Modelling and measurements of vertical strain-rates under ice domes and ridges.

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Ice domes and ridges are generally preferred drilling sites. In the vicinity of domes or ridges full-Stokes or higher order models have to be used instead to model the flow of ice in these areas. In particular, just underneath a dome, due to vanishing deviatoric stresses with depth, a non-linear Glen's rheology implies a highly viscous ice area. This area of highly viscous ice under the dome affects the vertical velocity profile of the ice which changes from the dome to the flank. As a consequence of this change, isochrones exhibit anticlines just under domes or sharp ridges. Such anticlines are visible on many radargrams, and are referred to as Raymond bumps.

The Raymond effect gives valuable information about ice rheology as it affects the vertical velocity profiles under the dome. The non occurrence of Raymond bumps in the central part of ice sheets is still matter of debate as low values of the Glen index, less than 2 and possibly close to 1, have been reported for this areas.

Hitherto modelling studies of dimensional applications have been for plane flow, but ice domes are rarely perfectly elongated or axisymmetric; often it seems that they are the meeting points of three ice divide ridges, or triple junctions and in such areas 3D effects can't be neglected.

We use Elmer, a finite element code which solve the 3 dimensional Stokes equations to study the Raymond effect as a function of the along-ridge flow. The Raymond effect is at its strongest when the along-ridge slope is null and weakens when the along ridge slope increases. The shape of the ridge is related with the strength of the Raymond effect. We also use Elmer to model the flow of ice under triple junctions. If a three-fold symmetry in the forcing is applied, the axisymmetric dome breaks up into three ridges subtending angles of 120 degrees. The along-ridge slope increases very quickly over a distance of one to two ice thicknesses. The Raymond effect is at its strongest at the dome, and weakens initially as one moves away from the divide along the ridges, but operates at distances many times the ice thickness from the dome. A set of experiments where the forcing was not exactly three-fold symmetric caused the triple junction to evolve into an elongated curved ridge. Modelled surface topography and internal layers are compared with data from Summit Greenland, Fletcher Ice Rise (Antarctica) and Thyssenhöhe (Berkner Island-Antarctica).

A phase sensitive radar has been used to measure precisely the vertical strain-rate displacement of internal layers between two visits in Greenland and in Fuchs Ice Rise (Antarctica). Profiles of the vertical strain-rate across the ice divides near the summit of the greenlandic ice cap, across the divide near the NEEM camp and across the divide of the Fuchs Ice Rise have been obtained. Variations of the surface vertical strain-rate across the divides are interpreted using the results of the numerical experiments.

These studies will give us a better understanding of the ice rheology at low strain-rates under ridges and domes and will allow us to chose the best emplacements for the next drilling.