ABLATION RATES AND THEIR DRIVERS IN GREENLAND – ASSESSING THE POTENTIAL OF THE WEGENER EXPEDITION FOR MODERN GLACIOLOGICAL RESEARCH

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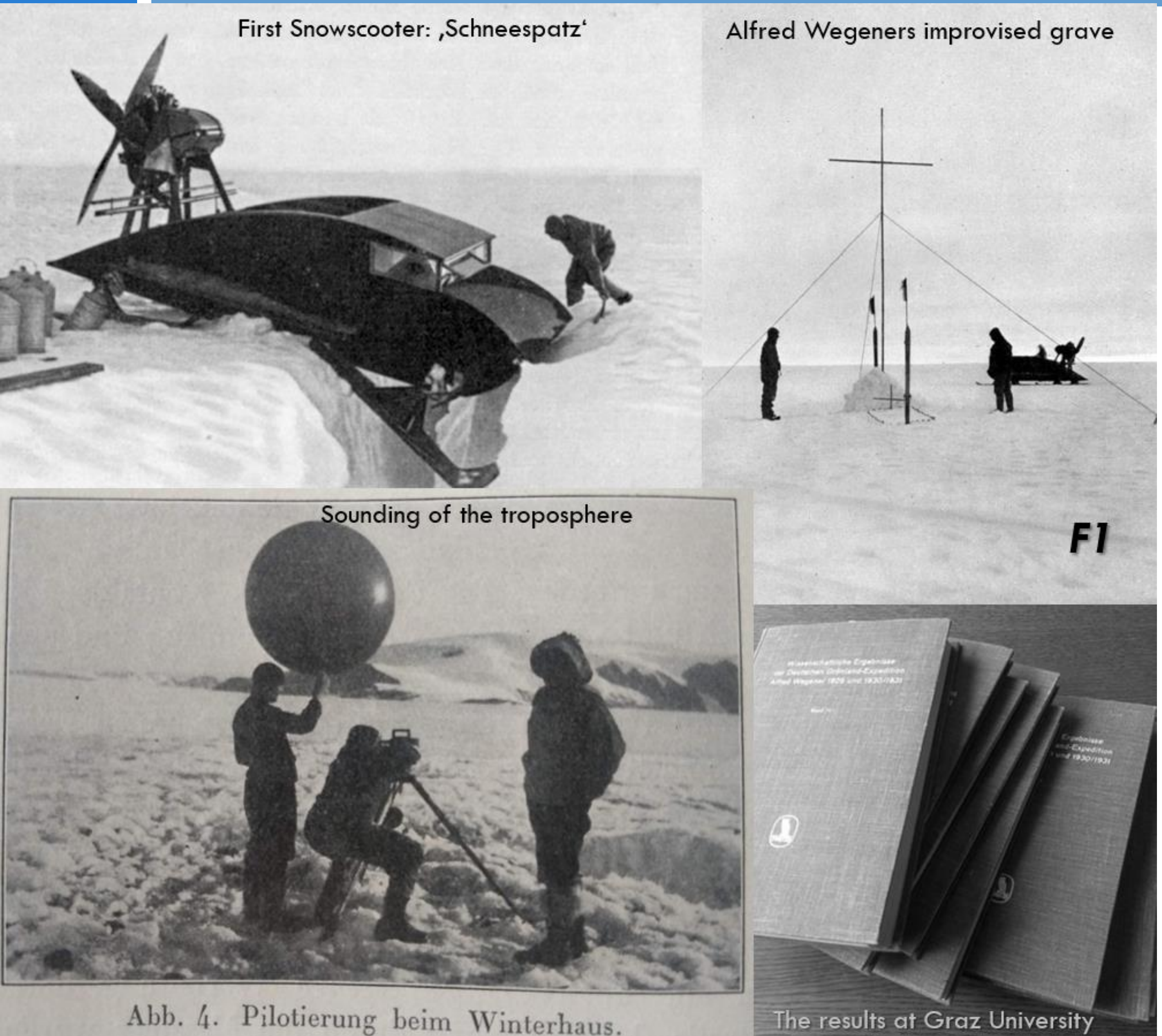
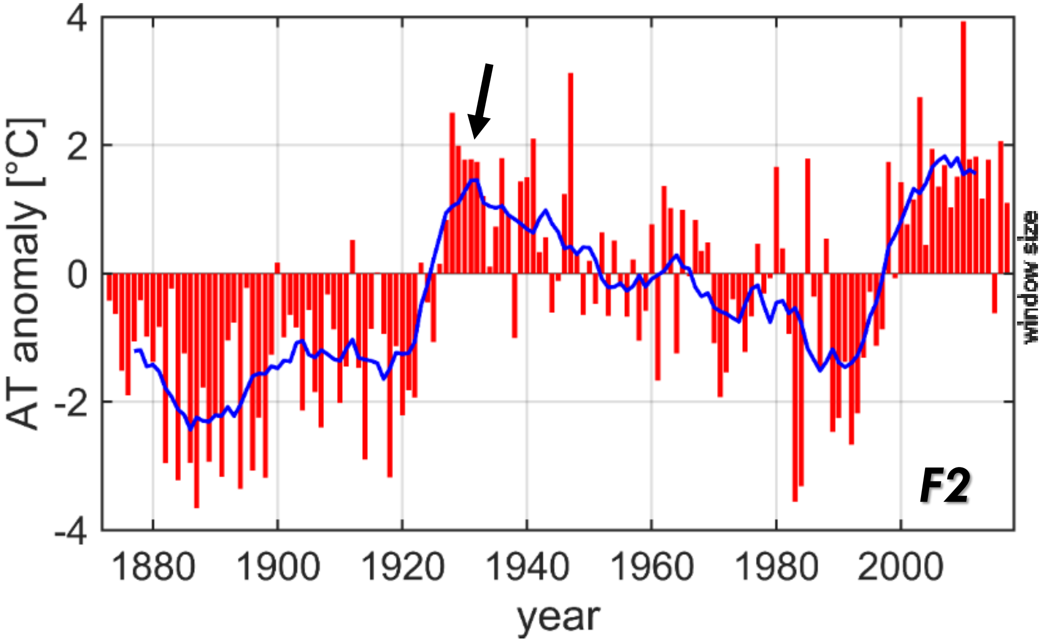
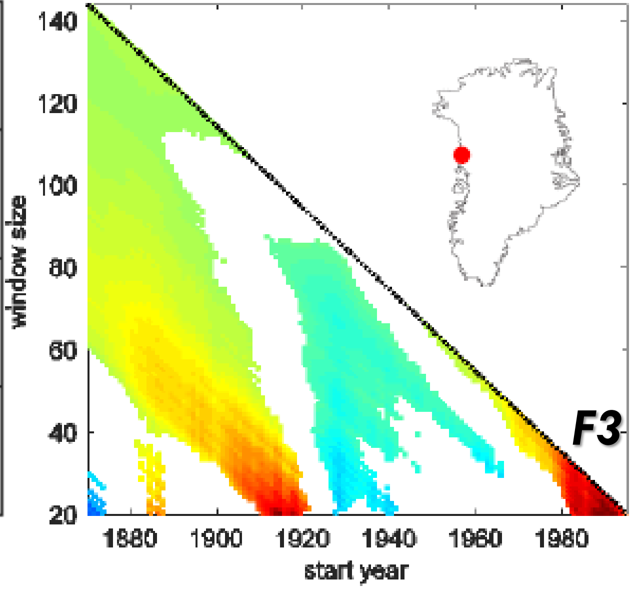
Background



