Ice rises: The double role of imprinting and archiving ice-dynamics at the sheet-shelf boundary of Antarctica

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Introduction

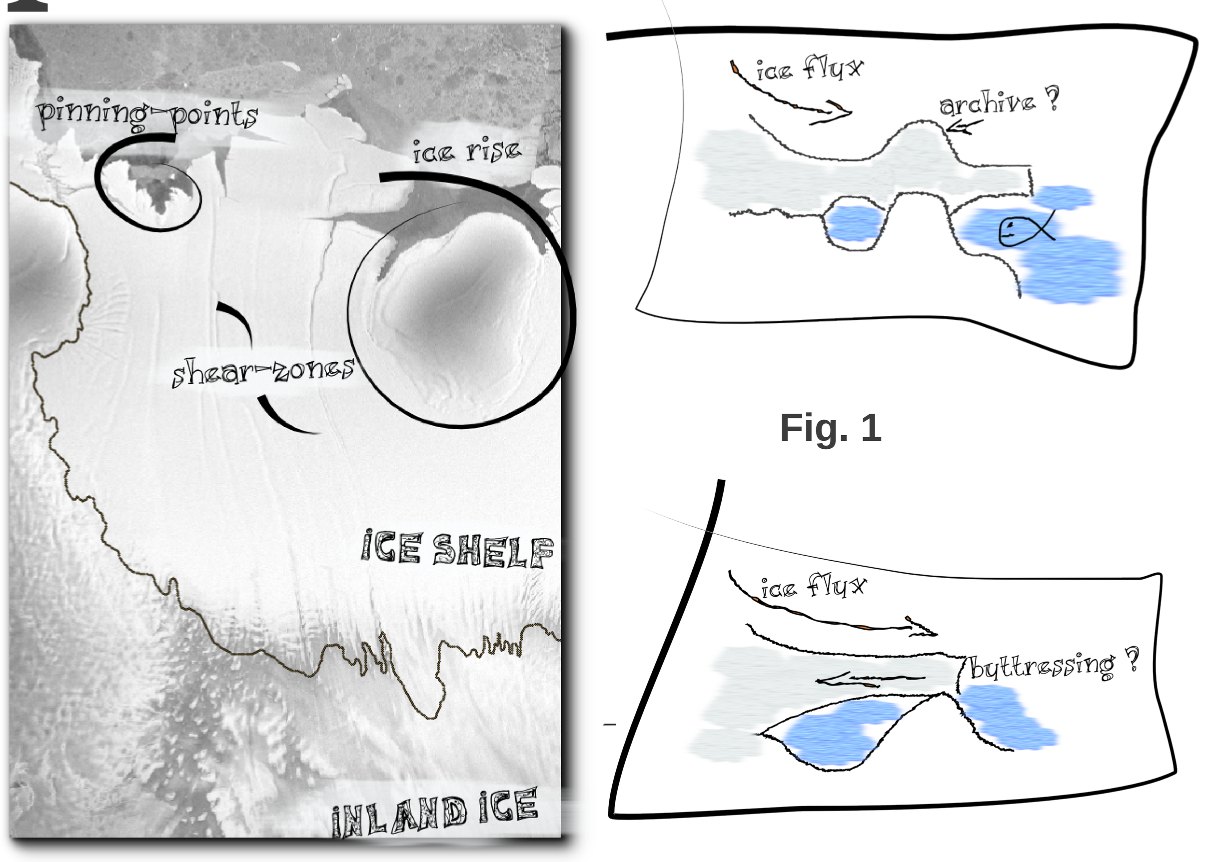

Fig. 1

The aim is to examine the ice-dynamical role of grounded features, which are enclosed by the ice shelf. The area of interest is the Roi Baudouin ice shelf which is confined by ice rises with a local flow regime, and two pinning-points with a width of only a few kilometers. Notwithstanding, the latter seem to define the seaward edge of the ice shelf and impact ice-flow in the hinterland. Scientific questions the arise out of this setting:

- Can we use the **ice-rise stratigraphy** as paleo-proxy for the flow-behaviour of the surrounding ice shelf by exploiting the **Raymond effect**?
- How important are **pinning-points** in **buttressing** the ice flux from the inland ice-sheet and what are the mechanisms involved?

