INTERNATIONAL JOURNAL OF CLIMATOLOGY
*Int. J. Climatol.* **33**: 1730–1760 (2013)
Published online 6 August 2012 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3546

RMetS
Royal Meteorological Society

# Atmospheric pressure changes in the Arctic from 1801 to 1920

Rajmund Przybylak,[a]* Przemysław Wyszyński,[a] Zsuzsanna Vízi[b] and Joanna Jankowska[a]

[a] *Department of Climatology, Nicolaus Copernicus University, Toruń, Poland*
[b] *Department of Space and Climate Physics, University College London, Holmbury St Mary, UK*

**ABSTRACT:** In this article, the results of an investigation into the atmospheric pressure conditions in the Arctic in the period from 1801 to 1920 are presented. For this period, which can be described as 'early instrumental', limited meteorological data exist from a network of regular stations. As a result, in order to get at least a rough idea of pressure conditions in the Arctic in the study period, data from different land and marine expeditions were collected. A total of 94 pressure series of monthly means have been gathered, the duration of which is usually less than 2 years. While the area and time periods covered by the data are variable, it is still possible to describe the general character of the pressure conditions. The results show that the areally averaged Arctic pressure in the early instrumental period (1861–1920) was 0.8 hPa lower than today (1961–1990). Lower values of atmospheric pressure were also observed in all study regions, excluding the Atlantic. The greatest negative differences (−2.1 hPa) have been found for the Canadian Arctic. The greatest changes between the historical and present times were noted in all winter months and in winter as a whole (−1.9 hPa), while in summer and autumn they were very small and their average differences came to −0.1 and −0.2 hPa, respectively. Comparison of historical and contemporary annual courses of atmospheric pressure in the whole of the Arctic and in its particular regions reveals general consonance. There is evidence to show that changes in Arctic atmospheric pressure during the whole study period were insignificant. Atmospheric pressure in the first International Polar Year (IPY) period (September 1882 to July 1883) was, on average, 1.4 hPa higher than in modern period (1961–1990). The greatest positive seasonal differences between historical and contemporary pressure values occurred in autumn (2.6 hPa), while the lowest were in winter (only 0.2 hPa). Spatial patterns of average annual and seasonal atmospheric pressure in the Arctic were very similar to present day ones. The pressure differences calculated between historical and modern mean monthly values show that almost all of them lie within one standard deviation from present long-term mean (1961–1990). Thus, this means that the atmospheric pressure in the early instrumental period was not significantly different to that of the present day. Recent, commonly used gridded datasets of the sea level atmospheric pressure (HadSLP2 and the 20th Century Reanalysis Project) reveal quite a large positive bias in the period 1850–1920 in comparison to the real data from the instrumental observations. Copyright © 2012 Royal Meteorological Society

KEY WORDS atmospheric pressure changes; Arctic; early instrumental period; historical climatology

*Received 8 March 2012; Revised 31 May 2012; Accepted 19 June 2012*

## 1. Introduction

In recent years, there has been a significant growth in interest in the reconstruction of global atmospheric circulation (including also atmospheric circulation in the Arctic) from the last few centuries (see Jones *et al*., 1997; Slonosky *et al*., 2001a, 2001b; Luterbacher *et al*., 2001, 2002; Polyakov *et al*., 2003; Wood and Overland, 2006). In many scientific institutions huge efforts have been undertaken in searching for and collecting as much historical atmospheric pressure data as possible, both from marine and land areas [for more details see, for example, the Atmospheric Circulation Reconstructions over the Earth (ACRE) Initiative, http://www.met-acre.org/Home (Allan *et al*., 2011) or the International Surface Pressure Databank (ISPD), http://reanalyses.org/observations/international-surface-pressure-databank]. During an International Arctic Science Committee (IASC) Working Groups Workshop held in Potsdam in January 2011, the Atmosphere Working Group chaired by James Overland from the National Oceanic and Atmospheric Administration (NOAA) fully endorsed this kind of activity (see IASC Working Groups Workshop Report, 2011). It is widely recognized that atmospheric pressure, in particular on regional and local scales, is a very important factor influencing changes in weather and climate.

In the Arctic, the majority of the research work undertaken up to now have been directed towards the reconstruction of the air temperature (see Przybylak, 2000, 2004; Wood and Overland, 2003, 2006; Przybylak and Panfil, 2005; Przybylak and Vizi, 2005a; Klimenko and Astrina, 2006; Vinther *et al*., 2006; Brohan *et al*., 2010; Klimenko, 2010; Przybylak, *et al*., 2010; Wood *et al*.,

*Correspondence to: R. Przybylak, Department of Climatology, Nicolaus Copernicus University, Toruń, Poland. E-mail: rp11@umk.pl

2010). However, the very good results which have been obtained in the reconstruction of thermal, precipitation and many other meteorological variables fields based on described surface pressure fields (Compo *et al.*, 2011) significantly strengthen the importance of pressure data from historical times. That is why, researchers in the Department of Climatology at the Nicolaus Copernicus University have developed an electronic database as part of the ACEIP project (*History of the Arctic Climate in the 19th Century and the Beginning of the 20th Century based on Early Instrumental Data*), which was the part of the International Polar Year (IPY) CARE project (*Climate of the Arctic and its Role for Europe*). The work was also supported by the Polish-Norwegian Fund as part of the project entitled *Arctic Climate and Environment of the Nordic Seas and the Svalbard-Greenland Area (AWAKE).*

Nevertheless, it is only recently that there has been a growth in interest in the analysis of atmospheric pressure data for the Arctic for early- and pre-instrumental times, and thus there is still a paucity of literature in the area (Przybylak and Panfil, 2005; Wood and Overland, 2006; Jónnson and Hanna, 2007; Vízi, 2008; Przybylak and Jankowska, 2009; Przybylak and Wyszyński, 2009; Brohan *et al.*, 2010; Küttel *et al.*, 2010).

In this article, we present a synthesis of our work carried out in recent years mainly as part of the ACEIP and AWAKE projects mentioned earlier. The best coverage and data quality are available for the first IPY, and that is why the most detailed analysis has been presented for this period. Atmospheric pressure in the Arctic in historical times (1801–1920) is compared with contemporary values (1961–1990).

## 2. Area, data and methods

For the present analysis, only monthly means of atmospheric pressure have been used to characterize changes of this variable in the study period. These data have been collected for the Arctic region defined according to Treshnikov (ed., 1985) (see Figure 1 and Przybylak 2003 for more details) for the period 1801–1920. The majority of atmospheric pressure measurements (Figure 1) were made during various exploratory and scientific land and sea expeditions, many of which took place following the first IPY 1882/1883 (Figure 2). As can be seen from Figures 1 and 2, these expeditions were sent mainly to the western and European parts of the Arctic. As a result, a large number of pressure series were collected for these areas (see Figure 2). Prior to IPY-1 the best coverage of data existed for the Canadian Arctic; subsequently coverage was better for the Baffin Bay, Atlantic and Pacific climatic regions (Figure 2). On the other hand, very few data series exist for the Siberian part of the Arctic. The number of expeditions and meteorological stations operating in the Arctic throughout the study period was variable. The majority of them (excluding eight series longer than 20 years) were recorded after 1880 (23 in 1881–1900 and 32 in 1901–1920) and between 1841 and 1860 (17), and the fewest were from 1801 to

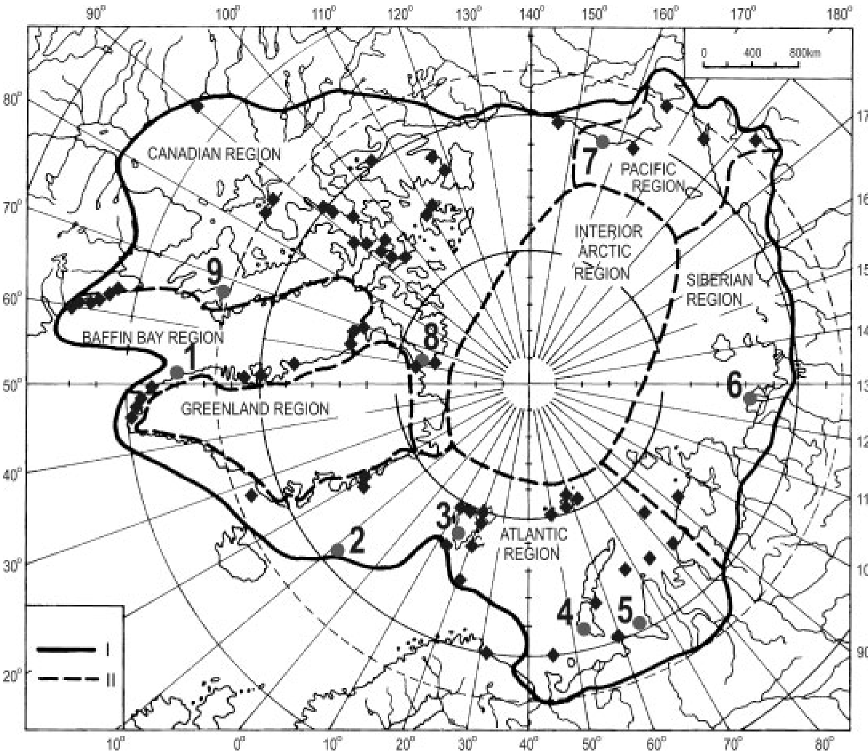


Figure 1. Location of measurement points operating in the high Arctic from 1801 to 1920. The Arctic and its climatic regions are defined according to Treshnikov (1985). The southern Arctic boundary has been delimited based on analysis using long-term averages of all meteorological variables, their seasonal cycles and variability characteristics. I, boundary of the Arctic; II, boundaries between climatic regions. IPY-1 stations: 1, Godthåb; 2, Jan Mayen; 3, Kapp Thordsen; 4, Malye Karmakuly; 5, Kara Sea; 6, Sagastyr; 7, Point Barrow; 8, Lady Franklin Bay; 9, Kingua Fjord.

 

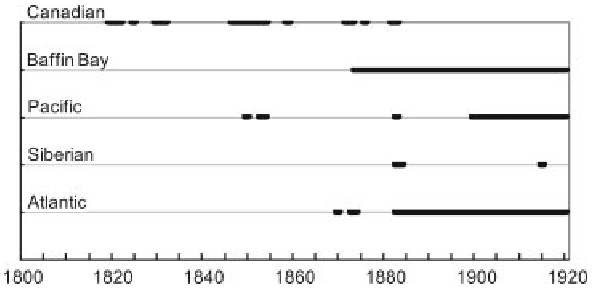


Figure 2. Temporal distribution of the atmospheric pressure observations in the climatic regions of the Arctic used in the study from 1801 to 1920.

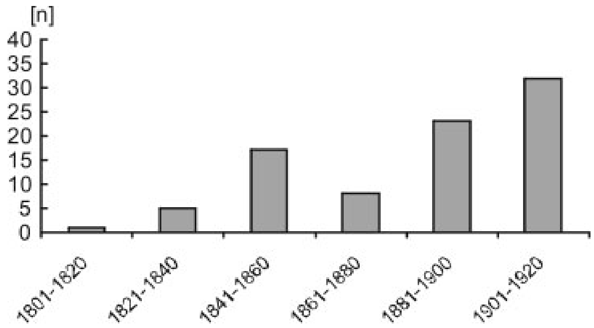


Figure 3. Number of atmospheric pressure series ($n$) in 20 year periods in the Arctic from 1801 to 1920.

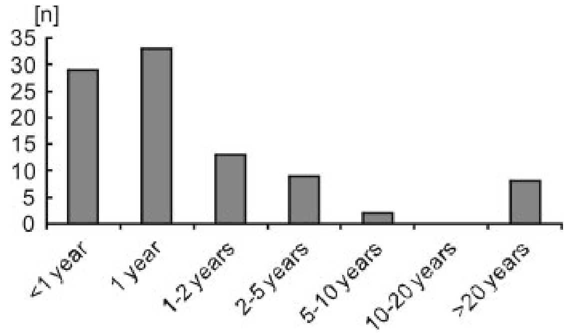


Figure 4. Number of atmospheric pressure series ($n$) with different periods of observations in the Arctic from 1801 to 1920.

1820 (1) (Figure 3). As summarized by Przybylak *et al.* (2010), the impulse for the organization of many expeditions in the last 40 years of the study period was the success of scientific investigations carried out during the first IPY 1882/1883. In turn, a secondary maximum in the number of expeditions working in the Arctic is seen in the period from 1841 to 1860. This maximum was evidently connected with the lost expedition under the command of Sir John Franklin in 1845. Following the disappearance of Franklin's expedition, the Royal Navy sent a great number of search expeditions to the Canadian Arctic. In addition to this, the intensive search for the North–West Passage conducted in the first half of the 19th century (also mainly by the Royal Navy) also resulted in a high level of coverage of data for this region up to 1880.

So far, 94 historical pressure series have been collected (Figure 4) for the Arctic ranging in duration from less than 1 to 48 years [Godthåb/Nuuk in south-western (SW) Greenland]. The majority are for the Atlantic (46) and Canadian (27) regions, while only two series are available for the Siberian region. The majority of the series (79.8%) are shorter than 2 years (Figure 4). The greatest number of series is for a year (33) or less (29), while only eight series are longer than 10 years.

More details of atmospheric pressure series (location, duration and sources of data) are available in the Table A1 and at http://www.zklim.umk.pl/. The series of mean monthly pressure data were taken directly from the various publications or have been calculated by the authors using available data of a higher resolution (e.g. daily or hourly). Taking together all the information presented in Figures 2–4 and in the Table A1, it is clear that information about atmospheric pressure conditions for different Arctic regions and for different seasons is variable and limited. Therefore the averaged results which are presented for individual regions and for the Arctic as a whole should be treated as the best approximation which currently exists of the real climate. We are still looking for new data series in the hope that, if they exist, they will allow us to improve our knowledge in the future. Thus any assistance which readers of this article may offer in providing such series would be welcomed.

The second dataset includes contemporary data (1961–1990) obtained for the historical sites. In some cases, the site locations of the observations in the two periods were identical. For those historical sites where this is not the case, the average long-term characteristics have been calculated using mathematical interpolation (kriging) based on the sea level pressure (SLP) data taken from adjacent meteorological stations available in Global Historical Climatology Network (GHCN) version 2 dataset (ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v2/, file: v2.slp.Z). The only exception was made for the area of Franz Josef Land, due to the lack of the measurement points in the GHCN dataset. Therefore, for comparison purposes, the data from nearest modern stations have been used, as they give a better approximation of the real pressure values than those obtained from the interpolation procedure (for more details see the Table A1). The modern values obtained in this way for historical sites were compared with those from the period 1801–1920. Using this procedure, the differences resulting from different geographical locations of historical and modern observation points were removed.

Mean monthly values of atmospheric pressure for the period 1961–1990 for the same historical and contemporary locations have been taken from the following sources: Arctic Climatology Project (2000), Norwegian Meteorological Institute (http://eklima.met.no), Canadian National Climate Data and Information Archive (http://www.climate.weatheroffice.ec.gc.ca), Danish Meteorological Institute (DMI) (Cappelen, 2009), among others.

Reliable pressure measurements need to introduce two corrections to the original readings, for temperature (to 0 °C), and for normal gravity (i.e. pressure reduction should be carried out according to gravity values observed at 0 m a.s.l and at latitude $\varphi = 45\,^{\circ}$N). According to Können *et al.* (2003), in the 19th century the pressure was generally reduced to 0 °C using Kämtz's formula (1832):

$$P(0^{\circ}) = P(\mathrm{t})(1 - 1.62 \times 10^{-4} T(^{\circ}\mathrm{C})) \quad (1)$$

where $P(t)$ means pressure measured at temperature $t$, and $T$ means temperature of the barometer.

For many Arctic pressure series we have found metadata indicating that a reduction of pressure to 0 °C has been carried out, but for some series there is no such information. Thus, based on Können *et al.* (2003), we have assumed that this was standard procedure at this time, and therefore the corrections were not introduced.

There is definitely less information available on the introduction of corrections for normal gravity to the original observations of atmospheric pressure in the Arctic (see Table I). According to the decision of the fourth International Polar Conference, held in Vienna in 17th to 24th April 1884, atmospheric pressure data collected during the IPY-1 1882/1883 period were corrected only to 0 °C (Wild, 1884). At the time of conference, most of processing and storage of the data from IPY-1 was at quite an advanced stage; furthermore the French Polar Committee had just started printing their reports and they did not want to introduce any changes to the publications. That is why the Polar Commission decided not to correct the data to normal gravity. However, the corrections, calculated according to the formula shown under Table II, were placed above tables with barometric observations published in the first IPY reports. In this study, we corrected the IPY pressure data as well as all data before this date to normal gravity using the equation given in Cappelen (2009). For the period after IPY-1 we assumed that gravity corrections should be introduced for the majority of pressure series, and therefore no action was taken. However, for measurements for which we have found information in metadata that such corrections were not made, then we introduced corrections for gravity. For example, such a situation occurred for pressure observations from Greenland in the period 1885–1892. Gravity corrections are shown in the DMI meteorological yearbooks above the tables with original data. Since 1893 pressure data have been corrected to normal gravity.

Knowledge about gravity corrections is very important. The possible scale of errors in the comparison of historical data with the present climate is shown in Table II.

Table I. Corrections introduced to barometer readings in original reports, meteorological yearbooks and logbooks.

| Corrections | 0 °C | Gravity ($\phi$45°+ A) | | Sea level |
|---|---|---|---|---|
| IPY-1 1882/1883[a] | + | – | | – |
| Greenland stations (DMI) | + | 1873–1892[c] | – | – |
| | | From 1893 to the present | + | – |
| Canadian region[b] | + | – | | – |
| Atlantic region | + | –/+ | | – |
| Siberian region | + | –/+ | | – |
| Pacific region | + | – | | – |

**+,** introduced; –, not introduced; A, altitude.
[a] According to the decision of the fourth International Polar Conference in Vienna, April 17–24 1884; calculated values of the gravity corrections have been placed above the tables with original barometric observations published in the IPY-1 reports.
[b] Strachan, 1879; 1880; 1882; 1885; 1888.
[c] From 1885 onwards, values of gravity corrections are known and they have been placed above tables with barometric observations published in the DMI meteorological yearbooks.

Table II. Possible scale of errors in the comparison of historical data to the present climate when corrections to normal gravity are not introduced.

| Corrections[a] | | (hPa) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 980 | 985 | 990 | 995 | 1000 | 1005 | 1010 | 1015 | 1020 |
| $\phi$ (°) | 90 | 2.54 | 2.55 | 2.56 | 2.58 | 2.59 | 2.60 | 2.62 | 2.63 | 2.64 |
| | 85 | 2.50 | 2.51 | 2.53 | 2.54 | 2.55 | 2.56 | 2.58 | 2.59 | 2.60 |
| | 80 | 2.39 | 2.40 | 2.41 | 2.42 | 2.43 | 2.45 | 2.46 | 2.47 | 2.48 |
| | 75 | 2.20 | 2.21 | 2.22 | 2.23 | 2.24 | 2.25 | 2.27 | 2.28 | 2.29 |
| | 70 | 1.94 | 1.95 | 1.96 | 1.97 | 1.98 | 1.99 | 2.00 | 2.01 | 2.02 |
| | 65 | 1.63 | 1.64 | 1.65 | 1.66 | 1.66 | 1.67 | 1.68 | 1.69 | 1.70 |
| | 60 | 1.27 | 1.28 | 1.28 | 1.29 | 1.30 | 1.30 | 2.31 | 1.31 | 1.32 |

[a] According to equation (Ekholm, 1890): correction $= -\mathrm{P}(0.00259\cos 2\phi + 0.000\,000\,196\,A)$; P, atmospheric pressure; $\phi$, latitude of observation; A, altitude.

 

For the majority of measurement sites the correction to old barometer readings was made using the equation according to Cappelen (2009), which was splitted by us to:

$$P_{\phi\text{corr.}} = P\left(1 - 0.00259\cos\left(\frac{2\phi\pi}{180}\right)\right) \quad (2)$$

$$\text{SLP} = P\left(1 + \frac{9.82}{287.04} \times \frac{h}{(T/10) + 273.15}\right) \quad (3)$$

where $P_{\phi\ \text{corr.}}$ is corrected atmospheric pressure to normal gravity, SLP is pressure at mean sea level, $P$ is atmospheric pressure measured to an accuracy of 0.1 hPa at station level, $\phi$ is the latitude in degrees, $h$ is the height of the barometer in meters above sea level and $T$ is the air temperature at station level (accuracy 0.1 °C)

The formula simply corrects pressure to normal gravity (Equation (2)) and reduces it to mean sea level (Equation (3)). For this calculation, the monthly means of $P$ and $T$ were used (excluding the IPY-1 observations, where hourly values were taken). Such a procedure may be seen as more liable to introduce errors, when compared to reduction carried out using the observed values. But, according to an investigation conducted by Cappelen (2009), the error resulting from the use of monthly data may be considered to be very small. Of course, we used Equations (2) and (3) where it was necessary and possible. Precise information about pressure corrections introduced to the data used in this work is contained in the Table A1. For data from ships exploring the Canadian Arctic in the middle of the 19th century, we did not introduce corrections to the sea level, because information about the exact height of the instrument is not available. However, we know that the height of barometer on the deck did not exceed a few feet (Strachan, 1879; 1880; 1882; 1885; 1888). This means that changes in the height of these barometers could only lead to a bias of less than 0.2 hPa.

Almost all historical pressure data used in the present work have been corrected for normal gravity (96.8%) and for the sea level (97.9%).

However, the reader must be aware of the fact that some sources of errors and biases still remained. For example, such errors and biases may result from the use of different types of instruments and recording schedules (which determined the methods for calculating daily means and monthly means). But these biases are not large enough to significantly affect the pressure series (see Przybylak and Vizi, 2005b; Ward and Dowdeswell, 2006; Jónnson and Hanna, 2007). For example, calculations of mean monthly pressure for Jan Mayen and Lady Franklin Bay (based on data from first IPY 1882/1883) conducted for eight different recording schedules (from 3, 4, 6, 8 and 12 measurements a day) confirm that biases are small and not important (see Table III). Differences in relation to monthly averages calculated using hourly data (24 measurements a day) exceed 0.1 hPa only in exceptional cases, and only in November and from February to May. The majority of the differences are lower than 0.05 hPa. It is worth adding that smaller biases were found for data taken from stations representing continental climate, i.e. from Lady Franklin Bay (Table III). Another source of possible errors may result from spatial sampling.

