

Evaluation of 20CR reanalysis data and model results based on historic (1930-1940) observations from Franz Josef Land

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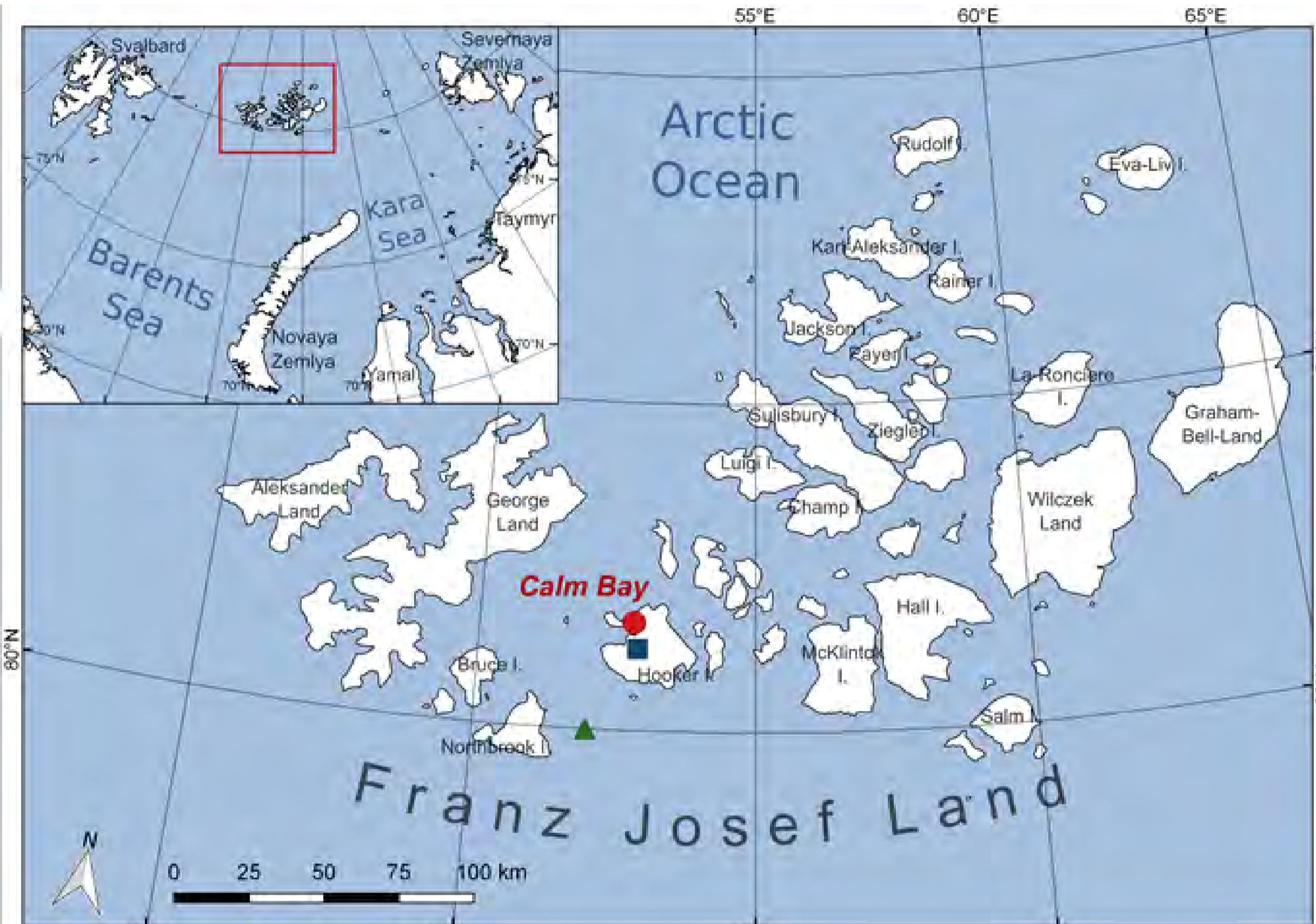
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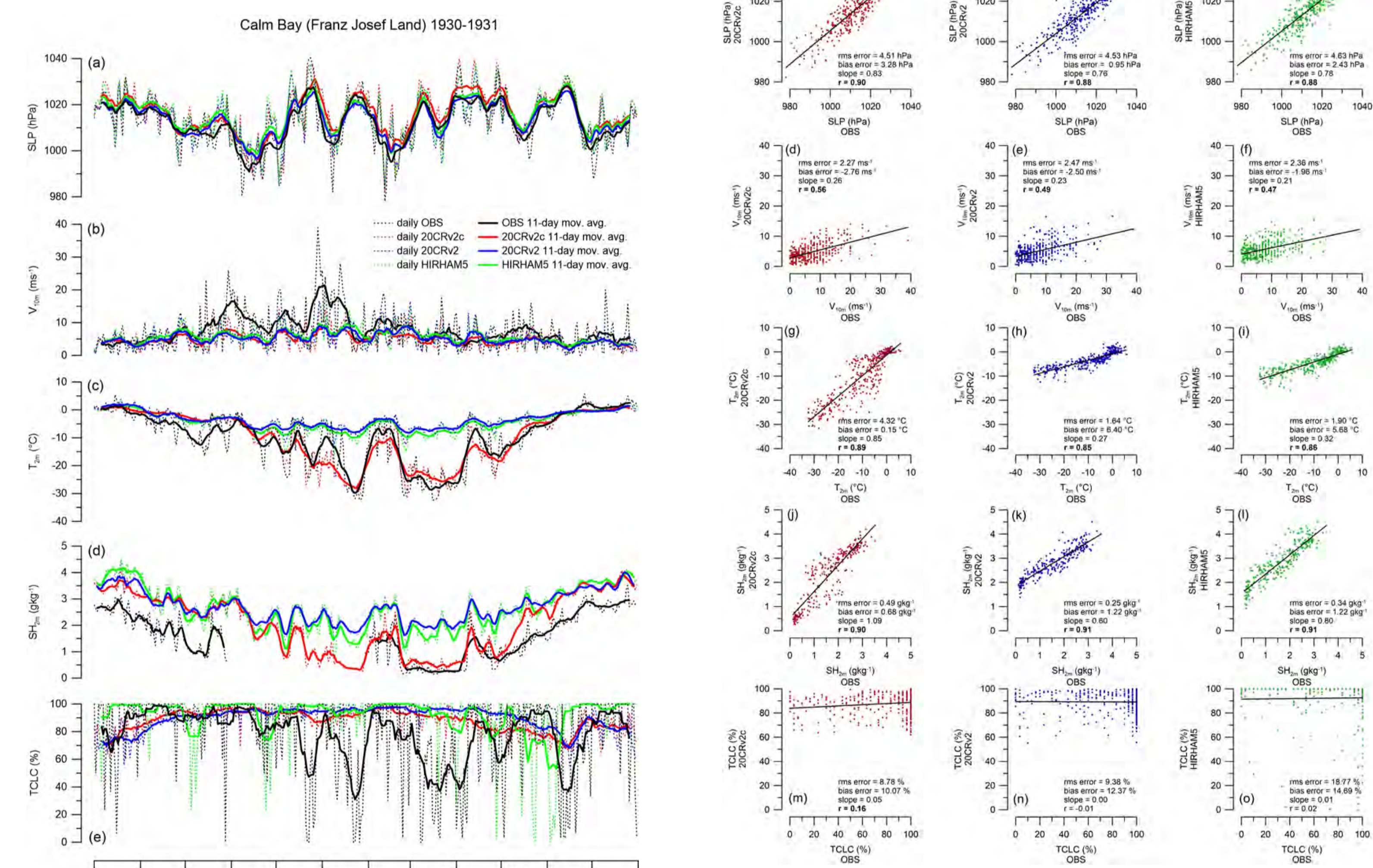
ABSTRACT