We hope this will help to constrain the ice-sheet history and eventually contribute to forecast its future..

Ice Rise and Raymond Effect

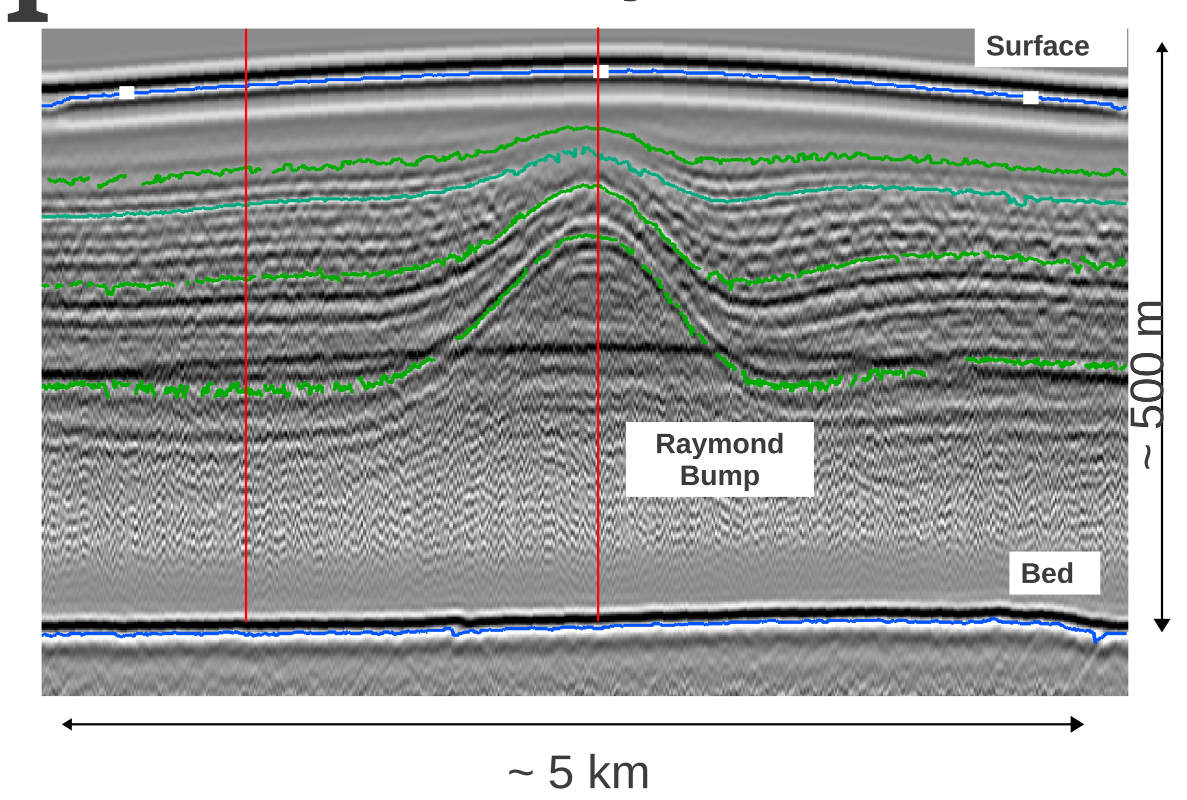

Fig. 2: Raymond Bump in a radar profile across the divide of Derwael Ice Rise (see location in inset of Fig. 4)

The internal stratigraphy (as seen by radar, Fig.1) bends upwards at the low deviatoric stresses beneath ice divides due to the non-linear ice viscosity. The shape of these 'Raymond Bumps' is influenced (among others) by the amount of along-ridge flow and the temporal stability of the divide. The upwarping alters the age-depth scale significantly (Fig. 2) which may be advantageous for drilling ice cores.

