ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

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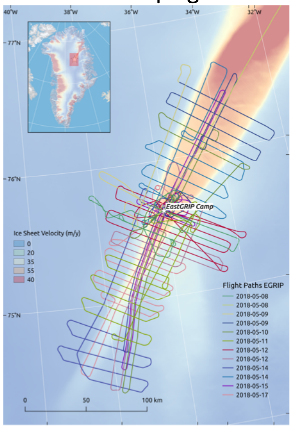
Deformation structures at the margins of ice streams

Airborne campaign 2018

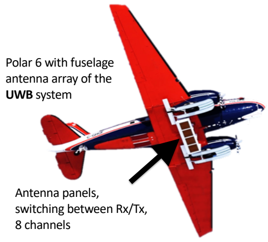


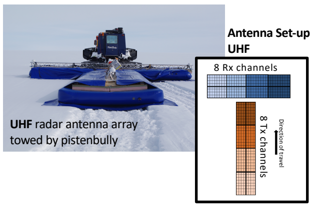
The North-East-Greenland Ice Stream (NEGIS)

The NEGIS has clear surface expression in velocity field as seen from satellites which gives a snapshot for present time and indicates the effective drainage of solid ice.

But beneath the surface the ice stream also leaves an imprint, made visible by distortion and deformation of the internal stratigraphy. These structures at depth of ice stream margins have not been investigated in detail so far, and the EGRIP Ice Core drilling project provides the possibility to do just that by extensive radar surveys

- **From the air:** using the 8-channel ultra-wide band radar on POLAR 6
- **On the ground:** with the new 8 channel UHF-Mills Cross radar and the 4 channel VHF Radar, both developed at University of Alabama





The Radar Instruments

The three deployed radars are Chirp radars, using different frequency ranges. For data evaluation, the raw data are interpolated to achieve a fixed trace separation.

- The **VHF** radar operates at 170-230 MHz, trace distance after processing usually 2 m
- **UHF** 600-900 MHz ("Mills Cross"), trace distance is 2.5 m
- The Ultra Wide Band (**UWB**) airborne radar has been operated in narrow band mode, 180-210 MHz, and is thus comparable to the VHF radar frequency range, trace distance after final processing is 15 m

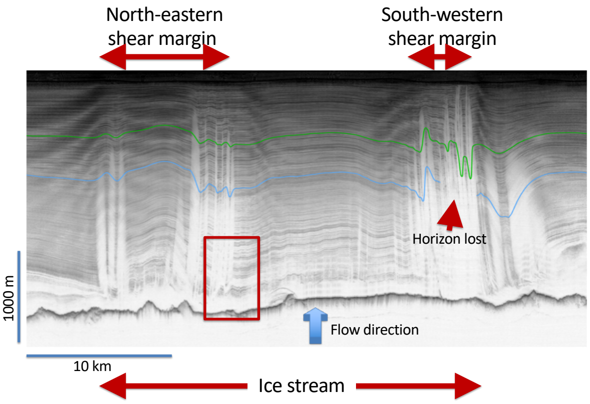
	VHF	UHF	UWB	Units
	ground	ground	airborne	
Polarization	Linear	Linear	Linear	
Frequency	200	750	195	MHz
Bandwith	60	300	30	MHz
Sweep lenght	10	10	1/3/10	µs
PRF	5	10	10	KHz
TX power	4,8	4,8	6	KW
Antenna Gain	25	60	30	dBi
Ice loss (3km -2way)	60	90	60	dB
Pulse compression gain	25	30	max 25	dB
Stacking gain	24	15	20	dB
Spreading loss (r2)	92	92	92	dB
System losses	8	10	10	dB
Processing gain	15	15	15	dB
SNR at bed	74	62	60	dB

System parameters

Section through the ice stream

The airborne campaign from spring 2018 covers a large region around the EGRIP drilling camp and thus provides the data to understand the impact of ice stream flow on stratigraphy on a larger scale. The profile shown to the right is located 5 km upstream of the Camp.

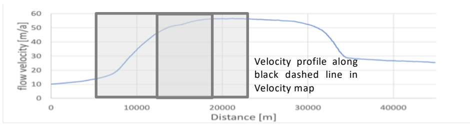
The shear margins show a distinctive pattern, which is due to the compressive stress regime the ice experiences when entering the ice stream, leading to chevron or zig-zag folding in the active margin. The folding is preserved when the ice is entering different regimes or if the stress regime is changing over time. Picking internal reflectors throughout the entire survey area and connecting them to horizons show the 3D-imprint of the ice stream at depth.

