

POLISH-NORWEGIAN  
RESEARCH  
PROGRAMME



# Atmosphere and climate change WP 6

- **T6.1. To study climate changes in the early instrumental period, NCU**
- **T6.2. To establish a homogenized West Spitsbergen (Hornsund and Isfjord Radio) air temperature time series 1934-present, met.no, NCU**
- T6.3. To study the north-south air temperature gradient on the Western Svalbard, met.no
- T6.4. Study the recent temperature anomalies on western Spitsbergen and its relation to circulation (e.g. strong mild southerlies, frequency of lows, periods of sustained along-shelf winds etc), sea ice, sea temperatures and ocean heat transport, met.no
- **T6.5. To recognize radiation and heat budget changes, NCU**
- **T6.6. To describe topoclimate data from different Hornsund regions based on historical sources and collected data, NCU**

# ISFORHOLDENE

ÅR 1876.

Fartøiets navn: *Nordhav*  
Kaptein: *Johansen*

ubrukt polaris  
nyis og sørpe  
isfjeld

# CHANGES OF AIR TEMPERATURE IN SVALBARD AND THE SURROUNDING SEAS FROM 1865 TO 1920

Farvand *Nordhav*  
Mørning = 14° 20'

Sex-Roise-fra *J. J. J. J. J. J.*

1876 Maaned.	Kl.	Paaserende Plads.		Barometer.		Temperatur.		Vind.		Sky- dække i 1000 Fath.	Regn, Sned, Isregn, Isfald.	na- ting and.	Anmerkinger.
		Bredde.	Længde.	Therm.	Højde.	L. u. F.	V. u. F.	Retning.	Styrke i 1000 Fath.				
~	4	~	~	9.0	28.15	1.8	0.0	~	1.0	7	1	0.0	Indf. færdigt 10.
~	8	~	~	8.0	28.15	1.8	0.0	~	1.2	10	10	0.0	Indf. færdigt fra 10. 10. 10.
~	~	~	~	~	~	~	~	~	~	~	~	~	~
~	MN.	~	~	10.3	28.11	0.6	0.1	~	~	~	~	~	Indf. færdigt 10.
~	4	~	~	~	~	~	~	~	~	~	~	~	~
~	8	~	~	~	~	~	~	~	~	~	~	~	~
~	MD	~	~	~	~	~	~	~	~	~	~	~	~
~	4	~	~	~	~	~	~	~	~	~	~	~	~
~	8	~	~	13.3	28.15	1.2	0.0	~	1.0	3-10	10	0.0	Indf. færdigt 10. 10. 10.
~	4	~	~	~	~	~	~	~	~	~	~	~	~
d. 16	MD.	71° 31' 05"	45° 10'	12.5	28.23	0.4	0.2	N	~	~	~	~	Indf. færdigt 10.
~	4	~	~	~	~	~	~	~	~	~	~	~	~
~	8	~	~	7.2	28.23	0.2	0.4	NW	~	~	~	~	~
d. 17	MD.	71° 46' 05"	47° 45'	7.3	28.25	0.6	0.5	NW	~	~	~	~	Indf. færdigt 10.
~	4	~	~	10.0	28.26	0.5	0.8	~	~	~	~	~	~
~	8	~	~	10.0	28.24	1.0	0.6	~	~	~	~	~	~
~	MN.	~	~	7.0	28.21	1.5	0.0	~	~	~	~	~	Indf. færdigt 10.
~	4	~	~	6.4	28.17	1.2	10.3	~	~	~	~	~	Indf. færdigt 10.

Rajmund Przybylak<sup>1</sup>, Przemysław Wyszynski<sup>1</sup>, Øyvind Nordli<sup>2</sup> & Tomasz Strzyżewski<sup>1</sup>

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<http://onlinelibrary.wiley.com/doi/10.1002/joc.4527/full#joc4527>



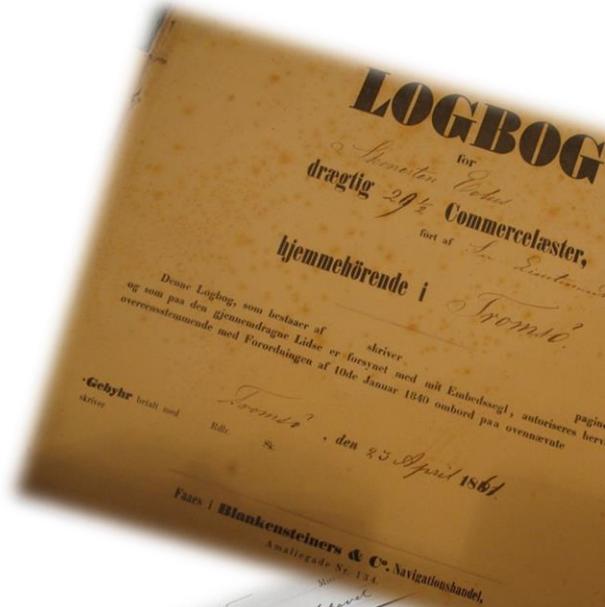
# Research area

**Svalbard and its vicinity: Norwegian, Greenland, Barents and Arctic Seas**



# AWAKE & AWAKE-2 data recovery projects

- Plenty of logbooks collected in NCU from the archives in Oslo, Tromsø and Stockholm
- Period 1855-1931
- Over 120 ships (e.g. yachts, schooners etc.), over 220 logbooks
- Meteorological data: atmospheric pressure, wind direction and force, air temperature, SST, weather phenomena and state of the sea
- Many descriptive records, e.g. ice conditions

The image shows a page from a logbook with a table of data. The table has columns for 'Paa Bøje fra', 'Dag', 'Kl.', 'Dagets Tid', 'Løbetid', 'Barometer', 'Temperatur', 'Vind', 'Vindretning', 'Vindstyrke', 'Vindhastighed', 'Vindretning', 'Vindstyrke', 'Vindhastighed', 'Vindretning', 'Vindstyrke', 'Vindhastighed'. The data is handwritten and includes various numerical values and text entries. The table is organized into sections for different days and times.

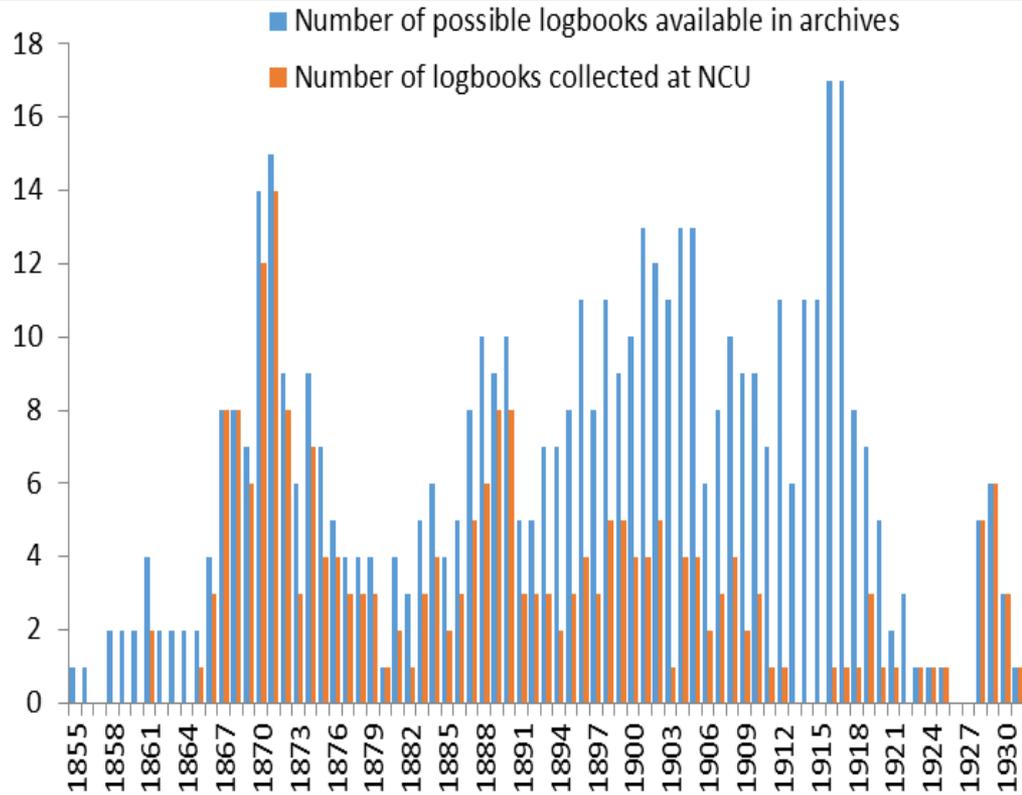




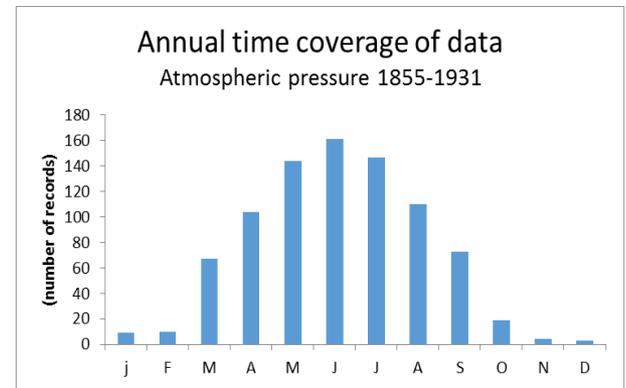
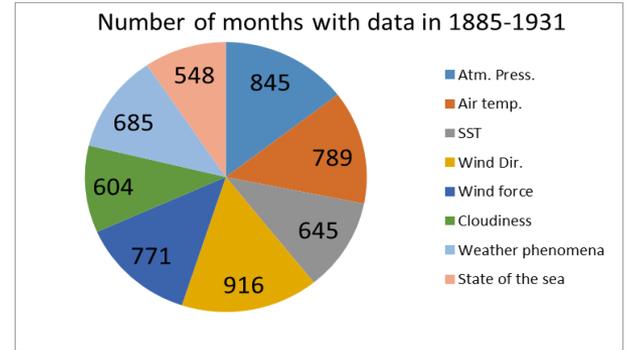


