Characterizing ice domes in Dronning Maud Land (Antarctica) with Radar and ice-flow models

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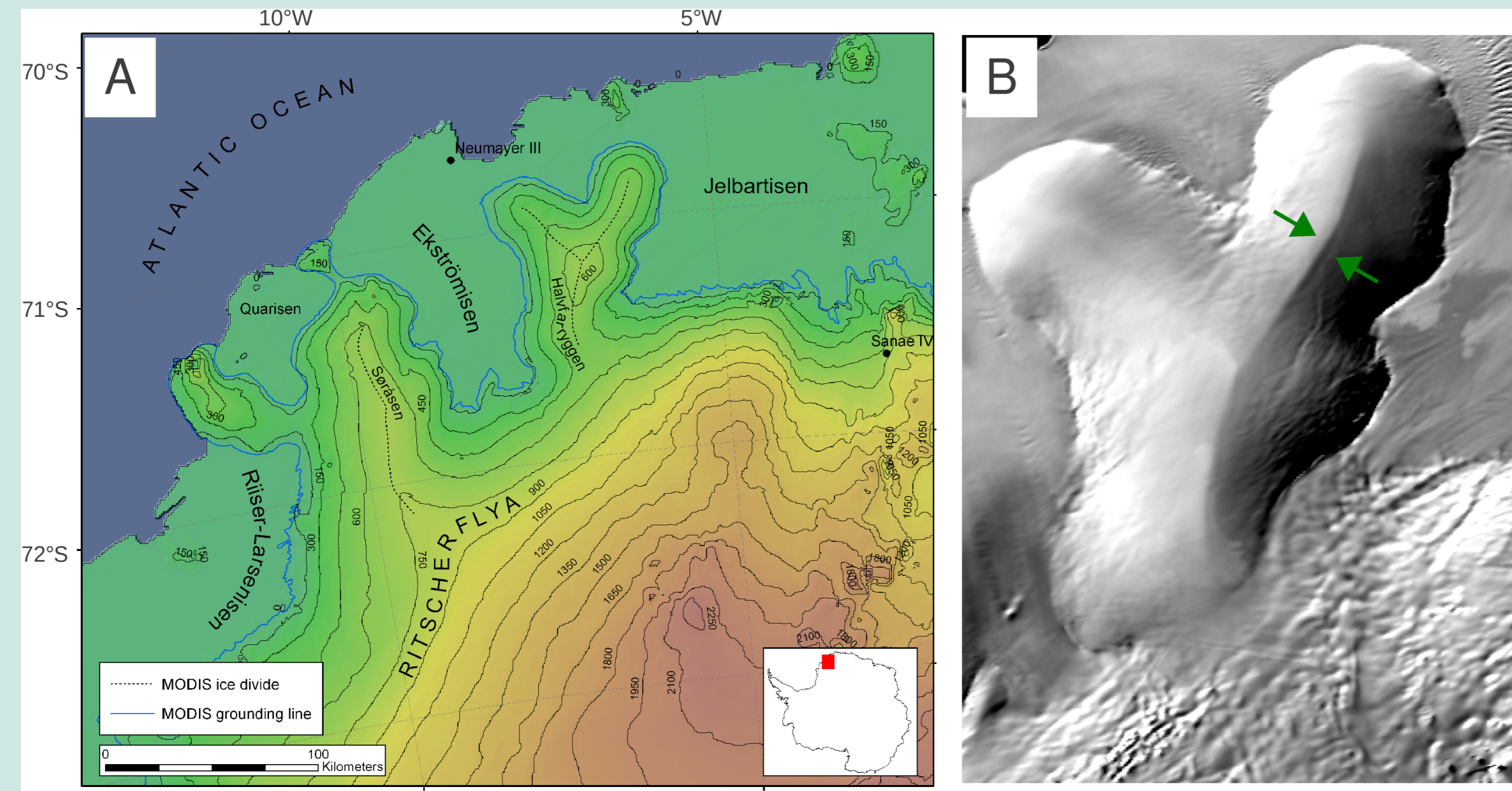
Why Study Ice Rises?

Fig. 1: Overview of study area on Halvfarryggen ice rise in Dronning Maud Land, Antarctica. The ice divides are Y-shaped and merge in a triple junction near the dome.

