Evaluation of reanalyses for the Arctic based on instrumental historical observations

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Rajmund Przybylak[1], Przemysław Wyszyński[1], Daniel Klaus[2], Klaus Dethloff[2] and Tomasz Strzyżewski[1]

[1] Nicolaus Copernicus University, Department of Meteorology and Climatology, Toruń, Poland

[2] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

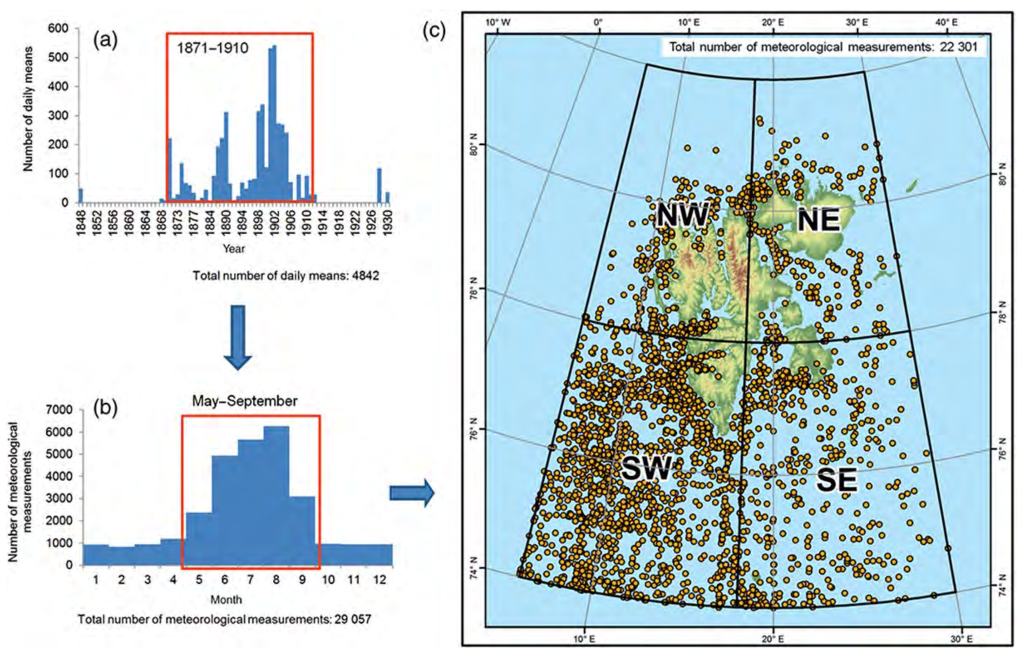
Contact: rp11@umk.pl, Przemyslaw.Wyszynski@umk.pl

NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ
Faculty of Earth Sciences

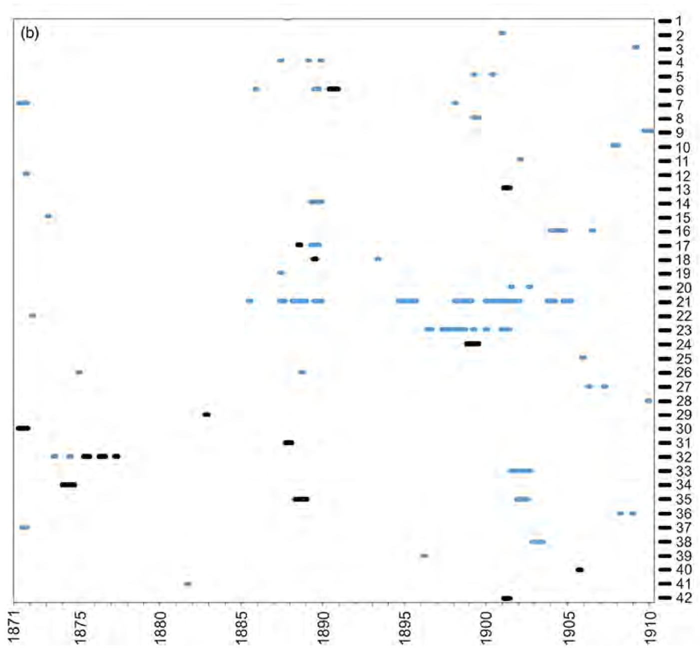
INTRODUCTION

The development of atmospheric reanalyses that assimilate only surface data thereby allowing one to extend the period of the datasets back to the mid 19th and early 20th century is one of the most significant advances in climate sciences. Our confidence in using these data sets to reconstruct past climate variability requires careful efforts to validate them against observations, especially in the Arctic, where the network of meteorological stations is sparse. Here we have compared different kinds of measured meteorological data with reanalysis products. One of our evaluation used air temperature taken from 20CRv2 and ERA20C reanalyses for the warm half-year in the periods 1871–1910 and 1901–1910, respectively. Data covered the maritime part of the Svalbard archipelago (74–82°N, 6–30°E). The majority of the data were taken from a Norwegian collection entitled Arctic Norwegian Logbook Data: 1867–1912 available at the Computational Information Systems Laboratory Research Data Archive (CISL RDA) at the National Center for Atmospheric Research (NCAR). Besides data downloaded from the CISL RDA, we also used air temperature data digitized from logbooks gathered by us as part of various data recovery projects. In this research we have compared air temperature data from observations made on ships and available in logbooks. Analysis was conducted for four regions (grid boxes, 4° latitude × 12° longitude) NW, NE, SW and SE. Secondly, we evaluated data available at 20CRv2 and its newer version (20CRv2c) for Calm Bay (Buchta Tikhaya) located in the Franz Josef Land archipelago for the period 1930–1940. This study investigates the quality of reanalyzed surface quantities, such as 2-m air temperature, 2-m specific humidity and 10-m horizontal wind speed. Comparison of vertical temperature structure produced by two versions of 20CR at Calm Bay was based on data taken from PANGAEA – Data Publisher for Earth & Environmental Science. This digital data library provides a historical archive of radiosondes and tracked balloons on standard pressure levels back to the 1920s.

AREA AND DATA 1 (Przybylak *et al.*, 2016, DOI: 10.1002/joc.4527)

