THE EARLY GLACIAL HISTORY OF ANTARCTICA: ICE SHEET RESPONSE TO EVOLVING CENOZOIC BOUNDARY CONDITIONS

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A Global Climate Model (GCM), asynchronously coupled to a dynamical ice sheet model, has been developed, tested, and applied to the glacial history of Antarctica. The coupled GCM-ice sheet approach allows us to test the sensitivity of the atmosphere-ocean-cryosphere system to evolving Cenozoic boundary conditions, including paleogeography, atmospheric carbon dioxide, changing orbital parameters, and changes in ocean heat transport. The model has been used to explore 1) the forcing mechanisms and internal feedbacks responsible for glacial inception near the Eocene-Oligocene boundary (34 Ma), 2) modes of Cenozoic ice-sheet variability over orbital and longer timescales, and 3) the possibility of complete continental deglaciation during periods of elevated atmospheric CO2. GCM-ice sheet simulations were run with CO2 declining steadily from 4x to 2x preindustrial levels over a 10-myr period, and with ocean heat transport adjusted to represent open vs closed Southern Ocean gateways (Tasmanian and Drake Passages). The results suggest that declining Cenozoic CO2 was the primary factor in the initial Paleogene glaciation of East Antarctica. Once a CO2 threshold is met (2.4 to 2.8x preindustrial levels), a continental ice sheet grows suddenly when an orbital configuration producing cold austral summers triggers snow/ice albedo and height-mass balance feedbacks. Changes in ocean heat transport, like those assumed to have occurred in response to the opening of Southern Ocean gateways, are shown to have a relatively small effect on the timing of glaciation. The early ice sheets exhibit the greatest response to orbital forcing around the time of the major glaciation, and less variability with lower CO2. The reverse scenario of an initially glaciated continent under increasing CO2 conditions exhibits hysteresis, with the CO2 threshold for
East Antarctic deglaciation delayed until CO2 climbs to around 3.5x. As in our glaciation simulations, orbital forcing appears to play an important role in the initiation of internal feedbacks leading to deglaciation once some CO2 threshold has been crossed. Simulated climates and ice sheets, like those described here, are now being integrated with paleoenvironmental information from the geologic record. It is our hope that integrated model-data studies will advance our understanding of the glacial history of the Antarctic continent and the evolution of climate through the Cenozoic.