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Nitrogen fixation within both Benguela Upwelling System and Eastern Equatorial Pacific as a strong contributor of the Pliocene cooling?

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During the Pliocene, the finale closure of the Panama Gateway after 2.73 Ma has induced a global climatic transition from a warm and relatively stable epoch to a colder world experiencing glacial/interglacial cycles. Although evidence from high- and low-latitudes, e.g. by the pronounced stratification of the Southern and Northern Pacific Oceans and the initiation of the modern Gulf Stream in the Caribbean Sea are considered as causes for this climatic change, only few studies focused on upwelling areas, known to have an impact on the carbon cycle. These highly productive regions during the Pliocene have undergone profound reorganization leading to a different redistribution in nutrient supply and therefore in the productivity and carbon sequestration. The modification of the nature of the biological pump at low-latitudes may have thus played a more significant role than expected by lowering or increasing the atmospheric CO_2 level through the Pliocene cooling.

Here, we provide a comparison over the past 3.5 Ma between the ODP Sites 1082 and 1239, respectively located within the Benguela Upwelling system and in the Eastern Equatorial Pacific. We used alkenones as sea surface temperature (SST) proxy and sedimentary nitrogen isotopes ratios (δ^{15}N) as an estimation of the degree of the nitrate utilization by the phytoplankton. At Site 1082, the results showed very low bulk-sediment δ^{15}N values reaching a minimum ($<1‰$) during the first Pliocene SST

cooling. Both proxy records were strikingly negatively correlated until the Pleistocene (1.5 Ma) leading progressively to conditions closer to the modern ones, colder temperature at the surface (∼18˚C) and higher bulk-sediment δ^{15}N (∼4-5‰). At Site 1239, the SST and sedimentary δ^{15}N values showed similar trends as at site 1082, however, with warmer SST in the Eastern Equatorial Pacific part (>22˚C). This is consistent with the fact that the site 1082 is located within an upwelling cell while the site 1239 is only influenced by the rim of the Peruvian upwelling. Despite the uncertainties linked to the stratigraphy at site 1239, the bulk-sediment δ^{15}N signal revealed a negative shift at 2.7 Ma coeval with that observed within the Benguela Upwelling System. Within both oceanic systems, the lowest isotopic ratio close to the atmospheric values (0‰) after 2.7 Ma may indicate N-fixation owing to warm stratified conditions and high siliceous productivity prevailing in these regions. Because the silicon was not completely utilized within the Southern and Northern Pacific Oceans and because the high-latitudes sea ice cover expanded during the Pliocene cooling, this could have gradually transferred the opal production centers to the low-latitudes coastal upwelling areas by Si-rich waters supply. An enhanced local nitrate pool by the N2-fixers as attest the low bulk-sediment δ^{15}N signal, then stimulated the diatom productivity. As a result, the siliceous phytoplanktonic productivity replacing the calcareous producers both in the eastern Pacific and Atlantic margins could have increased the atmospheric CO_2 sequestration and thereafter actively participated to the global cooling occurring after 2.73 Ma.