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A role for the surface ocean in the mid-Pleistocene climate transition

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For the last 640 kyr the climate system has been dominated by Glacial-Interglacial oscillations with a frequency of ca.100-kyr. This contrasts with lower amplitude, 41-kyr oscillations that dominated most of the late Neogene climate system. This shift in the dominant periodicity of the glacial cycles is defined as the mid-Pleistocene climate transition (MPT) and continues to be an enigma of climate research. The transition to 100-kyr cycles is preceded by an expansion of northern hemisphere ice-sheets at ca. 920 ka. Neither this event nor the shift to 100-kyr glacial cycles can be explained by external forcing mechanisms and must therefore have been driven by processes operating within the climate system itself.

Here, we examine the role of changes in surface ocean conditions in the Atlantic and tropical Pacific in driving the MPT. These changes influence the heat and moisture transport to the ice-sheet source regions and carbon cycling within the climate system. Four ODP sites have been examined for the interval 1500-500 ka, with a 5-kyr resolution. We use the alkenone U^{K}_{37}' proxy for sea-surface temperature reconstructions, chlorins and alkenones to investigate organic carbon export, and the relative abundance of the $C_{37:4}$ alkenone to infer changes in arctic/polar water masses. Our results show that from 1150 ka an increase in marine organic carbon export paralleled surface ocean cooling at a global scale, an expansion of the arctic/polar water masses

in the northern hemisphere, and a strengthening of Walker circulation in the tropical Pacific. Significantly, these changes began much earlier than the ice volume increase at ca. 920 ka conventionally used to define the onset of the MPT. Through their impact over moisture transport to the ice-sheets and the burial of CO_2 in the deep ocean, these events played a key role in driving and modulating the development of larger northern hemisphere ice-sheets around 0.92 Ma. The increased inertia of the larger ice-sheets may be critical to the increasing periodicity of the climate cycles from 41-kyr to 100-kyr. We propose that changes to the surface ocean during the mid-Pleistocene played an important role in the expansion of the northern hemisphere ice-sheets by: i) encouraging ice-sheet growth through global cooling; ii) modulating the ice-sheet response to this cooling; and iii) maintaining or enhancing the cooling trend through changes in the carbon cycle.