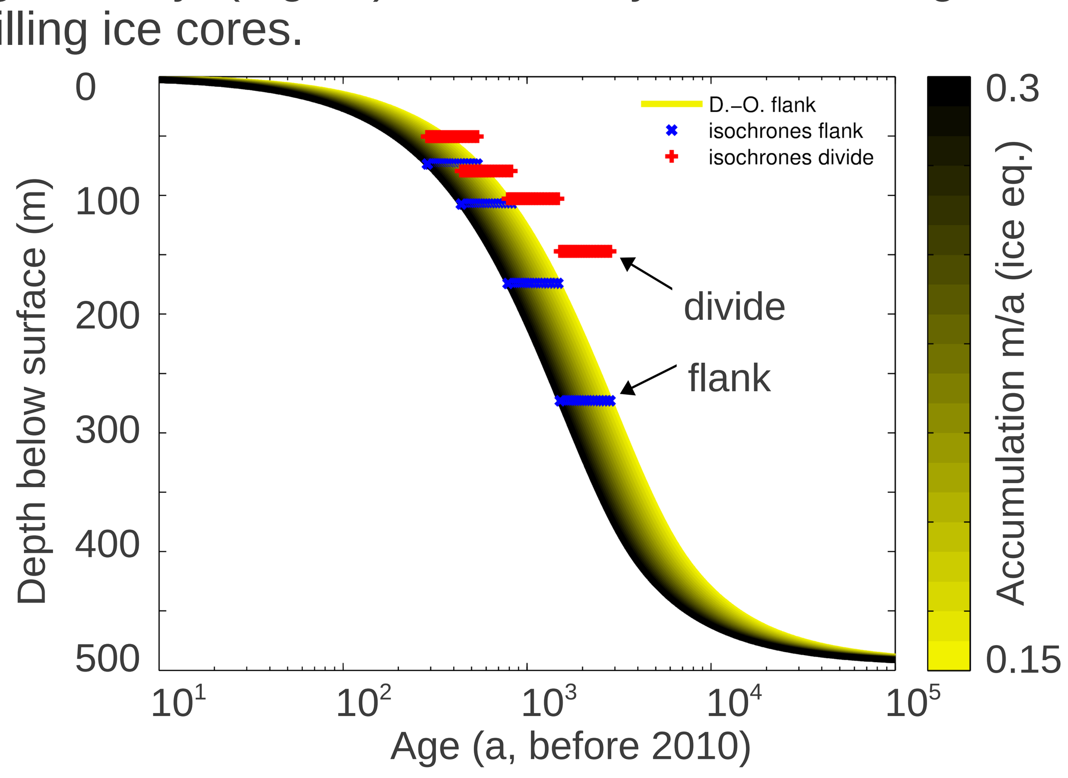

Fig. 3: Simple approach for the age-depth scale beneath the divide by tracing the Dansgaard-Oeschger scale (Dansgaard, JoG, 1969) in the flank along radar isochrones to the divide (red vertical bars in Fig. 1). The effect of a varying accumulation in the flank is color-coded.

As a first-order approach we apply a 1D age-depth model in the flank, and trace it along the (isochronal) radar layers to the divide.

However, in order to better understand (and exploit) the Raymond effect, most components of the stress tensor should be included (i.e. a higher-order or a full Stokes model). It is also unclear to what extent a 2D approach is feasible. For Derwael Ice Rise we present a 3D radar dataset, which shows that the **Bump-Amplitude varies along the divide (Fig. 3). Particularly on the south-western end, the Raymond stack appears muted, although bedrock and surface slope are comparable to other locations.**

