Complex basal conditions influence ice flow at the onset of the Northeast Greenland Ice Stream

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MOTIVATION

We analyse the basal conditions of the onset region of the Northeast Greenland Ice Stream (NEGIS) with airborne radar data from AWI's ultra-wideband radar system. We use our larger-scale data set to discuss the hypothesis of the genesis and development of the NEGIS[1] as well as the positioning of the shear margins in this region.

1 STUDY AREA

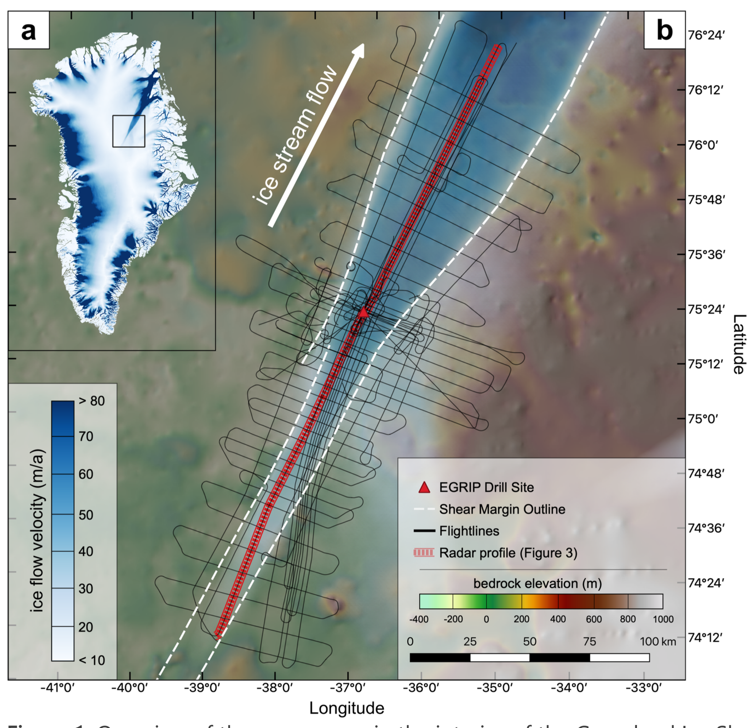

Figure 1: Overview of the survey area in the interior of the Greenland Ice Sheet (a) at the onset of fast flow of the NEGIS (b). The black lines, which are centred at the EGRIP drill site, represent the survey profiles of the EGRIP-NOR-2018 airborne UWB radar survey (Franke et al., 2020[4]). The white dashed lines show the outline of the shear margins and the dashed red line the radar profile shown in Figure 3. Ice flow velocity is based on the dataset of Joughin et al., 2017 [7]. This map and all following maps are shown in the coordinate system EPSG 3413.

METHODS

We make use of a spectral roughness analysis method[2] to characterise the subglacial topography parallel and perpendicular to ice flow. To investigate the basal roughness on finer spatial scales, we analyse the waveform abruptness[3] from the bed return echoes.

On the basis of an improved bed elevation model[4], we investigate subglacial water pathways[5] and combine these data with the distribution of bed return power[6] and the reflection patterns of the base to estimate where water is likely to be present.