Alfred Wegener's last groundbreaking research activity was a heavily-staffed 2 year expedition (1929-1931) with the ultimate aim to improve the understanding of Greenland in the climate system. He organized it during his time as a physics professor at Graz University. Major results include the formulation of Sorge's law[1], a basis for an accumulation map of Greenland's interior and a much improved quantification of ice volume and troposphere stability.
In autumn 1930 he and his Greenlandic travel partner died on the way back from ‚Eismitte'. The expedition results have been summarized under the guidance of his brother Kurt Wegener and remain hitherto scientifically underexploited. The results including most of the raw data is stored at Graz University library[3] (F1).

The climatological context

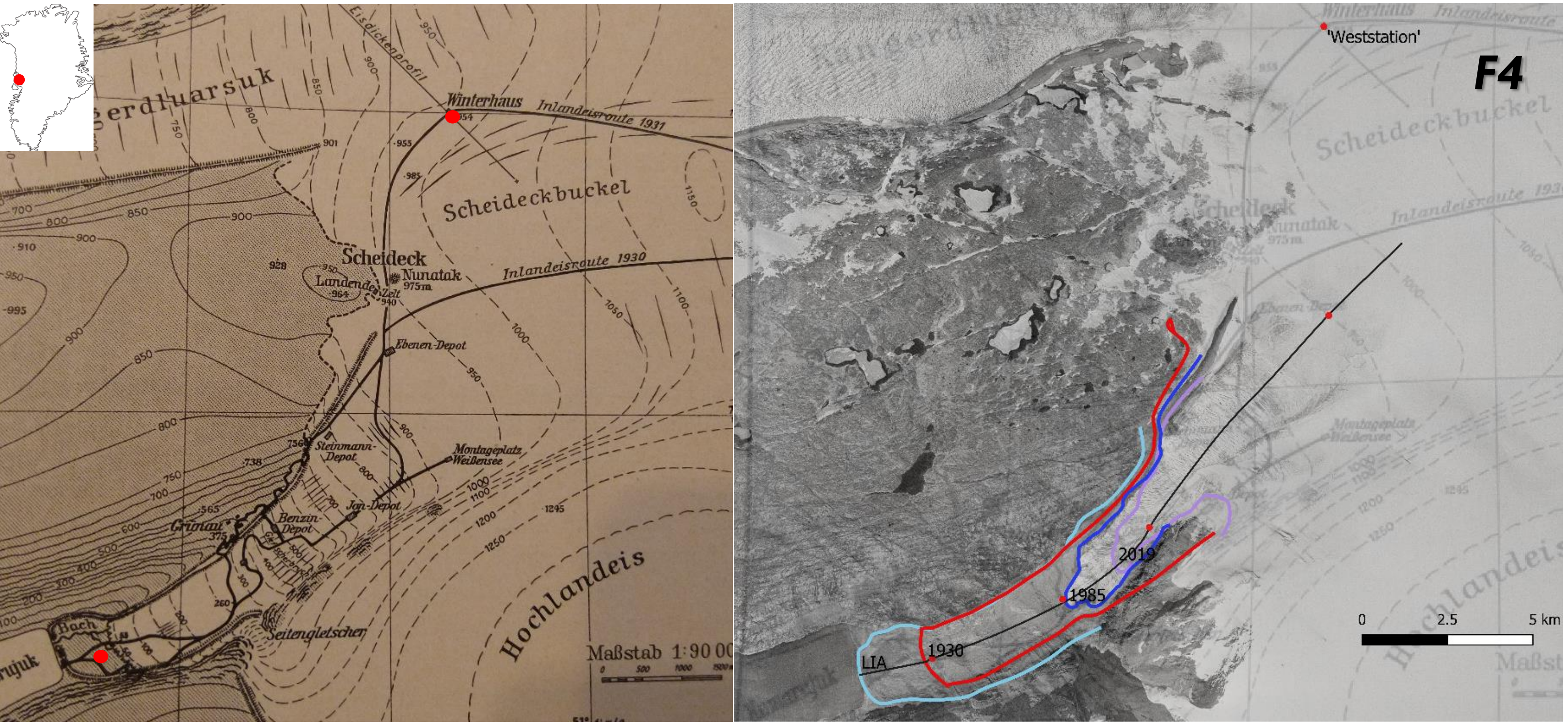




The expedition took place in regionally very warm years with anomalies comparable to the early 21st century[4] (F2 and F3).

Fig. 1: Left: Upernavik air temperature anomaly referring to 1981-2010 (Data from Capellen et al. 2019) right: Time-varying AT trends since 1880 for Upernavik, which is 240 km NW of the study site (Fig. from Abermann et al. 2017)

