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XXIX Seminarium Meteorologii i Klimatologii Polarnej
9-10.05.2019, Wrocław

Zmienność temperatury powietrza w NE Grenlandii w okresie 1927-2017

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CEArc

Project No. 2015/19/B/ST10/02933

NATIONAL SCIENCE CENTRE POLAND

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Motivation

- Long-term regular meteorological stations operate mainly in SW Greenland
- The longest ones: Ilulissat (former name: Jakobshavn): start date 1873; Upernavik 1873; Nuuk (Godthåb): 1874; Iviituut (Ivigtut): 1873

(Cappelen 2018)

Data set id	Station	First year of appearance
4202	Pituffik	1948
4211	Upernavik	1873
4221	Ilulissat	1807
4250	Nuuk	1784
34262	Ivittuut	1873
4270	Narsarsuaq	1961
4320	Danmarkshavn	1949
34339	Scoresbysund	1924
4339	Ittoqqortoormiit	1949
4360	Tasiilaq	1895

Cappelen 2018

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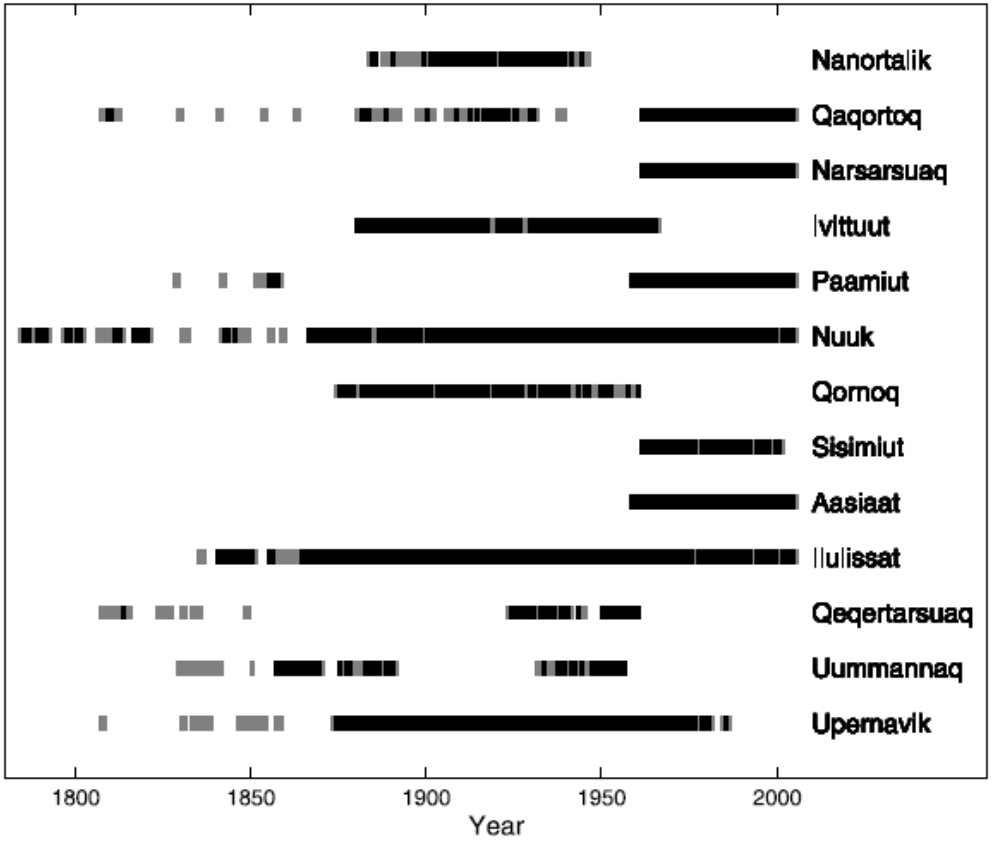
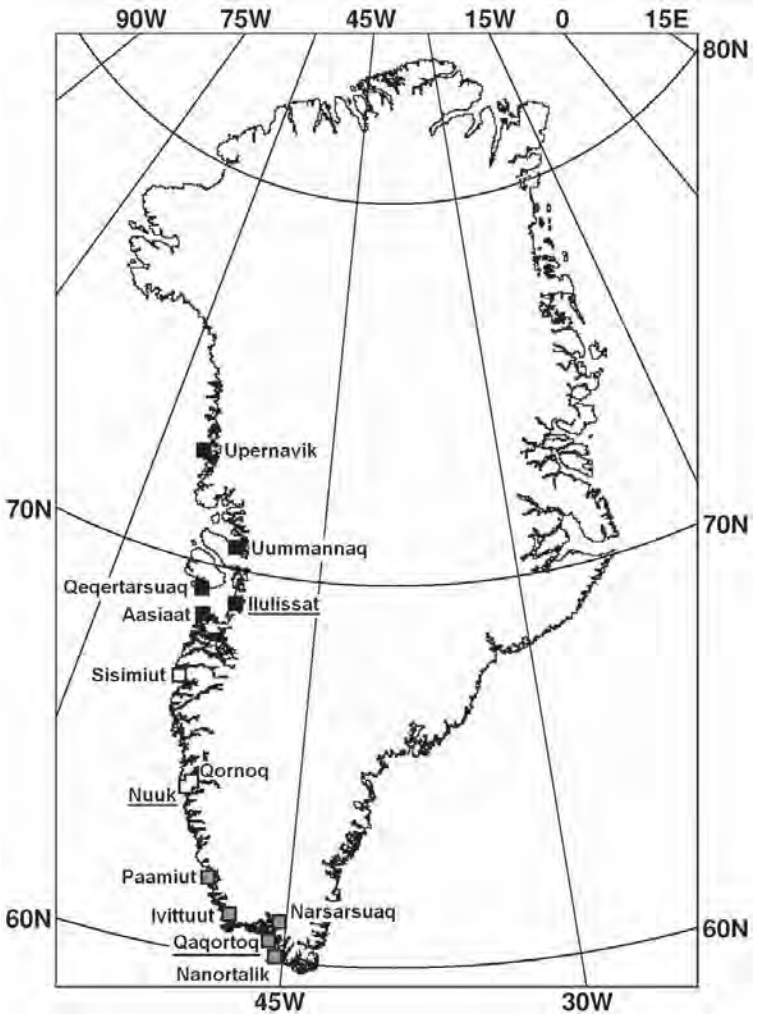
Motivation

- Extending Greenland temperature records into the late eighteenth century (Vinther *et al.* 2014)





Vinther *et al.* 2014

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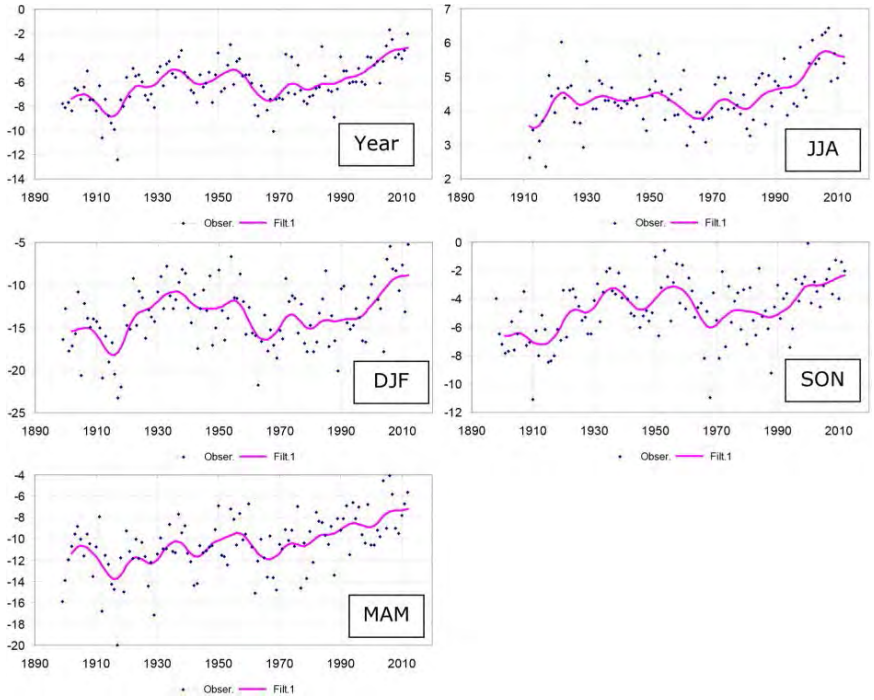
Motivation

- Extended Svalbard Airport temperature series, 1898–2012 (Nordli *et al.* 2014)



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Data rescue activity

PRELIMINARY ARCHIVAL RESEARCH

Norwegian Meteorological Institute and National Archive in Oslo, 2016 (Przemek and Øyvind)

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Data rescue activity

Sub-daily data for Myggbukta 1926-1957 and Torgilsbu 1932-1940 were digitised and QC in 2017:

T2m, daily $T2m_{min}$, relative, humidity, atmospheric pressure, wind direction and speed, precipitation, snow coverage and thickness, cloudiness (1-10)

Sub-daily data for other east Greenland stations nearby Myggbukta were digitised:

