ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CHINA

May 1st, 2020 to April 30th, 2021

New GEOTRACES or GEOTRACES relevant scientific results

- Surface and profile samples were collected from the western NPSG during the GP09 spring cruise and GPpr15 summer and winter cruises with an underway fish-towing system and a GEOTRACES standard rosette sampling system. N_2 fixation rates and diazotroph abundances were measured by $^{15}N_2$ gas dissolution method and *nifH* gene qPCR, respectively.
- Distribution of N_2 fixation rates in the western North Pacific is shown in Figure 1. Surface and depth-integrated rates ranged from below detection limit to 15.83 nmol N L^{-1} d^{-1} and below detection limit to 764.3 μmol N m^{-2} d^{-1}, respectively. High rates were mostly found in between 15°N and 20°N regions in the North Pacific Subtropical Gyre (NPSG), whereas rates were around the detection limits in the areas south of 15°N. Vertically, high rates were generally found in the upper 50 m water column and decreased dramatically at deeper depths. Among seasons, N_2 fixation rates were significantly higher during the warm seasons (spring and summer) than during winter.

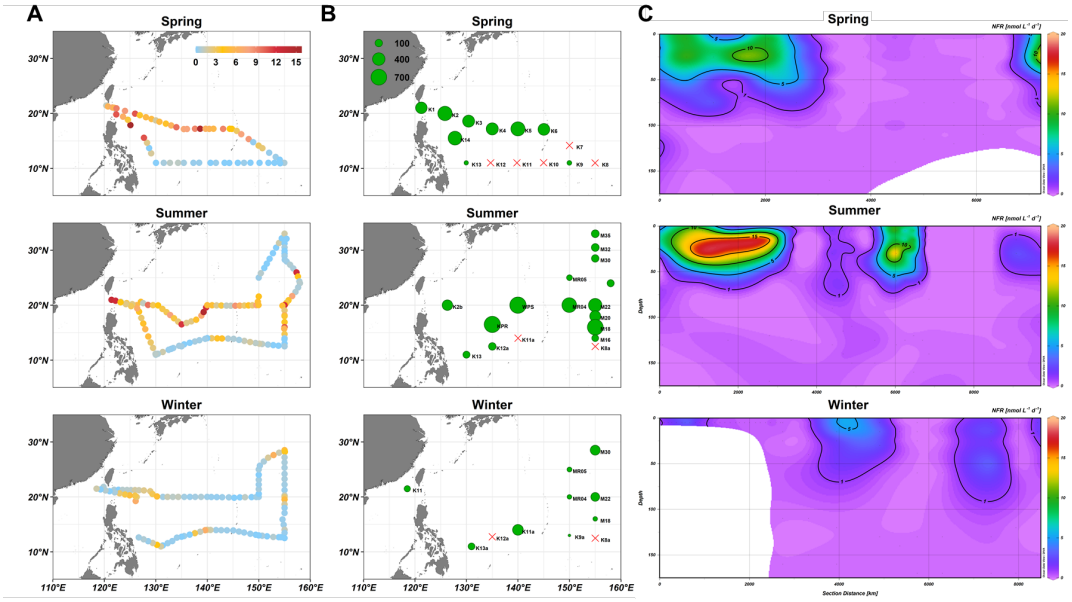

Figure 1. N_2 fixation rate in the western North Pacific during GP09 and GPpr15 summer and winter cruises. A. Surface N_2 fixation rate (nmol N L^{-1} d^{-1}). B. Depth-integrated N_2 fixation rate (μmol N m^{-2} d^{-1}). C. Vertical distribution of N_2 fixation rate (nmol N L^{-1} d^{-1}).

- We found that iron:nitrogen (Fe:N) supply ratios are the most important factor in regulating the distribution of N_2 fixation across the tropical ocean (Figure 3). Fe:N supply ratio shows a clear spatial coherence with both depth-integrated N_2 fixation rates and *nifH* gene abundances, with elevated values for NPSG stations and low values around the NEC where Ekman divergence shoals the nitracline upward to the euphotic depth, enhancing turbulent nitrate supply from below, and aerosol Fe supply from above is reduced.