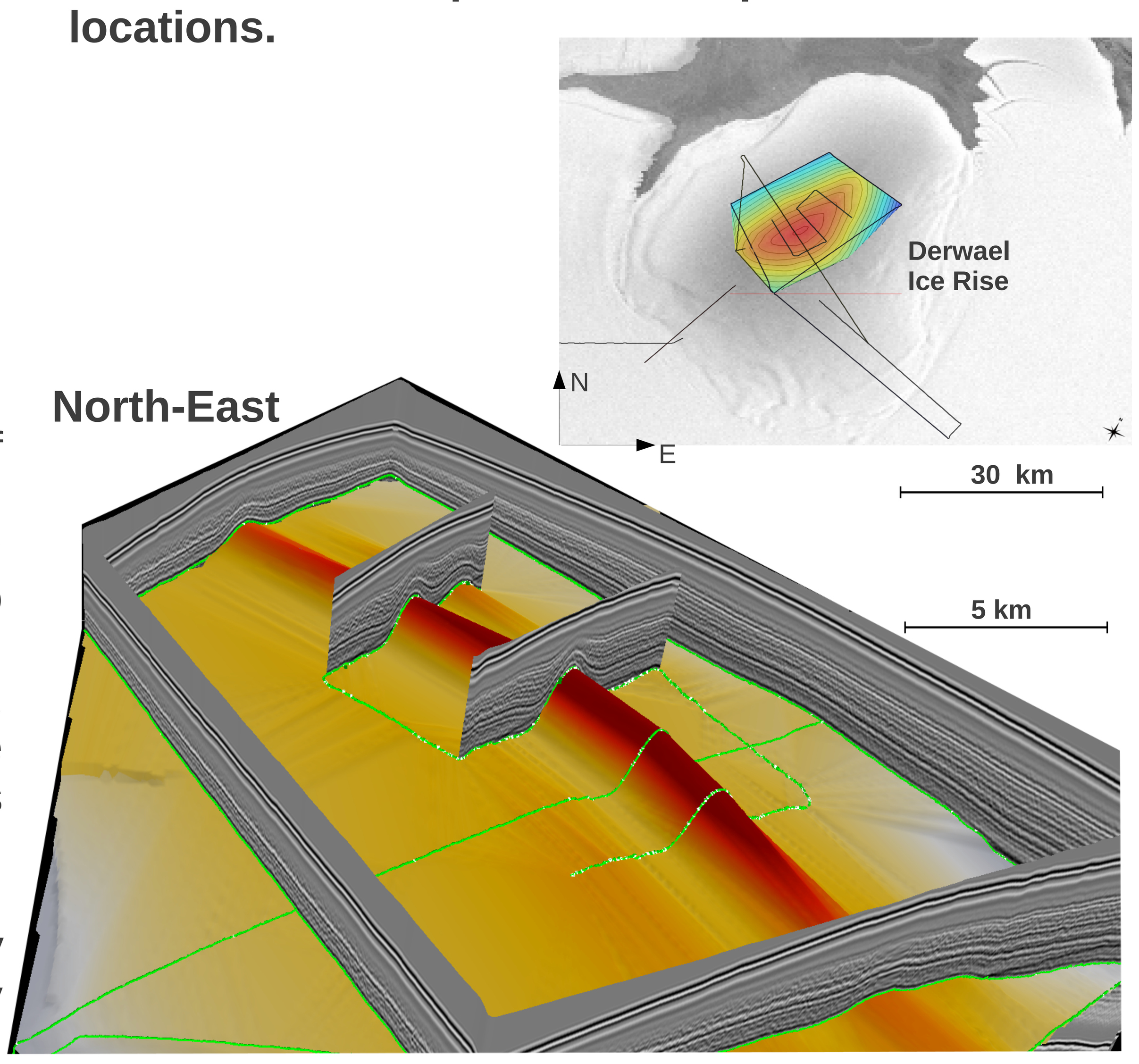

Fig. 4: 3D-interpolation of an internal reflection horizon around the divide which displays the spatial variation in Bump Amplitude along the divide.

We do not (yet) understand the spatial variations of the Raymond Bump. Potentially it is linked to changes in the neighbouring ice shelf, whose dynamics is partially controlled by the existence of pinning-points.

