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The effects of climatic forcing on the binge-purge oscillation of the Laurentide Ice Sheet: a conceptual modelling study

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Heinrich Events are observed as six discreet layers of sediment in deep-sea cores from the Eastern North Atlantic. These layers consist of ice-rafted debris. The source area for these layers has been identified as Eastern Canada. It is widely recognized that the cause of these layers is surges of the Laurentide Ice Sheet, but the cause of these surges is still debated. A likely explanation for the surges by the Laurentide Ice Sheet is that the bed of the ice sheet reached the melting temperature thereby reducing the basal shear stress and letting the ice flow velocity increase. Several studies have shown that the oscillation of the Laurentide Ice Sheet, also known as binge-purge oscillations, could occur through an internal dynamic without any external forcing.

To examine the effects of time-dependent temperatures and accumulation rates on the timing of the surges of the Laurentide Ice Sheet we use a 1-D thermo-mechanical model. The model is coupled to the profile of the ice sheet which is governed by the laws of a perfectly plastic solid. We show that external forcing, in terms of temperatures and accumulation rates, is important to include in simulations of the oscillations of the Laurentide Ice Sheet. By linearly coupling the equilibrium line to the temperature record obtained from the GRIP ice core and by having a time-dependent accumulation rate it is possible to explain the Heinrich Events by looking at the basal condition of the Laurentide Ice Sheet when reaching its melting temperature. The two constants that couple the equilibrium line with the temperatures are tuned such that the bed of the ice sheet reaches its melting temperature approximately at the same time as the Heinrich Events have been observed in deep sea sediment cores from the North Atlantic. Furthermore, we show that the timing of the surges of the ice sheet

are very sensitive to the snow accumulation rate. This highlights the important role of the surface temperature and the accumulation rate as a means of forcing the time and strength of the Heinrich Events.

Even though this is a simple model we find that the oscillation of the Laurentide Ice Sheet can be explained by internal oscillations in the ice sheet modulated by external conditions. This sheds light on the mechanism that caused the Wisconsian Laurentide Ice Sheet to surge with irregular intervals causing very significant climate changes in the North Atlantic during the last glacial period. Furthermore this study shows the importance of including a temporal surface temperature and accumulation rate when using more complex models.