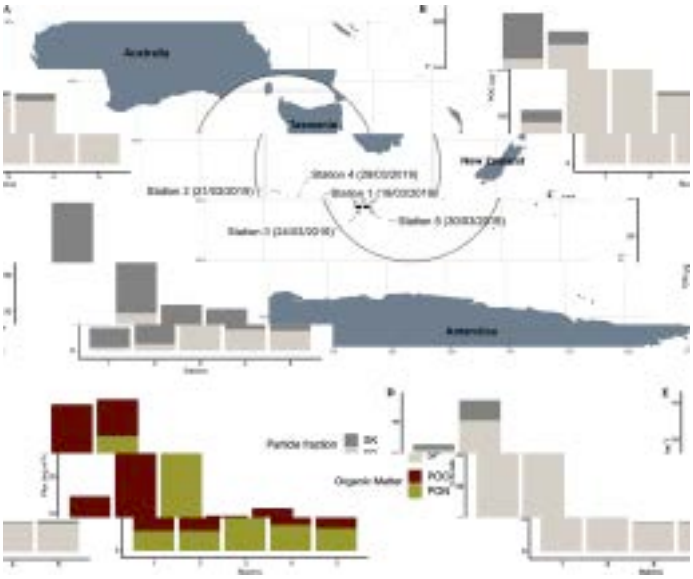


Figure SA-6. *Marine Snow Catcher (MSC) deployment at Southern Ocean Time Series sites (source: Dithugoe et al. 2023)*

Samanta et al. (2023) focussed on air-sea exchange and circulation using metal contaminants and investigated the exchange of dissolved lead (dPb) between the Indian and Atlantic Oceans south of South Africa. They observed an increased Pb flux from winter to summer, while the long-term (2008–2019) change in dPb corresponded to a change in atmospheric Pb emissions from South Africa. The study showcases that although air masses move towards the South African east coast (Indian Ocean), ocean circulation lead to concerns for the rich fishing grounds on the west coast (Atlantic Ocean; Figure SA-7).

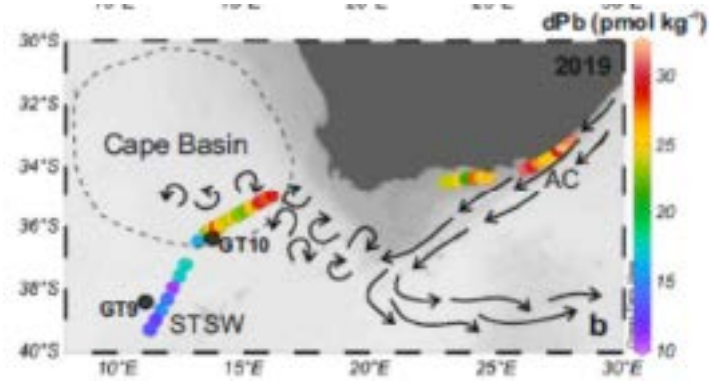


Figure SA-7. *Distribution of dPb in the Subtropical oceans around South Africa in 2019.(modified from Samanta et al. 2023)*

GEOTRACES or GEOTRACES relevant cruises

- Winter Cruise 2022 on board R/V SA Agulhas II, 11-31 July 2022
  - SCALE-WIN22 Cruise Report: https://doi.org/10.5281/zenodo.7901529.
  - Cruise track (Figure SA-8) can be found at: Vichi, Marcello. (2023). SCALE-WIN22 cruise track, stations, sea-ice edge, and SAR images on Google Earth [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7902992

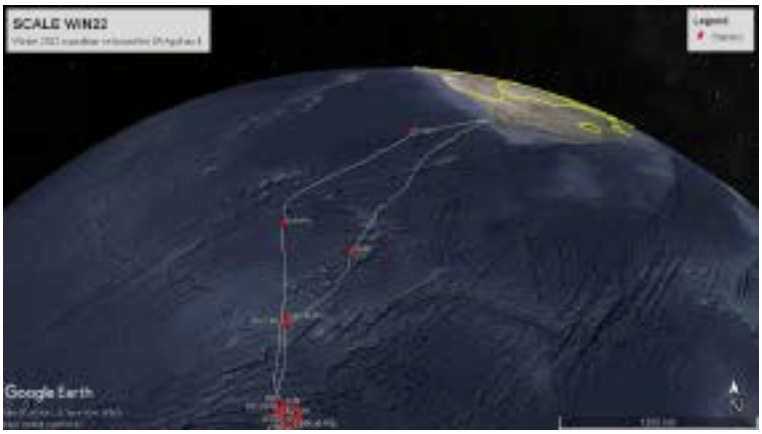


Figure SA-8. *Winter Cruise 2022 cruise track 11-31 July 2022 on board R/V SA Agulhas II*

New projects and/or funding

List of funded projects within the next South African Antarctic and Southern Ocean Research Plan (2024-2026) will be released end of 2023 or beginning of 2024.

Outreach activities conducted

- 2023-04, Ryan-Keogh T. TEDx Johannesburg (Figure SA-9): "A changing Southern Ocean: The impact of climate change", Ryan-Keogh explained that 26 years of data revealed that the phytoplankton in the Southern Ocean was becoming more iron-stressed with time. https://www.tedxjohannesburg.com/2023-countdown
- Newzroom Afrika: CSIR presents research on changing Southern Ocean:

https://youtu.be/XY8pVunXCcM

Figure SA-9. *Dr Ryan-Keogh at TEDx Johannesburg, South Africa*

New GEOTRACES or GEOTRACES-relevant publications

South African led publications

- Dithugoe C.D., et al. 2023 Bacteria and Archaea Regulate Particulate Organic Matter Export in Suspended and Sinking Marine Particle Fractions. mSphere. 2023 Jun 22;8(3):e0042022. https://doi.org/10.1128/msphere.00420-22
- Castillo D.J., et al. 2022. Microbial ecology of the Southern Ocean. FEMS Microbiology Ecology, 98, fiac123, https://doi.org/10.1093/femsec/fiac123
- Mdutyana, M., et al. 2022a. Controls on nitrite oxidation in the upper Southern Ocean: insights from winter kinetics experiments in the Indian sector, Biogeosciences, 19, 3425–3444, https://doi.org/10.5194/bg-19-3425-2022.

• Mdutyana, M., et al. 2022b. The kinetics of ammonium uptake and oxidation across the Southern Ocean. Limnology and Oceanography, 67(4), 973-991. https://doi.org/10.1002/lno.12050.

• Ryan-Keogh T.J., et al. 2023. Multidecadal trend of increasing iron stress in Southern Ocean phytoplankton. Science 379, 834-840. DOI:10.1126/science.abl5237

• Ryan-Keogh T.J., et al. 2023. Spatial and temporal drivers of fluorescence quantum yield variability in the Southern Ocean. Limnology and Oceanography, 68(3).

• Samanta, S., et al. 2023. Exchange of Pb from Indian to Atlantic Ocean is driven by Agulhas current and atmospheric Pb input from South Africa. Sci Rep 13, 5465. https://doi.org/10.1038/s41598-023-32613-5

• Singh A., et al. 2022. Spatial and temporal variability of phytoplankton photophysiology in the Atlantic Southern Ocean. Front. Mar. Sci. 9:912856. https://doi.org/10.3389/fmars.2022.912856.

• Singh A., et al. 2023. Photophysiological response of autumn phytoplankton in the Antarctic Sea-Ice Zone, Biogeosciences Discuss. [preprint], https://doi.org/10.5194/bg-2022-245 (revised version accepted)

• Thomalla S., et al. 2023. Southern Ocean phytoplankton dynamics and carbon export: insights from a seasonal cycle approach. Phil. Trans. R. Soc. A.3812022006820220068

• van Horsten, 2022. Early winter barium excess in the southern Indian Ocean as an annual remineralisation proxy (GEOTRACES GIPr07 cruise), Biogeosciences, 19, 3209–3224, https://doi.org/10.5194/bg-19-3209-2022

Publications with South African contribution

• Kauko, H. M., et al. 2022 First phytoplankton community assessment of the Kong Håkon VII Hav, Southern Ocean, during austral autumn, Biogeosciences, 19, 5449–5482, https://doi.org/10.5194/bg-19-5449-2022, 2022.

• Moreau, S., et al. 2023. Wind-driven upwelling of iron sustains dense blooms and food webs in the eastern Weddell Gyre. Nat Commun 14, 1303. https://doi.org/10.1038/s41467-

023- 36992-1.

• Fripiat, F., et al. 2023. The impact of incomplete nutrient consumption in the Southern Ocean on global mean ocean nitrate δ15N. Global Biogeochemical Cycles, 37, e2022GB007442

Completed GEOTRACES PhD or Master theses

• Choaro Dithugoe, PhD, Rhodes University/University of Pretoria/CSIR: Disentangling the role of prokaryotes in regulating export flux via suspended and sinking organic matter in the Southern Ocean.

• Diego Castillo, PhD, University of Pretoria: Microbial ecology of the Southern Ocean.

• Emtia Wium, MSc, Stellenbosch University: Impact of Trace Metals (Cu, Cd, Zn) on Phytoplankton in open and coastal oceans: A Southern African perspective. http://hdl.handle.net/10019.1/126991

• Johan Viljoen, PhD, Stellenbosch University: Phytoplankton and trace metal dynamics in the Southern Ocean.

- Raquel Flynn, PhD, University of Cape Town: Phytoplankton's role in the biological pump during the growth season across the Atlantic Southern Ocean
- Tara De Jong, MSc, Stellenbosch University: Fluorescence detection of trace aluminium using a sequential injection analyser. http://hdl.handle.net/10019.1/125935

GEOTRACES presentations in international conferences

- Burger J. et al. Seasonal inorganic aerosol ion concentrations across the Southern Ocean. SOLAS, Cape Town, 09/2022
- Cloete R. et al. Winter Copper and Nickel distributions from the Indian sector of the Southern Ocean. Goldschmidt Hawai'i 07/2022.
- Dithugoe C. et al. Disentangling the role of prokaryotes in regulating export flux via suspended and sinking organic matter in the Southern Ocean. Goldschmidt Hawai'i 07/2022.
- Ellis N. et al. Seasonality of Cadmium in the Southern Ocean. Geocongress Stellenbosch, 01/2023
- Fietz S. et al. Atmospheric trace metal over the oceans south off Southern Africa. SOLAS, Cape Town, 09/2022
- Flynn R., Discussion Leader for Keynote Session: Modelling the Ecology and Evolution of Marine Plankton: Mechanistic Models at the Global Ocean Scale. Gordon Research Seminar, Biogeochemical Processes Across Space and Time. Castelldefels, Spain, 05/2022
- Ryan-Keogh T. et al. Insights into phytoplankton iron limitation in the Southern Ocean. Goldschmidt Hawai'i 07/2022.
- Samanta S. et al. Decadal evolution of dissolved lead in the Cape Basin: the role of Agulhas Current in transporting anthropogenic lead from Southern Africa. Goldschmidt Hawai'i 07/2022.
- Samanta S. et al. Exchange of dissolved Pb between Indian and Atlantic oceans: Role of Agulhas Current and atmospheric Pb input from South Africa. Geocongress Stellenbosch, 01/2023
- Singh A. et al. The seasonal photophysiological responses of Atlantic Southern Ocean phytoplankton to iron addition. SOLAS, Cape Town, 09/2022
- Thomalla S et al. Building a national integrated observational and modelling capability to support the assessment of ocean CDR in South Africa for robust policy development. SOLAS, Cape Town, 09/2022

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

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

- Vertical profiles of ^{228}Ra (half-life: 5.75 years) in the ocean provide valuable information on water mixing and ages of the upper ocean. However, its application is hampered by extremely low levels of ^{228}Ra in the deep ocean. In this study, Cho H.M. et al. (2022) measured high-resolution ^{228}Ra/^{226}Ra ratio profiles (>21 depths) in the East Sea (Japan Sea) by mooring Mn-fiber. Using the measured ^{228}Ra profile from ^{228}Ra/^{226}Ra ratios and ^{226}Ra activities, together with other previously published data, we estimated the vertical eddy diffusivity (8.7–9.6 cm^2 s^{-1}) in the permanent thermocline and water ages (10–15 years) in the upper 500–1000 m range (Figure KOR-1). The estimated decomposition rate of organic carbon based on oxygen utilization rates using Ra-ages between 100 and 1000 m was 4.4 ± 0.8 mol C m^{-2} yr^{-1} (Figure KOR-2). Our results show that ~50% of the upward nutrients through 100 m support export production, and that dissolved organic carbon accounts for ~20% of carbon export (Figure KOR-2). This ^{228}Ra approach provides a holistic understanding of carbon and nutrient cycles in the ocean.