Pinning Points

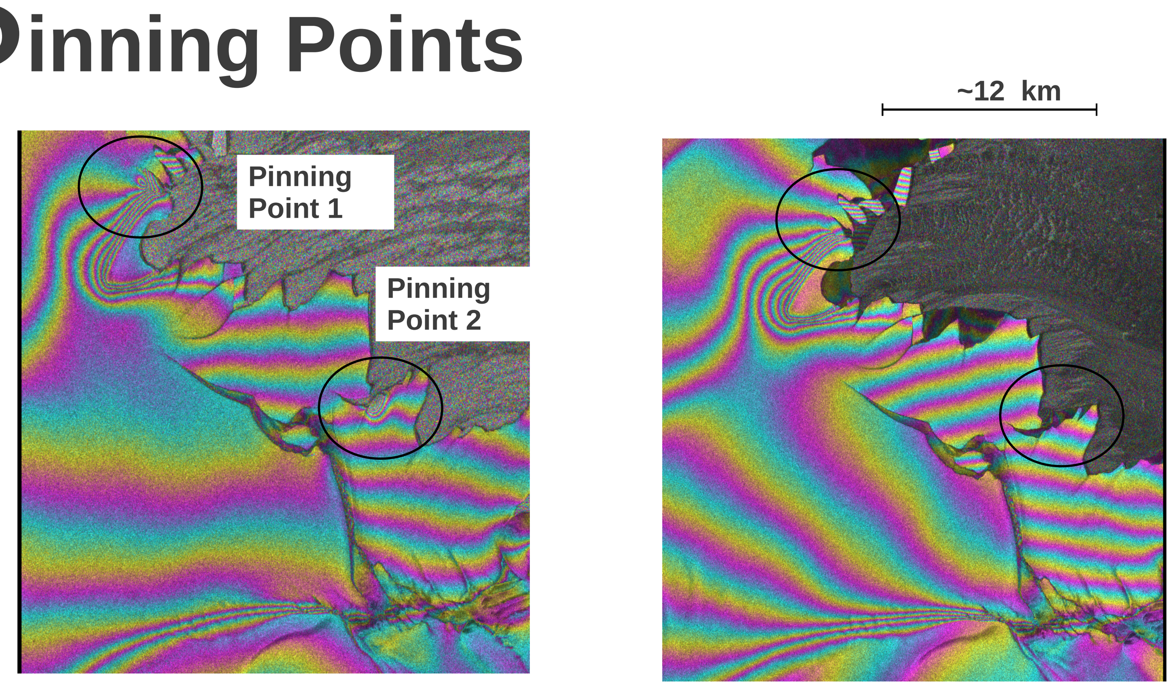

Fig. 5: Pinning-Points become evident in (satellite) interferometric SAR images, in which the tidal flexure zone is visible as a dense pattern of interferometric fringes (black circles, image in radar coordinates). One pinning point appears to detach during high-tide (right, and Fig. 6).

