Supplement of

Miocene Antarctic Ice Sheet area adapts significantly faster than volume to CO$_2$-induced climate change

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Figure S1. (A) Transient evolution of the forcing CO$_2$ level (green dashed) and the resulting ice volume over time, normalized with respect to the maximum integration time, for the 100-kyr (blue), 400-kyr (red) simulations, and the final cycle of the 40-kyr simulation (black). (B) Same for CO$_2$ and ice area. For the 100-kyr and 400-kyr simulations, we show the 10-kyr moving average (thick lines) in addition to the 1-kyr output (thin lines).
Figure S2. Ice volume plotted against ice area, for the 100-kyr (blue) and 400-kyr (red) simulations. The progression direction is counterclockwise. The connected symbols indicate the ascending branch (lightgreen) and return branch (darkgreen) equilibrium ice volume and area.

Figure S3. Map of present-day Antarctic grounding lines and coastlines (Morlighem et al., 2020). Indicated are the locations where ice sheet collapse occurs in successive order: 1) Coats Land, 2) Princess Elizabeth Land, 3) Wilkes Land, 4) George V Land, 5) Dome Fuji, 6) Dome Circe, and 7) Dome Argus.
Figure S4. Results for the 40-kyr simulation using an index method in which the interpolation of the climate forcing is solely based on the CO$_2$ level (NOFEEDB experiment in Stap et al., 2022). Transient evolution over time of ice area (cyan) and ice volume (purple) relative to their maximum sizes as obtained from the 280-ppm equilibrium simulation, $14.4 \times 10^6$ km$^2$ and 60.1 msle respectively. The green line shows the forcing CO$_2$ level. The right y-axis is reversed because CO$_2$ is generally negatively related to the benthic $\delta^{18}$O signal.
Section S1

We perform an additional experiment using a model set-up representative for Pleistocene glacial-interglacial variability of the North American ice sheet, that is described in detail in Scherrenberg et al. (2023). Briefly, we deploy the updated version 2.0 of IMAU-ICE. This version uses the DIVA approach - which is slightly different from the hybrid SIA/SSA approach - to calculate the dynamics of grounded and floating ice (Berends et al., 2022). The grid covers the North American continent on a 40x40-km resolution. We carry out an equilibrium and a transient simulation like those for the Miocene Antarctic ice sheet. An equilibrium simulation is conducted at a CO$_2$ level of 190 ppm. In the transient simulation, the CO$_2$ level is linearly decreased from 280 to 190 ppm, and then increased back to 190 ppm. In Fig. S4, we show the forcing CO$_2$ level and the resulting ice area and volume.

**Figure S5.** Results for the 40-kyr simulation of the North American ice sheet in settings representative for Pleistocene glacial-interglacial variability. Transient evolution over time of ice area (cyan) and ice volume (purple) relative to their maximum sizes as obtained from the 190-ppm equilibrium simulation, 15.5 x 10$^6$ km$^2$ and 98.9 msle respectively. The green line shows the forcing CO$_2$ level. The right y-axis is reversed because CO$_2$ is generally negatively related to the benthic $\delta^{18}$O signal.
Figure S6. Decay rate over normalized time, for the 400-kyr simulations of the reference experiment (red), an experiment using a simpler index method for the climate interpolation (excluding the albedo-temperature feedback; blue), and an experiment using Last Glacial Maximum sub-shelf melt rates (green).
REFERENCES