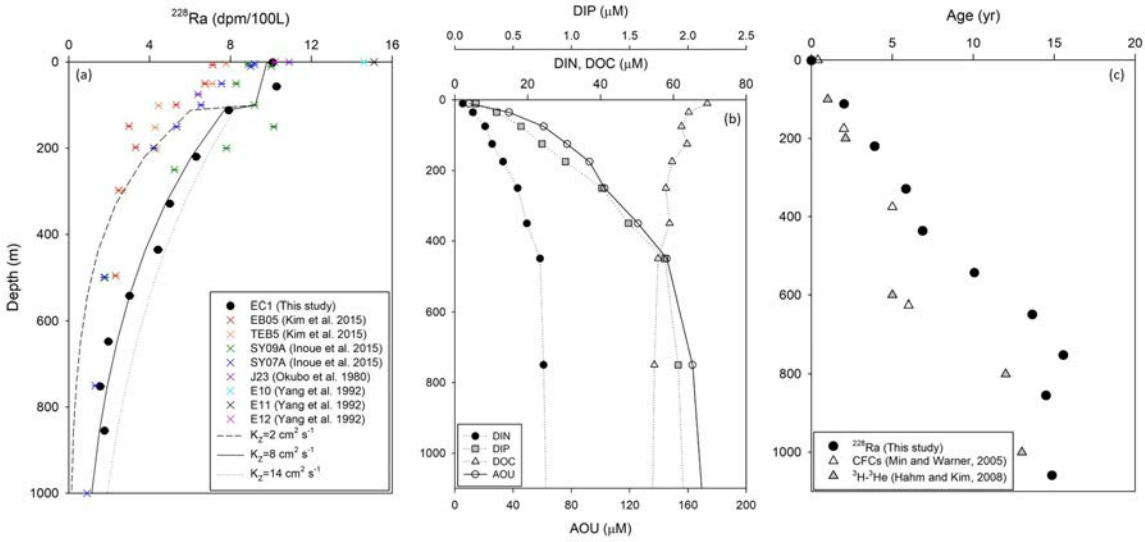


Figure KOR-1. *(a) Model estimates of K_z fitted to the ^{228}Ra profiles in the Ulleung Basin (UB). (b) Vertical profiles of apparent oxygen utilization (AOU), dissolved inorganic nitrogen (DIN) and phosphorus (DIP), and dissolved organic carbon (DOC) from 2006 to 2017 in the UB, East Sea. The dataset is available at the JOISS portal system (http://joiss.kr) which collects and provides marine research data in Korea. (c) Comparison of ^{228}Ra-ages (circles; this study), CFC-11/CFC-12 ratio ages (white triangle; Min and Warner, 2005) in the UB, and ^{3}H-^{3}He ages in the Japan Basin (Hahm and Kim, 2008).*

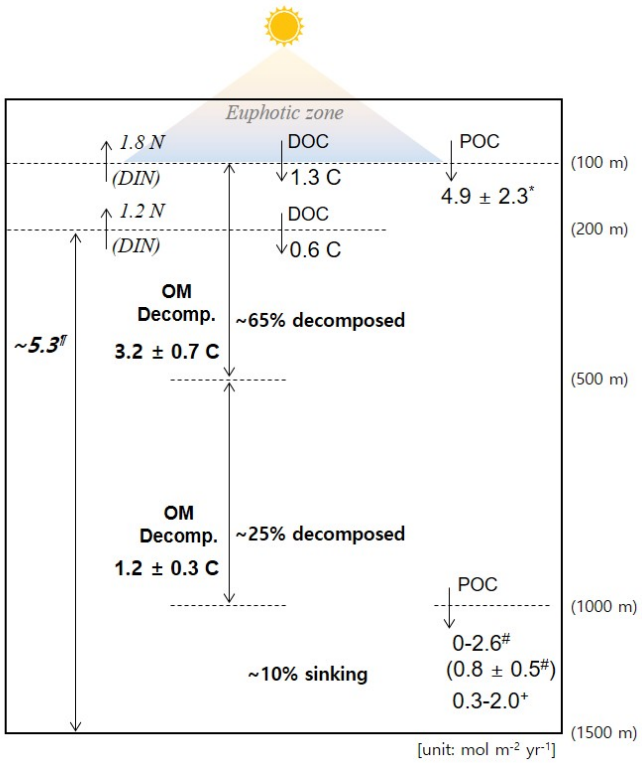


Figure KOR-2. *A schematic of the vertical fluxes of dissolved inorganic nitrogen (DIN) and organic carbon in the upper East Sea. The vertical fluxes of DIN and dissolved organic carbon (DOC) are based on the DIN and DOC gradients and the estimated eddy diffusivity. OM Decomp. denotes the decomposition rate of organic matter/carbon, which is estimated based on the Ra-age-based oxygen utilization rates (OUR). The downward fluxes of particulate organic carbon (POC) are from previous studies: #Sediment trap (at 1000 m, Kim et al., 2020), +Sediment trap (at 1000 m, Kwak et al., 2017), *234Th method (Kim et al., 2011), and ¶carbon export production using 3H and 3He tracers (Kim and Hahm, 2001).*

- Seo J.H. et al. (2022) examined particulate organic carbon (POC) export using ^{238}U-^{234}Th disequilibrium in the eddy-rich northwest Pacific Ocean in Septembers 2019 and 2020 (Fig. 1). In 2019, excess ^{234}Th activities with in acticyclonic eddy were observed caused by horizontal particle transport into the eddy core at the early stage of eddy formation (Figure KOR-3). However, this transport was not observed in an anticyclonic eddy in 2020 since the nutrient-depleted layer was so deep (~ 120 m) that water advection did not help to bring nutrients up from below. In the upper 500 m layer, Th flux at 300 and 500 m depths were not so low and comparable with that at more productive Station Papa (Figure KOR-3). This result suggests that POC flux to the ocean interior in the oligotrophic region may be higher than expected, presumably because production in the deep subsurface chlorophyll maximum layer and a small vertical density gradient. Thus, the examination of POC export at 100 m depth may have been underestimated in the extremely oligotrophic ocean.

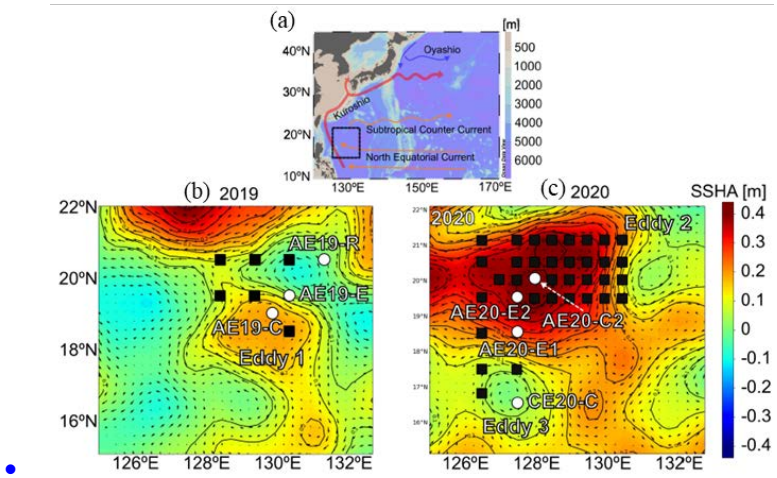


Figure KOR-3. *(a) Map showing the study region (black rectangle) and surface currents in the tropical northwest Pacific (modified from Gallagher et al., 2015). Blow-up map showing (b) the sampling stations (Eddy 1) in September 2019 and (c) sampling stations (Eddy 2 and Eddy 3) in September 2020. Circle (white) and squares (black) represent particulate and hydrography sampling, respectively. The background color shows the sea surface height anomaly (SSHA) averaged over the sampling period. The black arrows indicate the geostrophic current.*

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

- Seo, J., Kim, G., Park, J. H., Seo, H., Na, T., Kang, S. K., & Hwang, J. (2022). Export of particulate organic carbon (POC) in the eddy region of the tropical northwest Pacific. *Frontiers in Marine Science*, *9*, 976201.
- Cho, H. M., Han, Y., Kim, Y. I., Baek, C., & Kim, G. (2022). Tracing the depth-dependent changes in organic carbon and nutrient fluxes using high-resolution ^{228}Ra profiles in the upper East Sea (Japan Sea). *Frontiers in Marine Science*, *9*, 987315.

Completed GEOTRACES PhD or Master theses

- Seo, H. Ph.D. in Earth and Environmental Science, Seoul National University, Republic of Korea, 2022. Dissertation: *"Sources, fluxes, and behaviors of trace elements and radionuclides in the marginal seas of the northwestern Pacific Ocean"* (Advisor: Guebuem Kim)

GEOTRACES presentations in international conferences

- I. Kim, H. Lee*, (2022.12.) Distribution of dissolved trace elements in the northwest Pacifi c marginal seas around the Korean Peninsula *(poster)*, AGU 2022 Fall meeting, Chicago, USA
- I. Kim, J. Lee*. H. Lee, (2022.12.) Annual distribution and atmospheric deposition of ^{210}Po in aerosol in Busan, the largest port city in Korea *(poster)*, AGU 2022 Fall meeting, Chicago, USA
- H. Lee*, J. Lee, H. Lee, I. Kim (2022. 7.) Sectional distributions of trace elements in the East/Japan Sea (*poster*), Goldschmidt 2022, Hawaii, USA (online presentation)
- J. Lee*, H. Lee, H. Lee, I. Kim (2022. 7.) Annual distribution and atmospheric deposition of ^{210}Po and ^{210}Pb in aerosols from Busan, the largest port city in Korea (*poster*), Goldschmidt 2022, Hawaii, USA (online presentation)

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

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN SPAIN

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

- Polyphenols exudated by marine microorganisms can complex Fe(III), modifying the Fe(II) oxidation rates as well as promoting the reduction of Fe(III) to Fe(II) in seawater. Fe(III) is reduced to Fe(II) by gallic acid in a process that depends on the pH and composition of solution, being faster as pH decreases.
- Cu-binding ligands were determined in the Central Arctic waters. The importance of the Transpolar Drift (TPD) on the lateral transport of binding ligands from the Siberian Shelves toward the Central Arctic was evaluated.
- Cu-binding ligands were determined in Fram Strait and Greenland Shelf. The Transpolar Drift (TPD) and different coastal processes determine the concentration of ligands observed above the Greenland Shelf. The area was identified as a key region for the export of Cu-binding ligands from the Central Arctic to the Nordic Seas and North Atlantic Ocean.
- It has been estimated that the Chinstrap penguin population is recycling 521 tonnes iron yr-1 in the Atnarctic water

New projects and/or funding

- FeRIA, Fe Response In an Acidified ocean. (PID2021-123997NB-I00). IP: J. Magdalena Santana-Casiano, Aridane G. González
- Multi-CO2ast, Multidisciplinary Analysis of Blue Carbon Sinks in Coastal Waters (TED2021-130892B-I00). IP: Aridane G. González, J. Magdalena Santana-Casiano.
- Liquid micro-extraction based systems improving sampling of metals in the ocean surface micro-layer. Funded by the Regional government of Andalucía (Spain). IP: José A. López-López.
- *Contribution of Water Masses of Deception Island to biogeochemical inventories of the Southern Ocean: current budgets and future trends(DICHOSO). PID2021-125783OB-I00 Pis:* Antonio Tovar Sánchez & Emma Huertas Cabilla

Outreach activities conducted (please list any outreach/educational material available that could be shared through the GEOTRACES web site) *(We are particularly interested in recordings from webinars from GEOTRACES research)*

- Macaronight 2022. Metales traza en el océano: por qué y cómo estudiarlos. David González-Santana.