- Potential drill sites with high accumulation for the IPICS 2k/40k arrays

- Test area for further development of flow law

- Source of lateral friction on ice-shelves, deceleration of ice flow from the main land

- Derivation of flow history by exploiting the Raymond effect
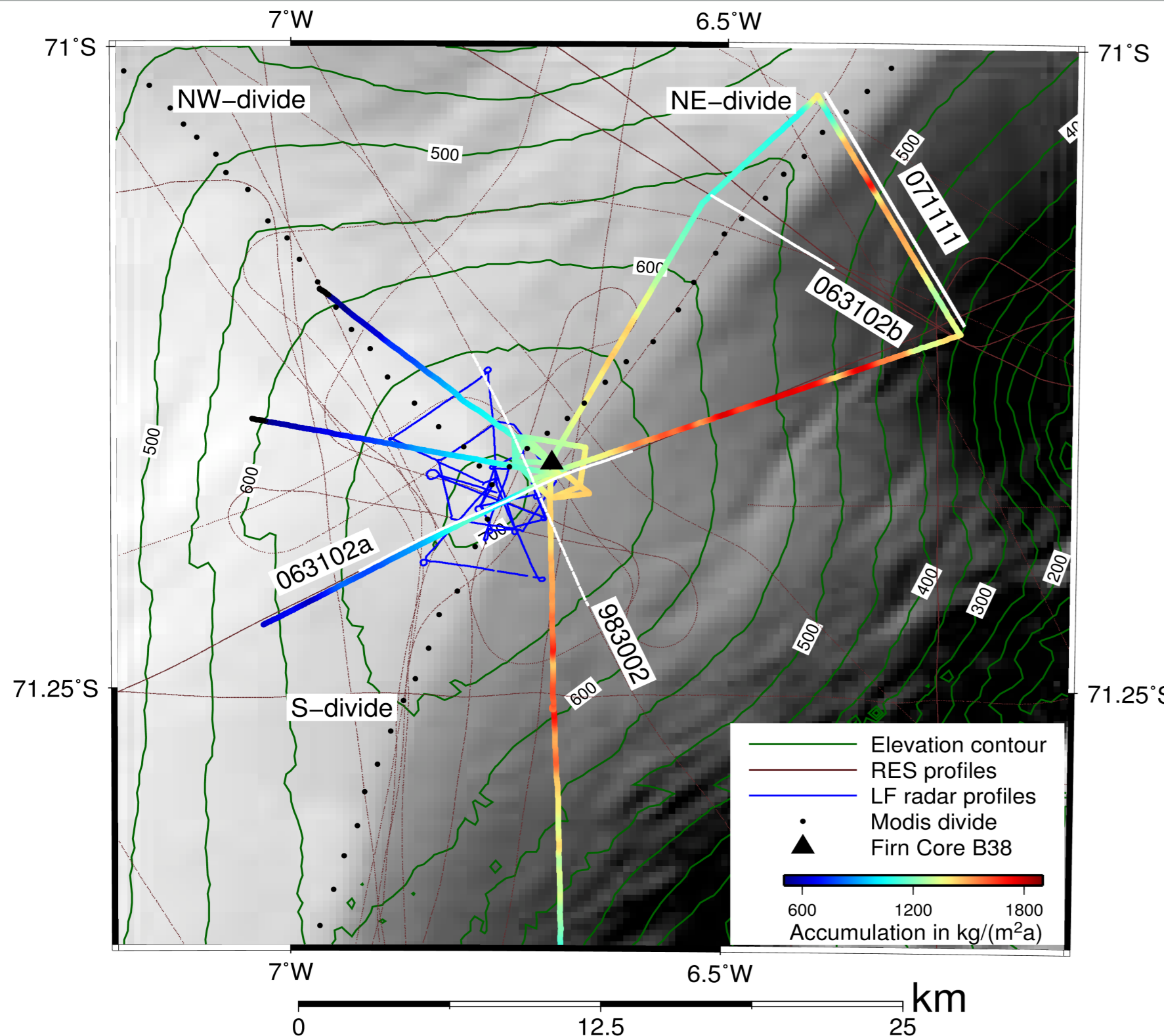
Observation with Radar