2 SPECTRAL BASAL ROUGHNESS

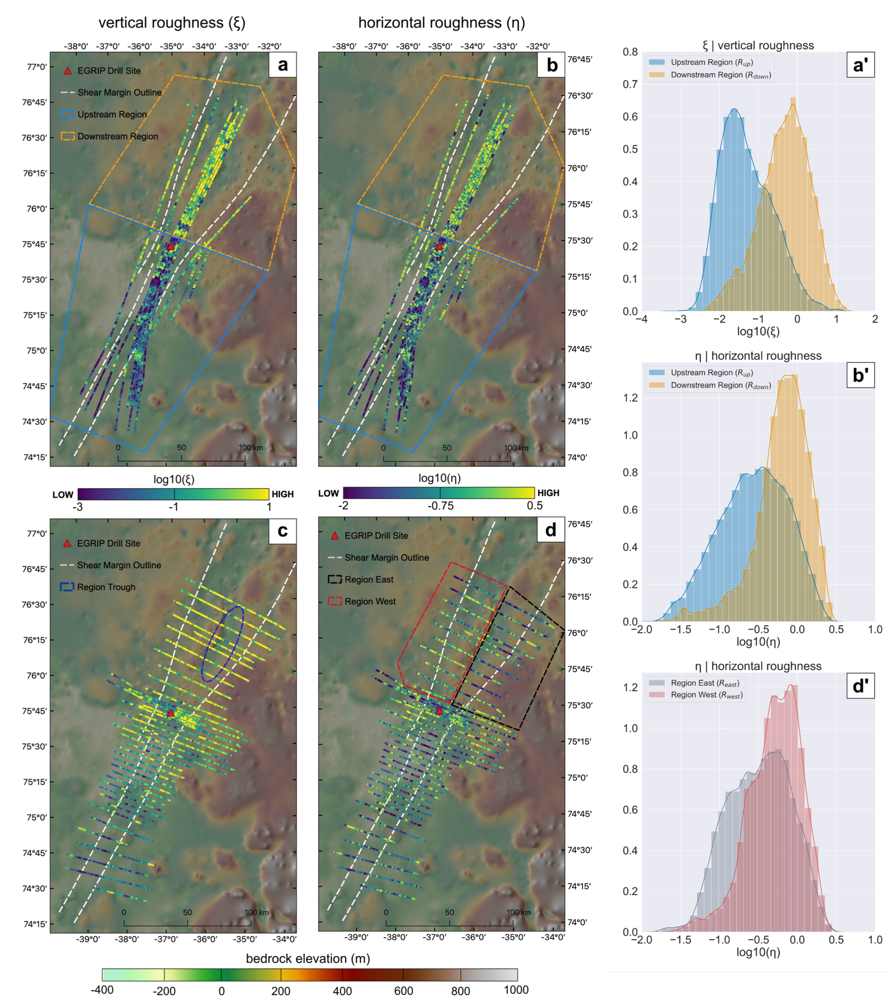

Figure 2: Survey area at the NEGIS showing (a) along- and (c) across-flow profiles of the vertical roughness parameter ξ and the horizontal roughness parameter η in (b) along and (d) across-flow profiles respectively. Both parameters are shown on a logarithmic scale. Histograms a' and b' show the distribution of ξ and η for the along-flow profiles for the upstream and downstream region, respectively (orange and blue outline in a and b). The y-axis on the histograms represents the kernel density estimation.