Table III. Mean monthly atmospheric pressure differences (hPa) between daily averages calculated using different formulas ($m_2$,..., $m_9$) and real daily average ($m_1$) in the Arctic during the IPY-1 1882/1883.

| Months | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan Mayen | | | | | | | | | | | |
| $m_2$-$m_1$ | 0.00 | −0.01 | −0.02 | 0.07 | −0.01 | −0.02 | −0.06 | −0.01 | 0.05 | −0.01 | 0.01 | 0.00 |
| $m_3$-$m_1$ | 0.03 | −0.02 | −0.05 | **0.18** | −0.05 | −0.03 | −0.03 | −0.05 | **0.12** | −0.03 | 0.02 | 0.01 |
| $m_4$-$m_1$ | **0.10** | 0.06 | 0.06 | 0.03 | −0.02 | −0.02 | −0.03 | **0.11** | **0.19** | −0.01 | 0.08 | 0.07 |
| $m_5$-$m_1$ | 0.01 | 0.00 | **0.10** | −0.04 | 0.02 | 0.00 | −0.03 | 0.04 | 0.00 | 0.01 | −0.01 | 0.02 |
| $m_6$-$m_1$ | 0.03 | 0.00 | 0.05 | **0.18** | −0.05 | −0.04 | **0.22** | −0.05 | 0.07 | −0.03 | 0.01 | 0.00 |
| $m_7$-$m_1$ | 0.09 | −0.05 | −0.02 | 0.01 | −0.05 | −0.04 | **−0.14** | −0.07 | **0.22** | −0.09 | 0.01 | 0.02 |
| $m_8$-$m_1$ | −0.01 | −0.04 | −0.06 | **0.12** | 0.00 | −0.03 | −0.04 | 0.01 | 0.02 | −0.01 | −0.01 | 0.00 |
| $m_9$-$m_1$ | 0.00 | −0.04 | 0.02 | 0.05 | −0.01 | −0.04 | 0.07 | −0.01 | 0.01 | −0.02 | −0.02 | −0.01 |
| | Lady Franklin Bay | | | | | | | | | | | |
| $m_2$-$m_1$ | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | −0.01 | −0.02 | 0.00 | 0.00 | −0.01 | 0.00 | 0.00 |
| $m_3$-$m_1$ | 0.01 | 0.01 | 0.00 | −0.02 | 0.03 | −0.02 | −0.04 | 0.00 | 0.02 | −0.05 | 0.01 | 0.00 |
| $m_4$-$m_1$ | 0.04 | −0.01 | 0.03 | 0.00 | −0.01 | −0.06 | **−0.13** | 0.09 | −0.01 | −0.09 | −0.01 | −0.03 |
| $m_5$-$m_1$ | 0.01 | −0.02 | 0.03 | 0.00 | −0.05 | −0.02 | −0.03 | −0.05 | 0.00 | 0.00 | −0.01 | 0.01 |
| $m_6$-$m_1$ | 0.02 | 0.03 | 0.03 | 0.00 | 0.05 | 0.02 | −0.03 | 0.05 | 0.03 | −0.04 | 0.01 | 0.00 |
| $m_7$-$m_1$ | 0.03 | 0.02 | 0.05 | 0.02 | 0.06 | −0.04 | −0.02 | **0.12** | **0.13** | **−0.14** | 0.02 | −0.01 |
| $m_8$-$m_1$ | 0.01 | 0.00 | 0.03 | −0.01 | −0.02 | 0.00 | −0.02 | −0.03 | 0.01 | 0.00 | 0.00 | 0.02 |
| $m_9$-$m_1$ | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.02 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 |

$m_1$ = (t01+t02+...+t23+t24)/24; $m_2$ = (t02+t04+...+t22+t24)/12; $m_3$ = (t4+t8+t12+t16+t20+t24)/6; $m_4$ = (t8+t14+t21)/3; $m_5$ = (t3+t9+t15+t21)/4; $m_6$ = (t5+t8+t12+t16+t20+t23)/6; $m_7$ = (t9+t17+t24)/3; $m_8$ = (t3+t4+t9+t10+t15+t16+t21+t22)/8; $m_9$ = (t3+t4+t5+t9+t10+t11+t15+t16+t17+t21+t22+t23)/12; where t01, t02,..., t24 mean real values of atmospheric pressure from hours 01, 02,..., 24. Values greater than 0.1 hPa and lower than −0.1 hPa are in bold.

 

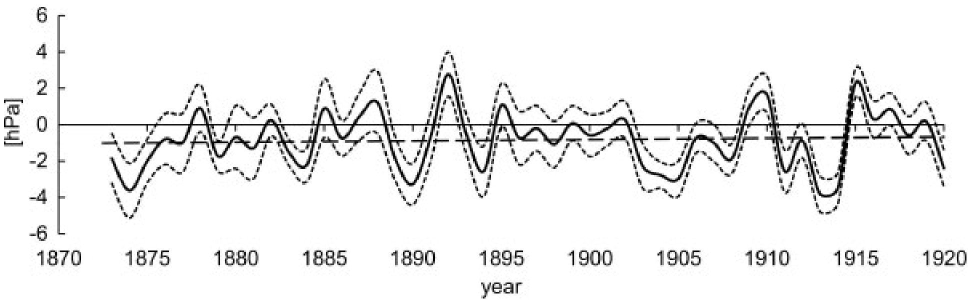


Figure 5. Year-to-year variability of mean annual anomalies of atmospheric pressure (reference period 1961–1990, solid line), their uncertainties (±2 standard errors, short-dashed lines) and trend (long-dashed line) in the Arctic in the period 1873–1920.

Using contemporary monthly mean pressure data from the GHCN dataset from period 1961 to 1990 a magnitude of those errors was estimated. Generally, the errors are relatively small when data are distributed evenly in the Arctic. For example, mean monthly areally averaged pressure values calculated from 48 and 13 stations differ usually by less than 0.2 hPa. This kind of error (i.e. difference in spatial distribution of stations in historical and present times) did not influence our results because we always compared historical and contemporary data for the same location. Later on, the pressure differences were averaged for regions and for the Arctic as a whole. The 95% confidence intervals for the annual mean values calculated from the period 1873 to 1920 are less than 1.5 hPa (see Figure 5). About two times greater confidence intervals are for means calculated for individual years for which data are available from the period 1801–1872. For more details about problems with homogeneity of the monthly pressure series see Slonosky *et al.* (1999).

To compare the historical instrumental pressure data presented in the paper with the existing gridded datasets (HadSLP2 and the 20th Century Reanalysis Project, hereafter 20CR), data from the grids located nearest the historical sites have been used. For example, for Sagastyr, Siberia (73.37 °N; 124.08 °E) we took respective grids – 20CR: 74.00 °N and 124.00 °E; HadSLP2: 75.00 °N and 125.00 °E. Temporal sampling was also done. In the case of Sagastyr, monthly means from gridded products for respective observational months (September 1882 to June 1884) were taken only. This procedure was applied to all 94 collected monthly pressure series.

The quality of reanalyses and gridded pressure reconstructions depends on the availability of raw pressure data assimilated into a model.

In the case of the 20CR version 2 for the high latitudes area (>60 °N), station pressure observations with daily resolutions were taken from the ISPD land component version 2.2.4. (Yin *et al.*, 2008). For particular decades of the analysed early instrumental period (1871–1880, 1881–1890, . . ., etc), the number of available stations is as follows: $n \leq 5$, $n \leq 19$, $n \leq 28$, $n \leq 37$, $n \leq 47$, respectively (statistics provided by courtesy of Dr Xungang Yin). Nevertheless most of these stations are mainly located in the Atlantic Subarctic. Only in the last decade (1911–1920) of the analysed period are a few stations (areas of Svalbard, Alaska, Taymyr Peninsula and East Greenland) available for the high Arctic. Maps showing the location of stations in a selected year can be also browsed at http://www.esrl.noaa.gov/psd/data/ISPD/v2.0/. For the marine component, observations of SLP for the period 1871–1951 were extracted from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) version 2.5. (Woodruff *et al.*, 2011). After examining the number of observations for the belt >60 °N (file: slp.nobs.nc at National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Physical Science Division, http://www.esrl.noaa.gov/psd/) it can be seen that until the 1870s, ships rarely reached very high latitudes. After this time marine pressure data are mainly available for the Greenland – Norwegian – West-Barents Sea basin. From the 1890s, it became most common to explore north-western part of the Baffin Bay and Russian territories on the east of the Atlantic region. Data for the Pacific region were provided during the period of the First World War. In conclusion, one can state that until the decade of 1911–1920, the spatial coverage of pressure data for the Arctic region was sparse. Assimilation of these data from the mentioned datasets into the experimental version of the US National Centers for Environmental Prediction Global Forecast System atmosphere/land model (NCEP/GFS) was performed using an Ensemble Kalman filter. As a result the 20CR dataset provides meteorological variables from 1871 to the present at 6 hourly temporal and 2° spatial resolutions. For more details see Compo *et al.* (2011).

HadSLP2 is a monthly historical SLP (MSLP) dataset covering the period from 1850 to 2004 with the 5° × 5° spatial resolution. Various terrestrial (see the list in Allan and Ansell, 2006) and marine (from ICOADS version 2.1., Worley *et al.*, 2005) data were blended and gridded. Spatially completed fields were created using Reduced Space Optimal Interpolation (RSOI, Kaplan *et al.*, 1997, 2000). On the basis of the number of monthly mean SLP observations at each grid point for every year (file: hadslp2_nobs obtained from Hadley Centre, http://www.metoffice.gov.uk/hadobs/hadslp2/), estimation of uninterpolated data coverage was carried out. Results show that spatio-temporal coverage for the belt 60–90 °N with 5° × 5° grid-point resolution amount from

2% in the early 1850s to 7% at the end of the 19th century and do not exceed 12% in the first two decades of the 20th century (see also spatial coverage in Figure 1 in Allan and Ansell, 2006).

## 3. Results

### 3.1. The entire period

#### *3.1.1. Annual means*

Areally averaged anomalies of mean annual values of atmospheric pressure calculated based on data gathered for large part of the Arctic (Atlantic, Baffin Bay and Pacific regions) are only available for period 1873–1920 (Figure 5). High frequency changes in the series can be observed. However, it is well seen that the pressure in the last 20 years of the 19th century is greater (on average by 0.5 hPa) than in the beginning of the 20th century. In line with this time changes in pressure also the highest and lowest values of mean annual pressure occurred respectively in 1892 (anomaly was equal to 2.8 hPa), and in 1913 (−3.8 hPa). However, there is not observed trend in the data in the whole analysed period (1873–1920) (Figure 5).

#### *3.1.2. Annual courses*

The annual courses of average atmospheric pressure calculated using all the data gathered for the entire study period (1801–1920) and for two sub-periods (1801–1860 and 1861–1920) are shown in Figure 6(a). However, to obtain more reliable results, the bias resulting from the rising quantity of data with time and changing spatial coverage was reduced by calculating 20 year means and then using them for calculation of area averages. For comparison purposes, Figure 6(b) shows the same characteristic for the modern period (1961–1990).

Analysis of Figure 6(a) shows that spatial differentiation of atmospheric pressure throughout the year in the Arctic was significant. Also, in each analysed climatic region, pressure changes in the annual course were very large. Region-to-region courses of atmospheric pressure are different (Figure 6(a)), except for the Atlantic and Baffin Bay regions which are under the strong influence of the Icelandic Low. This is now very active (Przybylak, 2003) and was probably also active in the study period throughout almost the whole year. In the regions mentioned the lowest values of atmospheric pressure in the period 1861–1920 were observed in winter, with a marked minimum in January (monthly averages amounting to 1004 and 1000 hPa for the Atlantic and Baffin Bay regions, respectively). On average, the highest pressure values are noted here in spring, particularly in May (Figure 6(a)), when they exceed 1012 hPa. Slightly lower pressure was also observed in summer months (more than 1010 hPa). The most irregular annual course of atmospheric pressure is noted for the Siberian region. Here three maxima and three minima are seen. A primary maximum (>1018–1020 hPa) is observed from February to April, while the primary minimum (<1008 hPa) is evident from September to October. In the Pacific region, one maximum and one minimum can be distinguished in the annual course of pressure (Figure 6(a)). Clearly the highest pressure values were noted in winter when all monthly averages exceeded 1012 hPa with maximum reaching 1020 hPa in February. Elevated pressure values have also been noted in spring. From June to November pressure was significantly lower, reaching a minimum in July (approximately 1008 hPa). Such a pattern of changes in this region means that the influence of the Aleutian Low is very limited. Pressure changes in the annual course are driven here mainly by the development of the seasonal baric centres (highs in winter and lows in summer) in Asia and North America. From Figure 6(a) it is clear that there are no pressure differences between the two sub-periods analysed and the whole period (except for November). In the Canadian Arctic, two maxima and two minima in the annual course of pressure can be distinguished. The primary maximum with pressure greater than 1016 hPa is very clear and was observed in spring, while the secondary one is seen in late autumn (Figure 6(a)). The lowest pressure values have been noted in summer, with a minimum in July (<1010 hPa). Similar to the Pacific region, there were no pressure differences between periods analysed in this article.

On average, in the whole Arctic the highest pressure in the annual course was observed in spring, with a maximum in May, and this is also true today (see Przybylak, 2003). Quite high values were also noted in summer. However, the lowest pressure values were observed in the winter months. Here we must add that, concerning the absolute values shown in Figure 6(a), those for the period 1861–1920 are definitely more reliable than those for the period 1801–1860. This is, of course, the effect of significantly better coverage for the former period than for the latter (see Figure 2). Values for the period 1801–1860 are certainly too high because data from only two regions (Canadian and Pacific) with relatively high annual pressure have been used to calculate the average Arctic pressure. As has been noted, there were insignificant pressure changes in the Canadian and Pacific regions in the whole study period.

Hanna *et al*. (2004) described the pressure changes in southwest Iceland for the period 1820–2002 and found ‘no significant overall trends for either the annual averages or any of the months’. From their Figure 2, it is clear that this is also true for the period 1820–1920. The region of Iceland is known to be a source region of cyclogenesis, which significantly influences the pressure patterns mainly in the Atlantic and Baffin Bay regions, as was stated earlier. Thus, based on results from Hanna *et al*. (2004) and on our results presented in this article for pressure changes in the Canadian and Pacific regions, we can assume that small pressure changes also occurred throughout the entire Arctic in the whole study period. If so, the monthly average pressure values calculated for the period 1861–1920 can probably also be used to correct the annual courses of pressure in the

 

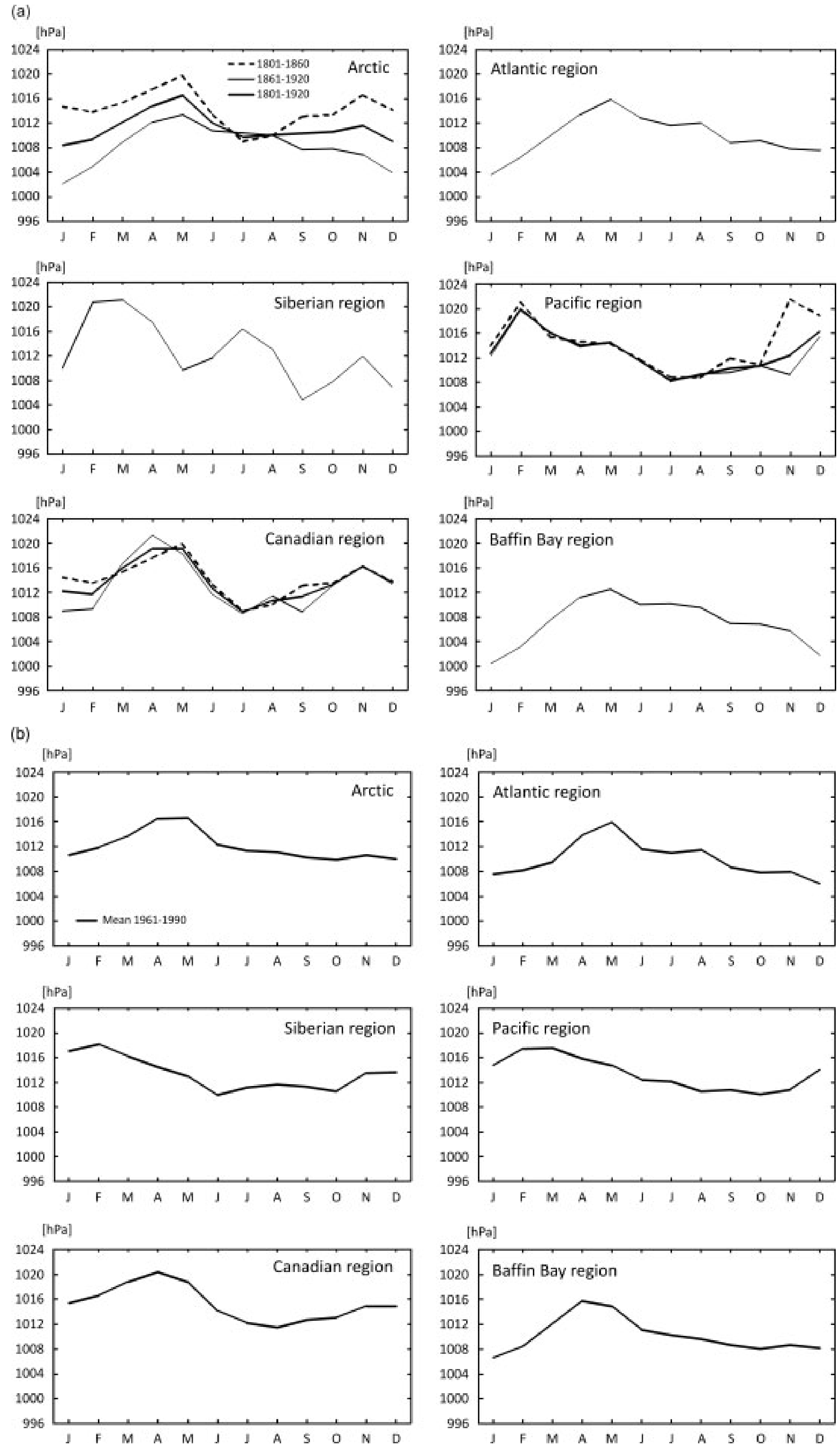


Figure 6. Average annual courses of atmospheric pressure in the Arctic in selected early instrumental (1801–1860, 1861–1920 and 1801–1920) (a) and modern (1961–1990) (b) periods.

periods 1801–1860 and then 1801–1920, as shown in Figure 6(a).

### *3.1.3. Comparison with present day climate*

Comparison of historical (Figure 6(a)) and contemporary (Figure 6(b)) annual courses of atmospheric pressure in the whole Arctic and in its particular regions reveals a very close similarity. As expected, smoother curves are observed for present day data, the time coverage of which is significantly more complete than for historical ones. A good example of this may be seen for the Siberian region. However, in all cases the main features in the annual pressure courses do not differ significantly between the historical and modern periods.

 

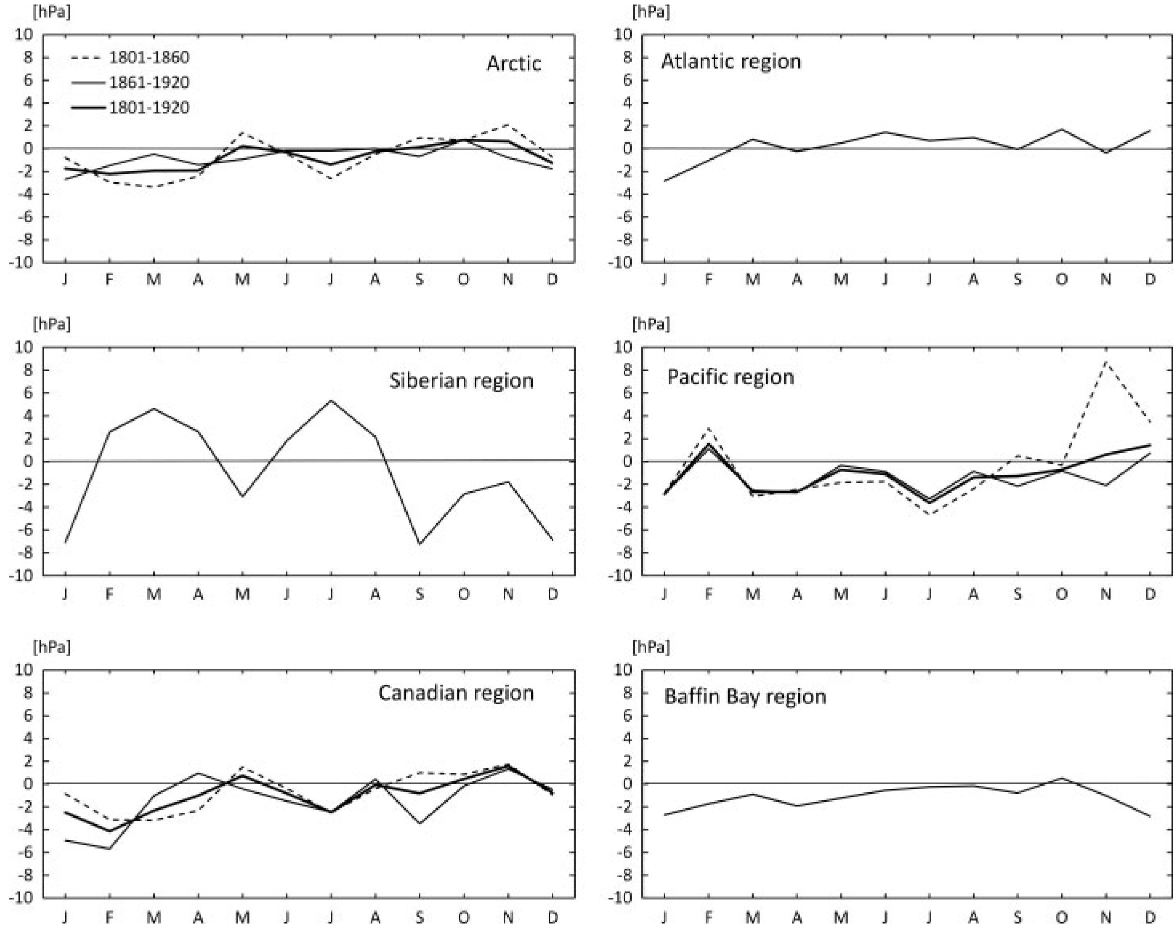


Figure 7. Atmospheric pressure differences (hPa) between mean monthly values from the historical and modern (1961–1990) periods for selected climatic regions and for the whole Arctic.

A detailed comparison of the historical and modern atmospheric pressure data is presented in Table IV and Figures 7–8. All the data gathered reveal that the Arctic in the historical study period had slightly lower pressure values than at present. On average, in the period 1861–1920 the mean annual pressure of the Arctic was lower by 0.8 hPa (Table IV). Lower values of atmospheric pressure were observed in all the study regions, excluding the Atlantic region. The greatest negative difference (−2.1 hPa) has been found for the Canadian Arctic. The greatest differences between the historical period and the modern period were noted in all the winter months and in the winter as a whole (see Table IV and Figures 7–8). In 1861–1920 winter pressure was about 2 hPa lower. However, in summer and autumn changes were very small and their average differences came to −0.1 and −0.2 hPa, respectively. In the Arctic, higher pressure in the historical period was noted only in October, while in other months the average values of differences were always ≤0.0 hPa (Table IV, Figure 7). In each region at least one monthly value was higher in the study period than it is today. Pressure differences for seasons are all negative in the Canadian and Baffin Bay regions, and are positive in the Atlantic region (except for winter). In the other two regions, a variety of differences can be noted.

The Canadian and Pacific regions are the only regions for which we have data for the whole study period (1801–1920). Both regions show slightly lower pressure (by 1.5 and 0.8 hPa, respectively) than can be noted for the modern period (Table IV, Figure 7). Thus, we can say that the pressure differences are here very similar to that observed for the whole Arctic, when data were taken from the period 1861–1920. Again, the majority of monthly differences are negative.

Figure 8 shows average seasonal and annual pressure differences between historical and modern (1961–1990) values for 20 year blocks for five climatic regions. It is clear that the number of negative differences is significantly greater than the number of positive ones, i.e. in the historical period atmospheric pressure was lower most of the time. When annual values are taken into account, only in three 20 year blocks (out of the 17 for which data exist) were slightly higher pressure values observed in the historical period than in the modern one (Table IV, Figure 8). For seasons, such situations are more frequent, ranging between five cases (in winter and spring) and seven cases (in autumn).

