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Editorial: Biogeochemical and ecological responses to wind- or tide-induced disturbances over marginal seas

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Editorial on the Research Topic
Biogeochemical and ecological responses to wind- or tide-induced disturbances over marginal seas

Introduction

Global warming caused by sustained increase in radiative forcing over time is known to increase the stratification of the ocean's surface layer. On the other hand, it can also alter the intensity, magnitude and duration of extreme meteorological events (climate warming, storms and typhoons) which are known to induce mixing of the surface layer and thus lead to pulse responses in chemical fluxes, water composition and biology. In the low-latitude marginal seas under consideration here, such disturbances play an especially important role in the summer, i.e. when the initial stratification is more intense than in the winter (Sarmiento et al., 2004; Doney et al., 2012; Shih et al., 2020). The aim of this Research Topic was to take stock of our current understanding of the role played by transient physical disturbances in the surface layer of marginal seas on the transport of chemicals and the productivity and community structure of marine organisms. This was achieved through an interdisciplinary collaboration comprising meteorologists, physical oceanographers, biogeochemists and marine biologists. Most of the papers relate to the South China Sea since a great deal of supporting information was already available for this region.

The studies included in this Research Topic fall into three categories based on the type of marine system considered and the nature of the physical forcing that induces the biogeochemical or ecological response. The first examines the surface ocean variability induced by (a) Kuroshio intrusions and (b) mesoscale eddies in the northern South China Sea (SCS). Mesoscale eddies can persist for many weeks, and their contribution to

chemical and biological variability of the top 100 m of the SCS strongly depends on whether or not they are associated with the meandering of the western-boundary Kuroshio Current (Chow et al.; Wang et al.). The second category of studies focuses on the physical, geochemical and biological responses to wind-induced mixing, ranging from extreme events, such as tropical cyclones (Chowdhury et al.), to low-intensity, seasonal variations in the local wind field (Li et al.). The third group of studies focuses on bays and lagoons situated within the marginal seas of interest and representing hot spots of organic matter production and destruction (Hsieh et al.; Lin et al.) and - in a carbonate shelf lagoon setting - of alkalinity production (Chou et al.).

Eddy-driven vertical mixing: upward flux of nutrients and downward flux of particles

In this Research Topic, three papers address the upward transport of sub-surface waters (> 100 m depth) brought about by cyclonic eddies in the SCS (Chow et al.; Wang et al.) together with the biogeochemical responses to mixing of SCS surface waters with Kuroshio Current waters (Lai et al.). Eddy pumping is a key contributor to vertical mixing and particle export in the SCS (Wang et al., 2018; Shih et al., 2020). In contrast with to wind-induced mixing, it can be long-lasting and also produce noticeable subsurface anomalies. Based on field measurement techniques, bathythermographs and Argo floats, Chow et al. analysed the effects of eddies on thermocline dynamics, nutrient supply and the biological carbon pump in the northern SCS. Interestingly, they found that eddy pumping was strengthened when warmer, lighter water below 100-m depth was advected northwards from the southern SCS by wind-induced Sverdrup transport, but that it was weakened during episodes of Kuroshio water intrusion. Using high-throughput sequencing of both 18S rDNA and rRNA, Wang et al. were able to disentangle the effects of spatial (Kuroshio intrusion) and environmental factors (temperature, nutrients, chlorophyll *a*), so as to show that variations in the nano-eukaryotic community at their northern SCS sites could be significantly explained by the fraction of Kuroshio water present. This may be due to the fact that Kuroshio intrusions lower the nutrient inventory of the upper 100 m and favour small cells such as ammonia oxidising archaea and bacteria. Conversely, Lai et al. found that weather systems associated with the southwest monsoon could drive SCS waters northeastwards to the point where they underwent mixing with the Kuroshio. Their study demonstrates, for the first time, that the pulses of high biomass that periodically occur in the Kuroshio Current are in fact associated with the NE transport of SCS waters.

