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Simulating LGM retreat of the Uummannaq Ice Stream and Rinks Isbrae, Western Greenland using a 1-D ice-stream model constrained by a suite of marine and terrestrial data

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We aim to understand what controlled the retreat pattern of the Uummannaq Ice Stream (UIS) during the last deglaciation. Evidence for the pattern of retreat is found in both the marine and terrestrial realms, but because the evidence is temporally and spatially discontinuous, it is challenging to coherently reconstruct both grounding-line retreat and ice-surface thinning such that they are in agreement. Marine stratigraphic and geophysical evidence indicates that the ice stream was grounded close to the continental shelf edge at the Last Glacial Maximum, and retreated rapidly and nonlinearly after 14.8 ka. Cosmogenic nuclide exposure dating on Ubekendt Island at the convergence zone of multiple feeder ice streams show that the ice surface thinned progressively and that the island became ice-free by ca. 12.4 ka. The ice stream then collapsed over the next 1-1.6 kyrs and the ice stream separated into a series of distinct inland arms. In the northernmost Rinks system, there is a 'staircase' of evidence showing ice surface thinning over time, but it is unclear where the grounding line was located during this phase of thinning. Furthermore, it is currently unclear what controlled the nonlinear retreat pattern identified in the Uummannaq system.

We develop a numerical model of ice-stream retreat using the marine geophysical data and measurements of sediment strength on the continental shelf to control the boundary conditions. The model has the capability to dynamically and robustly simulate grounding line-retreat behaviour over millennial timescales. We simulate the retreat of the UIS grounding line into the northernmost Rinks system in response to enhanced ocean warming, rising sea level and warming climate. We compare the simulated dynamic behaviour of the UIS against the geomorphological and cosmogenic exposure evidence for ice surface thinning onshore and against dated marine grounding line positions.

Our model results enable us to match grounding-line positions in the marine trough to distinct onshore ice-surface heights, and therefore provide a 2-dimensional reconstruction of the geometry of the UIS as it retreated after the LGM. We find that the nonlinearity in retreat rate is conditioned by the locations of vertical and lateral constrictions in the Uummannaq/Rink trough which provide temporary pinning points for the grounding line. When the grounding line retreats rapidly between pinning points, the ice surface thins rapidly inland. When the grounding line is pinned, thinning of the ice surface becomes much slower in locations corresponding to the deposition of moraines. We suggest that the slowdowns in retreat identified in the marine domain are therefore reflected by the generation of moraines in the terrestrial domain. Finally, we generate hypotheses about the timing of marine grounding-line retreat based upon the published terrestrial cosmogenic exposure ages.