Unique and independent historic observations, carried out in the central Arctic during the early twentieth century warming (ETCW) period, were used to evaluate the older (20CRv2) and newer (20CRv2c) versions of the 20th Century Reanalysis and the HIRHAM5 regional climate model. The latter can reduce several biases compared to its forcing data set (20CRv2) probably due to higher horizontal resolution and a more realistic cloud parameterization. However, low-level temperature and near-surface specific humidity agree best between 20CRv2c and the surface-based observations. This better performance results from more realistic lower boundary conditions for sea ice concentration and sea surface temperature, but it is limited mainly to polar night. Although sea level pressures are very similar, the vertical stratification and baroclinicity change in the transition from 20CRv2 to 20CRv2c. Compared to observed temperature profiles, the systematic cold bias above 400 hPa remains almost unchanged indicating an incorrect coupling between the planetary boundary layer and free troposphere. In addition to surface pressures it is therefore recommended to assimilate available vertical profiles of temperature, humidity and wind speed. This might also reduce the large biases in 10 m wind speed, but the reliability of the sea ice data remains a great unknown.

AREA

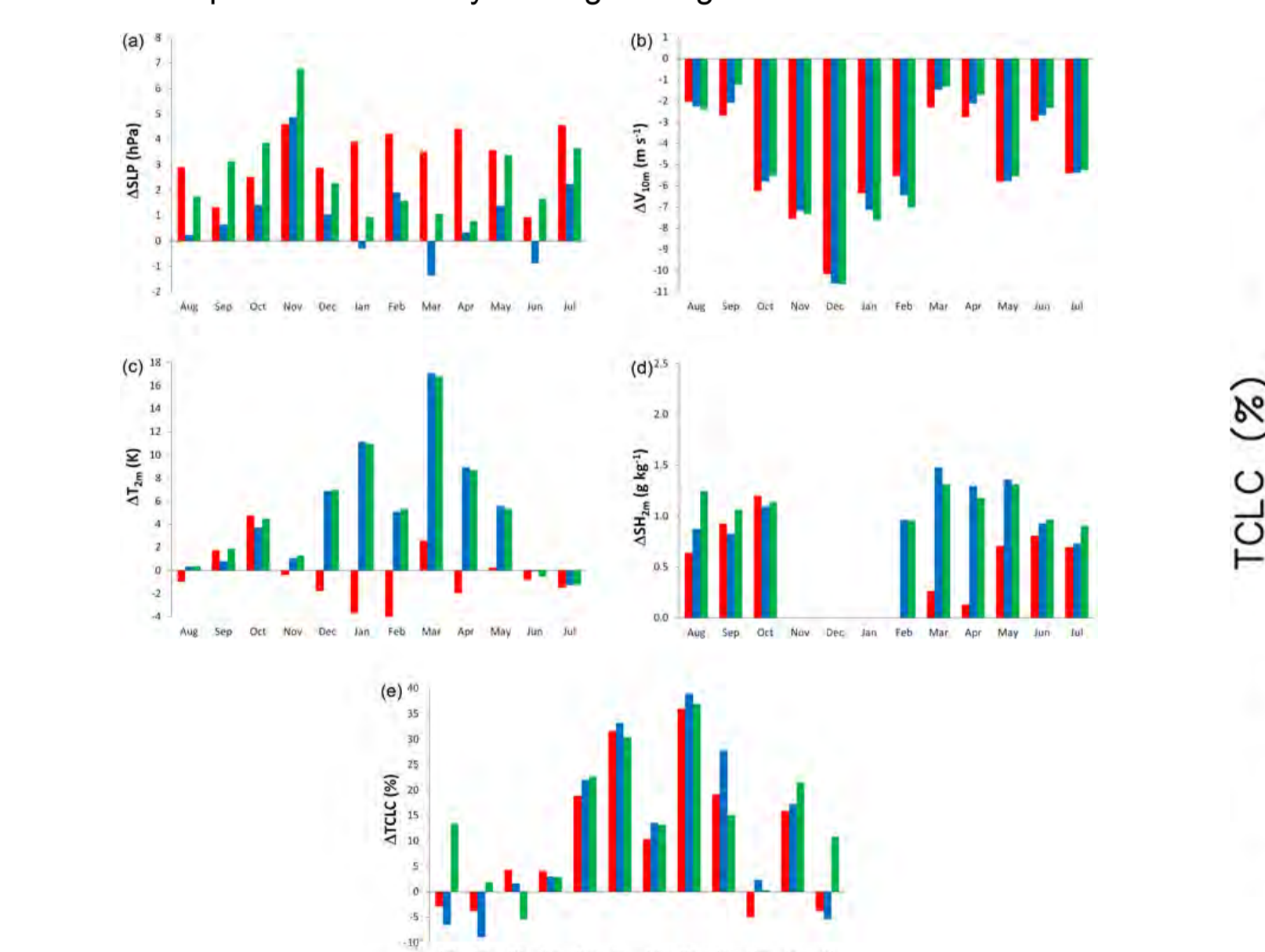


RESULTS



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.

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 $p \leq 0.05$ level.



Monthly mean (from August 1930 to July 1931) differences 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. These differences were obtained by subtracting the observations at Calm Bay from values produced by a version of 20CR (20CRv2 = blue, 20CRv2c = red) or the model (HIRHAM5 = green).

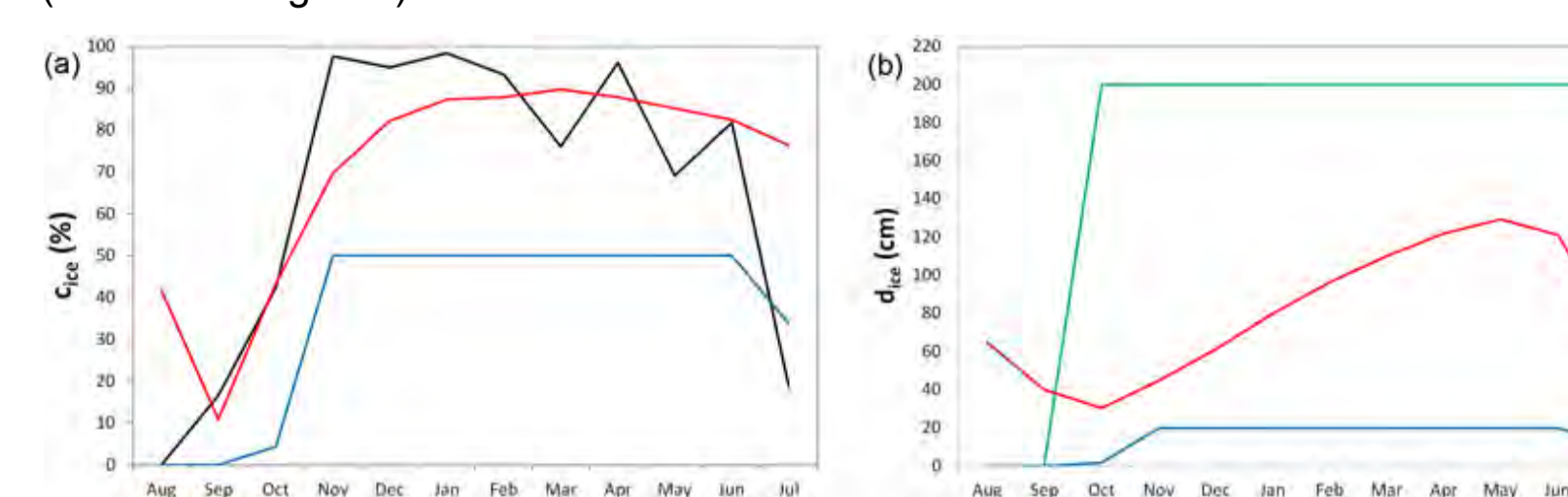


Chart on the left: Monthly means of the (a) sea ice concentration; (b) sea ice thickness from observations by Walsh et al. 2016 (black), the newer version of 20CR (20CRv2c; red), its older version (20CRv2; blue), and the model (HIRHAM5; green) for Calm Bay from August 1930 to July 1931. Due to the lower boundary forcing, the sea ice concentration of 20CRv2 is identical in HIRHAM5, but the model assumes 2 m thick ice for the part of the grid cell that is covered with sea ice.

