The response of ocean oxygen-deficient zones to past climate changes: Evidence from fossil-bound nitrogen isotopes

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The availability of dissolved oxygen (O_2) is among the most fundamental constraints on life in the ocean, and it impacts the marine cycles of most biologically important elements. Moreover, the distribution of oxygen in the ocean interior reflects the carbon storage associated with the ocean's biological pump, which is, in turn, sensitive to the ocean's circulation and biological productivity. Thus, the response of ocean oxygen to climate change – past, ongoing, and future – is of great consequence. Based on oxygen measurements over decades, it has been argued that that the ocean's oxygen-deficient zones (ODZs) have been expanding due to global warming. Numerical ocean models, however, provide a complex picture of the ODZs in the global warming future. Studies of past warmer-than-modern periods can provide unique insight. The "denitrification" (reduction of nitrate to N_2) that occurs in the ocean's ODZs is reflected in the nitrogen isotopic composition of oceanic nitrate and the organic matter produced from it. I will describe nitrogen isotopic measurements of the organic matter bound within biomineral fossils (of foraminifera, otoliths, and corals) over a range of time scales that, together, indicate smaller ocean ODZs under warmer climate. I will then consider possible mechanisms, the implications for the climate dependencies of the ocean's oxygen, nitrogen, and carbon cycles, and the significance of the findings for anthropogenic global warming.