

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN GERMANY

APRIL 1ST, 2021 TO APRIL 30ST, 2022

GEOTRACES or GEOTRACES relevant cruises

- Research cruise RainbowPlume ('Rainbow non-boyant hydrothermal plume GEOTRACES study') as part of German Corona Cruise Proposal Round. Cruise M176/2 (Emden_Germany – Emden_Germany) was sailed in period September 1 to October 5, 2021 (RV Meteor) and investigated plume geochemistry at Rainbow vent field (mid Atlantic Ridge). PIs Achterberg, Koschinsky, Browning, Frank, and important involvement by Jan Scholten and Walter Geibert. We will apply for GEOTRACES Process Study status.
- GP21 section cruise on FS Sonne (SO289, 'Biogeochemistry of trace metals and their isotopes in the South Pacific Ocean. Ocean Region: South Pacific between Chile and New Zealand') has been sailed in the period February 18-April 8 2022 PIs Achterberg, Frank, Koschinsky, and important involvement by Jan Scholten, Walter Geibert, S Galer, W Abouchami. Valparaiso_Chile – Nouméa_New Caledonia
- SO290 Nouméa-Nouméa, southeastern Tasman Sea (PI: K.Pahnke). Water column sampling for Nd and Si isotopes and REE (plus hydrography and nutrients) at 20 stations.
- GP11 section cruise on FS Sonne (SO298), in the Equatorial Pacific Ocean is scheduled for the period April 11- May 30 2023 PIs Achterberg, Frank, Koschinsky, and important involvement by Walter Geibert, S Galer, W Abouchami.
- Polarstern cruises PS133/1 and PS133/2 South Georgia and the adjoining Antarctic Circumpolar Current ('IslandImpact') are scheduled for late 2022. Process study application is under consideration.
- Heincke training cruise HE603 is scheduled for 12 July-15 July 2022 (GEOTRACES Summer School)

New projects and/or funding

- DFG Funding for Jan Scholten (Kiel Uni), Eric Achterberg & Aaron Beck (GEOMAR) and Walter Geibert (AWI) for two postdocs to conduct Ra, Th and He isotope work on GEOTRACES cruises. Postdocs (Dr L Vieira and Dr. X. Chen) started in September 2021 and February 2022, respectively.
- Funding of one Postdoc for 18 months with project 'Rainbow non-boyant hydrothermal plume GEOTRACES study', related to research cruise M176/2
- Funding of one Postdoc for 26 months within project 'Biogeochemistry of trace metals and their isotopes in the South Pacific Ocean. Ocean Region: South Pacific between Chile and New Zealand', related to research cruise SO289
- Funding for GEOTRACES Summer School 2022 (92k€) was received from Volkswagen Stiftung. Additional support by US GEOTRACES and SCOR for travel bursaries.

GEOTRACES workshops and meetings organised

The GEOTRACES Summer School 2022 was largely organized in the reporting period but will only take place in July 2022.

Outreach activities conducted (please list any outreach/educational material available that could be shared through the GEOTRACES web site)

- Press release for South Pacific GEOTRACES cruise GP21. <https://www.geomar.de/en/news/article/tracing-trace-elements>

Other GEOTRACES activities

- Leading role in creation of the IDP2021 (R.Schlitzer)
- Leading role in committee work (E. Achterberg: SSC. W. Geibert: co-chair S&I committee, now SSC)