The question arises of whether pressure differences between the historical and modern monthly means are significant. To check this, they were compared with year-to-year pressure variability of each month in the period

 

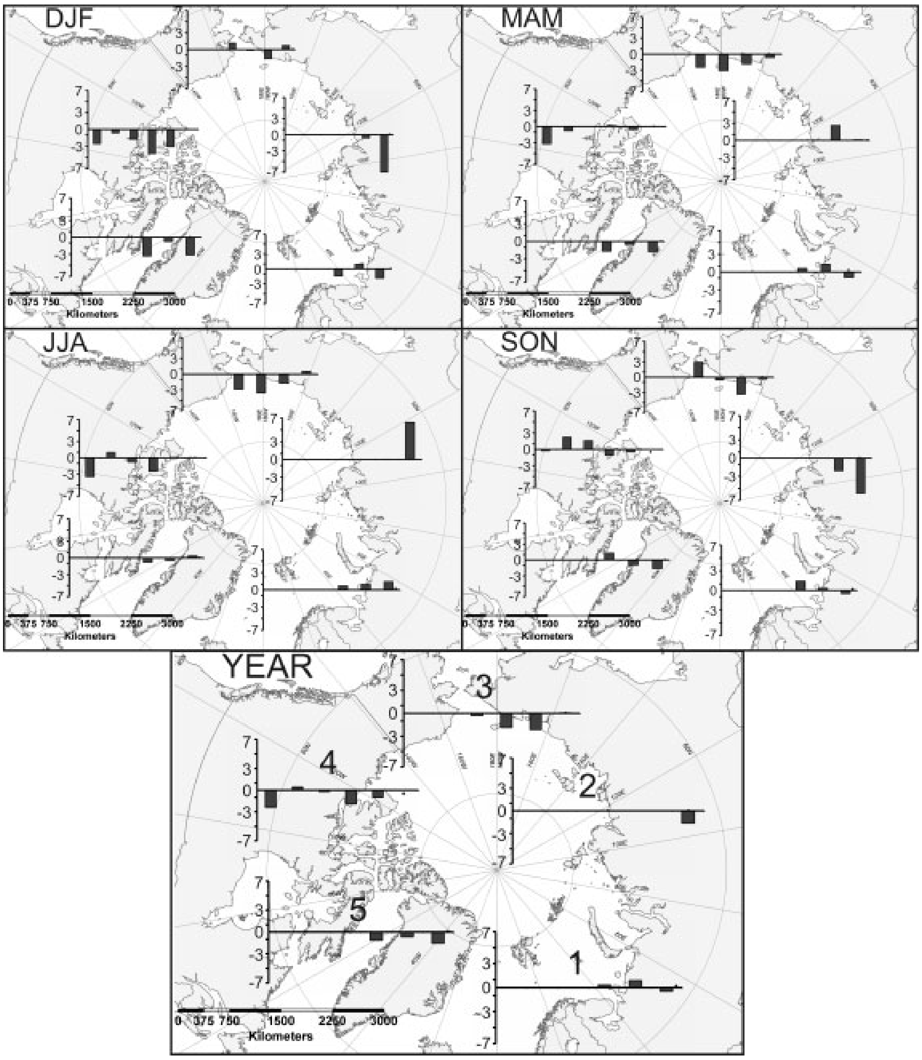


Figure 8. Atmospheric pressure differences (hPa) between mean seasonal (DJF, MAM etc.) and annual (year) values from the historical and modern (1961–1990) periods for selected climatic regions. From left to right the results are presented for the periods: 1801–1820, 1821–1840, etc. 1, Atlantic region; 2, Siberian region; 3, Pacific region; 4, Canadian region; 5, Baffin Bay region.

1961–1990, described using standard deviations (SDs). The results obtained for different areas (areally averaged data) and sites representing almost all the climatic regions of the Arctic are presented in Figure 9. The results show that atmospheric pressure changes in the Arctic between the periods 1801–1920 and 1961–1990 were not large. This conclusion is confirmed by the fact that almost all mean monthly atmospheric pressure values lie within 1 SD from the modern mean, and they never exceed the level of 2 SDs (see Figure 9).

The North Atlantic Oscillation (NAO) index was higher in the period 1861–1920 than in the period 1961–1990 (see http://www.cru.uea.ac.uk/~timo/datapages/naoi.htm). This behaviour of the NAO is in good agreement with changes in atmospheric pressure observed between these two periods in the Arctic, i.e. lower pressure occurred in the former period compared to the latter period. Correlation coefficients between mean seasonal pressure data and appropriate NAO index calculated for the period 1861–1920 for three climatic regions: Atlantic, Baffin Bay and Pacific are negative (see Table V and Figure 10). For Canadian and Siberian regions there are too few series of data to calculate meaningful correlations, and therefore results are not shown. Results presented in Table V for historical data are similar to those calculated for the modern period (1948–1999) based on data from the NCEP/NCAR Reanalysis (Cullather and Lynch, 2003, their Table I), which indirectly confirms the reliability of the historical data. The negative correlations found between the NAO index and pressure in the Arctic indicates, according to Cullather and Lynch (2003, p. 1176), that 'low pressure over the Arctic corresponds to lower pressure over Iceland relative to the Azores'.

The detailed analyses of long-term, continuous instrumental series of atmospheric pressure done for areas neighbouring the Arctic (SW Iceland, Hanna *et al*., 2004) and (southern Sweden, Bärring *et al*., 1999) also show very small and insignificant pressure changes between historical (19th century) and contemporary times. Analysis for the Canadian territory (>55 °N and east of 120 °W) also shows insignificant pressure changes between the late 19th century and the beginning of 20th century on

 

Table IV. Average atmospheric differences (hPa) between mean monthly (J, F, M, etc.), seasonal (DJF, MAM, etc.) and annual (YEAR) values from the historical and modern (1961–1990) periods for Arctic regions and for the area as a whole.

| Period | Regions[a] | J | F | M | A | M | J | J | A | S | O | N | D | DJF | MAM | JJA | SON | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1801–1820 | Canadian | **3.1** | *−8.2* | *−8.8* | *−3.4* | **2.5** | *−2.6* | *−5.5* | *2.4* | **1.4** | *−2.1* | *−0.2* | *−2.7* | *−2.6* | *−3.2* | *−3.5* | *−0.3* | *−2.4* |
| 1821–1840 | Canadian | *−1.7* | *−0.7* | *−1.2* | *−3.0* | **1.9** | **2.2** | **0.1** | **0.7** | **0.4** | **3.0** | **3.3** | **0.4** | *−0.7* | *−0.8* | **1.0** | **2.2** | **0.4** |
| 1841–1860 | Pacific | *−2.8* | **2.9** | *−3.1* | *−2.5* | *−1.8* | *−1.8* | *−4.7* | *−2.4* | **0.5** | *−0.3* | **8.7** | **3.5** | **1.2** | *−2.5* | *−2.9* | **3.0** | *−0.3* |
| | Canadian | *−4.0* | *−0.5* | **0.5** | *−0.6* | **0.1** | *−0.7* | *−2.1* | **0.5** | **1.2** | **1.6** | **2.0** | *−0.6* | *−1.7* | *0.0* | *−0.8* | **1.6** | *−0.2* |
| 1861–1880 | Atlantic | *−4.8* | *−3.2* | *−0.8* | **0.1** | **2.6** | **1.3** | *−0.8* | **1.7** | **0.3** | **1.6** | **2.4** | **3.8** | *−1.4* | **0.6** | **0.7** | **1.4** | **0.3** |
| | Siberian | | | | | | | | | | | | | | | | | |
| | Pacific | *−10.0* | **7.2** | *−4.3* | *−5.2* | **0.1** | *−2.0* | *−9* | **0.0** | **0.0** | **2.0** | *−3.8* | **2.4** | *−0.1* | *−3.1* | *−3.6* | *−0.6* | *−1.9* |
| | Canadian | *−6.1* | *−2.4* | *−0.6* | **2.5** | *−1.4* | *−2.1* | *−4.6* | *−0.7* | *−5.4* | *−1.4* | **3.5** | *−4.5* | *−4.3* | **0.2** | *−2.5* | *−1.1* | *−1.9* |
| | Baffin Bay | *−4.1* | *−3.5* | *−0.9* | *−1.9* | *−2.2* | *−0.6* | *−0.6* | *−1.4* | **0.9** | **1.8** | **1.4** | *−2.5* | *−3.4* | *−1.7* | *−0.8* | **1.3** | *−1.1* |
| | **Arctic** | *−4.6* | *−3.1* | *−1.0* | *−1.4* | *−1.7* | *−0.6* | *−1.2* | *−1.0* | **0.5** | **1.6** | **1.6** | *−1.9* | *−3.2* | *−1.3* | *−0.9* | **1.2** | *−1.1* |
| 1881–1900 | Atlantic | **0.2** | **2.3** | **4.5** | *0.0* | *−0.4* | **1.6** | **1.4** | *−0.1* | *−0.6* | **3.4** | *−1.8* | **0.4** | **1.0** | **1.3** | **1.0** | **0.4** | **0.9** |
| | Siberian | *−3.5* | **1.6** | **4.3** | **4.8** | *−1.2* | *−2.6* | **2.6** | *−0.2* | *−3.8* | *−1.6* | *−0.9* | **0.2** | *−0.6* | **2.6** | *−0.1* | *−2.1* | *0.0* |
| | Pacific | *−1.1* | *−2.8* | *−1.6* | *−2.3* | *−1.7* | *−1.9* | *−1.1* | *−2.1* | *−3.0* | *−4.0* | *−3.2* | *−1.0* | *−1.6* | *−1.9* | *−1.7* | *−3.4* | *−2.1* |
| | Canadian | *−3.8* | *−9.0* | *−1.5* | *−0.6* | **0.5** | *−0.8* | *−0.3* | **1.5** | *−1.6* | **1.1** | *−0.9* | **3.5** | *−3.1* | *−0.5* | **0.1** | *−0.5* | *−1.0* |
| | Baffin Bay | *−0.2* | **0.9** | **0.7** | *−2.4* | **0.0** | *−1.2* | *−0.7* | **0.5** | *−1.9* | **1.5** | *−2.5* | *−2.9* | *−0.7* | *−0.6* | *−0.5* | *−1.0* | *−0.7* |
| | **Arctic** | *−0.3* | **0.9** | **1.4** | *−1.8* | *−0.1* | *−0.8* | *−0.3* | **0.3** | *−1.7* | **1.6** | *−2.4* | *−2.1* | *−0.5* | *−0.2* | *−0.3* | *−0.8* | *−0.4* |
| 1901–1920 | Atlantic | *−3.9* | *−2.2* | *−1.2* | *−0.8* | *−0.7* | **1.5** | **1.5** | **1.3** | **0.1** | **0.1** | *−1.8* | **0.5** | *−1.9* | *−0.9* | **1.4** | *−0.5* | *−0.5* |
| | Siberian | *−10.7* | **3.6** | **4.9** | **0.4** | *−5.0* | **6.2** | **8.1** | **4.5** | *−10.7* | *−4.1* | *−2.7* | *−14* | *−7.0* | **0.1** | **6.3** | *−5.9* | *−1.6* |
| | Pacific | **2.4** | *−1.1* | *−1.7* | *−0.7* | **0.6** | **1.3** | **0.0** | **0.4** | *−1.4* | *−0.5* | **0.7** | **0.8** | **0.7** | *−0.6* | **0.5** | *−0.4* | **0.1** |
| | Canadian | | | | | | | | | | | | | | | | | |
| | Baffin Bay | *−3.8* | *−2.6* | *−2.5* | *−1.4* | *−1.5* | **0.1** | **0.6** | **0.4** | *−1.3* | *−1.7* | *−1.9* | *−3.1* | *−3.2* | *−1.8* | **0.4** | *−1.6* | *−1.6* |
| | **Arctic** | *−3.3* | *−2.3* | *−1.9* | *−1.1* | *−1.0* | **0.8** | **0.9** | **0.8** | *−0.8* | *−0.9* | *−1.6* | *−1.3* | *−2.3* | *−1.3* | **0.8** | *−1.1* | *−1.0* |
| 1801–1920 | Pacific | *−2.9* | **1.5** | *−2.7* | *−2.7* | *−0.7* | *−1.1* | *−3.6* | *−1.0* | *−1.0* | *−0.7* | **0.6** | **1.4** | **0.0** | *−2.0* | *−1.9* | *−0.4* | *−1.1* |
| | Canadian | *−2.5* | *−4.1* | *−2.3* | *−1.0* | **0.7** | *−0.8* | *−2.5* | *−0.1* | *−0.8* | **0.4** | **1.6** | *−0.8* | *−2.5* | *−0.9* | *−1.1* | **0.4** | *−1.0* |
| 1861–1920 | Atlantic | *−2.8* | *−1.0* | **0.8** | *−0.2* | **0.5** | **1.4** | **0.7** | **1.0** | *−0.1* | **1.7** | *−0.4* | **1.6** | *−0.8* | **0.3** | **1.0** | **0.4** | **0.3** |
| | Siberian | *−7.1* | **2.6** | **4.6** | **2.6** | *−3.1* | **1.8** | **5.3** | **2.1** | *−7.3* | *−2.8* | *−1.8* | *−6.9* | *−3.8* | **1.4** | **3.1** | *−4.0* | *−0.8* |
| | Pacific | *−2.9* | **1.1** | *−2.5* | *−2.7* | *−0.3* | *−0.9* | *−3.3* | *−0.6* | *−1.4* | *−0.8* | *−2.1* | **0.7** | *−0.3* | *−1.9* | *−1.6* | *−1.5* | *−1.3* |
| | Canadian | *−5.0* | *−5.7* | *−1.0* | **0.9** | *−0.4* | *−1.5* | *−2.5* | **0.4** | *−3.5* | *−0.2* | **1.3** | *−0.5* | *−3.7* | *−0.2* | *−1.2* | *−0.8* | *−1.5* |
| | Baffin Bay | *−2.7* | *−1.7* | *−0.9* | *−1.9* | *−1.2* | *−0.5* | *−0.2* | *−0.2* | *−0.8* | **0.5** | *−1.0* | *−2.8* | *−2.4* | *−1.3* | *−0.3* | *−0.4* | *−1.1* |
| | **Arctic** | *−2.7* | *−1.5* | *−0.5* | *−1.4* | *−0.9* | *−0.2* | *−0.2* | **0.0** | *−0.7* | **0.8** | *−0.8* | *−1.8* | *−2.0* | *−0.9* | *−0.1* | *−0.2* | *−0.8* |

[a] After Treshnikov (ed.) 1985, bold fonts – positive anomalies.

the one hand, and modern values on the other (Slonosky and Graham, 2005).

## 3.2. The first International Polar Year 1882/1883

The highest mean values of atmospheric pressure in the common period of observations in all the IPY-1 stations (September 1882 to July 1883) were noted in the most continental part of the Arctic, i.e. in Siberia and in the North American Arctic (Table VI, Figure 11). They ranged from 1016.9 hPa in Kara Sea to 1015.3 hPa in Lady Franklin Bay. The maritime part of the Arctic definitely shows significantly lower values than the continental part. Markedly the lowest mean pressure occurred in the Baffin Bay region (1006.0 hPa in Godthåb and 1009.7 hPa in Kingua Fjord) and in the western part of the Greenland Sea (1010.2 hPa in Jan Mayen). Similar spatial distribution also reveals mean monthly values calculated according to daily maximum and minimum measured values (Table VI). Extreme absolute pressure values indicate that pressure variation in the Arctic is huge. The highest observed atmospheric pressure was noted in the Kara Sea (1052.6 hPa, 8 April 1883), while the lowest was in Godthåb (944.2 hPa, 18 February 1883). Even if data are taken from one location the changes are very high, and very often exceed 60–70 hPa in a single year. The highest rate of pressure changes in the annual course (almost 100 hPa) was observed

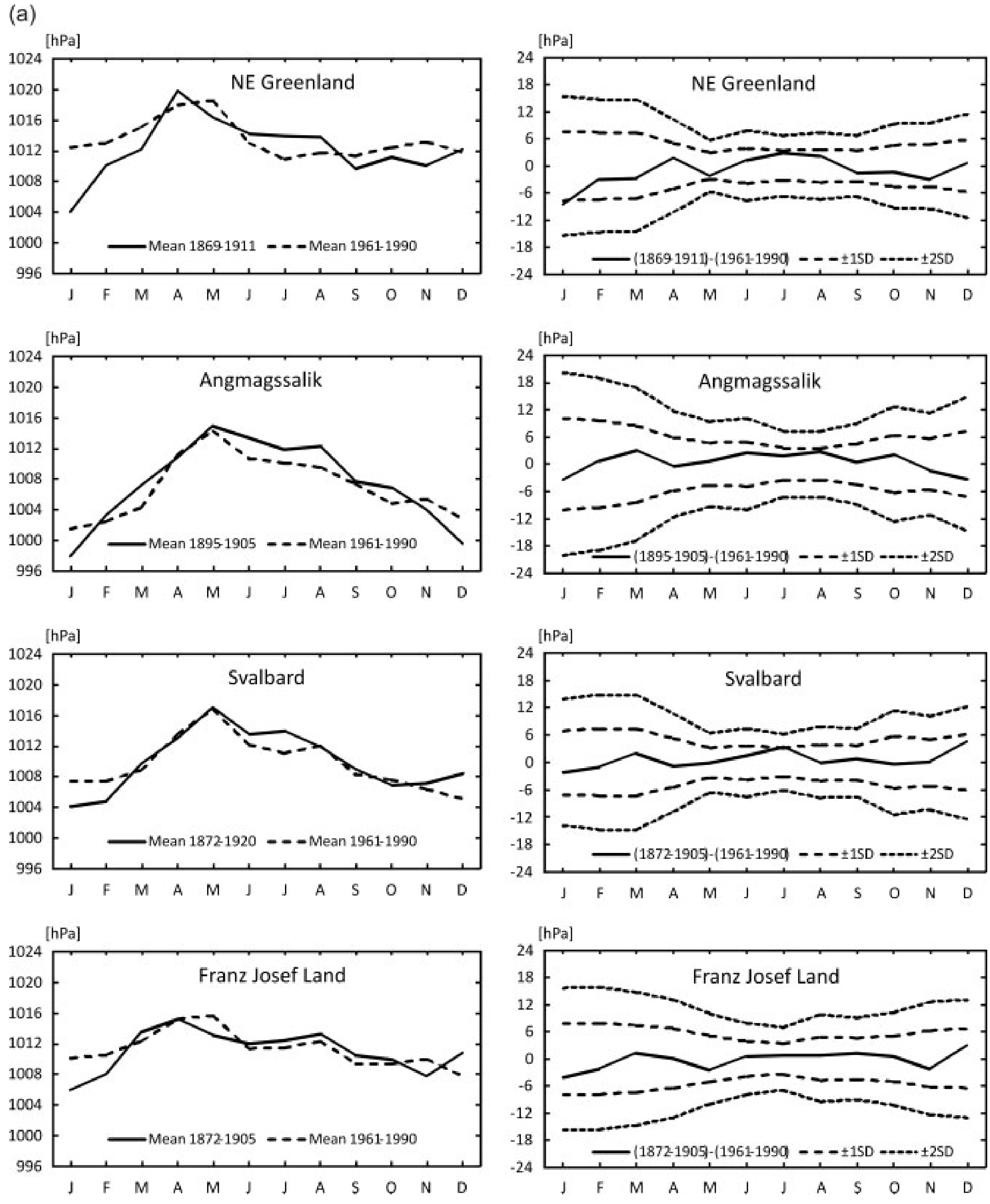


Figure 9. Annual courses of historical and modern atmospheric pressure based on monthly means (left panels) and differences between them (right panels) in selected areas of the Arctic (a and b). SDs have been calculated on the basis of present data (1961–1990).

 

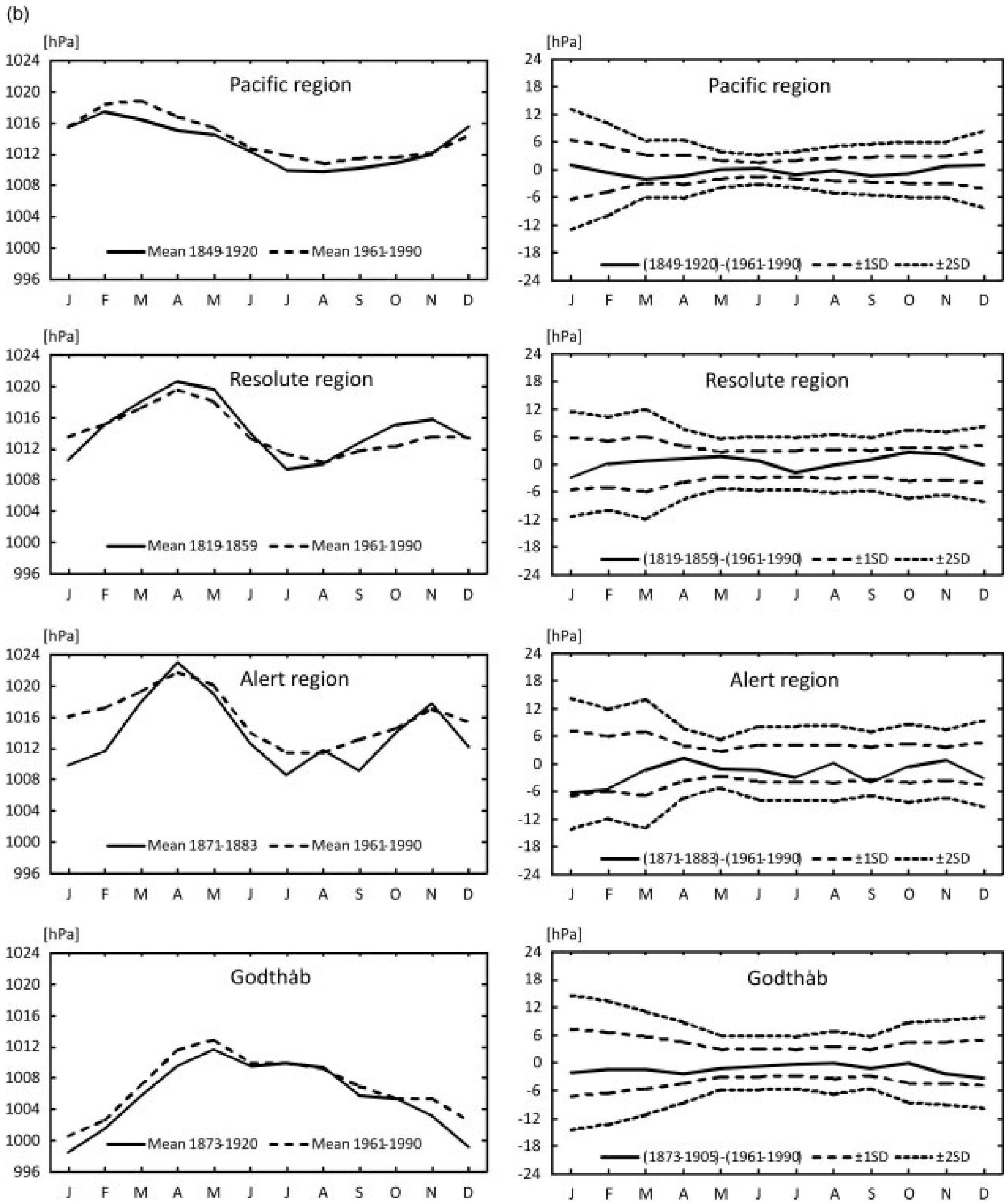


Figure 9. (*Continued*).