Other GEOTRACES activities

- Divulgation in http://eacfe-quima.blogspot.com/

New GEOTRACES or GEOTRACES-relevant publications

- Pérez-Almeida, N., González, A.G., Santana-Casiano, J. M., González-Dávila, M. 2022. Ocean acidification effect on the Iron-Gallic Acid redox interaction in seawater. *Frontiers in Marine Science, 9,* https://www.frontiersin.org/articles/10.3389/fmars.2022.837363/full
- González, A. G., Bianco, A., Boutorh, J., Cheize, M., Mailhot, G., Delort, A. M., Planquette, H., Chaumerliac, N., Deguillaume, L., Sarthou, G. 2022. Influence of strong iron-binding ligands on cloud water oxidant capacity. *Science of the Total Environment*, *829*, 154642. https://doi.org/10.1016/j.scitotenv.2022.154642
- *González-Santana, D., Lough, A. J., Planquette, H., Sarthou, G., Tagliabue, A., & Lohan, M. C. 2023. The unaccounted dissolved iron (II) sink: Insights from dFe (II) concentrations in the deep Atlantic Ocean. Science of the Total Environment, 862, 161179,* https://doi.org/10.1016/j.scitotenv.2022.161179
- Belbachir, I., Lopez-Lopez, J.A.*, Herce-Sesa, B., Moreno, C. (2022) A liquid micro-extraction based one-step method for the chemical fractionation of copper in seawater. Journal of Hazardous Materials, 430, 128505, DOI: 10.1016/j.jhazmat.2022.128505
- Juan J. Pinto , Carolina Mendiguchía , José A. López-López * , Mabel Martín-Barata, Macarena Silva and Carlos Moreno (2023) Improvement of Advanced Sample Preparation Systems for the Determination of Trace Ni in Seawater by Electro-Membranes, 13, 152, DOI: doi.org/10.3390/membranes13020152
- Jirsa F, López-López JA. In press. Ionic Liquids for Metal Extraction from Aqueous Matrices, in Ionic Liquids for Environmental Issues. Ed: Isabel Marrucho. Royal Society of Chemistry (Book Chapter).
- Giering, S. L. C. et al. Vertical imbalance in organic carbon budgets is indicative of a missing vertical transfer during a phytoplankton bloom near South Georgia (COMICS). Deep Sea Res. Part II Top. Stud. Oceanogr. 105277 (2023). 10.1016/j.dsr2.2023.105277
- Lérida-Toro, V. et al. 129I in sediment cores from the Celtic Sea by AMS through a microwave digestion process. Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms 529, 61–67 (2022). 10.1016/j.nimb.2022.08.016
- Luis M. Laglera, Hema Uskaikar, Christine Klaas, S. Wajih A. Naqvi, Dieter A. Wolf-Gladrow, Antonio Tovar-Sánchez. Dissolved and particulate iron redox speciation during the LOHAFEX fertilization experiment. Marine Pollution Bulletin 184:114161. 2022. doi: 10.1016/j.marpolbul.2022.114161.
- Armando Félix-Bermúdez, Francisco Delgadillo-Hinojosa, María L. Lares, Eunise V. Torres-Delgado, Miguel A. Huerta-Díaz, Antonio Tovar-Sánchez and Víctor F. Camacho-Ibar. Spatial variability of dissolved nickel is enhanced by mesoscale dynamics in the Gulf of Mexico. Frontiers in Marine Science, doi: 10.3389/fmars.2022.1036331.
- Oleg Belyaev, Erica Sparaventi, Gabriel Navarro, Araceli Rodríguez-Romero, **Antonio Tovar-Sánchez**. The contribution of penguin guano to the Southern Ocean iron pool. **Nature Communications 14.** Article number: 1781 (2023). https://doi.org/10.1038/s41467-023-37132-5

Completed GEOTRACES PhD or Master theses

Muñoz-Nevado, Carlos (supervisors: Villa-Alfageme, María and Hurtado, Santiago). Master tesis. ^{210}Po y ^{234}Th como trazadores de la eficiencia de exporte del carbono en el océano /

^{210}Po y ^{234}Th as Tracers for carbon export efficiency in the ocean (Universidad de Sevilla, September 2022).

GEOTRACES presentations in international conferences

- Arnone, V., González-Santana, D., González-Dávila, M., González, A. G., Santana-Casiano, J. M. (2023). Influence of coastal processes on the organic complexation of iron and copper in the Macaronesia region. XXI INTERNATIONAL IBERIAN MARINE CHEMISTRY (SIQUIMAR 2022; 6-8 July 2022). Oral.
- Pérez-Almeida, N., González, A. G., Santana-Casiano, M., González-Dávila, M. The role of gallic acid and ocean acidification in the redox chemistry of iron in seawater. XXI INTERNATIONAL IBERIAN MARINE CHEMISTRY (SIQUIMAR 2022; 6-8 July 2022). Oral.
- González A.G., Pérez-Almeida, N., Arnone, V., González Santana, D., González Dávila, M., Santana Casiano, J. M. Characterization of iron-polyphenols complexes in seawater. XXI INTERNATIONAL IBERIAN MARINE CHEMISTRY (SIQUIMAR 2022; 6-8 July 2022). Oral.
- González Santana, D., González Dávila, M., Lohan, M. C., Artigue, L., Tagliabue, A., Santana-Casiano, J.M. Iron (II) oxidation kinetics variability in the Atlantic Ocean and development of an improved theoretical equation. XXI INTERNATIONAL IBERIAN MARINE CHEMISTRY (SIQUIMAR 2022; 6-8 July 2022). Oral.
- J. Magdalena Santana-Casiano, Melchor González-Dávila, Aridane G. González, Norma Pérez-Almeida, Verónica Arnone, Carolina Santana-González, David González-Santana. Fe biogeochemistry in a high CO_2 Ocean. 5th International Symposium on the Ocean in a High CO2 world. Lima, Perú. 12-16 September 2022. Oral
- Arnone, V., González-Dávila, M., González, A.G., Santana-Casiano, J.M. Iron and copper complexation in the Macaronesian coastal waters. IV Congreso Jóvenes Investigadores de Canarias. II Congreso Internacional de Jóvenes por la Investigación (17-18 November 2022). Poster.
- González-Santana, D., González, A. G., Arnone, V., González-Dávila, M., & Santana-Casiano, J. M. (2023). Subaerial lava as a source of coastal hydrothermal iron (No. EGU23-9006). Copernicus Meetings. Oral.
- Arnone, V., Santana-Casiano, J.M., González-Dávila, M., Sarthou, G., Krisch, S., Lodeiro, P., Achterberg, E.P., González, A.G. Distribution of copper-binding ligands in Fram Strait and influences from the Greenland Shelf. 21st Arctic-Subarctic Ocean Fluxes Workshop (10-12 May 2023). Oral.
- Villa-Alfageme, M., Ceballos-Romero, E., Giering, S. L. C. & de Soto, F. C. Particle Sinking Velocity Influence on the Biological Carbon Pump: Gaps and Uncertainties. in *AGU fall meeting 2022* 12-16 December (2022).

Submitted by:

J. Magdalena Santana-Casiano (Magdalena.santana@ulpgc.es)

J.A. López-López (joseantonio.lopezlopez@uca.es)

M. Vila-Alfageme (mvilla@us.es)

A. Tovar-Sánchez (a.tovar@csic.es)

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN SWITZERLAND

May 1st, 2022 to April 30th, 2023

GEOTRACES or GEOTRACES-relevant cruises

- Dr. Isabelle Baconnais (University of Lausanne) collected an array of seawater and particulate samples in Georgia Strait and Saanich Inlet in October 2022 (SCrIPT Project).
- Dr. Anja Studer and Jochem Baan (University of Basel) collaborated with the Max Planck Institute for Chemistry (Mainz, Germany) to collect seawater and plankton net tow samples on S/V Eugen Seibold cruises ES22C16 (October 2022, Lanzarote) and ES22C18 (December 2022, Mauritanian Upwelling) for analysis of nitrate concentration, nitrate isotopes and diatom biomass- and frustule-bound N isotopes at the University of Basel.

New projects and/or funding

- Chun Fung Chiu began a Ph.D. project with Dr. David Janssen (EAWAG) entitled "Assessing the potential of metal stable isotopes as paleoproductivity proxies – a case study from the subantarctic Southern Ocean" based on samples from the GEOTRACES process study GPpr13.
- Swiss-South African Joint Research Programme. CARVICE – the fate of the marine biological carbon pump in the face of vanishing (sea-)ice: a tale of two polar systems. PIs Sarah Fawcett (University of Cape Town) & Samuel Jaccard (University of Lausanne): 2023-2026.

New GEOTRACES or GEOTRACES-relevant publications

- Deng, K., S. Yang, J. Du, E. Lian, D. Vance (2022). Dominance of benthic fluxes of REEs on continental shelves: implications for oceanic budgets. Geochemical Perspectives Letters 22, doi: 10.7185/geochemlet.2223.
- Du, J., B. A. Haley, A. C. Mix, A. N. Abbott, J. McManus, D. Vance (2022). Reactive-transport modeling of neodymium and its radiogenic isotope in deep-sea sediments: The roles of authigenesis, marine silicate weathering and reverse weathering. Earth and Planetary Science Letters 596, doi: 10.1016/j.epsl.2022.117792.
- Eisenring, C., S. Oliver, S. Khatiwala, G. F. de Souza (2022). Influence of GEOTRACES data distribution and misfit function choice on objective parameter retrieval in a marine zinc cycle model. Biogeosciences 19, doi: 10.5194/bg-19-5079-2022.
- Fripiat, F., Sigman, D. M., Martínez-García, A., Marconi, D., Ai, X.E., Auderset, A., Fawcett, S. E., Moretti, S., Studer, A. S., Haug, G. H. (2023). The impact of incomplete nutrient consumption in the Southern Ocean on global mean ocean nitrate δ15N. Global Biogeochemical Cycles, 37, doi: 10.1029/2022GB007442.
- Janssen, D. J., D. Gilliard, J. Rickli, P. Nasemann, A. Koschinsky, C. S. Hassler, A. R. Bowie, M. J. Ellwood, C. Kleint, S. L. Jaccard (2022). Chromium stable isotope distributions in the southwest Pacific Ocean and constraints on hydrothermal input from the Kermadec Arc. Geochimica et Cosmochimica Acta 342, 31-44.

- Janssen, D. J., J. Rickli, M. Wille, O. S. Steiner, H. Vogel, O. Dellwig, J. S. Berg, D. Bouffard, M. A. Lever, C. S. Hassler, S. L. Jaccard (2022). Chromium cycling in redox-stratified basins challenges δ53Cr paleoredox proxy applications. Geophysical Research Letters 49, doi: 10.1029/2022GL099154.
- Müsing, K., M. O. Clarkson, D. Vance (2022). The meaning of carbonate Zn isotope records: Constraints from a detailed geochemical and isotope study of bulk deep-sea carbonates. Geochimica et Cosmochimica Acta 324, doi: 10.1016/j.gca.2022.02.029.
- Taves, R. C., D. J. Janssen, M. A. Peña, A. R. S. Ross, K. G. Simpson, W. R. Crawford, J. T. Cullen (2022). Relationship between surface dissolved iron inventories and net community production during a marine heatwave in the subarctic northeast Pacific. Environmental Science: Processes and Impacts 24, doi: 10.1039/D2EM00021K.

Completed GEOTRACES-related PhD or Master theses

- Joy Schrepfer (2022). Species-specific radiolarian δ30Si across the last deglaciation. M.Sc. thesis, ETH Zurich.

