Biogeochemical linkages between the ocean and the atmosphere during phytoplankton blooms in the Oyashio region

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The Oyashio is a western boundary current of the western North Pacific, where a large phytoplankton blooms regularly occur in spring. The spring phytoplankton blooms leads to extensive transport of organic carbon to the deep ocean, causing the drawdown of nutrients and pCO_2. Therefore, the Oyashio plays an important role not only in the global carbon cycle, but also in supporting various marine resources.
The Coastal Oyashio Water (COW) has the characteristics of low temperature and low salinity. The COW spreads extensively over the Oyashio region and has a great influence on the phytoplankton bloom in the Oyashio region. Regarding the origin of the COW, influence of sea ice melt water from the Sea of Okhotsk and/or the East Sakhalin Current has been proposed, but that has not been fully understood yet. In addition, the COW might be influenced by river water and coastal sediments around the Hokkaido island.
Multi-scale vertical and horizontal ocean mixing processes can strongly influence the distribution of dissolved and suspended substances including macro- and micro-nutrient availability, and may impact on the phytoplankton bloom formation. The changes in nutrient dynamics generally affect the abundance, composition and metabolic activity of marine organisms such as phytoplankton and bacteria during the blooms.
Marine phytoplankton can produce volatile organic compounds and marine atmospheric aerosols, which strongly influence on atmospheric chemistry. Primary and secondary organic and inorganic components produced via marine phytoplankton activity can contribute to the formation of cloud droplets and subsequently affect the climate change. Therefore, the biogeochemical cycles related to the phytoplankton blooms have a tight linkage between the ocean and the atmosphere.
In order to investigate "Biogeochemical linkages between the ocean and the atmosphere during phytoplankton blooms”, a field campaing in the Oyasho region was carried out using the research vessel Hakuho-maru from March 6 to 26, 2015. In this presentation, we report the outline of the research cruise, especially focusing on the nutrient dynamics in the pre-bloom condition.

Keywords: phytoplankton bloom, linkages between the ocean and the atmosphere, Oyashio - Costal Oyashio water, micro- and macro-nutrients dynamics

Fine- and micro-scale observations in the Oyashio in winter

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During the R/V Hakuho-maru cruise in Mar. 2015, fine- and microstructure measurements in the Oyashio water were conducted using a CTD/LADCP and vertical microstructure profiler in order to know the spatial variability of wintertime turbulence field, which has not been reported so far at this area. At a station off the shelf break, whose bottom depth is about 530 m, one-day repeated observations were also conducted to know the temporal variability of turbulence intensity.
The energy dissipation rate, ε, was patchily elevated to $O(10^{-8})$ [W/kg] and was typically $O(10^{-10} - 10^{-9})$ [W/kg] in the upper 400 m depth (less dense than 27.0 σ_θ) across the Oyashio. Off the shelf break, where the one-day observation was conducted, strong turbulence with $\varepsilon = O(10^{-7})$ [W/kg] and $K\rho = O(10^{-3} - 10^{-2})$ [m^2/s] was observed at around 60 - 70 m depth (26.4 σ_θ), and $\varepsilon = O(10^{-8})$ [W/kg] and $K\rho = O(10^{-3})$ [m^2/s] at around 350 m depth (26.7 σ_θ) corresponding to the period of isopycnal heaving of about 50m. This strong mixing around 26.4 σ_θ(26.7 σ_θ) was enhanced when the along-isobath (down-sill) flow and its associated shear was strengthened. Harmonic analysis shows that the diurnal tidal flow was large in the upper 50 m, while the mean and semi-diurnal flow were also important at around 26.7 σ_θ suggesting that the tidal flow may impact on the turbulence field at this place.

Keywords: turbulent mixing, Oyashio

Differences in the composition and photosynthetic physiology of spring phytoplankton assemblages between coastal Oyashio and Oyashio waters

