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Exploring controls on ice stream destabilisation during the LGM/Holocene transition in West Greenland

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Newly emerging onshore and offshore deglacial chronologies from West Greenland enable investigation of the role of both climate and topography in controlling ice stream dynamics The Uummannaq ice stream system (UIS) now has a comprehensive deglacial chronology (eg. Lane et al; 2013; Ó Cofaigh et al., 2013; Roberts et al., 2013) which includes four dimensional control i.e. location and geometry of the ice margin and ice stream trunk and rates of thinning and retreat. This provides a framework for interpreting the main drivers and controls on ice stream dynamics under changing climatic conditions.

Deglaciation of the UIS began on the outer shelf at ∼14.8 ka, with Ubekendt Ejland becoming ice free at ∼12.4 ka. Staircases of lateral moraines on the southern flanks of Ubekendt point to step-wise thinning of the UIS as ice retreated from the shelf edge. This period of retreat coincided with a rise in air temperature between 16 –14.5 ka, increasing JJA solar radiation as well sea-level rise. The wide, mid-shelf trough (> 30km; which harboured the main UIS trunk zone) also had few constrictions which facilitated grounding line retreat. The UIS then withdrew rapidly with 80 - 100 km of retreat by ∼11.4 ka – 10.8 ka as the northern and southern feeder zones unzipped. This coincided with increasing insolation and peak sea-level, but topography and bathymetry were also influential on margin retreat (i.e. reverse slope over-deepening and fjord widening). This retreat occurred despite Younger Dryas air temperature cooling.

Along the southern arm of the UIS the grounding line retreated towards Store Gletscher becoming topographically pinned at ∼11.4 – 11.0 ka, but from 9.3 ka onwards retreat rates increased with the ice reaching the present Store Gletscher margin by 8.7 ka. This coincided with increased air temperatures and peak summer insolation at the start of the Holocene. The northern arm of the UIS also deglaciated quickly from Ubekendt, calving northward into Karrat/Rinks and Ingia Fjords. Lateral moraines north of Karrat again point to step-wise thinning of the UIS as ice retreated. At ∼11.3 ka the ice front in Karrat/Rinks Isfjord stabilised until ∼6.5 ka and seemingly became unresponsive to both climate and marine forcing for 5000yrs due to topographic pinning.

Ice sheet surface profile reconstructions based on two equilibrium models (perfectly plastic v Weertman-sliding profile; Roberts et al., 2013) combined with surface exposure ages have constrained likely minimum and maximum Last Glacial Maximum (LGM) ice surface geometries for the UIS.A 2D model, however, can simulate grounding line-retreat behaviour and surface thinning through time (e.g. Jamieson et al., 2012). Initial model results indicate that the non-linear retreat of the UIS is influenced by vertical and lateral constrictions in the marine trough system which partially regulates grounding line stability. It is apparent that during periods of rapid retreat the ice surface thins rapidly inland. Conversely, if the grounding line is pinned and relatively stable, surface thinning decelerates. This period of relatively slow ice surface thinning may be evidenced by the lateral moraine staircases which infer slow, incremental thinning along the margins of the UIS during different periods of retreat.