Compiled and submitted by Gregory de Souza, ETH Zurich (desouza@erdw.ethz.ch).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN TURKEY

May 1st, 2022 to April 30th, 2023

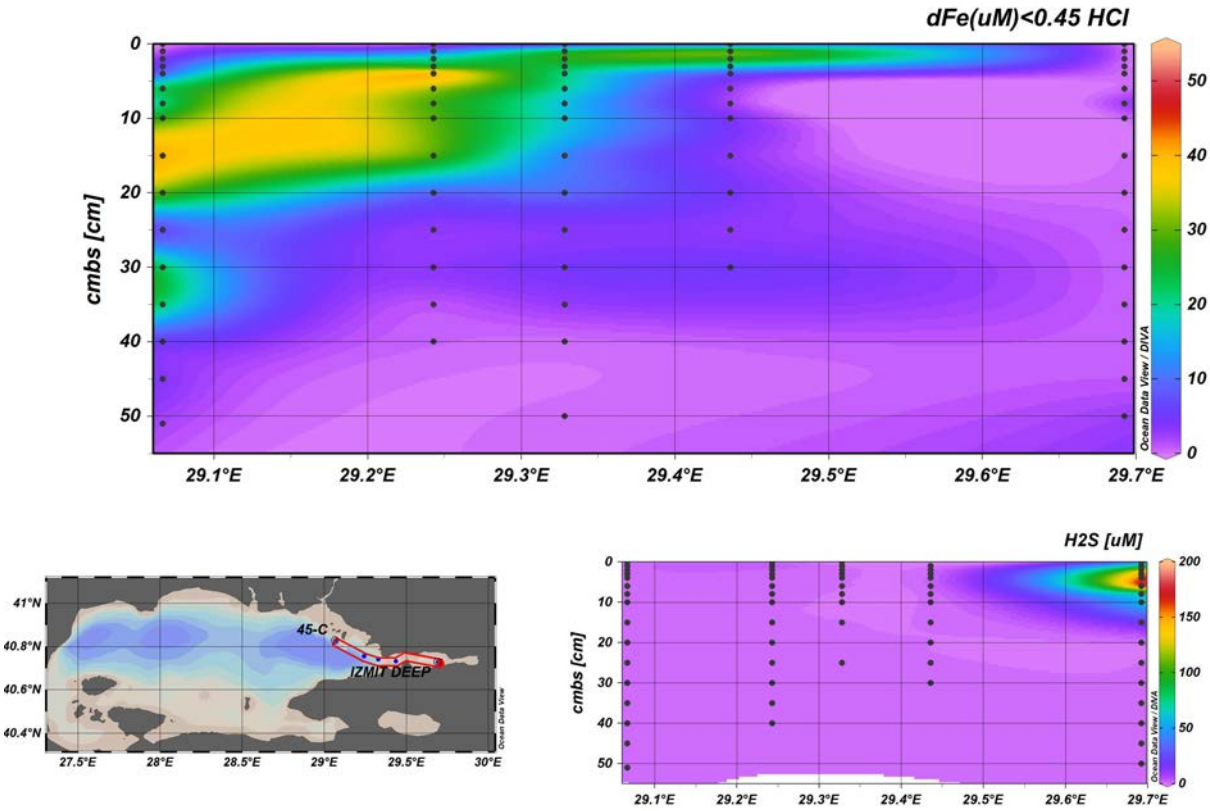
New GEOTRACES or GEOTRACES relevant scientific results

The period from May 2022 to May 2023 witnessed an intensive expedition activity in the seas surrounding Turkey In the Eastern Mediterranean, in the Sea of Marmara and the Black Sea with Turkey`s only oceanographic RV Bilim-2. These expeditions have been performed with the support of national funding (TÜBİTAK, strategic infrastructure funds) as well as European Union's Horizon Programme, to which Turkey is an associated partner.

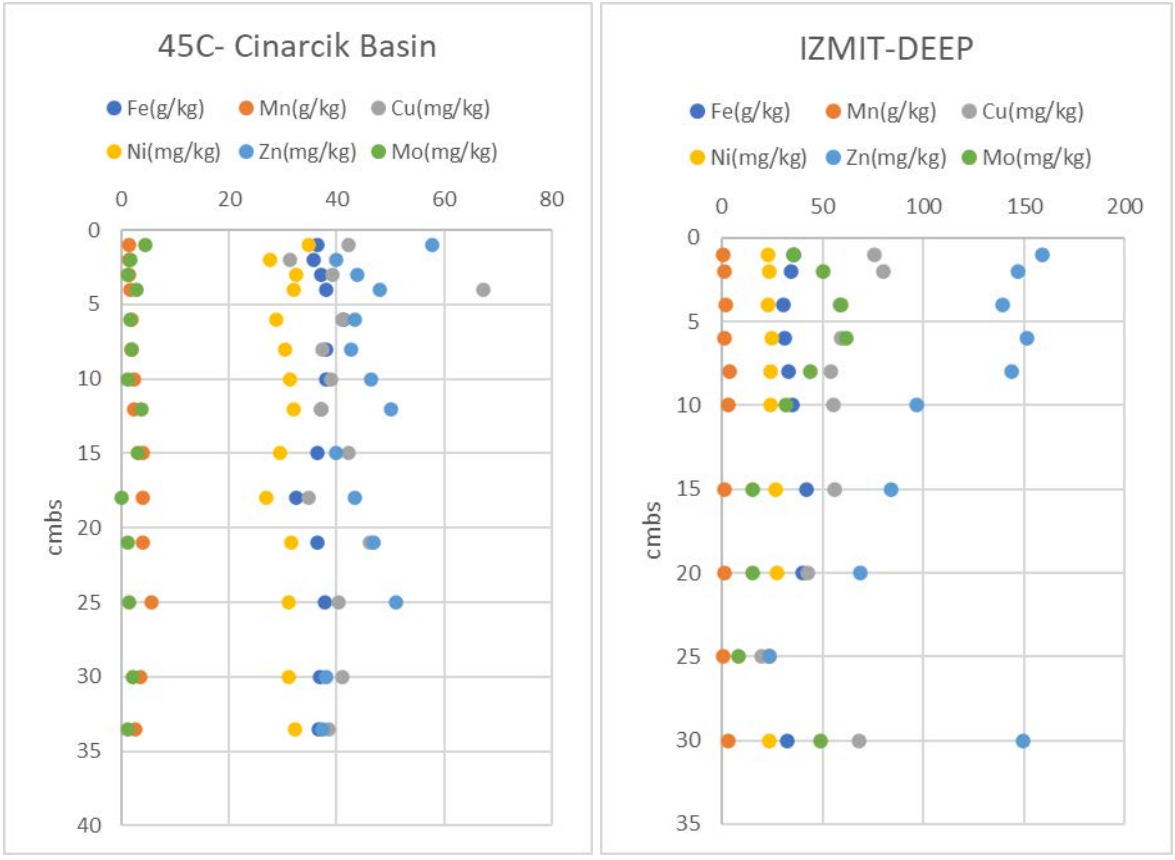
The work in the Black Sea encompassed over 100 CTD hydrocast and bottle sampling stations down to 1800 meters depth, in both western and eastern basins in the Turkish waters. The biogeochemical program of these cruises emphasized redox species such as oxygen, sulfide, iron and manganese. Preparatory work for future trace element sampling across the redox interface in the Black Sea has also been performed. Preliminary measurements

In terms of trace elements sedimentary metals and diffusive fluxes of iron, manganese and 10 other transition metals have been studied in detail in the Sea of Marmara given the expansion of hypoxia in this basin and associated release or uptake of previously sediment-bound elements.

Sedimentary porewater dFe and H2S measurements from June 2021 are given below depicting the sulfidic to iron rich sedimentary porewater characteristics along the transect from IZMIT-DEEP to Cinarcik Basin.



Some of the results on total trace elements, after the total digestion with HF-HNO_3 of the sediments taken during 2022 June Cruise are given below.



A publication regarding the dissolved Fe, H_2S and solid phase metal contents of the Sea of Marmara is currently under preparation.

GEOTRACES or GEOTRACES relevant cruises

- R/V Bilim, November - December 2022, Sea of Marmara and the Black Sea
- R/V Bilim, May-June 2023, Sea of Marmara and the Black Sea

New projects and/or funding

ERC Consolidator Grant Deep Trace to Prof. Dr. Mustafa Yücel, METU IMS, as the PI.

This 2.4 M Euro project has started in January 2023 and will run until 2028. As a new initiative funded by Horizon Europe's competitive European Research Council (ERC) Consolidator Grants, ERC project DeepTrace aims to build a new approach combining deep-ocean redox research with ocean world habitability analyses. Funded until 2028, the project will aim to uncover the metal nanoparticulate diversity produced across Earth's deep ocean redox gradients as a key tracer of potentially redox-active, chemical-disequilibria-rich conditions. The project will initially focus on the 5 cofactor metal elements but the scope will be broadened as the work progresses. DeepTrace has started to advance a ground-breaking mechanistic, analytical, and predictive framework on the nanoparticle-fuelled co-mobilization of catalyst metals across Earth's marine redox interfaces. We have selected to focus on Earth analogues of pelagic and deep-sea hydrothermal redox gradients and will present some of the first results in this presentation. We are starting to apply time-of-flight mass spectrometry-based single-particle nanoparticle analyses from a pelagic redox gradient in the Black Sea and developing this approach for the first time in order to detect multiple metal cooccurrences in marine nanoparticles across redox interfaces.

Job openings, both doctoral and postdoctoral, are open under this project and can be viewed in the web page below:

https://ims.metu.edu.tr/announcement/erc-deeptrace-project-seeking-phd-candidates

New GEOTRACES or GEOTRACES-relevant publications (published or in press) *(If possible, please identify those publications acknowledging SCOR funding)*

- Akcay I, **Yücel M** (2023). Distinct patterns of sedimentary phosphorus fractionation and mobilization in the seafloor of the Black Sea, Marmara Sea and Mediterranean ea. *Science of the Total Environment* 863: 160936 (https://doi.org/10.1016/j.scitotenv.2022.160936)
- Grégoire, M., Oschlies, A., Canfield, D., Castro, C., Ciglenečki, I., Croot, P., Salin, K., Schneider, B., Serret, P., Slomp, C.P., Tesi, T., **Yücel, M**. (2023). Ocean Oxygen: the role of the Ocean in the oxygen we breathe and the threat of deoxygenation. Rodriguez Perez, A., Kellett, P., Alexander, B., Muñiz Piniella, Á., Van Elslander, J., Heymans, J. J., [Eds.] Future Science Brief No. 10 of the European Marine Board, Ostend, Belgium. ISSN: 2593-5232. ISBN: 9789464206180. DOI: 10.5281/ zenodo.7941157

Completed GEOTRACES PhD or Master theses

- Master thesis by Nimet Alimli "Seafloor Iron Mobilization Across The Deep-Water Redox Gradients Of The Black Sea And The Sea Of Marmara" can be found in the link https://open.metu.edu.tr/handle/11511/99800

GEOTRACES presentations in international conferences

- https://conf.goldschmidt.info/goldschmidt/2023/meetingapp.cgi/Paper/16601

Submitted by Nimet Alimli (nimet@ims.metu.edu.tr)

New GEOTRACES or GEOTRACES relevant scientific results

Olivelli and co-authors (2023, see reference below) present total dissolvable lead (Pb) concentrations and isotope compositions for 23 surface waters collected in 2011 along a latitudinal transect offshore of the South American coast from Punta Arenas to the Equator (Leg 3 of the Dutch GEOTRACES GA02 section). They reveal that the mean Pb concentrations in the surface waters of the western South Atlantic Ocean decreased by 34 % between the 1990s and 2011. Pb isotope compositions also show a shift towards a more natural Pb isotope signal: 2011-samples show that natural Pb sources contributed 36 ± 6 % of the Pb present in western South Atlantic surface waters, while it was 24 ± 4 % in 1996.

As for the preceding work of the same team in the North Atlantic (Bridgestock and al, 2016 - read the science highlight here: https://www.geotraces.org/testament-of-environmental-policies/) these results evidence the positive effect of environmental and health policies that banned the use of leaded gasoline in South America since the 1990s.

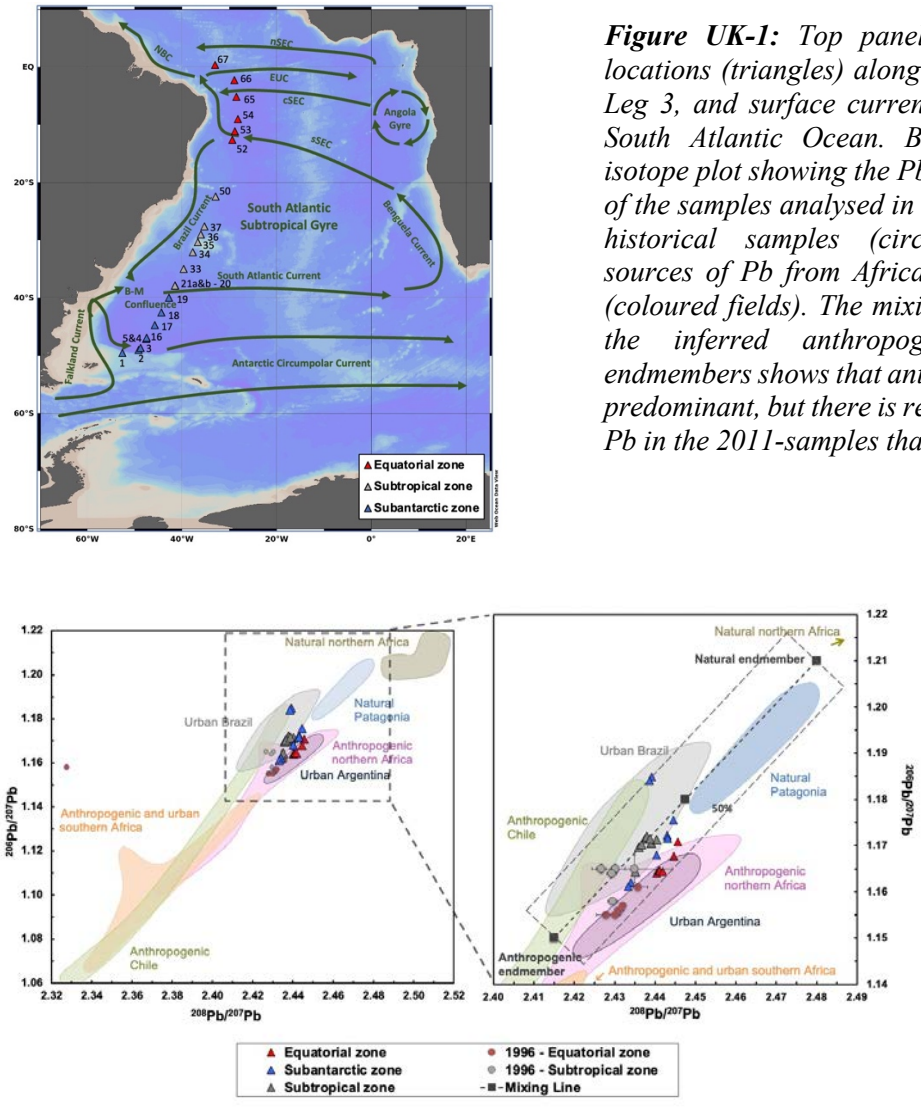


Figure UK-1: *Top panel: Map of sampling locations (triangles) along GEOTRACES GA02 Leg 3, and surface currents (green arrows) in South Atlantic Ocean. Bottom panel: three-isotope plot showing the Pb isotope composition of the samples analysed in this study (triangles), historical samples (circles) and potential sources of Pb from Africa and South America (coloured fields). The mixing envelope between the inferred anthropogenic and natural endmembers shows that anthropogenic Pb is still predominant, but there is relatively more natural Pb in the 2011-samples than in those from 1996.*

