Supplementary material

Rapid mass loss and climate-driven dynamics of the Juvfonne ice patch, Norway (2010–2025)

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Table S1. Area of Juvfonne in the period 1997-2023. See Figure 2. *Note that areal extent from 2012 and 2020 are partly based from the extents from 2013 and 2019, respectively. The area for 2018 was not estimated as only a small part of the terminus measured.

Year	Date	Area (km^2)	Source	Comment	Uncertainty (km^2)
2010	2010-08-25	0.149	GNSS		0.004
2011	2011-08-02	0.150	GNSS		0.005
2011	2011-09-17	0.1265	Orthophoto		0.004
2012	2012-09-12	0.160	GNSS*	Snow	0.005
2013	2013-08-12	0.151	GNSS		0.005
2014	2014-09-09	0.101	GNSS		0.003
2015	2015-09-11	0.186	GNSS	Snow	0.006
2016	2016-09-13	0.162	GNSS		0.005
2017	2017-08-01	0.183	GNSS	Snow	0.005
2018	2018-07-30		Only terminus*		
2019	2019-08-26	0.086	Orthophoto		0.003
2020	2020-09-19	0.093	GNSS*	Snow	0.003
2021	2021-08-31	0.100	Orthophoto		0.003
2022	2022-08-23	0.107	Orthophoto	Snow	0.003
2023	2023-08-31	0.090	Orthophoto		0.003
2024	2024-09-02	0.081	Orthophoto		0.002
2025	2025-09-02	0.090	Orthophoto	Lack small part	0.003

Table S2: Overview of surveys of Juvfonne referred to in this study. a-airborne, L-lidar, VP-Vertical aerial photographs, UAV-Uncrewed Aircraft Systems.

Year	Date	Type	Resolution	Surveyed by/Reference
2011	2011-09-11	aL+aVP	5p m^{-2}	COWI 2011
2016	2016-09-09	UAV	<0.10 m	NVE (Andreassen and De Marco, 2018)
2019	2019-08-26	aL+aVP	2p m^{-2}	TerraTec 2019
2020	2020-08-26	aL	5p m^{-2}	TerraTec 2020a
2020	2020-08-18	aL	2p m^{-2}	TerraTec 2020b
2023	2023-08-31	UAV	<0.10 m	NVE, this study
2025	2025-09-02	UAV	<0.10 m	UiO, this study

Table S3: Overview of the automatic weather stations (AWS) and measured parameters used in this study.

Station	Station no	Elev. (m a.s.l.)	Lat (N)	Long (E)	Start	Data used
Juvvasshøe	SN15270	1894	61.6775	8.369	1999-09-16	Air temperature, Relative humidity, Wind speed & direction, Air pressure, Short wave radiation
Juvvasshøe - Snow	SN15270	1838	61.6759	8.35584	2011-10-13	Snow depth
Juvflye	SN15262	1844	61.674	8.3685	2015-06-12	Air temperature & Wind speed
Fokstugu	SN16610	973	62.1133	9.2862	1968-06-01	Air temperature
Dombås - Nordigard	SN16560	638	62.0717	9.1147	1864-08-01	Air temperature
Bøverdal	SN15430	700	61.7195	8.2423	1902-01-01	Precipitation

Figure S1: The ice tunnel at Juvfonne has been covered in fabric since June 2016. (a) Photo 6 August 2016, Mai Bakken. (b) Photo 17 September 2024, Liss M. Andreassen.

