Remote estimation of phenological shifts in phytoplankton community in the Pacific Arctic Region

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Phytoplankton blooms in the Pacific Arctic Region (PAR) has been characterized as a huge single bloom in spring when light availability is high, the mixed layer is shallow and nutrients are abundant due to winter deep mixing. However, several studies have reported that recent increases in occurrence of a relatively small but evident second bloom in fall when light availability is still relatively high and storm-driven mixing replenishes nutrients in the upper well-lit layer. Here we explored interannual variations in phytoplankton phenology in PAR by focusing on biomass and size structure of phytoplankton community based on satellite data. In this study, phenology of phytoplankton community was divided into three types based on time-series chlorophyll-*a* (chl*a*) variations using a nonlinear least squares optimization function: fall bloom (FB), flat high (FH), and flat low (FL). The simple model for FH and FL was a straight line with slope 0, and FH and FL are divided by the chl*a* threshold of 2.5 mg m^{-3}. The complex parameterization of the time-series chl*a* variation for FB was a Gaussian model superimposed over a background concentration of phytoplankton. During our study period of 2003–2017, FB was dominant in the middle (65–67 °N) and southern PAR (62–65 °N), and accounted for 49.1 and 66.8%, respectively. On the other hand, FL was dominant and accounted for 45.9% in the northern PAR (67–70 °N). The proportions of FB and FL showed significant ($p < 0.05$) increasing and decreasing trends in northern PAR (67–70 °N), whereas both middle and southern PAR didn’t show any significant trend for temporal variations in these proportions. In addition, the amplitudes of FB in northern and southern PAR exhibited increasing and decreasing trends, respectively. When we compared the phytoplankton size structure during each phenology, the largest phytoplankton size structure was found in FH, followed by FB and then FL. Moreover, higher amplitude was consisted by larger phytoplankton size structure, suggesting the phytoplankton size structure during the bloom period directly influenced on the amplitude of FB. Since the phytoplankton size structure determines the sinking rate of phytoplankton, these results indicate that benthic organisms in northern and southern PAR would receive more and less fresh phytoplankton during fall. Our findings suggest that the spatiotemporal monitoring of phytoplankton community not only in spring bloom period but also after the period is important for understanding of variations in PAR, because even small changes in the phytoplankton community would have cascading effects on the higher trophic levels via the short and efficient energy pathways in this region. Overall, satellite monitoring of phytoplankton community could improve our understanding about processes of marine ecosystem variations which occurred and/or would occur in PAR.

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