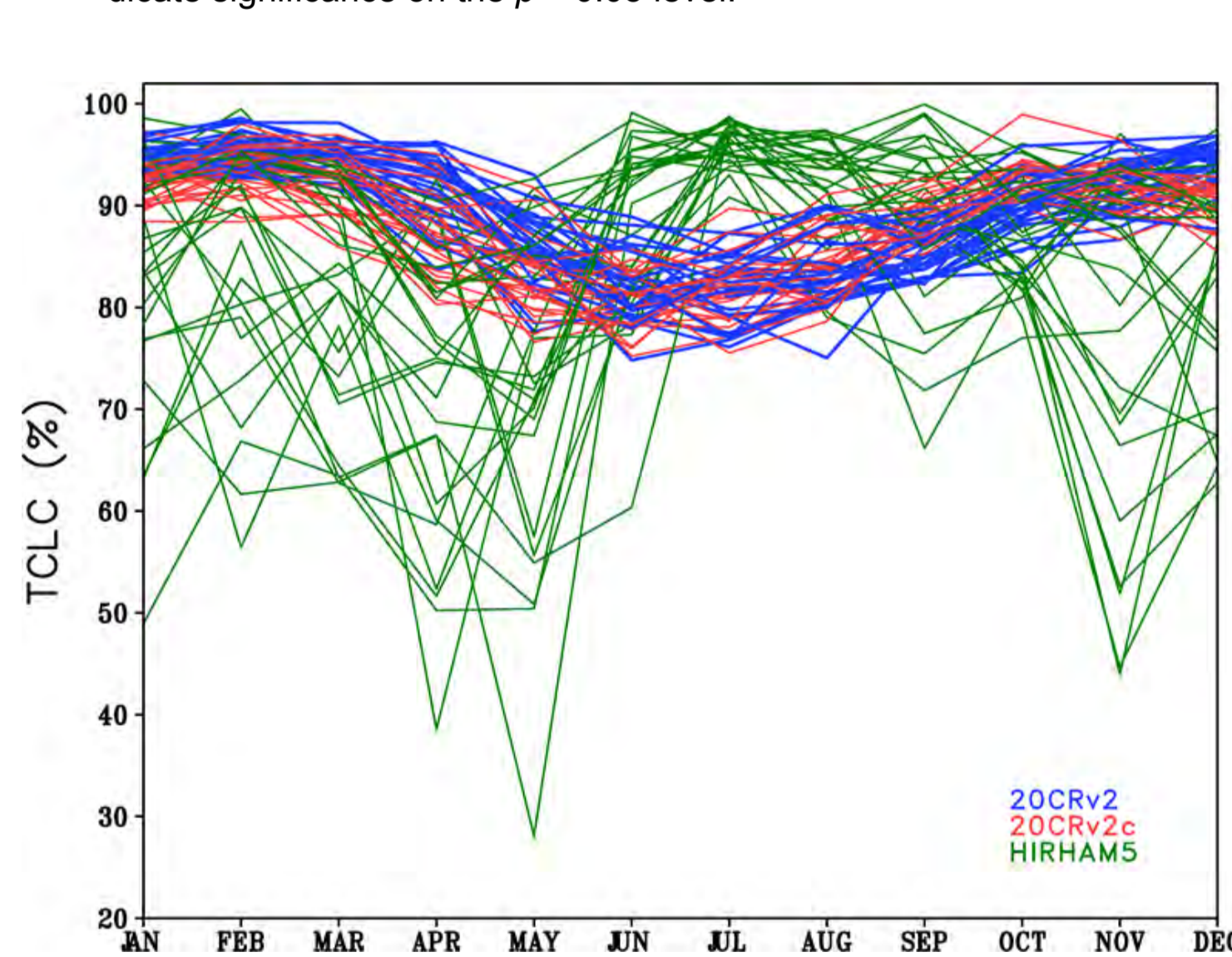
Location of the historic meteorological station Calm Bay (red dot) on Hooker Island belonging to Franz Josef Land as well as the nearest-neighbor grid points of the 20th Century Reanalysis (green triangle) and regional climate model HIRHAM5 (blue square), respectively.