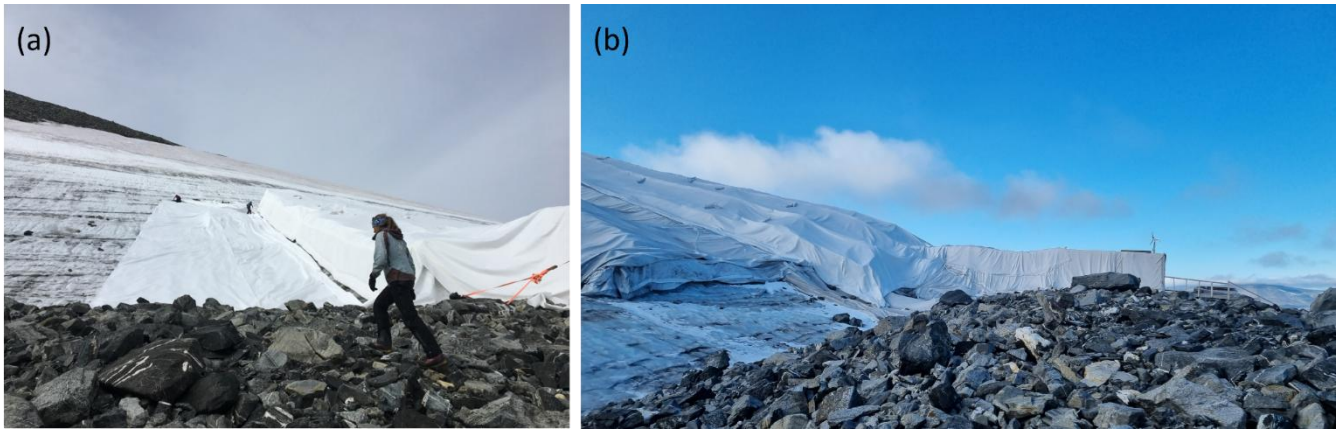
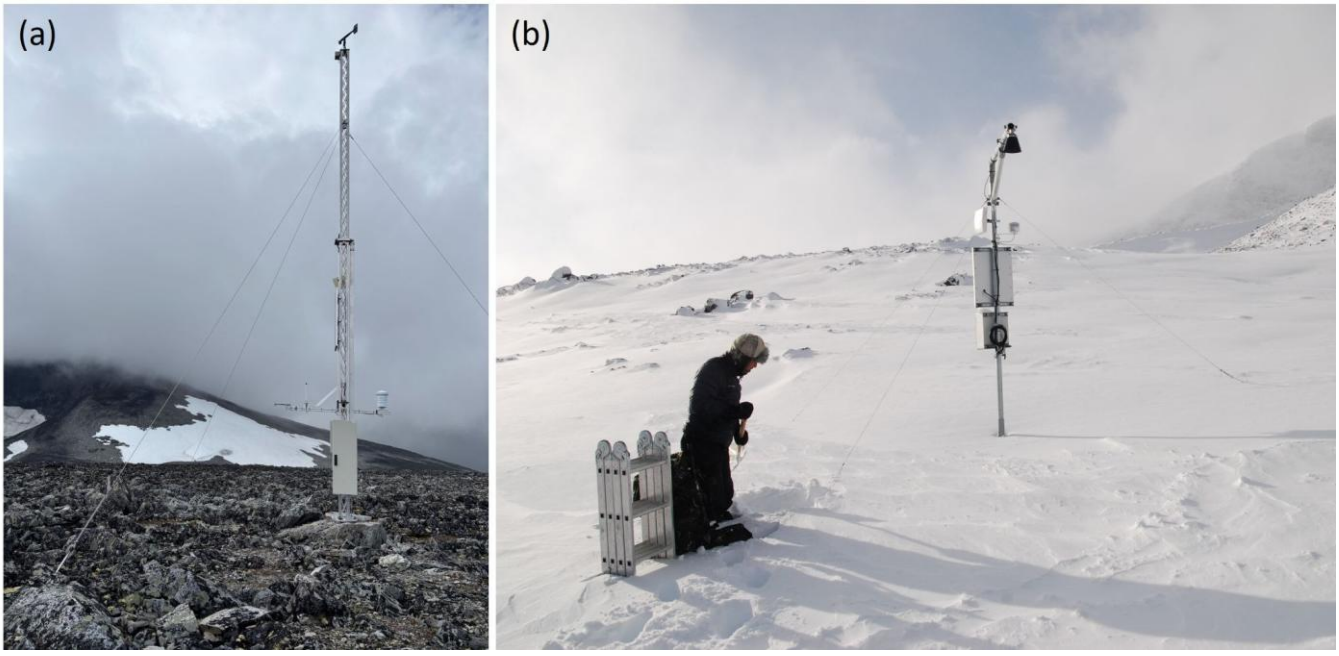


Figure S2: Pictures showing (a) the automatic weather station (AWS) and permafrost monitoring station on Juvvasshøe with Juvfonne in the background on 13 August 2025, and (b) the automatic snow depth station in front of Juvfonne on 18 October 2012. Photos: Solveig H. Winsvold and Ketil Isaksen. See also Figure 1 for location and Table S3.