- Jonsbu 1932-33
- Micardbu1938-39

and Polish expidition to

- Byornoya 1932-33

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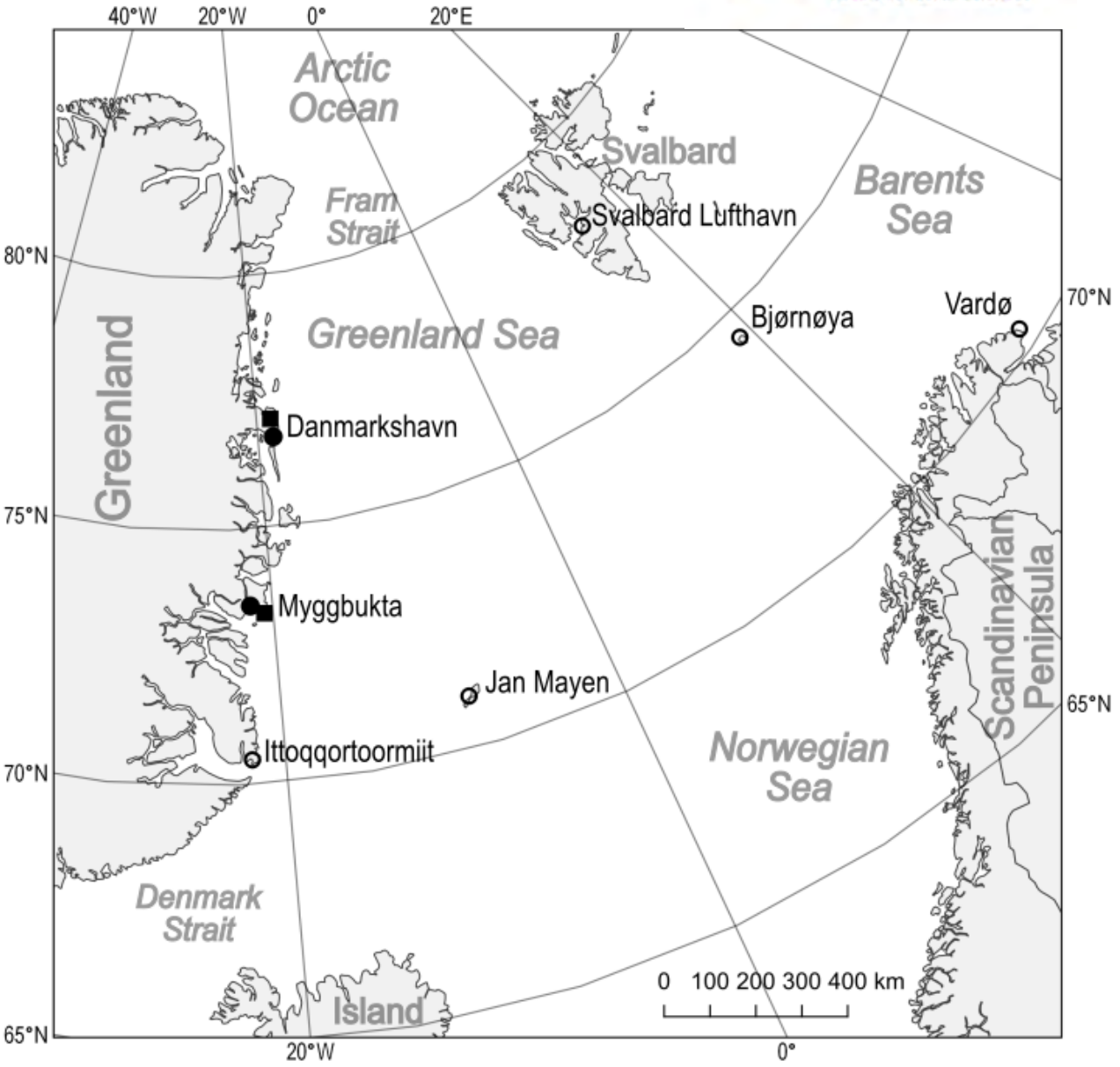
Area



Location of meteorological stations in the North Atlantic referred to in the paper. Filled dots show observational sites and squares show the nearest grid points from reanalysed data, which are included into the extended NE Greenland temperature series.

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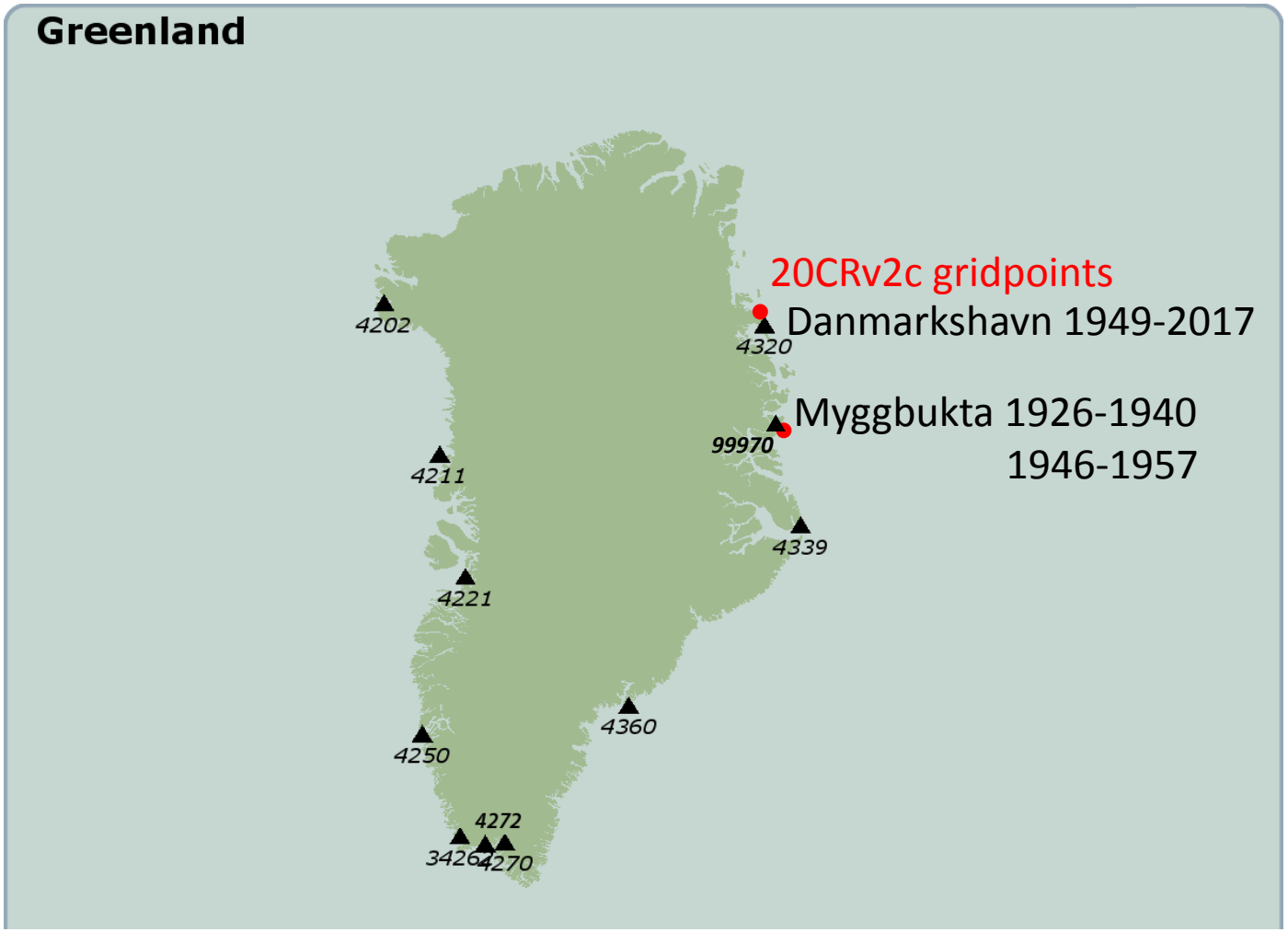
Area



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Data

Principle series and local series included in the composite NE Greenland series.

National station no.	Name	Latitude (°N)	Longitude (°W)	H. a.s.l. (m)	Whole period of observations	Inclusion in the composite series	Data resolution
4320	Danmarkshavn	76.77	18.67	14 (1948.11.04-1957.12.31) 11 1958.01.01-present	**1949.01.05-1992.12.31** (there are few gaps)	1949.01.01-1954.10.31 1954.12.01-1977.08.07 1977.08.26-1981.06.24 1981.11.01-1992-12.31	daily
					1993.01-2017.12	1993.01-2017.12	monthly
99970	Myggbukta	73.49	21.53	3	**1926.08.05-1940.07.31** (there are many gaps)	1926.08.05-1927.10.31 1927.12.01-1928.01.15 1928.05.18-1928.11.23 1928.11.19-1929.10.13 1929.12.13-1930.02.25 1930.04.24-1930.07.31 1930.09.28-1930.11.05 1930.12.26-1931.02.14 1931.05.28-1931.11.04 1931.12.11-1940.07.31	daily
					1946.09.01-1958.12.31	1946.09.01-1948.12.31	daily
gridpoint	20CRv2c	77.14	18.75		**1851.01.01-2012.12.31**	1977.08.08-1977.08.31 1981.06.25-1981.10.31	daily
gridpoint	20CRv2c	73.33	20.60		**1851.01.01-2012.12.31**	1926.08.01.1926.08.04 1927.11.01-1927.11.30 1928.01.16-1928.05.17 1928.11.24-1928.12.18 1929.10.14-1929.12.12 1930.02.26-1930.04.23 1930.08.01-1930.09.27 1930.11.06-1930.12.25 1931.02.15-1931.05.27 1931.11.05-1931.12.10 1940.08.01-1946.08.31	daily

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Methods

- Manual digitization and QC of subdaily data for Myggbukta

- Creating daily series for Myggbukta

  1926.08.05-1940.07.31
  1946.09.01-1958.12.31

- Manual digitization and QC of daily data for Danmarkshavn

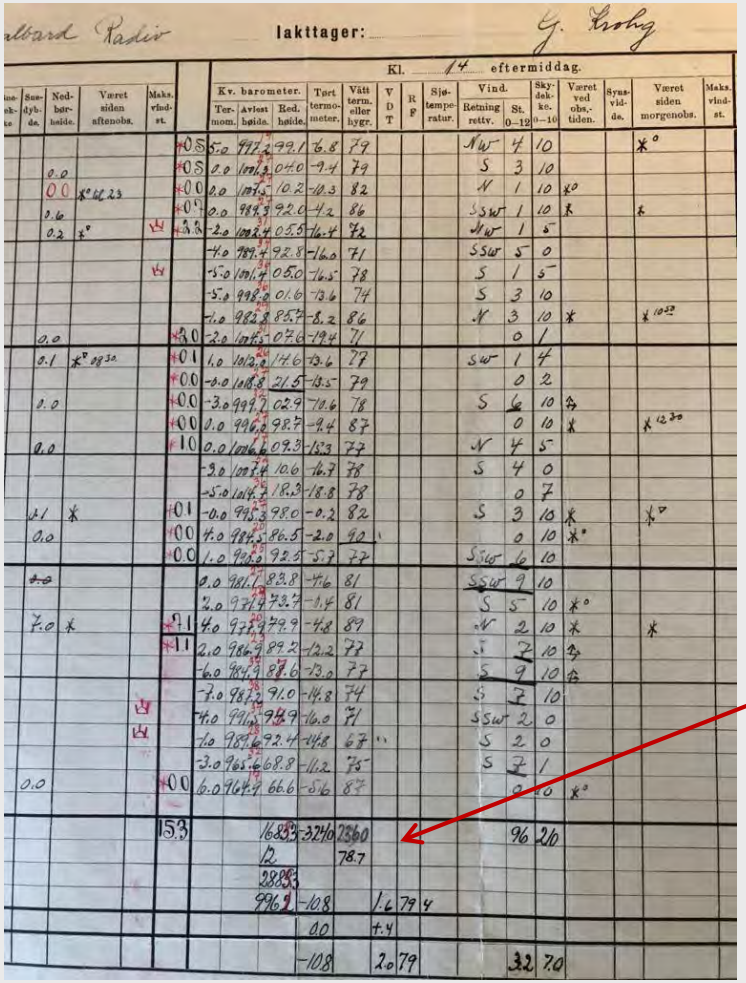
  1949.01.05-1992.12.31

  (Przybylak 1996)