DATA

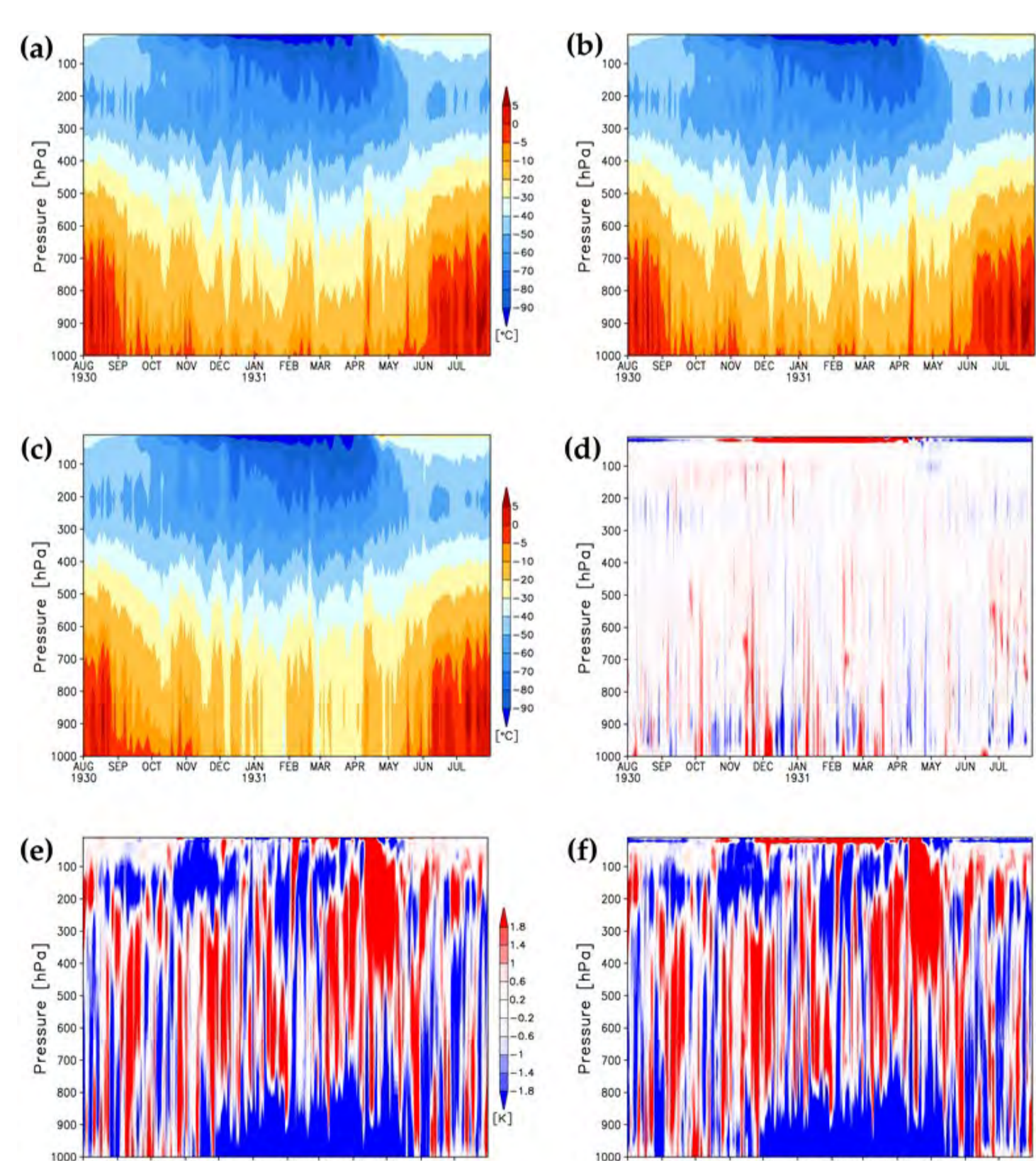
Geographic location of the historic station Calm Bay and the nearest-neighbor grid points of the 20th Century Reanalysis (versions 20CRv2 and 20CRv2c) and the HIRHAM5 model. Temporal usage and resolution of raw data for sea level pressure (SLP), horizontal wind speed (V_{10m}), air temperature (T), specific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