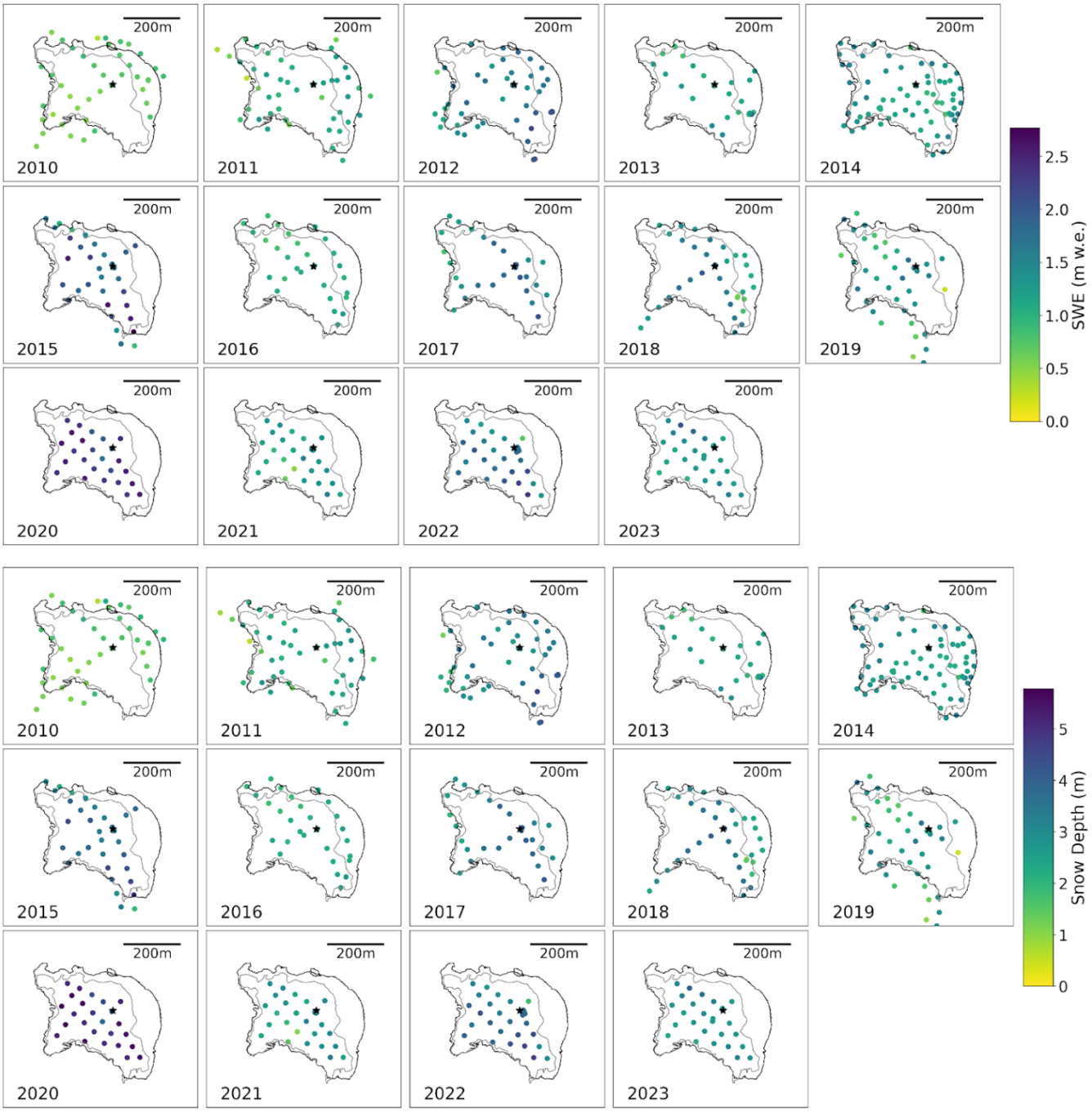


Figure S3: Snow distribution pattern for Juvfonne 2010-2023. The upper figure shows values in Snow Water Equvivalent (SWE), the lower figure shows values in snow depth. The 2011 (black) and 2019 (grey) outlines are shown. The star denotes stake 2 where density measurements are done.

Figure S4: Photos of Vesljuvbreen and surrounding around noon on 5 - 8 July 2020 from the Galhøpiggen summer ski centre webcam.

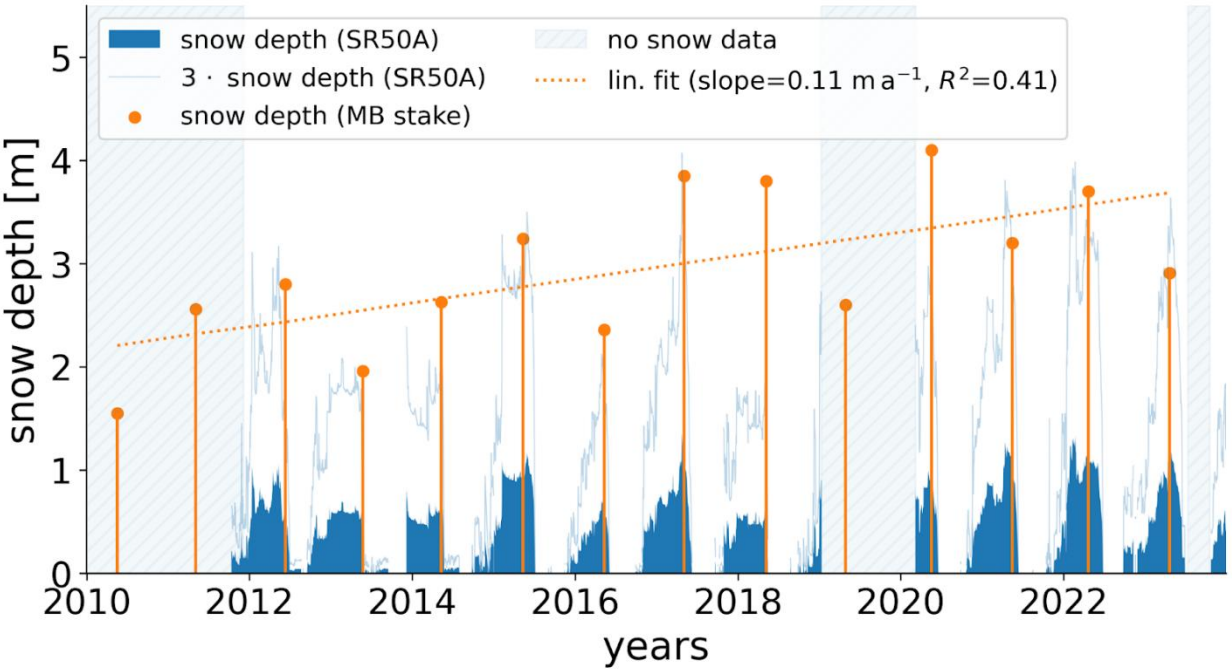


Figure S5: Comparison of snow depth from accumulation measurements at the mass balance stake on Juvfonne and continuous snow depth measurements at the nearby snow depth station.

