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Dansgaard-Oeschger cycles as a mode of internal climate variability

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Explanations for Dansgaard-Oeschger (D-O) events have commonly included a role for external forcings, including runoff from continental ice sheets. However, some recent studies have presented Earth System Model simulations exhibiting D-O like behaviour of similar amplitude and timing without the imposition of any external forcings [e.g. 1 and 2]. These studies both exhibit quasi-periodic oscillations with timescales and Atlantic Meridional Overturning Circulation (AMOC) variations of approximately 700 years and 20 Sv for Peltier and Vettoretti (2014) and 700 to 1200 years and 10 Sv for Brown and Galbraith (2016). The mechanisms of these oscillations exhibit some similarities, whereby heat accumulates under a relatively fresh surface layer in the northern North Atlantic and warm, saline water accumulates in the subtropical gyre [2,3]. Due to a thermal or saline instability, this subsurface heat is released, overturning is strengthened and amplified further by the ensuing poleward transport of warm, saline water from lower latitudes [1,2].

We present the results of a transient deglacial experiment using PlaSim, an Earth System Model of Intermediate Complexity that includes a wet, primitive-equation atmosphere, a simple biosphere, a large-scale, geostrophic ocean and single-layer, thermodynamic sea ice. The deglacial simulation exhibits multiple instances of oscillations with similar properties to those described above: these oscillations occur quasi-periodically with timescales of between 1 to 2 thousand years with the AMOC varying between 10 and 20 Sv. They involve abrupt retreats in sea ice and increases in Northern Hemisphere surface temperatures of more than 6 degC in less than a century followed by a slower recovery to earlier conditions. Based on over 10ka of simulation and at least 5 oscillation cycles, we develop an index to describe these variations as a mode of internal climate variability and trace their progression in time. We use this mode to assess the sequencing of physical processes in the atmosphere, ocean and sea ice during these events. This mode also allows us a consistent metric by which we can assess the state of the mode at all times in simulations and in observational records where available.

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