# Marine component

## Some statistics

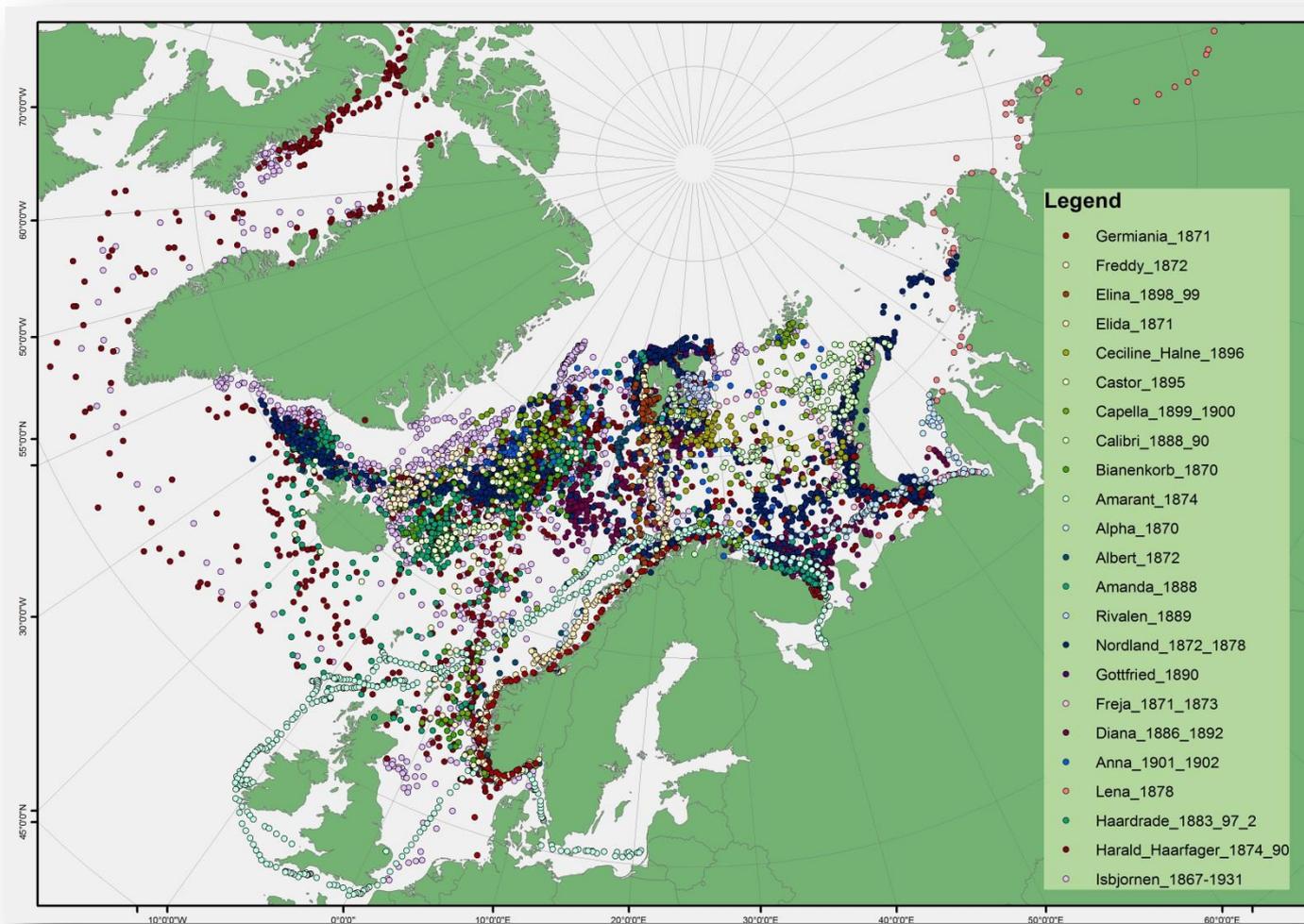


Year



# Marine component

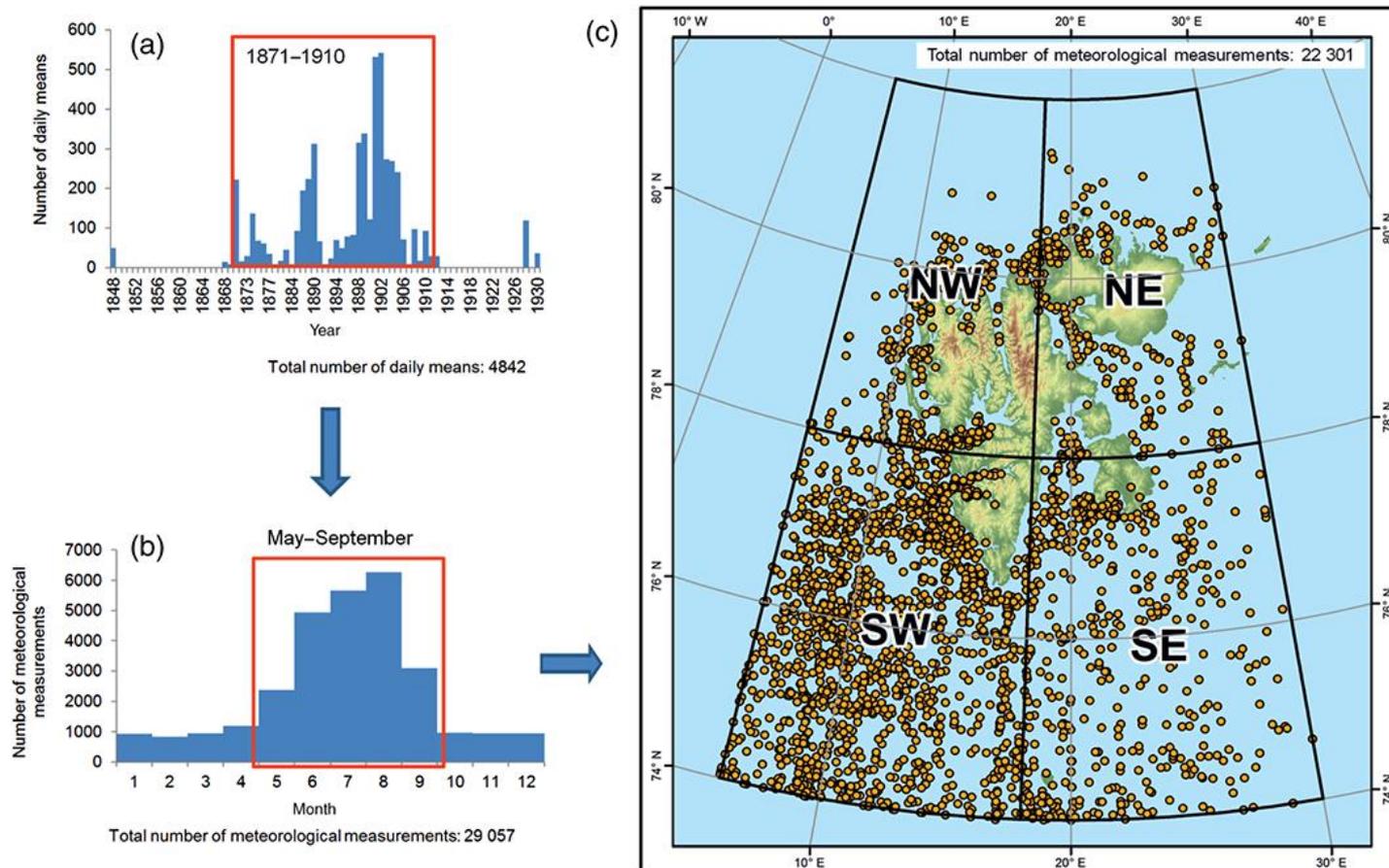
## Spatial coverage of data



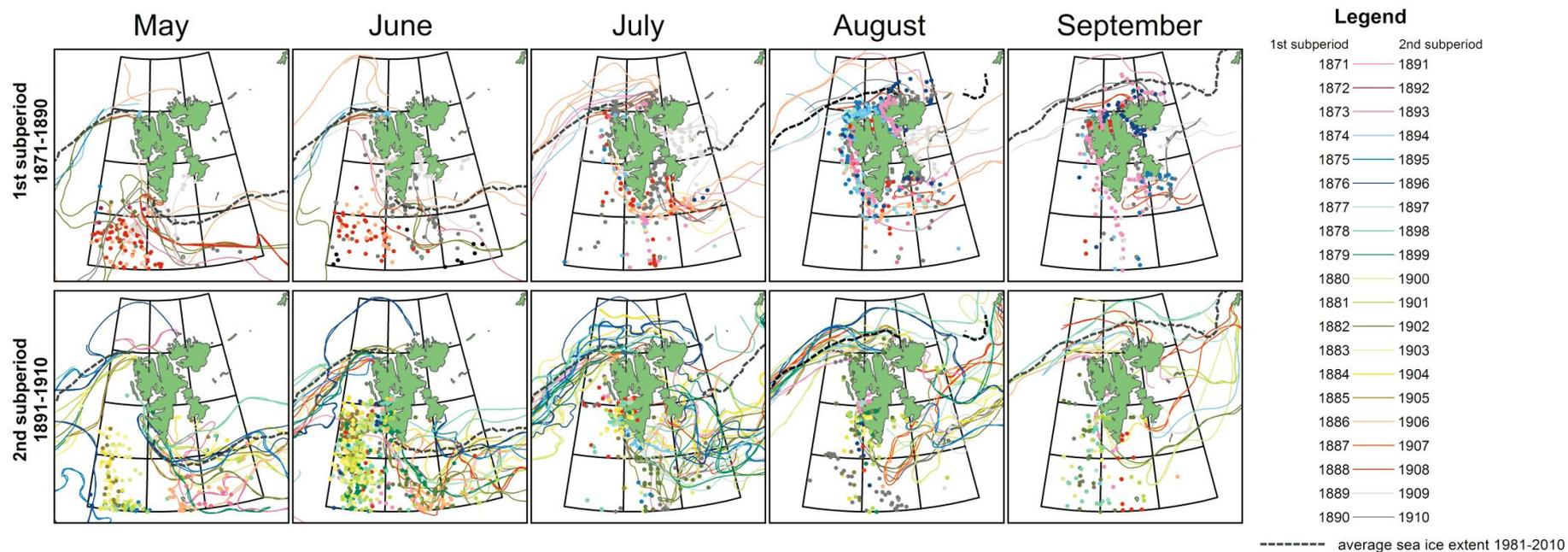
So far digitized: 23 yachts, 64 cruises, 9314 points (28.2% of collected material)

As at 22-11-2013

(a) Statistics of the collected data for all logbooks in the analysed area; the square marks the selected time frame. (b) Statistics of the collected data for the years 1871–1910 in the analysed area (monthly resolution); the square marks the selected time frame. (c) Mean daily positions (dots) of Norwegian ships in the waters surrounding Svalbard in the analysed period (1871–1910, May–September). The research area lies between 74–82°N and 6–30°E and was divided into grid boxes (black lines) with a resolution of 4° latitude and 12° longitude (SW, SE, NE and NW).