Myggbukta 1926-1957

Photo 1931

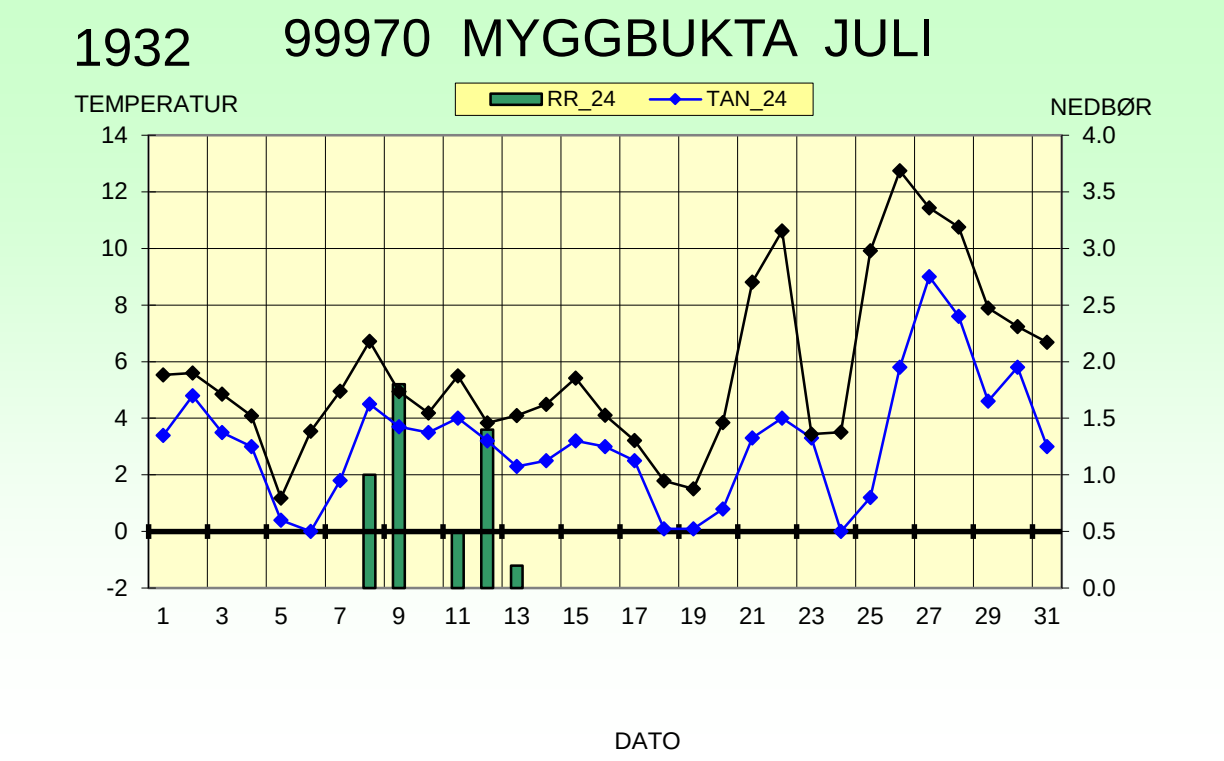
Digitalization, control # 1



Olav P. Amundgård

Column sums

Digitalization, control # 2



Thanks to Olav

Visual control: Diagrams for temperature and precipitation.

A special control: for Minimum thermometer.

Köppen's formula for mean temperature, T_m

$$T_m = \bar{T}_f - k\left(\bar{T}_f - \bar{T}_n\right)$$

$$\bar{T}_f = \frac{1}{3}\left(\bar{T}_{morning} + \bar{T}_{midday} + \bar{T}_{evening}\right)$$

$\bar{T}_n$ = mean of the daily minimum temperature.
k = Köppen's constant, for short also called the k-value.

Köppen's formula is also used for daily mean temperature, and:
The monthly mean is the arithmetic mean of all daily means in the month

The quality of Köppen's formula has shown to be good: (Köppen 1888; Birkeland 1936; Høgåsen 1993; Nordli and Tveito 2008; Nordli et al. 2015)

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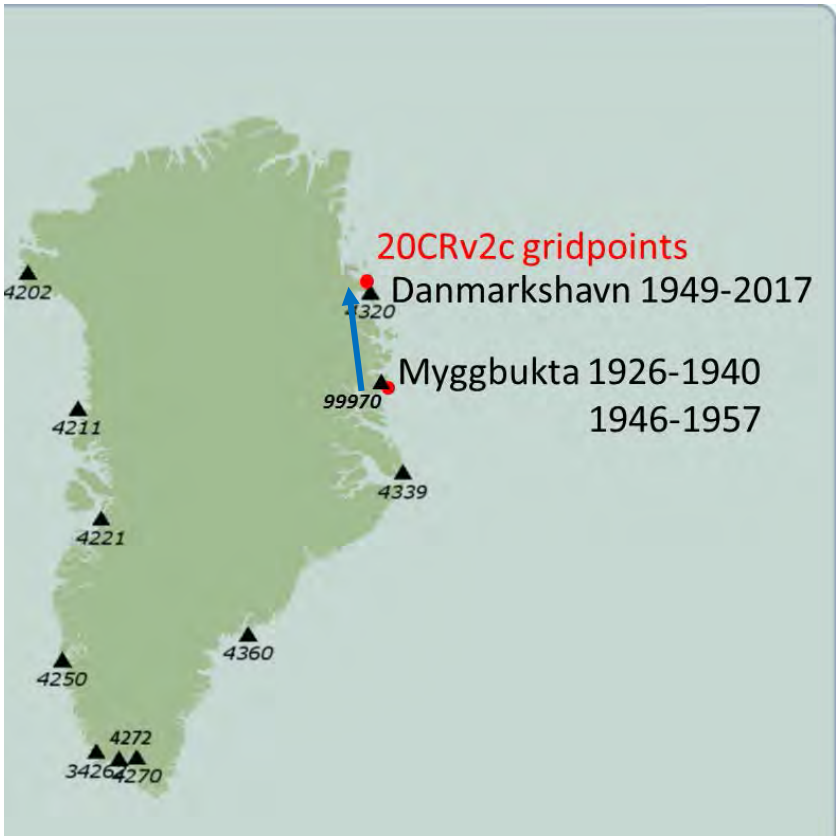
Methods (Nordli *et al.* 2014)

- Gaps filling by adjusted data, T_c (predictand), from the regression equation:

$$T_c = \alpha T_p + C \qquad (1)$$

where T_P is the daily mean temperature of a neighbouring series (predictor) and α and C are constants calculated by the least square method



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Regressions on daily values: α and C are coefficients in Eqn. 1, SSR/SST is the regression sum of squares divided by the total sum of squares in % (accounted for by the regression), RMSE (°C) is the root mean square of the residuals.

Coefficient	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Danmarkshavn-Myggbukta (overlapping period 1949.01.01-1958.12.31)												
α	0.621	0.604	0.585	0.627	0.739	0.773	0.530	0.544	0.830	0.641	0.548	0.560
C	-9.62	-9.52	-10.35	-7.56	-2.32	0.57	2.01	0.81	-2.42	-6.50	-9.52	-10.10
SSR/SST(%)	59	70	61	57	62	52	29	36	75	57	61	53
RMSE (daily)	4.3	4.0	3.5	3.4	2.8	2.1	2.4	2.0	2.0	3.3	3.4	4.3
RMSE (monthly)	0.8	0.7	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.6	0.6	0.8
Myggbukta-20CRv2c (overlapping period 1932.01.01-1940.07.31 and 1946.12.31 1958.12.31)												
α	1.118	1.132	0.740	0.728	0.882	1.419	1.150	0.688	0.895	1.014	1.005	1.075
C	-1.24	-0.74	-8.37	-7.34	-1.82	1.96	3.09	3.58	2.33	-0.55	-3.58	-2.44
SSR/SST(%)	48	49	29	35	43	20	70	11	41	44	37	44
RMSE (daily)	6.5	6.8	6.3	5.2	3.4	2.6	2.8	2.4	2.9	4.4	5.7	6.2
RMSE (monthly)	1.2	1.2	1.1	0.9	0.6	0.5	0.5	0.4	0.5	0.8	1.0	1.1
Danmarkshavn-20CRv2c (overlapping period1949.01.01-1992.12.31)												
α	0.682	0.599	0.511	0.44	0.641	0.865	0.600	0.678	0.686	0.633	0.645	0.669
C	-7.75	-9.94	-11.83	-10.08	-2.77	1.83	3.59	3.41	0.62	-4.58	-7.74	-7.98
SSR/SST(%)	54	48	40	35	42	22	13	23	49	48	47	49
RMSE (daily)	4.7	4.7	4.5	4.1	3.5	2.4	2.6	2.2	2.6	3.6	4.0	4.4
RMSE (monthly)	0.8	0.9	0.8	0.8	0.6	0.4	0.5	0.4	0.5	0.7	0.7	0.8

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Methods

- Estimation of uncertainties for the interpolated daily and monthly means (RMSE)
- Significance test of long-term trends (sequential Mann-Kendall test)
- Smoothing procedures (Gaussian low-pass filter with a standard deviation of three years, which corresponds to a rectangular filter of about 10 years)
- Temperature regime shifts by SRSD (Sequential Regime Shift Detector), Rodionov 2004
- Continentality (K-index, Ewert 1972).
- Dominance analysis in multiple regression (Budescu 1993).