Fig. 2: Profile lines from airborne and groundbased datasets. The color coded GPR profile (100 MHz) depicts the accumulation gradient from east to west.
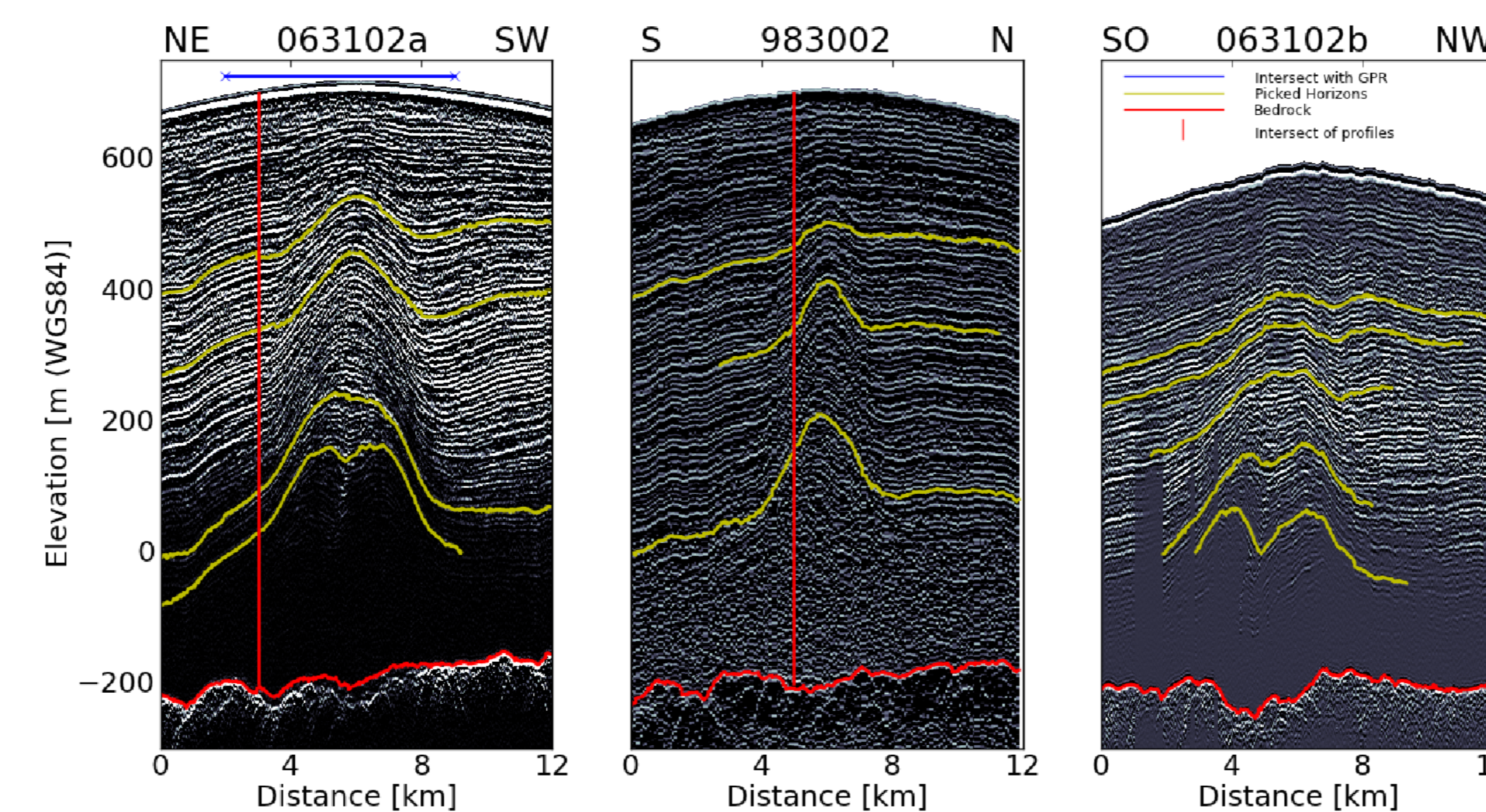