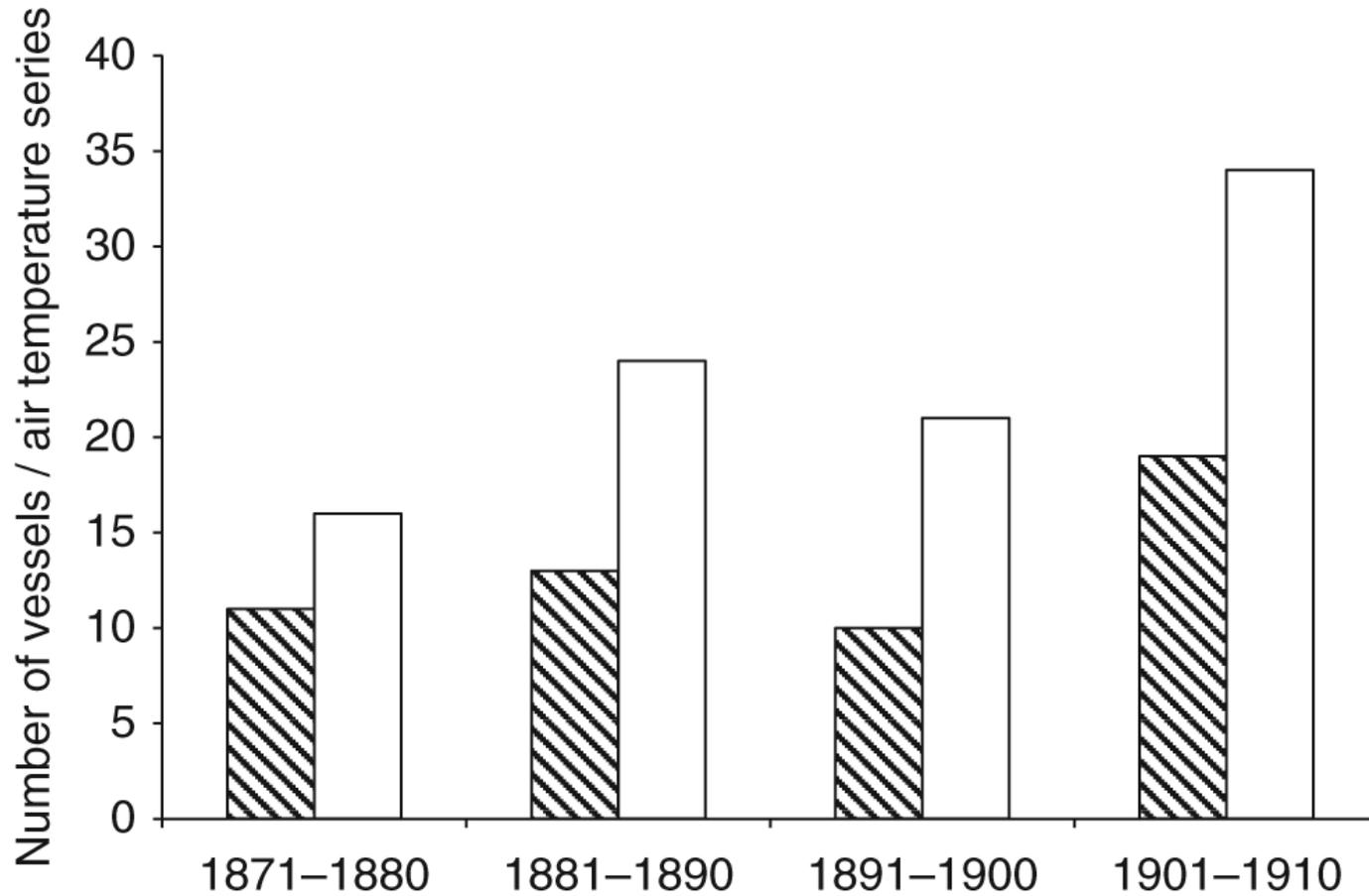


Mean ice extent (lines) and positions of ships (dots) in the Svalbard area during May to September 1871-1910. To make the picture clearer, the ice edge extent in the particular months was shown only for the years for which the meteorological measurements were collected in this study. The same colour indicates ice edge and vessel positions for a given year.



Source of data: historical ice edge extent according to ACSYS, 2003;  
 present average sea ice extent 1981-2010 was taken from the National Snow & Ice Data Center:  
<ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/shapefiles/>

Number of vessels (dashed bars) and marine air temperature series (white bars) in 10-year periods in the Svalbard area from 1871 to 1910.



Courses of air temperature (°C) based on daily means from ships (dots) in the historical period (1871–1910) and daily means (1981–2010) for land stations (solid lines) for the sub-regions at Svalbard during each month from May to September. Thresholds of 90 and 10 percentiles (dotted lines) were calculated on the basis of daily means from the present period. Note that for the NE region, the 79°N and 24°E grid point of the ERA-Interim reanalysis dataset was used, due to the lack of a meteorological station in this area.

Every daily mean air temperature ( $T$ ) available for a given month was adjusted to the time of the middle of that month ( $T_{adj}$ ) according to the formula:

$$T_{adj} = T + a_r (D_m - D)$$

where:

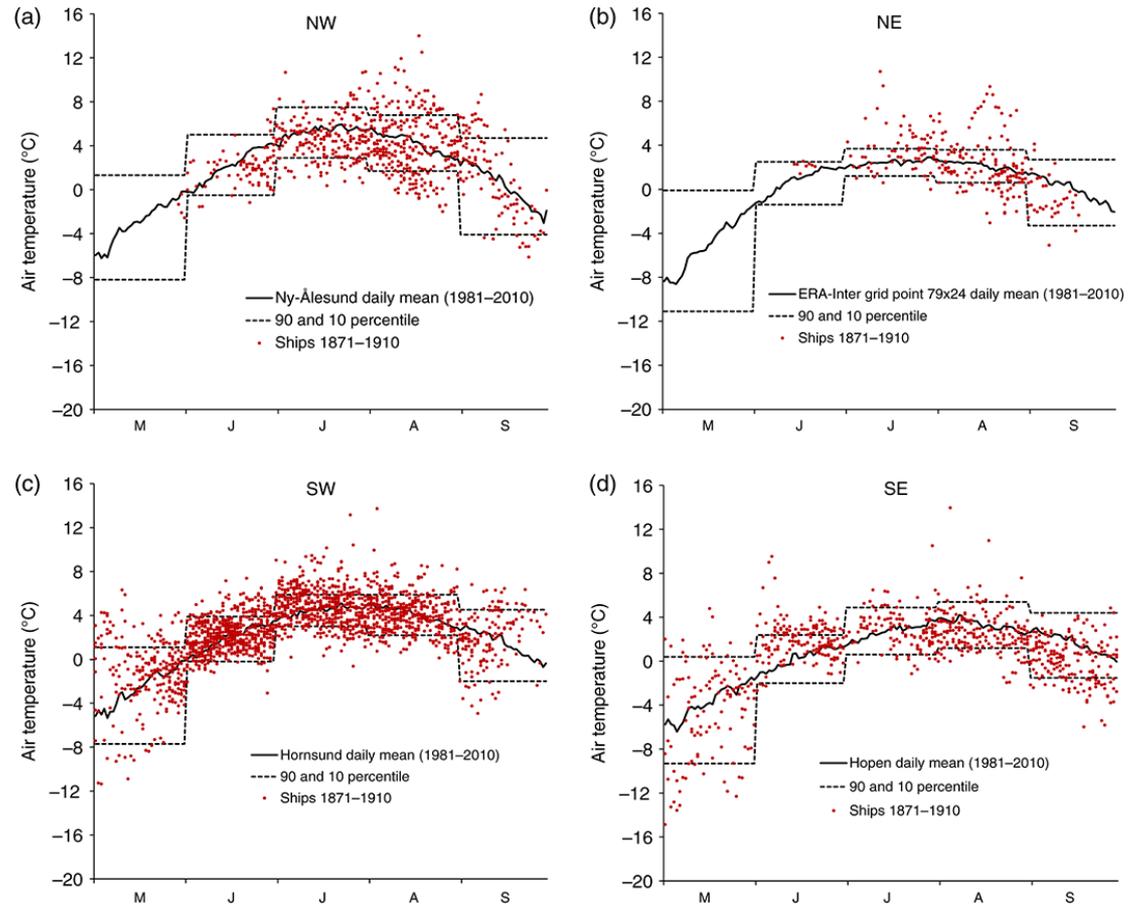
$T_{adj}$  – adjusted air temperature for the  $D$  day,

$T$  – mean air temperature of the particular day of the month,

$a_r$  – trend of daily mean air temperature

$D$  – the date of mean daily air temperature available in the particular month,

$D_m$  – the mid date in the month being 16 for May, July and August (which have 31 days) and 15.5 for June and September (which have 30 days).

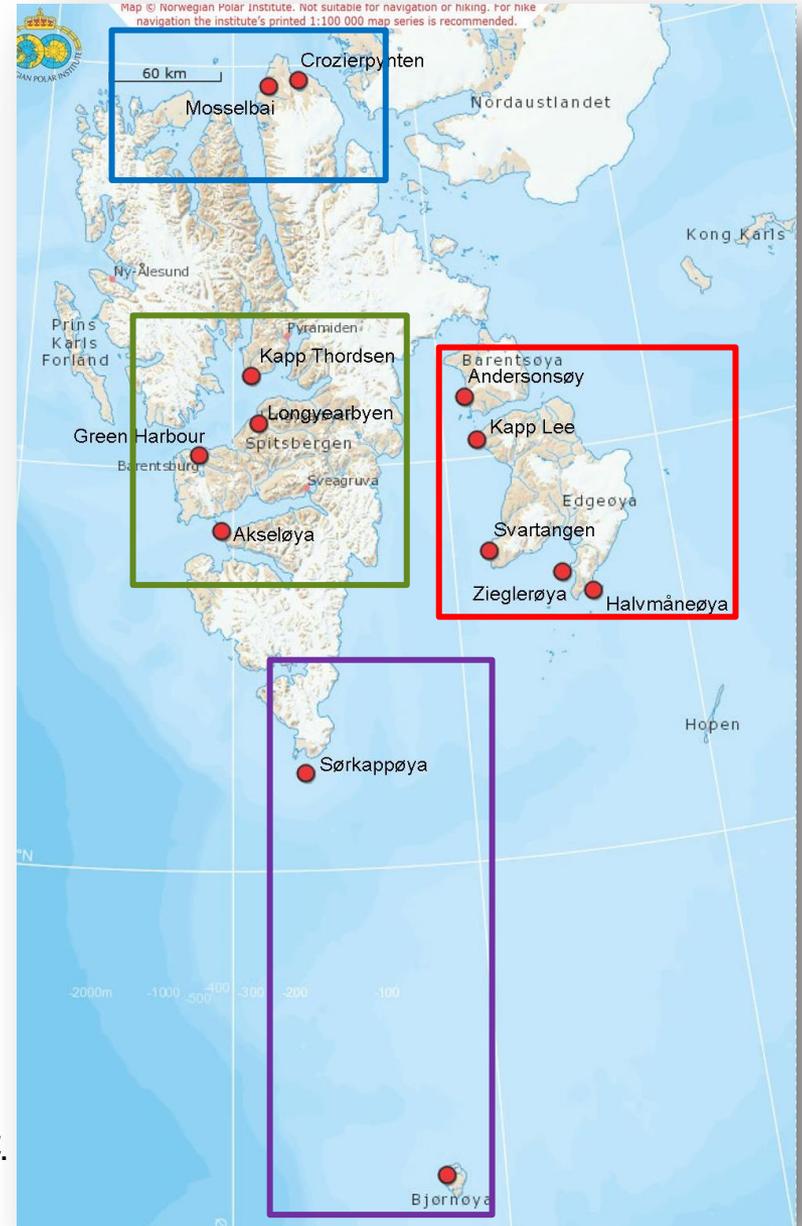
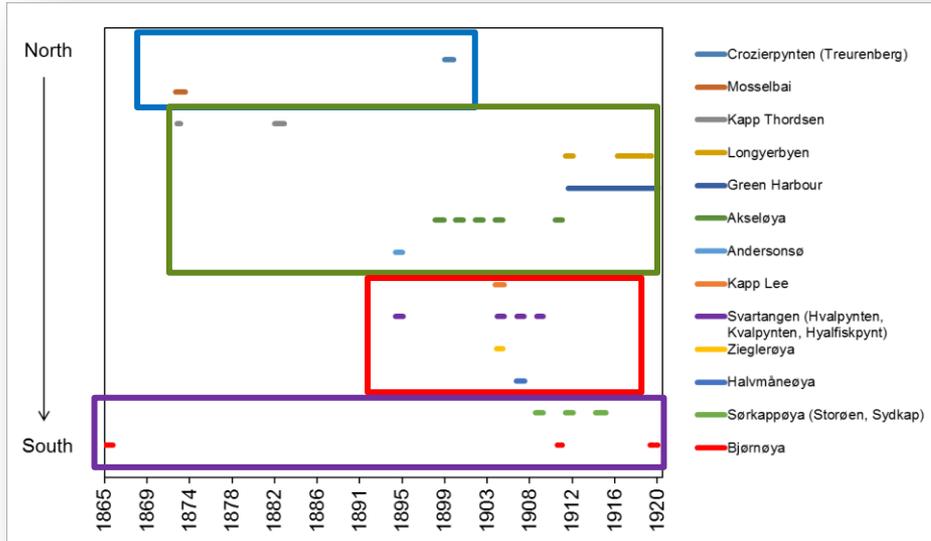


Adjustment factor,  $a_r$  (°C/day), for each Svalbard sub-region (SW – South-Western, SE – South-Eastern, NW – North-Western, NE – North-Eastern) given for months from May to September.