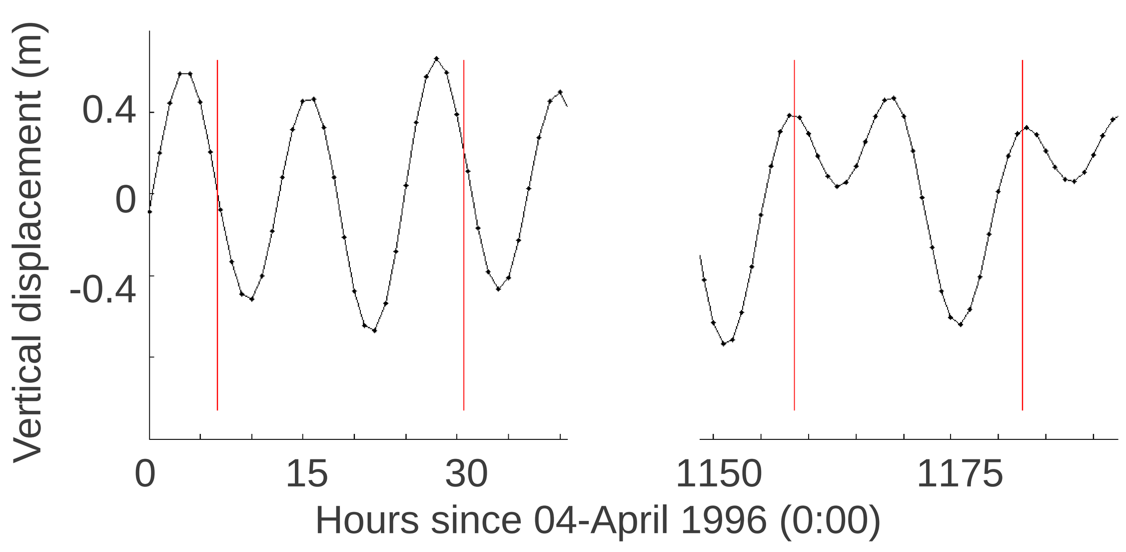

Fig. 6: The modelled vertical displacement by tides. The acquisition dates of the SAR images for Fig. 5 are marked with red lines.

Based on a tide modell (Padmann, AoG, 2002) the detachment of the second pinning-point in Fig. 5 is potentially related to the tidal uplift of the ice shelf. **Does this change in buttressing have an effect on the larger-scale flow pattern ?**

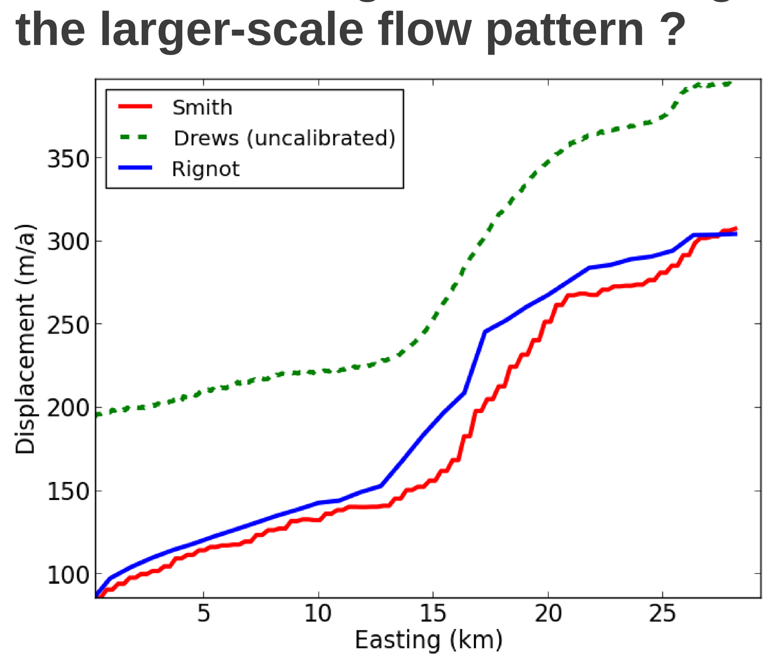

Fig. 6: Interferometric flow velocities from different sources in a profile perpendicular to pinning-point 1 (location black line in Fig. 7)

Different interferometric flow-velocities deviate in the vicinity of the pinning-points and potentially reflect temporal variations.