Area changes

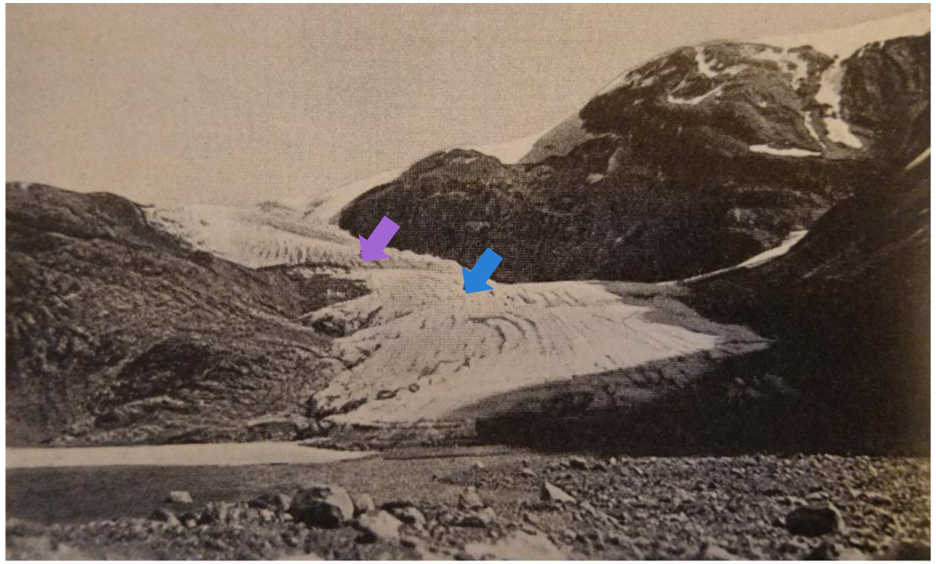


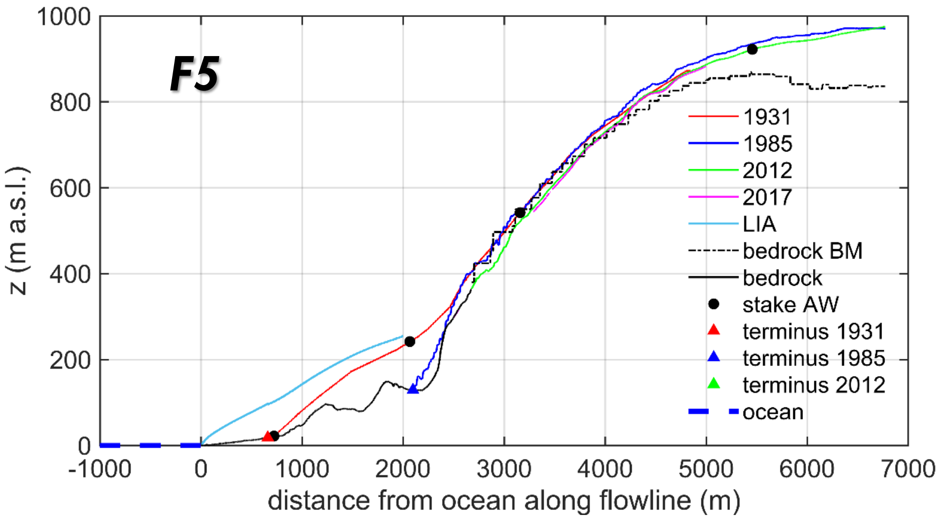
Georeferenced map 1930; different glacier stages, location ablation stakes: Qaamerujup fjord.

The major base for the expedition was in Qaamerujup Fjord in West Greenland (71°08'N; 51°10'W). While the ice margin reached the shore during the little ice age it underwent a significant retreat thereafter. Through digitization of map material from the expedition and several remote sensing products thereafter, we are able to draw a comprehensive picture of area changes since the Little Ice Age (LIA; F4): Between the LIA and 1930 the glacier tongue retreated ca. 800 m and continued another 1.5 km until 1985. After that a steeper slope with rather thin ice lead to a horizontal retreat of ca. 3 km by 2019 in total since the LIA.

Thickness changes

The ice tongue was more than 100 m thick during the LIA and also during the Wegener experdition it reached up to 120 m at its deepest (F5). Blue and purple arrow indicate the approximate lowest margin position in 1985 and 2017. Rapid down-wasting in the first decades of the 20th century removed low-lying ice without sustaining enough mass from above. The current tongue is particularly thin up to an elevation of around 800 m a.s.l. according to BedMachine.

