Nutrient and light conditions at subsurface chlorophyll maximum: physical-biogeochemical observations along a mid-Pacific meridional transect

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Subsurface chlorophyll maximum (SCM) occurs in a stratified water column that nutrient is depleted in the surface layer. When fully developed, such as those in calm subtropical regions, SCMs were often observed at depth where both nutrient and light availabilities are at a marginal level. Following resource competition theory, the low resource condition is likely generated by a group of phytoplankton with a low resource requirement, which expels other groups through decreasing nutrients and/or deepening the nutricline. Numerical models formulating the phytoplankton dependency on nutrients and light can reproduce some of characteristics of SCM including seasonal and geographical variability. However, comprehensive observations of the SCM and environmental conditions are still limited especially in the open ocean. In the present study, shipboard physical and biogeochemical observations were conducted along 170˚W from the South Pacific Subtropical Front up to Bering Sea during Boreal and Austral summers.

Characteristics of SCMs were estimated from multiple vertical profiles of chlorophyll fluorescence attached to a Conductivity Temperature Depth profiler (CTD), and nutrient concentrations were determined from water samples. Depths of profiles by sensors and water sample data were determined through projections onto potential density coordinate to eliminate effects of internal wave heaving, which are critical in analyzing processes around SCMs. To evaluate diffusive nutrient flux, vertical diffusivity was calculated using a microstructure profiler and multiplied by vertical gradient of nutrient concentrations. Vertical profiles of photosynthetically available radiation (PAR) were estimated using surface PAR from Moderate Resolution Imaging Spectroradiometer (MODIS), averaged over two weeks until shipboard observation, and diffuse attenuation coefficients of downwelling irradiance calculated from *in situ* PAR measurements.

In subtropical regions from 40˚S to 30˚N, except for that at the equator, SCMs were found in 80–150 m, around or slightly deeper than 1% light level relative to the surface. Depth of SCM was deepest in the middle of subtropical gyres, no shallower than 100 m in 15–25˚. Although considerably shallower than subtropical regions, SCMs were also observed at the equator and temperate and subpolar regions in the range of 15–40 m. There are significant positive correlations between the depths of SCM and 1% light level, where SCM depth was generally deeper than the 1% light level in the subtropical regions. However, PAR at SCMs was not uniform but ranged from 0.1–0.7 mol photon m^{-2} day^{-1} within the subtropical regions, and shows a negative correlation with the SCM depth. The SCM depth also shows a strong positive correlation with the depth of maximum subsurface nitrate flux. Considering effects of pure external factors that are not affected by phytoplankton to the SCM depth, we found a positive relationship with absolute dynamic topography indicating the depth of pycnocline.

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Although 1% light levels can indicate the SCM depth through the linear correlation for the wide geographical range in the mid-Pacific, it is not concluded that SCM was formed under the limitation of light alone. This is followed by a fact that PAR at the 1% levels is not uniform but depends on the surface PAR, by which the relationship between PAR values at SCMs and depths of SCMs become insignificant. As deep penetration of light is caused by the low productivity in the surface water, we cannot simply consider cause and effect for the above relationship. On the other hand, as the dynamic topography is not affected by phytoplankton, its relationship between the SCM depth suggests that the large-scale hydrographic structure has some influences on the formation of SCMs. In the presentation, we will further discuss the details of the physical processes and their possible impacts on subsurface phytoplankton production.

Keywords: Subsurface chlorophyll maximum, Diffusive nutrient flux, colimitation

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