ANNUAL REPORT ON GEOTRACES ACTIVITIES IN SOUTH AFRICA

May 1st, 2022 to April 30th, 2023

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.

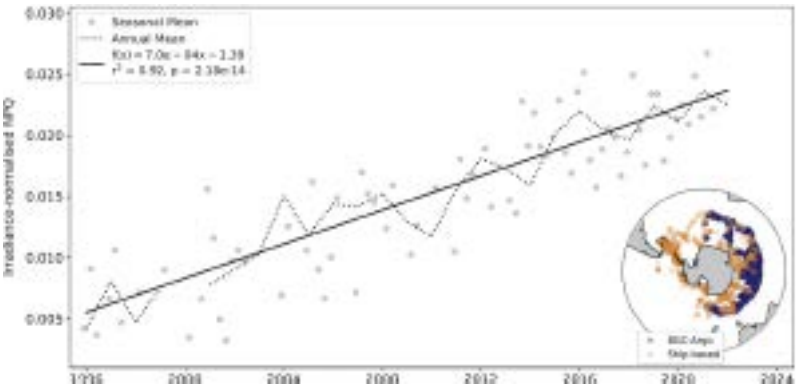

Figure SA-1. *Distribution and trend of irradiance-normalized non-photochemical quenching (NPQ). (source: Ryan-Keogh et al. 2023)*

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.

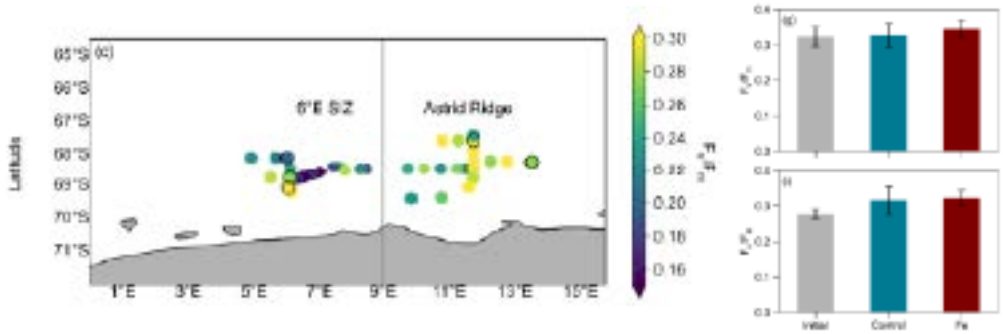

Figure SA-2. *(a) in-situ conditions of the study region (here: Fv/Fm) and (b) mean Fv/Fm from the initial, control and the Fe treatments in incubation experimentsconducted in the Sea-Ice Zone (source: Singh et al. 2023)*

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).

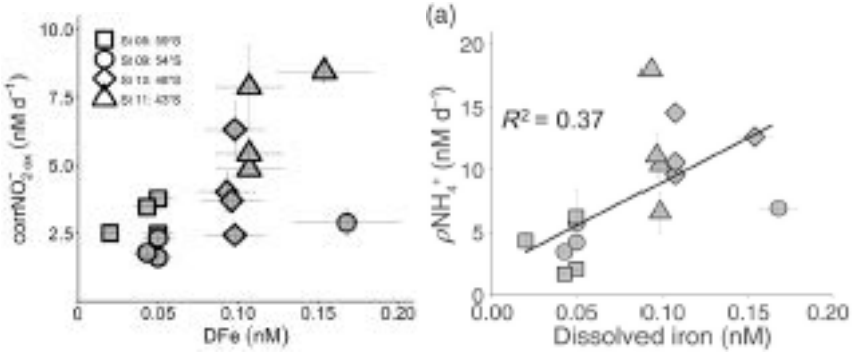

Figure SA-3. *Nitrite oxidation rates vs. dissolved iron concentrations (for details see source: Mdutyana et al. 2022a)*

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.

