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A 3-D Model of Antarctic Ice Shelf Surface Hydrology

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Understanding the surface hydrology of ice shelves is an essential first step to reliably project future sea level rise from ice sheet melt. The formation of surface meltwater has been linked with the disintegration of many ice shelves in the Antarctic Peninsula over the last several decades. The most notable ice shelf collapse occurred in 2002 when significant meltwater lake coverage was observed on the surface of the Larsen B Ice Shelf before its collapse over a period of just a few weeks. Such collapse can affect ocean circulation and temperature, and cause a loss of habitat. Additionally, it can cause a loss of the buttressing effect that ice shelves can have on their tributary glaciers, thus allowing the glaciers to accelerate, contributing to sea level rise. Despite the importance of surface meltwater production and transport to ice shelf stability, knowledge of these processes is still lacking and as a result of this, projections of future sea level rise still vary over an order of magnitude.

In order to better understand these processes we present a new 3-D model of surface hydrology for Antarctic ice shelves. This model takes the 1-D surface lake formation model of Buzzard et al. (2018) and expands it to three dimensions. It is the first comprehensive model of surface hydrology to be developed for Antarctic ice shelves, enabling us to incorporate key processes such as the lateral transport of surface meltwater. Recent observations suggest that surface hydrology processes on ice shelves are more complex than previously thought, and that processes such as lateral routing of meltwater across ice shelves, ice shelf flexure and surface debris all play a role in the location and influence of meltwater. Our model allows us to account for these as well as additional key physical processes and is calibrated and validated through both remote sensing and field observations.

Here we present results of coupling the 1-D model with a 3-D meltwater routing scheme. This includes calculations of the surface energy balance, meltwater production, percolation and refreezing and lake formation. Through case studies, calibrated and validated against observations, we will demonstrate the varied applications of the model.

This community-driven, open-access model, has been developed with input from observations, and allows us to provide new insights into surface meltwater distribution on Antarctica's ice shelves. This enables us to answer key questions about their past and future evolution under changing atmospheric conditions and vulnerability to meltwater driven hydrofracture and collapse.