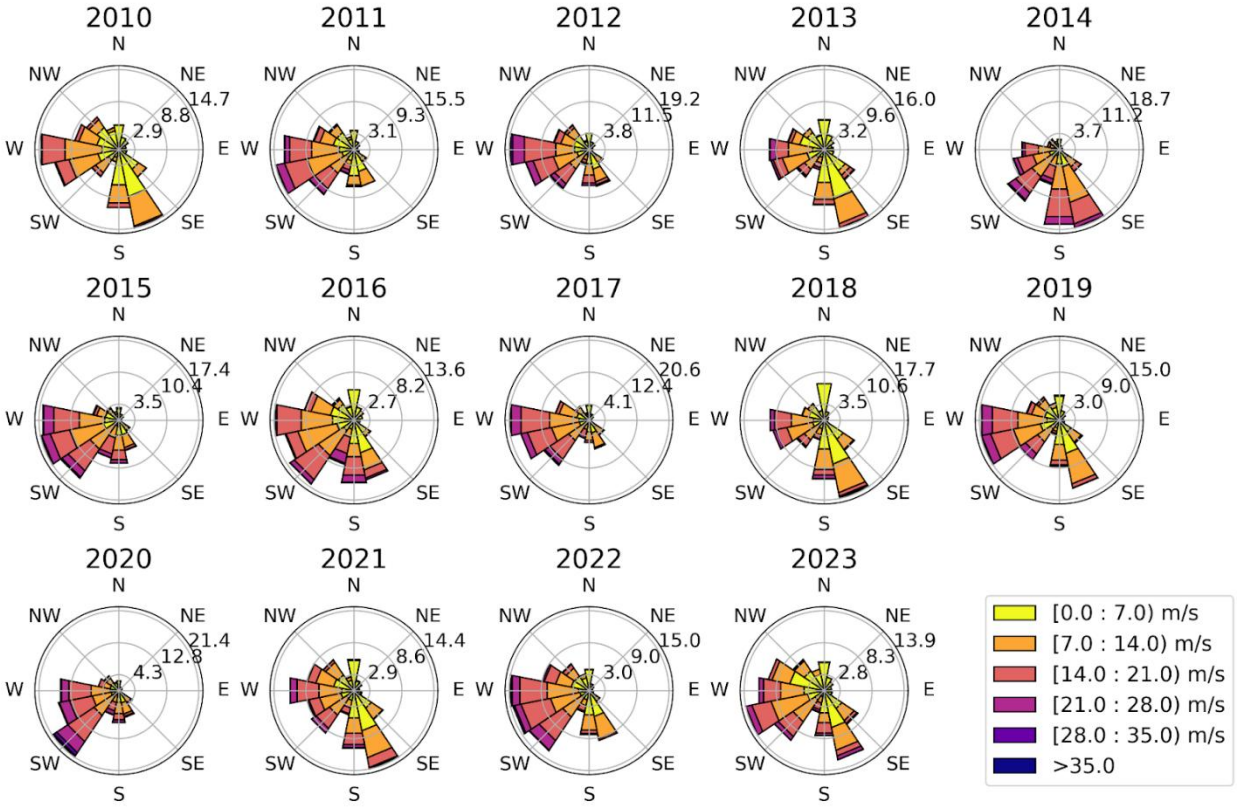


Figure S6: Windroses of each winter season (December-April) show the occurrence of wind directions and speed at Juvvasshøe in %.

