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Reduced N-fixation in the Low Latitude Atlantic during the Warmer Pliocene

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N_2 fixation is the primary pathway by which bioavailable nitrogen is added to the oceans. However, the drivers of N_2 fixation on orbital timescales are uncertain. We present high-resolution foraminifera-bound (FB) $\delta^{15}N$ records from the Western and Eastern tropical Atlantic Ocean (WTA and ETA respectively) throughout the late Pliocene (~3.60 to ~1.97 Ma), where WTA ODP Site 999 represents N_2 fixation changes and EEA ODP Site 662 represents changes in pycnocline $\delta^{15}N$. Our results show that, compared to the past 160 ka, N_2 fixation in the WTA was significantly lower throughout the late Pliocene as reflected by an average of ~2 ‰ higher FB-$\delta^{15}N$ values. A possible explanation to the higher Pliocene FB-$\delta^{15}N$ in the WTA could be lower rates of global denitrification that were balanced by lower global N_2 fixation levels. We suggest that this reduced N_2 fixation was due to decreased excess P in the pycnocline/subsurface ocean, driven by lower global water column denitrification, which implies a coupling between decreased water column denitrification and reduced level N_2 fixation rates under warmer climates. On orbital timescales, our N_2 fixation record display obliquity-paced cycles that progressively intensified after the Northern Hemisphere glaciation intensification ~ 2.8 Ma, and the onset of equatorial upwelling pulses documented during glacial periods in the EEA (ODP Site 662; [1]). Observed changes in N_2 fixation of the last 160 ka were previously explained by precession-paced upwelling in the eastern equatorial Atlantic that imported excess P into the oligotrophic WTA [2]. However, precessional cyclicity is not dominant in the Pliocene FB- $\delta^{15}N$, which calls for other candidates to explain the variations after 2.8 Ma. The best explanation is a response to sea-level paced sedimentary denitrification. Glacial lower sea levels exposed continental shelves, reducing regional benthic denitrification and inhibiting the supply of excess P, thereby limiting N_2 fixation in the WTA, whereas interglacial submerged shelves increased excess P availability.

[1] K. T. Lawrence, *et al.*, Time-transgressive North Atlantic productivity changes upon Northern Hemisphere glaciation. *Paleoceanography* **28**, 740–751 (2013).

[2] M. Straub, *et al.*, Changes in North Atlantic nitrogen fixation controlled by ocean circulation. *Nature* **501**, 200–203 (2013).