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

- Ardiningsih, Indah, Zhu, Kechen, Lodeiro, Pablo, Gledhill, Martha, Reichart, Gert-Jan, Achterberg, Eric P., Middag, Rob and Gerringa, Loes J. A. (2021) Iron Speciation in Fram Strait and Over the Northeast Greenland Shelf: An Inter-Comparison Study of Voltammetric Methods *Frontiers in Marine Science*, 7 . Art.Nr. 609379. DOI 10.3389/fmars.2020.609379.
- Balaguer, J., Koch, F., Hassler, C., Trimborn, S. 2022 Iron and manganese co-limit the growth of two phytoplankton groups dominant at two locations of the Drake Passage. *Nature Biol Comm*, doi:10.1038/s42003-022-03148-8.
- Böckmann, S., Koch, F., Meyer, B., Pausch, F., Iversen, M., Driscoll, R., Laglera, L. M., Hassler, C., Trimborn, S. 2021. Salp fecal pellets release more bioavailable iron to Southern Ocean phytoplankton than krill fecal pellets. *Current Biology*, doi:10.1016/j.cub.2021.02.033.
- Browning, T.J., Achterberg, E.P., Engel, A., Mawji, E. (2021). Manganese co-limitation of phytoplankton growth and major nutrient drawdown in the Southern Ocean. *Nature Communications* 10.1038/s41467-021-21122-6.
- Browning, T. J., Al-Hashem, A. A., Hopwood, M. J., Engel, A., Belkin, I. M., Wakefield, E. D., et al. (2021). Iron regulation of North Atlantic eddy phytoplankton productivity. *Geophysical Research Letters*, 48, e2020GL091403. <https://doi.org/10.1029/2020GL091403>
- 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>
- de Carvalho, L. M.; Hollister, A.P., Trindade, C.; Gledhill, M. and Koschinsky, A. (2021) Distribution and size fractionation of nickel and cobalt species along the Amazon estuary and mixing plume. *Marine Chemistry* 236: 104019. <https://doi.org/10.1016/j.marchem.2021.104019>
- Geißler, F., Martínez-Cabanas, M., Lodeiro, P., & Achterberg, E. P. (2021). Optimization of hyphenated asymmetric flow field-flow fractionation for the analysis of silver nanoparticles in aqueous solutions. *Analytical and Bioanalytical Chemistry*, 413, 6889-6904.
- Geißler, F., Achterberg, E.P., Beaton, A.D., Hopwood, M.J., Esposito, M., Mowlem, M.C., Connelly, D.P., Wallace, D. (2021). Lab-on-chip analyser for the in situ determination of dissolved manganese in seawater. *Sci Rep* 11, 2382. <https://doi.org/10.1038/s41598-021-81779-3>.

- Genuchten, C.M. van, Hopwood, M.J., Liu, T., Krause, J., Achterberg, E.P., Rosing, M.T., Meire, L. (2022). Solid-phase Mn speciation in suspended particles along meltwater-influenced fjords of West Greenland, *Geochimica et Cosmochimica Acta*, 326, 180-198, <https://doi.org/10.1016/j.gca.2022.04.003>.
- GEOTRACES Intermediate Data Product Group (2021). The GEOTRACES Intermediate Data Product 2021 (IDP2021). NERC EDS British Oceanographic Data Centre NOC. DOI: 10.5285/cf2d9ba9-d51d-3b7c-e053-8486abc0f5fd
- 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.
- Hollister, A. P.; Whitby, H.; Seidel, M.; Lodeiro, P.; Gledhill, M.; Koschinsky, A. (2021) Dissolved concentrations and organic speciation of copper in the Amazon estuary and mixing plume. *Marine Chemistry* 234: 104005. doi: 10.1016/j.marchem.2021.104005
- Hsieh, Y.-T., Geibert, W., Woodward, E. M. S., Wyatt, N. J., Lohan, M. C., Achterberg, E. P., and Henderson, G. M. (2021). Radium-228-derived ocean mixing and trace element inputs in the South Atlantic, *Biogeosciences* 18 (5), 1645-1671.
- Krause, J., Hopwood M.J., Höfer, J., Krisch, S., Achterberg, E.P., Alarcón, E., Carroll, D., González, H.E., Juul-Pedersen, T., Liu, T, Lodeiro, P., Meire, L., Rosing, M.T. (2021). Trace Element (Fe, Co, Ni and Cu) Dynamics Across the Salinity Gradient in Arctic and Antarctic Glacier Fjords. *Frontiers in Earth Science*. DOI:10.3389/feart.2021.725279.
- Krisch, S., Hopwood, M.J., Schaffer, J., Al-Hashem, A., Höfer, J., Rutgers van der Loeff, M.M., Conway, T.M., Summers, B.A, Lodeiro, P., Ardiningsih, I., Steffens, T., Achterberg, E.P. (2021). The 79°N Glacier cavity modulates subglacial iron export to the NE Greenland Shelf. *Nature Communications*, 12 (1), 1-13.
- Liguori, B.T.P., Ehlert, C., Nöthig, E.-M., van Ooijen, J.C., Pahnke, K., 2021. The Transpolar Drift Influence on the Arctic Ocean Silicon Cycle. *Journal of Geophysical Research: Oceans* 126, e2021JC017352. doi: <https://doi.org/10.1029/2021JC017352>.
- Lodeiro, P., Rey-Castro, C., David, C., Puy, J., Achterberg, E. P., & Gledhill, M. Seasonal variations in proton binding characteristics of dissolved organic matter isolated from the Southwest Baltic Sea. *Environmental Science & Technology* . DOI 10.1021/acs.est.1c04773.
- Marsay, C. and Achterberg, E.P. (2021). Particulate iron and other trace elements in near-surface waters of the high latitude North Atlantic following the 2010 Eyjafjallajökull eruption *Marine Chemistry*, <https://doi.org/10.1016/j.marchem.2021.103959>.
- McCain, J.S.P., A. Tagliabue, E. Susko, E. P. Achterberg, A. E. Allen, E. M. Bertrand (2021).
- Cellular costs underpin micronutrient limitation in phytoplankton. *Science Advances*, 7, eabg6501.
- Nehir, M., Esposito, M., Begler, C., Frank, C., Zielinski, O., Achterberg, E.P. (2021). Optimized Calibration and Data Processing Procedures of OPUS Optical Sensor for High-Resolution In Situ Monitoring of Nitrate in Seawater. *Frontiers in Marine Sciences*. DOI: 10.3389/fmars.2021.663800.
- Paffrath, R., Pahnke, K., Böning, P., Rutgers van der Loeff, M., Valk, O., Gdaniec, S., Planquette, H., 2021. Seawater-Particle Interactions of Rare Earth Elements and Neodymium Isotopes in the Deep Central Arctic Ocean. *Journal of Geophysical Research: Oceans* 126, e2021JC017423. doi: <https://doi.org/10.1029/2021JC017423>.
- Paffrath, R., Laukert, G., Bauch, D., Rutgers van der Loeff, M., Pahnke, K., 2021. Separating individual contributions of major Siberian rivers in the Transpolar Drift of the Arctic Ocean. *Sci. Rep.* 11, 8216. doi: 10.1038/s41598-021-86948-y.