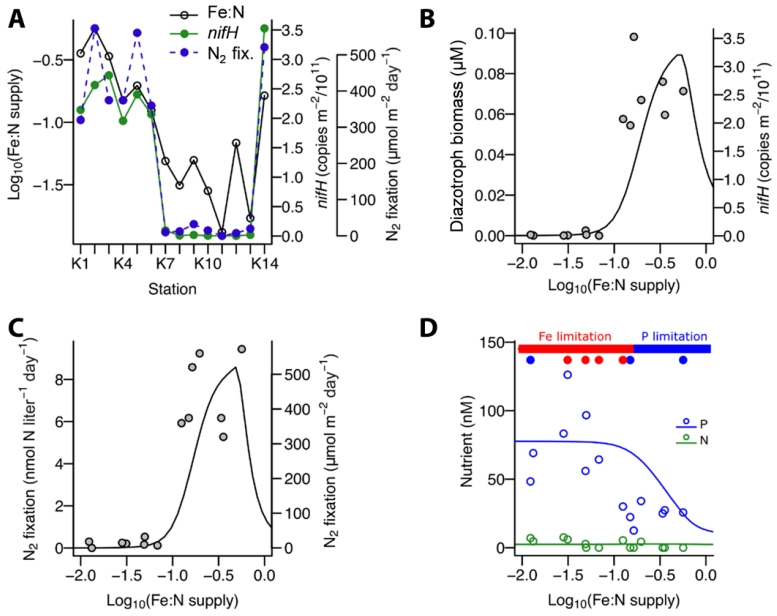

Figure 2. Regulation Fe:N supply ratios on N_2 fixation across the tropical western North Pacific.

- By conducting nutrient (iron and phosphate, Fe and P) amendment experiments across the western North Pacific, we found that switches of diazotroph nutrient limitation from the marginal north South China Sea (NSCS) to the NPSG. N_2 fixation rates were co-limited both Fe and P in the NSCS, nutrient-replete in Kuroshio, P-limited in the western Philippine Sea, and changed to Fe-limitation in the further Gyre region and the North Equatorial Current.

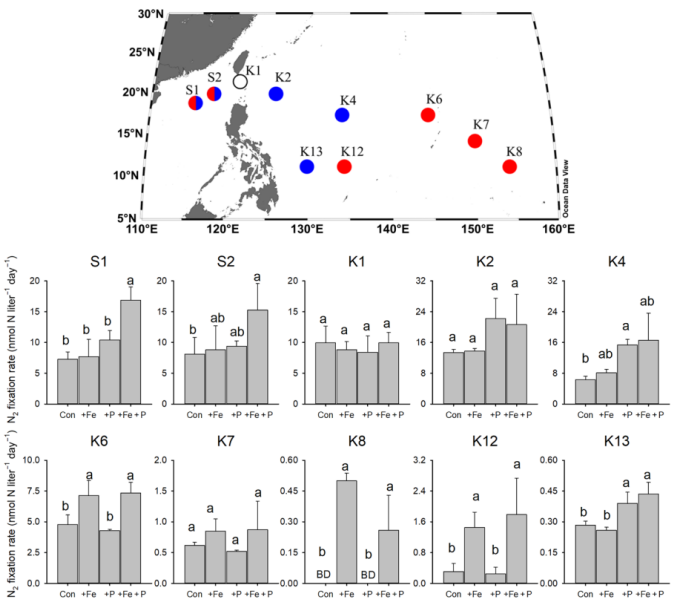

Figure 3. Response of N_2 fixation to nutrient addition. Symbols summarize the nutrient limitation of N_2 fixation found at each site: red, Fe limitation; blue, P limitation; split red/blue, Fe-P colimitation; white, Fe and P replete.

- Distribution of ^{226}Ra in the surface and bottom layers of the world ocean is shown in Figure 4. We synthesize historical dissolved ^{226}Ra data from multiple international research programs including GEOSECS, TTO, and GEOTRACES to build a global picture of ^{226}Ra distribution throughout the global ocean. The activities of ^{226}Ra in the world's ocean increase along the thermohaline circulation pathways. Deep and bottom water masses are found with characteristic ^{226}Ra properties confirming that ^{226}Ra is a good thermohaline tracer.