Olivelli, A., Murphy, K., Bridgestock, L., Wilson, D. J., Rijkenberg, M., Middag, R., Weiss, D. J., van de Flierdt, T., & Rehkämper, M. (2023). Decline of anthropogenic lead in South Atlantic Ocean surface waters from 1990 to 2011: New constraints from concentration and isotope data. Marine Pollution Bulletin, 189, 114798. doi:10.1016/j.marpolbul.2023.114798

Tagliabue and co-authors (reference below) bring together new year-round observations and modelling of the ocean iron cycle as part of the GEOTRACES process study GApr13 to assess the prevailing conceptual understanding of how ocean dissolved iron is regulated. They find that the changes in dissolved iron observed over the year are not consistent with prevailing control by ocean iron binding ligands. Instead, a new model is advanced that emphasises the cycling of colloidal iron phases, out of equilibrium with iron binding ligands that fuel a hitherto not well acknowledged authigenic particulate iron phase.

When represented in a global model, this new understanding permits a better reproduction of observed dissolved and particulate iron data, as well as the seasonal dynamics across dissolved, particulate and ligand bound iron phases. This introduces the production of dissolution of authigenic mineral iron as a critical determinant of the ocean inventory of iron in the ocean.

Tagliabue, A., Kristen Buck , Laura Sofen , Benjamin Twining , Olivier Aumont , Philip Boyd , Salvatore Caprara , William Homoky , Daniela König, Rod Johnson , Daniel Ohnemus , Bettina Sohst , Peter Sedwick. Authigenic mineral phases as a driver of the upper ocean iron cycle. Nature (Accepted, In press).

GEOTRACES or GEOTRACES relevant cruises

- PS132, September 2022, Bremerhaven – Cape Town, Aerosol chemistry and surface waters Th isotopes
- DY157 (AMT30), Feb – Mar 2023, Falkland Islands – Southampton, ditto (both as part of the NERC-funded ThorMap project)
- Forthcoming PICCOLO project to seek GEOTRACES process study

New projects and/or funding

- NERC funding project: Silicon Cycling in Glaciated Environments (SiCLING). This will start in Feb 2024, with fieldwork in Svalbard and West Antarctic Peninsula.

GEOTRACES workshops and meetings organized

- UK GEOTRACES Townhall strategy meeting conducted June 28th
- Arianna Olivelli*, Rhiannon Jones*, Amber Annett, Oscar Branson, Suzanne Robinson*, and Hana Jurikova convened Session T3: “Chemistry of nutrients, trace elements and their isotopes in the Ancient, Modern and Future Oceans” at the Challenger 150 Conference (London, September 2022).

Outreach activities conducted

- Olivelli, A. Lead in the ocean: pollution, policies and dynamics. Invited talk at the Environmental Network of the UK Department for Transport.

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

- Tagliabue, A., Kristen Buck , Laura Sofen , Benjamin Twining , Olivier Aumont , Philip Boyd , Salvatore Caprara , William Homoky , Daniela König, Rod Johnson , Daniel Ohnemus , Bettina Sohst , Peter Sedwick. Authigenic mineral phases as a driver of the upper ocean iron cycle. Nature (Accepted, In press).
- Moore, O.W., Lisa Curti , Clare Woulds , James Bradley , Peyman Babakhani , Benjamin Mills , William Homoky , Ke-Qing Xiao , Andrew Bray , Ben Fisher , Majid Kazemian , Burkhard Kaulich , Andy Dale , Caroline Peacock Long-term organic carbon preservation enhanced by iron and manganese. Nature (Accepted, In press).
- Lough, A. J. M., Tagliabue, Alessandro, et al, Tracing differences in iron supply to the Mid-Atlantic Ridge valley between hydrothermal vent sites: implications for the addition of iron to the deep ocean. Biogeosciences, 20(2), 405-420. 2023
- Gonzalez-Santana, D., A. J. M. Lough, H. Planquette, G. Sarthou, Alessandro Tagliabue, and M. C. Lohan, The unaccounted dissolved iron (II) sink: Insights from dFe(II) concentrations in the deep Atlantic Ocean, Sci Total Environ, 161179, doi:10.1016/j.scitotenv.2022.161179. 2022
- Tagliabue, Alessandro, A. J. M. Lough, C. Vic, V. Roussenov, J. Gula, M. C. Lohan, J. A. Resing, and R. G. Williams, Mechanisms driving the dispersal of hydrothermal iron from the northern Mid Atlantic Ridge, Geophysical Research Letters, 49(22), doi:10.1029/2022gl100615. 2022
- Pham, A. L. D., O. Aumont, L. Ratnarajah, and Alessandro Tagliabue, Examining the Interaction Between Free-Living Bacteria and Iron in the Global Ocean, Global Biogeochemical Cycles, 36(5), doi:10.1029/2021gb007194. 2022
- Huang, Y., Tagliabue, Alessandro, & Cassar, N. Data-driven modeling of dissolved iron in the global ocean. Frontiers in Marine Science. doi:10.3389/fmars.2022.837183. 2022
- Tagliabue, Alessandro, A. R. Bowie, T. Holmes, P. Latour, P. van der Merwe, M. Gault-Ringold, K. Wuttig, and J. A. Resing, Constraining the Contribution of Hydrothermal Iron to Southern Ocean Export Production Using Deep Ocean Iron Observations, Frontiers in Marine Science, doi:10.3389/fmars.2022.754517. 2022
- Chmiel, R., et al. (incl. Alessandro Tagliabue), Major processes of the dissolved cobalt cycle in the North and equatorial Pacific Ocean, Biogeosciences, 19(9), 2365-2395, doi:10.5194/bg-19-2365-2022. 2022
- Hawco, N. J., Alessandro Tagliabue, and B. S. Twining, Manganese Limitation of Phytoplankton Physiology and Productivity in the Southern Ocean, Global Biogeochemical Cycles, 36(11), doi:10.1029/2022gb007382. 2022
- König, D., T. M. Conway, D. S. Hamilton, and Alessandro Tagliabue, Surface Ocean Biogeochemistry Regulates the Impact of Anthropogenic Aerosol Fe Deposition on the Cycling of Iron and Iron Isotopes in the North Pacific, Geophysical Research Letters, 49(13), doi:10.1029/2022gl098016. 2022
- Neil Wyatt, Antony Birchill, Simon Ussher, Angela Milne, Heather Bouman, Elizabeth Shoenfelt Troein, Katsiaryna Pabortsava, Alan Wright, Oliver Flanagan, Thomas S. Bibby, Adrian P Martin, C. Mark MoorePhytoplankton responses to dust addition in the FeMn co-limited eastern Pacific sub-Antarctic differ by source region, PNAS.
- Zhao, M., Mills, B.J., Homoky, W.B., and Peacock, C.L. Oxygenation of the Earth aided by mineral-organic carbon preservation. Nature Geoscience 16 (3), 262-267 (2023).

- Longman, J., Ann G Dunlea, Philipp Böning, Martin R Palmer, Thomas M Gernon, James McManus, Hayley R Manners, William B Homoky, Katharina Pahnke (2023) Release of tephra-hosted iron during early diagenesis fingerprinted by iron isotopes. Earth and Planetary Science Letters, 605, 118006 (2022)
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Completed GEOTRACES PhD or Master theses

- Margot Debyser 2023 (University of Edinburgh): https://era.ed.ac.uk/handle/1842/39796
- Daniela Koenig 2023 (University of Liverpool):

GEOTRACES presentations in international conferences

- Olivelli, A., Murphy, K., Rehkämper, M., van de Flierdt, T., Weiss, D. (2022). *Lead concentrations and isotope compositions of surface waters from the western South Atlantic Ocean.* Challenger 150 Conference
- Invited Keynote W. Homoky: "The unreconciled significance of terrigenous iron supply for the ocean carbon cycle" at 2022 Goldschmidt Conference: Session 12a: *The interplay*

between terrigenous fluxes and the biological pump as reflected by trace elements and their isotopes in the oceans, Hawaii, USA.

Submitted by Alessandro Tagliabue (a.tagliabue@liverpool.ac.uk).

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN UNITED STATES

May 1st, 2022 to April 30th, 2023

New GEOTRACES or GEOTRACES relevant scientific results

With 54 peer-reviewed publications in the past year (see attached list) there are too many results to describe them all. Therefore, the approach here is to begin by listing the 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 GEOTRACES section GP17-OCE, completed in January 2023, and planning for GEOTRACES section GP17-ANT.

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

Highlight Date	**Lead P.I.**	**Synopsis**
February 10, 2023	J. Fitzsimmons	Fitzsimmons and Conway (doi:10.1146/annurev-marine-032822-103431) present a complete review of iron and its isotope sources, internal cycling and sinks in the ocean, and summarize the end-member isotope signature of different iron sources (dust, sediments, hydrothermal venting). Their study contributes to improving our understanding of marine iron biogeochemistry and oceanic iron distributions by disentangling multiple iron sources, identifying the redox state of the sedimentary sources, distinguishing anthropogenic versus natural dust sources, and investigating different hydrothermal processes. Iron isotope fractionation might be used to understand the internal oceanic cycling of iron, including speciation changes, biological uptake, and particle scavenging. The authors propose an overview of future research needed to expand the utilization of this tracer and highlight the role that GEOTRACES has played in the development of this exciting oceanic tracer.
February 7, 2023	J.N. Smith	Smith and colleagues (doi:10.1029/2021JC018120) determined iodine-129 (^{129}I), chlorofluorocarbons (CFC-11) and sulfur hexafluoride (SF_6), in the Arctic Ocean in samples collected during two 2015 GEOTRACES cruises (GN01 and GN04). The resulting large, quasi-synoptic tracer data sets provide an opportunity to use these transient tracers to determine water mass mean ages and mixing rates in a highly stratified, arctic, marine system. Their