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- Somes, C.,J., Dale, A.W., Wallmann, K., Scholz, F., Yao, W., Oschlies, A., Muglia, J., Schmittner, A., Achterberg, E.P. (2021). Constraining global marine iron source and scavenging fluxes with GEOTRACES dissolved iron measurements in an ocean biogeochemical model. *Global Biogeochemical Cycles*, DOI: 10.1029/2021GB006948.
- Steiner, Z., Sarkar, A., Liu, X., Berelson, W.M., Adkins, J.F., Sabu, P., Prakash, S., Vinaychandran, P.N., Byrne, R.H., Achterberg, E.P., Turchyn, A.V. (2021). On calcium-to-alkalinity anomalies in the North Pacific, Red Sea, Indian Ocean and Southern Ocean. *Geochimica et Cosmochimica Acta*, <https://doi.org/10.1016/j.gca.2021.03.027>.
- Vergara-Jara, M. J., Hopwood, M. J., Browning, T. J., Rapp, I., Torres, R., Reid, B., Achterberg, E. P., and Iriarte, J. L. (2021). A mosaic of phytoplankton responses across Patagonia, the southeast Pacific and the southwest Atlantic to ash deposition and trace metal release from the Calbuco volcanic eruption in 2015, *Ocean Sci.*, 17, 561–578, <https://doi.org/10.5194/os-17-561-2021>.
- Vieira, L. H., W. Geibert, I. Stimac, D. Koehler, and M. M. Rutgers van der Loeff (2021), The analysis of ²²⁶Ra in 1-liter seawater by isotope dilution via single-collector sector-field ICP-MS, *Limnology and Oceanography: Methods*.
- Wallmann, K., José, Y.S., Hopwood, M.J. et al. Biogeochemical feedbacks may amplify ongoing and future ocean deoxygenation: a case study from the Peruvian oxygen minimum zone. *Biogeochemistry* 159, 45–67 (2022). <https://doi.org/10.1007/s10533-022-00908-w>.
- Wang, X., Browning, T. J., Achterberg, E.P. and Gledhill, M. (2022). Phosphorus Limitation Enhances Diazotroph Zinc Quotas. *Frontiers in Microbiology*, 13. 853519. DOI 10.3389/fmicb.2022.853519.
- Wyatt, N. J., Milne, A., Achterberg, E. P., Browning, T. J., Bouman, H. A., Woodward, E. M. S., and Lohan, M. C. (2021). Seasonal cycling of zinc and cobalt in the Southeast Atlantic along the GEOTRACES GA10 section, *Biogeosciences*, 18 (14), 4265-4280
- Yao, W., Kvale, K. F., Koeve, W., Landolfi, A., Achterberg, E., Bertrand, E. M., & Oschlies, A. (2022). Simulated future trends in marine nitrogen fixation are sensitive to model iron implementation. *Global Biogeochemical Cycles*, 36, e2020GB006851. <https://doi.org/10.1029/2020GB006851>
- Zhou, Y., Shi, D., Liu, J., Xu, F., Zhou, K., Browning, T.J., Cai, Y., Cao, Z., Achterberg, E.P., Zhang, R. and Wen, Z. (2022). Nutrient co-limitation in the subtropical Northwest Pacific. *Limnology and Oceanography Letters*.
- Zhu, K., Birchill, A.J., Milne, A., Ussher, S., Humphreys, M.P., Carr, N., Mahaffey, C., Lohan, M.C., Achterberg, E.P., Gledhill, M. (2021). Equilibrium calculations of iron speciation and apparent iron solubility in the Celtic Sea at ambient seawater pH using the NICA-Donnan model. *Marine Chemistry*, 237, <https://doi.org/10.1016/j.marchem.2021.104038>.
- Zhu, K., Hopwood, M.J., Groenenberg, J.E., Engel, A., Achterberg, E.P., and Gledhill, M. (2021). Influence of pH and Dissolved Organic Matter on Iron Speciation and Apparent Iron Solubility in the Peruvian Shelf and Slope Region *Environmental Science & Technology* 55 (13), 9372-9383. DOI: 10.1021/acs.est.1c02477.
- Zitoun, R., Achterberg, E.P., Browning, T., Hoffmann, L.J., Krisch, S., Sander, S.G., Koschinsky, A. (2021). The complex provenance of Cu-binding ligands in the South-East Atlantic. *Marine Chemistry*, 237, 104047.
- Živković, I., Humphreys, M.P., Achterberg, E.P., Dumousseaud, C., Woodward, E.M.S., Bojanić, N., Šolić, M., Bratkić, A., Kotnik, J., Vahčić, M., Obu Vazner, K, Begu, E., Fajon,