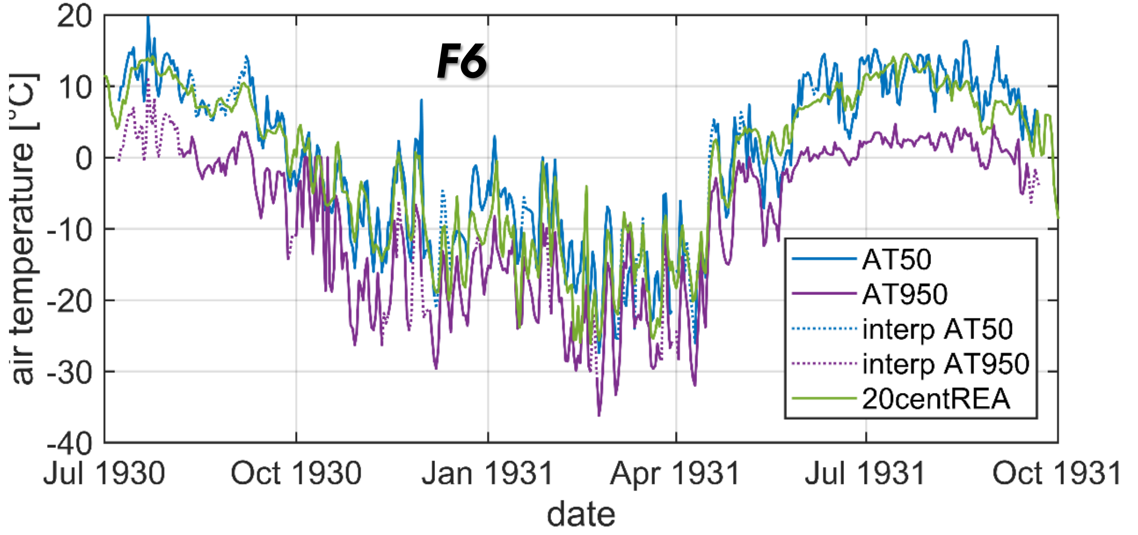


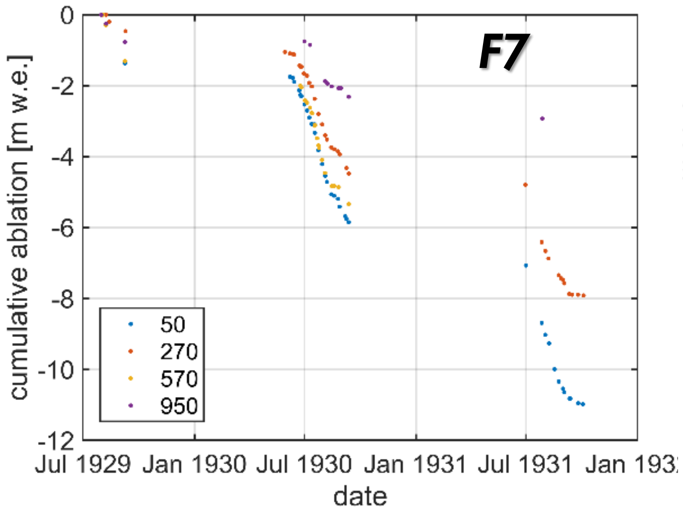


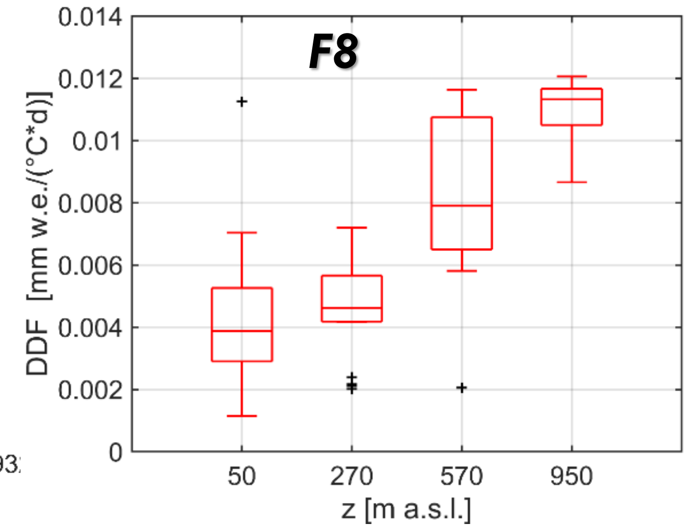
Icemelt and Reanalysis

A comparison of daily mean air temperatures at two AWS from the Wegener expedition with the nearest gridpoint of the 20 century reanalysis V3 shows a remarkable agreement (F6). We believe there is great potential in using this dataset as a driver for long-term changes. However, local conditions at the individual point-scale have changed considerably.

Historical melt rates on bi-weekly resolution are shown in F7 as cumulative ablation in different elevations. Averaged degree-day-factors increase with elevation (F8) which is counter-intuitive regarding albedo but in line with van den Broeke et al. (2010)[5] who attribute this to diurnal averaging. Reconnaissance measurements could answer centennial stability of such relations.