Month	SW	SE	NW	NE
May	0.088	0.120	0.138	0.248
June	0.095	0.092	0.091	0.119
July	0.058	0.056	0.040	0.023
August	-0.052	-0.035	-0.056	-0.040
September	-0.110	-0.096	-0.132	-0.116

# Land component

Temporal distribution of the air temperature observations on Svalbard used in the study from 1865 to 1920



13 meteorological sites, 26 air temperature series

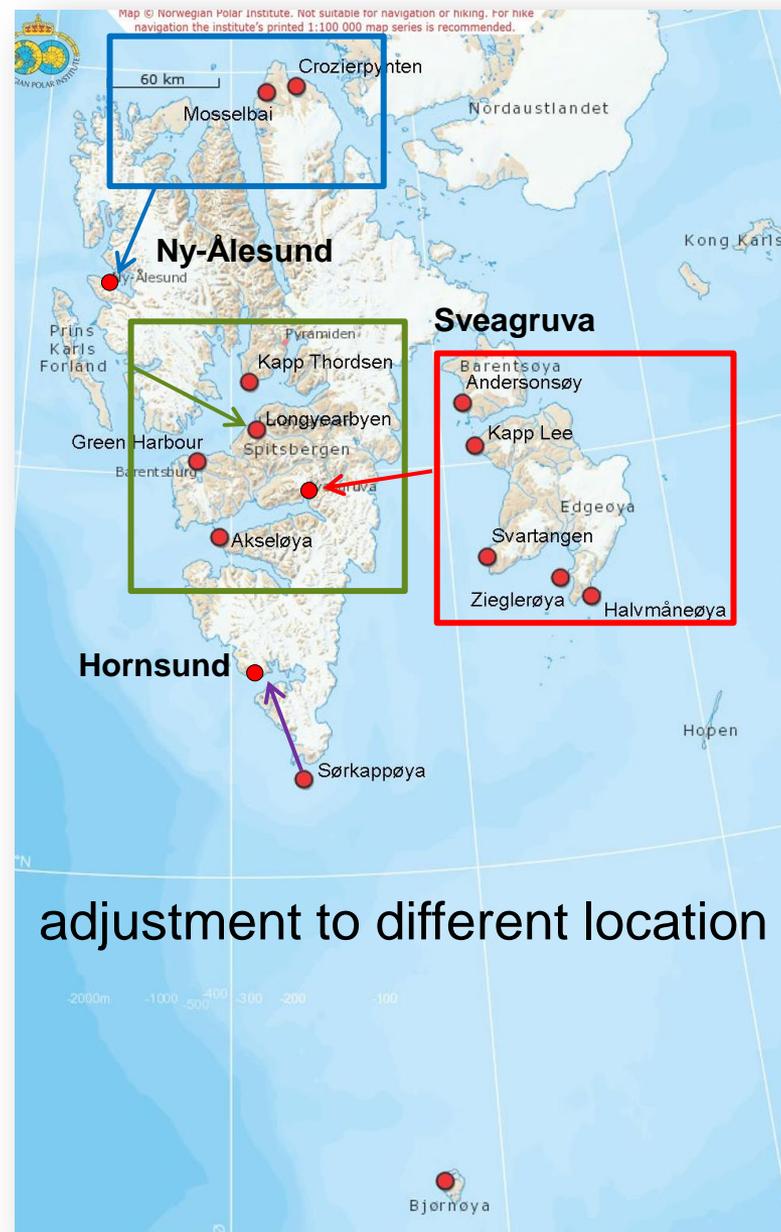
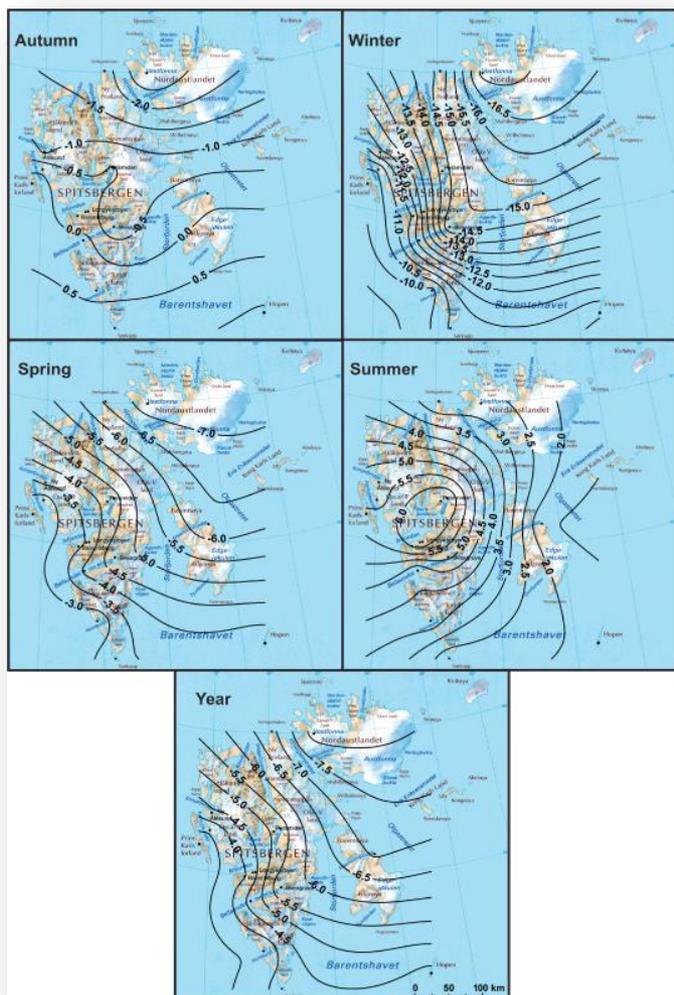


For more details about metadata of the stations see:  
 Nordli et al. 2014, *Polar Research*, 33, 21349.  
 Przybylak & Dzierżawski 2004, *Problemy Klimatologii Polarnej* 14.  
 Wyszynski & Przybylak 2014, *Polar Research*, 33 (in press)

# Land component

Comparison with present climatology (1981-2010)

Mean seasonal and annual air temperature ( $^{\circ}\text{C}$ ) at sea level in Svalbard (September 2010 to August 2011).



Przybylak et al. 2014

- International Journal of Climatology  
14 FEB 2014 DOI: 10.1002/joc.3937

Location of historical (dots) and modern (squares) land meteorological stations and campaign measurement sites in 2010–2011 (Przybylak *et al.*, 2014, triangles) on Svalbard. Shaded areas indicate split sub-regions; N, Northern; C, Central; E, Eastern; S, Southern.

Differences in air temperature ( $T_d$ ) between historical and contemporary (1981-2010) periods were calculated using the following formula:

$$T_d = T_h - (T_m + c)$$

where:

$T_h$  – monthly mean air temperature from a historical site,

$T_m$  – long-term monthly mean air temperature from the nearest modern station,

$c$  – spatial correction for different locations of historical and modern measurements sites calculated based on spatial diversity of air temperature on Svalbard presented by Przybylak *et al.* (2014).

The spatial correction “ $c$ ” was calculated using the following formula:

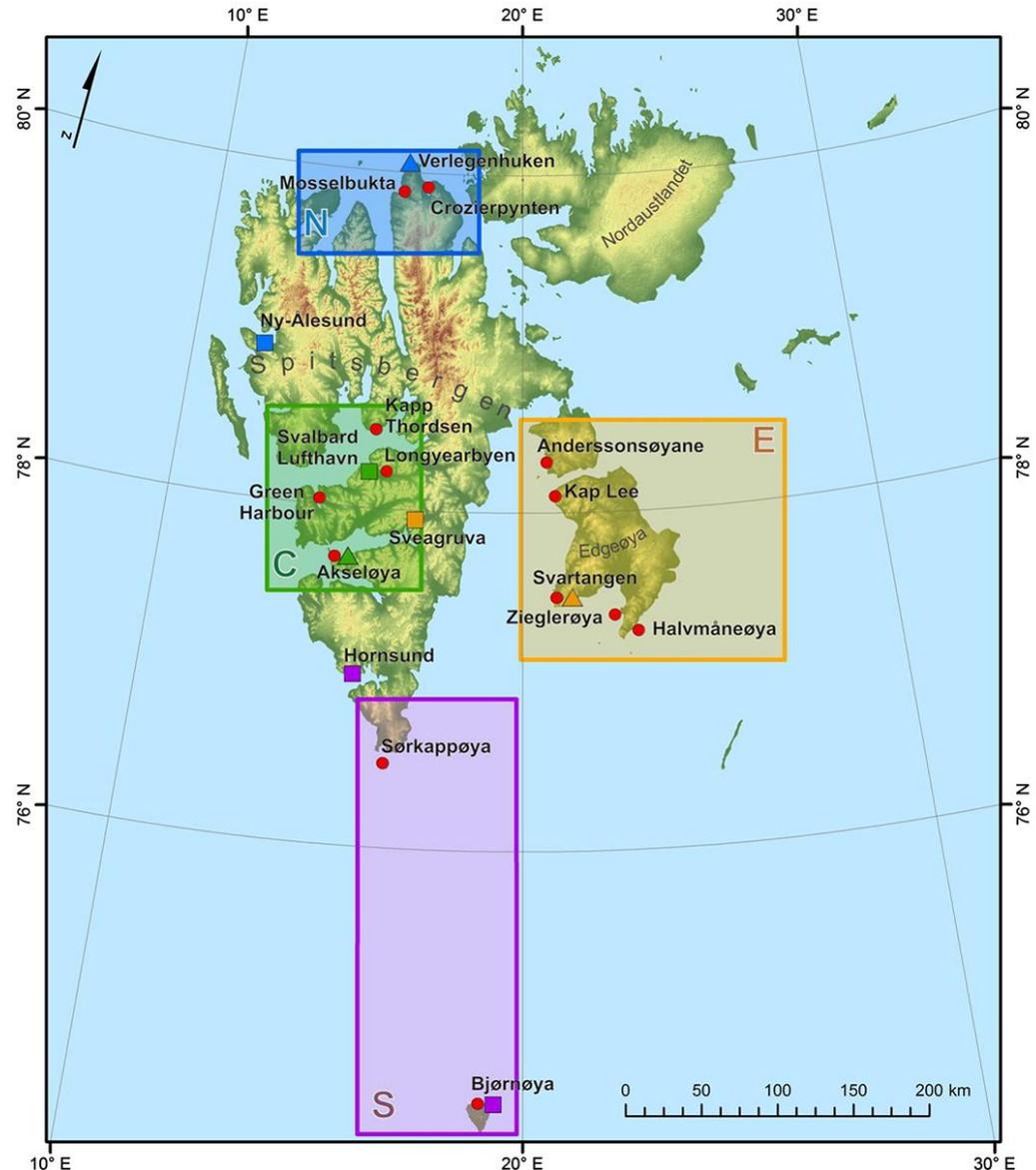
$$c = T_{h1} - T_{m1}$$

where:

$T_{h1}$  – monthly mean air temperature in the location of historical site in the period of 2010-2011

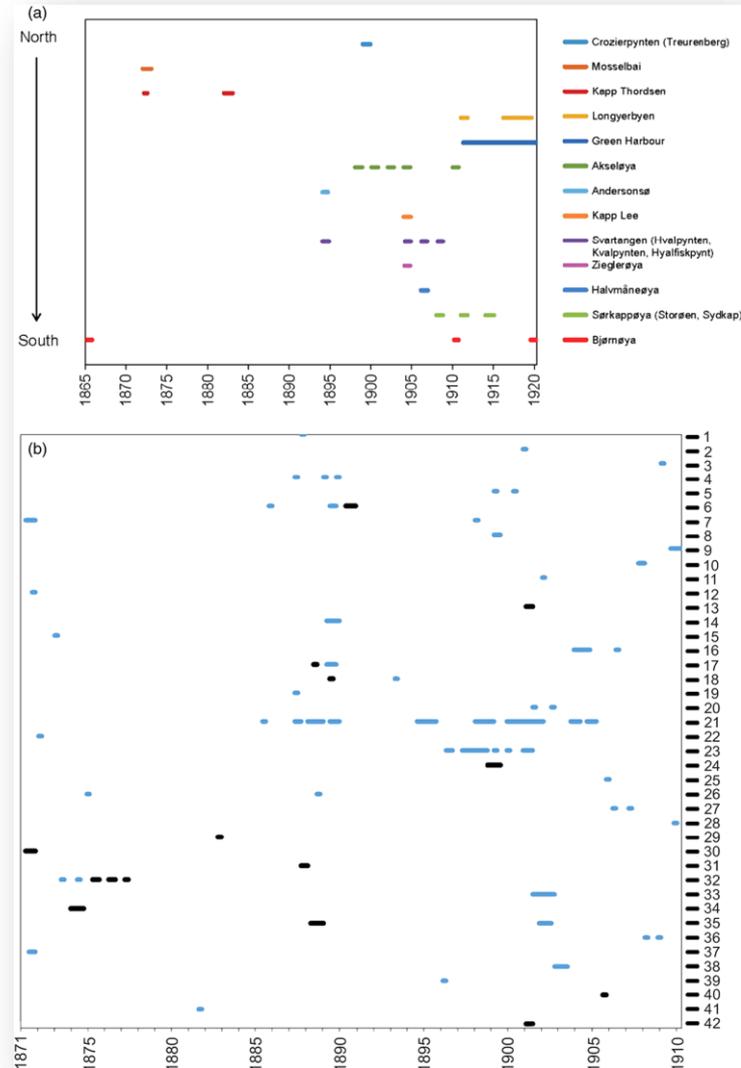
$T_{m1}$  – monthly mean air temperature in modern station in the period of 2010-2011

The modern values of air temperature obtained in this way for historical sites were compared with those from the period 1865-1920.



