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HadCM3L predictions of ocean temperature response to the growth of the Antarctic ice sheet during the Early Oligocene

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The abrupt and widespread glaciation of Antarctica in the earliest Oligocene marked a fundamental change in Earth's climate towards our current glaciated state. An increase in benthic delta-18O of up to 1.5 per mil occurred over a 300 to 400 kyr interval and is widely assumed to document both cooling and ice sheet growth marking the inception of the icehouse world. Resolving the relative contribution of ice volume and temperature changes to this shift is essential to understanding, and accurately modelling, this climate transition. In an attempt to quantify relative ice volume and temperature changes at the Eocene-Oligocene boundary we present results from two long (more than 4000 simulated years) Early Oligocene climate model experiments using the Hadley Centre Coupled Climate Model version 3 (HadCM3L). The simulations are identical in all respects except in the prescribed Antarctic ice volume (either zero ice volume or an ice volume close to modern as possible given the Early Oligocene land-sea mask employed). The response of sea-surface temperatures to the growth of an Antarctic ice sheet is spatially heterogeneous with some areas subject to changes of more than 3C. The model results indicate that intermediate and deep waters cool in response to the presence of an Antarctic ice sheet, but even after 4000 years of simulation deep ocean temperatures in HadCM3L have not reached equilibrium. These results suggest that a significant part of the delta-18O shift across the E/O boundary may be accounted for by deep ocean cooling and suggests that the presence of a large ice sheet in the Northern Hemisphere at this time may not be necessary.