Fig. 3: Exemplary RES lines across all three divides. The upward-arching of internal layers is referred to as Raymond Bumps. Note the double-bumps in profile 063102a.
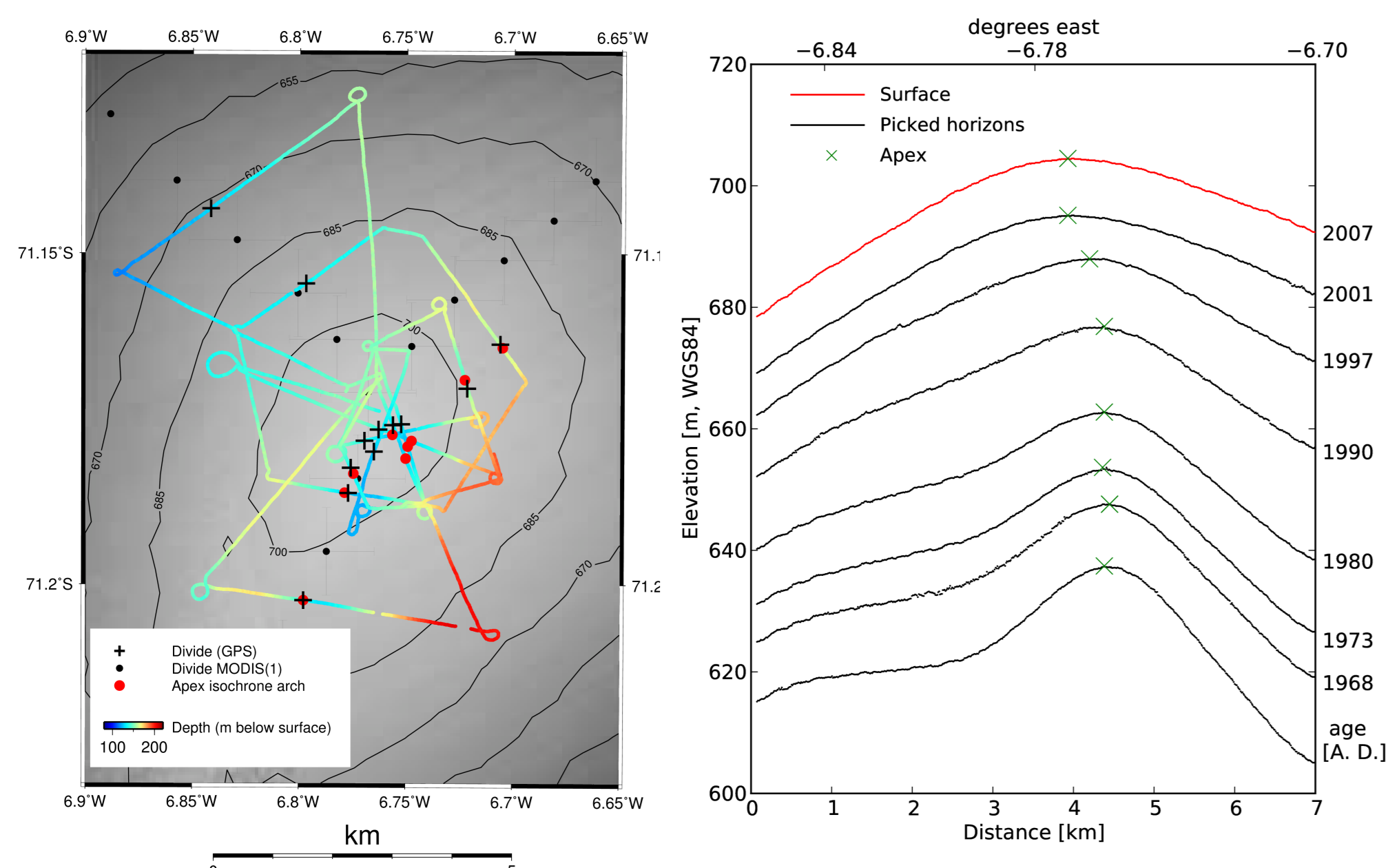

