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Deglacial ice-sheet meltdown: orbital forcing versus CO_2 effects

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Eighty thousand years of ice-sheet build-up came to a rapid end ∼20-10 thousand years before present (ka BP), when ice sheets receded quickly, and global mean surface temperatures increased by about 4°C. It still remains unresolved whether insolation changes due to variations of earth's tilt and orbit were sufficient to terminate glacial conditions.

Using a coupled fully three-dimensional climate–ice-sheet model (iLOVE=IcIES+LOVECLIM), we simulate the transient climate and Northern Hemisphere ice-sheet evolution from 78 ka BP to 0 ka BP in good agreement with sea level and ice topography reconstructions. Based on this simulation and a series of deglacial sensitivity experiments with individually varying orbital parameters and CO_2, we find that enhanced calving led to a slow-down of ice-sheet growth already 5 ka to 8 ka prior to the Last Glacial Maximum (LGM), as evidenced by the change in curvature of the simulated and reconstructed ice volume time series. Increasing obliquity and precession then led to accelerated ice loss due to ablation and calving, thereby initiating the glacial termination. The deglacial sensitivity experiments further reveal that the ∼100 ppmv rise of atmospheric pCO_2 after ∼18 ka BP was a key contributor to the deglaciation. Without it, the present-day ice volume would be comparable to that of the LGM and global mean temperatures would be about 3°C lower than today. We further demonstrate that neither orbital forcing nor CO_2 forcing alone were sufficient to complete the deglaciation.