Article

Supplementary Information - Darkening of the glacier surface at 79°N Glacier, Greenland, indicates high in-situ deposition of impurities

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1. Profile Lake CE

We are presenting here the reflectance of a profile crossing a lake in an area further upstream, to demonstrate that lag deposits are not the cause for the darkening at Lake iCUPE and the downstream area. We named it Lake CE and its position is shown in Fig. 1. In this area, the multi-year mean SMB is about 0.6m/a water equivalent. The ice moves with a speed of 360m/a. It takes the ice about 5.5yrs to move the downstream end of the lake at 6.2 km to the end of the profile at about 10.2 km. In this time a vertical column of about 0.6 m/a water equivalent × 5.5a = 3.3 m. This compares to the 2 years of 1.8 m/a water equivalent at Lake iCUPE leading to 3.6 m. Assuming a constant concentration of dust with depth, it should in both cases produce a roughly similar amount of lag deposit. The profile at Lake CE, however, does not show any significant decrease in reflectance with distance, whereas Lake iCUPE shows a decline in reflectance of about 0.2. This rule lag deposit as a origin of darkening in the lower elevated areas out. By no means we intend to say lag deposit does not take place, it is just not the origin of the darkening at the lower elevated area.

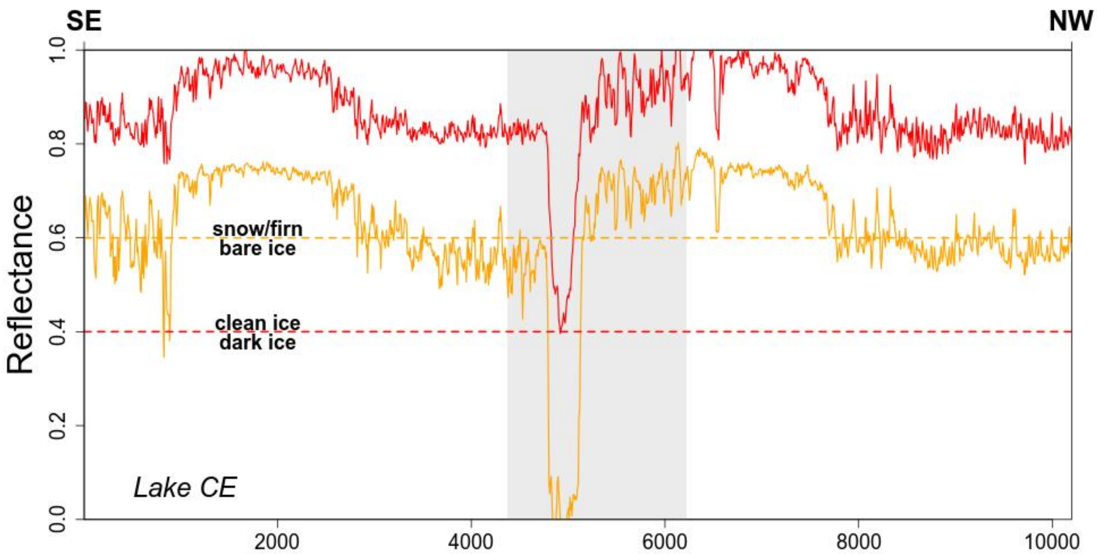

Figure S1. Transect across Lake CE (see Fig. 1) showing the reflectance along over distance. The gray area is the current lake extent. The ice is flowing from left to right in this figure.

2. Density and age

Simulated density at the surface using the approach of [1] has been adapted to a variety of flowlines in the region of 79NG. We present in Fig. S3 the resulting distribution of density at the surface and in Fig. S2 the simulated age of the surface layer. The results for the age are in general in agreement in that respect that ice with an age larger than 2000 yrs appears in an area north of 79NG, that is also confirmed by [2] to consist of ice of that age. As our simulations are based on present day climate and present day flow velocities, there is a mismatch in observed and simulated age, that can only be overcome with a real paleo forcing of accumulation rate and temperature and in particular simulated paleo flow velocity, as the results are highly sensitive to the flow speed as it governs the time spent in the ablation zone.

