The comparison of an observational dataset and CMIP5,6 models for deoxygenation in the North Pacific over the past half-century

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Ocean deoxygenation, which decreases dissolved oxygen in the global ocean, is proceeded by global warming. The IPCC Sixth Assessment Report reported an oxygen decrease of 0.5 to 3.3% in observations from the surface to 1000 m in the global ocean from 1970 to 2010. Scmidtko et al. (2017) showed that the dissolved oxygen decrease in the North Pacific is the largest among the global oceans. Decadal variations dominate the dissolved oxygen variability in the North Pacific, suggesting that global warming and natural climate change affect dissolved oxygen variability (Ito et al., 2018, Stramma et al., 2020). It has also been suggested that the decrease in water mass formation around the Sea of Okhotsk due to global warming is responsible for the oxygen decrease in the western North Pacific (Nakanowatari et al., 2007).
Natural climate variability cannot be detected in the multi-model ensemble mean (MME). Also, the dissolved oxygen trend of MME cancels out the characteristics of the dissolved oxygen trend pattern of each model, resulting in an underestimation of the dissolved oxygen decrease compared to the observed trend. Therefore, the purpose of this study is to know the spatio-temporal structure of the dissolved oxygen decrease in the North Pacific for CMIP5/6 models and to clear the relationship between CMIP models and observation.
The observation is the 3D gridded ocean dissolved oxygen dataset used by Ito et al. (2017). The horizontal resolution is 1 degree in latitude and longitude, and the vertical layers are 47 layers from 0 to 1000 m. The analysis period is from 1958 to 2010, a period of much data. A total of 20 numerical models were used: 10 models from CMIP5 and 10 models from CMIP6. To investigate whether there is a relationship between the strength of the trend of dissolved oxygen in the models and the mechanism that leads to a particular spatial pattern, we conducted an inter-model EOF analysis on the vertically averaged dissolved oxygen trend deviated from the MME. An inter-model EOF analysis is used to determine the common spatial pattern among models and the model loading, representing the amplitude of the pattern for each model. If an inter-model EOF analysis can extract a specific spatial pattern, the relationship between the strength of the mechanism that causes the specific spatial pattern and the strength of the dissolved oxygen trend in the model can be clarified.
The observation showed a dissolved oxygen decrease of -4.54×10^{12} mol/year, while the dissolved oxygen decrease trend of the MME was smaller than that of the observation at -1.52×10^{12} mol/year. Two models showed the same decrease trend as the observation, seven models showed a decreasing trend of less than half of the observation, and five models showed an increasing trend. To investigate the relationship between the strength of the dissolved oxygen trend of each model and the specific mechanism, we conducted an inter-model EOF analysis of the vertically averaged dissolved oxygen trend deviated from the MME. As a result, there is a strong trend of dissolved oxygen decrease in the subarctic circulation region, especially near the Sea of Okhotsk. The correlation between model loading and the dissolved oxygen trend was very high at -0.87. We calculated the loading corresponding to the spatial pattern of the EOF first mode for the observation. By taking the ratio of the loading of the EOF first mode to the trend of dissolved oxygen in the observation, the contribution of the mechanism represented by the EOF first mode among the factors causing the decrease in dissolved oxygen in the observation can be determined. As a result, the mechanism causing the spatial pattern of the EOF first mode explained two-thirds of the dissolved oxygen decrease in the observation. This result suggests that the reduction in dissolved oxygen

near the Sea of Okhotsk is significantly related to the decrease in dissolved oxygen in the entire North Pacific.

Keywords: the North Pacific subarctic circulation region, the Sea of Okhotsk