Millennial-scale climate variability in the 41 kyr world of MIS 50 to MIS 40 (1.5-1.28 Ma): Insights from planktonic foraminifera and sea surface temperature data from the southern Iberian margin

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During the early Pleistocene (prior to 1.25 Ma), obliquity dominated the cyclicity of climatic variations, resulting in glacial and interglacial cycles. A significant change occurred between 1.25 Ma and 0.7 Ma, which altered the dominant frequency from 41 kyr to 100 kyr. This transition period is known as the Mid-Pleistocene Transition (MPT). Although several climate models and records have focused on the MPT, our understanding of how climatic variations in the 41 kyr-world affected the planktonic foraminiferal fauna, and their response to the millennial-scale sea surface temperature (SST) oscillations remains limited. Here, we present a sub-millennial scale planktonic foraminiferal assemblage and G. bulloides stable isotope data from southern Iberian margin IODP Site U1387 (36°48.321´N 7°43.1321´W, 559 water depth), influenced by subtropical surface waters from the Azores current. The main goal is to reconstruct temporal trends in SST and to infer ecological changes during the interval from Marine Isotope Stage (MIS) 50 to MIS 40 (1.5-1.28 Ma).

Planktonic foraminifera assemblages show a distinct pattern between glacial and interglacial periods, correlating with changes in the mid-latitudinal North Atlantic's surface circulation. Interglacial periods (MIS 49, MIS 47, MIS 43) exhibit a strong influence of warm, oligotrophic waters. The abundances of subtropical species vary between 40% and 65%, whereas tropical species reach up to 10%. The SSTS were around 23.7°C during summer and 18.5°C during winter. In these periods, insolation appears to influence interglacial intensity, peaking at the onset of MIS 47 and MIS 43. In contrast, during cooler MIS 45, the subtropical species only reached values up to 20% and tropical species up to 2%, with temperatures about 21°C in summer and 16°C in winter. The expansion of the subtropical gyre during the interglacials, but also interstadial periods, could have played a significant role in those species' assemblages and the SST fluctuations.

In contrast, during glacial periods (MIS 50, MIS 48, MIS 46, MIS 44), extreme cold events of short duration were documented, with MIS 50 and MIS 48 recording distinct terminal stadial events. Those short-term episodes were marked by abrupt abundance increases of polar species N.
*pachyderma* up to 40% to 65%, respectively, and SSTs dropping down to 8°C in summer and 5°C in winter. The coldest temperatures were documented during the MIS 48 stadial terminal event and is consistent with alkenone-derived SST data, indicating colder deglacial conditions compared to MIS 46 and MIS 40. The SSTs, and the faunal data, including the increase in cold water calcareous nannofossil taxa, are consistent with evidence of the southward displacement of subpolar waters and the contraction of the subtropical gyre. In addition to the faunal data, changes in the *G. bulloides* δ¹⁸O record reveal a gradual increase of values during MIS 48 and abrupt oscillations during MIS 46, MIS 44, MIS 42, and MIS 40. Overall, we confirm the presence of millennial-scale climate variability during the 41 kyr-world with strong impacts on the planktonic foraminifera fauna and implications for the dimension of the subtropical gyre in the North Atlantic.