3 BASAL ROUGHNESS AND RADAR STRATIGRAPHY

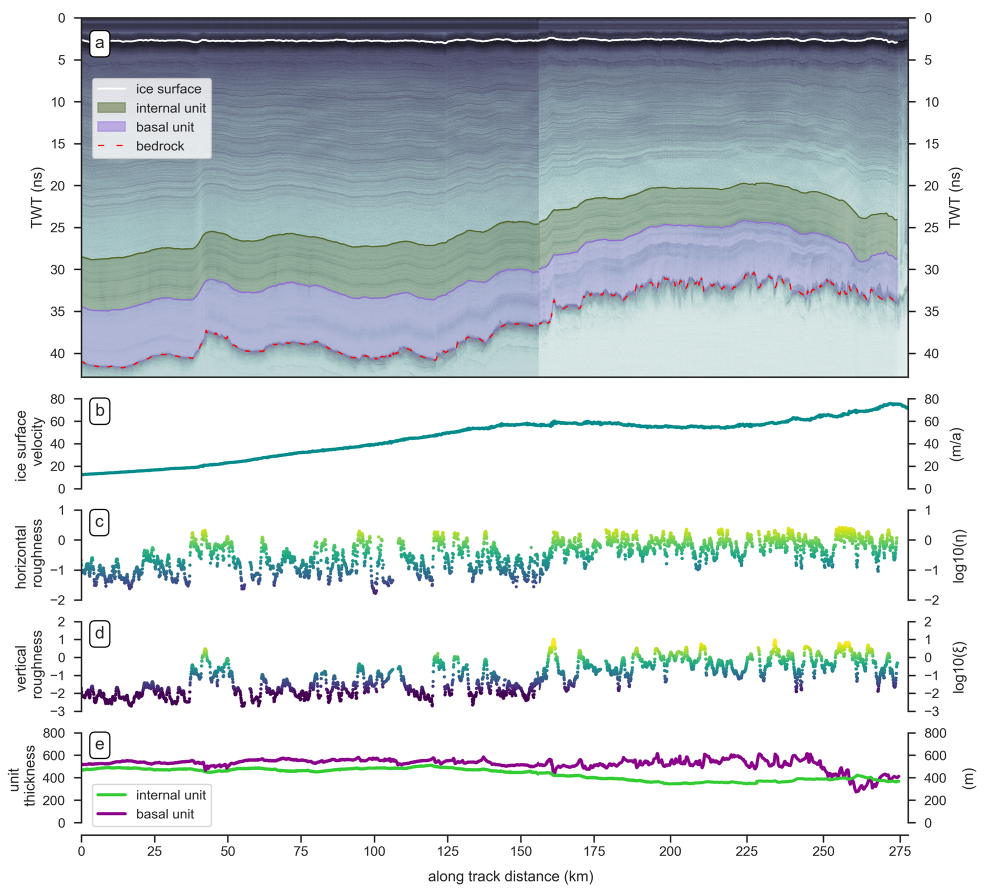

Figure 3: Evolution of several basal and englacial properties in ice flow direction, extending from far upstream to the downstream end of our survey area (red line in Figure 1). Because there is no continuous survey profile, the downstream part (right part of the dashed line) is offset ~ 1 km to the South-East (transverse to along-flow profile orientation) relative to the upstream profile (left of the dashed line). The transition between the two profiles marks the position of the EGRIP drill site (yellow triangle). Ice flow direction is from left to right. (a) along-flow radargrams with continuously tracked surface (white), two internal ice units (basal unit in purple and internal unit in green) and bed reflection (red dashed line); (b) ice surface flow velocity; (c) horizontal roughness η and (d) vertical roughness ξ, both with the same colour code and scaling as in Figure 2; and (e) the thickness of the internal and basal unit.

KEY FINDINGS

1. Basal roughness at the onset of the NEGIS points to a geomorphic anisotropy and a change in the geomorphological regime where the ice stream widens

2. Basal water is funnelled into the ice stream upstream of the EGRIP drill site and redistributed towards the shear margins further downstream

3. A smooth and progressively lubricated bed, reduces basal traction and favours the acceleration of the NEGIS at its onset

4. More regions in central Greenland could be a potential point of initiation of faster ice flow, and potential the development of farther inland reaching ice streams in a warming climate