Table V. Correlation coefficients ($r$−values) between annual and seasonal mean NAO Index (after Jones *et al.* 1997) and atmospheric pressure anomalies in the Arctic in the period 1820–1920.

| $r$ | SON | DJF | MAM | JJA | Annual |
|---|---|---|---|---|---|
| Atlantic | **−0.38** | **−0.72** | **−0.61** | −0.27 | **−0.68** |
| Baffin Bay | **−0.50** | **−0.70** | **−0.53** | **−0.29** | **−0.67** |
| Pacific | 0.06 | **−0.38** | −0.20 | 0.09 | −0.05 |
| Arctic | **−0.40** | **−0.69** | **−0.45** | **−0.33** | **−0.58** |

Values in bold are significant at $p < 0.05$.

in Godthåb (Table VI). In the majority of stations the absolute maximum pressure occurred in March or April, except for two stations – Sagastyr and Point Barrow – where they occurred in winter months, i.e. in January (1044.7 hPa) and in December (1051.5 hPa), respectively.

The spatial patterns of mean seasonal atmospheric pressure in the Arctic during the IPY-1 period (Table VI, Figure 11) were similar to present day ones (see Gorshkov, 1980; Treshnikov, 1985; Serreze *et al*., 1993; Cullather and Lynch, 2003; Przybylak, 2003). Two areas with high mean atmospheric pressure ranging from about 1013 to 1015 hPa can be distinguished in summer: the central part of the Atlantic Arctic (from Jan Mayen to Kara Sea) and the Canadian Arctic with Alaska. On the other hand, the lowest atmospheric pressure occurred in the Baffin Bay region (1008.4 hPa in Kingua Fjord) and in the centre of the Siberian region (1010.1 hPa in Sagastyr). Atmospheric pressure shows the lowest degree of spatial differentiation in summer during IPY-1, similar to present day conditions (Table VI, Figure 11).

 

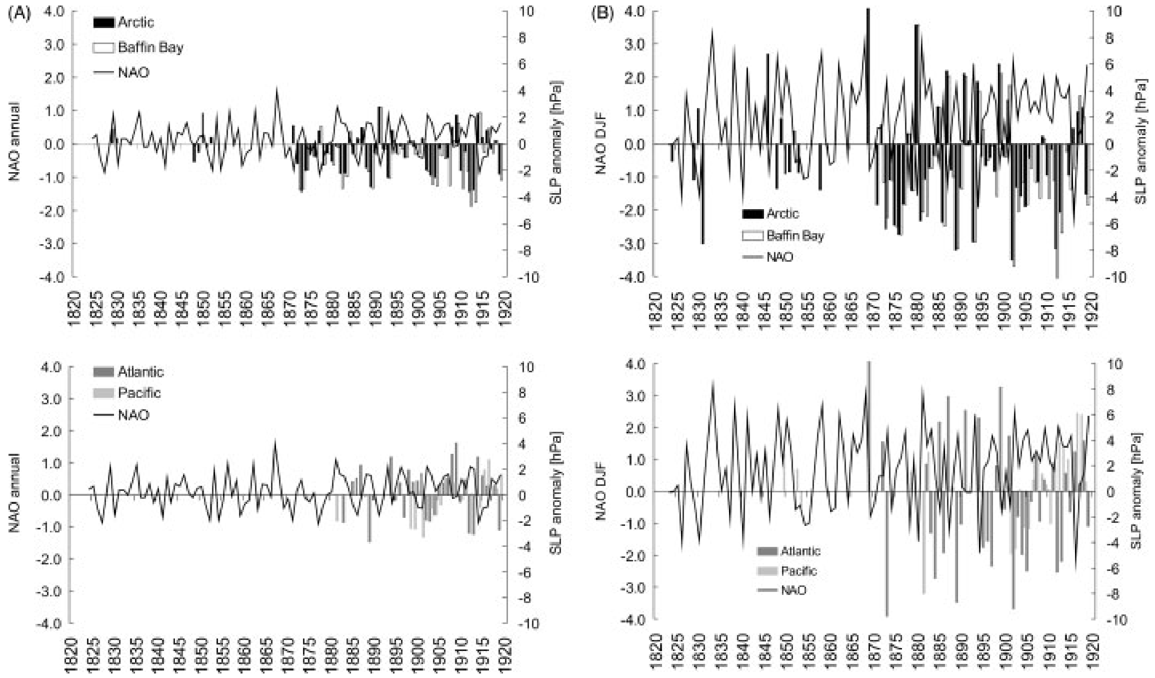


Figure 10. Year-to-year variability of (a) mean annual and (b) winter (DJF) NAO index (after Jones *et al.* 1997), and atmospheric pressure anomalies in the whole Arctic as well as the Atlantic, Baffin Bay and Pacific regions in the period 1820–1920.

In autumn and winter the lowest values of atmospheric pressure were noted markedly in the Baffin Bay region (Kingua Fjord and Godthåb) and in the western part of the Greenland Sea (Jan Mayen). On the other hand, maximal pressure values occurred in different areas: in autumn from the Barents Sea through Novaya Zemlya to the Kara Sea and in winter from the Kara Sea to Alaska (Table VI, Figure 11). The exceptionally high values of atmospheric pressure occurring in the Kara Sea (see also Table VII) throughout the whole year were one of the main reasons for the negative thermal anomalies observed here (Przybylak, 2004; Wood and Overland, 2006), which in turn led to harsh sea-ice conditions (Hovgaard, 1884). They were responsible for the fact that both the 'Varna' steamer of the Dutch expedition as well as the 'Dijmphna' vessel of the Danish expedition were ice-bound for almost the whole year. From winter to spring there were significant rises in pressure in the areas where low pressure had dominated, i.e. from the Baffin Bay region through the Greenland and Barents seas to Novaya Zemlya. In the rest of the Arctic small changes in pressure were noted. Spatial changes in spring pressure are comparable to that occurring during summer. However, the locations of areas with higher and lower pressure are completely different than in summer. In spring, there is a typical spatial pattern of pressure, which is also characteristic for the whole study period, i.e. higher values are observed in the continental part of the Arctic (above 1017 hPa, from the Kara Sea to the Canadian Arctic), while the lowest one is in the maritime Arctic (below 1017 hPa in the Baffin Bay region and the Norwegian Arctic) (Figure11).

In the annual course, according to monthly means, the lowest atmospheric pressure values in the majority of stations were noted in January and February; in Novaya Zemlya and Kara Sea they were also noted in March (Table VI, Figure 12). The reason for this is the strongly developed and very deep Icelandic Low which gives rise to dozens of cyclones entering the Baffin, Nordic and Kara seas (for details see Przybylak, 2003). In the Siberian Arctic (Sagastyr) the lowest pressure was observed in May and June, while in Alaska (Point Barrow) it was in August and September. The highest pressure values in the annual course during the IPY-1 period, similar to today, were mainly observed in spring (Table VI, Figure 12). Summarizing these results, two types of annual courses of pressure can be distinguished: continental (minimum in summer and maximum in spring or winter) and maritime (minimum in winter and maximum in spring). In the Asian and North American continents, the large seasonal pressure changes connected with the summer warming and winter cooling of these continents are the main reason for the quite large changes in pressure in the Arctic areas neighbouring them.

In winter, the differences between mean maximum (P max) and mean minimum (P min) pressure values ranged between 9 and 10 hPa, while in summer they were almost half these values (5–6 hPa). Annual courses of absolute pressure values (P max abs and P min abs) are similar to the mean maximum and minimum courses described earlier (Figure 12). Of course, the range of changes of absolute values over the course of a month and a year is markedly higher.

There is a shortage of synoptic maps for the Arctic for the 19th century which prevents us from estimating the level of cyclonic activity for this period. As a result, it is impossible to compare historical cyclonic activity with that of the present day. However, a good approximation of cyclonic activity can be supplied by the analysis of

 

Table VI. Main characteristics of atmospheric pressure for nine stations operating in the Arctic during the first IPY 1882/1883. The highest and lowest observed atmospheric pressure for each station and for the common period (SEP-JUL) are shown in bold.

| Station | Parameter | A | S | O | N | D | J | F | M | A | M | J | J | A | DJF | MAM | JJA | SON | SEP-JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Godthåb | P max abs | 1021.9 | 1030.1 | 1019.7 | 1025.6 | 1023.8 | 1015.8 | 1023.0 | **1043.3** | 1028.4 | 1032.4 | 1024.1 | 1026.1 | 1019.7 | 1023.8 | 1043.3 | 1026.1 | 1030.1 | 1043.3 |
| | P max | 1015.5 | 1009.7 | 1005.4 | 1011.3 | 1014.6 | 995.2 | 997.2 | 1018.6 | 1013.0 | 1017.1 | 1015.4 | 1014.7 | 1012.8 | 1002.3 | 1016.2 | 1014.6 | 1008.8 | 1010.2 |
| | P | 1012.7 | 1005.9 | 1001.4 | 1007.9 | 1010.9 | 990.8 | 990.3 | 1012.2 | 1008.9 | 1013.9 | 1011.9 | 1012.2 | 1010.3 | 997.4 | 1011.7 | 1011.8 | 1005.1 | 1006.0 |
| | P min | 1009.8 | 1001.9 | 997.3 | 1002.9 | 1006.8 | 986.0 | 982.2 | 1005.6 | 1003.9 | 1010.2 | 1008.0 | 1008.7 | 1007.8 | 991.7 | 1006.6 | 1008.6 | 1000.7 | 1001.2 |
| | P min abs | 998.0 | 986.9 | 983.7 | 991.4 | 979.1 | 952.2 | **945.7** | 982.5 | 984.0 | 986.9 | 992.6 | 995.3 | 991.2 | 945.7 | 982.5 | 991.2 | 983.7 | **945.7** |
| Jan Mayen | P max abs | 1021.5 | 1028.4 | 1031.5 | 1030.8 | 1033.9 | 1034.1 | 1022.8 | **1046.2** | 1035.8 | 1034.5 | 1025.5 | 1026.3 | | 1034.1 | 1046.2 | 1026.3 | 1031.5 | 1046.2 |
| | P max | 1010.9 | 1011.3 | 1015.0 | 1011.0 | 1018.5 | 1005.2 | 1003.6 | 1023.5 | 1015.7 | 1015.0 | 1018.9 | 1019.1 | | 1009.1 | 1018.1 | 1016.3 | 1012.4 | 1014.3 |
| | P | 1008.6 | 1007.1 | 1011.8 | 1006.2 | 1015.7 | 999.3 | 995.3 | 1018.6 | 1011.2 | 1012.0 | 1017.2 | 1017.8 | | 1003.4 | 1013.9 | 1014.5 | 1008.3 | 1010.2 |
| | P min | 1006.1 | 1002.9 | 1007.5 | 1002.1 | 1012.7 | 993.8 | 987.3 | 1013.4 | 1006.4 | 1009.1 | 1015.6 | 1016.4 | | 998.0 | 1009.6 | 1012.7 | 1004.2 | 1006.1 |
| | P min abs | 993.7 | 980.7 | 977.2 | 981.0 | 994.2 | 968.4 | **964.0** | 979.1 | 979.2 | 985.9 | 1005.6 | 1010.6 | | 964.0 | 979.1 | 993.7 | 977.2 | 964.0 |
| Kapp Thordsen[a] | P max abs | 1019.5 | 1024.2 | 1030.1 | 1030.9 | 1032.8 | 1031.2 | 1024.0 | **1038.1** | 1036.7 | 1035.2 | 1029.9 | 1027.6 | 1028.5 | 1032.8 | 1038.1 | 1029.9 | 1030.9 | 1038.1 |
| | P max | 1013.7 | 1012.0 | 1018.7 | 1016.7 | 1022.0 | 1008.8 | 1005.9 | 1019.8 | 1019.2 | 1022.7 | 1017.2 | 1017.8 | 1019.1 | 1012.2 | 1020.6 | 1016.9 | 1015.8 | 1016.4 |
| | P | 1012.1 | 1008.6 | 1015.4 | 1014.2 | 1018.7 | 1004.4 | 1001.4 | 1014.1 | 1016.6 | 1019.2 | 1015.3 | 1015.7 | 1017.7 | 1008.2 | 1016.6 | 1015.2 | 1012.7 | 1013.1 |
| | P min | 1010.7 | 1005.0 | 1011.6 | 1011.7 | 1015.3 | 999.7 | 996.8 | 1008.6 | 1013.8 | 1016.2 | 1013.3 | 1013.7 | 1016.4 | 1004.0 | 1012.9 | 1013.5 | 1009.4 | 1009.6 |
| | P min abs | 992.3 | 985.1 | 992.1 | 999.8 | 993.4 | 975.0 | 969.2 | **968.7** | 985.9 | 998.3 | 1007.4 | 1005.3 | 1005.9 | 969.2 | 968.7 | 992.3 | 985.1 | 968.7 |
| Malye Karmakuly[b] | P max abs | | 1029.4 | 1039.4 | 1032.4 | 1036.9 | 1027.7 | 1028.4 | 1032.3 | **1042.0** | 1032.2 | 1032.1 | 1025.1 | 1027.1 | 1036.9 | 1042.0 | 1032.1 | 1039.4 | 1042.0 |
| | P max | | 1018.6 | 1023.4 | 1018.9 | 1021.6 | 1011.3 | 1013.6 | 1008.9 | 1026.5 | 1021.4 | 1017.8 | 1011.8 | 1016.3 | 1015.5 | 1018.9 | 1015.3 | 1020.3 | 1017.6 |
| | P | | 1015.0 | 1019.8 | 1015.8 | 1017.8 | 1006.8 | 1009.0 | 1004.7 | 1024.0 | 1017.6 | 1014.8 | 1009.5 | 1014.4 | 1011.2 | 1015.4 | 1012.9 | 1016.9 | 1014.1 |
| | P min | | 1011.1 | 1015.9 | 1012.6 | 1013.8 | 1000.8 | 1004.6 | 1000.4 | 1021.5 | 1013.9 | 1011.2 | 1007.1 | 1012.4 | 1006.4 | 1011.9 | 1010.2 | 1013.2 | 1010.3 |
| | P min abs | | 995.8 | 986.3 | 993.9 | 991.1 | 978.7 | 981.8 | **973.6** | 1010.7 | 994.8 | 999.4 | 993.8 | 994.9 | 978.7 | 973.6 | 993.8 | 986.3 | 973.6 |
| Kara Sea[c] | P max abs | 1022.8 | 1029.2 | 1040.4 | 1036.8 | 1041.6 | 1030.0 | 1040.6 | 1029.6 | **1052.6** | 1036.3 | 1033.7 | 1031.7 | 1031.4 | 1041.6 | 1052.6 | 1033.7 | 1040.4 | **1052.6** |
| | P max | 1014.9 | 1019.1 | 1023.3 | 1020.7 | 1027.2 | 1016.4 | 1019.8 | 1013.2 | 1031.7 | 1023.8 | 1018.4 | 1014.7 | 1017.1 | 1021.1 | 1022.9 | 1016.3 | 1021.0 | 1020.7 |
| | P | 1012.9 | 1016.1 | 1018.3 | 1016.6 | 1023.7 | 1012.1 | 1014.6 | 1009.0 | 1028.4 | 1019.9 | 1015.3 | 1011.5 | 1015.0 | 1016.8 | 1019.1 | 1013.7 | 1017.0 | 1016.9 |
| | P min | 1010.6 | 1012.8 | 1013.7 | 1012.0 | 1020.3 | 1008.2 | 1008.8 | 1005.0 | 1023.3 | 1015.7 | 1011.8 | 1008.1 | 1012.3 | 1012.4 | 1014.6 | 1010.7 | 1012.8 | 1012.7 |
| | P min abs | 989.4 | 994.7 | 980.7 | 984.3 | 1004.4 | 997.2 | 995.4 | **976.5** | 987.2 | 997.4 | 1003.0 | 994.8 | 996.3 | 995.4 | 976.5 | 989.4 | 980.7 | 976.5 |
| Sagastyr | P max abs | | 1024.5 | 1026.5 | 1036.9 | 1042.9 | **1044.7** | 1035.6 | 1032.9 | 1041.7 | 1031.1 | 1026.0 | 1025.6 | 1027.3 | 1044.7 | 1041.7 | 1027.3 | 1036.9 | 1044.7 |
| | P max | | 1011.3 | 1017.9 | 1017.6 | 1022.3 | 1021.1 | 1025.4 | 1024.1 | 1027.4 | 1013.2 | 1009.7 | 1015.2 | 1013.4 | 1022.9 | 1021.6 | 1012.7 | 1015.6 | 1018.6 |
| | P | | 1007.9 | 1015.2 | 1014.5 | 1018.4 | 1018.1 | 1022.7 | 1021.4 | 1023.9 | 1010.2 | 1005.8 | 1013.1 | 1011.3 | 1019.7 | 1018.5 | 1010.1 | 1012.5 | 1015.6 |
| | P min | | 1004.4 | 1012.7 | 1011.3 | 1014.6 | 1015.2 | 1020.2 | 1018.4 | 1021.1 | 1007.1 | 1002.4 | 1011.1 | 1009.3 | 1016.7 | 1015.5 | 1007.6 | 1009.4 | 1012.6 |
| | P min abs | | 991.2 | 987.5 | 989.3 | 984.5 | 993.1 | 996.0 | 1006.6 | 1009.4 | 996.3 | **982.9** | 998.3 | 990.9 | 984.5 | 996.3 | 982.9 | 987.5 | 982.9 |
| Point Barrow[d] | P max abs | 1041.0 | 1034.0 | 1026.1 | 1035.8 | **1051.5** | 1050.7 | 1049.4 | 1046.8 | 1037.4 | 1038.6 | 1025.9 | 1027.8 | 1022.8 | 1051.5 | 1046.8 | 1041.0 | 1035.8 | 1051.5 |
| | P max | 1015.8 | 1014.9 | 1016.4 | 1016.4 | 1025.7 | 1023.3 | 1031.3 | 1023.4 | 1021.8 | 1016.5 | 1018.5 | 1016.1 | 1013.8 | 1026.8 | 1020.6 | 1016.0 | 1015.9 | 1020.4 |
| | P | 1011.8 | 1011.5 | 1014.3 | 1012.2 | 1022.2 | 1016.9 | 1025.6 | 1019.0 | 1019.0 | 1013.8 | 1016.1 | 1014.1 | 1010.5 | 1021.5 | 1017.3 | 1013.1 | 1012.6 | 1016.8 |
| | P min | 1007.9 | 1008.4 | 1011.6 | 1008.0 | 1018.3 | 1012.4 | 1019.8 | 1014.9 | 1016.6 | 1011.0 | 1014.0 | 1012.1 | 1007.0 | 1016.8 | 1014.2 | 1010.2 | 1009.3 | 1013.4 |
| | P min abs | 988.2 | 985.7 | 987.9 | 994.7 | 999.3 | 984.8 | **983.9** | 1001.1 | 996.0 | 989.1 | 1003.2 | 1002.4 | 994.8 | 983.9 | 989.1 | 988.2 | 985.7 | 983.9 |

Table VI. (*Continued*).

| Station | Parameter | A | S | O | N | D | J | F | M | A | M | J | J | A | DJF | MAM | JJA | SON | SEP-JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lady Franklin Bay | P max abs | 1022.1 | 1024.5 | 1030.0 | 1035.6 | 1038.4 | 1032.6 | 1025.8 | **1044.9** | 1041.7 | 1041.8 | 1025.8 | 1023.4 | | 1038.4 | 1044.9 | 1025.8 | 1035.6 | 1044.9 |
| | P max | 1014.2 | 1011.9 | 1017.5 | 1019.7 | 1025.9 | 1017.4 | 1008.6 | 1025.3 | 1023.1 | 1021.2 | 1014.6 | 1015.3 | | 1017.3 | 1023.2 | 1014.7 | 1016.4 | 1018.2 |
| | P | 1012.0 | 1009.6 | 1015.2 | 1017.0 | 1023.0 | 1014.2 | 1004.5 | 1020.1 | 1020.0 | 1018.5 | 1012.6 | 1013.9 | | 1013.9 | 1019.5 | 1012.8 | 1013.9 | 1015.3 |
| | P min | 1009.6 | 1007.2 | 1012.7 | 1014.3 | 1020.1 | 1010.7 | 1000.7 | 1014.5 | 1016.9 | 1015.6 | 1010.3 | 1012.3 | | 1010.5 | 1015.7 | 1010.8 | 1011.4 | 1012.3 |
| | P min abs | 1000.1 | 993.8 | 996.7 | 990.0 | 1004.5 | 988.6 | **983.4** | 996.4 | 995.1 | 1000.6 | 999.7 | 1001.9 | | 983.4 | 995.1 | 999.7 | 990.0 | 983.4 |
| Kingua Fjord[e] | P max abs | | 1020.0 | 1028.5 | 1032.6 | 1036.0 | 1028.0 | 1021.8 | **1042.7** | 1039.0 | 1030.4 | 1022.1 | 1031.2 | 1026.9 | 1036.0 | 1042.7 | 1031.2 | 1032.6 | 1042.7 |
| | P max | | 1012.3 | 1013.0 | 1015.4 | 1020.6 | 1007.1 | 1004.4 | 1017.9 | 1017.2 | 1017.5 | 1010.9 | 1011.1 | 1012.3 | 1010.7 | 1017.5 | 1011.4 | 1013.6 | 1013.4 |
| | P | | 1008.8 | 1009.8 | 1011.8 | 1017.5 | 1003.8 | 1000.0 | 1011.1 | 1014.0 | 1014.4 | 1006.9 | 1008.5 | 1009.8 | 1007.1 | 1013.2 | 1008.4 | 1010.1 | 1009.7 |
| | P min | | 1003.0 | 1007.1 | 1006.3 | 1013.5 | 1000.0 | 994.9 | 1000.8 | 1010.7 | 1010.9 | 1002.4 | 1005.7 | 1007.7 | 1002.8 | 1007.5 | 1005.3 | 1005.5 | 1005.0 |
| | P min abs | | 976.5 | 981.5 | 987.3 | 995.0 | 976.9 | 971.2 | **968.9** | 989.9 | 991.0 | 988.2 | 994.0 | 995.6 | 971.2 | 968.9 | 988.2 | 976.5 | 968.9 |

[a] August 1882 data without days 1–14, July 1883 data without days 24–31.
[b] December 1882 data without days 13–16.
[c] From August to September 1882 observations every 4 h, December 1882 data without days 25–31, January 1883 days 15–31, August 1883 data without days 25–31 and observations every 4 h.
[d] August 1883 data without days 28–31.
[e] September 1882 days 16–31; P max abs, P min abs – the highest and the lowest observed atmospheric pressure, P max, P min – mean monthly maximum and minimum atmospheric pressure, P – mean monthly atmospheric pressure.

day-to-day pressure changes (Hanna *et al*., 2008). Day-to-day changes in atmospheric pressure are significantly higher in winter (most often in February) than in other seasons, though the greatest differences are noted in particular in comparison to summer (Figure 13). Their monthly means in winter ranged between 8 and 12 hPa, while in summer the range was from 2 to 4 hPa. In autumn day-to-day pressure changes were higher than in spring, when anticyclones dominate in many places. The greatest differences in the annual course are seen in western parts of Greenland (Godthåb) and the Greenland Sea (Jan Mayen) as well as in Alaska (Point Barrow) (Figure 13). Here, in comparison to the rest of the Arctic, day-to-day changes in winter are significantly higher, while summer values are comparable. Niedźwiedź (2007) found that in Hornsund (South Spitsbergen) changes in atmospheric pressure are huge (up to ±10 hPa/3 h) when very deep cyclones are crossing the area. Very large day-to-day pressure changes were observed during the Swedish expedition working in Kapp Thordsen in Spitsbergen. On 22nd to 23rd January 1883 and 2nd to 3rd February 1883 pressure changes amounted to −27.6 hPa and +20.3 hPa, respectively.