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Results

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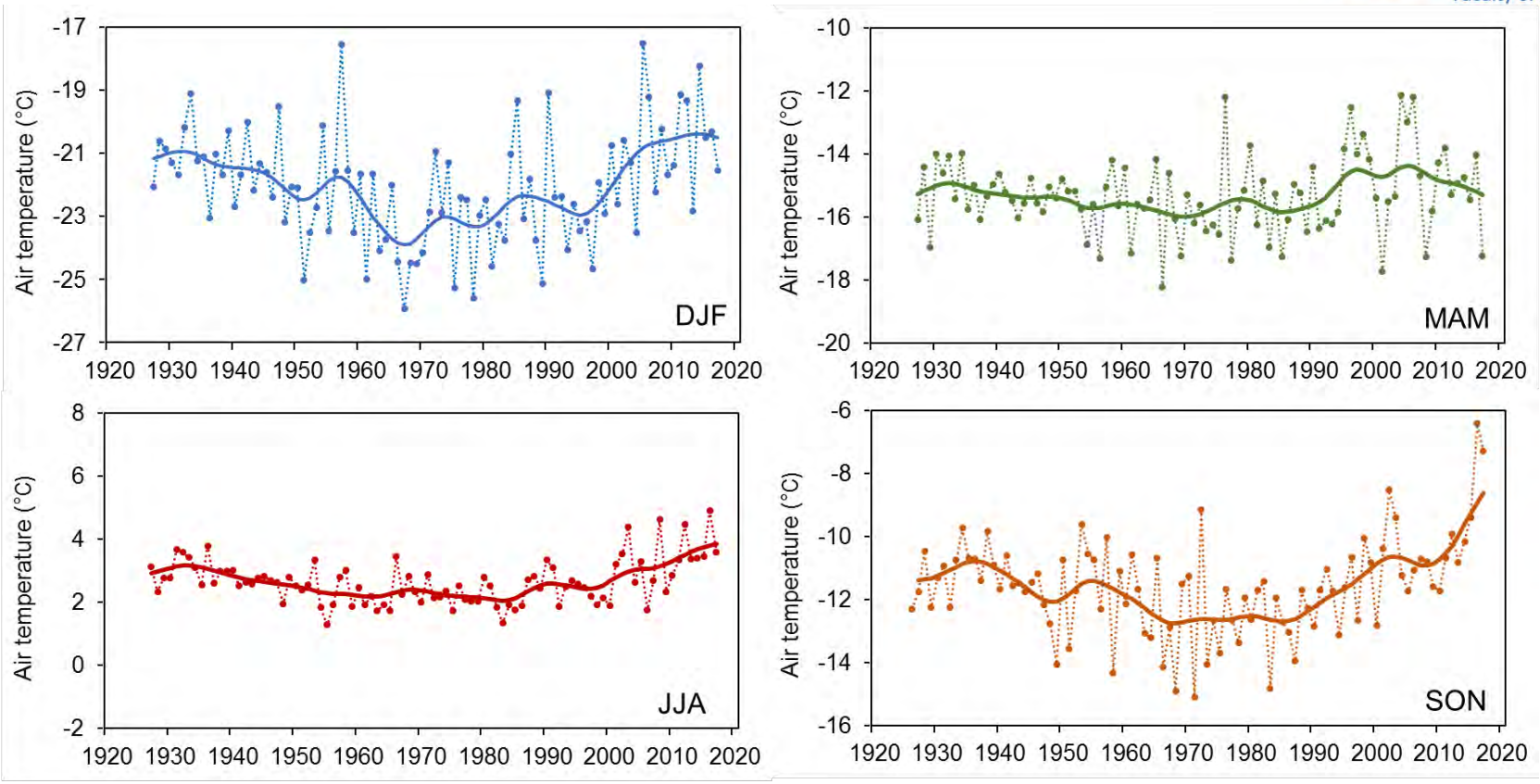

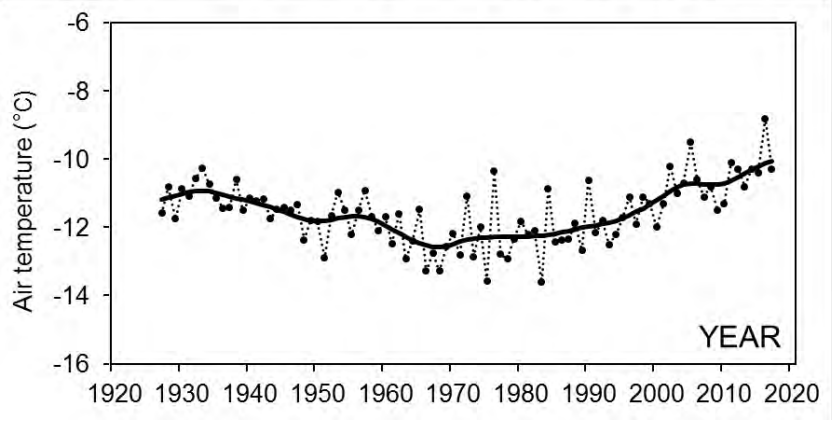

Long-term annual and seasonal mean temperatures (°C) for the extended NE Greenland series. Individual years (dots) are filtered by a Gaussian low-pass filter (thick curve) with a standard deviation of three years, which corresponds to a rectangular filter of about 10 years. The end of the curves is not significant because parts of the Gaussian weighting coefficients lie on unknown future observations. For 2017, this part is 38%, for 2011, 5%.

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Standard normals and decadal means of air temperature (°C) in the extended NE Greenland series

	DJF	MAM	JJA	SON	YEAR
1931-1960	-21.6	-15.3	2.7	-11.4	-11.4
1961-1990	-23.1	-15.8	2.3	-12.6	-12.3
1981-2010	-22.1	-15.1	2.6	-11.7	-11.6
Diff. (31-60) – (81-10)	0.5	-0.2	0.1	0.2	0.1
1927-1936	-21.1	-15.0	3.1	-11.1	-11.0
2008-2017	-20.5	-15.3	3.6	-9.9	-10.5
Diff. (27-36) – (08-17)	-0.6	0.3	-0.5	-1.2	-0.6

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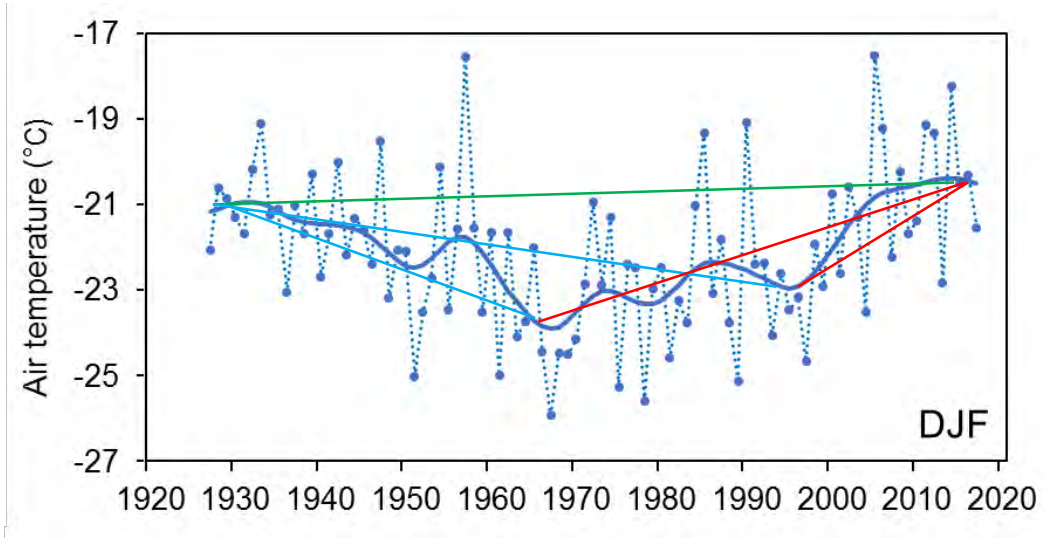

Linear trends (°C/decade) for the extended NE Greenland series. Numbers in boldface denote a trend significant at the 5% level.

Period	DJF	MAM	JJA	SON	YEAR
1927-2017	0.02	0.05	0.04	0.09	0.06
1927-1966	**-0.57**	-0.23	**-0.28**	**-0.33**	**-0.36**
1927-1996	**-0.31**	-0.05	**-0.11**	**-0.22**	**-0.18**
1968-2017	**0.70**	**0.28**	**0.32**	**0.77**	**0.53**
1978-2017	**0.88**	0.23	**0.46**	**0.98**	**0.66**

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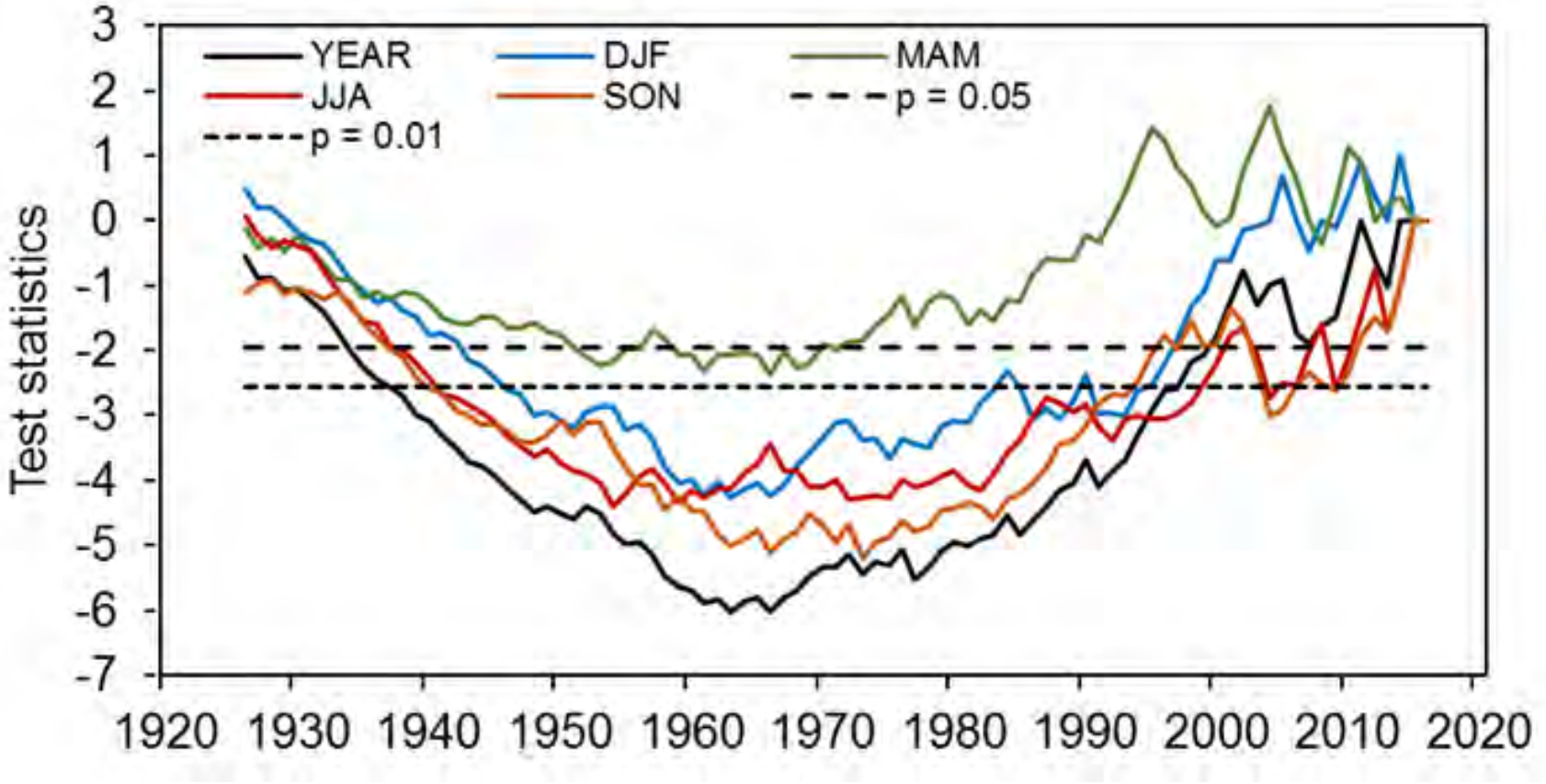

Significance of trends in the extended NE Greenland series. Test statistic of sequential Mann-Kendall test of annual and seasonal temperature means is shown. Beginning at the end of the time series, the test statistic is recalculated for every year added to the time series. Two horizontal lines showing the significance levels 5 % and 1 % are also included.

