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Rethinking Cenozoic glacial history: a model-data perspective

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The sudden growth of the East Antarctic Ice Sheet (EAIS) in the earliest Oligocene (34 Ma) has long been assumed to represent the first major glaciation of the Cenozoic. Earlier ephemeral glaciations have recently been proposed for the Cretaceous and Eocene. While the timing of the first significant ice on Greenland remains equivocal, the Northern Hemisphere is usually assumed to have remained mostly ice-free until the onset of 40-kyr glacial cycles in the Pliocene (2.7 Ma). Coupled GCM-ice sheet models have simulated the sudden continental-scale glaciation of Antarctica in the earliest Oligocene, in response to a combination of decreasing atmospheric CO2 and orbital forcing. The simulated ice sheet uses most of the available accommodation space and is roughly equivalent to the modern EAIS. However, it is too small by a factor of 2 or more to account for the ice volume implied by paired isotopic and Mg/Ca analyses of the event. Similar model-data inconsistencies apply to other isotopic shifts/glaciation events in the Paleogene and Neogene. Two possible explanations are: (i) significant ice sheets formed in the Northern Hemisphere much earlier than previously assumed, or (ii) interpretations of geochemical proxies of ice volume are faulty. We use a coupled GCM-ice sheet model to test these possibilities, by exploring the range of Cenozoic forcing required for Northern and Southern Hemisphere glaciation, and the possibility that the onset of Antarctic ice sheets preconditioned the climate system for episodic bipolar glaciation. While our coupled climate-ice sheet model shows some dependency on uncertain tectonic boundary conditions, it does support the possibility of some episodic glacial ice on Greenland and in the circum-Arctic through much of the Cenozoic. However, major bipolar glaciation events only appear to be possible at levels of atmospheric CO2 near or lower than modern values, which is inconsistent with proxy reconstructions of CO2 older than about 20 Ma.