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The (Micro-) Climate and Mass Balance of Qaamarujup Sermia, West Greenland 1929-2022

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1 Introduction

The interaction between the atmosphere and the cryosphere is central for predicting the impacts of the rapidly changing climate, particularly in the Arctic (Rantanen et al., 2022). With surface melt becoming the primary process driving mass loss in the Greenland Ice Sheet (GrIS) (Mattingly et al., 2020), understanding how the atmosphere affects melting is of utmost importance. Therefore, it is crucial to comprehend the feedback mechanisms between ice and climate, and to quantify them thoroughly at a local scale.

This study focuses on the Qaamarujup Sermia (QS) outlet glacier (West Greenland), the location of Alfred Wegener's expedition between 1929 and 1931. During this time, a high-resolution dataset was recorded, including sub-daily atmospheric observations as well as monthly to (bi-)weekly surface mass balance (SMB) measurements (Abermann et al. 2023). These years are within the period of the Early 20th Century Warming Period (ETCWP) with a temperature increase similar as the warming period since the 1990s (Chylek et al. 2006, Hanna et al. 2012). This similarity and unique historic dataset motivated the installation of a modernized monitoring network with sensors at the same locations as the historic measurements to eventually quantify climate/glacier feedbacks on a centennial scale. This similar, yet expanded and adapted instrumentation setup was installed in summer 2022. With the digitalized historic dataset, the first steps concentrated to identifying spatial patters of atmospheric conditions and ablation at QS.

2 Data

Historic observations:

- SMB stakes at 50, 270, 570 and 950 m a.s.l. and every 20 km along a transect to their station Eismitte (EM) (central ice sheet 3010 m a.s.l.) called RAxx for 'Randabstand' ('distance from the ice margin'), AWS at WEG_B, WEG_L and UMQ

Modern Monitoring Network:

- two automatic weather stations (AWS) at the bottom of the Qaamarujup fjord (WEG_B) and at 940 m a.s.l. on the Greenland ice sheet (WEG_L), additionally AWS in Uummannaq UMQ (operated by Mittarfeqarf iit) and Qaarsut QAR (operated by the Danish Meteorological Institute); three temperature and humidity sensors in (AT/RH) 50, 270 and 950 m a.s.l.; four autonomous ablations sensors (AblWeg) and six ablation stakes (SWeg) to quantify SMB

Unmanned Aerial Vehicles (UAV):

- summer 2022, 39 vertical flights with AT and humidity sensor, at the coast, through the valley over the lower glacier (marked UAV with A-F in Figure 1 iv) to investigate temperature and humidity profiles of the lowest 400 m of the atmosphere.

3 Objective

Identifying spatial patterns of atmospheric conditions and ablation.

First results to this objective are shown on this poster considering:

a. Spatial air temperature anomaly of UAV ascents during the field campaign 2022
b. Dominating wind direction at WEG_B in 2022 to investigate the influence of sea and glacier
c. Observed air temperature at WEG_B in 1930, 1931 and 2022
d. The historic SMB measurements in context of regional climate model output