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Every spring massive diatom blooms occur both in coastal Oyashio (COY) and Oyashio (OY) regions off East Hokkaido. In general, surface COY waters possess lower temperatures and salinities and higher nutrient levels as compared with those in the OY, so that marked differences in the abundance, community composition, and photosynthetic physiology of phytoplankton between the two water masses can be expected. These, in turn, could influence the biogeochemical processes and ecosystems in the two regions. However, such information has still been scarce thus far. Therefore, we carried out field campaigns using the R/V *Hakuho Maru* during 6–26 March 2015 and the TR/V *Misago Maru* during 16–17 April 2015. The abundance and community composition of phytoplankton were assessed from UHPLC pigment analyses. Diatom community composition was also estimated with a DNA metabarcoding technique. Furthermore, we evaluated the photosynthetic physiology of phytoplankton in terms of photosynthesis-irradiance curves, chlorophyll variable fluorescence, and diatom-specific *rbcL* gene expression. During the R/V *Hakuho Maru* expedition, phytoplankton little bloomed at most stations in the COY and OY where diatoms were predominant in the phytoplankton assemblages. On the other hand, diatoms proliferated in COY waters during the TR/V *Misago Maru* observations. The genus *Thalassiosira* was predominated in the diatom assemblages of the COY, whereas a mixture of *Thalassiosira, Minidiscus,* and *Fragilariopsis* dominated in the OY. In the 24-h bottle incubation experiments where temperatures increased by +7˚C from those of ambient seawater, increases in diatom-specific *rbcL* gene expression and chlorophyll *a*-normalized maximum photosynthetic rate were observed in COY waters, whereas no such temperature effect was confirmed in the OY. Our results suggested that *Thalassiosira* in the COY could respond sensitively to the increase in temperature and then form blooms rapidly.

Keywords: Phytoplankton, Spring bloom, Community composition, Photosynthetic physiology

Nitrogen and Carbon stable isotope ratios of zooplankton in the Oyashio region of the western North Pacific

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Carbon and nitrogen isotope ratios ($\delta^{15}N$ and $\delta^{13}C$) of organisms are controlled by not only biological factors, such as catabolism and assimilation, but also physical environmental conditions that influence the isotope ratios of primary producers (phytoplankton). To examine how different water properties (i.e., nutrients and temperature) affect $\delta^{15}N$ and $\delta^{13}C$ in marine food webs, we measured $\delta^{15}N$ and $\delta^{13}C$ of zooplankton in three distinct water masses: coastal Oyashio (COY), Oyashio (OY) and warm-core ring (WCR) water along the A-line monitoring transect (38N-42.5N, 144.5-147.5E) in March 6- 26, 2015, cruise of the KH-15-1 of the *R/V Hakuho-maru* of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and in February 28 –March 16, 2015, cruise of the WK-15-03 of the *R/V Wakataka-maru* of the Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency (FRA). Zooplankton samples were collected from 150 m depth to the surface using vertical tow of a NORPAC twin net (45cm mouth diameter, 0.355 mm mesh size). After collection, all samples were classified using a stereomicroscope into species or genus level, and only adults were used for isotopic analysis. Water samples were collected from the surface to 250m depth profiles for the measurements of $\delta^{15}N$ ($NO_3^+ + NO_2^-$). We compared the trophic fractionations of carbon and nitrogen isotopes ($\Delta\delta^{13}C$, $\Delta\delta^{15}N$) of zoopalankton among the three water masses. We found that $\delta^{15}N$ of chaetognatha at COY tended to be higher than OY and WCR, but a simple relationship between $\Delta\delta^{15}N$ and $\Delta\delta^{13}C$, regardless of species or water masses. Combined with this $\Delta\delta^{15}N$-$\Delta\delta^{13}C$ relation, the isotopic ratios of zooplankton would allow us to predict C and N isotope ratios of higher trophic consumers, such as carnivorous fish and seabirds.

Keywords: N and C isotope ratios, food chain, Oyashio region, isotopic fractionation

Contribution for the marine ecosystem at the North East Pacific Ocean by deposition of atmospheric nitrogen compounds

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It has become apparent that deposition of atmospheric species emitted from Asian region is one of pathways for the supply of nutrients and inhibitors in the ocean surface layer. However, there have been a few studies to estimate the contribution of marine ecosystem by the deposition of atmospheric species. In this study, we investigated contribution of deposition of atmospheric nitrogen compounds to the marine ecosystem at the North East Pacific Ocean using 3-D marine ecosystem model (NEMURO) combined with atmospheric regional chemical transportation model (WRF-CMAQ). The 3-D marine ecosystem model indicated that surface chlorophyll concentrations at sub-tropical region in North Pacific Ocean in summer was underestimate to those of the satellite observation by MODIS, suggesting rack of nutrient supply processes in summer. The atmospheric regional chemical transport model indicated that there are sufficient depositions for nitrate and ammonia at sub-tropical region in North Pacific Ocean calculated from 2009 to 2013, suggesting that atmospheric contribution as nutrients is potentially high. In the presentation, we are going to report the results for combination analysis by marine ecosystem model, atmospheric regional chemical transportation model, marine monitoring data by buoys, and satellite observation at sub-tropical region in North Pacific Ocean.

Keywords: atmospheric aerosol, deposition, marine ecosystem