Fig. 4 left: Low frequency (15 MHz) GPR mapping of the horizontal extend of the Raymond Bump. Right: Initial development of Bump in shallow ice. Note **the 500 m offset** of apex and peak in topography.
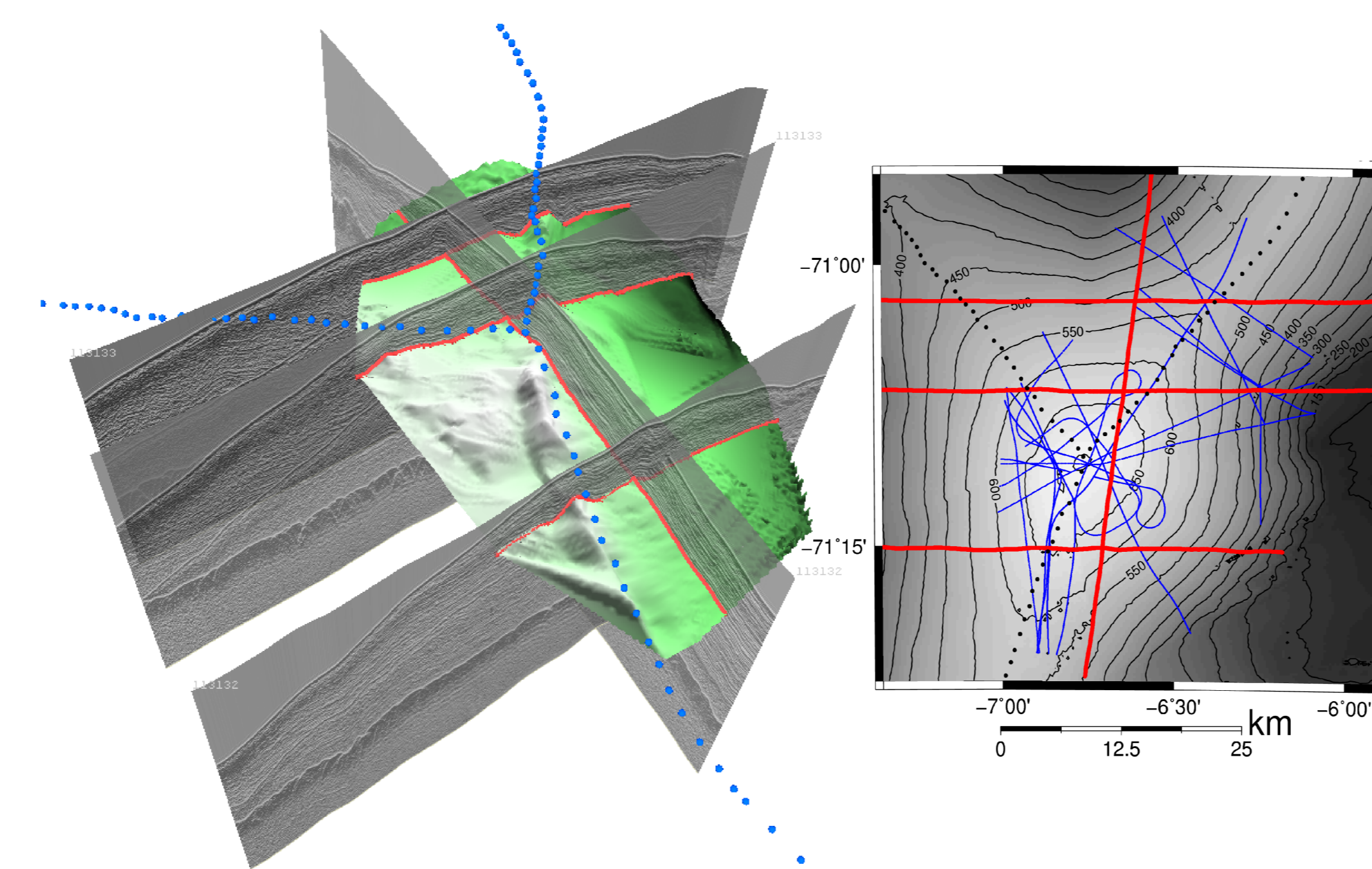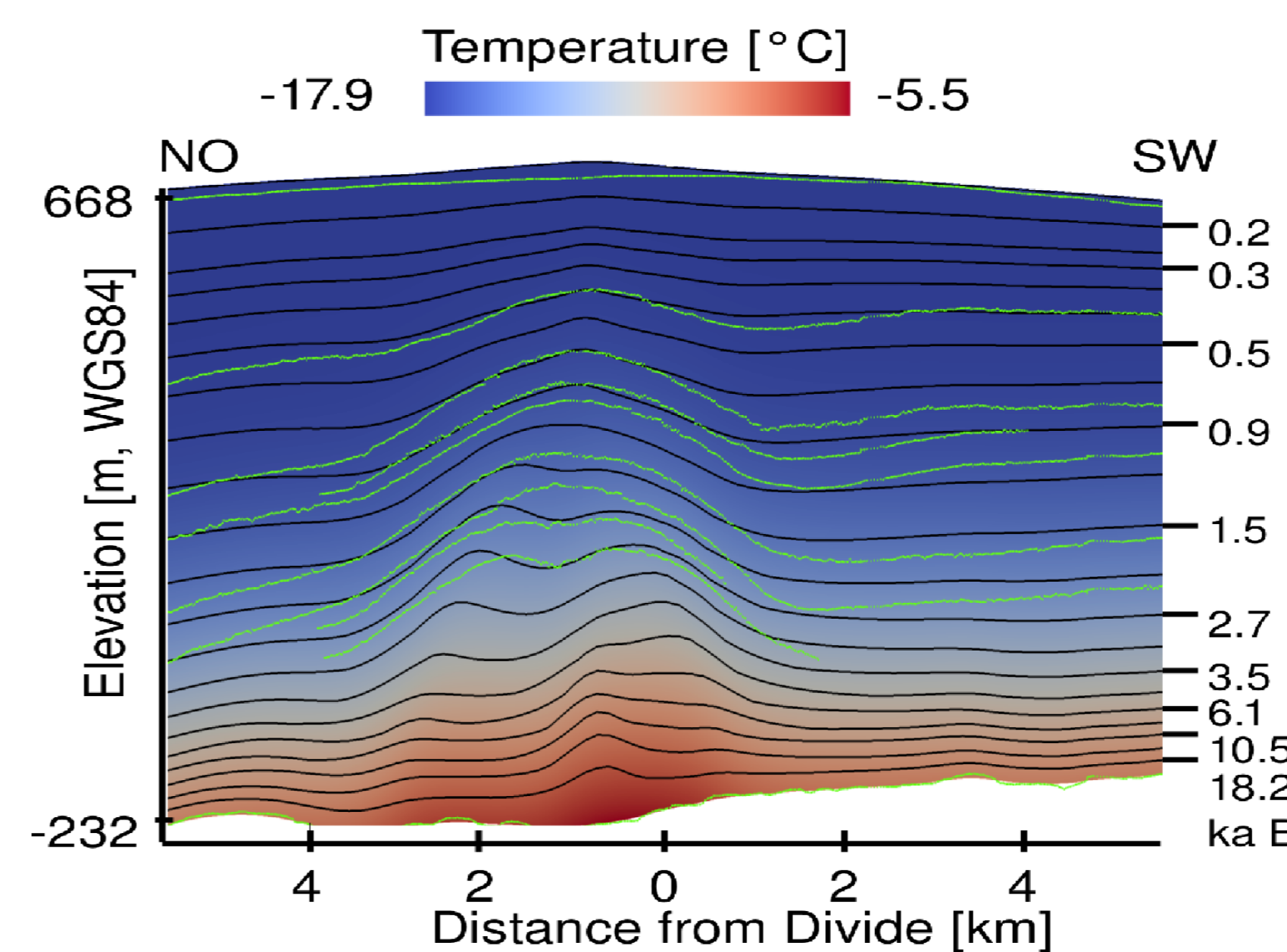

