

Spatial and temporal distribution of basal melting and freezing underneath West-Antarctic ice stream tributaries – Implications for the Holocene decay of the West-Antarctic Ice Sheet

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Over the past decades the instability of the West-Antarctic Ice Sheet (WAIS) and its possible contribution to global sea-level rise was in the focus of Antarctic research. High basal water pressure and a highly porous water saturated sediments play a key role in facilitating the fast motion of ice in ice streams draining most of the WAIS ice into the Ross Ice Shelf. With basal melting being the only source for basal water it is clear that the distribution of basal melting and freezing has to be incorporated into numerical models assessing the stability of the WAIS.

Borehole observations confirmed the presence of basal melt water at Byrd station, in the interior of the WAIS, and at different ice stream location along the Siple Coast. Representing a freeze-on history of several thousand years, the recent discovery of a 12 to 25 m thick basal ice layer at the Sticky Spot of Ice Stream C indicates that basal freezing had occurred upstream of its present day location. Using a thermo-dynamical numerical flow-line model we simulated the spatial and temporal distribution of basal melting and freezing in Ice Stream C tributaries upstream of its Sticky Spot. In the model we assessed the heat conduction away from the bed using a numerical model of thermodynamics of vertical heat conduction and vertical and horizontal advection.

The model was capable of reproducing the 12 to 25 m thick basal ice layer at the Sticky Spot using similar basal shear stresses as found in ice streams (1 to 10 kPa) and a geothermal heat flux of 70 mW/m².

Further-on time dependent model runs suggest that basal melting was highest in the early Holocene possibly initiating the Holocene decay of the WAIS after a thickening of the ice sheet. Under current conditions the model suggests that the amount of basal freeze-on in the northern Ice Stream C Tributary exceeds the basal melt production in the Byrd Subglacial Basin. Reducing the amount of basal water in the subglacial hydrological system the freeze-on of up to 25 m of basal ice could increase basal resistance and in turn reduce the flow of ice, which would be consistent with current force-budget models. However from the model it is unclear if the decay of the WAIS is coming to an end. Further fieldwork will be necessary to confirm the suggested hypothesis that basal freeze-on is currently occurring under large areas of West-Antarctic ice stream tributaries.