4 BED RETURN POWER AND WAVEFORM ABRUPTNESS

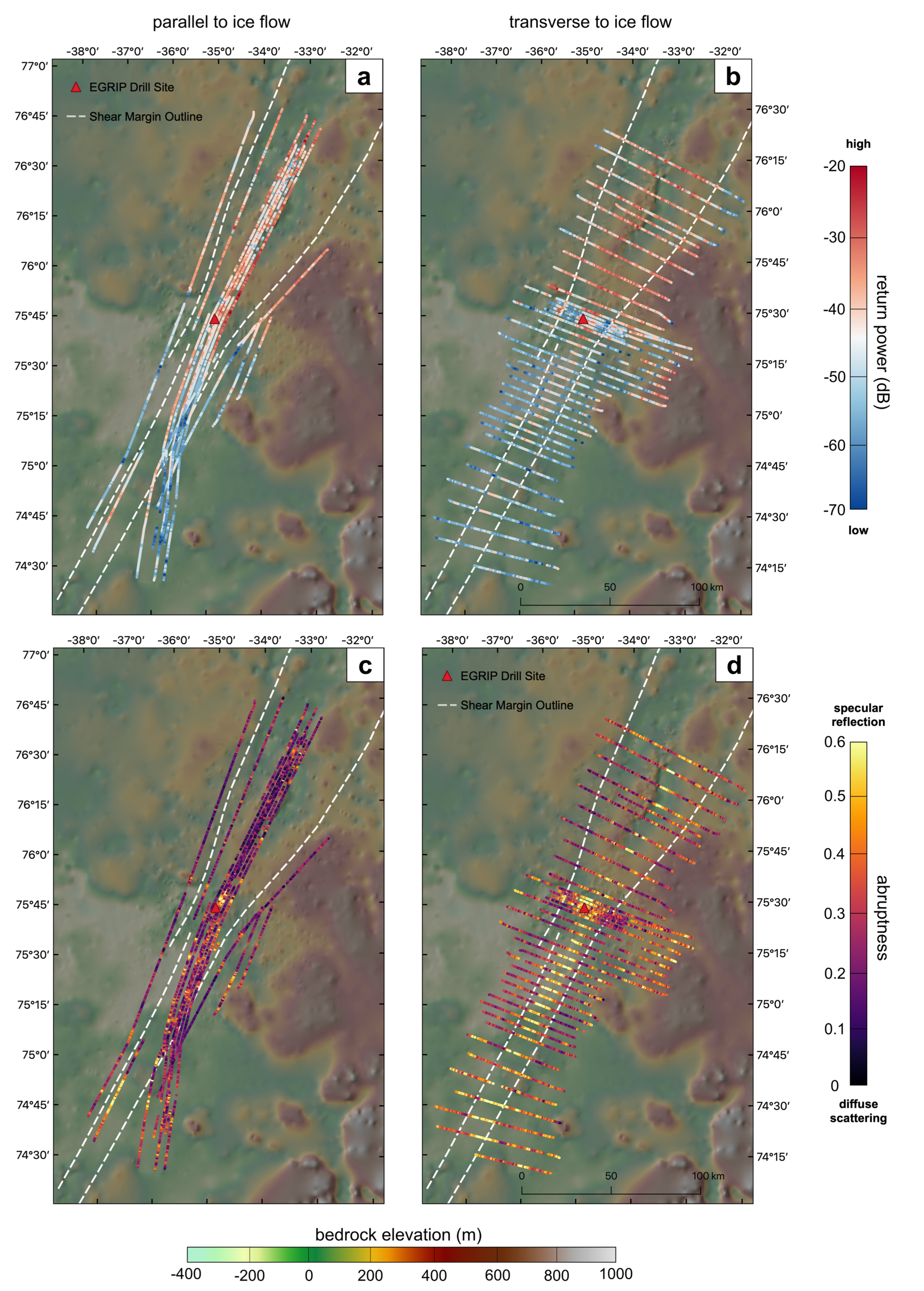

Figure 4: Bed echo characteristics for (a and b) basal return power and (c and d) waveform abruptness for profiles oriented along-flow (a and c) and across-flow (b and d), respectively. Basal return power is corrected for spherical spreading and displayed in decibel (dB with respect to unity). Waveform abruptness is expressed as the ratio between the maximum BRP and the integrated bed return power and is thus unitless. High values (yellow) represent the dominance of specular reflection and low values (dark purple) the dominance of diffuse scattering of the base.

5 ANISOTROPY || ICE FLOW

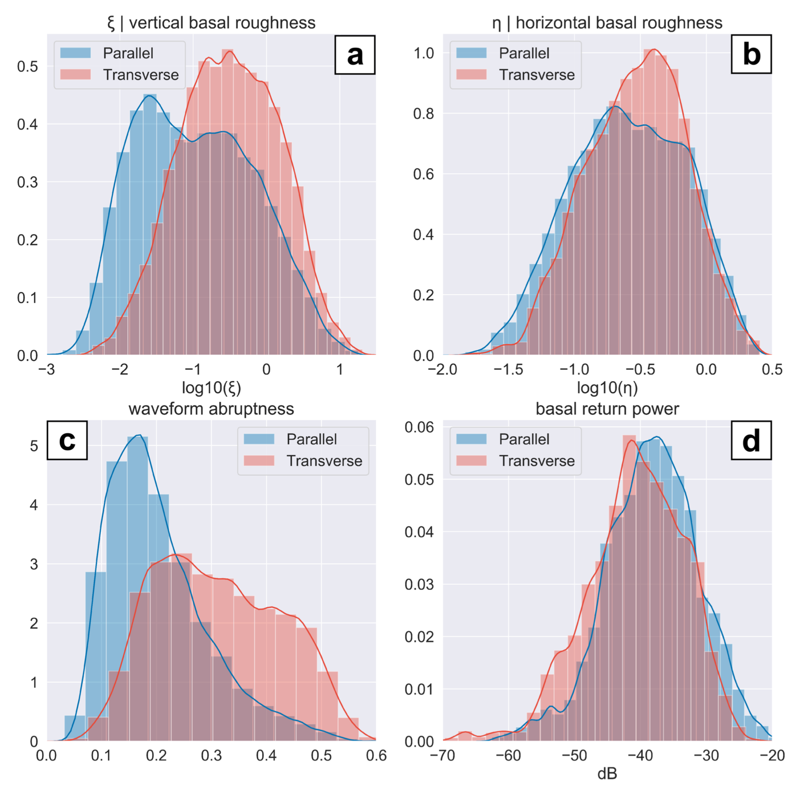

Figure 5: Histograms presenting the distribution of (a) vertical basal roughness, (b) horizontal basal roughness, (c) waveform abruptness and (d) basal return power for profiles oriented along- and across-flow for the location inside of the ice stream. Blue bins represent along- and red bins across-flow profiles. The y-axis shows the kernel density estimation.