Analysis of the above pressure characteristics in the Arctic during IPY-1 1882/1883 reveals that both spatial pressure patterns and annual pressure cycles are roughly similar to those of the modern period (see Przybylak, 2003). Of course some differences exist in observed values, but they are also rather small (Table VII, Figure 14). In comparison to present day values (1961–1990) atmospheric pressure in the IPY-1 period (September 1882 to July 1883) was, on average, higher by 1.4 hPa. Values higher than those currently prevailing were noted mainly in the Atlantic and Siberian Arctic with a maximum in the Kara Sea region (4–6 hPa). The rest of the Arctic experienced small decreases in pressure (up to about 2 hPa) during the historical period. The southern part of the Baffin Bay region saw the greatest changes of this kind (Table VII).

Seasonal analysis shows that the greatest positive differences between historical and contemporary pressure values occurred in autumn (2.6 hPa), while the lowest ones were in winter (only 0.2 hPa) (Table VII). In spring and summer they were very similar and amounted to 1.4 and 1.3 hPa, respectively. However, similar to the mean changes for the whole period, in all seasons not all areas had higher pressure during IPY-1 than they have today. In autumn, differentiation of changes was particularly great, from 9.7 hPa in Malye Karmakuly to −1.0 hPa in Lady Franklin Bay. Also, areas covered by negative and positive differences were comparable. In summer, changes in pressure were the most homogeneous, i.e. seven out of nine stations analysed showed higher pressure in IPY-1 than today. Only three stations (Kapp Thordsen, Malye Karmakuly and Kara Sea) experienced positive differences throughout the whole year. In the other stations, at least two seasons had negative differences (excluding only Jan Mayen) (Table VII).

 

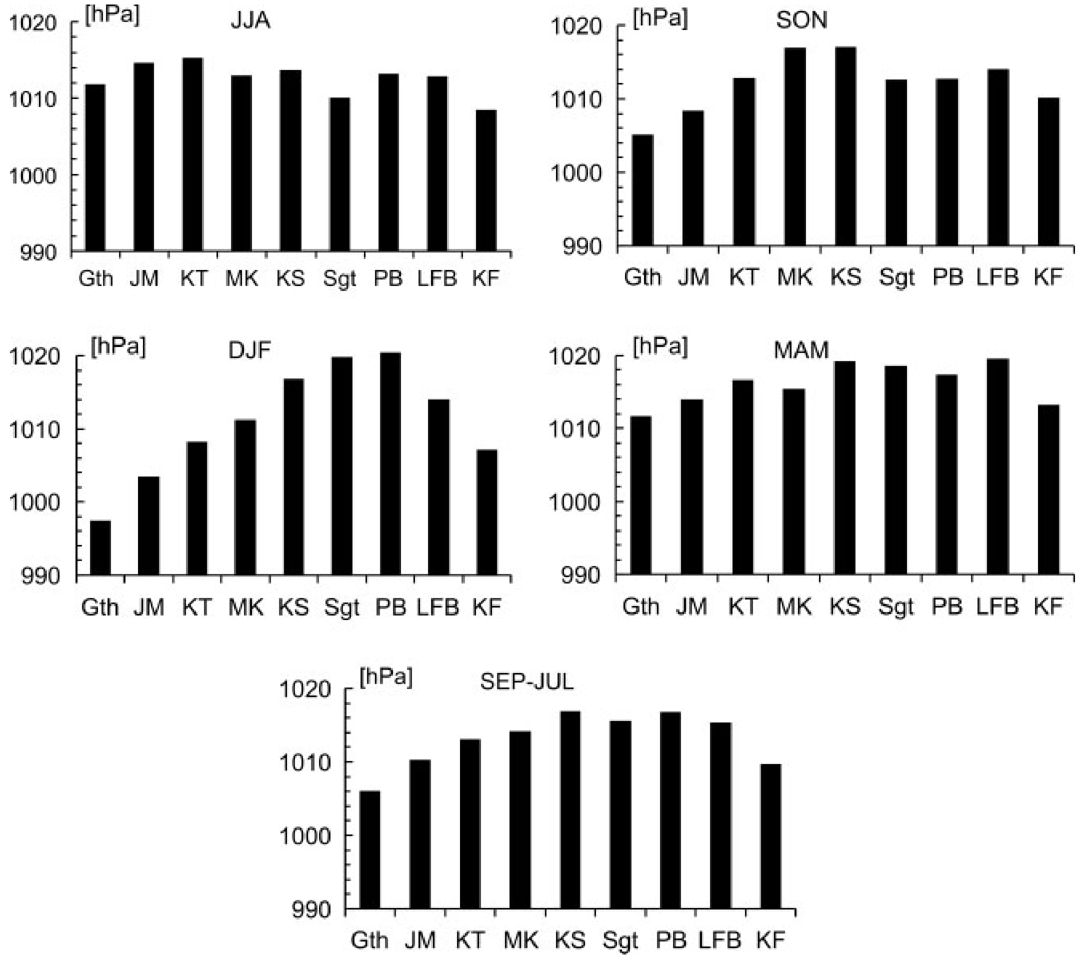


Figure 11. Seasonal means of atmospheric pressure (hPa) for nine stations operated in the Arctic during IPY-1 1882/1883. Gth, Godthåb; JM, Jan Mayen; MK, Malye Karmakuly; KS, Kara Sea; Sgt, Sagastyr; PB, Point Barrow; LFB, Lady Franklin Bay; KF, Kingua Fjord.

On average, in the annual course, the greatest positive differences clearly occurred in December (9.1 hPa). In other months they were at least half this value (4.4 hPa in October and 3.0 hPa in November and April). Only 3 months saw negative differences, of which two were quite big (−3.4 hPa in January and −5.1 hPa in February) (Table VII and Figure 14). Analysis of pressure changes for particular stations shows that no station had only positive or only negative differences between the periods analysed. Even in the Kara Sea there were 2 months (March and July) which had negative anomalies. On the other hand, the station with the greatest negative pressure changes (Kingua Fjord) from IPY-1 to the modern period, displays rises in pressure from October to December and in August. The greatest absolute positive monthly pressure changes occurred in the Kara Sea in April 1883 (15.3 hPa). Large changes were also noted here in December 1882 (14.2 hPa). Comparable values in this month also occurred in Kapp Thordsen and Malye Karmakuly (13.5 and 13.2 hPa respectively). On the other hand, the greatest absolute negative monthly changes from the historical period to the present day occurred in February in the Baffin Bay region (from −12.6 hPa in Lady Franklin Bay to −11.8 hPa in Kingua Fjord) (Table VII, Figure 14). From month-to-month very great changes were observed in pressure values between historical and contemporary times (including changes in sign), with the exception of stations representing most continental climate (i.e. Sagastyr and, in particular, Point Barrow).

The question arises of whether the observed changes between historical and modern pressure values are significant. To check this, a comparison was made of monthly differences in relation to SD calculated from the period 1961 to 1990 (Figure 14). Statistical calculations show that majority of monthly differences between the historical and modern periods (about 60%) lie within a distance of 1 SD from the present mean, and only 5% exceed 2 SD.

## 4. Discussion, conclusions and final remarks

Given the relatively large, quality controlled, and new dataset of measured pressure from the Arctic it is possible to check the reliability of the existing gridded datasets. For the analysis we took data from two such products: HadSLP2 and the 20CR, which currently do not incorporate data used in this study. Pressure data from the historical sites were compared with data taken from the above products for the nearest grids. Grid-point time-series from both datasets, together with time-series of

 

Table VII. Atmospheric pressure differences (hPa) between mean monthly values from the first IPY (1882/1883) and the modern period (1961–1990).[a] Positive and 0.0 values are shown in bold.

| Station | A | S | O | N | D | J | F | M | A | M | J | J | A | JJA | SON | DJF | MAM | SEP–JUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Godthåb | **3.7** | *−0.8* | *−3.9* | **2.6** | **8.4** | *−9.9* | *−12.3* | **5.6** | *−2.9* | **1.1** | **1.8** | **2.3** | **1.4** | **2.3** | *−0.7* | *−4.6* | **1.2** | *−0.7* |
| Jan Mayen | *−1.8* | **0.0** | **6.2** | **1.2** | **12.4** | *−4.9* | *−10.2* | **12.4** | *−1.5* | *−4.2* | **5.0** | **7.5** | | **3.5** | **2.5** | *−0.9* | **2.2** | **2.2** |
| Kapp Thordsen | **0.2** | **0.3** | **7.9** | **7.8** | **13.5** | *−2.6* | *−5.9* | **5.4** | **2.8** | **2.5** | **3.1** | **4.4** | **5.7** | **3.4** | **5.3** | **1.7** | **3.5** | **3.6** |
| Malye Karmakuly | | **6.4** | **13.1** | **9.7** | **13.2** | *−1.2* | *−1.4* | *−5.6* | **10.9** | **2.4** | **2.9** | *−3.3* | **1.7** | **0.5** | **9.7** | **3.5** | **2.6** | **4.3** |
| Kara Sea | **1.8** | **7.4** | **10.0** | **7.8** | **14.2** | **0.9** | **0.6** | *−3.6* | **15.3** | **5.4** | **5.1** | *−0.3* | **4.0** | **2.7** | **8.4** | **5.3** | **5.7** | **5.7** |
| Sagastyr | | *−4.1* | **3.6** | *−0.6* | **2.3** | *−2.0* | **2.3** | **3.1** | **8.7** | *−2.3* | *−3.9* | **2.6** | *−0.2* | *−0.5* | *−0.4* | **0.9** | **3.1** | **0.9** |
| Point Barrow | *−0.4* | *−1.1* | **1.7** | *−3.1* | **4.8** | *−2.7* | **5.3** | *−2.1* | *−0.3* | *−4.3* | **1.5** | **0.7** | *−1.7* | **0.1** | *−0.9* | **2.5** | *−2.2* | **0.0** |
| Lady Franklin Bay | **0.5** | *−3.5* | **0.7** | **0.0** | **7.6** | *−1.9* | *−12.6* | **0.8** | *−1.7* | *−1.5* | *−1.4* | **2.4** | | **0.5** | *−1.0* | *−2.3* | *−0.8* | *−1.0* |
| Kingua Fjord | | *−0.5* | **0.2** | **1.4** | **5.9** | *−6.0* | *−11.8* | *−4.4* | *−4.0* | *−1.3* | *−4.4* | *−1.1* | **0.5** | *−1.7* | **0.4** | *−4.0* | *−3.2* | *−2.4* |
| Arctic 1882/1883 | **0.7** | **0.4** | **4.4** | **3.0** | **9.1** | *−3.4* | *−5.1* | **1.3** | **3.0** | *−0.3* | **1.1** | **1.7** | **1.6** | **1.3** | **2.6** | **0.2** | **1.4** | **1.4** |

[a] For purposes of comparison, data from the following modern stations located nearest the historical stations have been used: Godthåb – Godthåb, Jan Mayen – Jan Mayen, Kapp Thordsen – Svalbard Lufthavn and Isfiord Radio, Malye Karmakuly – Malye Karmakuly, Kara Sea – Mys Kharasavey, Sagastyr – Sagyllah Ary and Ostrov Dunay, Point Barrow – Point Barrow, Lady Franklin Bay – Alert, Kingua Fjord – Iqaluit A, respectively.

historical measurements have been used to calculate the correlation between them. Results of these analyses are shown in Table VIII and Figures 15–17.

First, it has to be added that the authors of these two datasets provide information about the biases of their results for the high latitudes in the early instrumental period (until 1920). Uncertainties of monthly SLP values in HadSLP2 and 20CR often exceed 8–9 SD (in hPa) for the Arctic in historical data-sparse periods (details shown in Allan and Ansell, 2006; Compo *et al.*, 2011). Comparisons confirm this and show the occurrence of a mainly positive bias. Mean annual pressure values for the Arctic calculated using the HadSLP2 and the 20CR products are higher than the real data by 5.9 and 3.6 hPa, respectively (see Table VIII, Figure 15). Evidently, incorrect data have been found in the case of data taken from the HadSLP2, in particular for the Greenland area (Figure 16). In winter months mean values of pressure are higher here than those obtained from our database by more than 10–15 hPa, reaching sometimes even values as much as 25 hPa. On the other hand in summer months the pressure data values are too low. This means that annual variability of pressure based on data from the HadSLP2 is reversed compared to the real pressure changes.

The 20CR data was significantly better at reproducing the annual variability of pressure in area of Greenland. For other parts of the Arctic annual variability of pressure is significantly closer to the real values (Figure 16). Higher values of mean pressure in the Arctic as seen in the HadSLP2 dataset in comparison to instrumental data are probably a result of an erroneous hypothesis (existing until almost the mid-20th century) that a stable polar anticyclone occurs in the Arctic (for more details see Przybylak, 2003). Jones (1987) noted that all synoptic charts prior to about 1931 (the US Historical Weather Map series), as well as the NCAR and UKMO (United Kingdom Meteorological Office) grid-point pressure datasets constructed using these maps, show excessively high values of mean SLP in the Arctic (up to 8 hPa over the central Arctic away from the North Atlantic sector). Ansell *et al.* (2006) in a daily European-North Atlantic mean SLP reconstruction (EMSLP) also remarked that during the period with very poor data coverage (85–90% of the grid boxes have missing values), the pressure over Greenland appeared to be too high in winter. The RSOI technique used in EMSLP performed less well in data-sparse regions of the high latitudes. The question arises as to whether the data available in the HadSLP2 and the 20CR datasets were corrected and if so how well this procedure was done. For example, for the time of the first IPY the 20CR dataset used data from observations and therefore results are closer to those taken from our dataset (Figure 17). The observed differences, generally small, are probably the result of two kind of errors connected: (1) with the interpolation of pressure data to the nearest grid points and (2) with lack of corrections to account for the spatial variations in gravity which

 

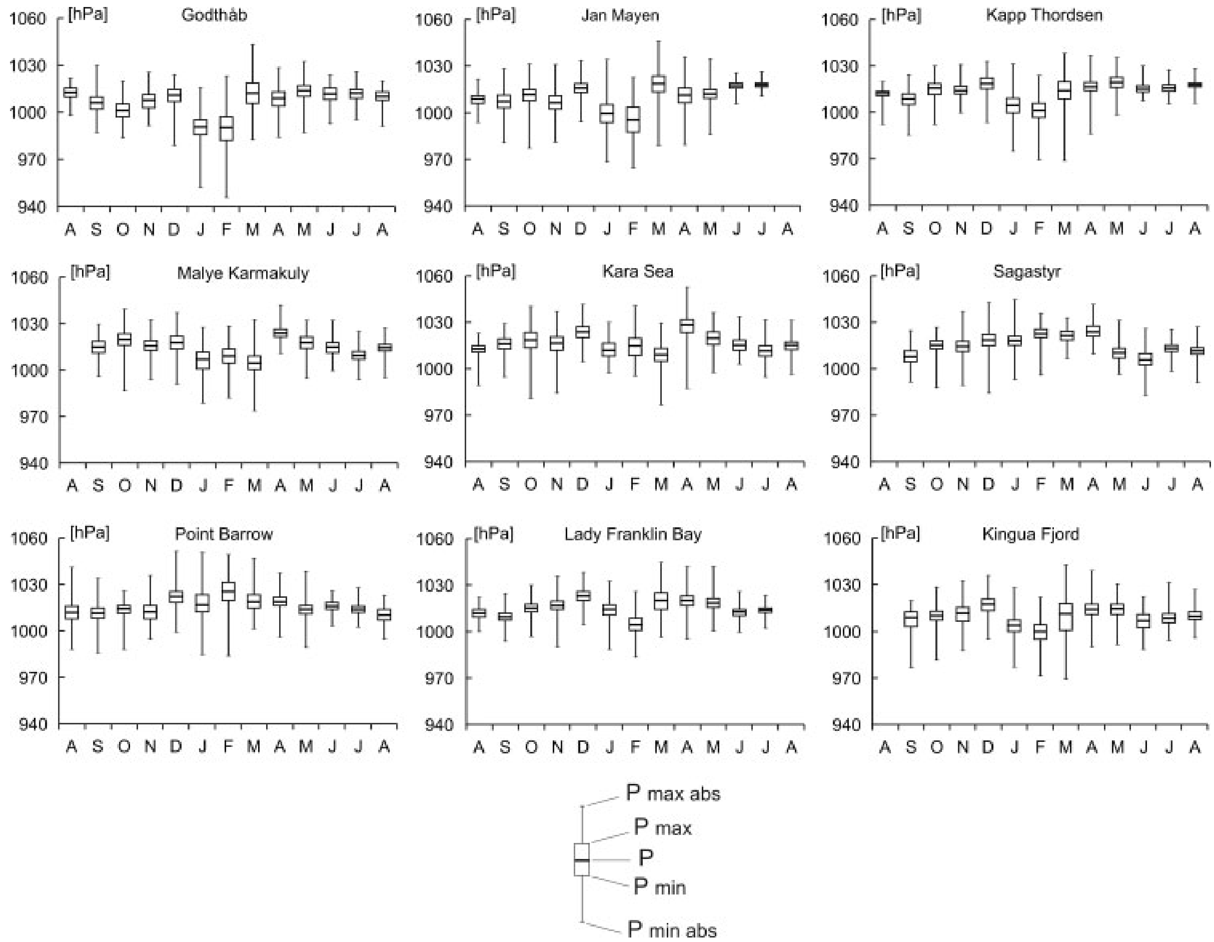


Figure 12. Annul courses of atmospheric pressure in the Arctic during the IPY-1 1882/1883 according to monthly values. P max abs: P min abs – the highest and the lowest observed atmospheric pressure; P max: P min – mean monthly maximum and minimum atmospheric pressure; P: mean monthly atmospheric pressure.

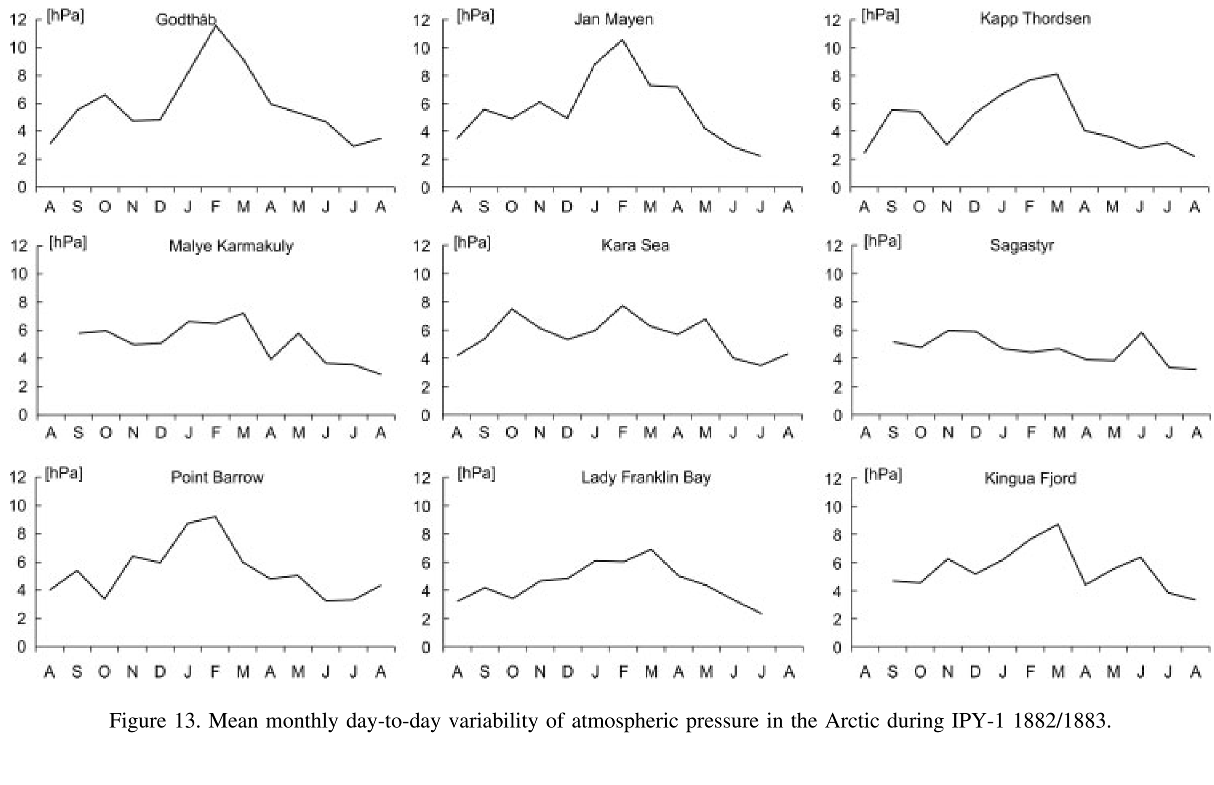


Figure 13. Mean monthly day-to-day variability of atmospheric pressure in the Arctic during IPY-1 1882/1883.

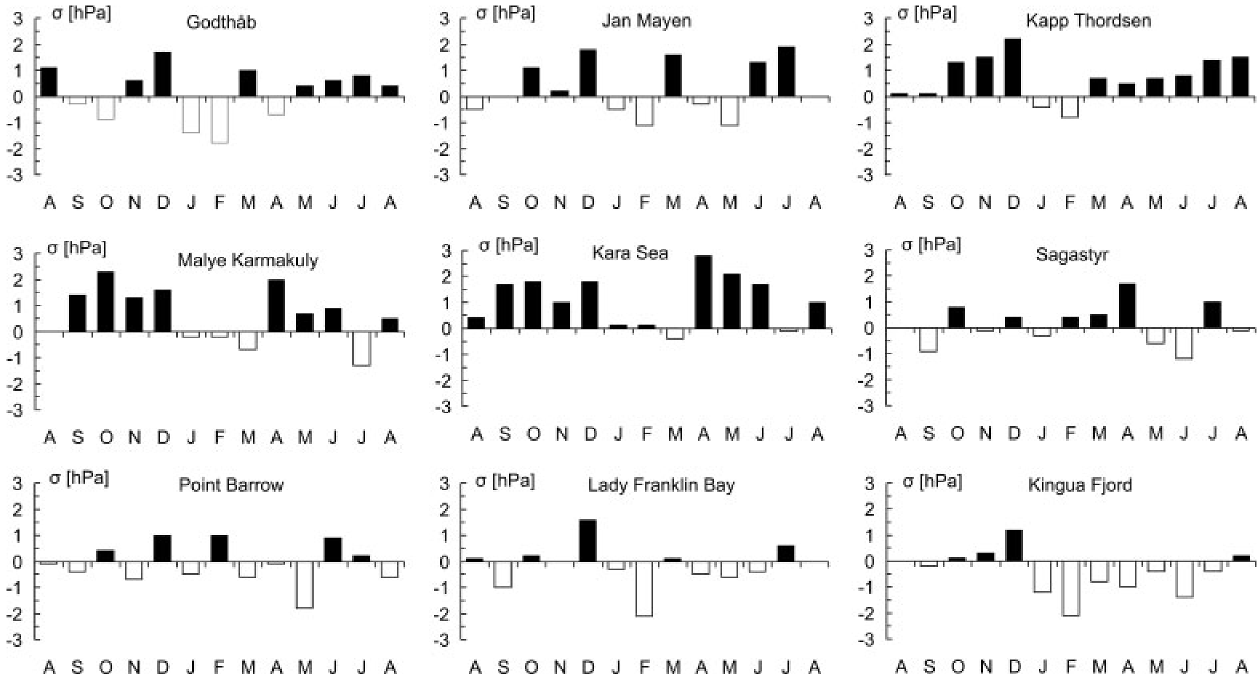


Figure 14. Atmospheric pressure differences between IPY-1 1882/1883 and the modern period 1961–1990. Differences are presented in values of SDs calculated from the reference period 1961–1990.