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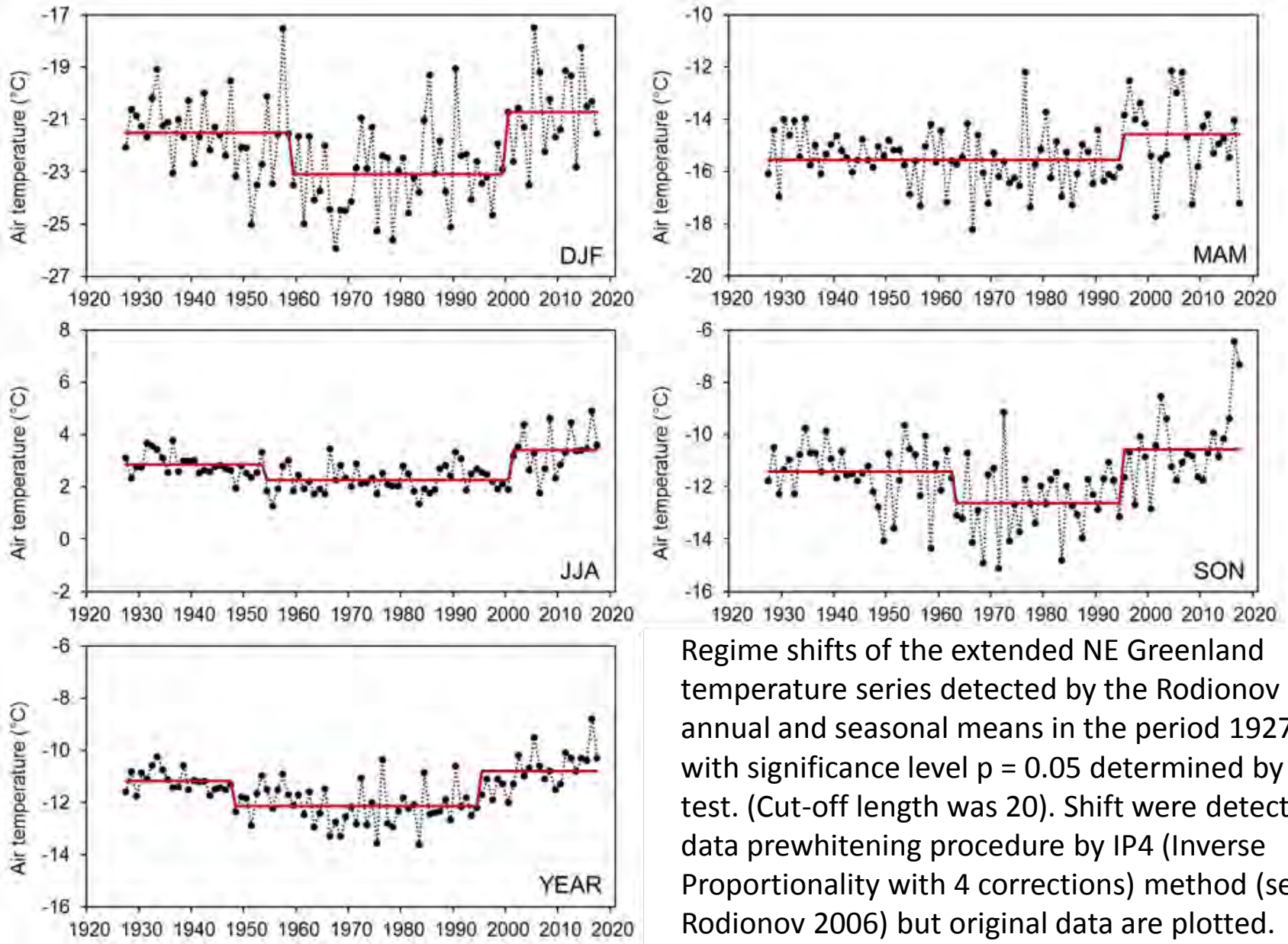

Regime shifts of the extended NE Greenland temperature series detected by the Rodionov test for annual and seasonal means in the period 1927-2017 with significance level p = 0.05 determined by Student's test. (Cut-off length was 20). Shift were detected after data prewhitening procedure by IP4 (Inverse Proportionality with 4 corrections) method (see Rodionov 2006) but original data are plotted.

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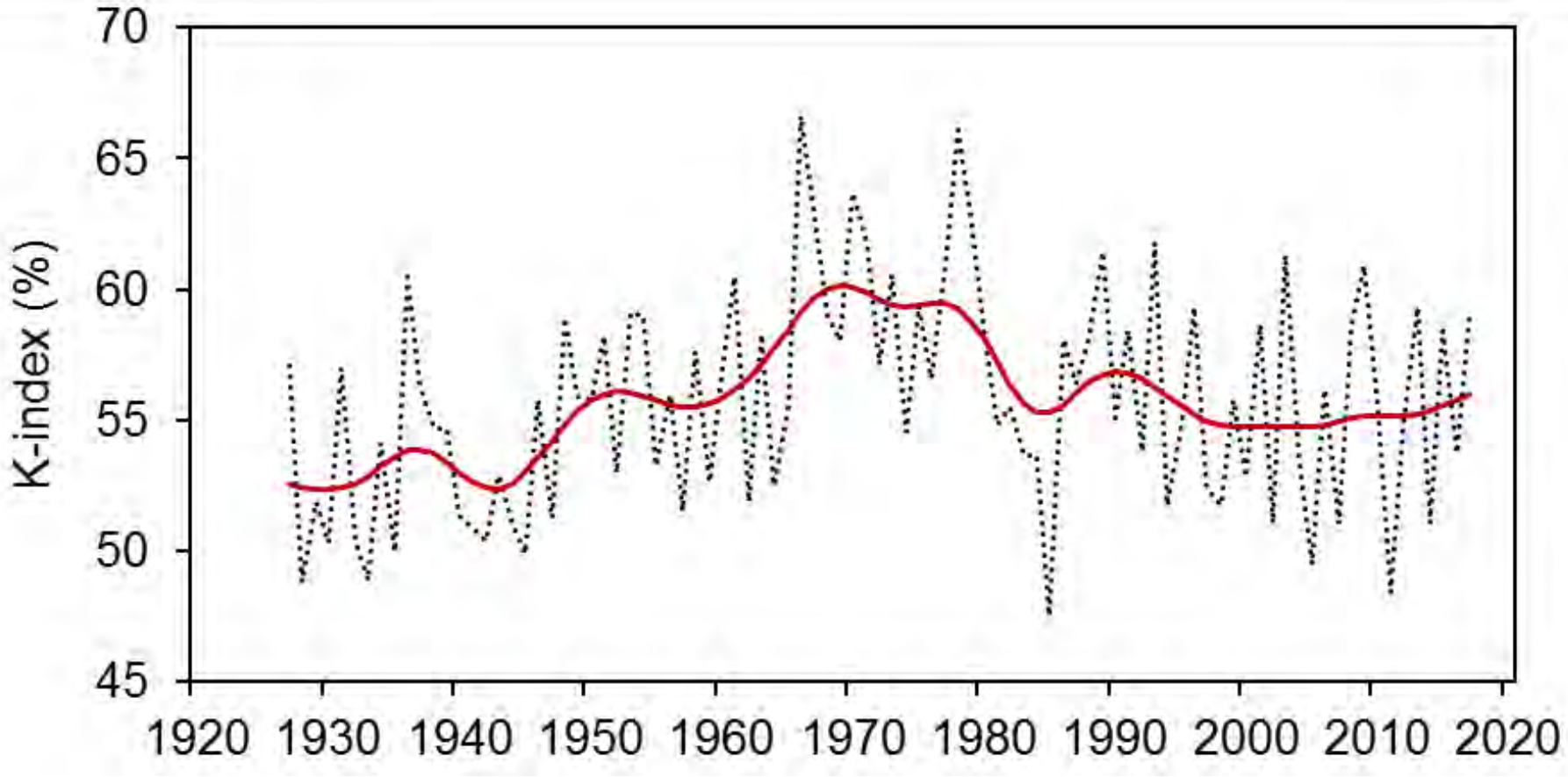

K-index (%) of the reconstructed NE Greenland series in the period 1927-2017. The time series has been filtered using a Gaussian filter with a standard deviation of three years. The unfiltered series is also included (dotted line). The end of the filtered curves is not significant because parts of the Gaussian weighting coefficients lie on unknown future observations.

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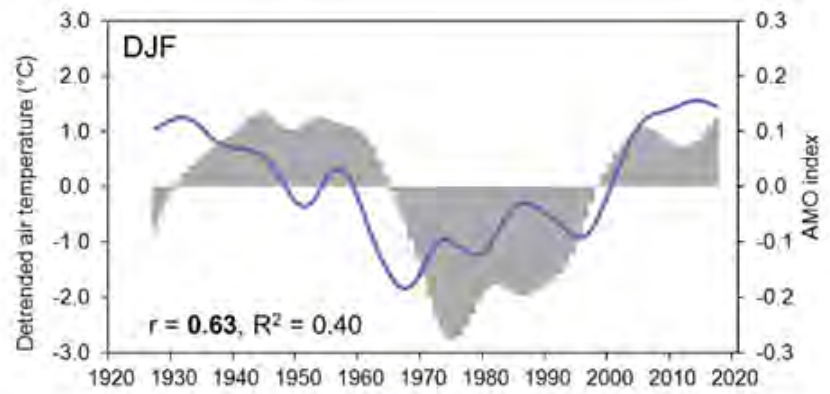

