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Editorial: Using high-resolution observation methods to reveal the effect and mechanism of coastal eutrophication, deoxygenation, and acidification

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Editorial on the Research Topic
Using high-resolution observation methods to reveal the effect and mechanism of coastal eutrophication, deoxygenation, and acidification

The coastal ocean is essential for many life forms. Due to climate change and human activities, coastal oceans over the entire globe are experiencing environmental issues such as eutrophication, deoxygenation, and acidification, which are potential threats to human and marine animals. Thus the process, effect, and mechanism need to be explored for preventing and dealing with these challenges. However, because the coastal ocean such as estuaries, bays, gulfs and lagoons, are very dynamic on various scales in time and space due to tide, topography and weather, traditional discrete sampling approaches alone are not adequate to map the temporal and spatial variations of the crucial parameters of nature hindering our ability to explore the impacts and mechanism of the growing environmental issues confidently. Therefore, high-resolution observation and data in time and space, e.g. underway instruments, moorings, profilers, remote sensing, gliders, AUV and so on are urgently needed. All these methods will help us to collect invaluable long-term and extensive data resources, to improve our knowledge of the effect and mechanism of coastal eutrophication, deoxygenation, and acidification.

In our Research Topic, authors use various high-resolution methods to study the mechanism of coastal hypoxia, factors controlling carbon sink/source, aerosol on marine microbes community, slow sinking POC, methods of quantifying submarine ground water etc. All papers addressed the potential threats of eutrophication, deoxygenation, and acidification from various aspects.

We have two papers about eutrophication. One is on submarine groundwater discharge (SGD), an important component of the global water and biogenic element (e.g., nitrogen, phosphorus, silicon and carbon) sources. Natural radon isotope (^{222}Rn, $t_{1/2} = 3.8$ $_{d}$) is an excellent tracer for studying SGD and other oceanographic processes including air-sea gas exchange, sediment-water diffusion, and earthquake prediction. However, the conventional radon measurement methods suffer many technical disadvantages. Zhao et al. developed a convenient submersible radon determination approach ("OUC-Rn") using a commercial pulsed ionization chamber (PIC) radon sensor and gas extraction membrane module to produce high precision and high resolution observations. They demonstrate the radon degassing efficiency of the membrane contactor is comparable to the shower-head type air-water exchanger but is independent of operating position. The radon measurement efficiency of the PIC is 2-fold higher than the RAD7 detector and is far less influenced by moisture. They successfully deployed the system in 2.5 meters water depth over a 100 hours period in an anthropogenic influenced bay. Based on high temporal resolution observations, the SGD flux was estimated to be 0-43.0 cm/d (mean: 25.4 ± 14.5 cm/d). The SGD fluxes pattern plotted together with the tidal variations revealed that tidal pumping may be the main force driving seawater recirculation into aquifers and thus affecting nutrient, carbon and other dissolved matters dynamics in coastal regions.

Another study is on terrigenous particle transportation and its impact on microbe-mediated biogeochemical processes in the estuarine ecosystem. To study the long-term impacts of terrigenous particles on autotrophic and heterotrophic microbial community structures due to *in situ* continuous particle input, Zhang et al. built a large-volume indoor incubation experiment setting up for over 40 days. The activity and community structures of keystone groups were largely correlated with biochemical components derived from the terrigenous particles. The system was then functionally dominated by heterotrophic microorganisms after the input of terrigenous particles because terrigenous particles created environments that allowed heterotrophs to proliferate better than chemoautotrophs. The input of terrigenous particles increased the relative intensity of humic-like compounds mainly through releasing nutrients and biological labile organic matter to the seawater, which promoted the microbial transformation of organic matter. This study illustrates that terrigenous particles can impact the balance between heterotrophic and chemoautotrophic microbes.

We have another two papers about deoxygenation in Baltic Sea and Changjiang Estuary. Liblik et al. found seasonal oxygen depletion occurs in the deep layer of the gulf. They conducted high-resolution observation of hourly measurements of dissolved oxygen, temperature, and salinity in the deep layer (50 m) of the gulf, thus observed the full cycle of development and relaxation of hypoxia in 2021 in Gulf of Riga, Baltic Sea. Hypoxia (<2.9 mg l^{-1}) first occurred on 27 June and was observed for 71 days until its complete decay on 22 October. Average oxygen decline of 0.10 mg l^{-1} d^{-1} from saturation in mid-April until mid-July and 0.04 mg l^{-1} d^{-1} onwards until the end of August were observed. This seasonal pattern was superimposed by short-term variability in time scales from hours to days and was probably caused by inertial oscillations, (sub)mesoscale processes, deep layer currents, and pycnocline movements. They also observed that ventilation events with a relatively low impact and duration of up to ten days occurred in the deep layer due to the inflows of the saltier water from the Central Baltic. The inflowing water originated from the upper layer in winter and the thermocline in summer and was almost saturated in oxygen. Mostly mixing with existing oxygen-depleted water in the Gulf of Riga, but also local consumption led to a decline in the oxygen levels in the inflow water before its arrival at the observing station.