Wind-driven disturbances: biogeochemical response and CO_2 fluxes

A further five papers examine the effects of surface wind over a very wide range of velocities, time scales and spatial scales. Chowdhury et al. document a relatively rare occurrence, i.e. the simultaneous occurrence of two cyclones in the Indian Ocean, one travelling towards the Arabian Sea and the other into the Bay of Bengal. They provide a thorough and rigorous analysis of the key atmospheric and oceanographic factors responsible for the simultaneous genesis of these two cyclones. They further explain the evolution of each cyclone as it relates to its original strength but also to the host of cyclonic and anticyclonic mesoscale eddies and other surface ocean conditions encountered by each cyclone along its pathway. Li et al. investigated the variations of CO_2 partial pressure in seawater and the air-sea CO_2 flux as it related to the dynamics of the Changjiang river plume during the summer monsoon. They found that the air-sea CO_2 flux is regulated by a combination of biological CO_2 uptake and upwelling events brought about by steady upwelling-favourable winds. At the outset of upwelling, surface plume waters were a carbon source to the atmosphere but they became a carbon sink after one week of sustained upwelling. Satellite remote sensing can be a powerful technique to estimate carbon fixation rate of phytoplankton. As such, Shih et al. compared integrated primary production (PP) derived from ship-based incubations with values derived from the satellite-based vertically generalized production model (VGPM) at the South East Asian Time-series Study (SEATS) station in the SCS from 2003 to 2016. Although they reported a consistent negative relationship between sea surface temperature and either PP or VGPM, they found that PP (*in situ*) estimates were ~50% lower than PP_{VGPM} estimates, likely due to an overestimation of the euphotic depth by the PP_{VGPM} method. Based on shipboard experiments conducted in the SCS over several years, Chen et al. described variations in the picoplankton community, including *Prochlorococcus, Synechococcus*, picoeukaryotes, and heterotrophic bacteria. They found that diel-to-seasonal variations of depth-integrated pico-phytoplankton biomass and composition in the euphotic zone was affected by nutrient supply. They report a good linear relationship between sea surface temperature and pico-phytoplankton biomass, suggesting that satellite-derived SST may be used to trace pico-phytoplankton abundance in the SCS. In the face of turbulent mixing, phytoplankton and cyanobacteria must remain suspended in the euphotic zone. Looking at a range of heterocystous cyanobacteria found in the South China Sea (SCS) and the Philippine Sea, Tuo et al. hypothesized that the short trichome length found in *C. rhizosoleniae* and *R. intracellularis* might be what helps them stay in the euphotic zone, regardless of whether they are free-living or associated with symbiotic diatoms.

Benthic processes in shallow water regions

There are four papers in this Research Topic which provide examples of the importance of benthic and/or diagenetic processes in shallow water sediments. Hsieh et al. examine the spatiotemporal variability of eutrophication and hypoxia in the Negombo Lagoon, one of the most productive and sensitive coastal ecosystems in Sri Lanka. Their survey suggests that elevated seawater temperature, sluggish water circulation and high organic matter inputs-partially supported by nutrient pollution-are triggering a sequence of events leading to eutrophication and hypoxia. The work by Chou et al. shows just how much the carbonate system of seawater in shallow semi-enclosed environments can be altered and how a substantial quantity of organic alkalinity may be present in such systems. Chou et al. compared the carbonate chemistry in overlying waters at two seagrass sites, i.e. sheltered site and site located outside the lagoon. They found differences in the variability of carbonate parameters between the two sites on seasonal and diurnal timescales with similar pattern with previous study (Chou et al., 2018). They attributed these differences to enhanced metabolic carbonate dissolution within the sediments of the lagoon. Their finding highlights the importance of taking this process into account when evaluating the 'blue carbon' potential of carbonate-rich coastal ecosystems. The study of Lin et al. reveals that sediment characteristics and carbon fluxes may strongly depend on the ability of benthic microalgae to migrate into the sediment in response to light penetration, nutrients and predation. Focusing on the benthic processes of tidal mudflats, Lin et al. found that net and gross primary production increased with increasing mud content of the sediment. This increase bore little relationship to microalgal biomass but instead was accompanied by a shift in the composition of benthic microalgae when proceeding from sandy to muddy sediments. Their results provide mechanistic evidence of how sediment mud content acts as a critical factor regulating carbon fluxes in tropical and subtropical unvegetated tidal flats. Finally, Darumas et al. investigated variations of nutritional values, carbon–nitrogen contents and renieramycin M concentrations in *Xestospongia* sp. in the Gulf of Thailand. They found that renieramycin M inhibited settlement of acorn barnacle. They argued that there was likely a homogeneous distribution of renieramycin within the sponge which nevertheless retained the ability to limit the metabolism and survival of competing marine organisms.

Future directions

This Research Topic expands our knowledge of the biogeochemical responses to physical disturbances in the surface layer of large marginal seas (Arabian Sea, Bay of Bengal, Philippine Sea, South China Sea). Overall, the collected articles help readers to better understand how climate variability and weather events interact with anthropogenic disturbances (eutrophication, hypoxia, global warming) to affect bacterial and phytoplankton assemblages, primary production, and both the physical and biological carbon pumps in different marine environments. It is apparent that in order to understand and model the complex interplay between forcing factors and biogeochemical responses, future research will need to be directed at the multiple effects of climate warming, storms and ocean acidification on water stratification, oxygen supply, nutrient input, marine ecosystems and food webs in marginal seas.

Author contributions

All authors listed have made intellectual contributions to this Research Topic and approved it for publication.

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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.

Publisher's note

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