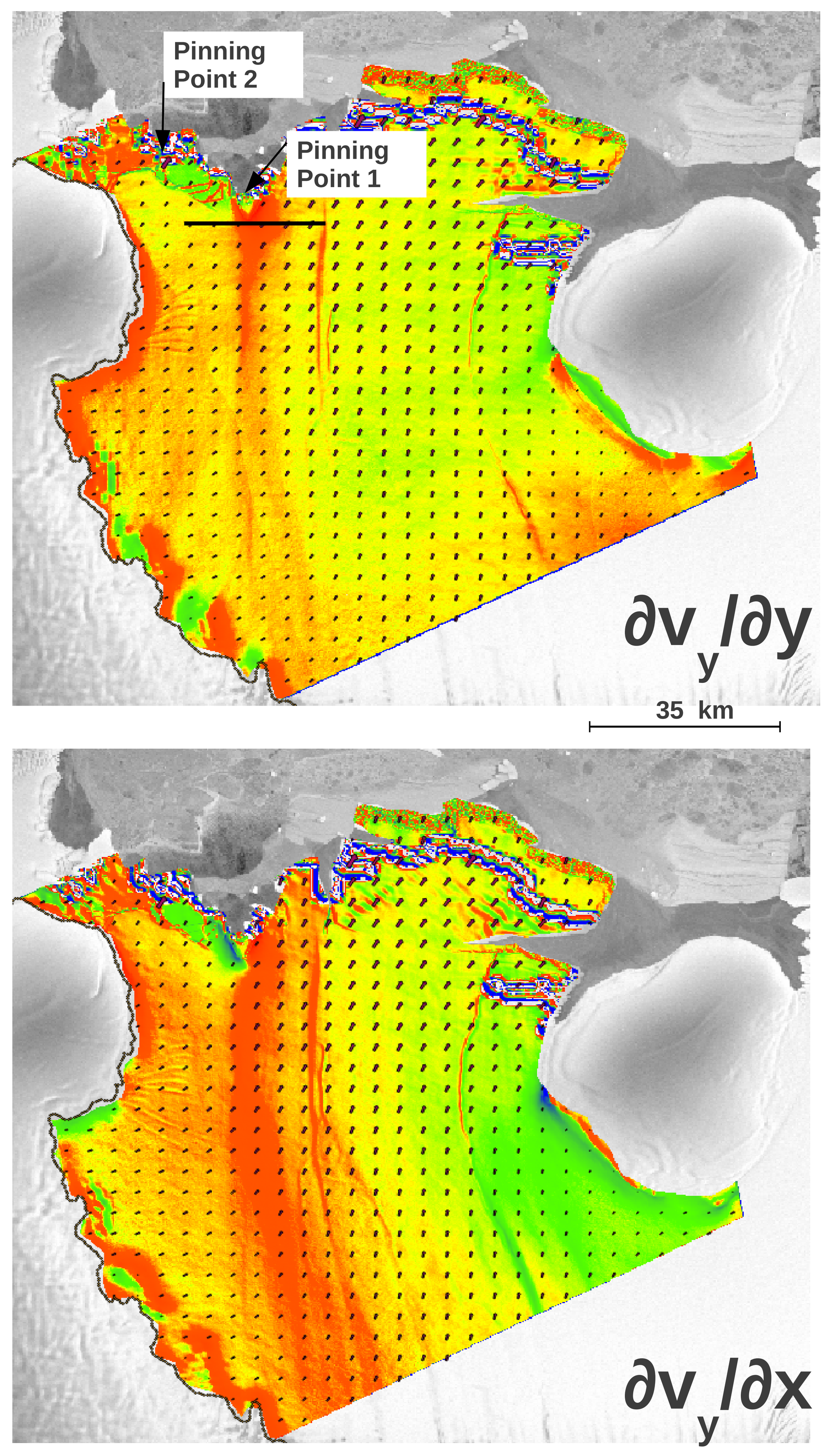

Fig. 7: Spatial derivation of velocity (~strain rates) derived for each pixel in the principal coordinate system (with y-axis aligned along-flow). Black arrows indicate the flow-direction.

The pinning points cause an along-flow compression (above) and a zone of horizontal shearing (below) which extends backwards into the ice-shelf. **Hence, the buttressing effect of these pinnning points is substantial, and influences the ice-shelf dynamics on a larger scale.**

