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# Ice sheet runoff and Dansgaard-Oeschger Cycles

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Many northern hemisphere climate records, particularly those from around the North Atlantic, show a series of rapid climate changes that recurred on centennial to millennial timescales throughout most of the last glacial period. These Dansgaard-Oeschger (D-O) sequences are observed most prominently in Greenland ice cores, although they have a global signature, including an out of phase Antarctic signal. They consist of warming jumps of order 10°C, occurring in typically 40 years, followed generally by a slow cooling (Greenland Interstadial, GI) lasting between a few centuries and a few millennia, and then a final rapid temperature drop into a cold Greenland Stadial (GS) that lasts for a similar period.

Most explanations for D-O events call on changes in Atlantic meridional overturning circulation strength, and the majority of such explanations use changes in freshwater delivery from ice sheets as a trigger. Many have relied on large inputs of freshwater from singular events (such as lake outbursts or iceberg armadas) to push the AMOC into its cold state. However the evidence for such events at the right time in each cycle is sparse. Here we investigate mechanisms that would arise from a change in the rate of ice sheet runoff, which would be a natural feedback from each rapid warming or cooling event. Recent work has suggested that AMOC is most easily disrupted by freshwater delivered through the Arctic. We investigate whether the proposed AMOC changes could have occurred as part of a natural oscillation, in which runoff from the Laurentide ice sheet into the Arctic is controlled by temperature around the North Atlantic. The Arctic buffers the salinity changes, but under warm conditions, high runoff eventually leads to water entering the North Atlantic with low enough salinity to switch AMOC into its weaker state. Under the colder conditions now prevailing, the Arctic is starved of runoff, and the salinity rises until a further switch occurs. Contrary to many previous studies, this mechanism does not require large freshwater pulses to the North Atlantic. Instead, steady changes in ice-sheet runoff, driven by the AMOC, lead to a naturally arising oscillator, in which the rapid warmings come about because the Arctic Ocean is starved of freshwater. The changing size of the ice sheets would have affected the magnitude and extent of runoff, and we suggest that this could provide a simple explanation for the absence of the events during interglacials and around the time of glacial maxima. We construct a simple model to investigate whether the timescales and magnitudes would in practice make this a viable mechanism, and we consider other roles that runoff could play. Heinrich events, delivering additional freshwater into the Atlantic during a Greenland stadial, play no direct role in this mechanism, but would serve to delay the switch to faster AMOC.