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Global oxygenation by enhanced deep convection in the Southern Ocean under millennial-scale global warming

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Global warming is expected to reduce oceanic oxygen content as reduction in oxygen solubility, enhanced stratification and slower ocean circulation tend to decrease the supply of oxygen into the ocean interior and to enhance biological oxygen utilization (Keeling et al., 2010). The resulting expansion of oxygen minimum zone may have adverse impacts on marine life such as widespread mortality and/or reduced available habitat. Previous modeling studies using Earth System Models of Intermediate Complexity show that oxygen reduction would persist for a thousand years or more, and that the decreases in the total oxygen concentration is as large as 20-50% (Schmittner et al., 2008; Shaffer et al., 2009). However, millennial-scale change in ocean oxygen concentration has not yet been investigated with a fully coupled atmosphere-ocean general circulation model (AOGCM).

Here we use a coupled AOGCM and offline biogeochemical model to simulate multi-millennial oxygen change under atmospheric carbon dioxide doubling and quadrupling. At the first 500 model years in the warming simulation, dissolved oxygen is decreased globally, which is consistent with the previous studies. Thereafter, however, O_2 concentration in the Southern Ocean between subsurface and deep ocean increases and overshoot rapidly, and that in the other deep ocean except the North Atlantic recovery gradually. Consequently, global mean O2 concentration recovers and overshoots by the end of warming experiment, in spite of surface oxygen reduction due to lower oxygen saturation and weaker Atlantic meridional overturning circulation. Recovery of deep ocean convection in the Weddell Sea after initial cessation enhances ventilation and supplies the oxygen into each of the three major basins through strengthened Antarctic Bottom Water, resulting in the oxygen overshoot in the deep ocean. Our results suggest that enhanced deep convection and ventilation in the Southern Ocean have global impact on millennial-scale oxygen change. The mechanisms of cessation and recovery of deep convection in the Weddell Sea will be discussed.

Keywords: dissolved oxygen, global warming, open ocean convection, thermohaline circulation