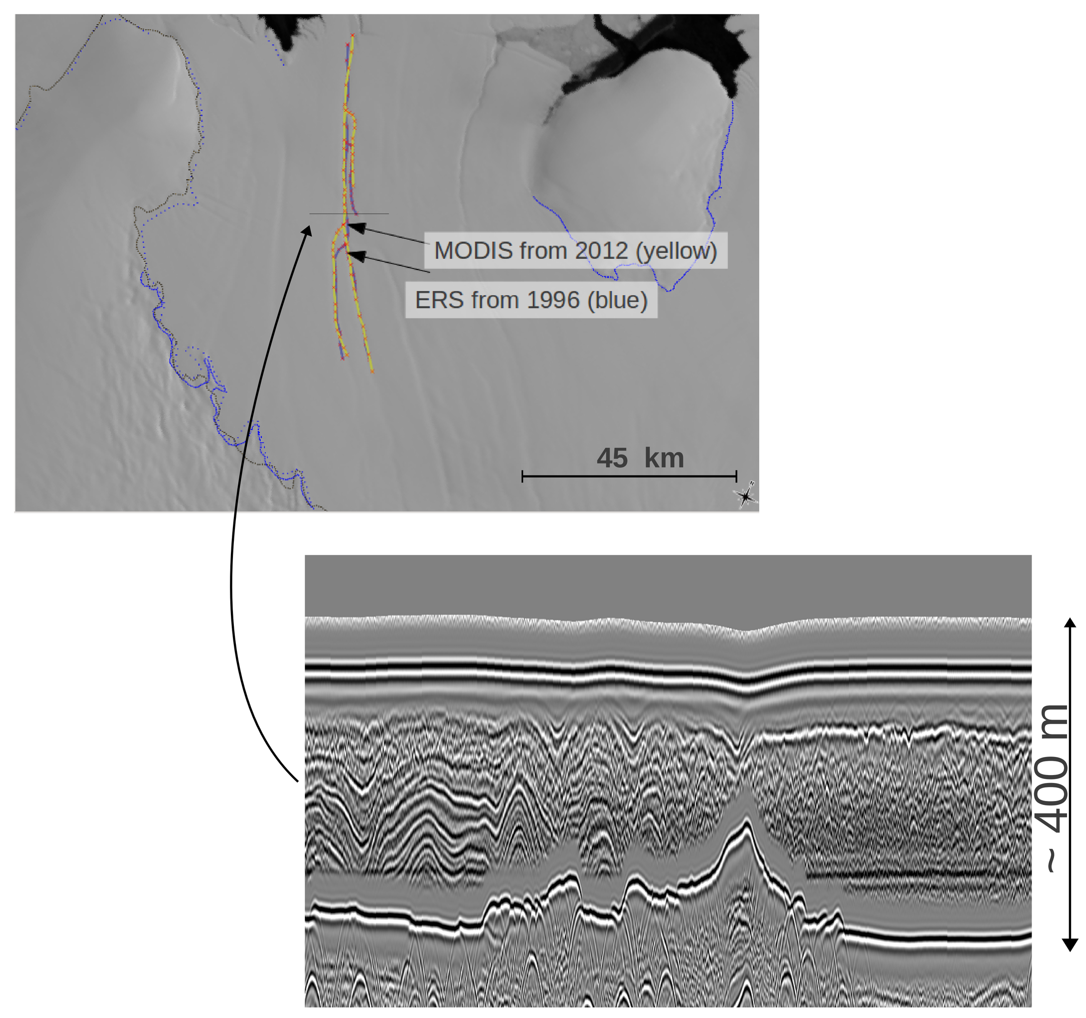

Fig. 7: In satellite imagery, the shear-zones from Fig. 6 can be connected to advected flow-stripe features which are visible on the ice-shelf surface (above). The flow-stripes correspond to sub-glacial crevasses evident in radar profiles (below).

A surface expression of the buttressing pinning-points are **the shear margins** which **align with flow-stripes on the ice shelf. The stripes** appear to be related **to weak spots in the ice shelf, which have been formed initially near the grounding zone area, and were then advected to the ice-shelf front.**

Outlook

We want to link the ice-shelf data with the data from Derwael ice rise by using ice-flow models. With additional field data, we aim to quantify the buttressing effect of the pinning-points (in time and space) and check, whether or not they play a more significant role in defining the dynamics of the surrounding area.