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The dynamics and geometry of pure ice streams: a new numerical approach

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The flow of ice in large ice sheets is anything but homogeneous. The majority of the flow is concentrated in relatively narrow corridors called ice streams, which have much higher flow velocities than their surroundings. Roughly 90% of the Antarctic discharge occurs in ice streams. The dynamics of ice streams therefore attract considerable interest.

A large portion of this ice discharge (40% in the W-Antarctic) occurs in so-called 'pure' ice streams, i.e. ice streams whose geometry and velocity are not affected by the underlying bedrock topography. This type of stream is mainly controlled by the accumulation and discharge of snow in the ice sheet and by internal processes of the system consisting of 1) ice 2) basis and bedrock and 3) outlet.

One peculiar feature of such pure ice streams is their characteristic elongate diamond shape seen in map perspective. Prominent examples displaying such a geometry are for instance the North East Greenland Ice Stream (NEGIS) and Ninnis Glacier in Antarctica. Understanding the geometry is a significant step towards understanding the inner workings of ice streams in general.

Here we introduce a conceptual model and its numerical implementation. The implementation is based on numerical codes originally developed for geodynamic processes. It is thus optimized for the modeling of large-scale systems under extreme deformation, and for anisotropic and highly heterogeneous materials. This makes it ideal for the numerical modeling of deforming large ice sheets. The model suggests that the properties of pure ice streams, including their geometry, result from a coupling of strain localization processes within the ice sheet with the development of the stress field and the ice topography. Coupling also leads to rapid propagation and decay of the ice stream, resulting in fast yet non-permanent flow.