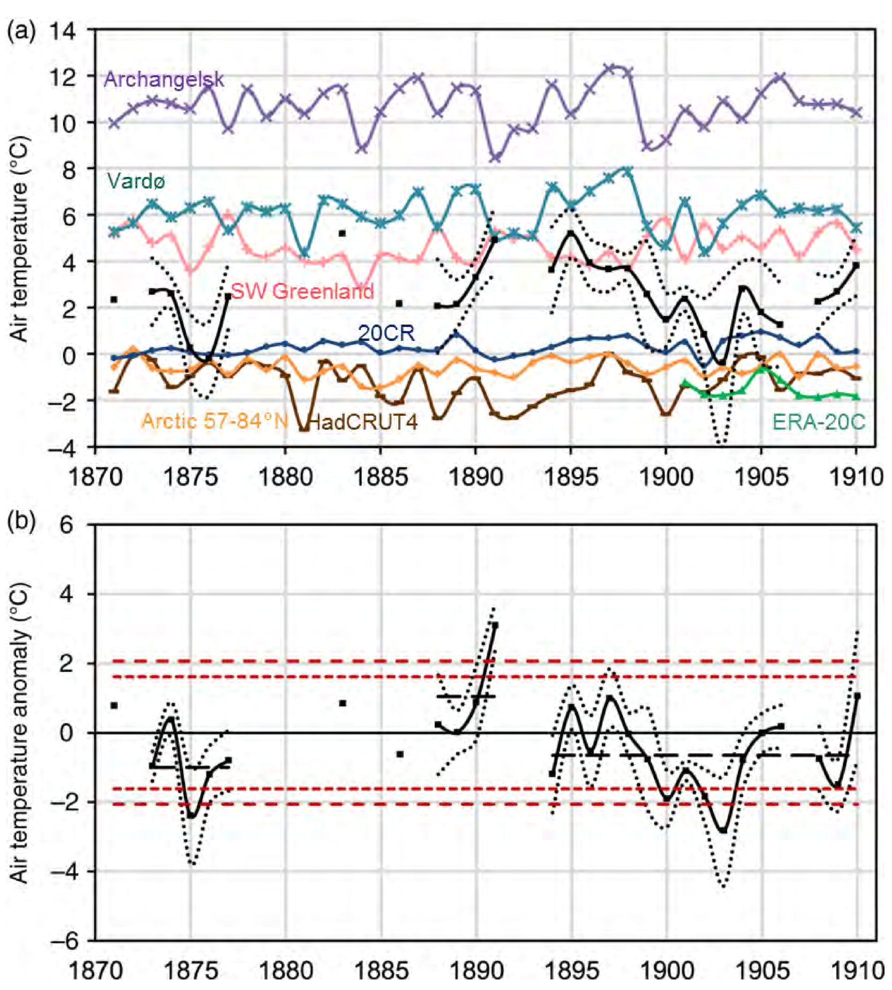


(a) Statistics of the collected data for all logbooks in the analysed area; the square marks the selected time frame. (b) Statistics of the collected data for the years 1871–1910 in the analysed area (monthly resolution); the square marks the selected time frame. (c) Mean daily positions (dots) of Norwegian 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).

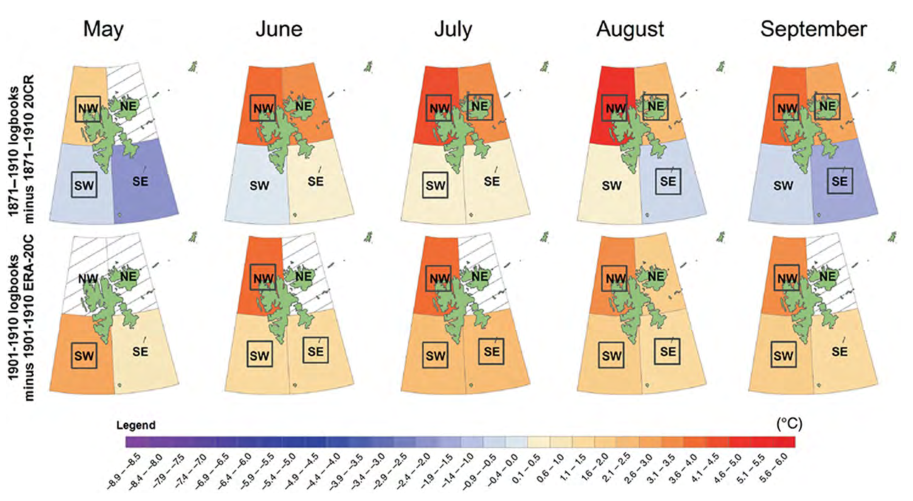


Temporal distribution of the air temperature observations from and ships (b), used in the study of the Svalbard archipelago and its surrounding seas from 1865 to 1920. Key to the lower panel: The black lines indicate data taken from the Arctic Norwegian Logbook Data: 1867–1912 at CISL RDA (http://rda.ucar.edu/,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