Station/ Nearest grid point	Longitude	Latitude	Temporal data usage	SLP (hPa)	V_{10m} (ms^{-1})	T ($^{\circ}C$)	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 - -	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	1940.12.31	6-h	6-h	6-h	6-h	6-h

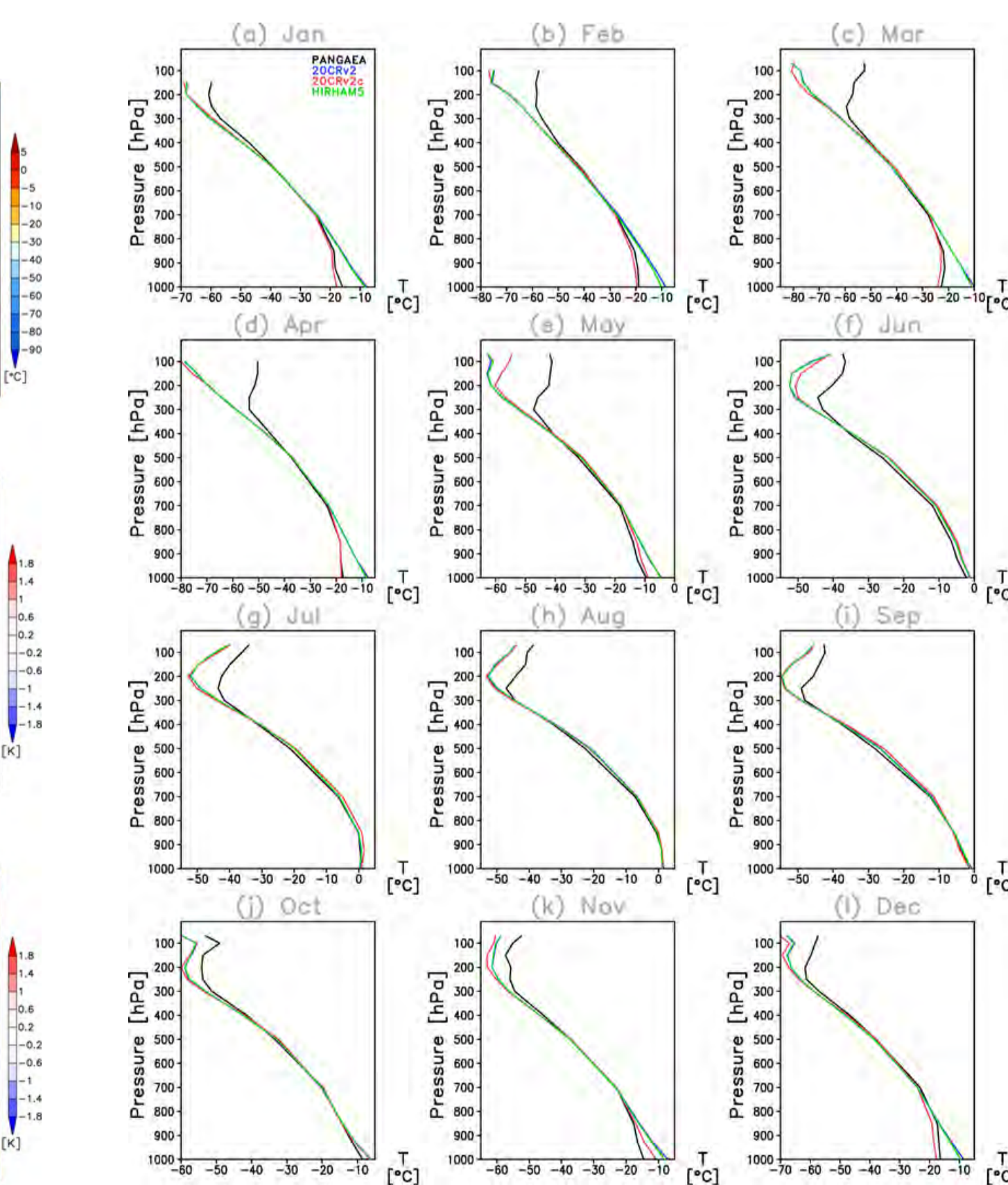
¹ hourly, ² three times a day (7, 13, 21 LMT) in 10 m a. g. l., ³ hourly in 2 m a. g. l., ⁴ irregular from 1000 hPa to 10 hPa, ⁵ 6-hourly at the corresponding height of observational data