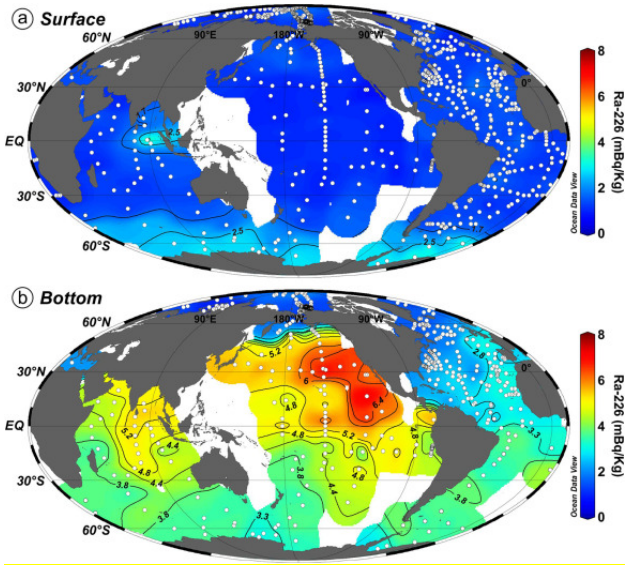

Figure 4. The white dots represent sampling stations extracted mainly from databases from multiple sources that are described with details in the *Data Sources* section. The original data and figure-gridding algorithms are presented in the Supplementary Information section.

- By investigating the distribution of Ra and Rn isotopes in coastal waters, submarine groundwater discharge nutrients into coastal waters were estimated. The results showed that submarine groundwater discharge plays a significant role in the nutrients cycle in coastal waters.
- We studied the reduction of Hg^{2+} mediated by microalgae and aerobic bacteria in surface marine water and microalgae cultures under dark and sunlight conditions. The comparable reduction rates of Hg^{2+} with and without light suggest that dark reduction by biological processes is as important as photochemical reduction in the tested surface marine water and microalgae cultures. The contributions of microalgae, associated free-living aerobic bacteria, and extracellular substances to dark reduction were distinguished and quantified in 7 model microalgae cultures. The results suggest it is the aerobic bacteria associated with microalgae that are directly involved in dark Hg^{2+} reduction. The aerobic bacteria in the microalgae cultures were isolated and a rapid dark reduction of Hg^{2+} followed by a decrease of Hg^0 was observed by aerobic bacteria *Alteromonas* spp., *Algoriphagus* spp., and uncultured bacterium clone Tir12-16S. The reduction of Hg^{2+} and re-oxidation of Hg^0 were demonstrated in aerobic bacteria *Alteromonas* spp. by using double isotope tracing ($^{199}Hg^{2+}$ and $^{201}Hg^0$). These findings highlight the importance of algae-associated aerobic bacteria in Hg transformation in oxic marine water.
- Mercury isotope dilution and isotope addition techniques were utilized to determine the methylation and demethylation potential of Hg at concentrations comparable to that in natural environments by 15 common marine microalgae (8 species of Diatoms, 4 species of Dinoflagellates, 2 species of Chlorophyta and 1 species of Chrysophyte). Methylation of inorganic Hg was found to be negligible in the culture of all tested marine microalgae, while 6 species could significantly induce the demethylation of methylmercury (MeHg). The rates of microalgae-mediated MeHg demethylation were at the same order of magnitude as that of photodemethylation, indicating that marine microalgae may play an important role in the degradation of MeHg in marine environments. Further studies suggest that the demethylation of MeHg by the microalgae may be mainly caused by their extracellular secretions (via photo-induced demethylation) and associated bacteria, rather

than the direct demethylation of MeHg by microalgae cells. In addition, it was found that thiol groups may be the major component in microalgal extracellular secretions that lead to the photo-demethylation of MeHg.

GEOTRACES or GEOTRACES relevant cruises

- 2021 Northwest Pacific Ocean Multidisciplinary Cruise (May 8 to Jun 18, 2021)

  Surficial and core samples were collected to analyze Hg species and isotopes during this cruise.

New projects and/or funding

- NSFC- General Fund: Cross-shelf transport of sedimentary iron in the South China Sea, #42176037, ¥590K, 2022-2025, PI: Yihua Cai
- NSFC-Youth Fund: The source, fractionation, and flux of particulate iron, zinc, cadmium in the northwestern Pacific Ocean, #42006045, ¥240K, 2021-2023, PI: Kan Zhang
- NSFC-Youth Fund: Effect of light intensity on the release and transfer of *Trichodesmium* derived nitrogen, #42106041, ¥300K, 2022-2024, PI: Zuozhu Wen

GEOTRACES workshops and meetings organized *(Please include the number of early-career researchers involved in each event, when possible)*

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

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Other GEOTRACES activities

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New GEOTRACES or GEOTRACES-relevant publications (published or in press) *(Please identify those publications acknowledging SCOR funding and for these publications include the number of Ph.D. or postdoc students involved, if possible)*