		calculated mean age sections conform to historical ideas of tracer ages while the mixing time is nearly constant in upper intermediate water, which reflects the influence of strong advective flow. The high mixing values found in the upper halocline are congruent with the nutrient maximum indicating that both are governed by winter shelf mixing processes.
October 17, 2022	S.J. John	John and co-authors (doi:10.1038/s41561-022-01045-7) test the lability and bioavailability of nickel (Ni) in the surface ocean using trace metal extraction from surface waters. They also test what controls the fluxes of Ni into the deeper ocean, with regards to the phosphate export and remineralization. A global Ni observation dataset was compiled to test Ni biogeochemical models (GEOTRACES Intermediate Data Product 2017) and data from samples collected during US GEOTRACES GP15. From the combined data-constrained global biogeochemical circulation modelling with culture experiments they find that Ni in oligotrophic gyres is both chemically and biologically labile and only minimally incorporated into diatom frustules. The authors suggest that slow depletion of Ni relative to macronutrients in upwelling regions can explain the residual Ni pool. They also propose that slower regeneration of Ni compared with macronutrients explains the strong Ni enrichment in deep waters.
September 15, 2022	A. Dastoor	Dastoor and co-authors (doi:10.1038/s43017-022-00269-w) revised the mercury (Hg) budget in the Arctic Ocean based on the recent Arctic Monitoring and Assessment Programme (www.amap.no) and new observations from 2015 GEOTRACES pan-Arctic transects. The revised Arctic Ocean mercury budget (~1,870 Mg) is lower than previous estimates (2,847–7,920 tons) and this implies a higher sensitivity to climate change and anthropogenic emissions. Particulate mercury settling (122 ± 55 tons per year) from surface waters to the shelf sediments is the largest mercury removal mechanism in the Arctic Ocean. The revised Arctic Ocean mass balance suggests that mercury burial in shelf sediments (42 ± 31 tons per year) may be underestimated by over 100% (52.2 ± 43.5 tons per year).
September 8, 2022	W.D. Gardner	Gardner and co-authors (doi: 10.1029/2021jc017970) presented an extensive description of particle concentrations and chlorophyll-a fluorescence (Chl-a) distribution along two GEOTRACES sections (GN01 and GN04) across the Arctic Ocean. The optical data acquired along the sections were paired with particle composition on filtered samples through the whole

		water column. Particle distributions in the Arctic are affected by currents, stratification, ice coverage and thickness, nutrient and light availability, and biological processes. The combination of cp (a proxy for particulate matter and particulate organic carbon) sections plotted with salinity, temperature, and Chl-a contours, adds a background and baseline across the entire Arctic Ocean that is useful in deciphering some of the particle dynamics of the Arctic.
July 6, 2022	S. Rahman	Rahman and co-authors (doi:10.1029/2022gb007330) using water mass mixing models along with the analysis of dissolved barium (dBa) from samples collected along GEOTRACES GA03 North Atlantic and GP16 Eastern Tropical Pacific sections, establish that most of dBa variations along those transects are controlled by conservative mixing. However, a close study of the non-conservative fractions, particulate excess Ba (pBa_{xs}), reveals that nonconservative processes are likely driving 30% of the supply/removal of dBa along both transects. Barite precipitation depletes dBa within oxygen minimum zones from concentrations predicted by water mass mixing, whereas inputs from continental margins, particle dissolution in the water column, and benthic diffusive flux raise dBa above predications. The authors also established that the global river dBa delivery (7 ± 4 Gmol $year^{-1}$; freshwater component) to the ocean is ∼50% lower than previous estimates. Associating radium isotopes to dBa distribution, they revealed that the western continental shelf of the North Atlantic supplies significant net new dBa to the ocean basin. This new addition of dBa is equal to or exceeds the combined dissolved plus desorbed particulate Ba global flux from rivers. They also present a re-evaluated residence time of dBa in the ocean, on the order of 3.5–5 kyr, ∼40%–60% lower than previously estimated.
June 21, 2022	Y. Huang	Huang and co-authors (doi:10.3389/fmars.2022.837183) present the first data-driven surface-to-seafloor dissolved iron (dFe) climatology (1°×1°resolution) based on the compilation of published dFe observations with environmental predictors from contemporaneous satellite observations and reanalysis products. The exponential growth in dFe measurements in the last three decades mostly from the GEOTRACES program provided the observational based distribution of dFe in the ocean; satellite observations and reanalysis products were used as the predictors in the machine learning (ML) algorithms. Based on the derived

		climatology and statistical tools, the authors confirmed that atmospheric iron input plays a major role in enriching the surface tropical waters. They also show that interplay between particle remineralization, scavenging, and current transport are controlling the deep-water Fe distribution. The climatology is used as a reference to evaluate the performance of 13 ocean biogeochemical models (OBM).
May 10, 2022	Y. Xiang	Xiang and co-authors (doi:10.1029/2021GB007292) compiled full ocean-depth size-fractionated (1–51 and >51 μm) particle concentration and composition of suspended particulate matter from three recent U.S. GEOTRACES cruises (GA03, GP16 and GN01) and combined these measurements with estimates of particle porosity to estimate particle sinking velocity and particle mass flux. The results show the importance of both particle characteristics and size distribution for mass fluxes, and similar methods can be applied to existing and future size-fractionated filtered particulate measurements to improve our understanding of the biological pump elsewhere.

US GEOTRACES continues to promote synthesis of GEOTRACES findings, and here we highlight three papers taking a broad look at mercury in the environment that have benefited from GEOTRACES contributions:

- Dastoor, A., H. Angot, J. Bieser, J. H. Christensen, T. A. Douglas, L.-E. Heimbürger-Boavida, M. Jiskra, R. P. Mason, D. S. McLagan, D. Obrist, P. M. Outridge, M. V. Petrova, A. Ryjkov, K. A. St. Pierre, A. T. Schartup, A. L. Soerensen, K. Toyota, O. Travnikov, S. J. Wilson, and C. Zdanowicz (2022), Arctic mercury cycling, Nature Reviews Earth & Environment, 3(4), 270-286, doi:10.1038/s43017-022-00269-w.
- Fisher, J. A., L. Schneider, A.-H. Fostier, S. Guerrero, J. R. D. Guimarães, C. Labuschagne, J. J. Leaner, L. G. Martin, R. P. Mason, V. Somerset, and C. Walters (2023), A synthesis of mercury research in the Southern Hemisphere, part 2: Anthropogenic perturbations, Ambio, 52(5), 918-937, doi:10.1007/s13280-023-01840-5.
- Schneider, L., J. A. Fisher, M. C. Diéguez, A.-H. Fostier, J. R. D. Guimaraes, J. J. Leaner, and R. Mason (2023), A synthesis of mercury research in the Southern Hemisphere, part 1: Natural processes, Ambio, 52(5), 897-917, doi:10.1007/s13280-023-01832-5.

GEOTRACES or GEOTRACES relevant cruises

- The first leg of the US GEOTRACES GP17 section (GP17-OCE) was completed earlier this year. The ship departed Papeete, Tahiti on 1 December 2022 and arrived in Punta Arenas, Chile on 25 January 2023. The chief scientist was Benjamin S. Twining of the Bigelow Laboratory for Ocean Sciences. Co-chief scientists were Jessica L. Fitzsimmons of Texas A&M University and Gregory A. Cutter of Old Dominion University. The cruise track is shown in Figure US-1.

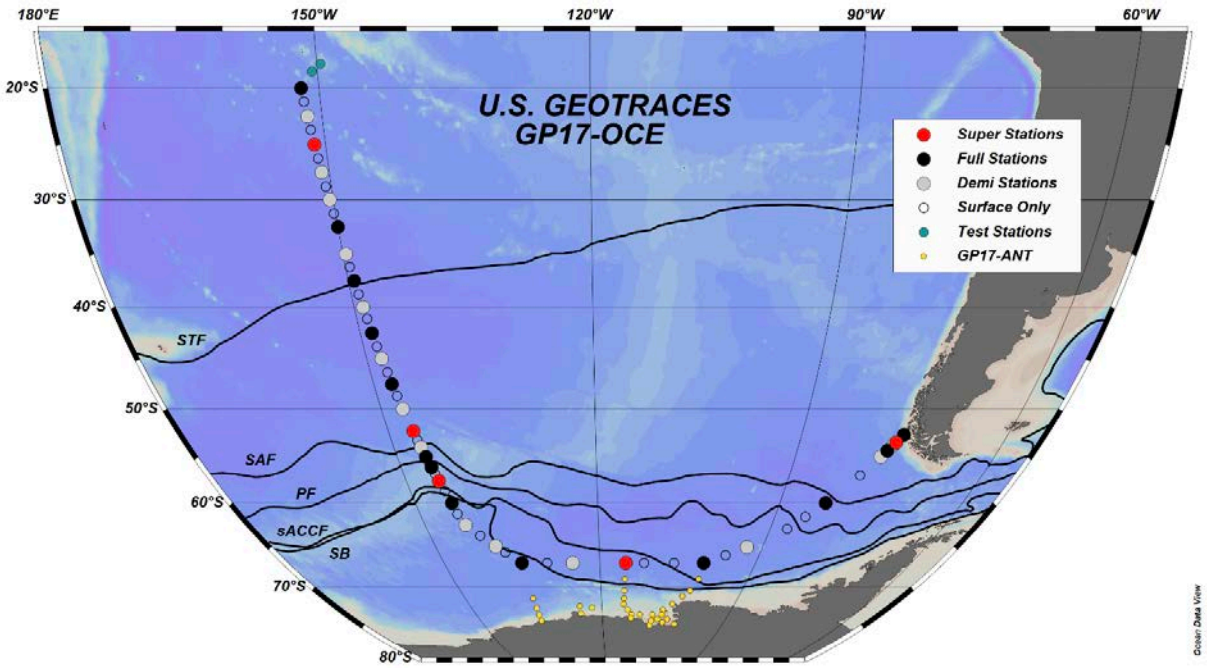

Figure US-1. *Track and station locations for GEOTRACES Section GP17-OCE.*

As illustrated in Figure US-1, sampling stations were compressed in the region of the Southern Ocean fronts during the southbound portion of the cruise in order to sample and characterize the trace element concentrations in each water mass as it surfaces in the Southern Ocean. Shipboard hydrographic data (Figure US-2) show that the stations (thin vertical lines) were well located to sample the various water masses, which are also identified in the figure.

Among the objectives of this section, scientists endeavored to determine the sources of iron to iron-limited ecosystems of the Southern Ocean, while also determining the biological uptake and internal cycling of iron and other trace elements. Shipboard measurement of dissolved iron concentrations (Peter Sedwick, Joseph Resing and Bettina Sohst) showed iron enrichment in Pacific Deep Water (PDW) and strong hydrothermal source of iron emitted by the Pacific-Antarctic Ridge (Figure US-3, top). Dissolved iron along zonal portion of the GP17-OCE section (Figure US-3, bottom) shows enrichment in PDW as it moves around South America into the Southern Ocean. US GEOTRACES investigators will attempt to combine dFe data with concentrations of noble gases and modelling to determine the amount of dFe carried to the Southern Ocean in PDW that reaches the surface where is it can be used by marine ecosystems.

New projects and/or funding

- This report finds us in the middle of completing GEOTRACES Section GP17. It was decided that 2 expeditions were needed to achieve all of the scientific objectives of the section. The first cruise, GP17-OCE, is described above. Planning for the second cruise is described below. All of the projects for GP17 were funded prior to to the current reporting period.

- The only new funding for US GEOTRACES during the current reporting period is that the US GEOTRACES project office received a three-year renewal of its funding, beginning 1 October 2022.

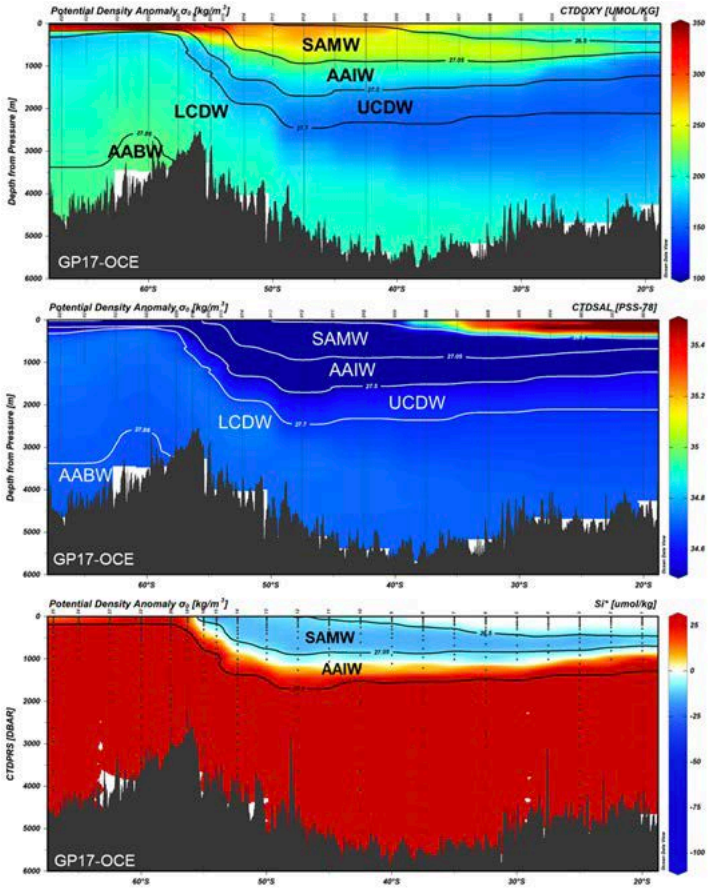

Figure US-2. *Hydrographic data along the meridional portion of GP17-OCE: oxygen (top), salinity (middle) and Si* (concentration of Si minus the concentration of nitrate; bottom). The thin vertical lines in the top and middle panels show the station locations, while the dots in the bottom panel show the sample depths at each station. Water masses are labelled according to traditional definitions: SAMW = Subantarctic Mode Water; AAIW = Antarctic Intermediate Water; UCDW = Upper Circumpolar Deep Water; LCDW = Lower Circumpolar Deep Water; and AABW = Antarctic Bottom Water. The low oxygen water at mid depth also encompasses Pacific Deep Water (PDW).*

GEOTRACES workshops and meetings organized

- The US GEOTRACES SSC met in person in Alexandria Virginia on 15 and 16 June 2022. After reviewing the status of existing and planned expeditions supporting GEOTRACES sections, the SSC decided that US GEOTRACES would undertake no more section cruises. The SSC reached this policy decision by concluding that the GEOTRACES global survey is nearly complete, and that it is time to transition into studies that are focused on specific processes that supply, cycle or remove TEIs in the ocean. US GEOTRACES also plans to pursue synthesis of GEOTRACES findings.
- A US GEOTRACES pre-cruise (GP17-ANT) logistics meeting was held on 13 and 14 March 2023 at Old Dominion University in Norfolk Virginia. About 60 participants attended in person and several more participated online. With 23 separately funded (by US NSF) projects participating in the GP17-ANT section, there were a large number of logistic issues to be resolved. GP17-ANT is the most logistically challenging cruise yet undertaken by US

GEOTRACES and the planning continues on a regular basis. The cruise is scheduled to depart Punta Arenas in late November 2023.