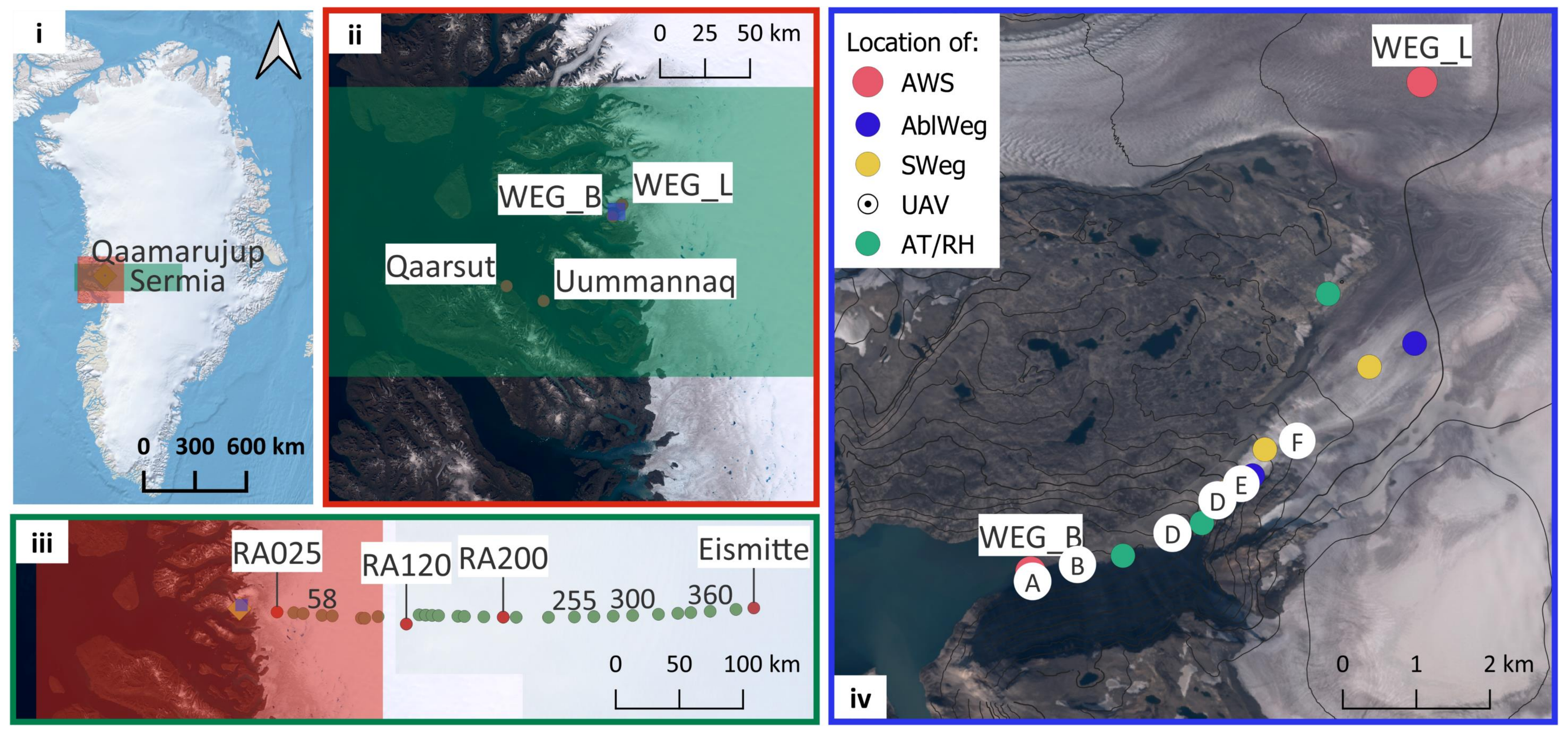


Figure 1: QS at the Westcoast of Greenland (i), settlements Qaarsut and Uummannaq, the locations of Automatic Weather Stations (AWS) at QS (ii). (iii) shows the historic transect from QS to EM. (iv) is a detailed map of QS with monitoring network installed 2022: AWS, SMB sensors (AblWeg) and stakes (Sweg), locations of the vertical profiles observed with UAVs (A-F), air temperature and relative humidity sensors (AT/RH).