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.



Time height cross sections of daily mean air temperature from (a) 20CRv2; (b) HIRHAM5; (c) 20CRv2c, and corresponding difference plots (d) 20CRv2 - HIRHAM5; (e) 20CRv2c - 20CRv2; (f) 20CRv2c - HIRHAM5 for Calm Bay from August 1930 to July 1931. Model data were interpolated to the same 24 pressure levels as in the files provided by ESRL PSD from NOAA.



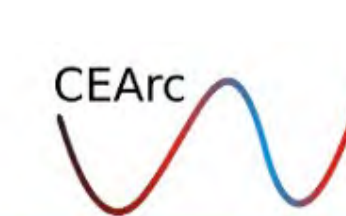
Multi-year (10 September 1934 - 31 December 1940) monthly temperature profiles for Calm Bay from PANGAEA observations (black), the newer (20CRv2c; red) and older (20CRv2; blue) version of 20CR, and the HIRHAM5 model (green). The calculation of monthly means always exploited the missing values from the 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.

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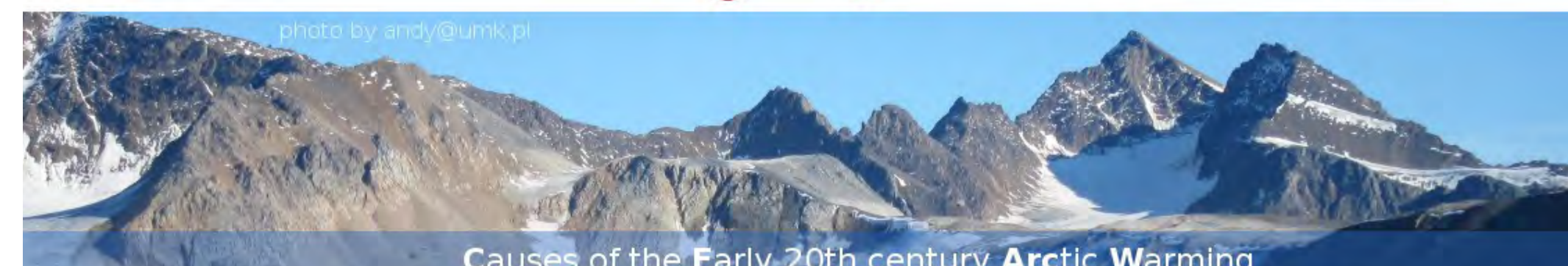


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