Temporal distribution of the air temperature observations from meteorological land stations (a), and ships (b), used in the study of the Svalbard archipelago and its surrounding seas from 1865 to 1920. Key to the lower panel: The black lines indicate data taken from the Arctic Norwegian Logbook Data: 1867–1912 at CISL RDA (<http://rda.ucar.edu/>, dataset 539.1), and the blue lines indicate data from the Nicolaus Copernicus University database.

Numbers describe names of ships:  
 1—Amanda, 2—Anna, 3—Bela,  
 4—Calibri, 5—Capella, 6—Diana,  
 7—Elida, 8—Elina, 9—Farm,  
 10—Foenix, 11—Fora den Blinde,  
 12—Freja, 13—Gjøa, 14—Gottfried,  
 15—Greenland, 16—Gurim,  
 17—Harald Haarfagre, 18—Hekla,  
 19—Hoidfisken, 20—Hvalfiskpynt,  
 21—Hvidfisken, 22—Isbjørnen,  
 23—Jasai, 24—Johan Hagerup,  
 25—Laura, 26—Magdalena,  
 27—Maria, 28—Minerva, 29—No  
 name 1, 30—No name 2, 31—No  
 name 8, 32—Nordland, 33—Ost  
 Spitsbergen, 34—Polarstjernen,  
 35—Rivalen, 36—Roald, 37—  
 Samson, 38—Tromsø, 39—Vega,  
 40—Victoria, 41—Viking, 42—Yjra.  
 Note that for Fig. 1B. data only for  
 May–September in the period  
 1871–1910 are shown.



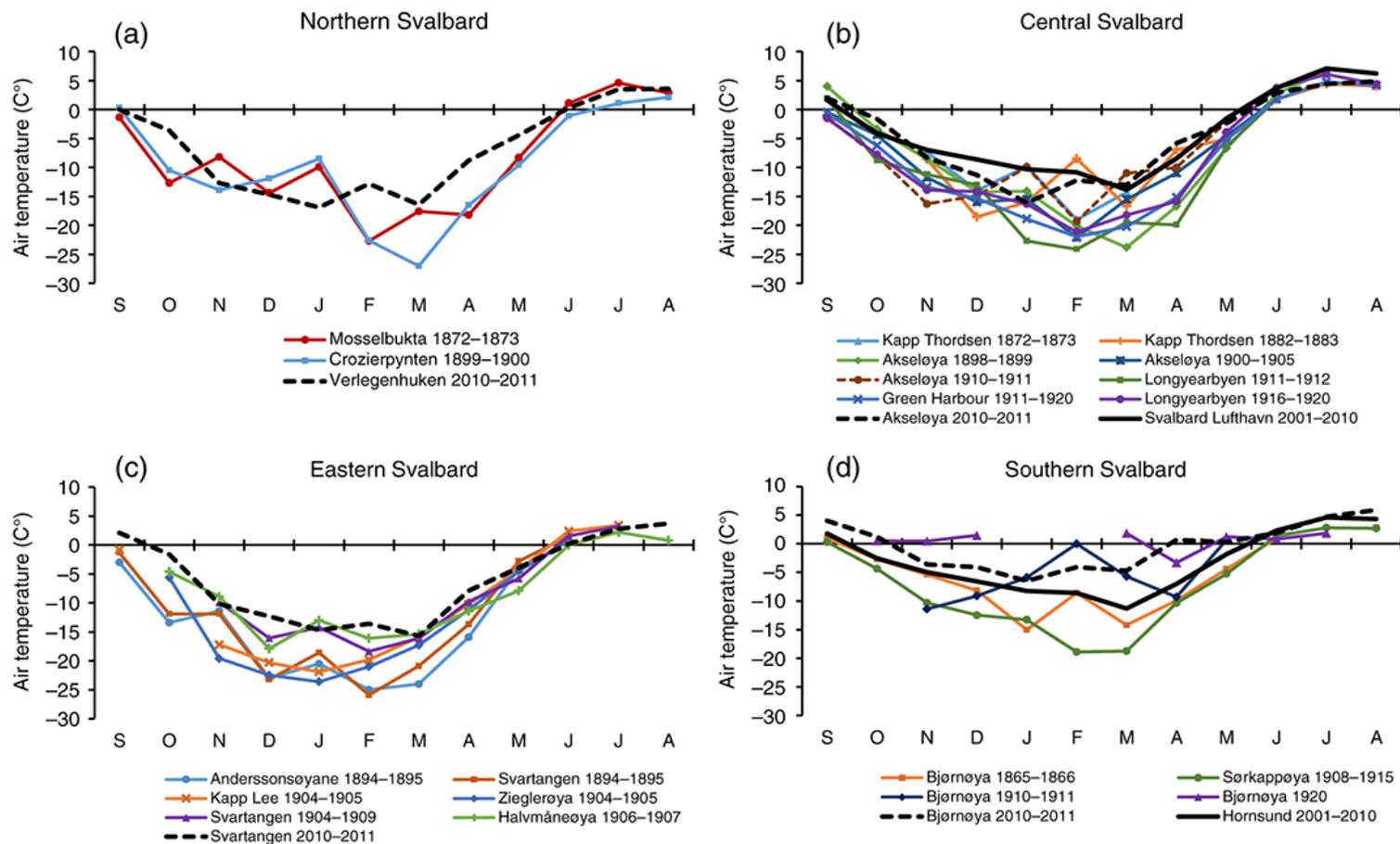


Monthly and seasonal means of air temperature in Svalbard in the period 1865-1920 and their differences between the historical and contemporary period (1981-2010). Calculations are based on land stations. Italics indicate negative values.

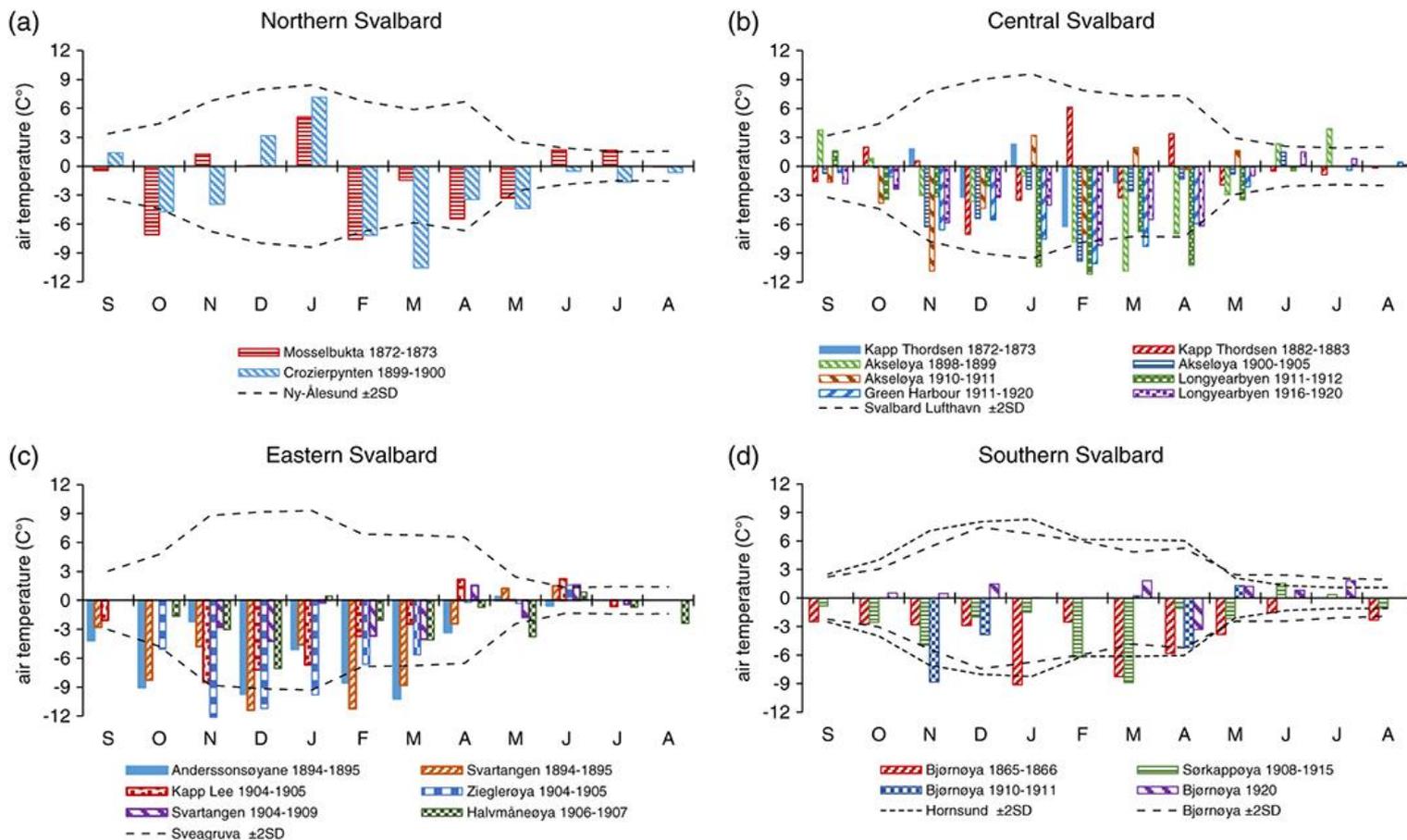
Region	S	O	N	D	J	F	M	A	M	J	J	A	SON	DJF	MAM	JJA	SEP-AUG
	Air temperature means (°C)																
Northern 1872-1900	-0,5	-11,6	-11,1	-13,2	-9,2	-22,7	-22,3	-17,4	-9,0	0,0	2,9	2,5	-7,7	-15,0	-16,2	1,8	-9,3
Central 1872-1920	0,1	-6,0	-11,4	-15,0	-15,4	-19,5	-17,4	-13,6	-4,8	2,3	5,5	4,2	-5,8	-16,6	-12,0	4,0	-7,6
Eastern 1894-1909	-1,7	-8,9	-13,2	-20,5	-18,6	-21,0	-18,3	-12,0	-4,9	1,3	3,0	0,8	-7,9	-20,1	-11,7	1,7	-9,5
Southern 1865-1920	0,6	-2,1	-7,3	-8,4	-11,4	-13,7	-10,7	-9,2	-2,1	1,9	4,8	2,8	-2,9	-11,2	-7,3	3,1	-4,6
Svalbard 1865-1920	-0,4	-7,2	-10,7	-14,3	-13,7	-19,2	-17,2	-13,1	-5,2	1,4	4,0	2,6	-6,1	-15,7	-11,8	2,6	-7,7
	Differences of air temperature (°C)																
Northern 1872-1900	0,5	-5,9	-1,3	1,6	6,1	-7,4	-6,0	-4,5	-3,9	0,6	0,0	-0,3	-2,3	0,1	-4,8	0,1	-1,7
Central 1872-1920	-0,1	-1,1	-4,2	-4,3	-2,9	-6,8	-4,6	-4,0	-1,5	0,7	0,9	0,1	-1,8	-4,7	-3,4	0,6	-2,3
Eastern 1894-1909	-3,0	-6,0	-5,7	-8,4	-4,3	-6,0	-5,9	-0,5	-0,7	1,2	-0,6	-2,4	-4,9	-6,2	-2,3	-0,6	-3,5
Southern 1865-1920	-1,6	-1,6	-4,0	-1,8	-3,5	-4,4	-3,8	-3,8	-0,9	0,3	1,1	-1,7	-2,4	-3,2	-2,8	-0,1	-2,1
Svalbard 1865-1920	-1,1	-3,7	-3,8	-3,2	-1,2	-6,1	-5,1	-3,2	-1,7	0,7	0,3	-1,1	-2,9	-3,5	-3,3	0,0	-2,4

