POLISH POLAR RESEARCH
vol. 39, no. 3, pp. 371–392, 2018 doi: 10.24425/118752

The influence of synoptic conditions patterns on air temperature and humidity in Petuniabukta (Svalbard) in summer 2016

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Abstract: This article aims to analyse the influence of weather types on meteorological conditions in Petuniabukta (Svalbard) during July and August of 2016. The paper analyses the daily courses of air temperature and humidity at four measurement points located on the west bank of Petuniabukta near Adam Mickiewicz University Polar Station during two different types of weather conditions: (i) cloudy and windy, (ii) calm and clear. These weather types, distinguished on the basis of wind speed and cloudiness, allowed for the creation of composite maps of the synoptic situation (SLP and geopotential height of 500 hPa distribution) and its anomalies. In the study area, the air temperature range in windy and cloudy weather conditions was larger (-10°C to 15°C) than that in sunny and calm weather (0°C to 15°C), which contrasts the range of humidity values. The diurnal cycle of meteorological elements in sunny and calm days is strongly related to the sun elevation angle. In the above-mentioned weather types, the air temperature was higher by several degrees (median 5°C to 8°C) than on windy and cloudy days (median about 0°C to 6°C) at each measurement point. On days with sunny and calm weather, a smaller vertical temperature gradient of air is observed (for sunny and calm days 0.63°C and for windy weather 0.8°C).

Key words: Arctic, Spitsbergen, diurnal cycle, atmospheric circulation, meteorology, weather types.

Introduction

The polar regions are considered to be the most vulnerable to climate change, particularly to global warming observed in recent decades (*e.g*. Przybylak 2000, 2003, 2007; Moritz *et al*. 2002; Polyakov *et al*. 2003; Johannessen *et al*. 2004;

Comiso 2006; Turner *et al*. 2006). This global warming is especially pronounced in the Arctic (*e.g*. Serreze *et al*. 2009; Walsh 2014). The Arctic amplification is response to increasing atmospheric green-house gas concentraction. For instance, the Svalbard Lufthavn composite series revealed a current trend of 2.6°C *per* century for the mean yearly data from the period 1898–2012 (Nordli 1990; Nordli *et al*. 2014).

Various topographical conditions, coupled with Spitsbergen's land coverage, make up some of the most important factors that can bring about vast spatial differentiation in many meteorological element fields, such as air temperature, humidity, wind speed, and others, within the boundary layer. These problems have been pointed out and described in many studies concerning topoclimatic conditions in Svalbard (Wójcik *et al*. 1998; Migała *et al*. 2008; Bednorz and Kolendowicz 2010; Láska *et al*. 2012, 2013, 2017; Araźny *et al*. 2017). The changes in air temperature regarding their vertical profile were analyzed in studies conducted by Argentini *et al*. (2003), Vihma *et al*. (2011), Mayer *et al*. (2012), Ambrožová and Láska (2017). Their results indicate complicated mechanisms that influence the formation of air temperature inversions in particular. The vertical temperature changes within the atmospheric boundary layer have been analysed in some studies on Svalbard, that were mostly based on data from the summer observations (Wójcik *et al*. 1998; Migała *et al*. 2008; Araźny *et al*. 2010; Bednorz and Kolendowicz 2010). However, Araźny *et al*. (2011) published results of air temperature research based on whole year data from the ice-free area (Forlandsundet region) at up to 590 m a.s.l. The results of that work as well as the AWAKE project (Przybylak *et al*. 2014) have indicated a correlation between the near-surface lapse rate and land cover grades and topography. Moreover, a very important role for both air temperature field and lapse rate is played by atmospheric circulation, as suggested by Niedźwiedź (2003).

Taking into consideration atmospheric circulation and topography as the main factors affecting meteorological conditions within the near-surface layer, the purpose of this study is to determine the impact of two synoptic weather conditions on air temperature and relative humidity and their altitudinal changes, *i.e*. (i) sunny and clear weather, and (ii) cloudy and windy weather, on temperature and humidity conditions, as well as variations in air temperature and relative humidity with altitude within the vicinity of the Adam Mickiewicz University Polar Station in Petuniabukta.