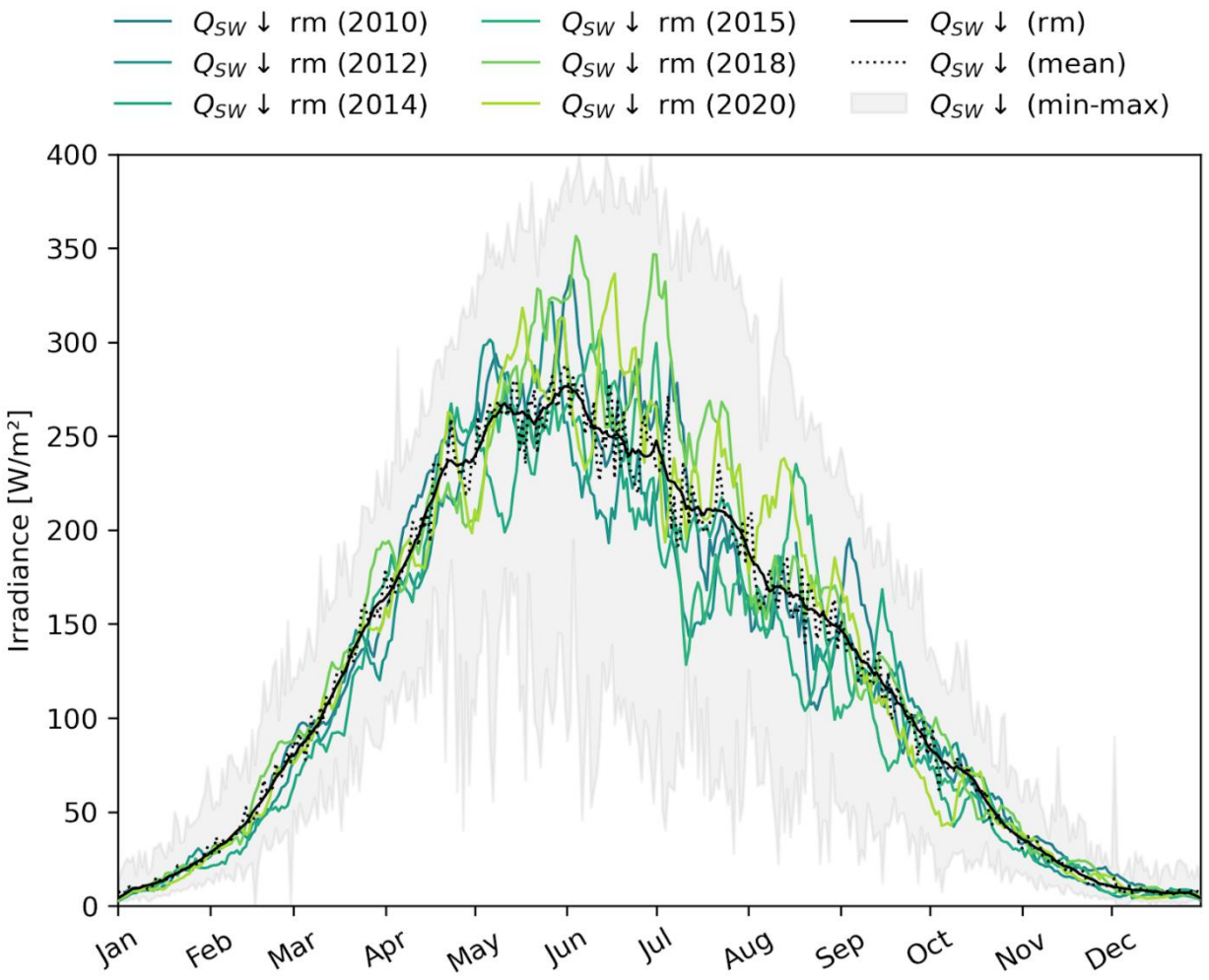


Figure S7: Incoming shortwave radiation is shown as 10 days running mean (rm) for years with high or low summer mass balances. The black line and grey shading show the mean of 2000 to 2022 and minimum and maximum values, respectively.