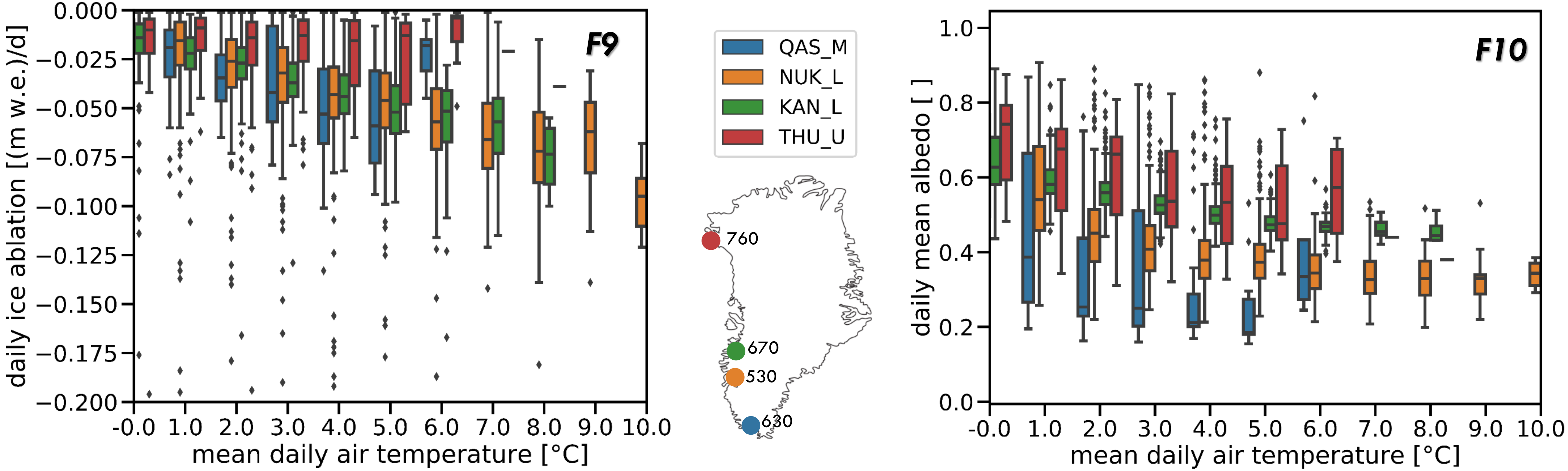






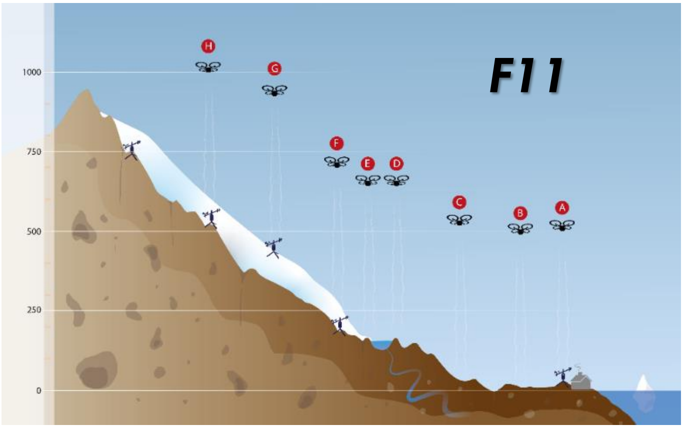
Ice melt, temperature, latitude

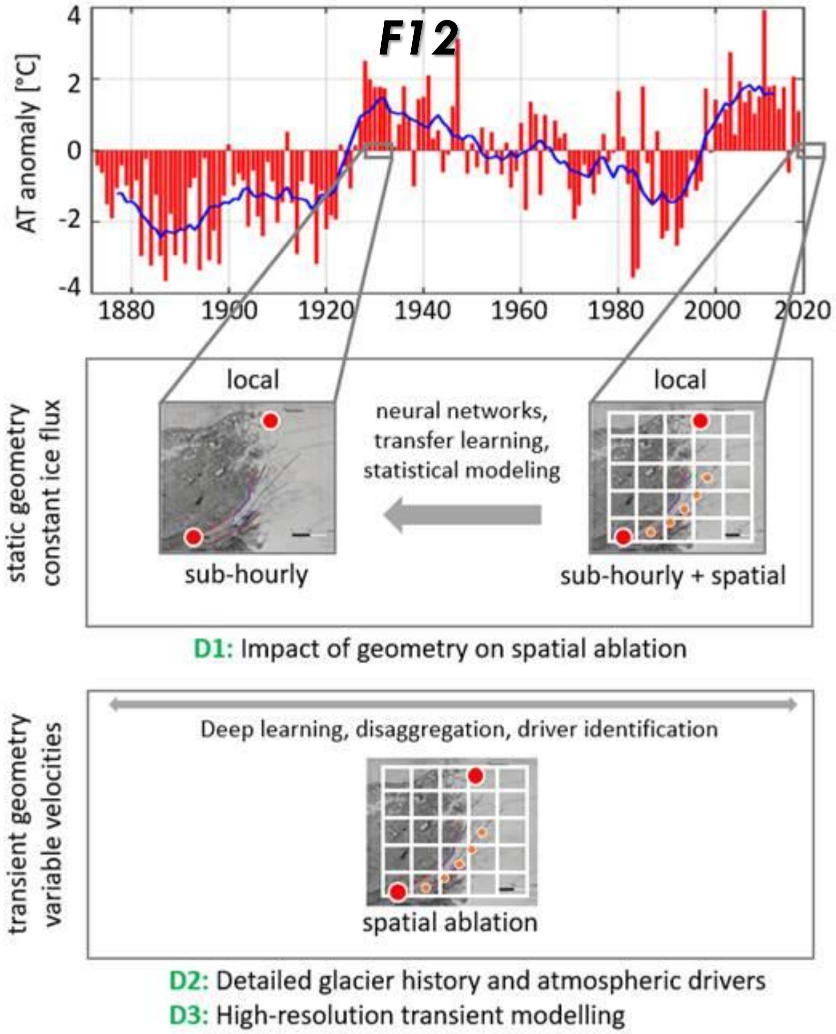
The PROMICE dataset allows for a latitudinal comparison of daily ablation rates vs. latitude for similar elevations. Higher latitudes show lower melt rates at a given positive temperature (F9); this coincides with higher albedo (F10). Stations in elevations within 250 m elevation span are shown. With a reanalysis of the Wegener expedition material we are able to assess long-term validity of these relations.



