# The tipping point for pervasive ocean anoxia

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There are growing concerns about the expansion of oxygen-poor environments in the ocean. A quantitative understanding of the magnitude, pattern, and biogeochemical consequences of ocean deoxygenation is essential for understanding the feedbacks to climate. Recent advances in biogeochemical models reveal the spatial and temporal scales of ocean deoxygenation and its uncertainty on millennial timescales. However, the ocean deoxygenation could last for longer timescales, given the long residence time of critical nutrient phosphorus in the ocean (˜15-20 kyr) which exerts fundamental controls on biological productivity and oxygen consumption in the ocean. Understanding the mechanistic link between the global phosphorus cycle and ocean deoxygenation on timescales exceeding 10 kyr would also help shed light on the questions regarding the causal mechanisms for large-scale ocean anoxia that occurred in the geological past.

Here, a new Earth system model of low complexity, CANOPS, was used to assess the tipping point for the global-scale ocean anoxia. Special attention has been paid to the importance of the redox-dependent phosphorus recycling in marine sediments because it has a significant impact on the global ocean redox state by creating a positive feedback loop between ocean $O_2$ levels, phosphorus recycling, and biological productivity. The sensitivity experiments support the previous arguments that the enhanced phosphorus input to the ocean is a critical factor responsible for large-scale oceanic anoxia and that the development of anoxia in coastal regions would have the potential to dramatically change the oceanic $O_2$ inventory. The stochastic approach also provides an integrated, quantitative, and statistically informative picture of future ocean deoxygenation and highlights the remaining uncertainties. The importance of the coupled C-P-S cycles will also be discussed.

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