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Late Pliocene ice sheet response to Milankovitch forcing

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The consistency between spectral peaks in benthic foraminiferal oxygen isotope records and Milankovitch frequencies indicated a close relationship between glacial-interglacial ice volume changes and astronomical perturbations. Hence, emphasis has been taken on establishing chronologies of sedimentary records by tuning benthic isotope records to astronomical-forced patterns of climate change. In the widely applied astronomical tuning procedure of Imbrie and Imbrie [1980], it is assumed that the ice sheets have a fixed response time (Tm), which results in different time lags with respect to the various Milankovitch frequencies. For the late Pleistocene a Tm value of 17 kyr has been estimated, which results in 5-kyr and 8-kyr time lag of global ice volume with respect to the precession and obliquity parameters, respectively. The smaller ice sheets during the late Pliocene would have resulted in a smaller time constant and hence in a reduction of the time lag between the perturbating astronomical cycle and ice volume response [Chen, et al., 1995; Lisiecki and Raymo, 2005]. Here we present high-resolution benthic oxygen isotope records of marine oxygen isotope stages (MIS) 101-95 (˜2.56-2.4 Ma) from ODP Site 967 (E. Mediterranean)and applied an inverse model [Bintanja et al., 2005a, b] to deduce changes in global ice volume and northern Hemisphere annual air temperatures. Since the age model of Site 967 is independent from glacial-interglacial cycles [Lourens, et al., 2001], these data allow us to evaluate the response times of the different climate components with respect to obliquity forcing in detail. Our results show that the response times between minimum obliquity and 1) maximum d18O values, 2) maximum ice volume and 3) minimum air temperatures arrive at respectively 6.3-kyr, 8.0-kyr, and 3.4-kyr on average. The presence of significant spectral power at 80 and 28-kyr frequencies indicates moreover that nonlinear interactions between individual astronomical perturbations may have played an important role in determining the frequency characteristics and shape of the glacial/interglacial succession.