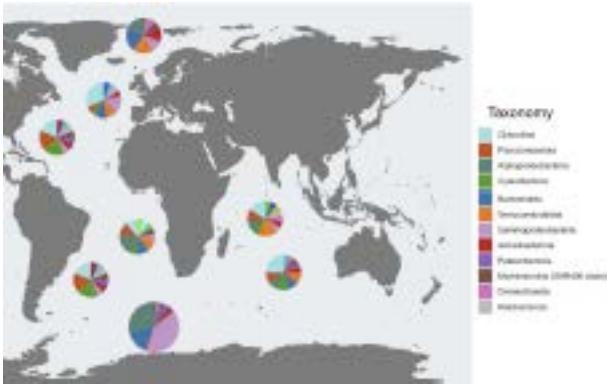

Figure SA-5. *Southern Ocean prokaryotic composition (modified from Castillo et al. 2022)*

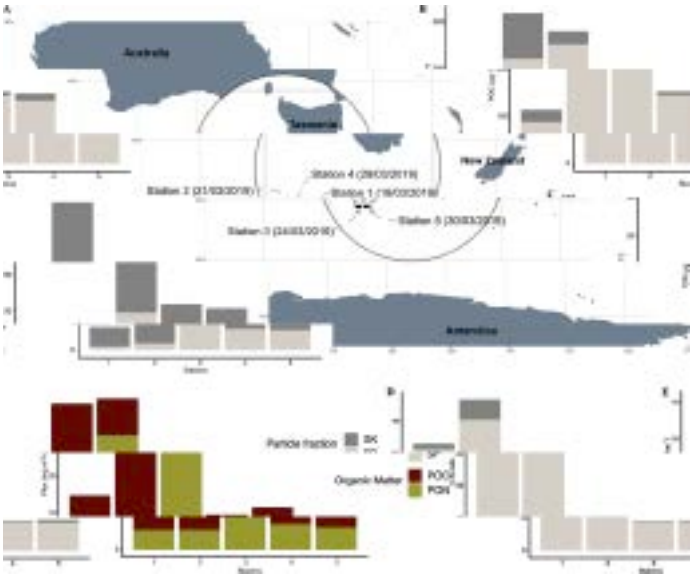

Figure SA-6. *Marine Snow Catcher (MSC) deployment at Southern Ocean Time Series sites (source: Dithugoe et al. 2023)*

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).

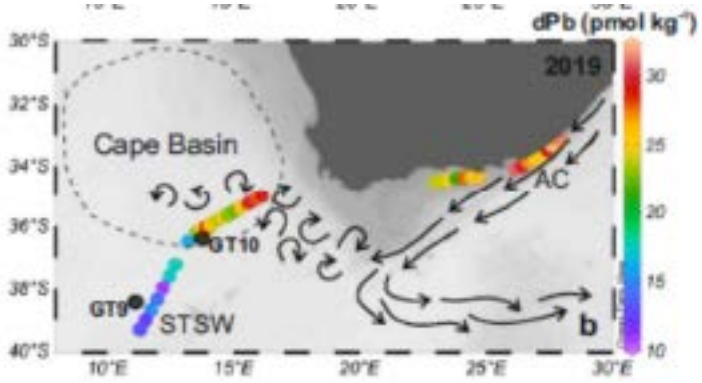

Figure SA-7. *Distribution of dPb in the Subtropical oceans around South Africa in 2019.(modified from Samanta et al. 2023)*

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

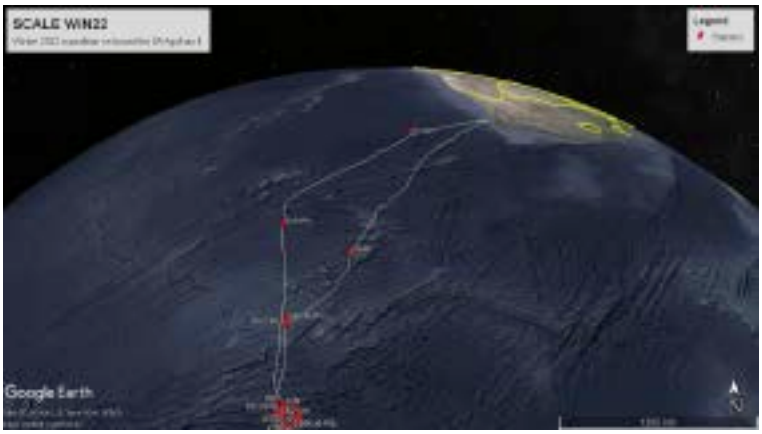

Figure SA-8. *Winter Cruise 2022 cruise track 11-31 July 2022 on board R/V SA Agulhas II*

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).