Table VIII. Mean differences and correlation coefficients ($r$—values) between annual atmospheric pressure values in the Arctic in the early instrumental period[a] according to different datasets: instrumental (used in this study), HadSLP2 (Allan and Ansell, 2006) and 20CR Project (Compo *et al.*, 2011).

| | Datasets | Atlantic[b] | Baffin Bay[c] | Pacific[d] | Arctic[e] |
|---|---|---|---|---|---|
| mean differences | HadSLP2 – instr. | 8.9 | 9.5 | −4.8 | 5.9 |
| | 20CR – instr. | 3.9 | 3.6 | −0.3 | 3.6 |
| | HadSLP2–20CR | 4.3 | 5.8 | −3.4 | 2.3 |
| r | HadSLP2 – instr. | 0.24 | **0.49** | 0.03 | **0.50** |
| | 20CR – instr. | 0.32 | **0.66** | 0.27 | **0.54** |
| | HadSLP2–20CR | **0.50** | **0.38** | −0.02 | **0.53** |

Values in bold are significant at $p < 0.05$.
instr., instrumental.
[a] Common periods.
[b] 1884–1920.
[c] 1873–1920.
[d] 1899–1920.
[e] 1872–1920.

was introduced to the instrumental data presented in this article.

Correlation coefficients calculated between all three analysed datasets are mainly positive, but statistically significant only for the Baffin Bay region and for the Arctic (Table VIII). Lowest correlation between series of mean annual pressure data was found for the Pacific region. For the series called 'Arctic' correlation coefficients are very close and oscillate between 0.50 and 0.54.

Analysis of the all atmospheric pressure data from the historical period (1801–1920) allows us to draw the following conclusions:

(1) The Arctic in the historical period analysed had slightly lower pressure values than at present. On average, in the period 1861–1920, the mean annual pressure of the Arctic as a whole was lower by 0.8 hPa (Table IV). Lower values of atmospheric pressure were observed in all the study regions, excluding the Atlantic region.
(2) The Canadian and Pacific regions are the only ones for which we have data for the whole study period (1801–1920). Both regions experienced slightly lower pressure (by 1.5 and 0.8 hPa, respectively) than in the modern period (Table IV, Figure 7).
(3) The greatest changes from the historical period to present day were noted in all winter months and in winter as a whole (see Table IV and Figures 7 and 8). In 1861–1920 winter pressure was about 2 hPa lower. In summer and autumn changes were very

 

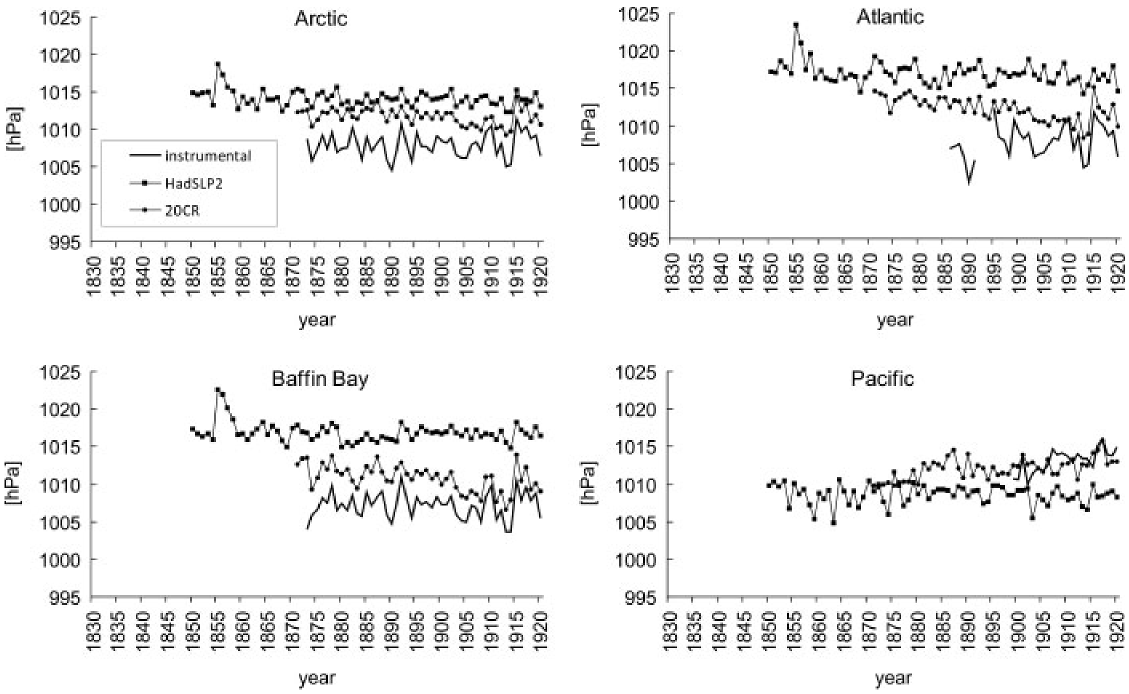


Figure 15. Year-to-year variability of mean annual atmospheric pressure in the Arctic, Atlantic, Baffin Bay and Pacific regions in the early instrumental period* according to different datasets: instrumental (used in this study), HadSLP2 (Allan and Ansell, 2006) and 20CR (Compo *et al.*, 2011). *Common periods: 1, 1884–1920; 2, 1873–1920; 3, 1899–1920; 4, 1872–1920.

small and their average differences came to −0.1 and −0.2 hPa, respectively.

(4) The results showed that atmospheric pressure changes in the Arctic between periods 1801–1920 and 1961–1990 were not large. This conclusion is confirmed by the fact that almost all mean monthly atmospheric pressure values lie within 1 SD from the modern mean, and they never exceed the level of 2 SD (see Figure 9).
(5) Recent, commonly used datasets of sea level atmospheric pressure (HadSLP2 and 20CR) reveal quite a large positive bias in the period 1850–1920 in comparison to the real data from the instrumental observations (Table VIII, Figure 15).

Meteorological data gathered for the Arctic during IPY-1 (including the atmospheric pressure analysed here) are definitely the best in terms of coverage, quality, resolution, etc. out of all the early instrumental data available for the area. As a result, IPY-1 was taken as the beginning of systematic research of the Arctic climate (Dolgin, 1971). That is why, we decided in this article to present the results of pressure conditions during that period in detail (see also Przybylak *et al.*, 2010 for temperature). The main results obtained from the analysis of the atmospheric pressure data from IPY-1 1882/1883 can be summarized as follows:

(1) Spatial pattern of atmospheric pressure in the Arctic was very similar to the present day (1961–1990) one. According to annual values, the Siberian region as well as Alaska and the Canadian Arctic had higher pressure than the Baffin Bay region and the Norwegian Arctic (Figure 11). Comparison of pressure patterns in the historical and modern periods in particular seasons also reveals significant similarity.
(2) Two types in the annual courses of pressure have been distinguished: continental (minimum in summer and maximum in spring or winter) and maritime (minimum in winter and maximum in spring) (Figure 12).
(3) Day-to-day changes in atmospheric pressure are significantly higher in winter (most often in February) than in other seasons; however, the greatest differences are noted in comparison to summer (Figure 13). Their monthly means in winter ranged between 8 and 12 hPa, while in summer they ranged from 2 to 4 hPa.
(4) In comparison to the present day (1961–1990) values atmospheric pressure in the IPY-1 period (September 1882 to July 1883) was, on average, 1.4 hPa higher. In seasons the greatest positive differences between historical and contemporary pressure values occurred in autumn (2.6 hPa), while the lowest ones were in winter (only 0.2 hPa) (Table VII).
(5) The majority of monthly pressure differences (about 60%) between historical and modern periods lie within a distance of 1 SD from the present day mean (1961–1990), and only 5% exceed 2 SD (Figure 14).

The search for pressure data measured during different land and marine expeditions to the Arctic revealed that they are quite extensive. We found only slightly fewer monthly series for pressure than for temperature (see Przybylak *et al.*, 2010). Correction of the pressure

 

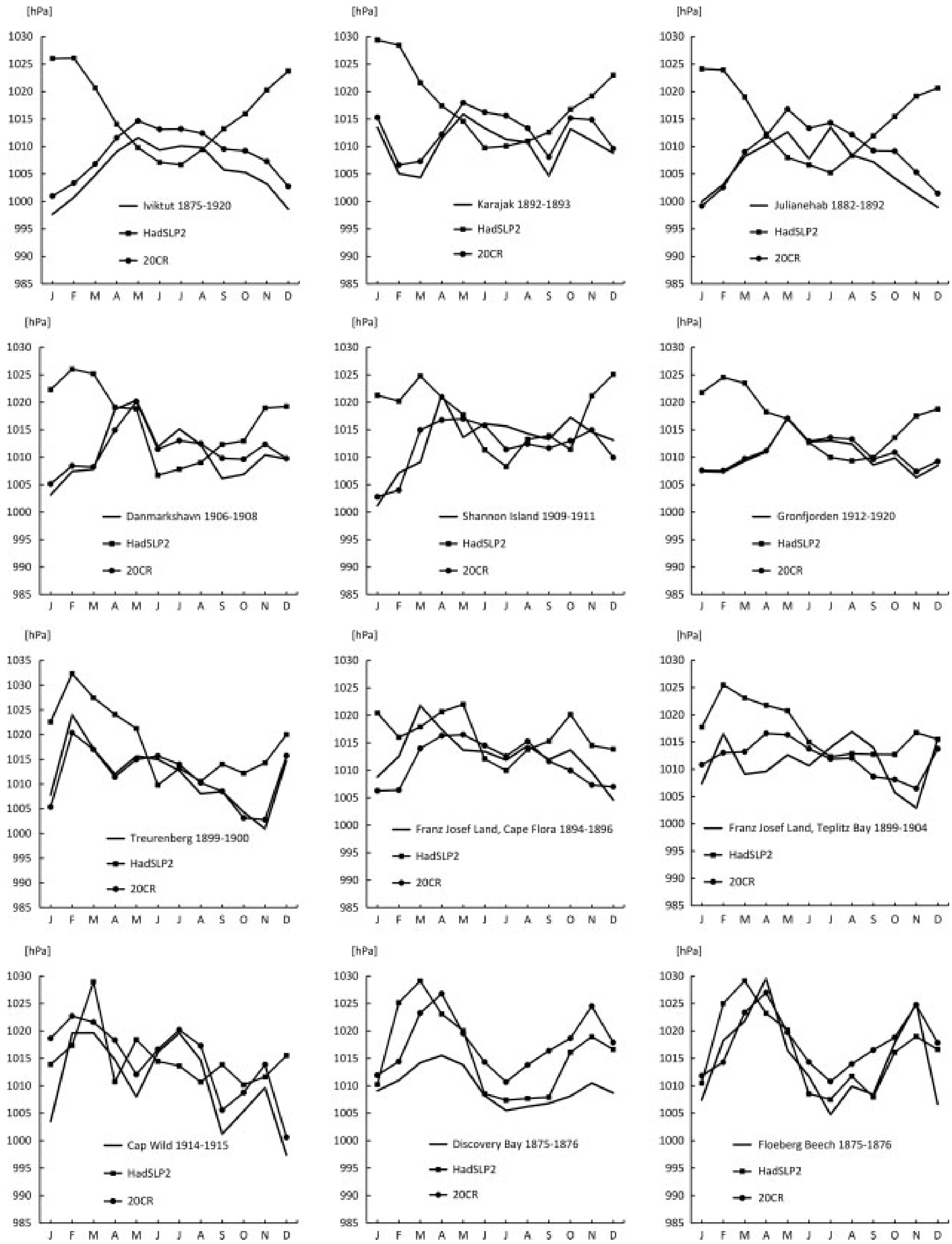


Figure 16. Annual variability of mean monthly atmospheric pressure in different areas of the Arctic in selected early instrumental stations according to original and gridded (HadSLP2 and 20CR Project) data.

data, however, is more difficult and needs more information concerning measurement – type of instruments, times, location (including height of barometer), barometer temperature and means of elaboration (e.g. whether or not corrections for temperature and normal gravity were introduced). As a result, the analysis of pressure data is more time consuming than in the case of air temperature. However, surface pressure data for the Arctic are urgently needed to improve the quality of reanalysis, which uses this variable to reconstruct all other variables for the entire Arctic troposphere (Compo *et al.*, 2011). That is why in recent years we have intensified our search for pressure data in the Arctic within the ACRE initiative as well as ACEIP and AWAKE projects. Recently, a large quantity of pressure data described in the article was incorporated into the version 3 of the ISPD dataset (Dr Xungang Yin, personal communication), and will be used in the new version of the 20CR Project.

## Acknowledgements

The research in this article was supported by the Polish-Norwegian Fund as part of the project entitled 'Arctic Climate and Environment of the Nordic Seas and the Svalbard-Greenland Area' (AWAKE). We thank Dr Øyvind Nordli for sending us some pressure data from

 

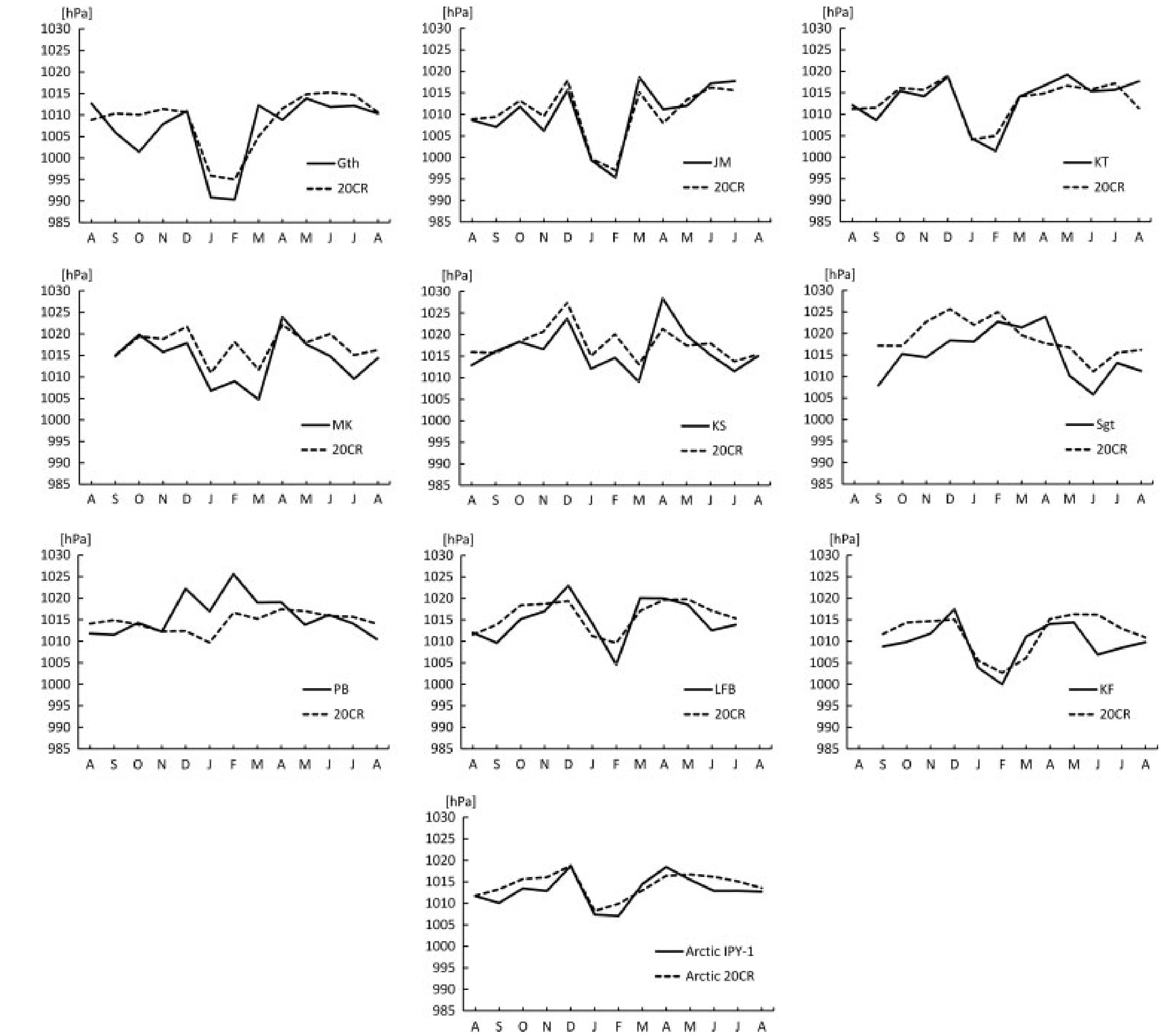


Figure 17. Annual variability of mean monthly atmospheric pressure in the Arctic during the IPY-1 1882/1883 according to original data and 20CR Project. Gth, Godthåb; JM, Jan Mayen; MK, Malye Karmakuly; KS, Kara Sea; Sgt, Sagastyr; PB, Point Barrow; LFB, Lady Franklin Bay; KF, Kingua Fjord.

the hunting expeditions which took place in Svalbard and metadata about measurement sites. The provision by Dr Xungang Yin (Global Climate Applications Division, National Climatic Data Center) of statistical information of the ISPD dataset version 2.2.4. is greatly appreciated. Support for the 20th Century Reanalysis Project dataset is provided by the US Department of Energy, Office of Science Innovative and Novel Computational Impact on Theory and Experiment (DOE INCITE) program, and Office of Biological and Environmental Research (BER) and by the National Oceanic and Atmospheric Administration Climate Program Office. 20th Century Reanalysis V2, ISPD and ICOADS data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/. We would also like to thank Drs John Kearns, Adam Lea and Emma Gale for assistance with the English. We also thank anonymous reviewers for their constructive and helpful suggestions and comments, which significantly help to improve the article.

 

# Appendix

Table A1. Atmospheric pressure database for the Arctic used in this article

| No. | Region[a] | Location | φ | λ | Altitude m a.s.l. | Instrument | Source data with introduced corrections: To gravity | Source data with introduced corrections: To SLP | Final data set with introduced corrections (including corrections added by authors): To gravity | Final data set with introduced corrections (including corrections added by authors): To SLP | Ship/Station | Captain/ Observer | Years | Number of months | Resolution of observations | Comparable station | φ | λ | Period | Sources of historical data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Atlantic region | Akseløya | 77°42′N | 14°50′E | 3 | Aneroid/ barometer | – | – | daa | + | Station | – | 09.1902 – 07.1903 | 11 | t | | | | | Norwegian Meteorological Institute. |
| 2 | | Akseløya | 77°42′N | 14°50′E | 3 | Aneroid/ barometer | – | – | daa | + | Station | – | 11.1904 – 06.1905 | 10 | t | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | |
| 3 | | Aleksadrovsk | 69°12′N | 32°28′E | 30 | Barometer | + | – | + | + | Station | – | 01.1900 – 12.1904 | 60 | m | | | | | History of the Murmansk Biological Station from1899–1905, K.M.Derjugin. |
| 4 | | Angmagssalik | 65°06′N | 38°04′W | 29 | Barometer | + | + | + | + | Station | – | 01.1895 – 12.1920 | 312 | m | Angmagssalik | 65°06′N | 38°04′W | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 5 | | Barents Sea, Belusha Bay | 71°14′N | 48°29′N | ~0 | Barograph | Unknown | Unknown | daa | (+) | Ship | Charles Benard, Major Candiotti | 07.1908 – 08.1908 | 2 | varied | Modern data (1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | Mission Arctique Cammandee par M. Charles Benard, Stations Scientifiques Cartographie - Meteorologie, Fascicule VI., Bordeaux, Au Siege dela societe,hotel de la marine nationale, 1911. |
| 6 | | Bjømøya | 74°31′N | 19°01′E | 26 | Aneroid/ barograph | – | + | daa | + | Station | C.A. Forsberg, | 07.1889 – 08.1899 | 2 | h | | | | | Meteorologische und Wasserstand-Beobachtungen auf Der Baren – Isel wahrendder Schwedischen expedition 1899 von C.A. Forsberg, Mitgeteilt den 11 October 1899, Hasselberg. |
| 7 | | Bjømøya | 74°31′N | 19°01′E | 16 | Barometer | + | + | + | + | Station | – | 01.1911 – 04.1911 | 4 | m | Bjørnøya | 74°31′N | 19°01′E | 1961–1990 | |
| 8 | | Bjømøya | 74°31′N | 19°01′E | 16 | Barometer | + | + | + | + | Station | – | 03.1919 – 04.1919 | 2 | m | | | | | Norwegian Meteorological Institute, eKlima: http://sharki.oslo.dnmi.no/portal/page_pageid=73,39035, 73_39049&_dad=portal&_schema=PORTAL. |
| 9 | | Bjømøya | 74°31′N | 19°01′E | 16 | Barometer | + | + | + | + | Station | – | 01.1920 – 12.1920 | 12 | m | | | | | |
| 10 | | Bolvanskiy Nos | 70°45′N | 59°07′E | 13 | Barometer | + | + | + | + | Station | – | 07.1914 – 06.1918 | 47 | m | Balvanskiy Nos | 70°45′N | 59°07′E | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 11 | | Bolvanskiy Nos | 70°45′N | 59°07′E | 13 | Barometer | + | + | + | + | Station | – | 08.1920 – 12.1920 | 5 | m | | | | | |
| 12 | | Danmarkshavn | 76°46′N | 18°46′W | 6.3 | Barometer | – | + | + | + | Station | – | 08.1906 – 07.1908 | 24 | h | Danmarkshavn | 76°46′N | 18°46′W | 1961–1990 | Brand W., 1911, Stundliche Werte des Luftdrucks und der Temperatur am Danmarks-Havn, Meddelelse rom Gronland, 14(5), Kobenhavn, 357-445, Wegener A. 1911, Meteorologische Terminbeobachtungen am Danmarks-Havn,Meddelelser om Gronland, 14(4), Kobenhavn,125-355. |
| 13 | | Dikson | 73°50′N | 80°23′E | 42 | Barometer | + | + | + | + | Station | – | 09.1916 – 08.1920 | 48 | m | Dikson | 73°50′N | 80°23′E | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |

Table A1. (*Continued*)

| No. | Region[a] | Location | φ | λ | Altitude m a.s.l. | Instrument | Source data with introduced corrections: To gravity | Source data with introduced corrections: To SLP | Final data set with introduced corrections (including corrections added by authors): To gravity | Final data set with introduced corrections (including corrections added by authors): To SLP | Ship/Station | Captain/ Observer | Years | Number of months | Resolution of observations | Comparable station | φ | λ | Period | Sources of historical data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | | Franz Josef Land | 79°43'N – 79°51'N | 59°33'E – 58°56'E | ~0 | Barometer | – | – | + | (+) | ship 'Tegetthof | Weyprecht and Payer | 08.1872 – 04.1874 | 21 | m | O Heisa | 80°37'E | 58°03'E | 1961–1990 | Hann, J. Einige. 1904. Ergebnisse der meteorologischen Beobachtungen auf Franz JosefsLand zwischen1872 und 1900. Aus: Meteorologische Zeitschrift, p. 547-555 (after:) Wullerstorf-Urbair, Bernard von. Die meteorologischen Beobachtungen und die Ananlyse des Schiffcurses Wahrend der Polarexpedition unter Weyprecht und Payer, 1872–1874. Kaiserliche Akademire der Wissenschafteb, Denkschriften. Mathematisch-naturwissenschaftlisch Classe, 1878. Band 35, p.1-25. |
| 15 | | Franz Josef Land, Cape Flora | 79°50'N | 49°41'E | 14 | Barometer | – | – | + | + | 'Elmwood Hous' station, ship 'Windward' | Jackson-Harmsworth Polar Expedition/ Albert B. Armitage (obs.) | 09.1894 – 09.1896 | 25 | m | Nagurskaya | 80°80'N | 47°63'E | 1961–1990 | Hann J. Einige. 1904. Ergebnisse der meteorologischen Beobachtungen auf Franz Josefs-Land zwischen 1872 und 1900. Aus: Meteorologische Zeitschrift, p. 547-555 (after:) Some results of meteorological observations made at Cape Flora, Franz Josef Land. ByMr. Strachan, Meteorological Office, London. (in:) Jackson, Frederick George. A thousand days in the Arctic. With a preface by Admiral Sir Francis Leopold McClintock. London and New York: Harper and Brothers, 1899. 2 vols. |
| 16 | | Franz Josef Land, Cape Tegetthoff | 80°06'N | 58°52'E | Unknown | Aneroid/ barograph | – | – | daa | (+) | station Harmsworth House | W.Wellman | 08.1898 – 07.1899 | 12 | m | O Heisa | 80°37'E | 58°03'E | 1961–1990 | Hann, J. Einige. 1904. Ergebnisse der meteorologischen Beobachtungen auf Franz Josefs Land zwischen1872 und 1900. Aus: Meteorologische Zeitschrift, p. 547-555 (after:) Met. Obser. of the socond Wellmann Expedition by Evelyn B. Baldwin, Observer Weather Bereau, Report of the Chief of the Weather Bareau1889-1900. Part VII, Washington 1901. p. 349-436. |
| 17 | | Franz Josef Land, Nansen's Winter House | 81°13'N | 55°20'E | 7.5 | Unknown | Unknown | – | – | + | station Nansens Winter-Hütte | Fridhj of Nansen | 09.1895 – 04.1896 | 8 | m | O Rudolfa | 81°48'E | 57°58'E | 1961–1990 | Hann, J. Einige. 1904. Ergebnisse der meteorologischen Beobachtungen auf Franz JosefsLand zwischen1872 und 1900. Aus: Meteorologische Zeitschrift, p. 547-555. |
| 18 | | Franz Josef Land, Teplitz Bay | 81°47'N | 58°04'E | 4.1 | Barometer | + | + | + | + | station | Luigi Amadeo di Savoia | 08.1899 – 08.1900 | 13 | m | O Rudolfa | 81°48'E | 57°58'E | 1961–1990 | Umberto Cagni and Luigi Amedeo di Savoia. Osservazioni Scientifiche eseguitedurante La Spedizione Polare di S.A.R. 1899-1900 (Italian), Milano:Ulrico Hoepll, 1903, 723p., data: p. 223-415. |
| 19 | | Franz Josef Land, Teplitz Bay | 81°47'N | 57°56'E | 9.3 | Barometer | + | – | + | + | station, ship 'America' | William J. Peters | 10.1903 – 04.1904 | 7 | m | O Rudolfa | 81°48'E | 57°58'E | 1961–1990 | Fleming John A. (ed.). The Ziegler Polar expedition 1903-05. Scientific results obtained under the direction of William J. Peters. Washington: National Geographic Society,1907. 630p., data: p. 369-487, Section C: Meteorological Observations and Compilations by W. J. Peters and J.A. Fleming. |
| 20 | | Franz Josef Land, Cape Flora | 79°57'N | 50°05'E | 15.1 | Aneroid/ | + | + | + | + | Elmwood Hous station of the Jackson-Harmsworth Polar Expedition 1894–97, ship 'America' | William J. Peters | 06.1904 – 07.1905 | 14 | m | Nagurskaya | 80°80'N | 47°63' E | 1961–1990 | |
| 21 | | Grønfjorden | 78°18'N | 15°30'E | 4 | Barometer | + | + | + | + | Station | – | 12.1911 – 12.1920 | 109 | m | | | | | Norwegian Meteorological Institute, eKlima: http://sharki.oslo.dnmi.no/portal/page_pageid=73,39035, 73_39049&_dad=portal&_schema=PORTAL |
| 22 | | Halmanesøya | 77°17'N | 23°05'E | 9.5 | Aneroid/ | – | – | daa | + | Station | – | 09.1906 – 08.1907 | 12 | t | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | Norwegian Meteorological Institute |
| 23 | | Isfiord Radio | 78°01'N | 13°06'E | 7 | Barometer | + | + | + | + | Station | – | 01.1911 – 12.1911 | 12 | m | | | | | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 24 | | Jan Mayen | 71°00'N | 8°28'W | 10.7 | Barometer | – | – | + | + | Station | – | 08.1882 – 07.1883 | 12 | h | Jan Mayen | 71°00'N | 8°28'W | 1961–1990 | Wohlgemuth. E.E. Von 1886, Osterreichische Polareexpedition nach Jan Mayen. Beobachtungs-Ergebnisse. Wien: Der Kaiserliche-Konigliche Hof und Staatsdruckerei.2 vols.III Theil,1 Abtheilung Meteorolgie bearbeitet von Adolf Sobieczky |
| 25 | | Julianehåb (Qaqortoq) | 60°44' N | 45°59' W | 8 | Barometer | – | – | + | + | Station | – | 10.1882 – 04.1892 | 72 | m | | | | | Meteorologisk Aarbok Udgivet af det danske meteorologiske Intitut, Kjøbenhavn |
| 26 | | Kapp Lee | 78°06'N | 20°55'E | 5 | Aneroid/ | – | – | daa | + | Station | – | 09.1904 – 08.1905 | 12 | t | | | | | Norwegian Meteorological Institute |
| 27 | | Kapp Thordsen | 78°28'N | 15°42'E | 75.7 | Barometer | – | – | + | + | Station | prof. Nils Ekholm | 08.1882 – 08.1883 | 13 | h | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | Ekholm, N.G., 1890. Observations faites au Cap Thorsden, Spitzberg, par l'expédition suédoise. Stockholm: Kongl. Boktryckeriet. P.A. Norstedt & Söner. Tome I:3.Observations Météorogiques. |

Table A1. (*Continued*)

| No. | Region[a] | Location | φ | λ | Altitude m a.s.l. | Instrument | Source data with introduced corrections: To gravity | Source data with introduced corrections: To SLP | Final data set with introduced corrections (including corrections added by authors): To gravity | Final data set with introduced corrections (including corrections added by authors): To SLP | Ship/Station | Captain/ Observer | Years | Number of months | Resolution of observations | Comparable station | φ | λ | Period | Sources of historical data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | | Kara Sea | 70°00'N – 71°45'N | 62°29'E –65°25'E | 1.15 ; 2.5 0.8 | Barometer | – | – | + | + | Ship 'Varna' | – | 09.1882 – 08.1883 | 13 | h | | | | | Snellen M., Ekama H. 1910, Rapport sur Iexpedition Neerlandaise qui a hiverne dans la Mer de Kara en 1882/83, Utrecht: J.Van Boekhoven |
| 29 | | Kara Sea | Drift | | 1.2 | Barometer and barograph | + | – | + | (+) | Ship 'Eclipse' | I. Trzemesky | 08.1914 – 09.1914 | 2 | t | | | | | Observations faites per le Dr. I. Trzemesky a bord du Vaisseau 'Eclipse' eu 1914–1915, Pietrogrod, 1917 |
| 30 | | Kara Sea | Drift | | 1.2 | Barometer and barograph | + | – | + | (+) | Ship 'Eclipse' | I. Trzemesky | 08.1915 – 09.1915 | 2 | t | | | | | Observations faites per le Dr. I. Trzemesky a bord du Vaisseau 'Eclipse' eu 1914–1915, Pietrogrod, 1917 |
| 31 | | Kara Sea | Drift | | 1.2 | Barometer and barograph | + | – | + | (+) | Ship 'Eclipse' | I. Trzemesky | 08.1916 – 09.1916 | 2 | t | Modern data (1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | |
| 32 | | Longyearbyen | 78°18'N | 15°30'E | 37 | Barometer | + | + | + | + | Station | – | 09.1911 – 05.1912 | 10 | m | | | | | Norwegian Meteorological Institute, eKlima: http://sharki.oslo.dnmi.no/portal/page_pageid=73,39035, 73_39049&_dad=portal&_schema=PORTAL |
| 33 | | Malye Karmakuly | 72°23'N | 52°36'E | 7.1 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | Malye Karmakuly | 72°23'N | 52°36'E | 1961–1990 | Lenz R. (ed.), 1886b. Beobachtungen der Russischen Polarstation auf Nowaya Semlja. Expedition der Kaiserl. Russischen Geographischen Gesellschaft. II. Theil. Meteorologische Beobachtungen bearbeitet von K. Andrejeff. |
| 34 | | Mare-Sale | 69°72'N | 66°82'E | 24 | Barometer | + | + | + | + | Station | – | 09.1914 – 08.1918 | 48 | m | Mare-Sale | 69°72'N | 66°82'E | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 35 | | Mare-Sale | 69°72'N | 66°82'E | 24 | Barometer | + | + | + | + | Station | – | 09.1920 – 12.1920 | 4 | m | | | | | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 36 | | Mosselbukta | 79°53'N | 16°04'E | 12 | Barometer | – | – | + | + | Station | – | 09.1872 – 06.1873 | 10 | m | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | Wijkander und Koldewey 1876. Resultate der meteorolischen Beobachtungen auf Spitzbergen und Ost-Grönland. Geographie und Erfordchung der Polar-Regionen, Nr 119. Aus der 'Zeitschrift der Österr. Gesellschaft für Meteorologie', Nr. 8. |
| 37 | | Nanortalik | 60°8'N | 45°11' W | 9 | Barometer | – | – | + | + | Station | – | 01.1884 – 12.1884 | 12 | m | | | | | Meteorologisk Aarbok Udgivet af det danske meteorologiske Intitut, Kjøbenhavn |
| 38 | | Nanortalik | 60°8'N | 45°11' W | 7 | Barometer | – | – | + | + | Station | – | 10.1889 – 05.1920 | 244 | m | | | | | Meteorologisk Aarbok Udgivet af det danske meteorologiske Intitut, Kjøbenhavn |
| 39 | | Pustervig | 76°57'N | 21°01'W | 4 | Barometer | – | + | + | + | Station | – | 11.1907 – 05.1908 | 7 | h | | | | | Brand W., Wegener A., 1912, Meteorologische Beobachtungen der Station Pustervig (in.) Meddelelser om Gronland, 42(6), Kobenhavn, 447-562 |
| 40 | | Sabine Insel | 74°32'N | 18°49'W | Unknown | Barometer | – | – | + | – | Station | – | 08.1869 – 07.1870 | 12 | m | | | | | Wijkander und Koldewey 1876. Resultate der meteorolischen Beobachtungen auf Spitzbergen und Ost-Grönland. Geographie und Erfordchung der Polar-Regionen, Nr 119. Aus der 'Zeitschrift der Österr. Gesellschaft für Meteorologie', Nr. 8. |
| 41 | | Shannon Island | 75°17'N | 18°00'W | 7 | Barometer | + | + | + | + | Station | – | 09.1909 – 08.1911 | 20 | m | | | | | Hansen H.1922. Meteorological observations on the Alabama Expedition, 215-295 (in:) Meddelelser om Grønland udgvine af Kommissionen dor Ledelsen af de Geologiske og Geografiske undersøgelser i Grønland. Bind LII, København, pp. 295 |
| 42 | | Svarttangen | 77°30'N | 20°50'E | 9.5 | Aneroid | – | – | daa | + | Station | – | 11.1904 – 03.1905 | 5 | t | | | | | |
| 43 | | Svarttangen | 77°30'N | 20°50'E | 9.5 | Aneroid | – | – | daa | + | Station | – | 11.1906 – 07.1907 | 9 | t | | | | | Norwegian Meteorological Institute |
| 44 | | Svarttangen | 77°30'N | 20°50'E | 9.5 | Aneroid | – | – | daa | + | Station | – | 10.1908 – 07.1909 | 8 | t | | | | | |

Table A1. (*Continued*)

| No. | Region[a] | Location | φ | λ | Altitude m a.s.l. | Instrument | Source data with introduced corrections: To gravity | Source data with introduced corrections: To SLP | Final data set with introduced corrections (including corrections added by authors) To gravity | Final data set with introduced corrections (including corrections added by authors) To SLP | Ship/Station | Captain/ Observer | Years | Number of months | Resolution of observations | Comparable station | φ | λ | Period | Sources of historical data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | | Treurenberg | 79°55′N | 16°51′E | 9 | Barometer | + | – | + | + | Station | Jaderin Edvard | 08.1899 – 08.1900 | 13 | h | | | | | Westman J., 1904, Physique terrestre. Meteorologie. Histoire naturelle. 8ieme section. Meterologie. A. Observations a la station d'hivernage. Observations meterologiques faitesen1889–1901 a la Baiede Treurenberg, Spitzberg [in:] Jaderin, Edvard, leader. Missions scientifiques pour lamesured'un arc de meridienau Spitzberg enterprises en 1889-1900 sous les auspices des gouvernements russe etsuedois: Mission suedoise. T.2. Physique terrestre, meterologie, historie naturelle. Sect. 7-8. Stockholm: Aktiebolaget Centraltryckeriet, 2 (8A): ss. 218. |
| 46 | | Zieglerøya | 77°20′N | 22°02′E | 6.5 | Unknown | – | – | – | + | Station | – | 10.1904 – 06.1905 | 9 | t | | | | | Norwegian Meteorological Institute. |
| 47 | Siberian region | Cap Wild | 75°39′N | 91°26′E | 1.2 | Barometer | + | – | + | + | Station, ship 'Eclipse' | – | 09.1914 – 08.1915 | 12 | t | | | | | Observations faites per le Dr. I. Trzemesky a bord du Vaisseau "Eclipse" eu 1914-1915, Pietrogrod, 1917. |
| 48 | | Sagastyr | 73°22′N | 124°5′E | 4.9 | Barometer | – | – | + | + | Station | Lt. N. Jourgens | 09.1882 – 06.1884 | 22 | h | Sagyllah Ary<br>Osrtov Dunay | 73°09′N<br>73°56′N | 128°54′E<br>124°30′E | 1961–1990 | Lenz R. (ed.), 1886a. Beobachtungen der Russischen Polarstation an der Lenamündung. Expeditionder Kaiserl. Russischen Geographischen Gesellschaft. II. Theil. Meteorologische Beobachtungen bearbeitet von A. Eigner. |
| 49 | | Anadyr | 64°08′N | 177°06′E | 64 | Barometer | + | + | + | + | Station | – | 01.1899 –12.1920 | 264 | m | Anadyr | 64°08′N | 177°06′E | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 50 | | ChamissoIsland | 66°13′N | 161°49′W | ~0 | Barometer | – | – | + | (+) | Ship 'Plover' | T. E. L. Moore | 01.1849 – 12.1850 | 12 | m | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | Strachan R. Contributions toOur Knowledge of the Meteorologyof the Arctic Regions, Authority of the Meteorology: London; PartI (1879), Part II(1880), Part III (1882), Part IV (1885), Part V (1888). |
| 51 | Pacific Region | Point Barrow | 71°14′N | 156°40′W | ? | Barometer | – | – | + | (+) | Station | Commander Rochfort Maguire | 01.1852 – 01.1854 | 23 | m | Barrow | 71°17′N | 156°40′W | 1961–1990 | Ray P.H. 1885, Report of the International Polar Expedition to Point Barrow, Alaska, Washington, D.C., Government Printing Office |
| 52 | | Point Barrow | 71°14′N | 157°40′W | 5.2 | Barometer | – | – | + | + | Station | Lt. P. Henry Ray | 10.1881 – 08.1883 | 23 | m | | | | | |
| 53 | | Vega Expeditionens-Pitlekaie | 67°05′N | 173°23′W | ~0 | Barometer | – | – | + | (+) | Ship "Vega" | Nordenskiold, Serze Kamen | 10.1878 – 07.1879 | 10 | h | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | VEGA – Expeditionens, Vetenskapliga Iakttagelser bearbetade af deltagare i resan och andra forskare , A.E. Nordenskiold, Stockholm 1882 |
| 54 | Baffin Bay region | Godthåb | 66°55′N | 53°40′W | 20 | Barometer | + | + | + | + | Station | – | 01.1873 – 12.1920 | 569 | m | Godthåb | 66°55′N | 53°40′W | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 55 | | Gronnedal | 61°14′N | 48°6′W | 32 | Barometer | + | + | + | + | Station | – | 01.1879 – 12.1920 | 516 | m | Gronnedal | 61°14′N | 48°6′W | 1961–1990 | |
| 56 | | Hebron | 58°12′N | 62°21′W | 15 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | | | | | Neumayer G.B, Börgen C.N.J., 1886. Die Beobachtungs-Ergebnisse der Deutschen Stationen. Berlin: Verlag von A. Asher & Co., BandI. Kingua-Fjord und die meteorologischen Stationen II. Ordnung in Labrador: Hebron, Okak, Nain, Zoar, Hoffenthal, Rama, sowie die magnetischen Observationen in Breslau und Göttingen. |
| 57 | | Hoffenthal | 55°27′N | 60°12′W | 7.6 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | Modern data(1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | Neumayer G.B, Börgen C.N.J., 1886. Die Beobachtungs-Ergebnisse der Deutschen Stationen.Berlin: Verlag von A. Asher & Co., BandI. Kingua-Fjord und die meteorologischen Stationen II. Ordnung in Labrador: Hebron, Okak, Nain, Zoar, Hoffenthal, Rama, sowie die magnetischen Observationen in Breslau und Göttingen. |
| 58 | | Inglefield Bay | 77°20′N | 67°30′W | unknown | Barometer | + | – | + | – | Station | – | 01.1916 – 10.1920 | 40 | m | | | | | Meteorologisk Aarbok Udgivet af det danske meteorologiske Intitut, Kjøbenhavn. |
| 59 | | Iviktut | 61°12′ N | 48°11′W | 5 | Barometer | – (1875–1889)/ + (1890–1920) | – (1875–1889)/ +(1890–1920) | + | + | Station | – | 01.1875 – 12.1920 | 543 | m | | | | | years 1875–1889: Meteorologisk Aarbok Udgivet af det danske meteorologiske Intitut, Kjøbenhavn.;years 1890–1920: Cappelen, J., E. V.Laursen, P. V. Jørgensen, and C. Kern-Hansen (2005), DMI monthly climate data collection 1768–2004, Denmark, the Faroe Islands and Greenland, Tech. Rep. 09-05, Dan. Meteorol. Inst., Copenhagen. |

Table A1. (*Continued*)

| No. | Region[a] | Location | φ | λ | Altitude m a.s.l. | Instrument | Source data with introduced corrections: | | Final data set with introduced corrections (including corrections added by authors) | | Ship/Station | Captain/ Observer | Years | Number of months | Resolution of observations | Comparable station | φ | λ | Period | Sources of historical data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | To gravity | To SLP | To gravity | To SLP | | | | | | | | | | |
| 60 | | Jakobshavn | 69°14'N | 51°04'W | 39 | Barometer | + | + | + | + | Station | – | 08.1873 – 12.1920 | 549 | m | Jakobshavn | 69°14'N | 51°04'W | 1961–1990 | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 61 | | Karajak | 70°26'N | 50°33'W | 22. 5 | Barometer | – | – | + | + | Station | – | 08.1892 – 07.1893 | 12 | m | | | | | Stade H. 1897. Meteorologishe Beobachtungen (in:) Grönland - Expedition der Gesellschaft für Erdkunde zu Berlin 1891–1893 unter Leitnung von Erich von Drygalski. Zweiter Band. Berli, W. H. Kühl. |
| 62 | | Nain | 56°33'N | 61°41'W | 4.2 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | | | | | Neumayer G.B, Börgen C.N.J., 1886. Die Beobachtungs-Ergebnisse der Deutschen Stationen. Berlin: Verlag von A. Asher & Co., Band I. Kingua-Fjord und die meteorologischen Stationen II. Ordnung in Labrador: Hebron, Okak, Nain, Zoar, Hoffenthal, Rama, sowie die magnetischen Observationen in Breslau und Göttingen. |
| 63 | | North Star Bay | 76°30'N | 68°55'W | 6.5 | Barometer | + | – | + | + | Station | – | 10.1910 – 05.1913 | 29 | m | | | | | Meteorologisk Aarbok Udgivet af det danske meteorologiske Intitut, Kjøbenhavn. |
| 64 | | Okak | 57°34'N | 61°56'W | 7.5 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | | | | | Neumayer G.B, Börgen C.N.J., 1886. Die Beobachtungs-Ergebnisse der Deutschen Stationen. Berlin: Verlag von A. Asher & Co., Band I. Kingua-Fjord und die meteorologischen Stationen II. Ordnung in Labrador: Hebron, Okak, Nain, Zoar, Hoffenthal, Rama, sowie die magnetischen Observationen in Breslau und Göttingen. |
| 65 | | Rama | 58°53'N | 63°15'W | 3.3 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | Modern data (1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | |
| 66 | | Upernavik | 72°47'N | 55°10'W | 19 | Barometer | + | + | + | + | Station | – | 01.1874 – 12.1920 | 560 | m | | | | | Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. Journal of Climate, 16: 2067–2077. |
| 67 | | Zoar | 56°07'N | 61°22'W | 9.5 | Barometer | – | – | + | + | Station | – | 09.1882 – 08.1883 | 12 | m | | | | | Neumayer G.B, Börgen C.N.J., 1886. Die Beobachtungs-Ergebnisse der Deutschen Stationen. Berlin: Verlag von A. Asher & Co., Band I. Kingua-Fjord und die meteorologischen Stationen II. Ordnung in Labrador: Hebron, Okak, Nain, Zoar, Hoffenthal, Rama, sowie die magnetischen Observationen in Breslau und Göttingen. |
| 68 | Canadian region | Assistance Bay | 74°40'N | 94°16'W | ~0 | Barometer | – | – | + | (+) | Ship 'Sophia' | Alex Sewart | 05.1850 – 09.1851 | 17 | m | | | | | |
| 69 | | Beechey Island | 74°43'N | 91°54'W | ~0 | Barometer | – | – | + | (+) | Ship 'North Star' | J.W.S. Pullen | 08.1852 – 08.1854 | 25 | m | | | | | |
| 70 | | Cambridge Bay | 69°03'N | 105°12'W | ~0 | Barometer | – | – | + | (+) | Ship 'Enterprise' | Sir Richard Collins | 10.1852 – 08.1853 | 11 | m | Cambridge Bay | 69°06'N | 105°08W | 1961–1990 | Strachan R. Contributions to Our Knowledge of the Meteorology of the Arctic Regions, Authority of the Meteorology: London; Part I (1879), Part II (1880), Part III (1882), Part IV (1885), Part V (1888). |
| 71 | | Camden Bay | 70°08'N | 145°29'W | ~0 | Barometer | – | – | + | (+) | Ship 'Enterprise' | Sir Richard Collins | 09.1853 – 07.1854 | 11 | m | Modern data (1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | |
| 72 | | Dealy Island | 74°56'N | 108°49'W | ~0 | Aneroid | – | – | daa | (+) | Ship 'Resolute', 'Intrepid' | Sir H. Kellett | 11.1852 – 08.1853 | 10 | m | | | | | |
| 73 | | Dealy Island | 74°56'N | 108°49'W | ~0 | Aneroid | – | – | daa | (+) | Ship 'Resolute', 'Intrepid' | Sir F.L. McClintock | 09.1852 – 08.1853 | 12 | m | | | | | |
| 74 | | Discovery Bay | 81°44'N | 65°03'W | ~0 | Barometer | – | – | + | (+) | Ship 'Discovery' | Sir George S. Nares | 09.1875 – 08.1876 | 12 | m | | | | | Results derived from the Arctic Expedition, 1875–1876, I.- Physical observations by Captain Sir Georges Nares, R.N. and Captain Feilden, &c (in:) Accounts and Papers: 39 (8) Arctic Expeditions, Session 17 January-16 August 1878, Vol. LII, London, Printed by G. E. Eyre and M. Spottiswoode, Printers to the Queen's Most Excellent Majesty, For Her Majesty's Stationery Office, 1878. http://www.umanitoba.ca/libraries/units/archives/collections/subject/arcticstudies/arcticbb/viewbb.php?t=1878&p=i1. |
| 75 | | Felix Harbour | 69°59'N | 92°01'W | ~0 | Barometer | – | – | + | (+) | Ship'Victory' | Sir John Ross | 11.1829 – 08.1830 | 10 | m | | | | | Strachan R. Contributions to Our Knowledge of the Meteorology of the Arctic Regions, Authority of the Meteorology: London; Part I (1879), Part II (1880), Part III (1882), Part IV (1885), Part V (1888). |