Key: Stations from the Northern, Central, Eastern and Southern regions were compared with the following modern stations: Ny-Ålesund, Svalbard Lufthavn, Sveagruva and Hornsund or Bjørnøya, respectively.

Annual courses of air temperature ( $^{\circ}\text{C}$ ): in historical times 1865–1920 (thin solid lines); average 10-year means 2001–2010 (thick solid line), and 1-year 2010–2011 mean (dashed line) in sub-regions of Svalbard. Note that for the historical stations Akseløya 1900–1905, Svartangen 1904–1909 and Sørkappøya 1908–1915, the annual courses were averaged based on a few 1-year long overwinterings; for more details, see Figure 2(a) or Table S1.



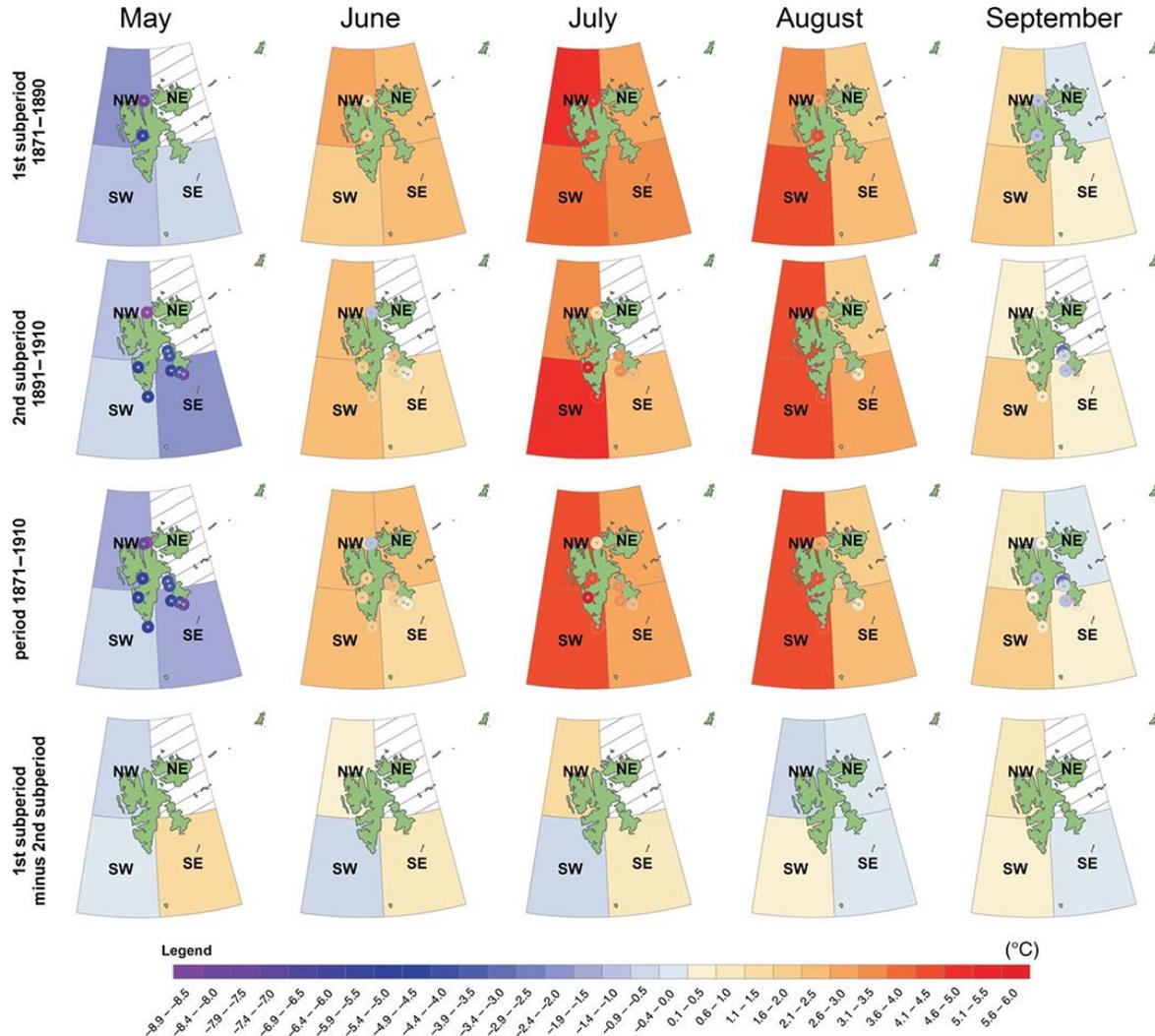
Air temperature differences ( $^{\circ}\text{C}$ ) between monthly values from the historical and present (1981–2010) periods for selected sub-regions in Svalbard. Standard deviations ( $\pm 2$  SD, shaded lines) have been calculated on the basis of the present period. Bars with anomalies for particular stations are placed chronologically in each month. Note that for the historical stations Akseløya 1900–1905, Svartangen 1904–1909 and Sørkappøya 1908–1915, monthly differences were averaged based on a few 1-year long overwintering expeditions; for more details, see Figure 2(a) or Table S1.



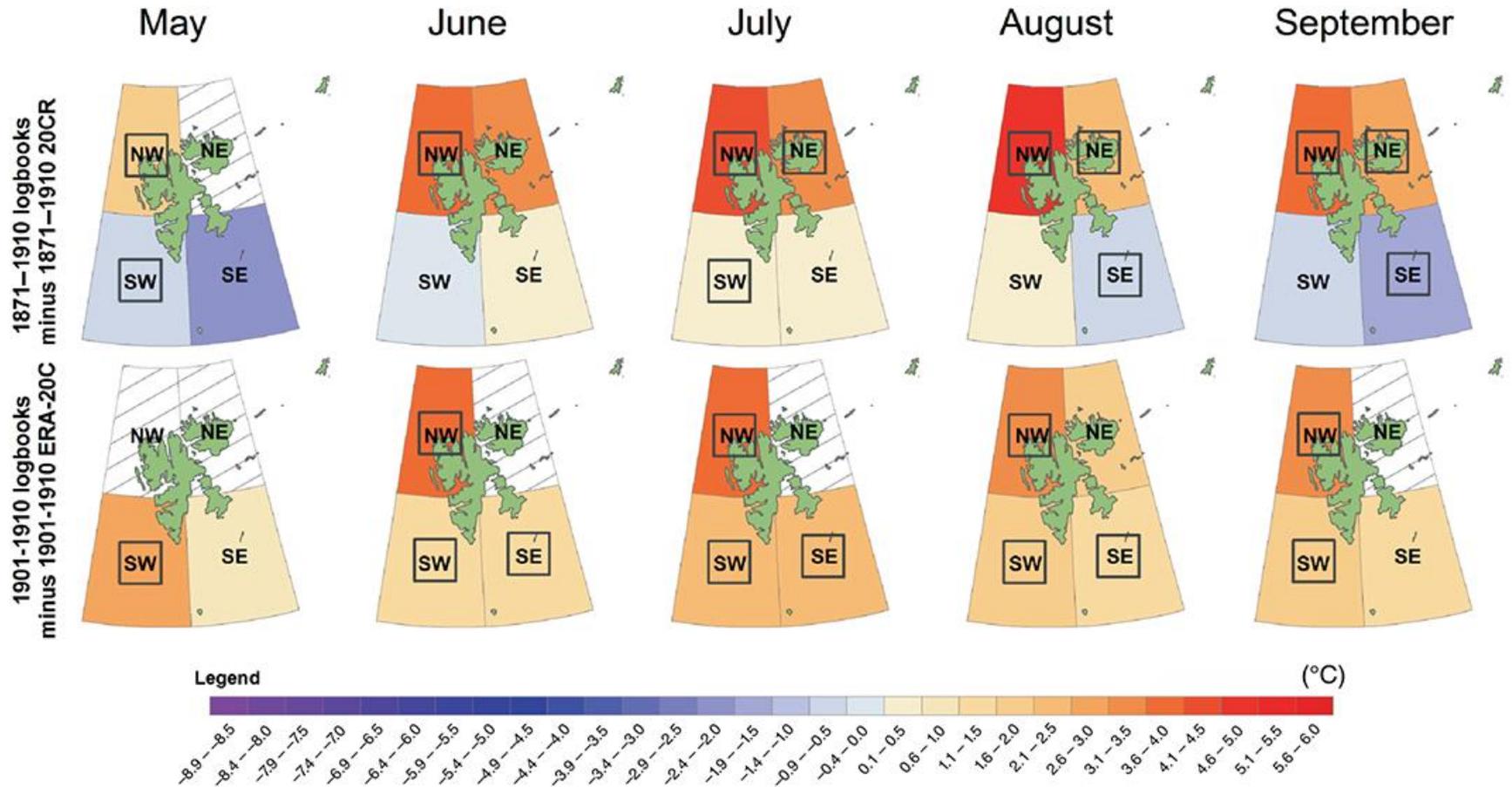
Air temperature differences in various regions of the Arctic between the historical and standard normal period (1961-1990). Italics indicate negative values.