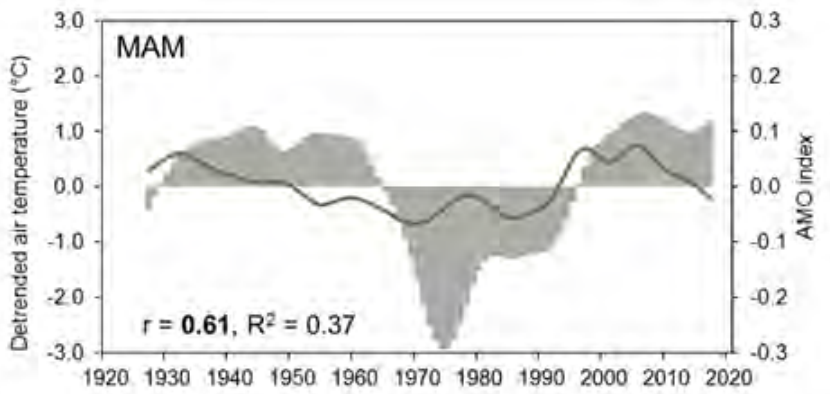

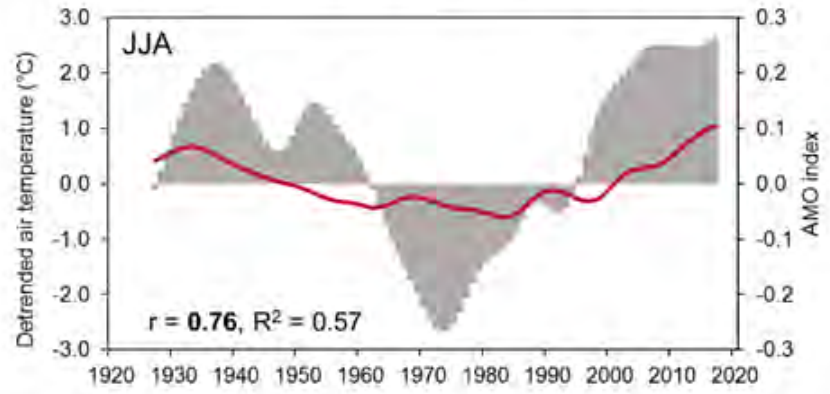

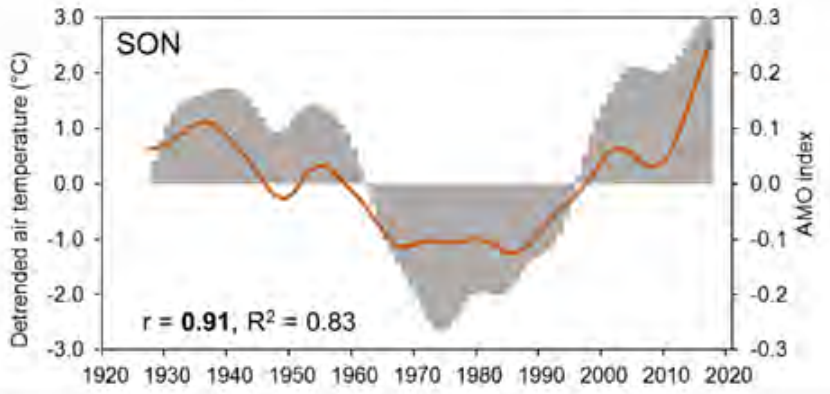

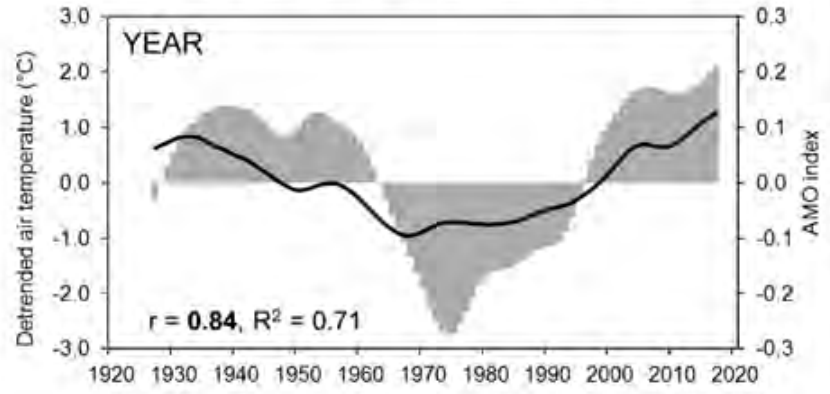

Seasonal and annual year-to-year courses the extended NE Greenland temperature series (lines) and the **Atlantic Multidecadal Oscillation** (AMO, shadows) index. Both, temperature and AMO index, time series have been filtered using a Gaussian filter with a standard deviation of three years. Correlation coefficients (r in bold) show significance on the $p \leq 0.05$ level.

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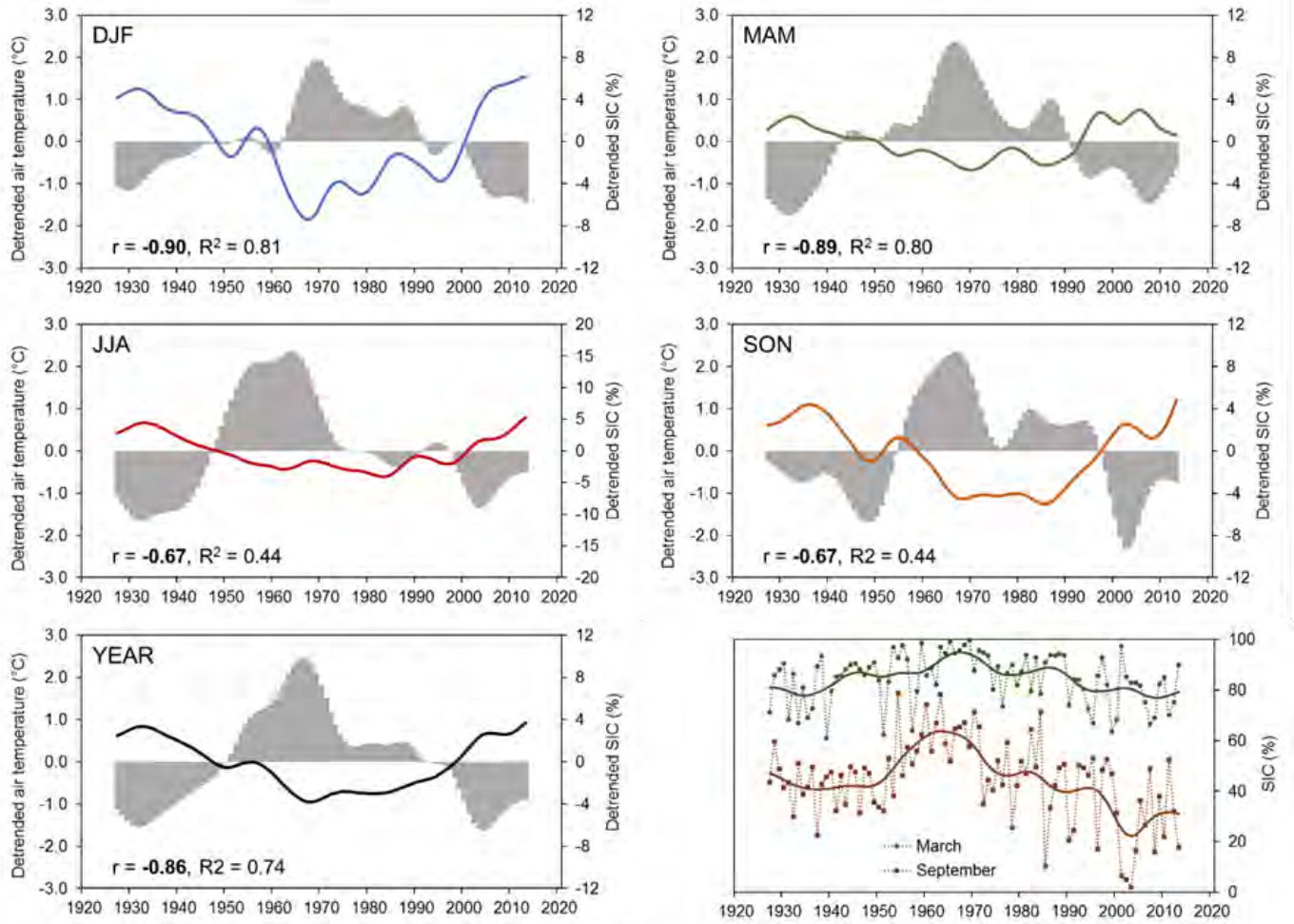

Seasonal and annual year-to-year courses the extended NE Greenland temperature series (lines) and **sea ice concentration** (SIC, shadows; after Walsh et al. 2016). Average SIC was calculated for the area 80-70°N and 30-10°W. Both, temperature and SIC, time series have been filtered using a Gaussian filter with a standard deviation of three years. Correlation coefficients (r in bold) show significance on the $p \leq 0.05$ level. Analysis was conducted for the period 1927-2013.

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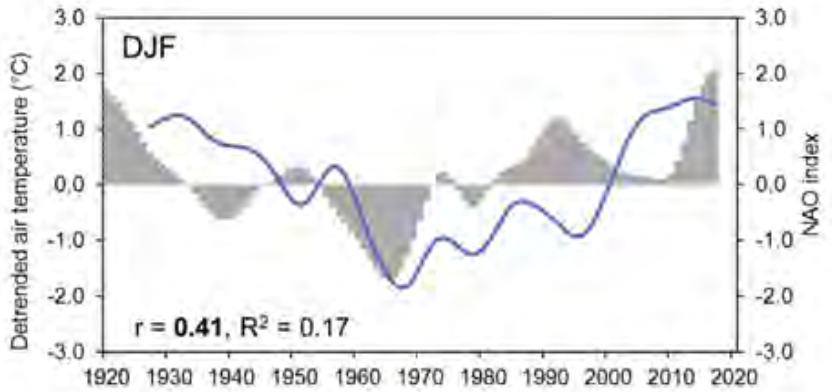