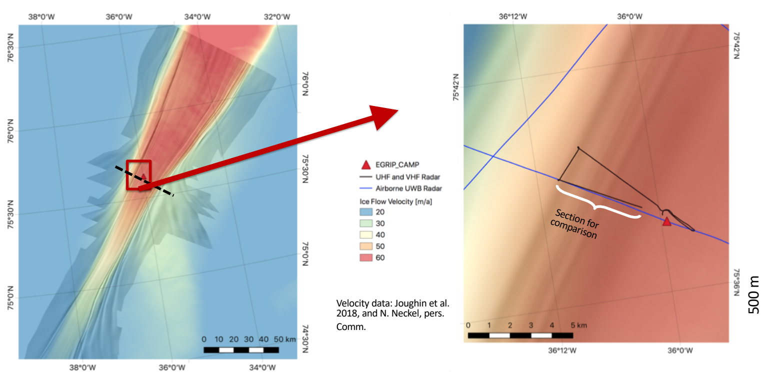


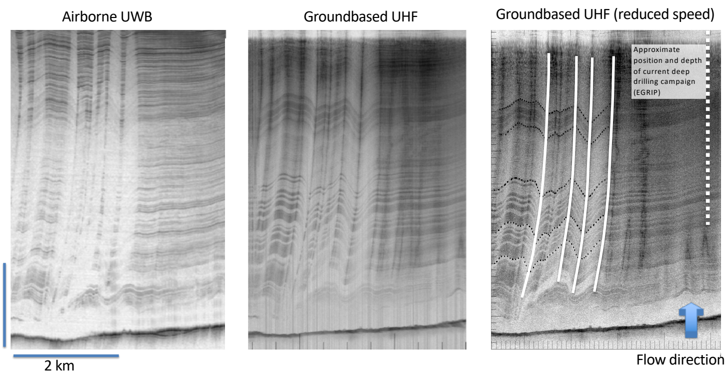
Comparison of different data sets

The map shows the location of the profiles measured with different radar instruments. Colour represents ice flow, and the grey-shaded layer is the 7259 y horizon, indicating the position of the folds.

The airborne data gives a good representation of the folded reflectors. However, due to the slower survey speed and resulting narrower trace distance, the ground based data from the VHF and UHF instruments resolve even the steeply dipping flanks of the folds. This becomes even more apparent when further reducing survey speed, as shown below to the right, with an approximate trace distance of 1 m after processing.

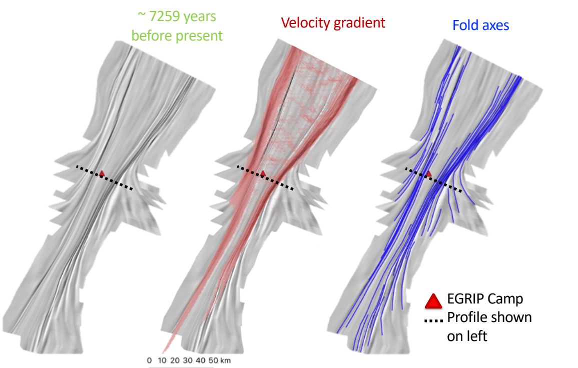






3-D Horizons from picked reflections

The ice stream margins leave a distinct folding pattern imprinted into the radar stratigraphy. The high velocity gradients lead to a compressive stress regime perpendicular to the flow direction, causing the characteristic chevron folds. Larger irregular features are also entering the ice stream and are assimilated into the shear margins from the sides. This is most prominent at the western shear margin. Advection of older features outside of the ice stream leads to a tilt in the vertical fold plane, which is probably causing the strong distortion of the radar layers in the west, where in deeper reflection the continuity is lost.



Preliminary dating of layers after Vallelonga et al, 2014.

Summary

- Airborne radar data are essential for understanding large scale structures in ice sheet stratigraphy, and the quality of the data allows for analysing highly deformed structures, as found in the shear margins of ice streams
- In some areas the folds could not be retraced, as the steep reflectors, which are also subject to a secondary deformation process likely due to shearing (bended fold axes, see above) are lost.
- For a detailed analysis of highly deformed ice as in shear margins or in the lowermost part of the ice sheets it is necessary to perform ground based surveys to close the gaps.

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Vallelonga P, and others (2014) Initial results from geophysical surveys and shallow coring of the Northeast Greenland Ice Stream (NEGIS). Cryosphere, 8(4), 1275–1287, ISSN 19940424 (doi:10.5194/tc-8-1275-2014)

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