ANNUAL REPORT ON GEOTRACES ACTIVITIES IN ISRAEL

May 1st, 2022 to April 30th, 2023

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.

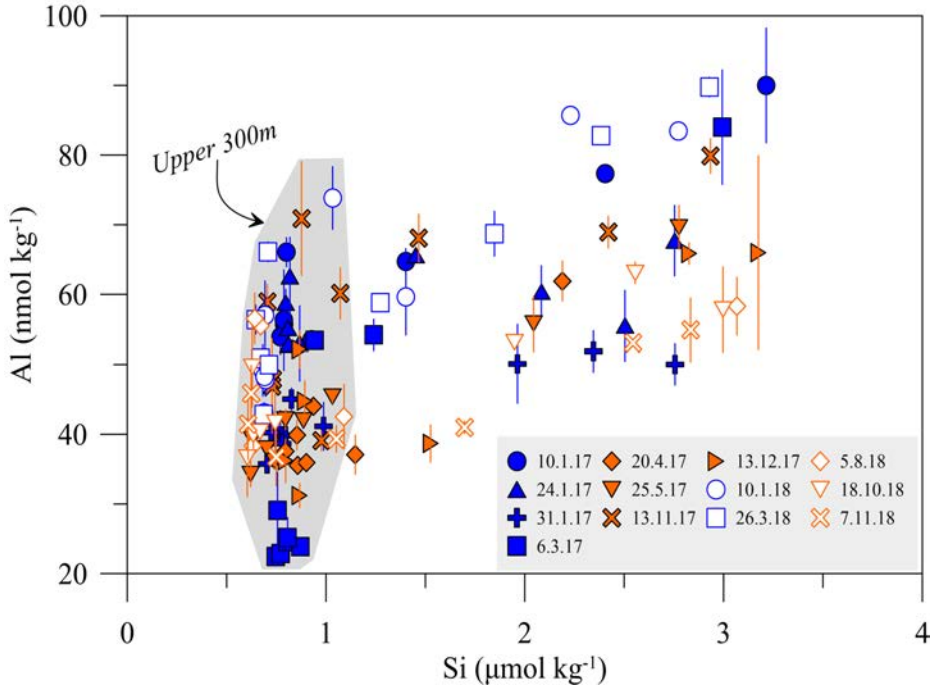

Figure ISR-1. *Dissolved Al and Si relationship in the deep profiles sampled in Station A, GOA during 2017 (full symbols) and 2018 (empty symbols). January – March and April – December profiles are marked by blue and orange symbols, respectively. The grey field represents the decoupling of Al and Si 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.

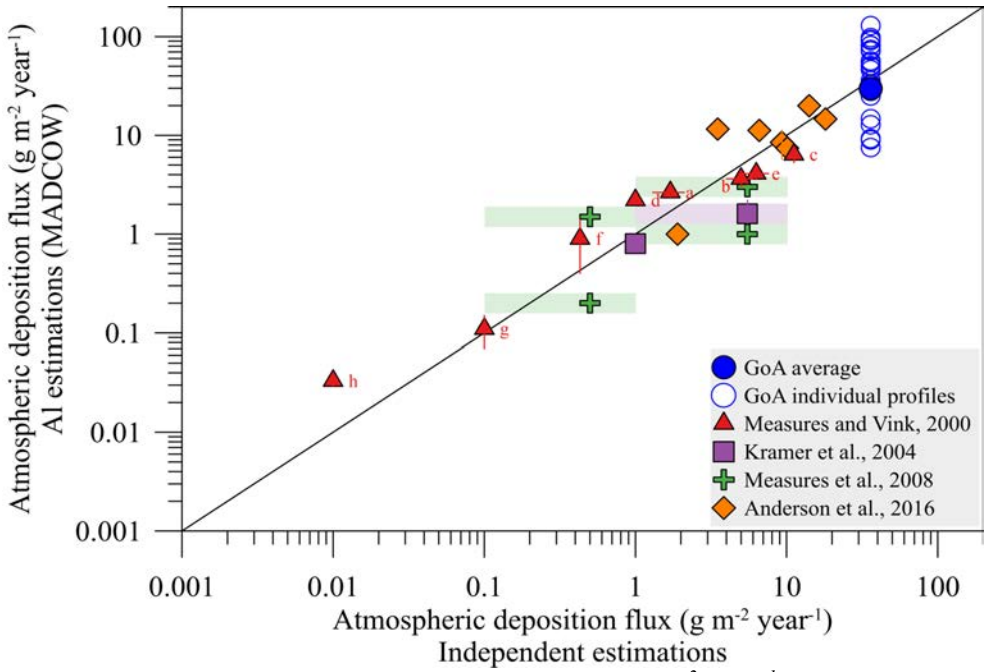

Figure ISR-2. *Compilation of atmospheric deposition flux (g m^{-2} $year^{-1}$) estimates derived from dissolved mixed layer Al measurements (MADCOW model) against independent flux estimates obtained by other means for the GOA and other oceanic regions (black line represent 1:1 ratio). A full blue circle 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.

