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Nitrogen Cycle Perturbation During the Paleocene-Eocene Thermal Maximum

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Modern climate change is already negatively impacting the nitrogen cycle and ecosystem structure as a consequence of ocean acidification and warming. However, much less is known on the long-term impact of prolonged warming, acidification, and deoxygenation on the nitrogen cycle, which greatly affects the trophic state of the ocean. Here, we studied the nitrogen cycle perturbation during the Paleocene-Eocene Thermal Maximum (PETM), one of the best-studied analogues to inform on future climate change. To elucidate changes in the nitrogen cycle during the PETM, we integrated nitrogen isotope and biomarker data from eight globally distributed sites to track the state of the nitrogen cycle, together with intermediate complexity Earth system model (cGEnIE) implemented with a nitrogen cycling module. Based on our data, nitrogen cycle perturbation exhibited significant regional heterogeneity. Fixed nitrogen loss was predominantly confined to enclosed or semi-enclosed basins, where enhanced deoxygenation promoted denitrification over nitrogen fixation. Surprisingly, ammonia oxidation increased globally despite ocean acidification, which was previously thought to decline in response to ocean acidification. Intensification of nitrification during the PETM was likely caused by ammonia supply from the deep hypoxic ocean. Enhanced nitrification may have protected surface ecosystems from ammonia toxicity. Overall, our results indicate that deoxygenation during the PETM was not extensive enough to cause nutrient inventory collapse throughout the ocean. Instead, global N inventory increased by 35% during the PETM, driven by enhanced phosphorous supply from the continents. This suggests that future nitrogen cycle perturbation may be spatially highly variable and nitrification may not be as sensitive to ocean acidification as previously thought.