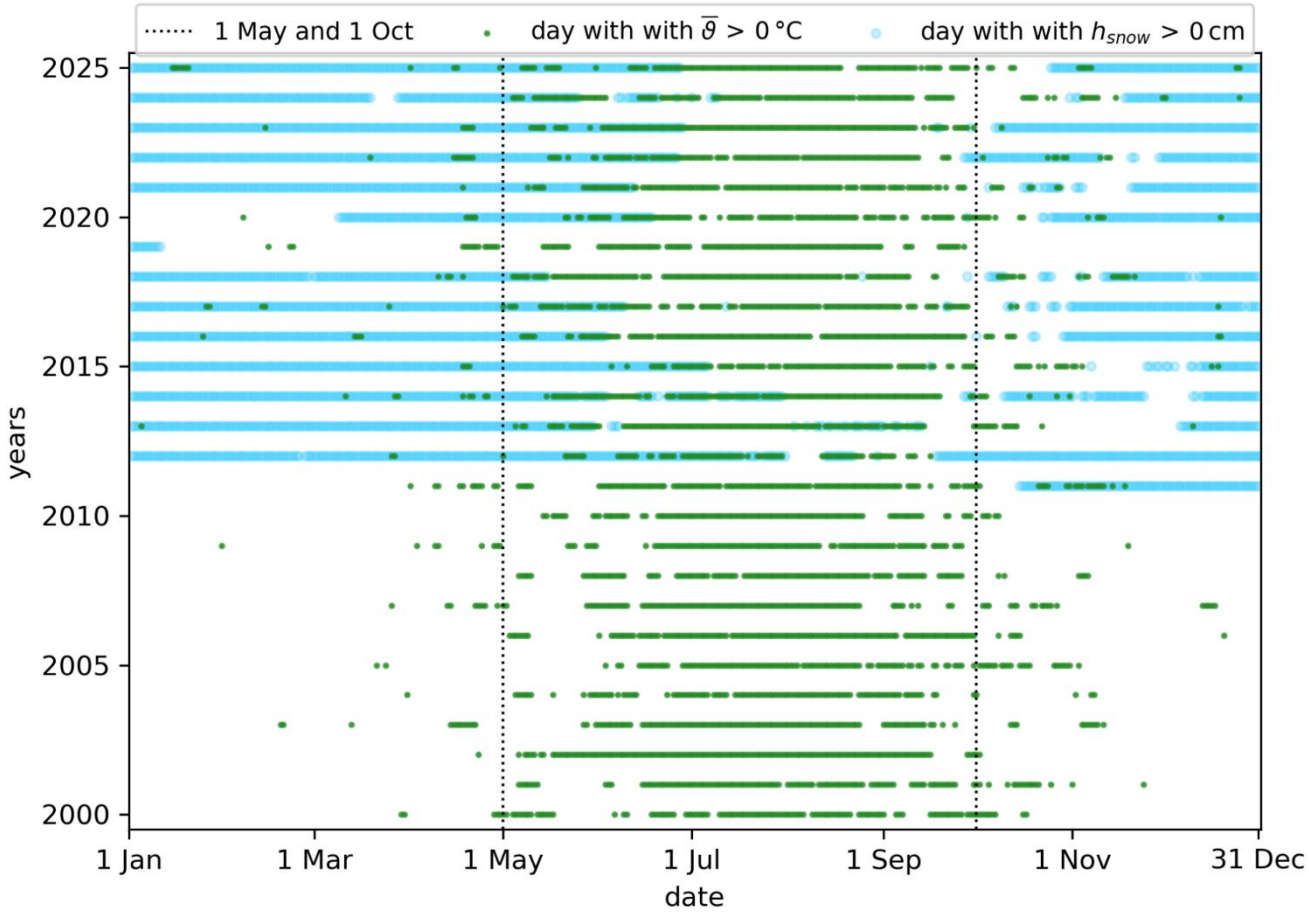
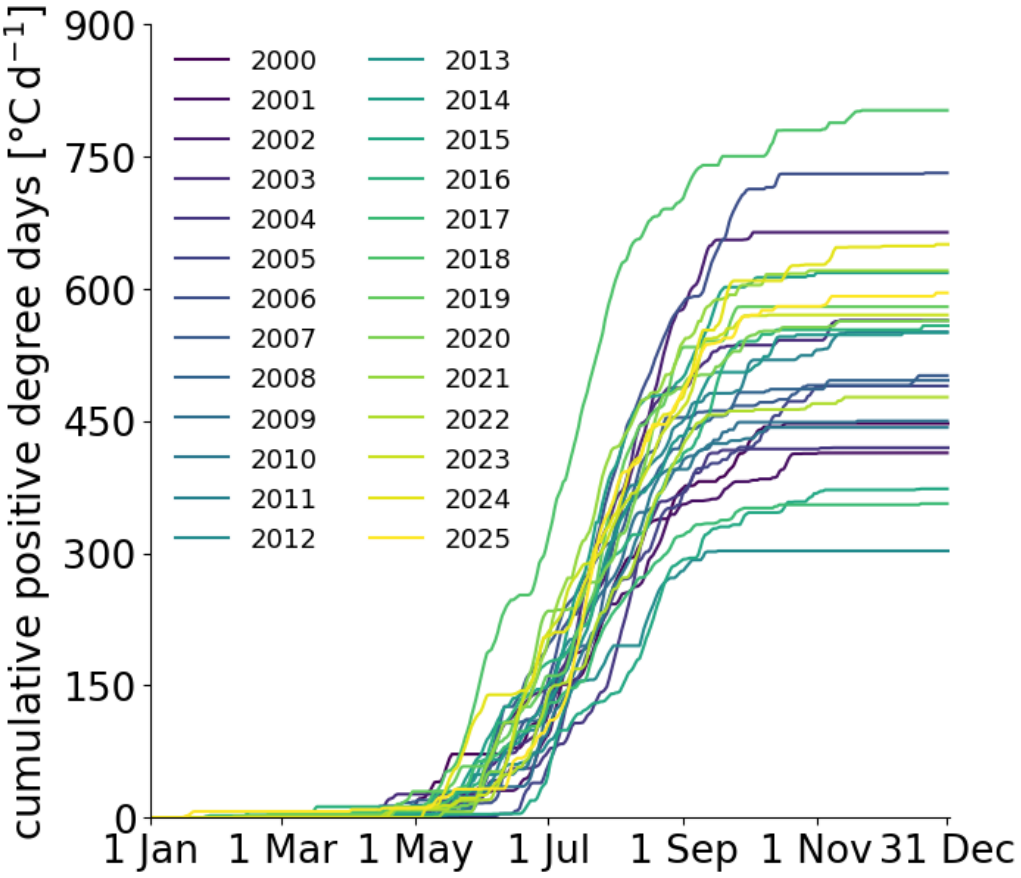


Figure S8: Characterisation of the melt season and outlying melt events based on days with a mean temperature above the freezing point (green) and days with a snow depth greater than 0 (blue).



