Understanding of nutrients cycle based on phenology of primary production in the subarctic North Pacific Ocean

Takuro Kaneko[1], *Toru Hirawake[1], Jun Nishioka[2]

1. Faculty/Graduate School of Fisheries Sciences, Hokkaido University, 2. Institute of Low Temperature Science, Hokkaido University

The subarctic North Pacific Ocean is one of the most productive and largest sink of CO2 in the world oceans. Rich nutrients existing in the middle layer and exported from the Okhotsk Sea support high primary production of phytoplankton in this region. However, asymmetric and ununiformed distributions in both nutrients and primary production have been reported, and thus, linkage between nutrients and primary production in the whole of the subarctic North Pacific Ocean with a large spatio-temporal scale was not sufficiently understood. Global primary production data estimated using satellite data for ~20 years, a large dataset of ship-based nutrients and temperature-salinity from Argo floats are available today. Here, we used such dataset to reveal nutrients cycle from phenology of primary production in the subarctic North Pacific Ocean.

Net primary production was retrieved with phytoplankton absorption-based model using the GlobColour satellite ocean color data. Data of nitrate and phosphate concentration were obtained from the WOD 2013. Gridded sea ice concentration data of the AMSR-E was used to define open water. Climatological geostrophic current data was obtained from the AVISO. Mixed layer depth (MLD) was calculated from the Argo floats data. 8 days mean and 32 km gridded climatology of each satellite data was computed and data in open water for the period March-October was analyzed. Cluster analysis was applied to the primary production data to group sites with their similar phenology. For each cluster, we extracted and averaged nutrients, PAR and MLD values.

Distribution of the clusters was consistent with climatological geostrophic currents. This suggests that cluster reasonably reflects marine environments including nutrients of each current. Annual mean phosphate concentration, PAR and MLD of each cluster significantly correlated with annual mean primary production. Thus, the clusters exhibit biogeochemical provinces representing marine environments and corresponding primary production; so call "biome" hereafter.

Meanwhile, no significant relationship between annual means of nitrate concentration and primary production was found, particularly in the range more than 8 μmol L^{-1} a regression between the annual means had large residual expressing a difference between primary production expected from nitrate and actual one. Biomes with negative residual, which show low primary production despite high nitrate, were found in most of open oceans in the study area. It implies that other factors than nitrate are controlling primary production in those biomes. The highest (positive) residual was appeared in the biome near Aleutian Islands where high primary production was sustained in spite of lower nitrate concentration throughout spring-autumn. This suggests that there is a process to supply sufficient nutrients to the surface layer continuously and phytoplankton consume them immediately. Biomes with less residual distributed in south of subarctic gyre. Nitrate is one of controlling factors of photosynthesis in those biomes.

Amplitude of bloom had significant correlation with difference of MLD between the maximum and the minimum, suggesting effects of nutrients supply from the middle layer by mixing in winter and

stratification in summer. Duration of bloom had no significant relation with the difference of MLD and might be controlled by nutrients supply other than mixing in winter season. Longer bloom durations were found in the biomes near the Aleutian Island and south of Western Subarctic Gyre (Subarctic Front) where upwelling associated with tidal mixing and several physical forcing around the boundary, respectively.

These results provide evidences that nutrients supply by vertical mixing as well as lateral transport is important for primary production.

Keywords: Phenology, Primary production, Nutrient

