Structures related to very strong shear localization in ice streams and ice shelves - towards a numerical model

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The mass balance of the Antarctic and Greenlandic ice sheets is determined by the difference between the accumulation of snow in the interior and the gravity driven flow of ice towards the exterior. The importance of flow-generated internal structures within the ice mass for its flow dynamics has been recognized only recently. Here, we focus on the formation and the significance of tabular zones of strong shear localization for structures forming in flowing ice.

The deformation of ice during its flow causes strain weakening in the deformed area. Strain weakening can trigger a feedback process, which leads to strongly localized shear zones. (Fig. 1). Structurally, these narrow (curvi-) planar shear zones develop by a process of semi-random nucleation at local instabilities and subsequent propagation. Much like brittle shear zones and faults, these zones control shape and flow field of the ice stream. In addition they may alter the local stress field, causing further deformation of the ice.

Several processes contribute to the strain weakening of deforming ice. Generally, the viscous rheology of ice can be described by the power law $\dot{\epsilon} = A\sigma^n$, due to its crystal plastic behaviour. It has been shown recently that the stress exponent $n = 4$ (Bons et al., 2018). This is higher than $n = 3$, the exponent that has been generally assumed and applied for modeling of ice flow until today. As a consequence ice under deformation at elevated stresses is generally *softer* than previously assumed, which leads to an even stronger localization and accumulation of shear in shear zones. Other major processes involved in the strain weakening are a) the texture evolution and b) shear heating.

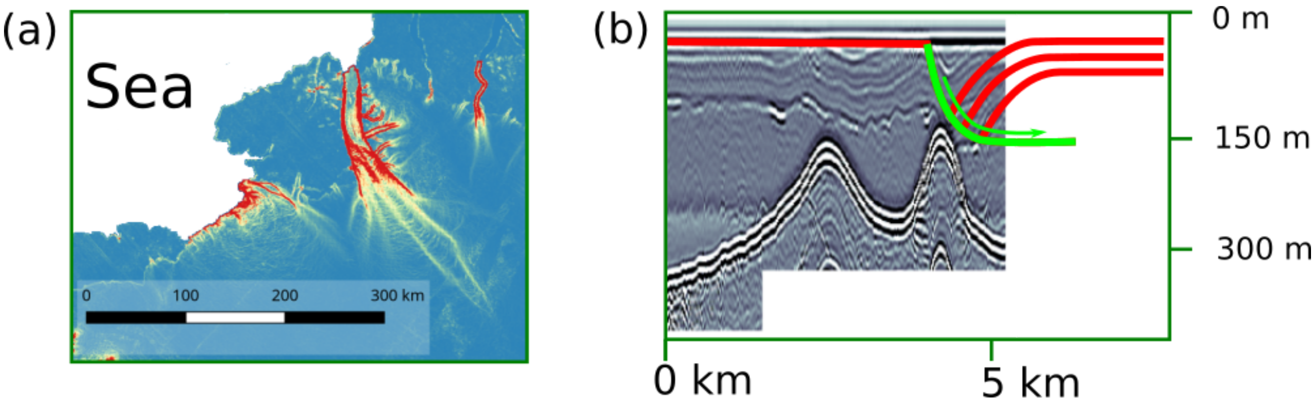

Figure 1*. Structures in ice, actually or possibly related to strongly localized shear zones. (a) The Petermann Ice Stream and outlet glacier in NE-Greenland. Yellow and red are areas of intense shearing, which represent the boundary between fast and slow ice flow. (b) Radiogram-section through a "channel" in the Antarctic Koning Boudewijn ice shelf, including the structural interpretation. Layering (partly marked with red lines) is due to contemporaneous deposition and deformation of ice. The green line is a potential curviplanar shear zone leading to roll-over folding (radiogram published in Drews, 2015).*

Lateral ice-internal shear zones define and exercise some control on so-called ice streams, which form corridors of fast flowing ice within ice-sheets (Fig. 1 a). The flow velocity in such ice streams exceeds the ice velocity in the surrounding ice mass roughly by a factor of up to 200. Because of the large flow velocity, ice streams are the most important means to transport ice from the interior of ice shields to outlets.

Channels traversing ice shelves are another type of large-scale structure in polar ice, which is potentially controlled by curviplanar zones of intense shearing. In the structural interpretation shown in Fig 1 b, the shear zone acts as a detachment within the floating slab of shelf ice under extension.

We present a numerical model under development which is geared at fulfilling the following properties:

- the ability to model large-scale deformation of materials with very large viscosity differences,
- tracing of the material as it deforms, e. g. isochrone layers in ice,
- incorporation of the main weakening processes outlined above,
- strong parallelization of the computations.

The numerical code is based on the geodynamics code '*Underworld2*'. Here, we show first results.

References

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