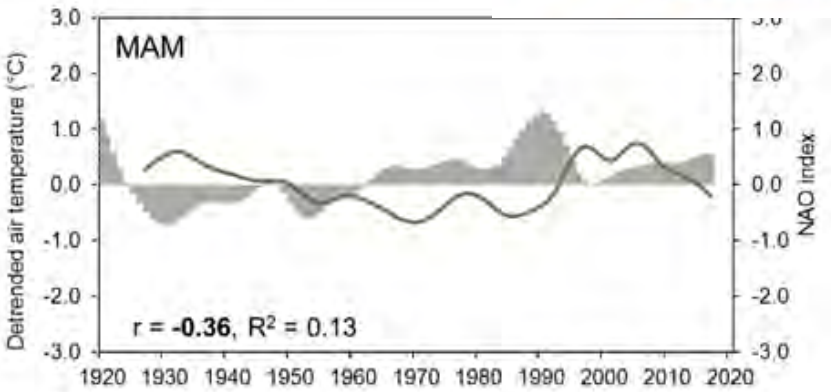

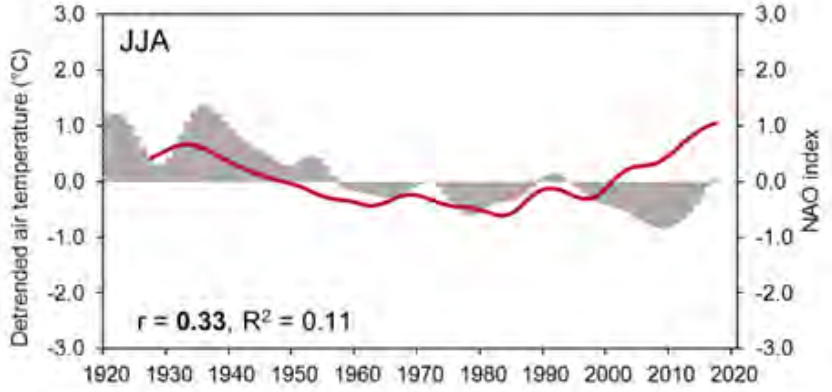

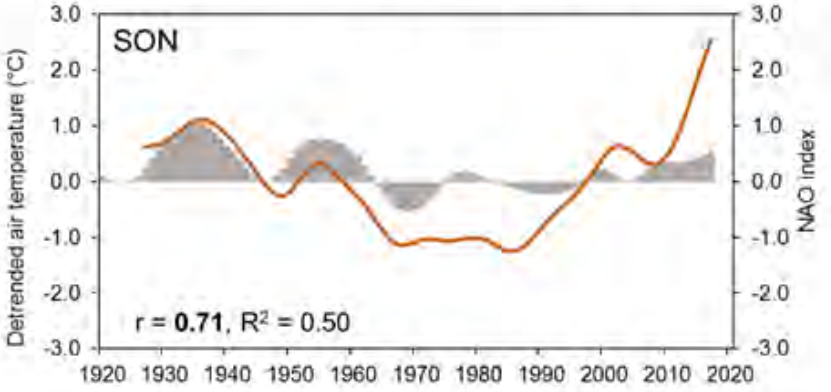

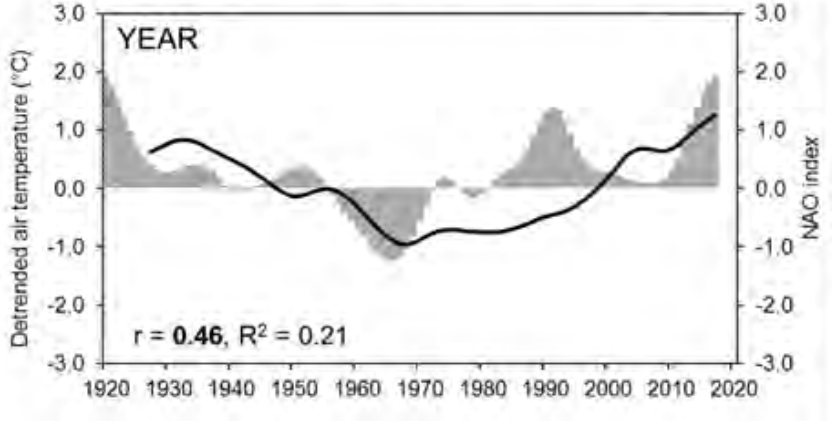

Seasonal and annual year-to-year courses the extended NE Greenland temperature series (lines) and **North Atlantic Oscillation** (NAO station-based index, shadows; after Hurrell 1995, updated). Both, temperature and NAO, time series have been filtered using a Gaussian filter with a standard deviation of three years. Correlation coefficients (r in bold) show significance on the $p \leq 0.05$ level.

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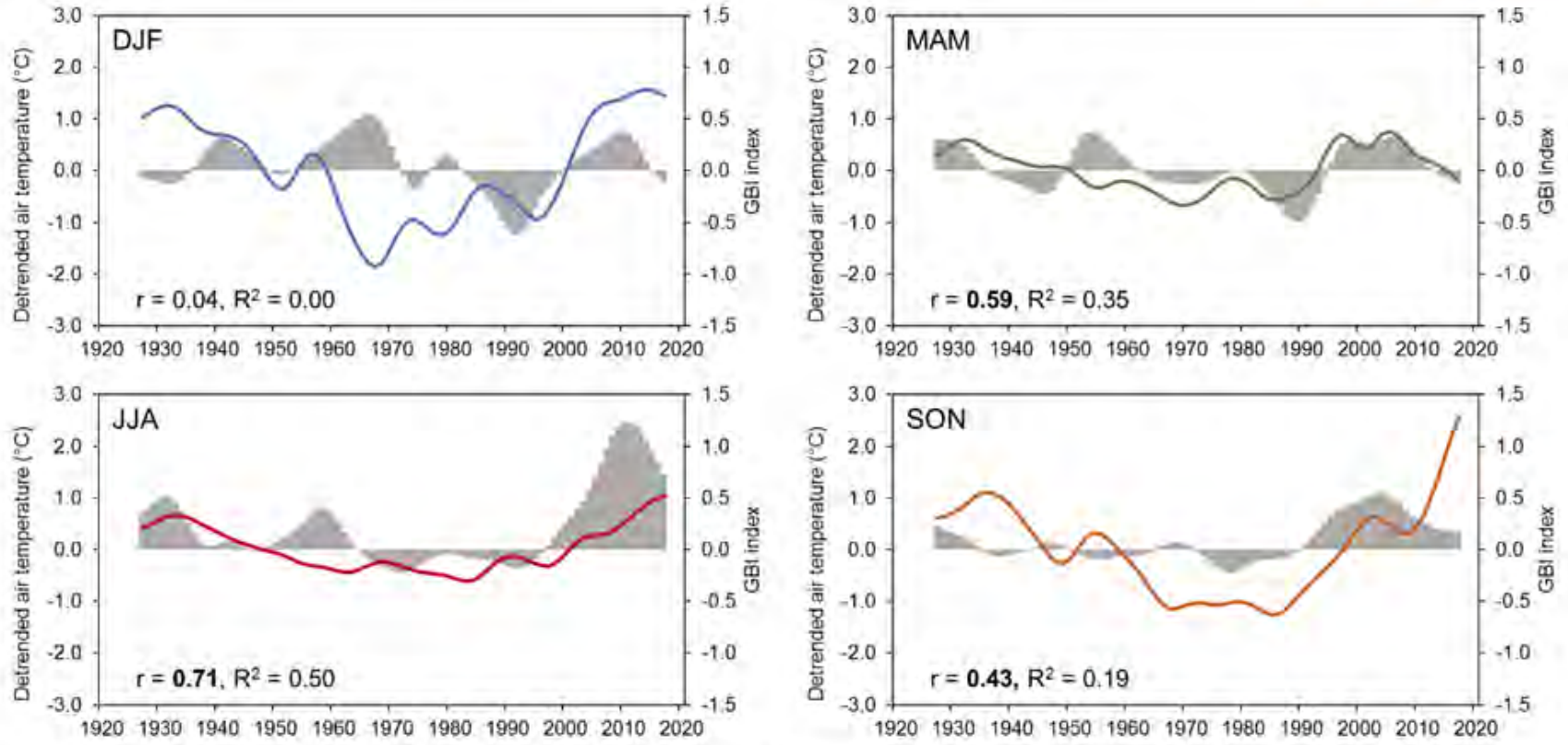

Seasonal and annual year-to-year courses the extended NE Greenland temperature series (lines) and **Greenland Blocking Index** (GBI, shadows; after Hanna et al. 2016, updated). Both, temperature and GBI, time series have been filtered using a Gaussian filter with a standard deviation of three years. Correlation coefficients (r in bold) show significance on the $p \leq 0.05$ level.

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Dominance of individual factors (predictors) in explaining the variability of the extended NE Greenland temperature (predictand) in the period 1927-2013. R^2 of individual factors were obtained by **multivariate regression** (MVR).

Dominance	Season	AMO	SIC	NAO	GBI	Sum of R^2
General	DJF	0.19	0.51	0.08	0.03	0.82
	MAM	0.16	0.53	0.04	0.13	0.86
	JJA	0.23	0.23	0.16	0.28	0.90
	SON	0.38	0.15	0.29	0.09	0.91
	YEAR	0.31	0.37	0.07	0.18	0.93
Rescaled	DJF	23.5	62.4	10.0	4.0	100
	MAM	18.6	61.9	4.1	15.4	100
	JJA	25.4	25.9	18.0	30.7	100
	SON	41.8	16.3	31.6	10.4	100
	YEAR	33.4	40.0	7.1	19.6	100

Note: Rescaled dominance (in %) was computed by dividing the general dominance estimates by the sum of R^2. Dominance analysis in multiple regression was performed by the method provided by Budescu (1993).

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Dominance of individual factors (predictors) in explaining the variability of the extended NE Greenland temperature (predictand) in the period 1927-2013. R^2 of individual factors were obtained by **locally weighted regression** (LOWESS).

Dominance	Season	AMO	SIC	NAO	GBI	Sum of R^2
General	DJF	0.21	0.53	0.11	0.14	0.99
	MAM	0.19	0.46	0.10	0.25	0.99
	JJA	0.22	0.30	0.26	0.22	1.00
	SON	0.34	0.27	0.24	0.13	0.98
	YEAR	0.27	0.42	0.09	0.22	1.00
Rescaled	DJF	20.8	53.3	11.3	14.6	100
	MAM	19.2	46.2	9.7	24.9	100
	JJA	22.2	29.7	26.1	22.0	100
	SON	34.9	27.9	24.0	13.2	100
	YEAR	27.0	41.7	9.0	22.3	100

Note: Rescaled dominance (in %) was computed by dividing the general dominance estimates by the sum of R^2. Dominance analysis in multiple regression was performed by the method provided by Budescu (1993).

