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The influence of shear bands on the grounding line retreat in Pine Island Glacier

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Pine Island Glacier (PIG), West Antarctica, is known as the weak underbelly of the West Antarctic Ice Sheet. During the last 30 years, it has undergone a dramatic acceleration along with a retreat of its grounding line. The main ice stream draining PIG is laterally bounded by two thin bands of damaged ice. These shear bands may play a key role in the dynamics of the grounding line since they likely decrease the ice-shelf buttressing. The traditional approach is generally to infer the viscosity from surface velocity using data assimilation methods. However, in that case the inverse problem is under-constrained when it is coupled to the inversion of basal drag: different set of basal drag and viscosity pattern solution can lead to a good match between modelled and observed surface velocities, but would lead to different prognostic solutions associated to different grounding line migrations.
Here, we follow a simpler approach and perform a sensitivity study on the shear bands effective viscosity, and its consequences for the ice dynamics. The areas of fractured ice at PIG are located using a recent SPOT satellite image. The non-fractured ice viscosity depends on ice temperatures while the fractured ice viscosity is decreased through a sensitivity study to reproduce the damaged ice of the shear bands. Using two different higher-order models (Elmer/Ice and BISICLES), we investigate the influence of the shear bands' damage on the grounding line dynamics. Each experiment in the sensitivity study gathers successively (i) the determination of basal drag through assimilation methods, (ii) a geometry relaxation over 15 years and (iii) transient perturbation experiments driven by different calving sizes. The initial geometry of the ice sheet arises from the ALBMAP data set on a 1 km grid resolution, velocities were acquired during the last International polar Year, and non-fractured ice viscosities are deduced from prescribed temperatures computed with a higher order model.
We show that the presence of the shear bands modifies the buttressing state in the ice shelf, i.e. the amount of back stress transmitted to the grounding line. The discharge of grounded ice in response to a calving event is thus influenced by the estimation of the ice shelf rheology. This suggests that future projections of PIG behaviour will have to carefully evaluate the ice-shelf stress pattern and its evolution.