4 Results

a. Spatial air temperature anomaly of UAV ascents during the field campaign 2022

- Evaluation of UAV profiles by averaging observed temperature onto 12m vertical grid; glacier surface is set to 0°C; then linearly interpolation between locations (method according to Hansche et al. 2022)
- temperature anomaly compared to the average temperature at WEG_B during the flight
- **elevated inversion layer above valley/riverbed and ground layer is warmer**
- **surface based inversion layer above the glacier**
- WEG_B measured west wind that day, based on observation it was clear sky, later fog in the valley

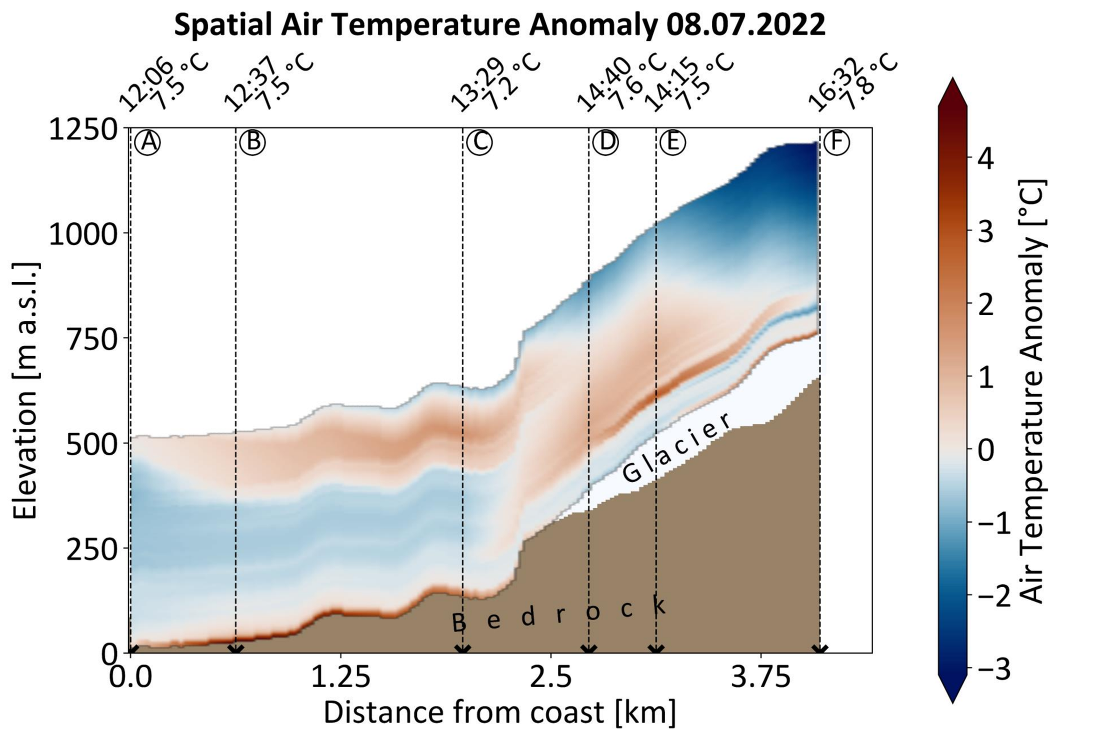


Figure 2: Air temperature anomaly based on vertical UAV ascents along the valley axes. Starting at the coast (A) through the riverbed (B/C) and over the glacier (D/E/F). The topography is extracted from ArticDEM Mosaics (Porter et al. 2018). The colour refers to anomalies relative to the average measured AT at WEG_B during the ascent (this AT is noted above the location of an ascent together with the time of the profile).

b. Dominating wind direction at WEG_B in 2022 to investigate the influence of sea and glacier

- Wind direction at WEG_B; the colours of the symbol indicate whether it is warmer/colder at WEG_B compared to QAR.
- **Direction change from westerly to easterly wind in wintertime at WEG_B**
- WEG_B warmer than QAR
  - Even when influenced by air masses from the ice sheet/glacier
  - Probably large-scale influence when it is colder at WEG_B rather than glacier