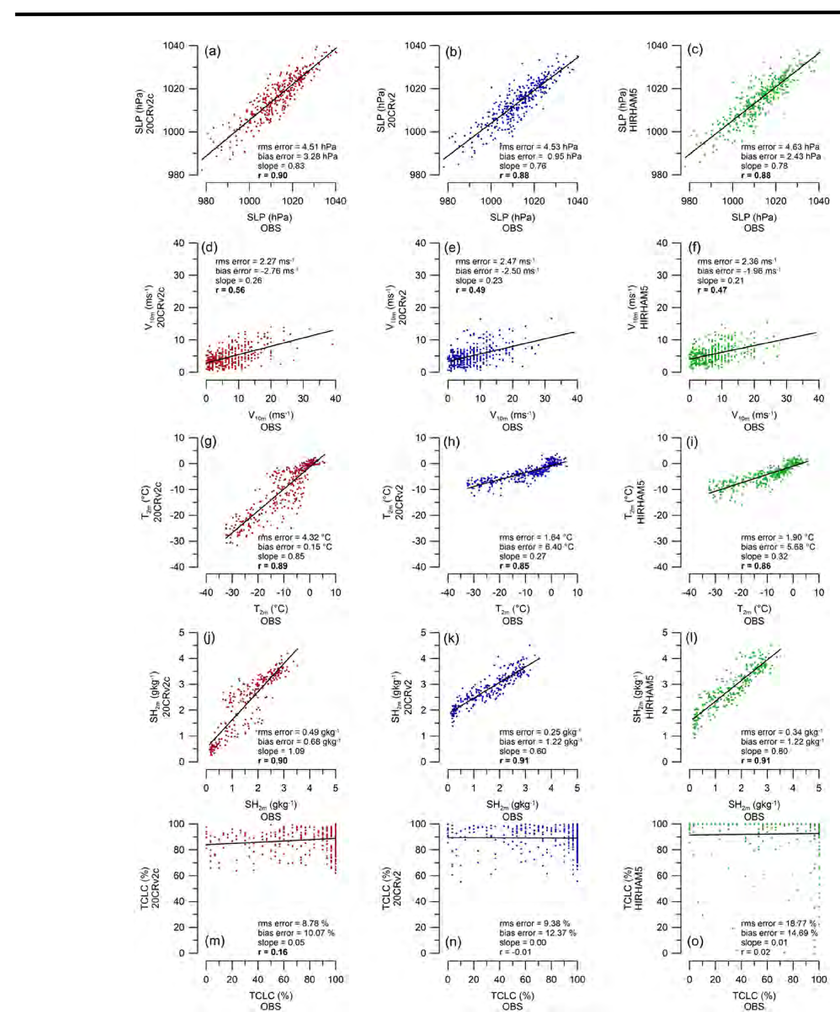
RESULTS 1



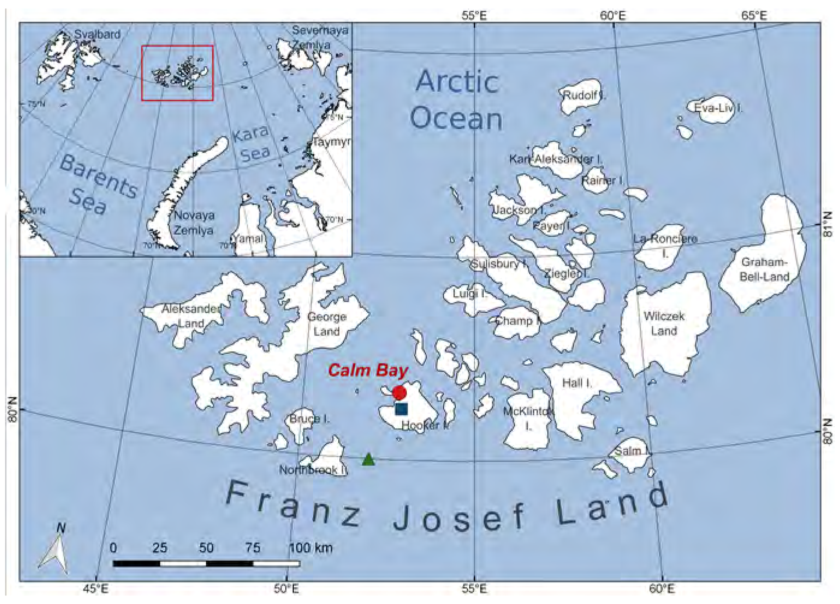
Air temperature variability in the Svalbard area (74–82°N and 6–30°E) in the period May–September 1871–1910, with comparison to other datasets (a) and present climatology 1981–2010 (b). Panel (A): reconstruction based on areally averaged data used in this study (black with squares) with a 95% confidence 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); ±3SDs 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.



Mean monthly differences of air temperature (°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 ≤ 0.05 level are shown by a grid label with squares.



AREA AND DATA 2 (Klaus *et al.*, submitted)



