Biological contributions to dissolved oxygen concentration in a marginal sea based on a coupled physical-biogeochemical model

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論　文　内　容　の　要　旨

Thesis Summary

The substantial decrease in dissolved oxygen (DO) concentration has been observed in the deep layer of the marginal sea east to Korean Peninsula or northwest to Japanese archipelago (hereafter EJS). Gamo et al. (1986) have suggested the three possibilities for the long-term decline in DO concentration: 1. Reduction or cessation of the new deep and bottom water supply; 2. Increase of falling organic matters; 3. Enhancement in vertical mixing between the deep and bottom waters. The first cause, that is the slow-down of the deep convection by the global warming, has been considered as the most reasonable to explain the long-term decrease in DO concentration (e.g., Gamo et al., 1986; Minami et al., 1999; Kim et al., 2001; Kang et al., 2004; Yoon et al., 2018).

The increase in falling organic matters as the second possibility leads to a consumption of the DO through the process of decomposition in the deep layers. Moreover, the third case could result in the change in DO concentration as expected from the material balance between the deep and bottom waters. But, the changes in DO concentration attributed to the second and third causes still remain unclear. The major objective of this study is to clarify the effects of the three possible causes on the long-term variation in DO concentration by taking advantage of a coupled physical-biogeochemical model. In particular, we mainly discuss the second cause that how the biological changes in the upper layer influence on the biogeochemical environment in the lower layer with the long-term perspective.

First of all, we simulated the seasonal variations of the DO concentration in the EJS and clarified the biological contribution influencing on the DO variation. The comparative experiments, with and without the biogeochemical model, allowed us to quantify the biological contributions influencing on the seasonal variation of DO concentration.

Taking the biogeochemical factors into account gave better estimations for the spring-to-autumn seasonal migration of the subsurface DO maximum. In spring, the depth of the maximum DO concentration is deeper than the surface where the spring bloom occurred. During the summer season, the peak DO concentration found at the depth of 30m is identical with the chlorophyll-a maximum depth. In the euphotic zone, the biological contribution on the DO concentration is substantial in the Subpolar Gyre

region due to their abundant dissolved inorganic nitrogen (DIN) environment associated with the deep mixed layer depth.

As surface mixing begins in autumn, the subsurface DO maximum rapidly goes deeper level, in particular, it is found below the 100 m in the Tsushima Warm Current (TWC) region. The peak DO concentration shifts to below the euphotic layer by the intrusion of the Tsushima Warm Water (TWW) with the low-oxygen property. The low-oxygen characteristic of the TWW is formed passed through the East China Sea by the decomposition process of organic materials. It cannot be realistically simulated without consideration of the biogeochemical activities.

Below the euphotic zone, the decomposition of organic matters consumes the DO concentration throughout the year. The strongest negative biological effect on DO concentration occurs in the TWC region below 150 m depth because the water is poorly ventilated by the relatively weak winter convection.

Finally, the long-term trends in biogeochemical environment were realistically represented by the model based on the successful simulation in all of the biological processes. The model results showed the enhancement in biological production in the upper ocean during the last few decades. The increase in photosynthetic production results from the rise in amount of DIN available in the euphotic zone. It is attributed to the deepening of the mixed layer by the intensification of the TWC.

The increased biological production in the upper layer has increased the sedimentation of organic matters toward the lower layer and it finally accelerated the decline in DO concentration by encouraging the decomposition process. The enhancement in sinking flux of organic materials decreases the DO concentration, and it accounts for 7% relative to the total decline in DO concentration for the 23 years (1990 to 2012). Whereas, the physical processes without biological decomposition result in the increase in about 35% of the total reduction in DO concentration over the lower layer.

The decrease in DO concentration of 128% relative to the total decrement is attributed to the first possible cause of Gamo (1986), that is the fundamental biological consumption with the passage of time under the supply of new water almost ceased. Therefore, the cessation of the deep convection is the crucial cause of the long-term decrease in the DO concentration in the deep layer as proposed by the previous studies. But, we found the changes in physical and biogeochemical environments can decelerate or accelerate the decline in DO concentration from a few to tens of percent in the deep layer.