V., Shlyapnikov, Y., Horvat, M. (2022). Enhanced mercury reduction in the South Atlantic Ocean during carbon remineralization, *Marine Pollution Bulletin*, 178, 113644, <https://doi.org/10.1016/j.marpolbul.2022.113644>.

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

- Kechen Zhu (2021). Impact of pH, temperature and dissolved organic matter on iron speciation and dissolved iron inventories in seawater. University of Kiel/GEOMAR
- Wanxuan Yao (2021) Implications of iron model complexity for the projection of global biogeochemical cycles. University of Kiel/GEOMAR
- Stephan Krisch (2021) Iron Biogeochemistry in Fram Strait and on the Northeast Greenland Shelf. University of Kiel/GEOMAR

GEOTRACES presentations in international conferences

- Hollister, A.P., Gledhill, M., Koschinsky-Fritsche, A. Distribution and Flux of Trace Metals (Al, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and U) in the Amazon and Pará River Estuary and Mixing Plume (cruise M147). Online poster presentation. Statuskonferenz Forschungsschiffe, February 2022, Oldenburg, Germany. (online meeting due to COVID-19)
- Hollister, A. P., Gledhill, M., Koschinsky-Fritsche, A. Distribution and Flux of Trace Metals in the Amazon Estuary and Plume. Online oral presentation. Virtual Ocean Sciences Meeting, February 2022, Hawaii, USA. (online meeting due to COVID-19)
- Mara Sutorius, The coupling of REE and organic matter cycling during a phytoplankton spring bloom. ASLO Aquatic Sciences Meeting, online, 2021.
- Schlitzer, Reiner, GEOTRACES IDP2021. What does it include and how can it be accessed, IDP2021 online Release Event, Nov 2021.
- Schlitzer, Reiner, Accessing and utilizing the GEOTRACES 2021 Intermediate Data Product, Ocean Sciences Meeting Town Hall TH33, Feb 2022

Submitted by Walter Geibert (walter.geibert@awi.de).