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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 deglatiation, 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 deglation be triggered for plausible atmospheric CO2 concentrations.