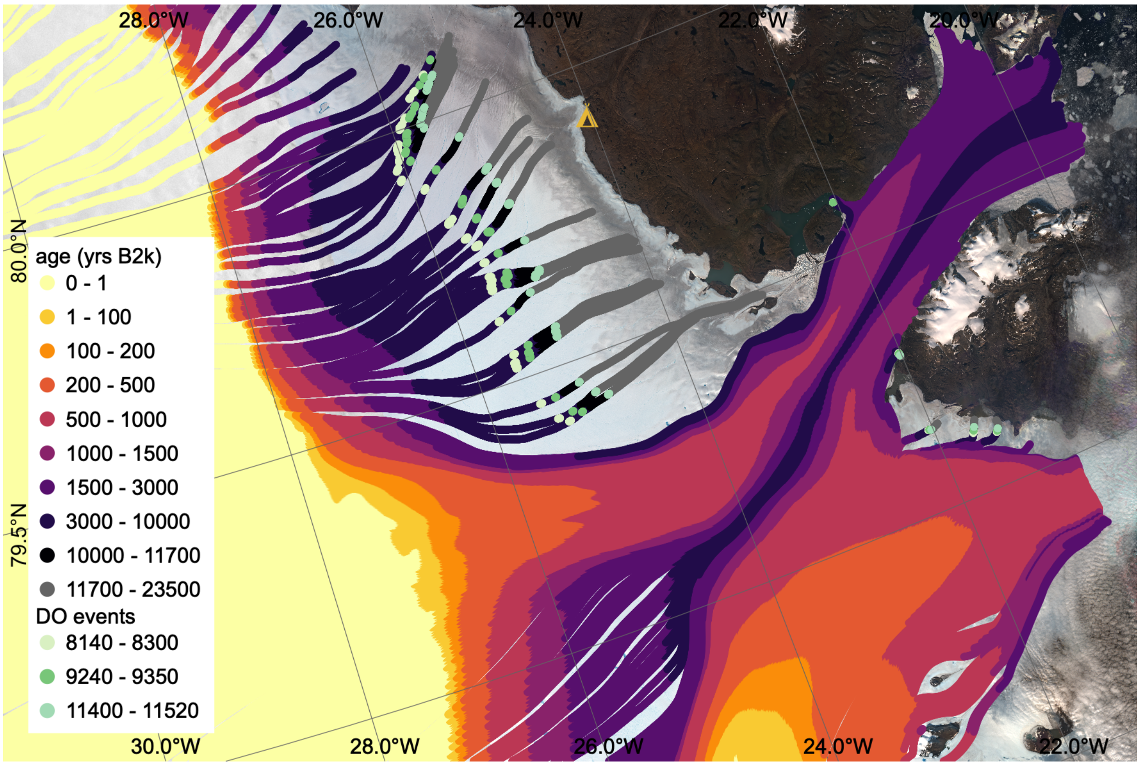

Figure S2. Simulated age of the upper layer.