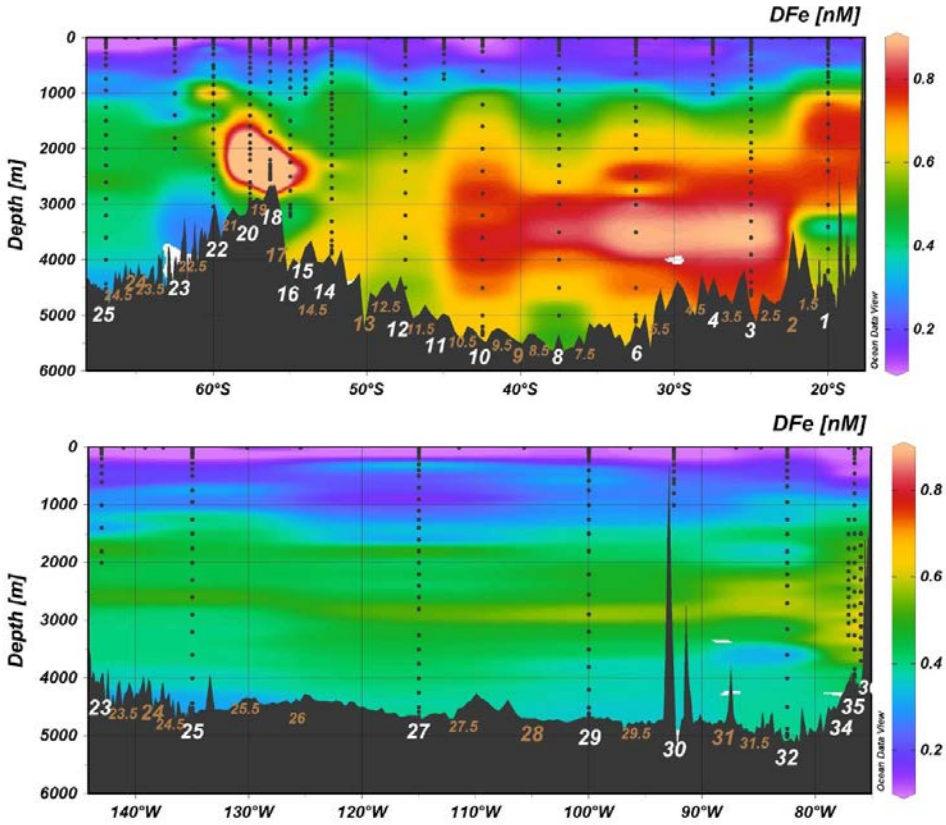

Figure US-3. *Top: Shipboard dissolved iron concentration along meridional portion of the GP17-OCE section. Dissolved iron is enriched in Pacific Deep Water from approximately 25° south to 45° south. High concentrations of dissolved iron are also observed around the crest of the Pacific-Antarctic Ridge. Bottom: Shipboard dissolved iron concentration along zonal portion of the GP17-OCE section. Dissolved iron is enriched in Pacific Deep Water as it moves around South America into the Southern Ocean. White numbers at the bottom show the cruise stations at which iron concentration were measured aboard the ship.*

Outreach activities conducted

- For the first time, US GEOTRACES attempted to create a virtual reality experience during GP17-OCE. Production of this virtual reality outreach product was under the direction of Christina Wiederwohl, at Texas A&M University, who presented a first look at the production during the 2023 Goldschmidt meeting in a presentation entitled "Reimagining oceanographic biogeochemistry: bringing the ocean to the community through virtual reality".

- The US GEOTRACES website < https://usgeotraces.ldeo.columbia.edu> is currently being re-designed to accommodate educational and outreach materials that can be used by the US GEOTRACES Community.

Other GEOTRACES activities

- The US GEOTRACES project office continues to offer small amounts of funding (<$5k) to support travel and/or publication costs related to synthesis papers. Currently, the project office is providing travel support for a synthesis group working on trace elements in the halocline of the Arctic Ocean. A draft of the paper produced by this group is currently under internal review.

New GEOTRACES or GEOTRACES-relevant publications (published or in press) *(If possible, please identify those publications acknowledging SCOR funding)*

- A list of publications is appended at the end of this report

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

- 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 < boba@ldeo.columbia.edu>

Claudia Giulivi < claudiag@ldeo.columbia.edu>

2022-2023 US GEOTRACES and GEOTRACES-related Publications
References 1 May 2022 – 30 April 2023 plus papers missed in previous reports

54 publications, 5 PhD Dissertations

US GEOTRACES and Related Publications

Related Publications include:

1) US GEOTRACES PIs publishing results that support the GEOTRACES mission but the results are not from GEOTRACES cruises,
2) Papers that use data from US GEOTRACES cruises but do not include US GEOTRACES PIs as co-authors, and
3) Papers describing international collaboration on which US GEOTRACES PIs appear as co-authors.

Publications

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ANNUAL REPORT ON BIOGEOTRACES ACTIVITIES

September 2022 to July 2023

by Maite Maldonado & all co-authors mentioned below

Promoting internationally BioGEOTRACES and the GEOTRACES IDP2021

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)

GEOTRACES IDP 2021 & CMAP

To facilitate co-localization of GEOTRACES chemical and physical data sets with biological data sets generated by the broader biological oceanography research community, the Simons CMAP team has begun ingestion of a portion of the IDP2021. The Simons Collaborative Marine Atlas Project (CMAP; (Ashkezari et al., 2021, https://simonscmap.com/) 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 GEOTRACES sections could input the latitude / longitude / depth / time information from the cruise path to CMAP and retrieve any other data sources matching those spatiotemporal coordinates.

The developers of CMAP (Ashkezari and Armbrust, University of Washington; Ashkezari et al., 2021) reached out to the GEOTRACES Data Management Committee in the spring of 2022 in order to improve cross-platform access to diverse GEOTRACES data sets, including the BioGEOTRACES 'omics data. Members of the GEOTRACES DMC have had several meetings with Dr. Diana Haring, a Data Engineer at the University of Washington, School of Oceanography. So far, the GEOTRACES IDP2021 CTD sensor data have been ingested (inclusive data 2007-01-19 through 2018-11-23) in CMAP, can be found at the following URL: https://simonscmap.com/catalog/datasets/GEOTRACES_Sensor; and can be easily downloaded at CMAP website.

Information on the Fair Use Agreement is prominently displayed for each GEOTRACES data product on CMAP to ensure compliance with GEOTRACES' policies on data use and reuse. Further information on data sources, data distribution centers, and the IDP2021 is further referenced on each GEOTRACES data product page within CMAP.

Dr. Diana Haring and team are also working on adding links to detailed cruise documents, such as the cruise report or (in the GEOTRACES example) to dedicated cruise pages maintained by BODC.

Datasets in the GEOTRACES IDP 2021

The BioGEOTRACES data sets from Chisholm Laboratory (MIT) that were incorporated in the GEOTRACES IDP2021 include data from GA02, GA03, GA10, and GP13 sections: a) metagenomic data (Biller et al., 2018), b) 16S/18S rRNA gene amplicon sequences to facilitate high resolution taxonomy (McNichol et al., 2021), and c) 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).

A major challenge while incorporating the omics data in the GEOTRACES IDP2021 was that the omics data are dynamic (changes depending on ever-growing genome reference databases) while the TEI data is static.
The solution was to provide linkages between the omics data in NCBI (i.e., 480 Metagenomes; 14 Single-Cell genomes; and 273 16S-18S-rRNA gene analyses) and EMBL-EBI (480 16S/18S amplicons for microbial community taxonomic & functional structure and abundance) websites and the GEOTRACES IDP 2021 data. Thus, in the GEOTRACES IDP 2021, one can find 4 types of sample descriptors for omics data in the Metadata variables (which are associated with specific GEOTRACES bottle numbers): accession numbers at NCBI or EMBL-EBI; or links to functional and taxonomic analyses webpages.

Therefore, the OMICs linkages in GEOTRACES IDP 2021 Metadata VARIABLES # are:

Variable # 11. NCBI_Metagenome_BioSample accession #:
Variable #13. NCBI_16S-18S-rRNA-gene_BioSample accession #:
@ https://www.ncbi.nlm.nih.gov/biosample/
Variable #12. NCBI_Single_cell_genome_BioProject accession #:
@ https://www.ncbi.nlm.nih.gov/bioproject/
Variable #14. EMBL_EBI_Metagenome_MGNIFY_Analysis_Accession #:
@https://www.ebi.ac.uk/metagenomics/analyses/MGYA

For the next IDP

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).

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

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Twining led the GP17-OCE section cruise across the South Pacific Gyre and Southern Ocean. Samples were collected for several BioGEOTRACES parameters, including cellular metal quotas (Twining), proteins (Saito), 16s/18s amplicon sequencing and some eukaryote metatranscriptomics (2 depths: Dreux Chappell and Sophie Clayton), photosynthetic pigments (Twining), particulate ATP (Alexander Bochdansky), phytoplankton community composition (via Imaging FlowCytobot; Twining).

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

NSF AccelNet Grant

An NSF AccelNet grant was recently funded for the development of BioGeoSCAPES "AccelNet - Implementation: Development of an International Network for the Study of Ocean Metabolism and Nutrient Cycles on a Changing Planet (Biogeoscapes)". The Accel-Net program (Accelerating Research

through International Network-to-Network Collaborations program) is designed to accelerate the process of scientific discovery and prepare the next generation of U.S. researchers for multiteam international collaborations. This grant will fund international workshops on science integration and planning, informatics and data management, intercalibration review and assessment, and science implementation and infrastructure, and modeling and data integration. In addition, there are significant educational components including a BioGeoSCAPES summer school and a partnership with the Coastal Ocean Environment Summer School in Ghana. While this grant does not fund science directly, it is hoped to catalyze the international coordination needed to launch the BioGeoSCAPES program. Numerous US and international researchers have contributed to the ongoing BioGeoSCAPES effort through participation in workshops and conference sessions as well as in letters of support and contributing to the writing of this grant.

Publications

2023

Chmiel, R.J., Kellogg, R.M., Rao, D., Moran, D.M., DiTullio, G.R. and Saito, M.A., 2023. Low Cobalt Inventories in the Amundsen and Ross Seas Driven by High Demand for Labile Cobalt Uptake Among Native Phytoplankton Communities. *EGUsphere*, *2023*, pp.1-47.

2022

Kellogg, R.M., Moosburner, M.A., Cohen, N.R., Hawco, N.J., McIlvin, M.R., Moran, D.M., DiTullio, G.R., Subhas, A.V., Allen, A.E. and Saito, M.A., 2022. Adaptive responses of marine diatoms to zinc scarcity and ecological implications. *Nature Communications*, *13*(1), pp.1-13. https://www.nature.com/articles/s41467-022-29603-y

Marshall, T., Granger, J., Casciotti, K.L., Dähnke, K., Emeis, K.C., Marconi, D., McIlvin, M.R., Noble, A.E., Saito, M.A., Sigman, D.M. and Fawcett, S.E., 2022. The Angola Gyre is a hotspot of dinitrogen fixation in the South Atlantic Ocean. *Communications Earth & Environment*, *3*(1), p.151.