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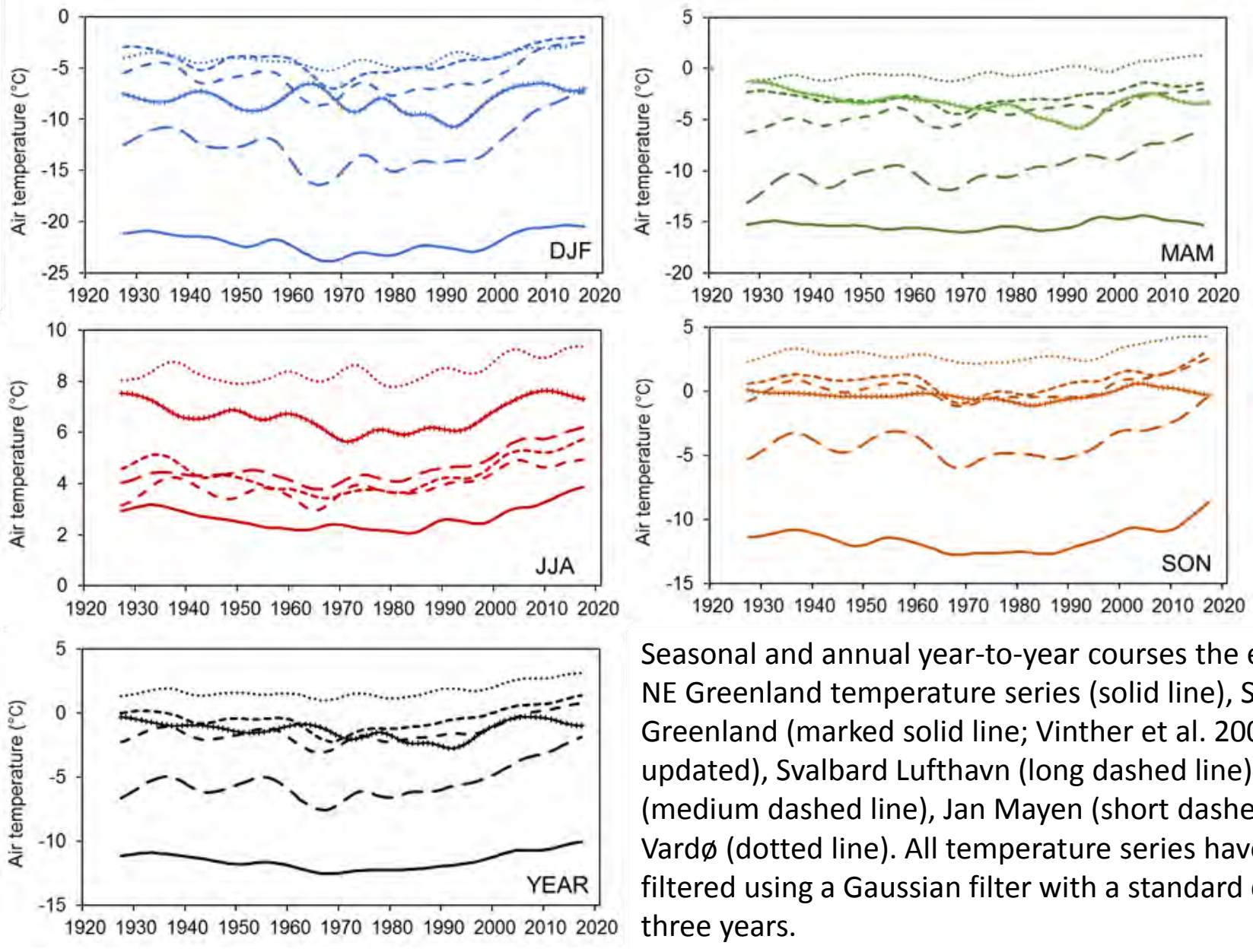

Seasonal and annual year-to-year courses the extended NE Greenland temperature series (solid line), SW Greenland (marked solid line; Vinther et al. 2006, updated), Svalbard Lufthavn (long dashed line), Bjørnøya (medium dashed line), Jan Mayen (short dashed line) and Vardø (dotted line). All temperature series have been filtered using a Gaussian filter with a standard deviation of three years.

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Mean seasonal and annual correlation coefficients (r) of air temperature between the extended NE Greenland series and nearest long-term meteorological stations. Correlation coefficients in bold indicate significance on the $p \leq 0.05$ level.

r	DJF	MAM	JJA	SON	YEAR
Jan Mayen	0.63	0.39	0.58	0.67	0.76
Svalbard Lufthavn	0.71	0.42	0.41	0.70	0.73
Bjørnøya	0.66	0.31	0.25	0.65	0.65
Vardø	0.37	0.25	0.25	0.39	0.51
SW Greenland	0.15	0.11	0.49	0.14	0.25

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Wnioski

- W okresie wczesnodwudziestowiecznego ocieplenia (ETCW) najcieplejszą okazała się dekada 1927-1936, która jednak była średnio rocznie chłodniejsza o 0.6°C od ostatniej dekady współczesnego ocieplenia (2008–2017).

- Dla całego badanego okresu 1927–2017 nie stwierdzono istotnych statystycznie trendów zmian sezonowej i rocznej temperatury powietrza. Wielkości trendów wahają się w granicach 0,02-0,06°C/dekadę.

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Wnioski

- W okresie pierwszych 40 lat (1927-1966) temperatura powietrza przeważnie spadała. W ostatnich badanych 40 latach (1978-2017) największe ocieplenie stwierdzono jesienią i zimą, kiedy wzrost temperatury wyniósł odpowiednio 0,98°C/dekadę i 0,88°C/dekadę. W obu wspomnianych wyżej podokresach zmiany średniej temperatury (spadek/wzrost) wiosny były nieistotne. Należy dodać jednak, że w ostatnim dwudziestoleciu (1998–2017) stwierdzono nawet nieistotną statystycznie tendencję jej ochładzania (-0,44°C/dekadę). Natomiast pozostałe sezony znacząco się w tym czasie ociepliły, szczególnie jesień i lato, kiedy trendy temperatury wyniosły odpowiednio 1,16°C/dekadę i 0,83°C/dekadę.

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Wnioski

- Stosując test Rodionova stwierdzono występowanie dwóch zmian reżimu termicznego, pierwsza wystąpiła na przełomie lat 50 i 60. XX w., czyli w momencie zakończenia się ETCW i rozpoczęcia ochłodzenia, a druga w połowie lat 90. XX w., kiedy w Arktyce, w tym w NE Grenlandii, obserwowano istotny wzrost tempa ocieplenia się klimatu.

- Okres ETCW wyróżniał się większym stopniem oceanizmu klimatu niż okres współczesny (K-indeks był niższy o ok. 2-3%). Natomiast w okresie chłodniejszym klimat wykazywał cechy bardziej kontynentalne.

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Wnioski

- Zrekonstruowana seria temperatury NE Grenlandii najlepiej koreluje z temperaturą powietrza ze stacji Jan Mayen, Svalbard Lufthavn i Bjørnøya. Współczynniki korelacji (r) średniej temperatury rocznej oraz zimy i jesieni kształtują się na poziomie od 0,63 do 0,76, natomiast wiosny i lata są dużo niższe (0,25–0,58). Korelacja serii NE Grenlandii spada do poniżej 0,50 w stosunku do obszarów położonych na wybrzeżu Morza Barentsa (stacja Vardø). Nie stwierdzono natomiast korelacji ze zrekonstruowaną przez Vinther'a i in. (2006) serią temperatury dla obszaru SW Grenlandii, z wyjątkiem sezonu letniego, dla którego jest istotnie statystyczna, r = 0,49.

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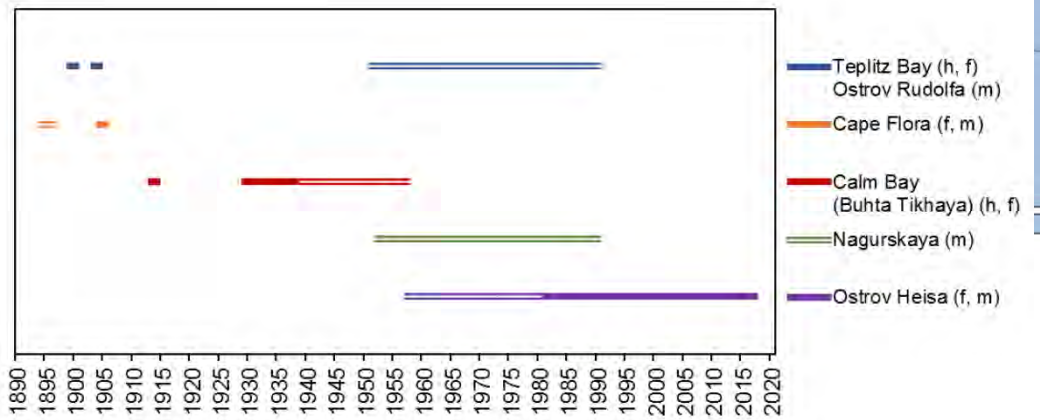
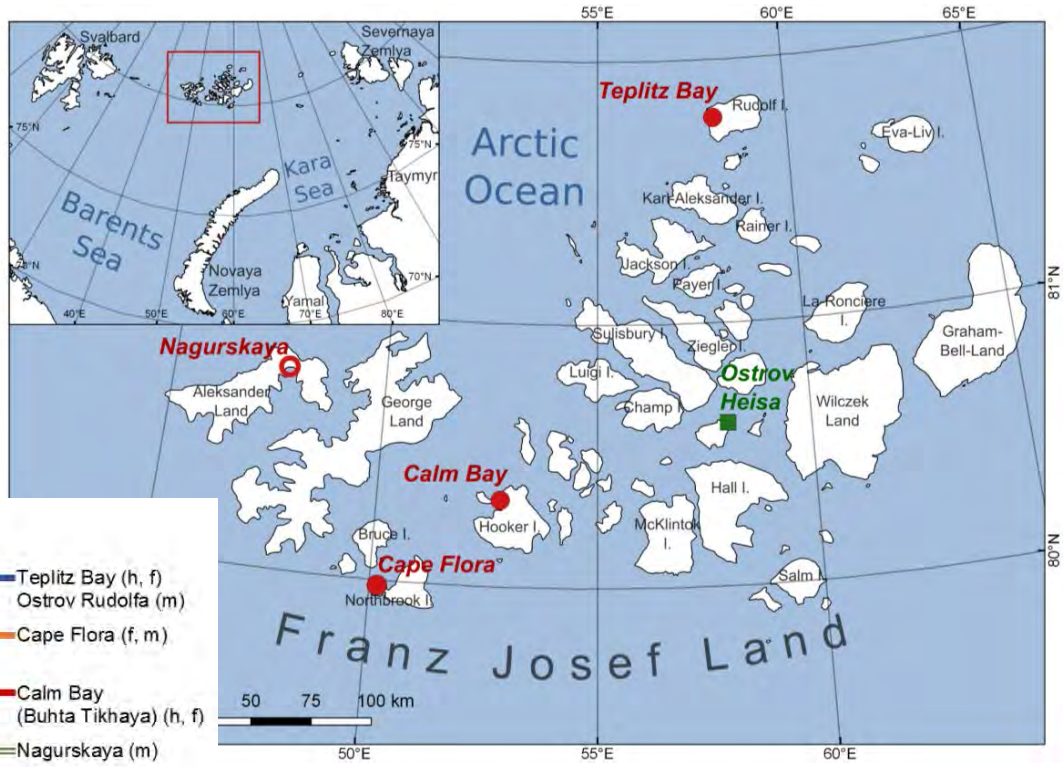
Next work

- Przemysław Wyszyński, Pavel Sviashchennikov, Rajmund Przybylak
  „The extended Franz Josef Land temperature series, 1929-2018”

Temporal distribution of the air temperature observations from meteorological land stations in Franz Josef Land. Key: filled lines – data used, blank lines – data not used, h – hourly resolution of data, f – fixed (sub-daily, see table below), m – monthly.





Location of land meteorological stations in Franz Josef Land. Filled dots and square indicate historical and present stations, respectively.

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XXIX Seminarium Meteorologii i Klimatologii Polarnej
9-10.05.2019, Wrocław

Dziękujemy za uwagę!

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