Fig. 5: 3D-Visualization of internal reflection horizon in airborne RES data around the triple junction. The Raymond Bump is clearly visible beneath the southern and the north-eastern divide. It is muted beneath the north-western divide.

Radar as input for Ice-Flow Modelling

Fig. 6: Model results from a transient thermo-mechanical full Stokes model that considers anisotropic rheology (based on C. Martìn et al., JGR, Vol 114, F04001, 2009). Green lines are radar layers (063102a in Fig. 2). The model reproduces the onset of the double-bump and the tilt of the Raymond stack.
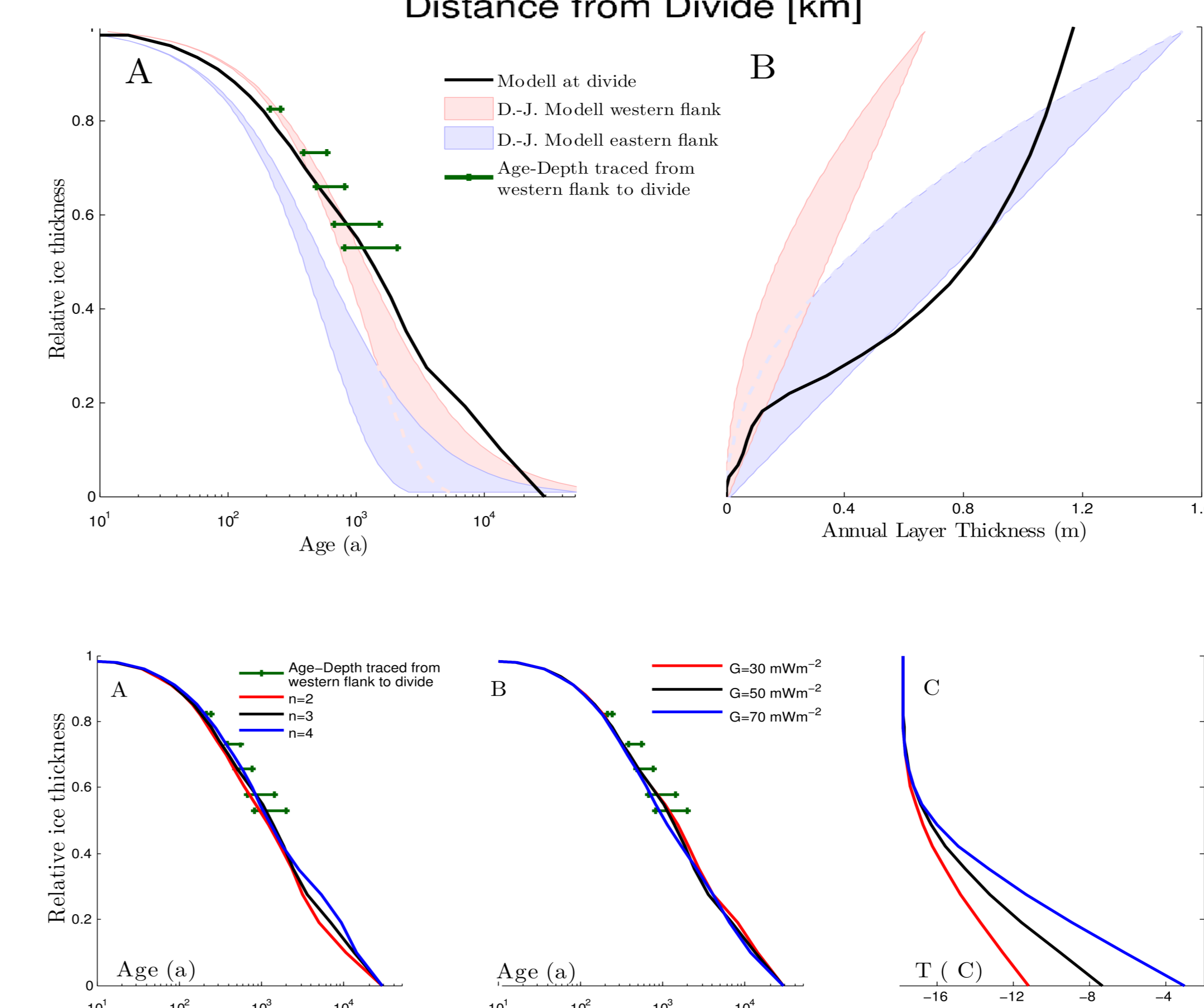

Fig. 7: Modelled Age-Depth (A) and layer thickness (B) beneath the divide (@063102a in Fig. 2) with Dansgaard-Johnsen model at both flanks and traced with radar layers beneath the divide. Width of curves gives uncertainty in choosing the onset of shearing (0 and 0.75% of ice thickness). Black line is the full Stokes model beneath the divide.

Fig. 8: Sensitivity analysis of the full Stokes model for different exponents in the flow law (A), varying geothermal heat flux (B) and the corresponding temperature profiles (C).

Conclusions

- Accumulation in the summit area is high (600-1800 kgm^{-2}), with a strong east-west gradient governed by changing surface slope and preferred wind directions.

- Halvfarryggen Ice Rise is suited for the IPICS 2k array. The accumulation gradient allows to fit the annual layer thickness to the corresponding (paleoclimatic) application.

- The 3D mapping of the Raymond stack hints to a **stable divide position** (>10 ka) and highlights the role of along-ridge flow in muting the bump amplitude.

- The appearance of a double-bump at larger depths can only be reproduced with an **anisotropic rheology.** We therefore expect an anisotropic alignment of the crystal orientation fabric.

- We have no conclusive evidence to explain the **observed offset** in shallow ice (30-60 m below the surface) between the apex of the Raymond bump and the peak in surface topography.