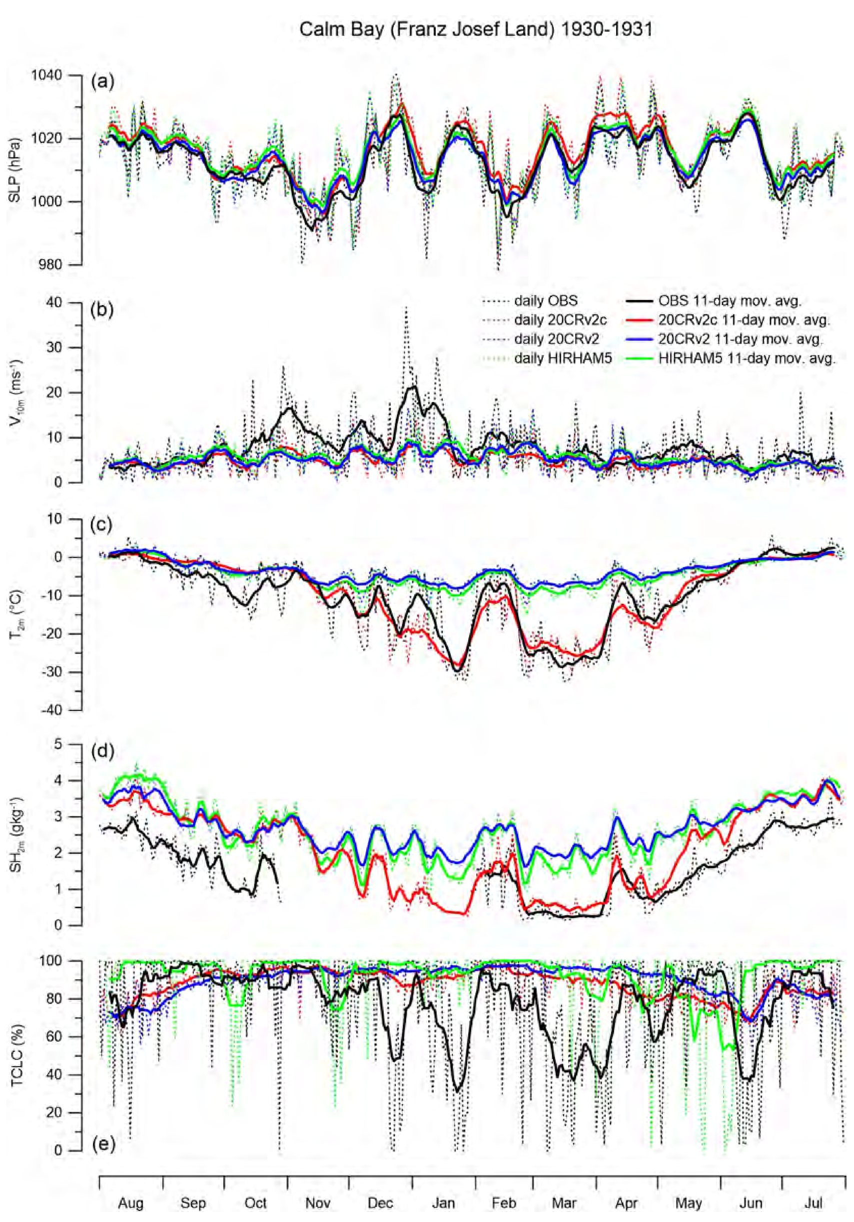
Location of the historic meteorological station Calm Bay (red dot) on Hooker Island belonging to Franz Josef Land as well as the nearest-neighbor grid points of the 20th Century Reanalysis (green triangle) and regional climate model HIRHAM5 (blue square), respectively.

Geographic location of the historic station Calm Bay and the nearest-neighbor grid points of the 20th Century Reanalysis (versions 20CRv2 and 20CRv2c) and the HIRHAM5 model. Temporal usage and resolution of raw data for sea level pressure (SLP), horizontal wind speed (V_{10m}), air temperature (T), specific humidity (SH_{2m}) and total cloud cover (TCLC).

Station/ Nearest grid point	Longitude	Latitude	Temporal data usage	SLP (hPa)	V_{10m} (ms^{-1})	T (°C)	SH_{2m} (gkg^{-1})	TCLC (%)
Calm Bay *(surface observations)*	52.80°E	80.32°N	1930.08.01 - 1931.07.31	h[1]	t[2]	h[3]	t	t
Calm Bay *(vertical profiles)*			1934.09.10 - 1940.12.31	--	-	i[4]	-	-
20CRv2c	52.00°E	80.00°N	1915.01.01 - 1940.12.31	6-h[5]	6-h	6-h	6-h	6-h
20CRv2				6-h	6-h	6-h	6-h	6-h
HIRHAM5	52.88°E	80.25°N		6-h	6-h	6-h	6-h	6-h

[1] hourly, [2] three times a day (7, 13, 21 LMT) in 10 m a. g. l., [3] hourly in 2 m a. g. l., [4] irregular from 1000 hPa to 10 hPa,[5] 6-hourly at the corresponding height of observational data

