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Ocean Oxygenation Response to Climate Change: Lessons from Past Warm Periods

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Cenozoic warm periods can provide insight into the future of ocean oxygenation in a warming world, as they had temperatures aligned with those projected under future warming scenarios and tectonic configurations not too dissimilar to the modern. During the Miocene Climatic Optimum (~16 Ma), the two strongest oxygen minimum zones (OMZs), in the Pacific Ocean and Arabian Sea, were both better oxygenated than today, then deoxygenated during the cooling that followed (Hess et al., 2023; Hess, Auderset et al., 2026). Here, we use complementary paleo-oxygenation proxies that respond to different oxygen concentrations (Mn/Ca and I/Ca in planktonic foraminifera, and foraminifera-bound nitrogen isotopes) to semi-quantitatively reconstruct the (de)oxygenation history of these OMZs through the Miocene. Despite both being better oxygenated during the warm climatic optimum, we find regional differences in the magnitude of oxygenation and timing of deoxygenation, with the Pacific being better oxygenated and deoxygenating earlier than the Arabian Sea.

Thus, the response of these OMZs to climatic warming appears to be driven at least in part by regional processes. We use a variety of geochemical proxies to explore two possibilities: (1) wind-driven upwelling, linked to Walker Circulation in the Pacific and the South Asian monsoon in the Arabian Sea, and (2) high-latitude ventilation of both OMZs from the Southern Ocean and of the Pacific OMZ from the North Pacific. Additional insights into the possibility of North Pacific ventilation come from a more recent warm period, the Pliocene (~3 Ma).

High-pCO_2 model simulations with spin-up times designed to approach equilibrium show that despite initial deoxygenation, a re-oxygenation trend follows, beginning 100s to 1000s of years into the simulation. Increased oxygenation of OMZs during the warm Miocene is consistent with these models and suggests that the modern deoxygenation trend will ultimately reverse. Regional differences may also be expected, highlighting the importance of understanding the complexity of drivers for ocean oxygenation.