Region	SON	DJF	MAM	JJA	Annual
Central Svalbard 1865-1920 (this paper)	<i>-0.7</i>	<i>-2.3</i>	<i>-1.3</i>	<i>-0.1</i>	<i>-0.7</i>
SW Greenland 1861-1920 (Vinther et al., 2006)	<i>-0.7</i>	<i>-2.2</i>	<i>-0.5</i>	<i>-0.1</i>	<i>-1.0</i>
Resolute region 1848-1859 (Przybylak and Vízi, 2005)	<i>-0.1</i>	<i>-2.7</i>	<b>2.3</b>	<b>0.7</b>	<b>0.1</b>
Atlantic Arctic 1861-1920 (Przybylak et al., 2010)	<i>-1.3</i>	<i>-1.9</i>	<i>-0.6</i>	<i>-0.1</i>	<i>-0.7</i>
Whole Arctic 1861-1920 (Przybylak et al., 2010)	<i>-0.7</i>	<i>-1.7</i>	<i>-0.2</i>	<i>-0.3</i>	<i>-0.7</i>

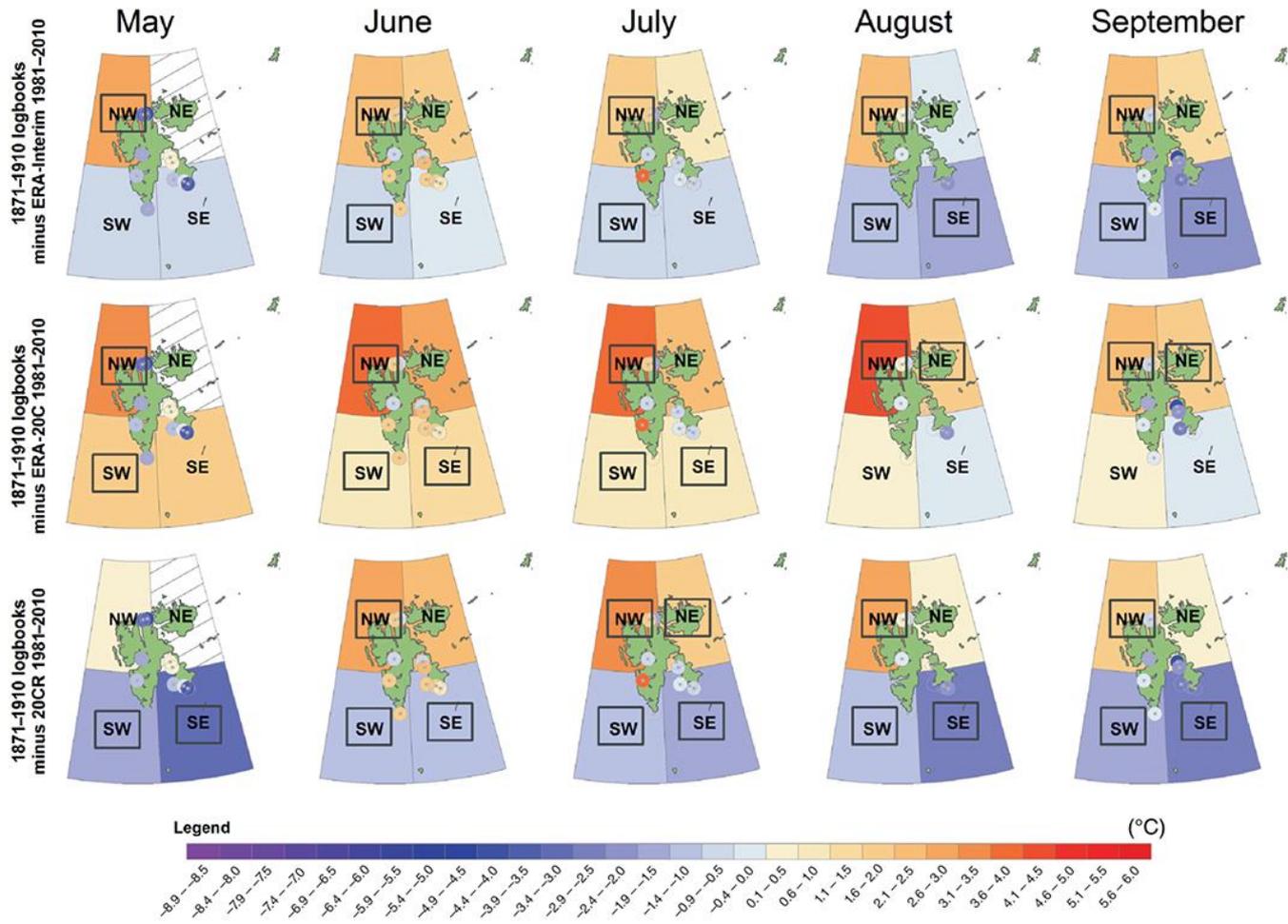
Mean monthly air temperature (°C) based on land stations (dots) and marine expeditions (grid boxes) in Svalbard and its surrounding seas, from May to September in the entire analysed period of 1871–1910, and its sub-periods 1871–1890 and 1891–1910, as well as the differences between them. White patterned grid boxes indicate areas with a lack of data.



Mean monthly differences of air temperature ( $^{\circ}\text{C}$ ) between measurements taken from logbooks and the 20CR reanalysis (upper panel, for 1871–1910) and the ERA-20C reanalysis (lower panel, for 1901–1910) in the seas surrounding Svalbard. White patterned grid boxes indicate areas with a lack of data. Statistically significant differences at the  $p \leq 0.05$  level are shown by a grid label with squares.

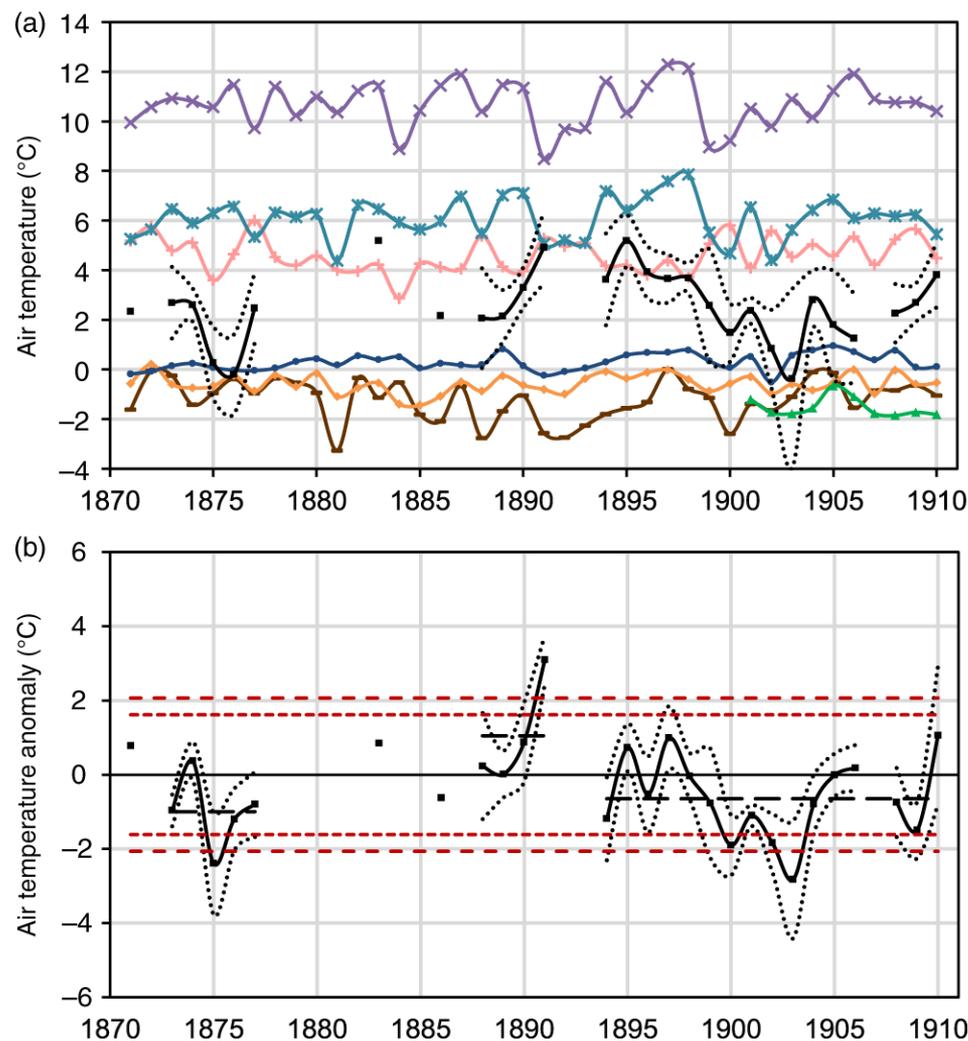


Mean monthly differences of air temperature (°C) between historical (1871–1910) and contemporary (1981–2010) times. Dots indicate differences between historical land sites and present land stations. Grid boxes indicate differences between historical logbooks and present reanalysis: ERA-Interim (upper panel), ERA-20C (middle panel) and 20CR (lower panel). White patterned grid boxes indicate areas with a lack of data. Statistically significant differences at the  $p \leq 0.05$  level are shown by a grid label with squares.



# Air temperature variability in the Svalbard area (74–82°N and 6–30°E) in the period May–September 1871–1910, with comparison to other datasets (a) and present climatology 1981–2010 (b).

Panel (A): reconstruction based on areally averaged data used in this study (black with squares) with a 95% confidence interval (dotted); Archangelsk (crosses); Vardø (stars); SW Greenland (Vinther *et al.*, 2006, pluses); 20CR (Compo *et al.*, 2011, circles); Arctic 57–84°N (Polyakov *et al.*, 2003, \*\*updated, rhombuses); HadCRUT4 (Morice *et al.*, 2012, dashes); and ERA-20C (triangles). Panel (B): air temperature anomalies based on data used in this study (black with squares) with a 95% confidence interval (black dotted) with respect to the reference period 1981–2010 based on ERA-Interim reanalysis; short-term means of the anomalies (horizontal black long-dashed);  $\pm 3$ SDs of the mean ERA-Interim 1981–2010 (Dee *et al.*, 2011, horizontal short-dashed); 3SDs of the mean observational 1981–2010 as an average of Ny-Ålesund, Svalbard Lufthavn, Hornsund, Bjørnøya and Hopen (horizontal medium-dashed). Note that data were not available for all regions in all years (NW, NE, SW and SE), therefore mean daily anomalies for the entire area were calculated in the following way: the daily mean for each location in the given region was subtracted from the mean air temperature for 1981–2010 taken from ERA-Interim for the same region. In the next step, all obtained daily anomalies were averaged for the entire area and for each year separately.



Air temperature trends (°C/10 years) in the Svalbard archipelago in 1871-1910 on the basis of daily data from logbooks. Values in bold indicates significance on the  $p \leq 0.05$  level.

Month	SW	SE	NW	NE
May	-0.31	–	-0.37	–
June	0.08	0.02	<b>0.55</b>	–
July	0.18	-0.34	<b>0.41</b>	–
August	<b>-0.24</b>	0.00	-0.04	0.22
September	0.02	<b>0.28</b>	<b>0.55</b>	-0.33

Key: SW – South-Western, SE – South-Eastern, NW – North-Western, NE – North-Eastern regions divided according to 18°E meridian and 78°N parallel



# Conclusions

ISFORHOLDENE  
ÅR 1876.

Farvand Næstj Sømlø  
Middling = 14.20  
Jagt

Måneds	Dag	Vind	Højde	Temperatur.		Vind	Sky	Regn	Sne	Ist	Anmerkninger.
				L. u. F.	V. u. F.						
4	-	-	9.0	28.5	1.8	0.0	1.0	8	1	0.0	Indfaldet m.
8	-	-	8.0	28.5	0.5	-0.2	0	1.2	10	1.0	Varst Østvendt

## ❖ LAND DATA

- Analysis reveals that in 1865–1920, Svalbard was markedly colder than today (by about 3 °C) in all seasons, except summer when the air temperature was similar in both periods. However, the majority of mean monthly air temperatures in historical times still lie within two SDs from the modern, 1981–2010 mean. This means that values of air temperature in historical times lie within range of contemporary air temperature variability.
- Seasonal patterns of air temperature changes in the Svalbard archipelago between the historical and standard normal (1961–1990) periods show a generally good correspondence with analogical changes calculated not only for the Atlantic region but also for some other Arctic regions (e.g. SE Greenland, Canadian Arctic, the Barents and Kara seas), as well as also for the entire Arctic. All these sources concluded that annual air temperature in historical times was generally colder than the standard normal period (1961–1990) by about 0.5–1.0 °C. When we took as the reference period the new normal period (1981–2010), the difference increases to about 1.5–2.5 °C.





# ISFORHOLDENE

ÅR 1876.