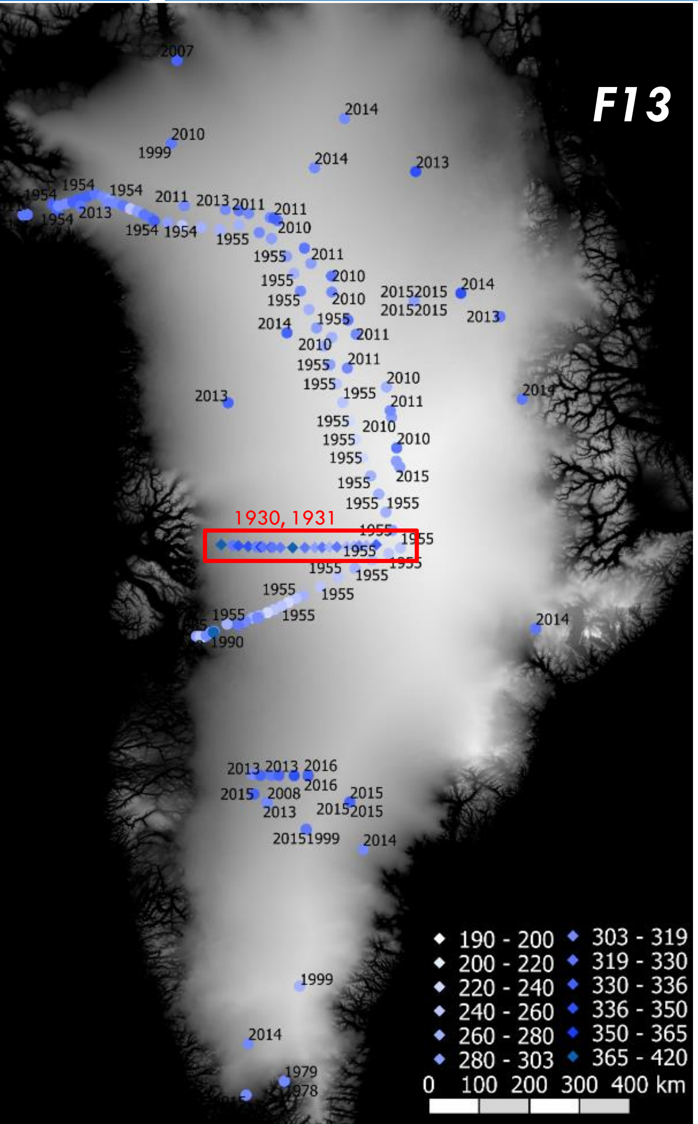
Basis for transient modelling

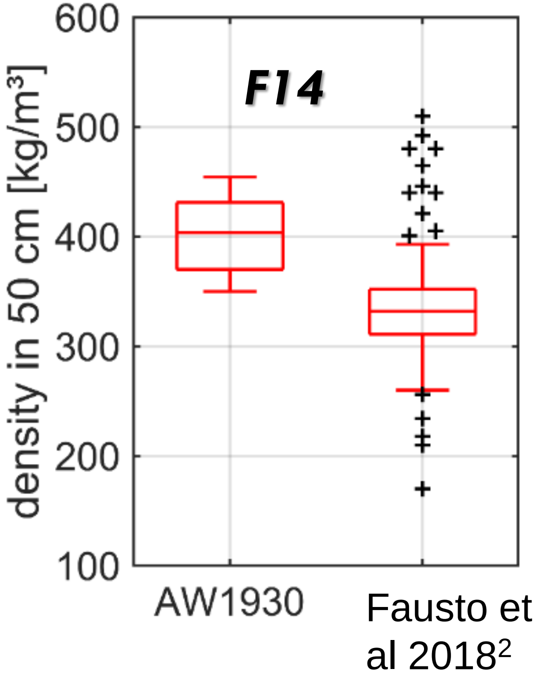
We plan to re-do the measurements of the Wegener expedition at the exact same locations (under a very different geometry) and expand them methodologically to obtain a 3D-coverage of atmospheric measurements with UAVs (F11). That way we will be able to train machine-learning algorithms to today‘s conditions and model back in time. By comparing the results with historical meteorological data and ablation rates from the 1930s, we hope to be able to disentangle the effect of a changed surface and geometry from the climate signal (F12).





Other data in the ‚Wegener treasure trove‘





Lots of additional accumulation area data exists. We show in **F13** all available 20th century **snow density** measurements in 50 cm depth (circles; from Fausto et al. 2018[2]) and add the Wegener data (squares). There is some indication for higher than average snow densities (**F14**) which may be related to concurrent high air temperatures (**F2**).

Conclusions and Outlook

- Very warm years 1929-1931 have exceptionally well documented and broad glaciological data in the Alfred Wegener legacy
- The history of a land-based outlet in West Greenland can be drawn particularly well back to the LIA
- A thorough reconnaissance expedition could challenge long-term stability of glacier/environment feedback mechanisms
- Under-explored additional data exists; feel free to contact us if you need some to constrain your work

Thanks

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References

AWS Data for Fig 9 and 10 from the Programme for Monitoring of the Greenland Ice Sheet (PROMICE) were provided by the Geological Survey of Denmark and Greenland (GEUS) at http://www.promice.dk.

[1]Bader H (1954) Sorge's Law of Densification of Snow on High Polar Glaciers. J. Glaciol. 2(15), 319–323 (doi:10.3189/s0022143000025144)

[2]Fausto RS, Box JE, Vandecrux B, van As D, Steffen K, MacFerrin MJ, Machguth H, Colgan W, Koenig LS, McGrath D, Charalampidis C and Braithwaite RJ (2018) A Snow Density Dataset for Improving Surface Boundary Conditions in Greenland Ice Sheet Firn Modeling. Front. Earth Sci. 6(May), 1–10 (doi:10.3389/feart.2018.00051)

[3]Wegener K (1933) Wissenschaftliche Ergebnisse der Deutschen Grönland-Expedition Alfred Wegener 1929 und 1930/31.

[4]Yamanouchi T (2011) Early 20th century warming in the Arctic: A review. Polar Sci. 5(1), 53–71 (doi:10.1016/j.polar.2010.10.002)

[5]van den Broeke M, Bus C, Ettema J and Smeets P (2010) Temperature thresholds for degree-day modelling of Greenland ice sheet melt rates. Geophys. Res. Lett. 37(18) (doi:10.1029/2010GL044123)