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The simulated transition from a hard snowball Earth

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Geological evidence suggests that Earth's past featured periods during which the planet was largely or even entirely covered by ice, a state termed "snowball Earth". Model based studies confirm that one of Earth's equilibrium states is a fully glaciated planet (hard snowball) but it is not clear how this state could have been left once it had been established. We use simulations with the Max-Planck-Institute for Meteorology's Earth system model to investigate the conditions that enable the transition out of the snowball-state. We show that the high albedo of pure snow would have prevented deglaciation, even for extremely high atmospheric CO₂ concentrations. Terminal deglaciation is only triggered for surface albedos corresponding to old, darkened snow or sea-ice. Here, increasing snowfall rates, resulting from the intensification of the hydrological cycle with rising CO₂ concentrations, would have prohibited the gradual build-up of dust that leads to a darkening of the surface. Only when assuming dust deposition fluxes at least similar to present-day fluxes, can the deglaciation be triggered for plausible atmospheric CO₂ concentrations.