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A climate tipping point for ocean deoxygenation during the Early Cretaceous

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Ocean deoxygenation events linked to warm climate states are intermittent in Earth's past and provide important analogues that connect the timescales, mechanisms, and feedbacks associated with expanding marine anoxia to the broader Earth-life-climate system. In this work, we use high-resolution geochemical data and models to show that dramatic climate-driven changes to ocean oxygenation states occurred on remarkably rapid timescales during the Aptian hyperthermal event of the Early Cretaceous (OAE1a). Our data and models reveal that the development of widespread oceanic anoxia during OAE1a was triggered by the traversal of a climate-based tipping point for ocean oxygen. Notably, this climate tipping point for ocean deoxygenation was surpassed with a mere doubling of pCO_2 above the background Cretaceous atmosphere, driven by massive volcanism associated with the Ontong Java Large Igneous Province (LIP). Recovery from widespread anoxia, furthermore, was protracted and proceeded at a pace set by the silicate weathering feedback, which ultimately drew pCO_2 down to below the threshold after ~1 Myrs, resulting in a rapid (<25 kyrs) reoxygenation of the oceans. Critically, however, the Earth system remained in a sufficiently warm state for an additional >1 Myrs, such that orbitally driven climate dynamics led to cyclic transitions across the climate threshold and the repeated re-emergence of low-oxygen conditions on Milankovitch timescales. Our results thus reveal a tight coupling between climate and ocean oxygen contents that is characterized by a pCO_2 tipping point and is relevant to anthropogenic climate warming and contemporary ocean deoxygenation. Indeed, the identified absolute pCO_2 threshold can be crossed in high anthropogenic-emissions scenarios (e.g., Representative Concentration Pathway (RCP) 8.5). It thus appears that OAE1a-like conditions could emerge under the range of possible climate future scenarios unless CO_2 emissions are reduced and/or it is deliberately removed from the atmosphere through engineered carbon dioxide removal (CDR) from the atmosphere.