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Controls on West Greenland ice stream destabilisation during the LGM/Holocene transition

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The continental shelf of West Greenland harbours the imprint of at least six large, cross-shelf ice streams that reached the shelf edge at the LGM controlling ice and sediment flux to the ocean. Little is known of the offshore deglacial history of Melville Dyb, Upernavik Dyb, Holsteinborg Dyb and Sukkertoppen Dyb, but newly emerging onshore and offshore chronologies from the Uummannaq and Disko ice stream systems enable investigation of the importance of both climate and topography on ice stream dynamics (eg. Ó Cofaigh et al., 2013a, b; Roberts et al., 2013). The Uummannaq ice stream system (UISS) now has a comprehensive deglacial chronology and affords the opportunity to evaluate the response of the ice stream to rapidly changing climatic forcing during retreat from the shelf to present coast.

Deglaciation of the UISS began on the outer shelf at ∼14.8 cal. kyrs BP, with Ubekendt Ejland becoming ice free at ∼12.4 ka. This period of retreat of appears to be an initial response to increasing JJA solar radiation and sea-level rise, with an additional rapid rise in air temperature between 16 –14.5 cal. kyrs BP in the run up to the Bølling Interstadial. The wide mid-shelf trough (> 30km) with no constrictions also facilitated grounding line calving and retreat. The UISS then withdrew rapidly with 80 - 100 km of retreat by ∼11.4 ka – 10.8 cal. kyrs BP as the northern and southern feeder zones unzipped. This appears to have been driven by a continuing increase in insolation, peak sea-level and topography (i.e. reverse slope over-deepening and fjord widening). This occurred despite Younger Dryas air temperature cooling. Along the southern arm of the UISS the grounding line retreated towards the current location of Store Gletscher becoming topographically pinned and stabilised due to fjord narrowing at ∼11.4 – 11.0 ka. From 9.3 ka onwards retreat rate increases with the ice margin reaching the present Store Gletscher margin by 8.7 ka. This is interpreted to be a response to increased air temperatures at the start of the Holocene and peak summer insolation. It is difficult to reconcile this behaviour with abrupt climate cooling events at 9.3 and 8.2 ka (cf. Young et al., 2013), but more data is required. The northern arm of the UISS deglaciated quickly from Ubekendt, calving northward through Igdlorsuit Sund and into the fjord mouths of Karrat/Rinks and Ingia Fjords. At ∼11.3 ka the ice front in Karrat/Rinks Isfjord became topographically pinned as a result of fjord narrowing. The ice margin remained stable for the next 5000 yrs (until ∼6.9 – 6.5 ka) and was unresponsive to both climate and marine forcing. Hence, the northern and southern feeder outlet glaciers of the UISS behaved asynchronously during the LGM/Holocene transition.

This asynchroneity is also evident at a larger scale when comparing the behaviour the other large cross-shelf ice streams along the West Greenland coast. For example, it is clear that Jakobshavn Isbrae deglaciated from the mid to inner shelf much later than the UISS and was present on the outer shelf during the Younger Dyras stadial (12.8 – 11.7 cal. kyrs BP) (Ó Cofaigh et al., 2013a), only reaching in the inner coast fjords at 10.3 to 10.0 ka (Young et al., 2013) – over 1000 years later than the UISS reached the shelf/inner fjord boundary. This asynchronous behaviour is not surprising given the large scale topographic and bathymetric contrasts in their trough morphologies. The UISS effectively calved rapidly through a wide, deep trough back to the shelf/inner fjord boundary, while Jakobshavn Isbrae probably underwent a series of temporary grounding line stabilisations controlled by a series of pinning points and constrictions on the mid shelf and had to retreat through a shallower inner shelf zone back to the shelf/inner fjord boundary. It is evident therefore, that the stability of major marine ice stream outlets are extremely sensitive to changes in trough topography. Determining the interactions between trough geometry, atmospheric and marine forcing over both short and long term dynamic behaviour is vital for the prediction of future marine-based ice stream behaviour.