Latitudinal and temporal variations in phytoplankton size structure within mesoscale eddies from space

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Phytoplankton plays a critical role in a number of key ocean processes. One of the most important functions of phytoplankton is to determine the energy transfer efficiency in marine ecosystems. Although the energy flow from the base of the food web to higher trophic levels depends on both the biomass and size structure of phytoplankton community, phytoplankton size structure is particularly important because energy flow in marine pelagic food webs is largely based on size specific predator-prey relationships. Therefore, spatiotemporal dynamics in size structure of phytoplankton community can trigger changes in the ecosystem’s functioning through trophic cascade effects in the trophic chain. With the development of remote sensing techniques, mesoscale eddies, nearly ubiquitous features of the World Ocean, has been recognizing as important feature for the distribution of phytoplankton not only the direct transport of phytoplankton and eddy trapping, but also the vertical flux of nutrients. Recent studies have examined regional variations in the influence of mesoscale eddies on phytoplankton community. Namely, phytoplankton production is enhanced in cyclonic eddies (CEs) than that of anticyclonic eddies (ACEs) because of upwelling inside the eddy; this view, on the other hand, does not hold for a substantial portion of eddies within oceanic subtropical gyres, the largest ecosystems in the ocean. However, previous efforts have focused mainly on variations in chl*a*, whereas quite a few studies have worked on that in the size structure of phytoplankton community because remote estimations of phytoplankton size structure are newly established techniques during the last decade. Here we improved a chl*a* size distribution (CSD) model which estimates the synoptic size structure of phytoplankton community, to assess the impact of mesoscale eddies on spatiotemporal variations in phytoplankton size structure. Original CSD model was based on the spectral features of the phytoplankton absorption coefficient ($a_{ph}(\lambda)$), which estimation accuracy becomes poor in areas of the low productivity, such as subtropical gyres. To avoid this, we used not only $a_{ph}(\lambda)$ but also chl*a* to improve estimation accuracy of the CSD model. The resulting estimation error of the improved CSD model was the median absolute percent difference of 26.0% between the measured and satellite-matched values, and global distribution of the phytoplankton size structure was reliable even in subtropical gyres. The phytoplankton size structure showed a clear latitudinal variation: larger and smaller assemblages in temperate (>30˚S and >30˚N) and low latitudes (30˚S–30˚N) latitudes, respectively. When comparing the phytoplankton size structure within ACEs and CEs, a larger phytoplankton size structure was found in ACEs especially in low latitudes. This result was consistent with a previous report that ACEs are more productive than CEs in subtropical gyres because of winter mixing. In addition, we found increasing trends ($p < 0.05$) in differences between the phytoplankton size structure within ACEs and CEs in low latitudes for the years 2003–2014, suggesting a growing importance of ACEs for phytoplankton and in turn marine ecosystem. Consequently, this study demonstrates significant advantages of satellite remote sensing for biogeochemical and ecological studies.

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