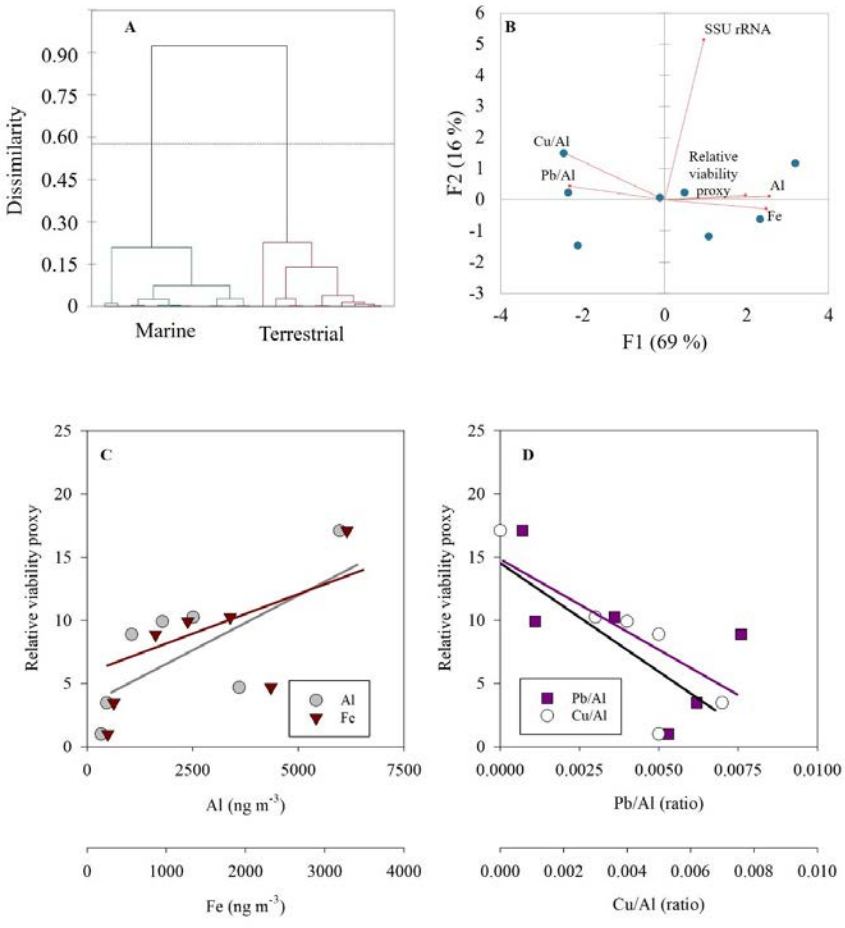

Figure ISR-3.

(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.

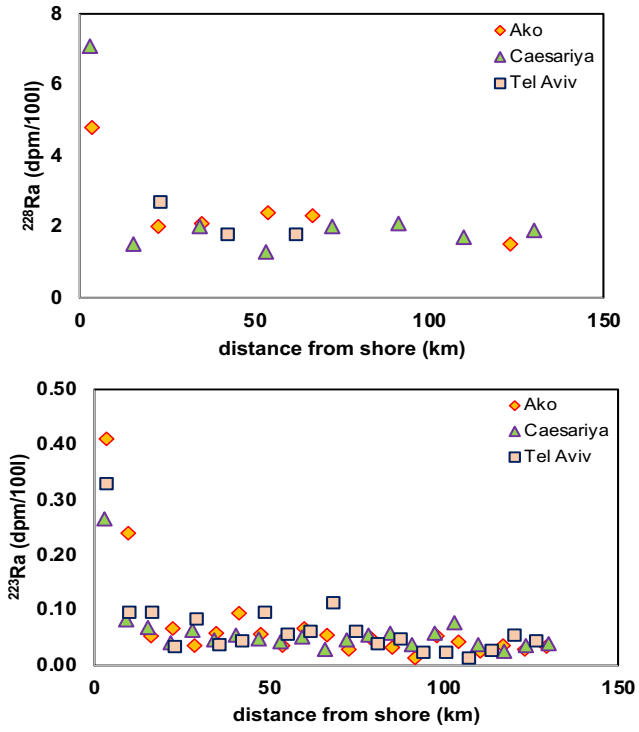

Figure ISR-4. *Radium transects offshore Israel. Akko is located in northern Israel, Caesariya and Tel Aviv are in central Israel.*

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.

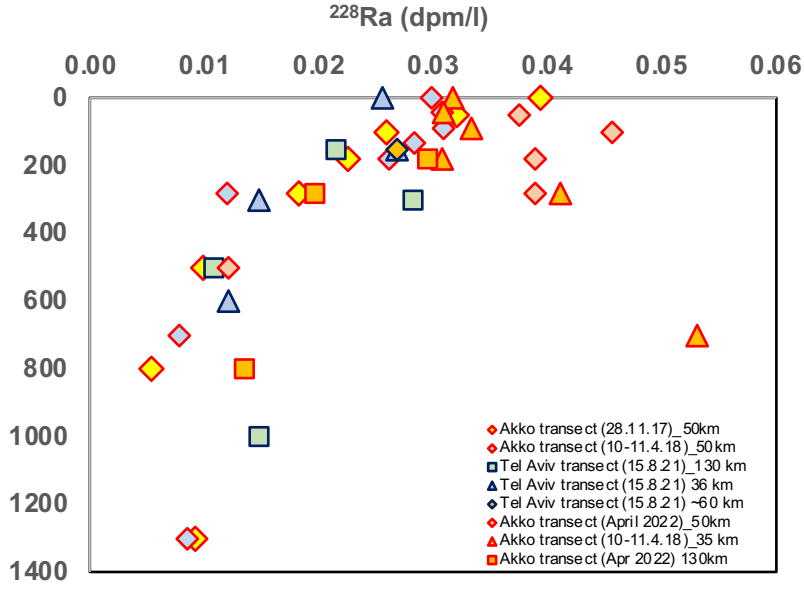

Figure ISR-5. *^{228}Ra depth profiles 35-130 km from shore, offshore northern and central Israel (Akko and Tel Aviv, respectively).*

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).