Fartøiets navn: *Nordlys*  
 Kaptein: *Johansen*

- ubrutt polaris
- landfast vinteris
- store isflorer
- tæt drivis
- spredt drivis
- nyis og sørpe
- isfjeld



# Thank You!

Farvand *Nordlys*  
 1876  
 d. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31.

1876 Juni Maaned.	Kl.	Paaværende Plads.		Barometer.		Temperatur.		Vind.		Sky- dække 0-100 100-200 200-300 300-400 400-500 500-600 600-700 700-800 800-900 900-1000	Regn, Sned, Isregn, Isfald.	Bøl- gæng. 0-9	Anmerkninger.
		Bredde.	Længde.	Therm.	Højde.	L. u. F.	V. u. F.	Retning.	Styrke u. c.				
~	4	~	~	9.0	28.15	1.8	0.0	~	1.0	~	~	~	~
~	8	~	~	8.0	28.15	1.5	-0.2	~	1.2	~	~	~	~
d. 14	MD.	71° 18'	43° 16'	9.0	28.67	1.5	-0.1	~	2-3	~	~	~	~
~	4	~	~	13.7	28.10	1.3	-0.3	~	~	~	~	~	~
~	8	~	~	14.3	28.15	0.8	-0.3	~	~	~	~	~	~
~	MN.	~	~	10.3	28.11	0.6	-0.1	~	~	~	~	~	~
~	4	~	~	9.0	28.11	0.2	-0.6	~	~	~	~	~	~
~	8	~	~	8.5	28.10	0.6	-0.4	~	~	~	~	~	~
d. 15	MD.	71° 15' 00"	43° 14' 50"	9.0	28.12	0.5	0.0	~	~	~	~	~	~
~	4	~	~	14.2	28.16	0.0	0.0	~	~	~	~	~	~
~	8	~	~	13.3	28.15	1.2	0.0	~	~	~	~	~	~
~	MN.	~	~	8.7	28.12	0.6	0.4	~	~	~	~	~	~
~	4	~	~	10.0	28.12	0.7	0.4	~	~	~	~	~	~
~	8	~	~	10.0	28.12	0.2	0.2	~	~	~	~	~	~
d. 16	MD.	71° 15' 00"	43° 14' 50"	9.0	28.12	0.4	0.2	~	~	~	~	~	~
~	4	~	~	4.0	28.27	-0.4	0.0	~	~	~	~	~	~
~	8	~	~	15.0	28.28	-1.7	-0.3	~	~	~	~	~	~
~	MN.	~	~	9.5	28.28	-1.5	-0.2	~	~	~	~	~	~
~	4	~	~	6.4	28.24	-0.5	-0.2	~	~	~	~	~	~
~	8	~	~	7.2	28.23	0.2	-0.4	~	~	~	~	~	~
d. 17	MD.	71° 46' 00"	47° 45' 00"	7.3	28.25	-0.6	-0.5	~	~	~	~	~	~
~	4	~	~	10.0	28.26	-0.5	-0.8	~	~	~	~	~	~
~	8	~	~	10.0	28.24	-1.0	-0.6	~	~	~	~	~	~
~	MN.	~	~	7.0	28.21	-1.5	0.0	~	~	~	~	~	~
~	4	~	~	6.4	28.17	-1.2	10.3	~	~	~	~	~	~

Rajmund Przybylak<sup>1</sup>, Przemysław Wszyński<sup>1</sup>, Øyvind Nordli<sup>2</sup> & Tomasz Strzyżewski<sup>1</sup>

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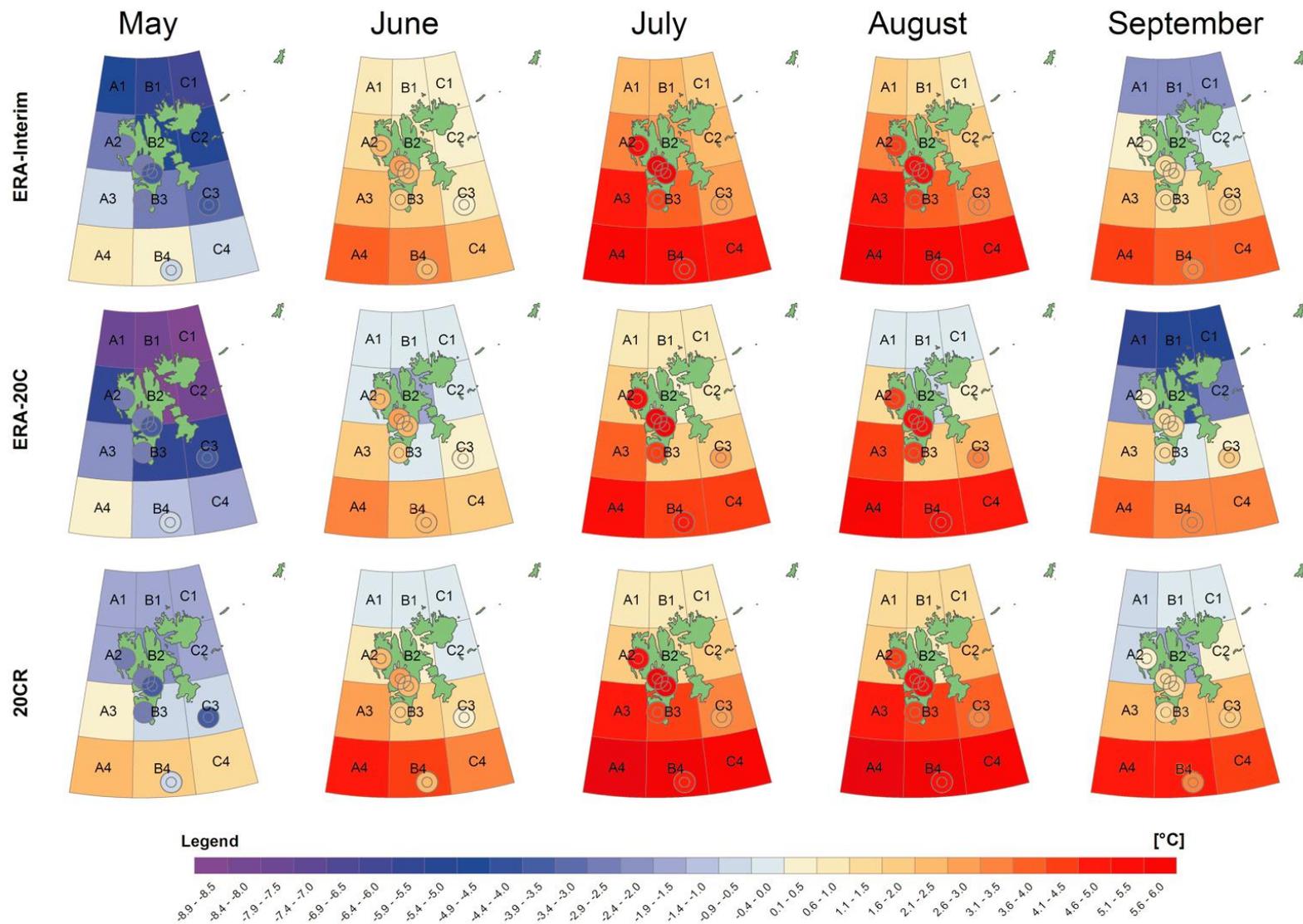


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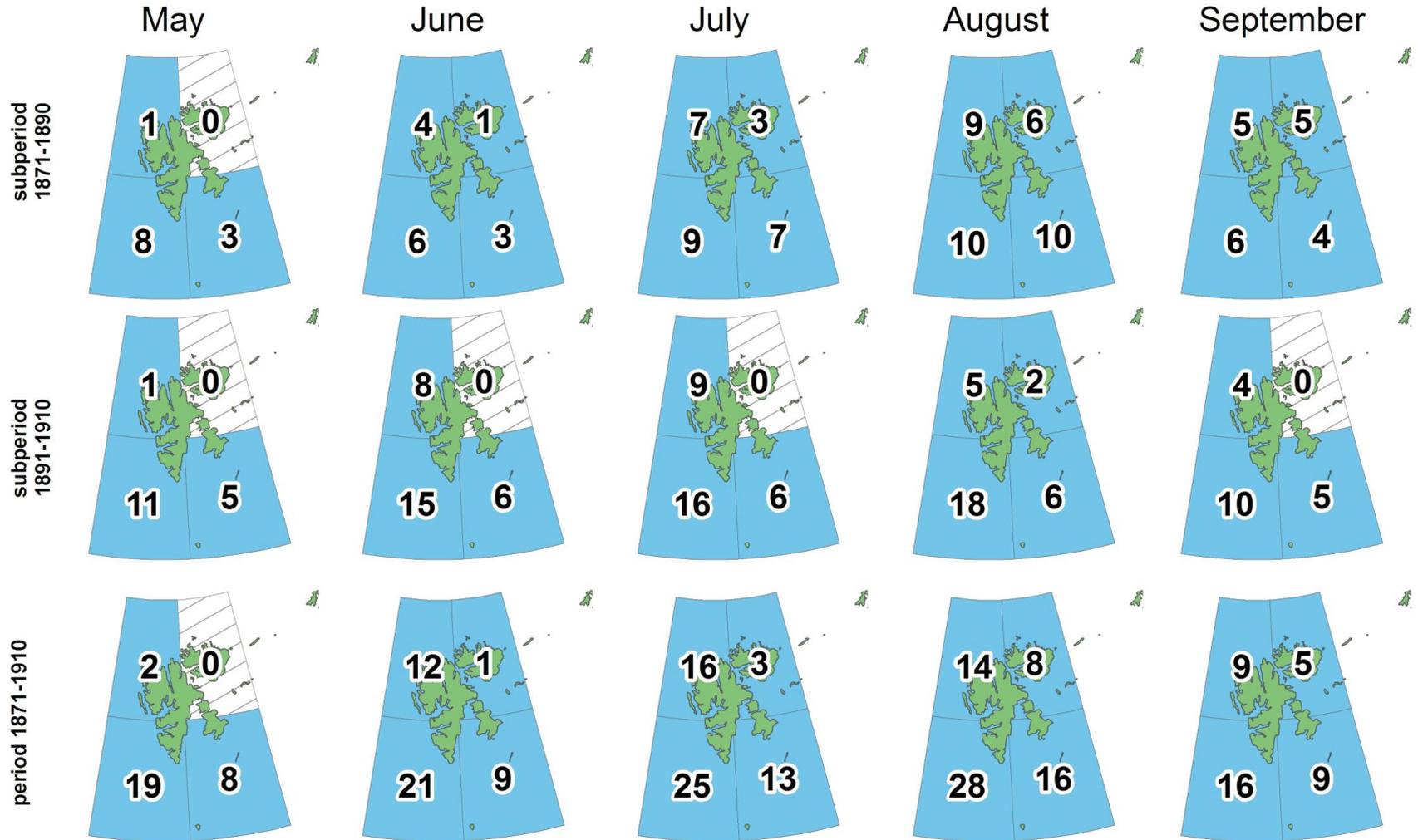
ADDITIONAL SLIDES



Mean monthly air temperature (°C) based on land stations (dots) and reanalyses (grid boxes): ERA-Interim (upper panel), ERA-20C (middle panel) and 20CR (lower panel) in Svalbard and its surrounding seas, during May to September 1981-2010.



Number of reconstructed monthly means of air temperature (°C) in each grid box in the seas surrounding Svalbard in 1871-1910 and its sub-periods 1871-1890 and 1891-1910.



Mean monthly differences of air temperature ( $^{\circ}\text{C}$ ) between historical (1871-1910) and contemporary five warmest months, selected from 1981-2010. Grid boxes indicate differences between historical logbooks and the present reanalysis: ERA-Interim (upper panel), ERA-20C (middle panel) and 20CR (lower panel). White patterned grid boxes indicate areas with a lack of data.