1. Wen, Z., Browning, T. J., Cai, Y., Dai, R., Zhang, R., Du, C., Jiang, R., Lin, W., Liu, X, Cao, Z., Hong, H., Dai, M., Shi, D. (2022). Nutrient regulation of biological nitrogen fixation across the tropical western North Pacific. *Science Advances*, 8, eabl7564.
2. Xu B, Li S., Burnett W C., Zhao S., Santos I R., Lian E., Chen X., Yu Z. (2022). Radium-226 in the global ocean as a tracer of thermohaline circulation: Synthesizing half a century of observations. *Earth-Science Reviews*, 226, 103956.
3. Cao, Z., Rao, X., Yu, Y, Siebert, C, Hathorne, Ed C., Liu, B, Wang, G., Lian, E., Wang, Z., Zhang, R., Gao, L, Wei, G., Yang, S., Dai, M., Frank, M (2021). Stable barium isotope dynamics during estuarine mixing. *Geophysical Research Letters*, 48, e2021GL095680.
4. Chen, X., Du, J., Yu, X., Wang, X. (2021). Porewater-derived dissolved inorganic carbon and nutrient fluxes in a saltmarsh of the Changjiang River Estuary. *Acta Oceanologica Sinica*, 40, 32-43.
5. Wang, X., Chen, X., Liu, J., Zhang, F., Li, L., Du, J. (2021). Radon traced seasonal variations of water mixing and accompanying nutrient and carbon transport in the Yellow-Bohai Sea. *Science of the Total Environment*, 784, 147161.
6. Peng, T., Zhu, Z., Du, J., Liu, J. (2021). Effects of nutrient-rich submarine groundwater discharge on marine aquaculture: A case in Lianjiang, East China Sea. *Science of the Total Environment*, 786, 147388.
7. Liu, J., Du, J., Yu, X. (2021). Submarine groundwater discharge enhances primary productivity in the Yellow Sea, China: Insight from the separation of fresh and recirculated components. *Geoscience Frontiers*, 12, 101204.
8. Peng, T., Liu, J., Yu, X., Zhang, F., Du, J. (2022). Assessment of submarine groundwater discharge (SGD) and associated nutrient subsidies to Xiangshan Bay (China), an aquaculture area. *Journal of Hydrology*, 610, 127795.
9. 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.
10. Liu, J., Du, J., Wu, Y., Liu, S. M. (2022). Radium-derived water mixing and associated nutrient in the northern South China Sea. *Frontiers in Marine Science*, 9, 874547.
11. Che, H., Zhang, J., Liu, Q. He, H. Zhao, Z. (2022). Refining the contribution of riverine particulate release to the global marine Nd budget. *Progress in Earth and Planetary Science*, 9, 22.
12. Liu Q, Zhang J, He H, Ma L, Li H., Zhu, S. Matsuno T. (2022). Significance of nutrients in oxygen-depleted bottom waters via various origins on the mid-outer shelf of the East China Sea during summer. *Science of the Total Environment*, 826, 154083.
13. Guan, W., He, H., Zhang, J. (2022). Sources and fluxes of rare earth elements in wet deposition at a Chinese coastal city downstream of the Asian continental outflow. *Atmospheric Environment*, 269, 118843.
14. Zhang, X., Guo, Y., Liu, G., Liu, Y., Song, M., Shi, J., Hu, L., Li, Y., Yin, Y., Cai, Y, Jiang, G. (2021). Dark Reduction of Mercury by Microalgae-Associated Aerobic Bacteria in Marine Environments. *Environmental Science & Technology*, 55, 14258-14268.
15. Li, Y, Li, D, Song, B., Li, Y. (2022). The potential of mercury methylation and demethylation by 15 species of marine microalgae. *Water Research*, 215, 118266.

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

- Wei Lin. Biogeochemistry of barium in the western North Pacific and its application of tracing organic carbon remineralization in the twilight zone. Master thesis, 2021.
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GEOTRACES presentations in international conferences

- Zhimian Cao, Wei Lin, Yating Li, Xinting Rao. Barium concentrations and isotopes along the GEOTRACES-GP09 transect in the western North Pacific. AGU Fall Meeting, 2021, New Orleans, LA, USA (Poster).
- Jinlong Wang, Quantification of oceanic input contribution to radionuclides and trace metals in marginal seas. Ocean Science Meeting, 2022, Online (Oral Session).

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