55 **Figure S9: Cumulative positive degree days of the years 2000 to 2025.**

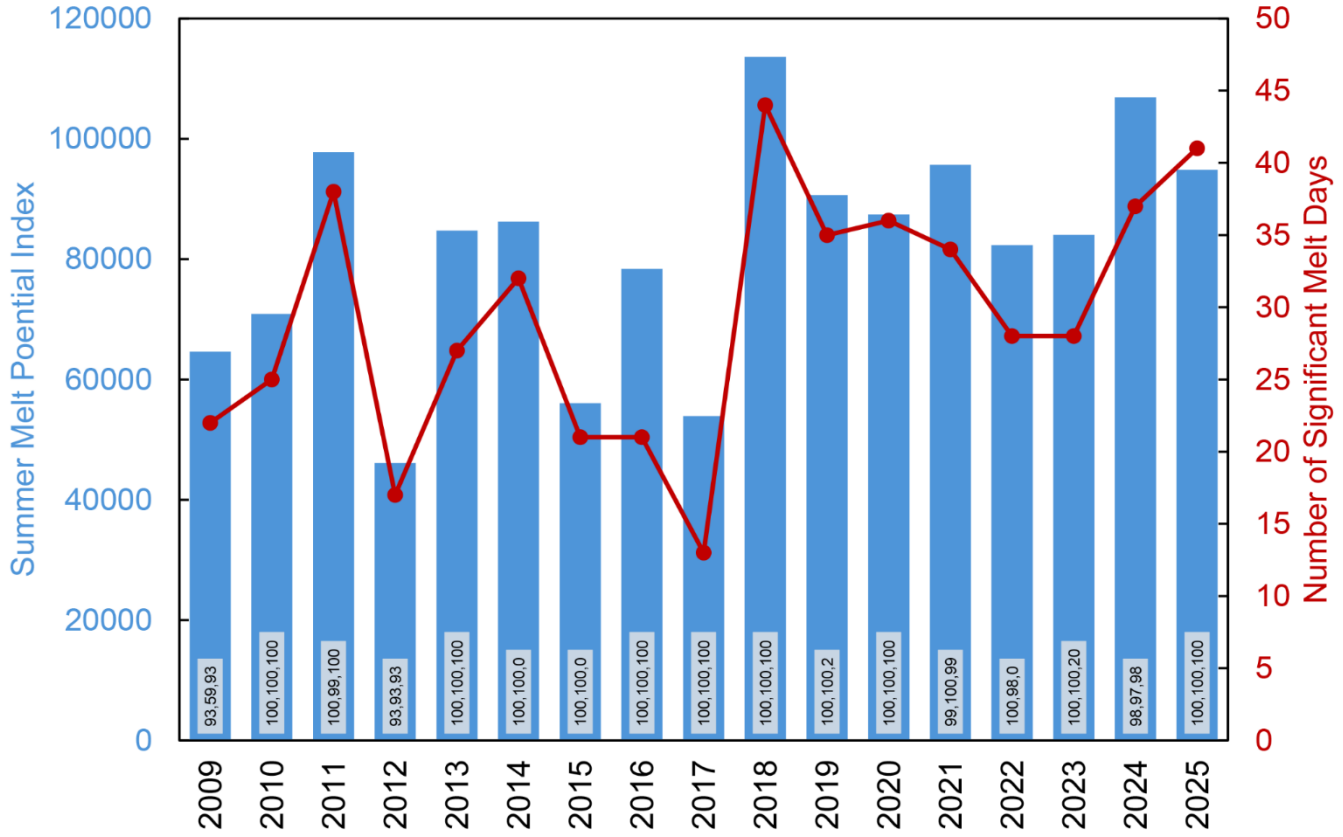
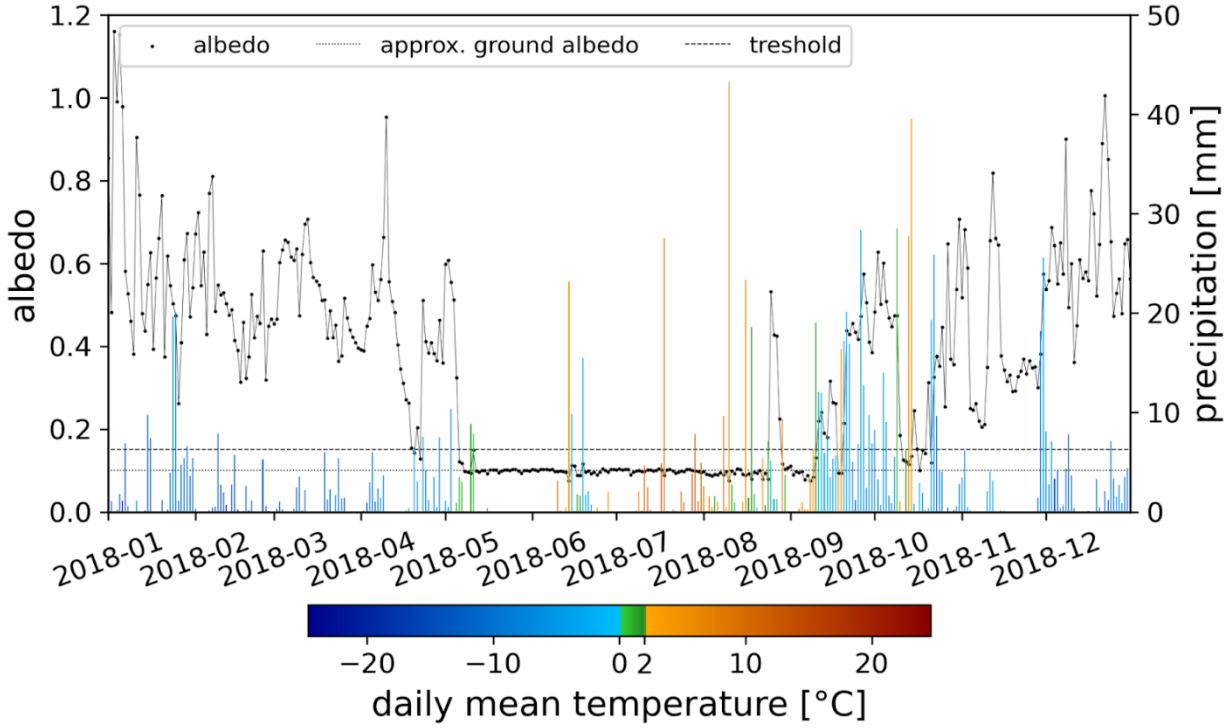