RESULTS 2

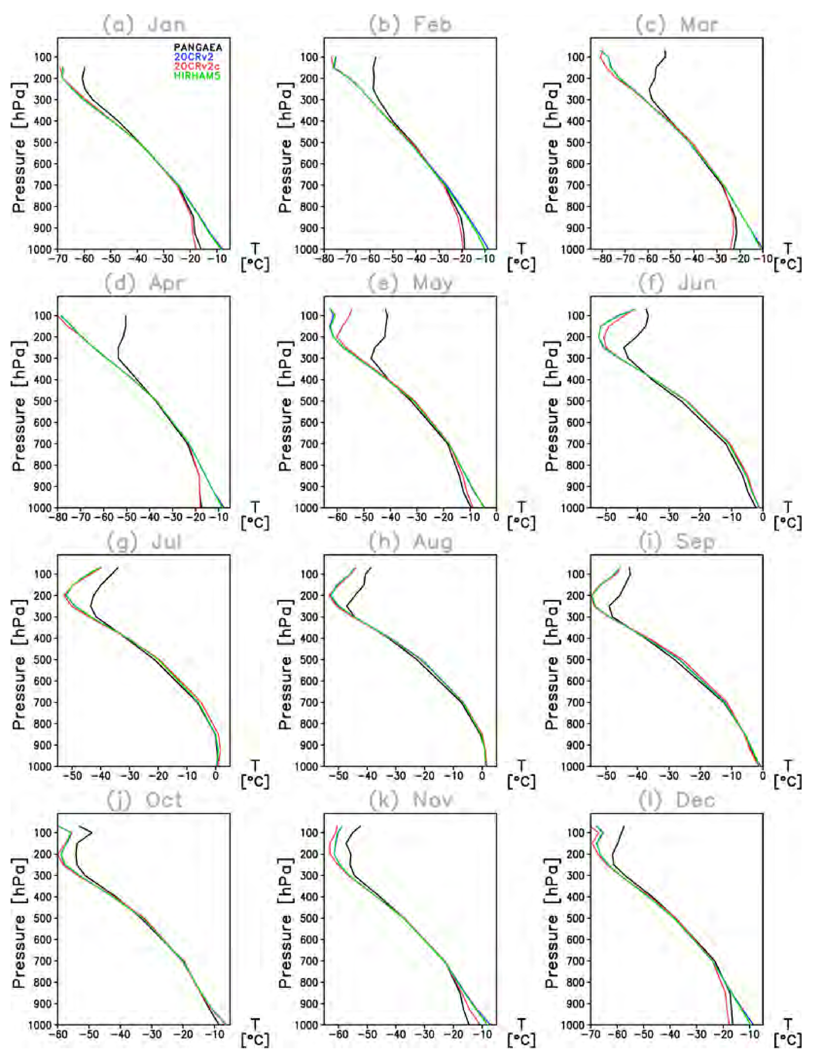


Upper chart

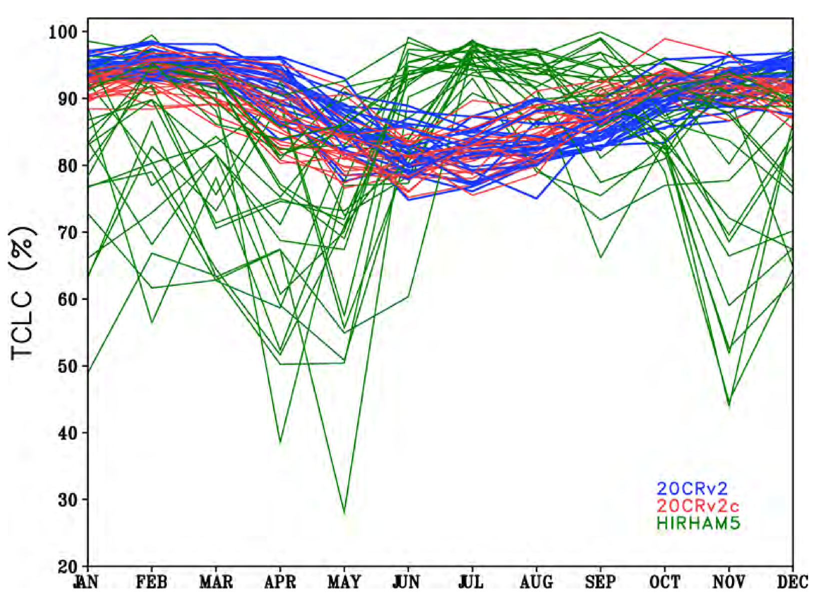
Annual courses of the (a) sea level pressure; (b) 10 m horizontal wind speed; (c) 2 m air temperature; (d) 2 m specific humidity; and (e) total cloud cover from the surface-based observations (black), the two versions of 20CR (20CRv2 and 20CRv2c, blue and red, respectively), and the HIRHAM5 model (green) for Calm Bay from 1 August 1930 to 31 July 1931. Dotted lines indicate daily means, while thick lines represent the 11 -day moving averages.