 

Table A1. (*Continued*)

| No. | Region[a] | Location | φ | λ | Altitude m a.s.l. | Instrument | Source data with introduced corrections: To gravity | Source data with introduced corrections: To SLP | Final data set with introduced corrections (including corrections added by authors): To gravity | Final data set with introduced corrections (including corrections added by authors): To SLP | Ship/Station | Captain/ Observer | Years | Number of months | Resolution of observations | Comparable station | φ | λ | Period | Sources of historical data |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 76 | | Floeberg Beach | 82°27′N | 61°22′W | ~0 | Barometer | – | – | + | (+) | Ship 'Alert' | Sir George S. Nares | 08.1875 – 08.1876 | 13 | m | | | | | Results derived from the Arctic Expedition, 1875–1876,I-Physical observations by Captain Sir Georges Nares, R.N. and Captain Feilden, &c (in:) Accounts and Papers: 39 (8) Arctic Expeditions, Session 17 January-16 August 1878, Vol. LII, London, Printed by G. E.Eyre and M. Spottiswoode, Printersto the Queen's Most Excellent Majesty, For Her Majesty's Stationery Office, 1878. http://www.umanitoba.ca/libraries/units/archives/collections/subject/arcticstudies/arcticbb/viewbb.phpt=1878&p=i1. |
| 77 | | Griffith Island | 74°34′N | 95°20′W | ~0 | Barometer | – | + | + | + | Ship 'Resolute' | Sir Horati T. Austin | 10.1850 – 09.1851 | 12 | m | | | | | Strachan R. Contributions to Our Knowledge of the Meteorology of the Arctic Regions, Authority of the Meteorology: London; Part I (1879), Part II (1880), Part III (1882), Part IV (1885), Part V (1888). |
| 78 | | Kingua Fjord | 66°36′N | 67°19′W | 10.6 | Barometer | – | – | + | + | Station | Dr W. Giese | 09.1882 – 08.1883 | 12 | m | | | | | Neumayer G.B, Börgen C.N.J., 1886. Die Beobachtungs-Ergebnisse der Deutschen Stationen.Berlin: Verlag von A. Asher & Co., BandI. Kingua-Fjord und die meteorologischen Stationen II. Ordnung in Labrador: Hebron, Okak, Nain, Zoar, Hoffenthal, Rama, sowie die magnetischen Observationen in Breslau und Göttingen. |
| 79 | | Lady Franklin Bay | 81°44′N | 64°45′W | 7.4 | Barometer | – | – | + | + | Station | – | 08.1881 – 08.1883 | 25 | m | | | | | Greely A.W., 1886. Report on the Proceedings of the United States expedition to Lady Franklin Bay, Grinnell Land. Washington, D.C.: Government Printing Office. 2 vols. |
| 80 | | Melville Island | 74°42′N | 110°22′W | ~0 | Barometer | – | – | + | (+) | Heda/Griper | W.E. Parry/M. Liddon | 09.1819 – 08.1820 | 12 | m | | | | | Strachan R. Contributions to Our Knowledge of the Meteorology of the Arctic Regions, Authority of the Meteorology: London; Part I (1879), Part II (1880), Part III (1882), Part IV (1885), Part V (1888). |
| 81 | | Mundy Harbour | 70°18′N | 91°35′W | ~0 | Barometer | – | – | + | (+) | Ship'Victory' | Sir John Ross | 09.1831 – 04.1832 | 8 | m | | | | | |
| 82 | | Northumberland Sound | 76°52′N | 97°00′W | ~0 | Barometer | – | – | + | (+) | Ship 'Assistance' | Sir E. Belcher | 09.1852 – 08.1853 | 12 | m | | | | | |
| 83 | | Polaris Bay | 81°36′N | 62°15′W | 10.7 | Barometer | – | + | + | + | Station | C.F. Hall | 11.1871 – 08.1872 | 10 | m | | | | | Bessels E. 1876. Scientific results of the United States Arctic expedition, steamer Polaris, C.F.Hall commanding. Vol.1. Physical observations, Washington, DC: Government Printing Office. |
| 84 | | Polaris House | 78°18′N | 70°15′W | 2.6 | Barometer | – | + | + | + | Station | C.F. Hall | 11.1872 – 05.1873 | 7 | m | | | | | |
| 85 | | Port Bowen | 73°13′N | 88°55′W | ~0 | Barometer | – | – | + | (+) | Ship 'Hecla', 'Fury' | Sir W.E. Parry, H. P. Hoppner | 09.1824 – 08.1825 | 12 | m | | | | | Strachan R. Contributions to Our Knowledge of the Meteorology of the Arctic Regions, Authority of the Meteorology: London; PartI (1879), Part II (1880), Part III (1882), Part IV (1885), Part V (1888). |
| 86 | | Port Kennedy | 72°01′N | 94°14′W | ~0 | Aneroid | – | + | daa | + | Ship 'Fox' | Sir F.L. McClintock | 09.1858 – 08.1859 | 12 | m | | | | | |
| 87 | | Port Leopold | 73°50′N | 90°12′W | ~0 | Barometer | – | – | + | (+) | Ship 'Enterprise', 'Investigator' | Sir James Clark Ross, E. J. Bird | 09.1848 – 08.1849 | 12 | m | | | | | |
| 88 | | Princess Royal Islands | 72°47′N | 117°35′W | ~0 | Barometer | – | – | + | (+) | Ship 'Investigator' | Sir Robert J. McClure | 09.1850 – 08.1851 | 12 | m | Modern data (1961–1990) for historical sites have been interpolated (kriging method) based on SLP data taken from adjacent meteorological stations (GHCN Ver.2 dataset). | | | | |
| 89 | | Repulse Bay | 66°32′N | 86°56′W | ~0 | Barometer | – | – | + | (+) | Ship | – | 10.1846 – 07.1847 | 9 | m | | | | | |
| 90 | | Victoria Harbour | 70°08′N | 91°35′W | ~0 | Barometer | – | – | + | (+) | Ship'Victory' | Sir John Ross | 09.1830 – 08.1831 | 12 | m | | | | | |
| 91 | | Walker Bay | 71°35′N | 117°39′W | ~0 | Barometer | – | – | + | (+) | Ship 'Enterprise' | Sir Richard Collins | 09.1851 – 08.1852 | 12 | m | | | | | |
| 92 | | Wellington Channell | 75°31′N | 92°10′W | ~0 | Barometer | – | – | + | (+) | Ship 'Assistance' | Sir Edward Belcher | 09.1853 – 08.1854 | 12 | m | | | | | |
| 93 | | Winter Island | 66°11′N | 83°10′W | ~0 | Barometer | – | – | + | (+) | Ship 'Hecla', 'Fury' | Sir W.E. Parry, | 08.1821 – 07.1822 | 12 | m | | | | | |
| 94 | | Wolstenholm Sound | 76°34′N | 68°45′W | ~0 | Aneroid | – | – | daa | (+) | Ship 'North Star' | James Saunders | 08.1849 – 07.1850 | 12 | m | | | | | |

+, correction introduced;–, correction not introduced; ~0, for ships precise height of barometer is unknown, probably oscillated between 0.5 and 3.0 m a.s.l., for more information see the text; (+), for ships with height of barometer denoted as ~0 we assumed that the pressure values measured can represent pressure at sea level; daa, do not apply to aneroids and barographs.

[a]After Treshnikov (ed.) 1985.

 

## References


Arctic Climatology Project, Arctic Meteorology and Climate Atlas, ver. 1 2000. *Environmental Working Group, Joint U.S.-Russian Arctic Atlas*, Fetterer F, Radionov V (eds). National Snow and Ice Data Center. CD-ROM: Boulder, CO.

Allan R, Ansell T. 2006. A New Globally Complete Monthly Historical Gridded Mean Sea Level Pressure Dataset (HadSLP2): 1850–2004. *Journal of Climate* **19**: 5816–5842, DOI: 10.1175/JCLI3937.1.

Allan R, Brohan P, Compo GP, Stone R, Luterbacher J, Brönnimann S. 2011. The International Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative. *Bulletin of the American Meteorological Society* **92**: 1421–1425, DOI: 10.1175/2011BAMS3218.1.

Ansell TJ, Jones PD, Allan RJ, Lister D, Parker DE, Brunet M, Moberg A, Jacobeit J, Brohan P, Rayner NA, Aguilar E, Alexandersson H, Barriendos M, Brandsma T, Cox NJ, Della-Marta PM, Drebs A, Founda D, Gerstengarbe F, Hickey K, Jónsson T, Luterbacher J, Nordli Ø, Oesterle H, Petrakis M, Philipp A, Rodwell MJ, Saladie O, Sigro J, Slonosky V, Srnec L, Swail V, García-Suárez AM, Tuomenvirta H, Wang X, Wanner H, Werner P, Wheeler D, Xoplaki E. 2006. Daily Mean Sea Level Pressure Reconstructions for the European–North Atlantic Region for the Period 1850–2003. *Journal of Climate* **19**: 2717–2742, DOI: http://dx.doi.org/10.1175/JCLI3775.1.

Bärring L, Jönsson P, Achberger C, Ekström M, Alexandersson H. 1999. The Lund instrumental record of meteorological observations: reconstruction of monthly sea-level pressure 1780–1997. *International Journal of Climatology* **19**: 1427–1443, DOI: 10.1002/(sici)1097-0088(19991115)19 : 13<1427::aid-joc429>3.0.co;2-h.

Brohan P, Ward C, Willetts G, Wilkinson C, Allan R, Wheeler D. 2010. Arctic marine climate of the early nineteenth century. *Climate of the Past* **6**: 315–324, DOI: 10.5194/cp-6-315-2010.

Cappelen J (ed). 2009. *DMI monthly climate data collection 1768–2008, Denmark, The Faroe Islands and Greenland, Technical Report*09-05. Dan. Meteorol. Inst.: Copenhagen, 53.

Compo GP, Whitaker JS, Sardeshmukh PD, Matsui N, Allan RJ, Yin X, Gleason BE, Vose RS, Rutledge G, Bessemoulin P, Brönnimann S, Brunet M, Crouthamel RI, Grant AN, Groisman PY, Jones PD, Kruk M, Kruger AC, Marshall GJ, Maugeri M, Mok HY, Nordli Ø, Ross TF, Trigo RM, Wang XL, Woodruff SD, Worley SJ. 2011. The Twentieth Century Reanalysis Project. *Quarterly Journal of the Royal Meteorological Society* **137**: 1–28, DOI: 10.1002/qj.776.

Cullather RI, Lynch AH. 2003. The annual cycle and interannual variability of atmospheric pressure in the vicinity of the North Pole. *International Journal of Climatology* **23**: 1161–1183, DOI: 10.1002/joc.942.

Dolgin IM. 1971. *Meteorological Regime of the Foreign Arctic*. Gidrometeoizdat, Sankt: St Peterburg (in Russian), 227.

Ekholm NG. 1890. *Observations faites au Cap Thorsden, Spitzberg, par l'expédition suédoise*, Kongl. Boktryckeriet. P.A. Norstedt & Söner Tome I: 3. Observations Météorogiques: Stockholm.

Gorshkov SG. 1980. Military Sea Fleet Atlas of Oceans: Northern Ice Ocean. USSR: Ministry of Defense: 1–184 (in Russian).

Hanna E, Jónsson T, Box JE. 2004. An analysis of Icelandic climate since the nineteenth century. *International Journal of Climatology* **24**: 1193–1210, DOI: 10.1002/joc.1051.

Hanna E, Cappelen J, Allan R, Jónsson T, Blanco F, Lilington T, Hickey K. 2008. New insight into North European and North Atlantic Surface Pressure Variability, Storminess, and Related Climate Change since 1830. *Journal of Climate* **21**: 6739–6766.

Hovgaard A. 1884. Die Eiszustände im Karischen Meere. *Mitteilungen aus Justus Perthes' Geographischer Anstalt,* **30**: 253–259.

IASC Working Groups. 2011. Workshop – Report, Potsdam 11–14 January, 20.

Jones PD. 1987. The early twentieth century Arctic high – fact or fiction? *Climate Dynamics* **1**: 63–75.

Jones PD, Jonsson T, Wheeler D. 1997. Extension to the North Atlantic oscillation using early instrumental pressure observations from Gibraltar and south-west Iceland. *International Journal of Climatology* **17**: 1433–1450, DOI: 10.1002/(sici)1097-0088(19971115)17 : 13<1433::aid-joc203>3.0.co;2-p.

Jónnson T, Hanna E. 2007. A new day-to-day pressure variability index as a proxy of Icelandic storminess and complement to the North Atlantic Oscillation index 1823–2005. *Meteorologische Zeitschrift* **16**: 25–36.

Kaplan A, Kushnir Y, Cane MA, Blumenthal MB. 1997. Reduced space optimal analysis for historical datasets: 136 years of Atlantic sea surface temperatures. *Journal of Geophysical Research* **102**: 27 835–27 860.

Kaplan A, Kushnir Y, Cane MA. 2000. Reduced space optimal interpolation of historical marine sea level pressure: 1854–1992. *Journal of Climate* **13**: 2987–3002, DOI: http://dx.doi.org/10.1175/1520-0442(2000)013<2987:RSOIOH>2.0.CO;2

Kämtz LF. 1832. *Lehrbuch der Meteorologie, Bd II*. Gebauerschen Büchhandlung: Halle, 238–239.

Können GP, Zaiki M, Baede APM, Mikami T, Jones PD, Tsukahara T. 2003. Pre-1872 extension of the Japanese instrumental meteorological observation series back to 1819. *Journal of Climate* **16**: 118–131.

Klimenko VV. 2010. A composite reconstruction of the European part of the Russian Arctic climate back to A.D. 1435. In *The Polish Climate in the European Context: An Historical Overview*, Przybylak R, Majorowicz J, Brázdil R, Kejna M (eds). Springer: Dordrecht/Heidelberg/London/New York, 295–326.

Klimenko VV, Astrina NA. 2006. Documentary evidence of strong climate fluctuations of the Russian Arctic in the XV–XXth centuries. *History and Modernity* **1**: 179–217.

Küttel M, Xoplaki E, Gallego D, Luterbacher J, Garcia-Herrera R, Allan R, Barriendos M, Jones PD, Wheeler D, Wanner H. 2010. The importance of ship log data: reconstructing North Atlantic, European and Mediterranean sea level pressure fields back to 1750. *Climate Dynamics* **34**: 1115–1128, DOI 10.1007/s00382-009-0577-9.

Luterbacher J, Xoplaki E, Dietrich D, Jones PD, Davies TD, Portis D, Gonzalez-Rouco JF, von Storch H, Gyalistras D, Casty C, Wanner H. 2001. Extending NAO reconstructions back to 1500. *Atmospheric Science Letters* **2**: 114–124.

Luterbacher J, Xoplaki E, Dietrich D, Rickli R, Jacobeit J, Beck C, Gyalistras D, Schmutz C, Wanner H. 2002. Reconstruction of sea level pressure fields over the Eastern North Atlantic and Europe back to 1500. *Climate Dynamics* **18**: 545–561.

Niedźwiedź T. 2007. *Atmospheric pressure*. In *Climate of Polish Polar Station in Hornsund–state, changes and causes.* Wydawnictwo Akademii Morskiej, Gdynia, Marsz AA, Styszyńska A (eds). 65–69 (in Polish).

Polyakov IV, Bekryaev RV, Alekseev GV, Bhatt US, Colony RL, Johnson MA, Maskshtas AP, Walsh D. 2003. Variability and Trends of Air Temperature and Pressure in the Maritime Arctic, 1875–2000. *Journal of Climate* **16**: 2067–2077, DOI: 10.1175/1520-0442(2003)016<2067:VATOAT>2.0.CO;2.

Przybylak R. 2000. Air temperature in the Canadian Arctic in the mid-nineteenth century based on data from expeditions. *Prace Geograficzne* **107**: 251–258.

Przybylak R. 2003. *The Climate of the Arctic* (Atmospheric and Oceanographic Sciences Library, 26), Kluwer Academic Publishers: Dordrecht/Boston/London, 288.

Przybylak R. 2004. Air temperature in the Arctic in the period of First International Polar Year 1882/83. *Polish Polar Studies*, XXX Międzynarodowe Sympozjum Polarne, Katedra Meteorologii i Oceanografii Nautycznej AM: Gdynia; 307–320 (in Polish).

Przybylak R, Jankowska J. 2009. Atmospheric pressure in Eurasian Arctic from 1841 to 1920. *Problemy Klimatologii Polarnej* **19**: 81–98 (in Polish).

Przybylak R, Panfil M. 2005. Climatic conditions at Sagastyr station (Lena estuary) for the period from 1st September 1882 to 30th June. *Polish Polar Studies*, XXXI Sympozjum Polarne, Stacja Monitoringu US: Kielce, 143–152 (in Polish).

Przybylak R, Vizi Z. 2005a. Air temperature changes in the Canadian Arctic from the early instrumental period to modern times. *International Journal of Climatology* **25**: 1507–1522, DOI: 10.1002/joc.1213.

Przybylak R, Vizi Z. 2005b. Estimation of the accuracy of methods used for the calculation of mean and extreme daily air temperature values in the American Arctic in the 19th century. *Problemy Klimatologii Polarnej* **15**: 27–39 (in Polish).

Przybylak R, Wyszyński P. 2009. Atmospheric pressure in the Arctic in the period of the First International Polar Year 1882/83. *Problemy Klimatologii Polarnej* **19**: 99–114 (in Polish).

Przybylak R, Vízi Z, Wyszyński P. 2010. Air temperature changes in the Arctic from 1801 to 1920. *International Journal of Climatology* **30**: 791–812, DOI: 10.1002/joc.1918.

Serreze MC, Box JE, Barry RG, Walsh JE. 1993. Characteristics of Arctic synoptic activity, 1952–1989. *Meteorology and Atmospheric Physics* **51**: 147–164, DOI:10.1007/BF01030491.


 

Slonosky VC, Graham E. 2005. Canadian pressure observations and circulation variability: links to air temperature. *International Journal of Climatology* **25**: 1473–1492, DOI: 10.1002/joc.1191.

Slonosky VC, Jones PD, Davies TD. 1999. Homogenization techniques for European monthly mean surface pressure series. *Journal of Climate* **12**: 2658–2672, DOI: 10.1175/1520-0442(1999)012<2658:HTFEMM>2.0.CO;2.

Slonosky VC, Jones PD, Davies TD. 2001a. Atmospheric circulation and surface temperature in Europe from the 18th century to 1995. *International Journal of Climatology* **21**: 63–75, DOI: 10.1002/joc.591.

Slonosky VC, Jones PD, Davies TD. 2001b. Instrumental pressure observations and atmospheric circulation from the 17th and 18th centuries: London and Paris. *International Journal of Climatology* **21**: 285–298, DOI: 10.1002/joc.611.

Strachan R. 1888. *Contributions to Our Knowledge of the Meteorology of the Arctic Regions*, Authority of the Meteorology: London, Part I (1879), Part II (1880), Part III (1882), Part IV (1885), Part V (1888)

Treshnikov AF (ed). 1985. *Atlas Arktiki*. Glavnoye Upravlenye Geodeziy i Kartografiy: Moscow.

Vinther BM, Andersen KK, Jones PD, Briffa KR, Cappelen J. 2006. Extending Greenland temperature records into the late eighteenth century. *Journal of Geophysical Research* **111**: D11105, DOI: 10.1029/2005jd006810.

Vízi Z. 2008. Variability of the American Arctic climate in the 19th century. Ph.D., Nicolaus Copernicus University, Toruń, 115.

Ward C, Dowdeswell JA. 2006. On the meteorological instruments and observations made during the 19th century exploration of the Canadian Northwest Passage. *Arctic, Antarctic, and Alpine Research* **38**: 454–464.

Wild H. 1884. Protokolle der Vierten Internationalen Polar-Conferenz zu Wien 17.-24. April 1884., 215–266. In *Communications from the International Polar Commission*. Imperial Academy of Science, St. Petersburg, 364.

Wood KE, Overland JE. 2003. Accounts from 19th-century Canadian Arctic Explorers' Logs reflect present climate conditions. *EOS* **84**: 410, 412.

Wood KR, Overland JE. 2006. Climate Lessons from the First International Polar Year. *Bulletin of the American Meteorological Society* **87**: 1685–1697, DOI: 10.1175/BAMS-87-12-1685.

Wood KR, Overland JE, Jónsson T, Smoliak BV. 2010. Air temperature variations on the Atlantic-Arctic boundary since 1802. *Geophysical Research Letters* **37**: L17708, DOI: 10.1029/2010GL044176.

Woodruff SD, Worley SJ, Lubker SJ, Ji Z, Eric Freeman J, Berry DI, Brohan P, Kent EC, Reynolds RW, Smith SR, Wilkinson C. 2011. ICOADS Release 2.5: extensions and enhancements to the surface marine meteorological archive. *International Journal of Climatology* **31**: 951–967, DOI: 10.1002/joc.2103.

Worley SJ, Woodruff SD, Reynolds RW, Lubker SJ, Lott N. 2005. ICOADS release 2.1 data and products. *International Journal of Climatology* **25**: 823–842, DOI: 10.1002/joc.1166.

Yin X, Gleason BE, Compo GP, Matsui N, Vose RS. 2008. *'The International Surface Pressure Databank (ISPD) land component version 2.2'*, National Climatic Data Center: Asheville, NC, Available at ftp://ftp.ncdc.noaa.gov/pub/data/ispd/doc/ISPD2 2.pdf

 