

## Trends of oxygen with bidecadal oscillations in the Oyashio region and its propagation to the western North Pacific

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Over the past decades, secular trends toward decrease in dissolved  $O_2$  have been observed in a variety of regions and depths in the North Pacific [Keeling et al., 2010, and references therein]. In the western North Pacific,  $O_2$  decrease has been markedly found around  $26.8\sigma_\theta$  that corresponds to the core of North Pacific Intermediate Water (NPIW) along the  $137^\circ\text{E}$  section [Takatani et al., 2012] and the  $165^\circ\text{E}$  section [Sasano et al., 2015]. NPIW is formed in the subsurface of the Kuroshio-Oyashio Interfrontal Zone in the region offshore of northern Japan, and the Oyashio water is considered as one of the source of NPIW. In the Oyashio region, Ono et al. [2001] have found the trends toward increase in AOU and its bidecadal oscillations between  $26.7\sigma_\theta$  and  $27.2\sigma_\theta$  using time series data for the period of 1968–1998 in winter. They speculated that the reduction of ventilation caused the decreases in  $O_2$ . However, because the depth of isopycnal horizon of  $27.2\sigma_\theta$  is much deeper than that of  $26.7\sigma_\theta$  and does not outcrop in the western North Pacific, it is necessary to improve our understanding of these controlling factors. In this study, the controlling factors of secular trends in dissolved  $O_2$  in the Oyashio region was investigated based on long-term hydrographic and biogeochemical measurements made over 1954–2014. We also evaluated the bidecadal oscillations in dissolved  $O_2$  in the Oyashio region. Through the comparison of secular trends and bidecadal oscillations with those along the  $165^\circ\text{E}$  section, their propagation from the Oyashio region to the wide range of the western North Pacific was evaluated.

Significant linear trends toward decreasing  $O_2$  were detected between  $26.6\sigma_\theta$  and  $27.5\sigma_\theta$  in the Oyashio region. The contribution of the decrease in the saturation concentration of  $O_2$  due to warming was small (<10%). The largest decreasing rate in  $O_2$  was found on  $26.7\sigma_\theta$  ( $-0.72 \pm 0.11 \mu\text{mol kg}^{-1} \text{yr}^{-1}$ ) while it was attributed to a deepening effect of isopycnal horizons by approximately 33%. Because this density corresponds to temperature minimum layer formed in winter convection in the subarctic zone and surface density in winter has been decreasing, the decreasing  $O_2$  around  $26.7\sigma_\theta$  would be predominantly attributed to the reduction of ventilation. At  $27.0\sigma_\theta$ ,  $O_2$  decline would be attributed to that in the Sea of Okhotsk where  $O_2$  has been decreasing in this density due to the decrease in the formation of dense shelf water (DSW) in association with the decrease in sea ice forming. In deeper layers with densities up to  $27.5\sigma_\theta$ ,  $O_2$  decreases would also be explained by the reduction of DSW that propagates through diapycnal mixing in the Bussol' Strait. Furthermore, the  $O_2$  reduction in deep layer might be attributed to the increasing contribution of Western Subarctic water through strengthening of the Aleutian Low. In the Oyashio region, bidecadal oscillations of  $O_2$  have been observed in  $26.6\sigma_\theta$ – $27.5\sigma_\theta$ . The periodicities were almost constant at 16.4–19.6 years, and were vertically synchronized within 1 year. Along the  $165^\circ\text{E}$  section, the bidecadal oscillations were also found horizontally in  $30^\circ\text{N}$ – $42.5^\circ\text{N}$  on  $26.8\sigma_\theta$  with a time lag of 1–3 years from the Oyashio region, and vertically in  $40^\circ\text{N}$  up to the subtropical OML at  $27.5\sigma_\theta$ . It suggests that the bidecadal oscillations extended horizontally and vertically to the regions where the subarctic water influences. These results demonstrate that the western subarctic North Pacific is playing an important role as an origin for secular trends and natural variability in dissolved  $O_2$ .

Keywords: deoxygenation, bidecadal oscillation, western North Pacific