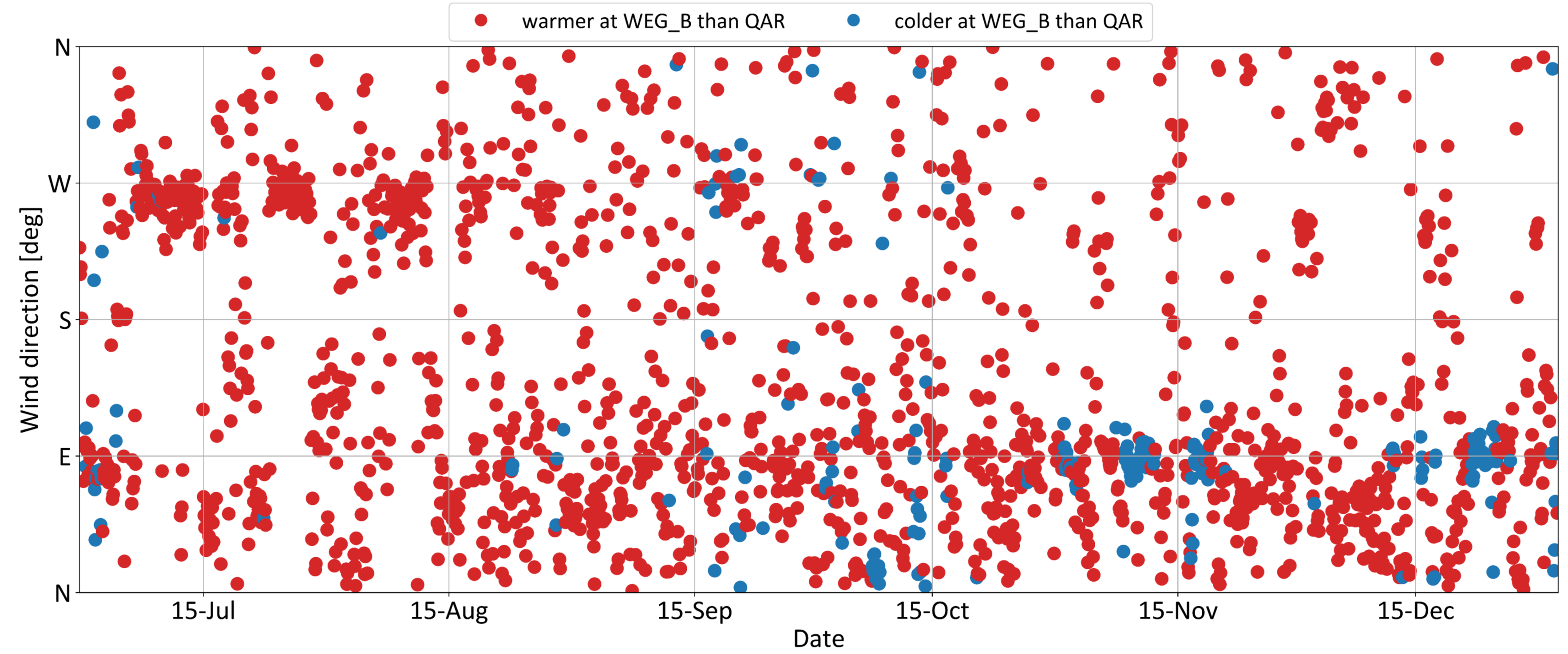
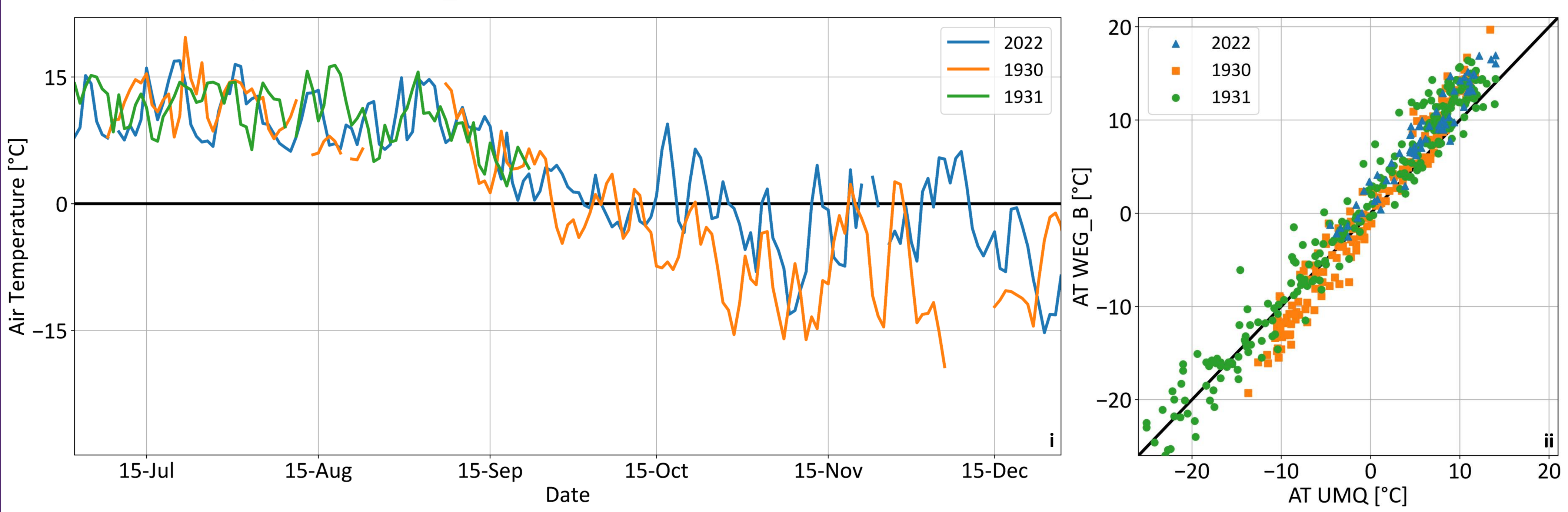