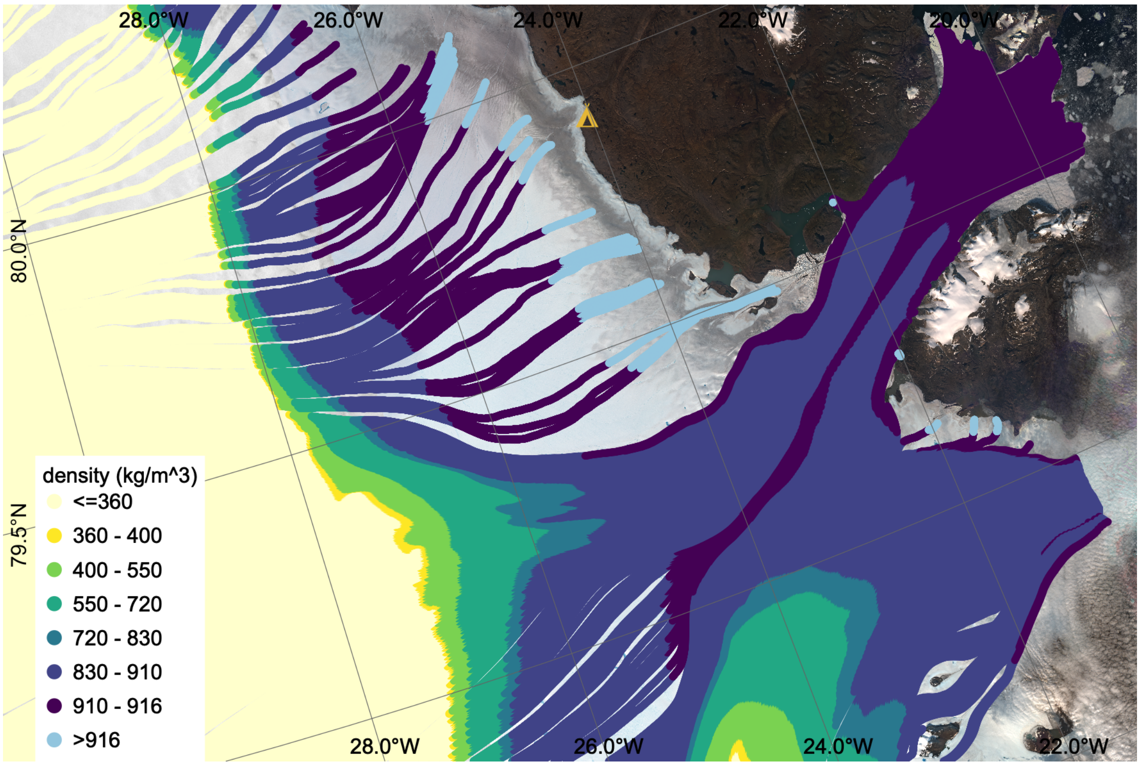

Figure S3. Simulated density of the upper layer assuming ablation leading to loss of surface material without melt water percolation and refreezing.

2.1. *Stratigraphy in the upper layers from UWB*

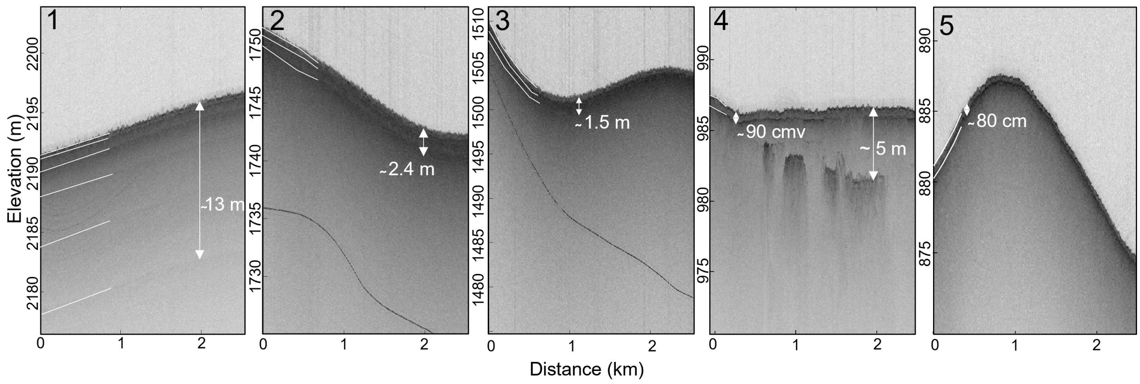

Figure S4. Stratigraphy of the upper layers as seen by the UWB-M radar in 2018. In the accumulation zone the stratigraphy can be resolved down to 13 m, with a decline to 1.5 m at the onset of the ablation zone (Panel 1-3). Panel (4) displays the cross section over a supraglacial lake with a frozen surface and a snow layer on the lake ice. Panel (5) displays the layer of the last summer prior to the impurity covered area. Further downstream no reflections of the last summer were found at all.

