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A statistical fracture model for Antarctic ice shelf regions

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Creating an effective model of the calving process in Antarctica is a challenging task in ice sheet modelling.

The recent calving of Larsen B and Larsen C ice shelves has raised a number of questions as to the nature of the key factors that triggered these calving events and whether they are caused by natural ice sheet dynamics or climate change. To address this, a reliable calving model is required and previous studies and models have not been able to be utilised across the Antarctic continent. In fact, a comprehensive calving model needs to include components such as information about surface and basal crevasses (location and depth), advection of the crevasses downstream, the intersection of the surface and basal crevasses as well as estimation of the critical depth of a crevasse when calving occurs.

The purpose of this research is to use observational data to construct a fracture model that can be applied to any selected ice shelf/glacier in Antarctica. The main aspects explored are the determination of the location of both surface and basal fractures as well as propagation of surface crevasses when meltwater is added.
First, the basis of this project was to create a statistical model that can improve the predictability of the location of surface fractures. We used a logistic regression algorithm and a set of predictors taken from observations of glaciers/ice shelves. The modelled probability function varies from zero to one and in this way is similar to the previously proposed damage function. It can predict fractures for grounded ice as well as for floating ice shelves.

Second, we used Linear Elastic Fracture Mechanics as a basis for modelling the depth of fractures. Then, based on the misfit between observed and modelled fracture depth we were able to perform an inversion for melt rate and, thus, obtain a depth of crevasses in better agreement with observations.

Lastly, we explored the correlation between surface troughs and basal crevasses using altimetry data for over 45 glacier regions. Our findings confirm the previously suggested theory that these two processes are highly correlated. We use this results together with statistical algorithms to predict the location of basal crevasses.

We found that statistical methods can provide valuable information for predicting zones of fractures. Our model shows a good agreement with the data about fractures taken from satellite imagery for any selected ice shelf in Antarctica. Furthermore, we found that different conditions of fracturing require different water levels inside crevasses in order to keep them open. Our inversion allows for predicting the depth of crevasses in a better agreement with the observed depth of crevasses obtained from radar data sets. The combination of these methods provides a good basis for future calving parameterisation.

Significance statement

This research provides a background for modeling of calving process in Antarctica by combing statistical and physics-based methods. More precise prediction of the location and depth of surface and basal crevasses can help to estimate where on an ice shelf calving is more likely to take place.

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