2021

Mazzotta, M.G., McIlvin, M.R., Moran, D.M., Wang, D.T., Bidle, K.D., Lamborg, C.H. and Saito, M.A., 2021. Characterization of the metalloproteome of Pseudoalteromonas (BB2-AT2): Biogeochemical underpinnings for zinc, manganese, cobalt, and nickel cycling in a ubiquitous marine heterotroph. *Metallomics*, *13*(12), p.mfab060. https://pubmed.ncbi.nlm.nih.gov/34694406/

2020

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

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 data workshop was conducted in September of 2021 and a manuscript has been published: Saito, M. et al. 2019. Progress and Challenges in Ocean Metaproteomics and Proposed Best Practices for Data Sharing DOI: 10.1021/acs.jproteome.8b00761. J. Proteome Res. 2019, 18, 1461−1476

***The Ocean Protein Portal*:** https://proteinportal.whoi.edu/, received renewed NSF funding in 2021 to develop a full version for enhanced capabilities and sustainability.

Saito MA, Saunders JK, Chagnon M, Gaylord DA, Shepherd A, Held NA, Dupont C, Symmonds N, York A, Charron M, Kinkade DB. Development of an Ocean Protein Portal for Interactive Discovery and Education. J Proteome Res. 2021 Jan 1;20(1):326-336. doi: 10.1021/acs.jproteome.0c00382. Epub 2020 Dec 17. PMID: 32897077; PMCID: PMC8036901

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. These GP15 protein datasets was submitted for the 2021 IDP, and a manuscript was preparation by graduate student Becca Chmiel (see above).

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)

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

Publications

Manuel Colombo, Julie LaRoche, Dhwani Desai, Jingxuan Li, Maria T. Maldonado. 2023. Control of particulate manganese (Mn) cycling in halocline Arctic Ocean waters by putative Mn-oxidizing bacterial dynamics. *Limnology and Oceanography*, in press

Robicheau, B.M., Tolman, J., Bertrand, E.M., Laroche, J., 2022. Highly-resolved interannual phytoplankton community dynamics of the coastal Northwest Atlantic. ISME Communications; https://doi.org/10.1038/s43705-022-00119-2

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

ANNUAL REPORT ON BIOGEOSCAPES ACTIVITIES

September 2022 to July 2023

We continue to communicate ongoing BioGeoSCAPES activities in our new website (https://biogeoscapes.org/events/). In 2021, there were various efforts to acquire funding to coordinate the upcoming BioGeoSCAPES program at an international level. The upcoming BioGeoSCAPES program was recently awarded a US National Science Foundation Accel-Net award to contribute to the development and launch of the international BioGeoSCAPES program, entitled **NSF AccelNet award *Development of an International Network for the Study of Ocean Metabolism and Nutrient Cycles on a Changing Planet (BioGeoSCAPES)***. We are hoping to launch the program in 2025/2026.

The Accel-Net program focuses on the acceleration of international networks to "tackle grand research challenges that require significant coordinated international efforts". The 5-year project will support four international workshops: 1) science planning, 2) intercalibration review and assessment, 3) informatics and data management, and 4) integration with modeling, to help with BioGeoSCAPES program development. Extensive educational activities are also planned, including BioGeoSCAPES summer schools and inter-laboratory exchanges for early career researchers.

The Accel-Net program does not directly fund scientific research activities, but instead focuses on these critical international networking efforts. Improvements to the BioGeoSCAPES website and newsletter communications are also planned. Webinars will begin at the end of January 2023 as pre-work preparation for the workshops. Among other activities, we are also planning the 1st International Science Plan Meeting workshop in November 6-9, 2023, in Woods Hole Oceanographic Institution (Falmouth, Massachusetts, US). In preparation for this, we are asking all nations that would like to be involved to complete their National Planning Workshops. National Planning Workshops have occurred in Japan, the UK, Canada, China, the US, France, Finland, the Netherlands, PanEuropean (Croatia), etc.

Public interest to date:

Self-identified ambassadors from more than 26 nations
~ **300** newsletter subscribers
>900 followers; #biogeoscapes
2513 unique users from **60 countries** @ **www.biogeoscapes.org**
44 abstracts submitted to Ocean Sciences 2022 BioGeoSCAPES session

- **New BioGeoSCAPES Fellows Program:** see more info here.

We are excited to launch a BioGeoSCAPES Fellows program funded by the **NSF AccelNet award *Development of an International Network for the Study of Ocean Metabolism and Nutrient Cycles on a Changing Planet (BioGeoSCAPES)***. This new program will bring together an international, interdisciplinary cohort of early career (postdocs and senior graduate students) researchers working in the areas of ocean metabolism, biogeochemical cycling, biological oceanography, chemical oceanography, and marine microbiology. We encourage applicants from both experimental and modeling backgrounds.

Program goals

1. Develop an international community of early career BioGeoSCAPES scientists
2. Catalyze research collaborations among BioGeoSCAPES science disciplines
3. Support international collaborations and development of global BioGeoSCAPES scientist communities
4. Develop the next generation of leaders in ocean biogeochemistry

Each Fellow will each receive up to 5,000 USD professional development award that can be used for travel related to laboratory exchanges, courses, workshops or conferences (this award can be spent over

a ~2 year period). A cohort of up to 8 Fellows will participate in monthly networking events for at least one year, as well as an in-person workshop in summer 2024.

- **WEBINAR Series**

Bioinformatics for BioGeoSCAPES: Panel Discussion
July 26, 2023 @ time to be announced

Organizing Intercalibration Efforts for BioGeoSCAPES: Panel Discussion
January 25 @ 11am-1pm EST

Overview:
Producing data that can be effectively compared across space and time is a critical aspect to developing an international microbial biogeochemistry collaborative program. Intercalibration activities, involving validation of precision and accuracy and the development of intercomparison standards, are foundational to the production of interoperable data. With BioGeoSCAPES aiming to launch mid-decade further progress must be made to ensure high quality data collection. This virtual panel will hear perspectives from a variety of communities (nucleic acids, metabolomics, proteomics, rates) and encourage brainstorming through small group discussions. This panel discussion initiates the pre-work effort building towards an eventual in person BioGeoSCAPES workshop in the coming years.

- **National workshops:**

Upcoming:
Italy national workshop: September 26 and 27, 2023

Completed in 2023:
Finland national workshop: May 11, 2023, organized by David N. Thomas
Netherlands national workshop: February 2023, organized by Rob Middag and Susanne Wilken.
2nd Canada national workshop: May 1-2, 2023 (Halifax) organized by and Erin Bertrand and Maite Maldonado

Ongoing Intercalibration and standardization efforts

- **Ocean Metabolomics Intercalibration and Standardization; Labile DOM Workshop: September 19-20, 2022, University of Georgia, Athens (GA) For a review see this link.** Session on "*Strategies to address methodological challenges; Roadblocks and key points necessary for standardization across C-CoMP and BioGeoSCAPES; Data analysis challenges and desirable integration with other 'omics*"
- **An OCB Ocean Nucleic Acids 'omics Intercalibration and Standardization** Workshop occurred in January of 2020. The workshop report provides an overview of the current status of nucleic acid 'omics approaches and proposes future activities towards community intercalibration and standardization efforts.

- **An Ocean Metaproteomic Intercomparison Workshop** occurred in September of 2021, sponsored by the US Ocean Carbon and Biogeochemistry office. The workshop examined the results of the first ocean metaproteomic intercomparison, using samples from the North Atlantic. A total of 16 laboratories participated in the study: 9 in the wet-lab component and 9 in the informatic component, with some labs participating in both activities. The results demonstrated reproducible protein identifications and quantitation, and a manuscript of the results is being prepared for publication. Future metaproteomic intercalibration efforts will be planned as a follow-up.

Past Events:

Meetings

- The US National BioGeoSCAPES Workshop report was released in January of 2023
- The international Royal Society Marine Microbes in a Changing Climate meeting occurred Sept 12-13 2022, organized by A. Tagliabue, T. Mock, J.Robidart, P. Sanchez-Baracaldo.
- 6-8 Sept 2022, Challenger 150: The Challenger Society Conference 2022 in London included several BioGeoSCAPES presentations.
- A Pan-European workshop, EU 2022 Euromarine, to further foster BioGeoSCAPES collaborations, occurred in June of 2022 in Zagreb, Croatia. Organized by Martha Gledhill (GEOMAR Helmholtz Centre for Ocean Research) and Sandi Orlic (Institut Ruđer Bošković, Zagreb, Croatia). For further details contact Martha Gledhill (mgledhill@geomar.de)
- BioGeoSCAPES had a major presence at the 2022 Ocean Sciences Meeting Virtual Meeting, February 24 - March 4, 2022, with 44 submissions distributed into 5 sessions and 80-100 participants attending each session. The session was titled: "Towards BioGeoSCAPES: Linking cellular metabolism with ocean biogeochemistry" under the topic Ocean Biology and Biogeochemistry.

Cruises with a BioGeoSCAPES-like mission, aiming to elucidate the coupling between microbial ecology and functionality with nutrient cycles:

Completed cruises:

- **INDIA:** CSIR-NIO, lndian Ocean, Mapping the Genomes, 90 days, March-May 2021; ~ 30 scientists, RV Sindhu Sadhana; (Sunil Kumar Singh)
- **INTERNATIONAL**: Tara Oceans mission microbiomes was completed. For nearly two years the laboratory-ship Tara travelled along the coasts of S. America, into the Weddell Sea and up the coast of west Africa. Overseen by the European AtlantECO program alongside the Foundation Tara Ocean, with scientific partners including the CNRS, CEA and EMBL, this mission involves 42 research structures across the world in studying the benefits of the ocean microbiome and its interactions with the climate and pollution.
- **FRANCE:** Swings cruise completed: collected samples for abundance of heterotrophic and autotrophic prokaryotes and pico- and nano-eukaryotes (flow cytometry), prokaryotic diversity, metatranscriptomics and metaproteomics

Planned cruises:

- **JAPAN**: June 2023, part of GEOTRACES GP22, PI: Hajime Obata in the NW Pacific (Leg 1 and 2 completed, Leg 3, June 2023)
- **TAIWAN:** August 2023 (lead PI: Haojia Ren, National Taiwan University). Tung-Yuan and Chuan Ku: temporal variation on community structure of phytoplankton and interactions with microbes-phytoplankton
- **AUSTRALIA:** Jan-Feb 2024: Multidisciplinary Investigations of the Southern Ocean (MISO): Linking physics, biogeochemistry, plankton, aerosols, clouds, and climate" proposal for shiptime on the RV Investigator (Phil Boyd)
- **SOUTH AFRICA:** SAPRI, submitted to the South African Research Infrastructure program, Dept. Science and Innovation (Daniel Adams)

Science workshops

We are planning to have the 1st International Science Plan Meeting workshop November 6-9 (2023) in Woods Hole Oceanographic Institution (Falmouth, Massachusetts, US). In preparation for this, we are

asking all nations, that would like to be involved, to complete their National Planning Workshops. In these national workshops, we encourage you to discuss the following questions:

1) *Thoughts on* preliminary BioGeoSCAPES Mission statement *this? How could this be improved?* "**To improve our understanding of the functioning and regulation of ocean metabolism and its interaction with nutrient cycling within the context of a hierarchical seascape perspective"**.
2) *How would your nation best contribute to BioGeoSCAPES efforts?* – e.g. fieldwork, laboratory work, modelling, intercalibration efforts, project coordination, data management, bioinformatics
3) *What science questions are most important to your nation within the broad scope of BioGeoSCAPES on a 10-year timeframe?*
4) Are there any impediments that the international community could seek to mitigate via training or collaboration?

After your workshop, we would like to request a 2-page summary report answering the questions above. If you have any questions, please contact Maite Maldonado (mmaldonado@eoas.ubc.ca)

In addition to the website (www.biogeoscapes.org), 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.

If you would like to get involved in BioGeoSCAPES activities, please contact your country's ambassador listed here. If your country is not listed and you wish to be added as a representative, please contact us (Mak Saito, Alessandro Tagliabue or Maite Maldonado).

On behalf of BioGeoSCAPES consortium and Accel-Net. Thanksfor showing interest in BioGeoSCAPES!

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