6 BASAL WATER ROUTING

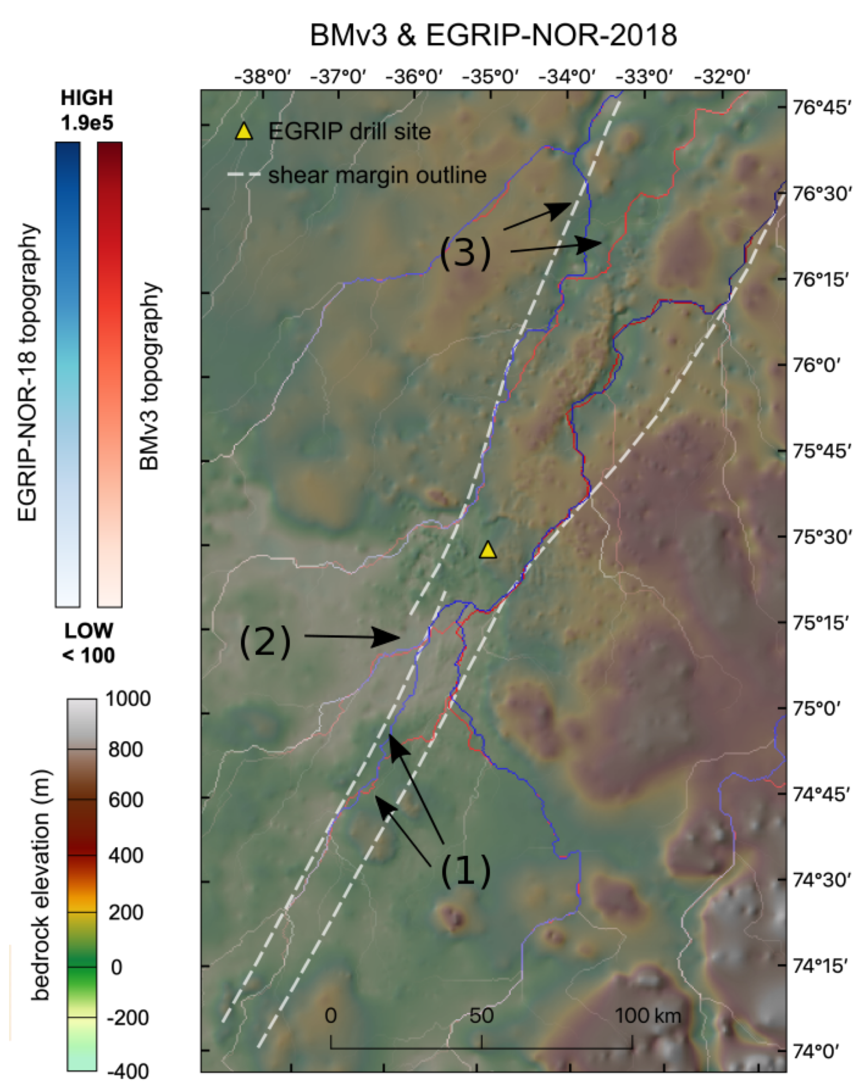

Figure 6: Basal water routing pathways calculated based on EGRIP-NOR-2018 bed elevation ([4]Franke et al. (2020); in blue) as well as pathways calculated with the bed elevation model BMv3 ([8]Morlighem et al. (2017); in red). Both data sets use the same surface DEM for ice thickness calculation. The basal water routing colour saturation represents the number of accumulated upstream cells. Pixels containing less than 100 upstream cells are transparent. High values and dark colours represent pathways that transport larger amounts of upstream cells. Features 1 – 3 present locations where the routing pathways from the two bed elevation models show the largest deviations. The background map represents the bed elevation of the EGRIP-NOR-18 data.

