EGU2020-19947, updated on 17 Oct 2021
https://doi.org/10.5194/egusphere-egu2020-19947
EGU General Assembly 2020


# The Petermann Ice Shelf Estuary and its impact on ice-shelf stability

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In a warming world, increased meltwater will form on Antarctica's ice shelves. The fate of this meltwater will be critical to future ice-shelf and ice-sheet stability. Two main observations define the current theoretical framework for understanding the influence of surface hydrology on ice-shelf stability. The first is the collapse West Antarctica's Larsen B Ice Shelf that was triggered by the formation of thousands of surface ponds atop the ice shelf. The second is the observation of a waterfall on the Nansen Ice Shelf, in East Antarctica, that is hypothesized to protect the ice shelf from hydrofracture by removing meltwater from the ice-shelf surface.

We present a third process that couples ice-shelf hydrology to atmospheric and ocean forcing: the development of an ice-shelf estuary on the Petermann Ice Shelf in northwest Greenland. High-resolution imagery and digital elevation models (DEMs) shows that channelized surface meltwater on the Petermann Ice Shelf in northwest Greenland incises into underlying ice to form an estuary that propagates fractures along the ice shelf. The estuary at the front of the Petermann Ice Shelf is indicated by the convergence of sea ice at the river mouth, the upstream transport of sea ice in the channel as far as 460 m from the calving front, and the persistence of water in the channel following the end of seasonal surface melt. Between 2013 and 2018, the estuarine reach of the river tripled in width and a 1.5 km longitudinal crack propagated along the bottom of the channel. The Petermann Ice Shelf Estuary forms on top of a basal channel, where basal melting has led to ice-shelf thinning, and the creation of the linear surface depression in which the estuary forms.

The Petermann Estuary may be the first of several ice-shelf estuaries to develop in a warming climate. Widespread surface melting on ice shelves in Greenland and Antarctica increases the urgency to determine the influence of surface hydrology on ice-shelf stability. We hypothesize that surface rivers may initially buffer ice shelves from collapse by terminating in waterfalls and preventing the formation of damaging lakes. However, with increased meltwater transport across ice shelves, channels can incise to sea level and establish estuaries. Once an estuary is established, estuarine weakening can lead to fracture propagation and enhanced calving, destabilizing ice-shelves, and increased ice-sheet mass loss.