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Comparison of different mechanisms explaining the absence of Northern Hemisphere ice sheets prior to ∼2.75 Ma

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During the warm climates of the early and middle Pliocene (∼3-5 million years ago), ice sheets were absent in the Northern Hemisphere. The onset of glaciation took place approximately 2.75 My ago. Several hypotheses have been proposed to date to explain why the climate of the early and middle Pliocene prevented the establishment of ice sheets. Some of these are reduced obliquity and eccentricity forcing (Maslim et al. 1998), increased atmospheric CO_2 concentrations (Mudelsee and Raymo, 2005), an open Central America seaway causing a weaker Atlantic Meridional Overturning Circulation and associated reduced moisture suppy to the areas of ice sheet formation (Haug and Tiedemann, 1998), decreased seasonality in the North Pacific caused by decreased ocean stratification (Haug et al. 2005), and/or permanent El Niño conditions (Wara et al. 2005). In our study these hypotheses are compared via simulations with an Atmospheric General Circulation Model coupled to a slab ocean model in combination with an Equilibrium Line Altitude Model (Rupper and Roe, 2008). The Equilibrium Line Altitude (ELA) is the height at which ablation equals accumulation. There is a positive gain of mass at locations higher than the Equilibrium Line, which is the condition for the establishment of glaciers; thus changes in the ELA may be used as a diagnosis of tendency to glaciation. For each hypothesis, we present the relative contribution of ablation and moisture anomalies to the simulated changes in the Equilibrium Line.