7 SYNOPSIS OF NEGIS CHARACTERISTICS

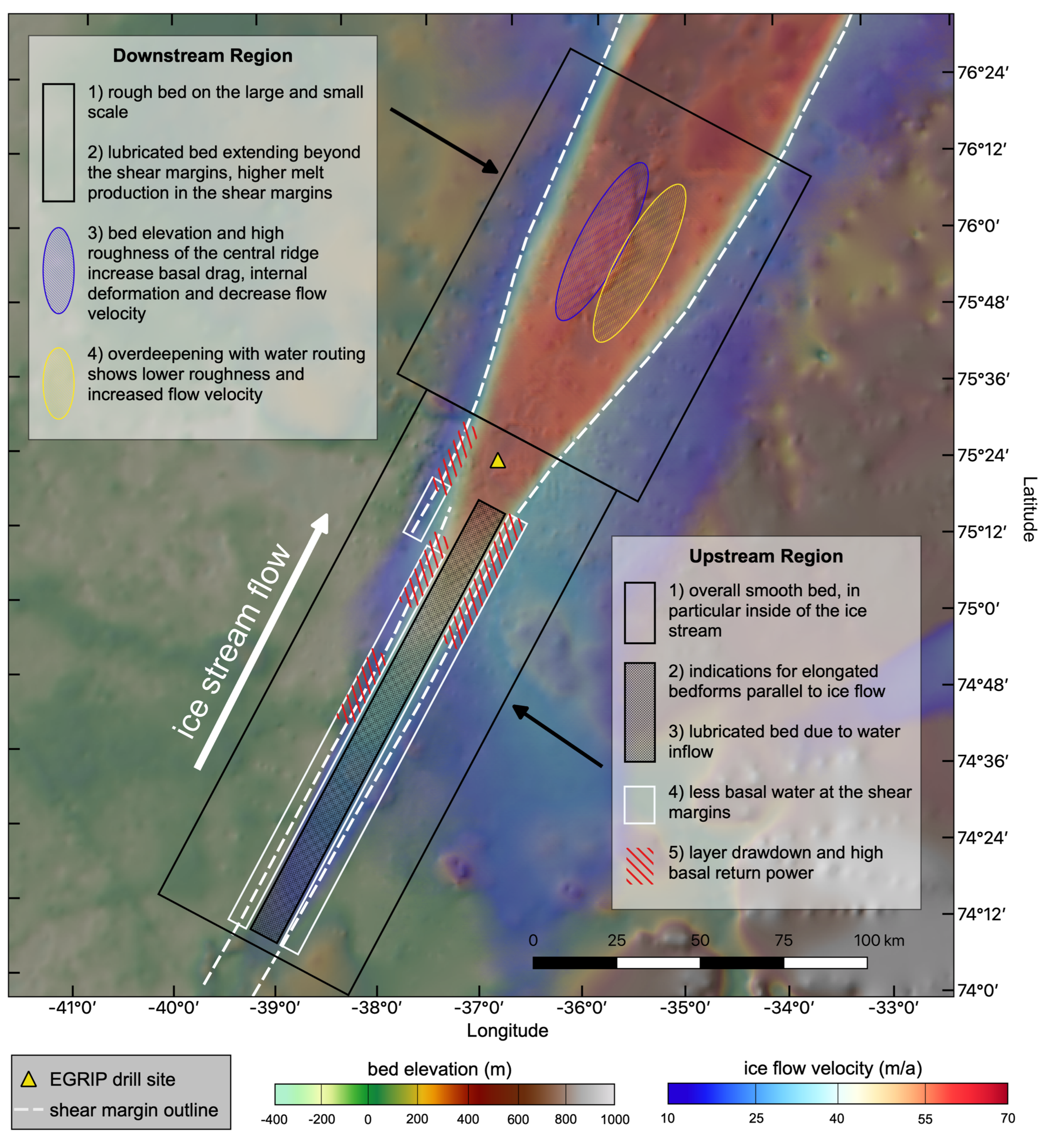

Figure 7: Summary of the basal properties of the (a) upstream and the (b) downstream survey region.

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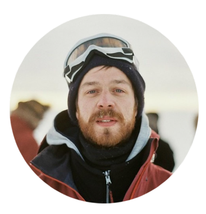

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