Based on detailed observational data in the summer of 2013, Wei et al. revealed the essential linkages between physical-biogeochemical processes and spatial variability of hypoxia off the CE. The river plume, stratification, front, upwelling and localized high phytoplankton biomass combine to shape the spatial morphology and scope of hypoxia. The spatial heterogeneity of hypoxic magnitude in horizontal direction is mainly regulated by the intensity variability of stratification and phytoplankton blooms. The position of bottom front formed by the offshore Taiwan Warm Current (TWC) and coastal water under tidal mixing controls the shoreward boundary of hypoxic zone, while the river plume front-dominated outer edge of phytoplankton blooms in upper layers plays a role in determining the seaward limit of the reach of bottom hypoxia. The stratification depth controlled by the upwelling and river plume governs the upper limit of the top reach of hypoxia, and shapes the vertical morphology of hypoxic zone. The authors contextualize the role of physical-biogeochemical drivers to the spatially variable hypoxia in a conceptual diagram. Their findings would considerably contribute to our understanding of the spatially variability in hypoxia in river plume-upwelling-front coupled estuarine systems, providing a sound basis for prediction and simulation under anticipated future.

The other three papers in our Research Topic were about biological carbon pump and ocean acidification. For one example, the driving mechanism for ocean acidification in mesopelagic open water is still poorly understood. Yang et al. used an inverse model with the high-resolution profiles of ^{210}Po and ^{210}Pb, examined sinking velocity and flux attenuation of particulate organic carbon (POC) for the first time in the northeastern South China Sea (SCS), to reveal the remineralization of POC in the mesopelagic zone. The sinking velocity of particles was estimated to vary from 3 to 34 m d^{-1} with the mean value of 15 ± 9 m d^{-1}, indicating that the slow sinking particles largely contribute to the POC flux in the SCS. Beneath the euphotic zone, a consistent decline in the sinking speed implied continuous remineralization of sinking POC in the twilight zone. A preliminary estimate revealed that 1.9-5.4 mmol-C m^{-2} d^{-1} remineralized back to carbon dioxide within 100-500 m, representing about 70% of the exported autochthonous POC from the euphotic zone. In 100-1000 m, 2.4-6.6 mmol-C m^{-2} d^{-1} (i.e., 84%) remineralized. Thus, the upper twilight zone (i.e., 100-500 m) is the dominant layer of POC remineralization, and POC-induced acidification could be unneglectable there. These results provided insights into the POC-induced acidification mechanism in the mesopelagic water, especially in the upper mesopelagic layer.)

In the second example, Mo et al. investigated the factors that control the partial pressure of carbon dioxide (pCO_2) in the Pacific sector of the Southern Ocean in April 2018, onboard the icebreaker, ARAON, based on a continuous underway observation method.

The mean of the sea surface pCO_2 was estimated to be 431 ± 6 µatm in the north of the Ross Sea (NRS), 403 ± 18 µatm in the Amundsen–Bellingshausen Sea (ABS), and 426 ± 16 µatm in the western Antarctic Peninsula and Weddell Sea (WAP/WS). The pCO_2 in the ABS and western WAP/WS displayed a strong correlation with salinity. Furthermore, $\Delta O_2/Ar$ and sea ice formation appear to be the dominant factors that control pCO_2 in the Confluence Zone (CZ) and northern parts of WAP/WS. The estimated air–sea CO_2 fluxes (positive and negative values indicate the source and sink for atmospheric CO_2, respectively) range from 3.1 to 18.8 mmol m^{-2} d^{-1} in the NRS, −12.7 to 17.3 mmol m^{-2} d^{-1} in the ABS, and −59.4 to 140.8 mmol m^{-2} d^{-1} in the WAP/WS. They also saw a biological activity drive large variations in the air–sea CO_2 flux in the CZ.

For the third example, NCP is a key parameter for evaluating the efficiency of carbon sequestration by the biological pump. Wang et al. reviewed previous research on satellite-based NCP and classified the methods into two primary categories: empirical methods and semi-analytical methods. They pointed out that future research should focus on the precise calculation of satellite-based NCP by investigating the underlying processes and mechanisms that regulate NCP, developing regional models, and increasing the resolution of satellite sensors, as well as applying satellite lidar and coordinated multi-sensor observation technology.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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