Figure S10: Estimated summer melt potential (May–September) at the Juvvasshøe weather station (1894 m a.s.l.) for the period 2009-2025. The blue bars represent the cumulative Summer Melt Potential Index, calculated as a function of hourly sensible and latent heat exchanges. These fluxes are derived from observations of air temperature, relative humidity, and wind speed using a simplified bulk aerodynamic approach (e.g., Hock, 2005; Ohmura, 2001). The red line indicates the annual count of significant melt days, defined as days exceeding the 75th percentile of the daily melt index distribution over the study period. The values at the base of each bar indicate the hourly data coverage (in %) for air temperature (T), wind speed (W), and relative humidity (RH), respectively. For periods with missing relative humidity data (e.g., 2014, 2015, 2019, 2022, and parts of 2023), a constant RH of 75% was assumed to compute the latent heat component.


albedo
approx. ground albedo
treshold
albedo
precipitation [mm]
2018-01
2018-02
2018-03
2018-04
2018-05
2018-06
2018-07
2018-08
2018-09
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2018-12
−20
−10
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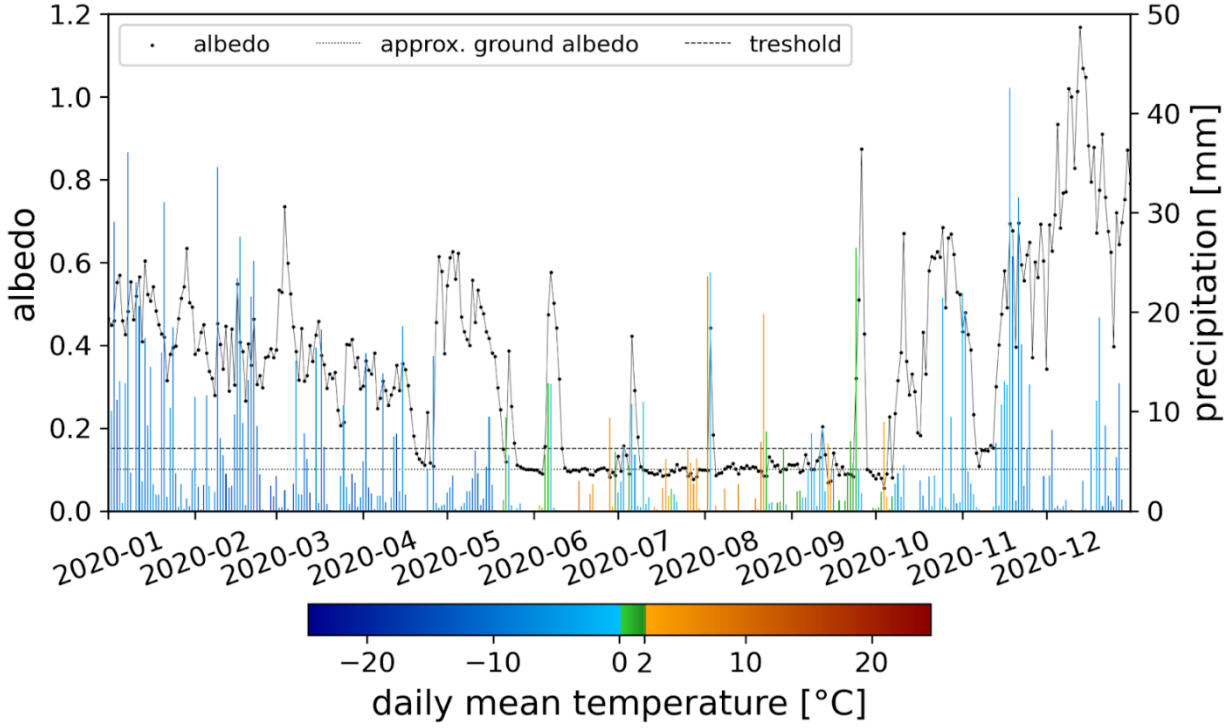
10
20
daily mean temperature [°C]


albedo
approx. ground albedo
treshold
albedo
precipitation [mm]
2020-01
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2020-05
2020-06
2020-07
2020-08
2020-09
2020-10
2020-11
2020-12
−20
−10
0 2
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20
daily mean temperature [°C]

Figure S11: For 2018 and 2020 the daily average observed albedo at Juvvasshøe is shown as black dots and the daily precipitation is shown as bars, whose colour indicates the daily mean air temperature. The thin dotted line indicates the approximate albedo of the bare ground and the thicker dotted line is the threshold for bare or snow covered ground, which was found by comparing the albedo to webcam images of Vesle Juvbreen close to Juvfonne (Fig. S4).

Figure S12: Estimated LIA maximum extents of Juvfonne during its Little Ice Age extent. Dashed outline from Baumann et al. (2009) and available in GLIMS viewer. The blue and cerise coloured outlines are drawn from orthophoto taken 18 September 2024. Source: Norgeibilder.no.