Figure 3: Wind direction observed 2022 at WEG_B. The colour of the symbols indicate whether it is warmer/colder at WEG_B compared to QAR.

c. Observed air temperature at WEG_B in 1930, 1931 and 2022



- time series of daily average AT at WEG_B in 2022, 1930, 1931 with warming periods observed in winter, warmer in 2022
- Correlation between daily average AT at WEG_B and UMQ
  - In general WEG_B warmer than UMQ for AT > 0°C
  - In 1930 WEG_B colder than UMQ in 1930 for AT < -8°C
- **WEG_B more continental climate than climate at UMQ**

*Figure 4: Observed daily average AT at WEG_B in 1930, 1931 and 2022 as time series (i). The correlation to the observed daily AT at UMQ shown in (ii). Averaged accordingly to historic method (2*AT(8am)+2*AT(2pm)+5*AT(9pm))/9*

d. The historic SMB measurements in context of regional climate model output

- Regional climate model used: Modèle Atmosphérique Régional (MAR) (Fettweis et al. 2017)
- monthly accumulated SMB starting each year at the 15th of September
- observed height difference transformed to m w.e. with the measured density at RA locations and 900 kg/m³ as an estimated ice density at the 950 m a.s.l. (ST950)
- 1929/30 less mass gain than 1930/31
- **observations are reasonable well represented by MAR; but stake locations on the outlet glacier below 950 m a.s.l. are not resolved in MAR**