2.2. Surface temperature along profiles

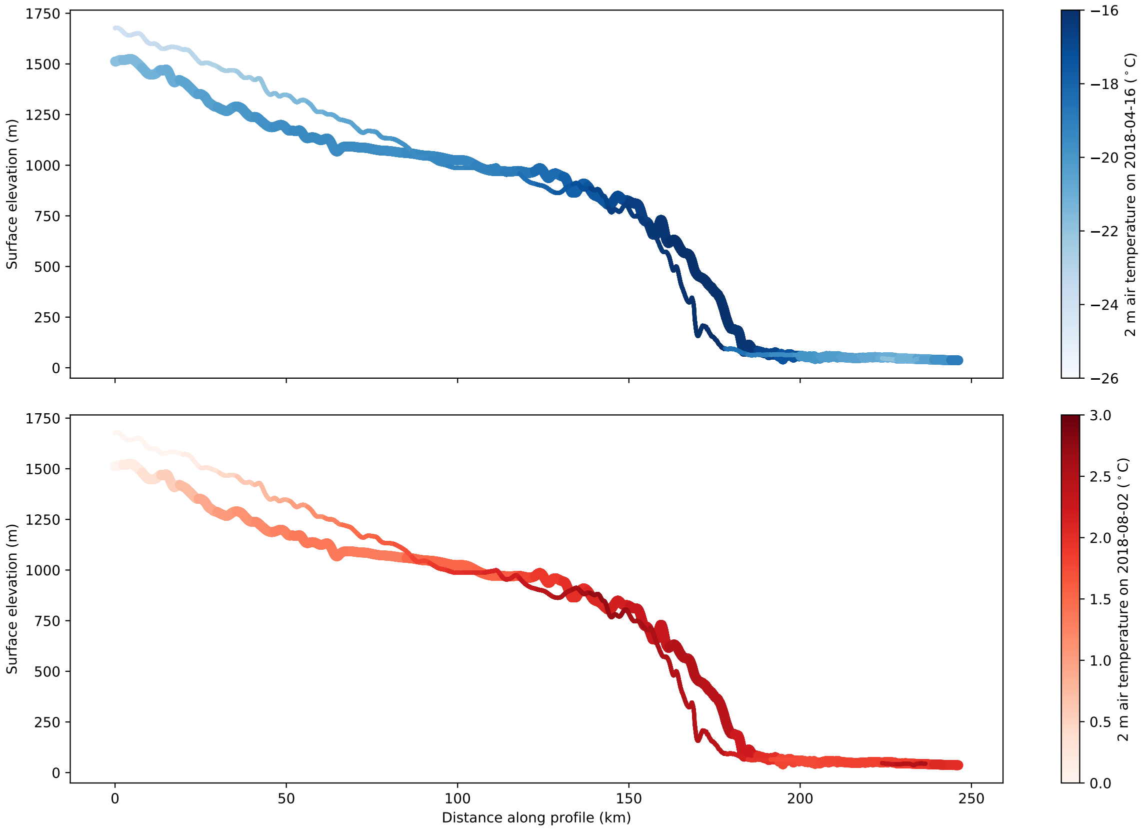

Figure S5. ERA5 2 m air temperature [3] along the profiles southern branch (thick lines) and northern branch (thin lines) as shown in Fig. 1. The upper panel displays the temperature on 2018-04-16 and the lower panel on 2018-08-02, representing the time periods in Figs. 4-6.

1. Schultz, T.; Müller, R.; Gross, D.; Humbert, A. Modelling the Transformation from Snow to Ice Based on the Underlying Sintering Process. *Proceeding in Applied Mathematics and Mechanics* **2020**, *20*. submitted.
2. Bøggild, C.E.; Brandt, R.E.; Brown, K.J.; Warren, S.G. The ablation zone in northeast Greenland: ice types, albedos and impurities. *Journal of Glaciology* **2010**, *56*, 101–113. doi:10.3189/002214310791190776.
3. Hersbach, H.; Dee, D. ERA5 reanalysis is in production, ECMWF Newsletter, 147, 7, 2016.