Chart on the left

Scatter plots of the (a - c) sea level pressure; (d - f) 10 m horizontal wind speed; (g - i) 2 m air temperature; (j - l) 2 m specific humidity; and (m - o) total cloud cover relating the surface-based observations with (a, d, g, j, m) the newer version of 20CR; (b, e, h, k, n) its older version; (c, f, i, l, o) the model for Calm Bay, based on daily data from 1 August 1930 to 31 July 1931. Beside the slope all subfigures include values for the root mean square (rms) error and bias error and correlation coefficients (r) in bold indicate significance on the p ≤ 0.05 level.



Multi-year (10 September 1934 - 31 December 1940) monthly temperature profiles for Calm Bay from PANGAEA observations (black), the newer (20CRv2c; red) and older (20CRv2; blue) version of 20CR, and the HIRHAM5 model (green). The calculation of monthly means always exploited the missing values from the daily PANGAEA data to take into account unavailable or vertically interrupted temperature profiles also in the reanalysis and model data. Temperatures are shown on the 16 standard pressure levels used by PANGAEA.



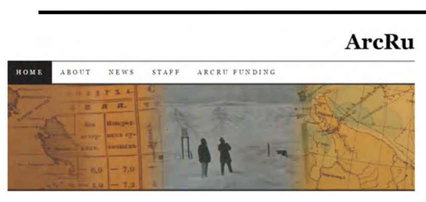
Reanalyzed (20CRv2 = older 20CR version, 20CRv2c = newer 20CR version) and simulated (HIRHAM5) annual cycle of monthly total cloud cover (TCLC) for each year of the entire simulation period 1915-1940.

CONCLUSIONS 1

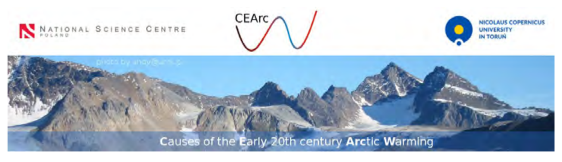
1. Reanalyses are usually too cold in comparison with observations, except some southern grid boxes in the case of 20CR. In particular, large differences (2–5 °C) have been found in northern regions.
2. For a comparison of air temperature reconstructions based on marine data with present-day conditions, better reanalysis products are needed, because the current ones still show worse climate simulations for the Arctic than for the lower latitudes.

CONCLUSIONS 2

1. The model shows predominantly an improved performance compared to its forcing data set (20CRv2) due to the use of higher horizontal resolution and apparently more realistic sub-grid scale parameterizations. HIRHAM5 can slightly reduce the positive T_{2m} and SH_{2m} bias relative to its forcing data set (20CRv2) during polar night. However, T_{2m} and SH_{2m} is captured most realistically by 20CRv2c. The systematically and significantly larger V_{10m} in the observational data give evidence that storm variability (cyclone strength) is underestimated by 20CR and HIRHAM5.
2. HIRHAM5 produces (for the entire simulation period 1915-1940) mainly a realistic annual cycle of total cloud cover (TCLC) with more Arctic clouds during summer and autumn but less clouds during winter. In contrast, 20CRv2 and 20CRv2c show generally a reverse annual cycle of TCLC.
3. The different lower BCs (sea ice concetration and SST) and the more realistic values of sea ice thickness change the vertical stratification and baroclinicity in the transition from 20CRv2 to 20CRv2c, although the SLP is very similar in both versions of this reanalysis product. Compared to observed vertical temperature profiles from PANGAEA, the systematic upper-level (above 400 hPa) cold bias remains almost unchanged indicating an incorrect coupling between the planetary boundary layer and free troposphere.



https://arcru.wordpress.com



http://cearc.umk.pl/

REKLIM
Helmholtz-Verbund Regionale Klimaänderungen

http://www.reklim.de/

National Science Centre Poland

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