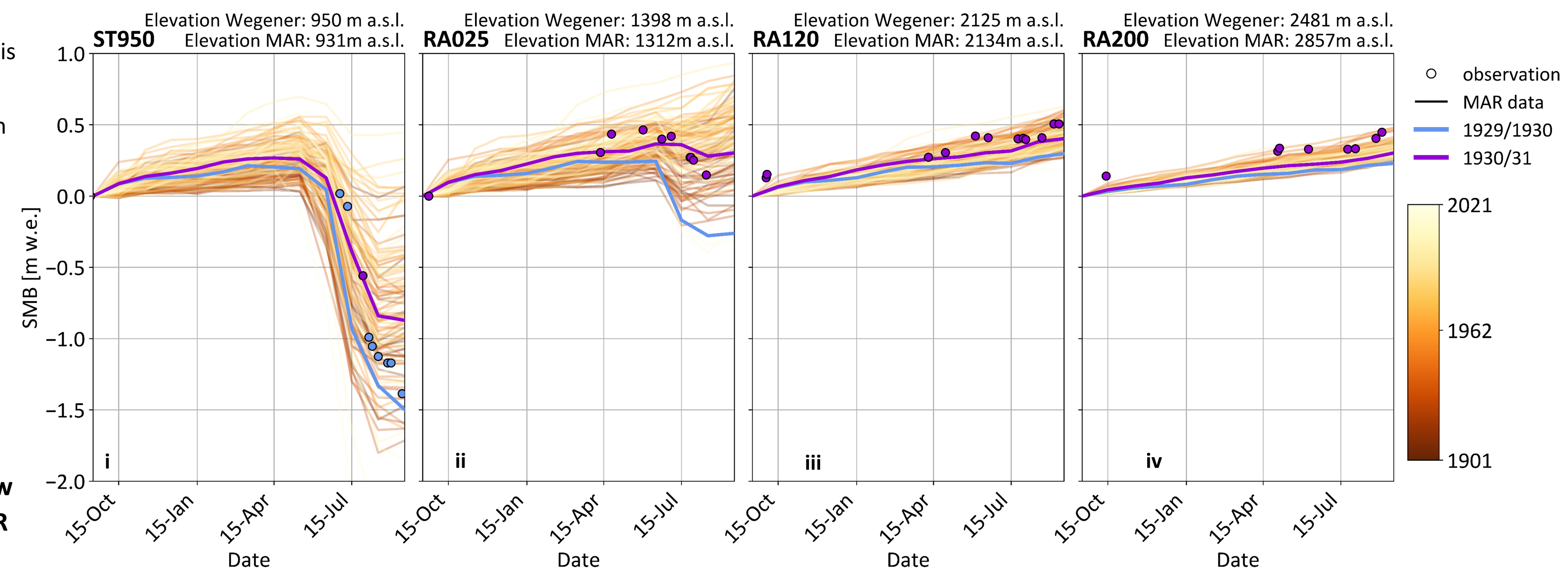


Figure 5: Monthly accumulated SMB observation at four historic observation sites. (i) 950 m a.s.l. (ii),(iii) and (iv) at 25, 120 and 200km distance from the ice margin Observations indicated with dots, regional climate model output shown as lines.

5 Summary

- UAV ascents show inversion layers during the field campaign in summer 2022 → impact on the vertical AT gradient and through that the ice/snow melt calculations (Chutko and Lamoureux 2009)
- Seasonally shifting dominating wind direction → origin of advected air masses changes
- AT differences between WEG_B, QAR/UMQ variable → relation to large scale patterns to be explored
- Historic recorded SMB can validate modelled SMB → but indicates error source for complex topography which is not resolved in models

→ Atmospheric patterns (inversions/wind direction) relevant for SMB can be identified in modern and historic dataset; SMB observations are essential on local scale to resolve small outlet glaciers

6 Outlook

The modern dataset is growing continuously, and more data is retrieved from the field in April 2023. This includes SMB from 2022/2023. Additional historic data sources were found and will be digitalized. Those other historic compilations are from the archive of DMI, the British Arctic Air Route Expedition and the Greenland expeditions from University Michigan and include meteorological observations from the same years (1930/31) at locations with modern monitoring networks from DMI and the Programme for Monitoring the Greenland Ice Sheet (PROMICE). With this extended dataset the change of characteristic atmospheric and SMB patterns can be evaluated on a larger scale.

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