Study area

The study area covers the central part of Spitsbergen, the largest island in the Svalbard archipelago. The measurement points were situated on the west bank of Petuniabukta (Fig. 1) near the Adam Mickiewicz University Polar Station

(AMUPS). Petuniabukta is oriented along the N–S axis and forms the northern part of Billefjorden. Measurements were taken every 3 hours at 4 measuring points located in a profile from the west coast of Petuniabukta to Pyramiden massif, 1.5 m above ground level (altitude difference between successive measurement points is about 200 metres) in the summer period between July 9 and August 30, 2016.

The area is situated on the eastern slope of Mount Pyramiden (937 m a.s.l.) that rises up over Petuniabukta. The elevation of surrounding mountains from the west, north and east shore of the bay is approximately 600–800 m a.s.l., the highest of which is Mount Pyramiden. Mountain chains obstruct the free flow of air masses from the west into the study area. On the eastern side, the airflow is modified by mountain crests reaching 600–700 m a.s.l. and the nearby Ebbadalen, and these also affect local atmospheric conditions (Rachlewicz 2003).

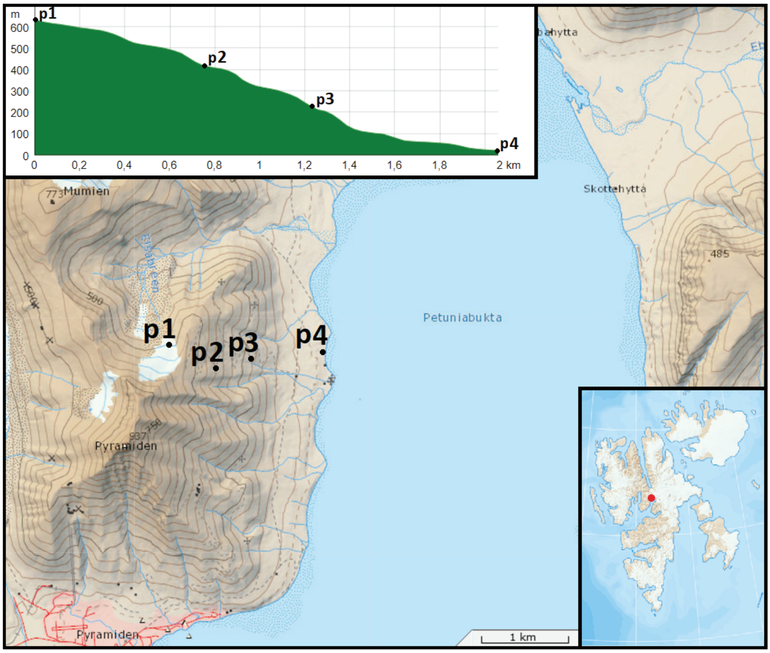


Fig. 1. Location of the measurement points (p1–p4) and the slope profile with marked points p1–p4 (in the upper part of the map) and location of Petuniabukta on Svalbard archipelago. Based on: < *http://toposvalbard.npolar.no/*> ©Norwegian Polar Institute

Taken into consideration mean weather conditions for the researched area, the data from Svalbard Lufthavn from the period 1976–2017 were used. The average annual temperature of the research region is approximately -4.1°C. For the particular seasons of the average year, the temperature values were for spring (MAM) -7.8°C, summer (JJA) 5.2°C, autumn (SON) -3.6°C, and for winter (DJF) -10.4°C. Compared to the average thermal conditions, the year

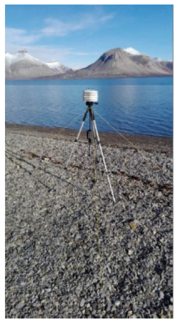
2016 belonged to the warmest. The mean annual air temperature was -0.1°C for MAM -0.1°C, JJA 6.6°C, SON 2.2°C, and for DJF -5.1°C. The usual summer temperature for Petuniabukta is between 5–6°C, even though it recently exceeded 7°C (Rachlewicz 2003; Kendzierski 2017).

Data collection and analysis

In this study, the air temperature, relative humidity, wind speed data, as well as observations of cloudiness performed near the Adam Mickiewicz University Polar Station (p4) were used. Detailed information about the location of the measurement points is included in Table 1. For the purpose of measuring the temperature and relative humidity, data loggers HOBO Prov2 (with an accuracy of ± 0.21°C in the range 0°C to 50°C) were used. The measuring accuracy for determining relative humidity was ± 2.5%.

Table 1

Localisation of measuring points in Petuniabukta shown on Fig. 1.

Measurement point	p1	p2	p3	p4
Latitude (°N)	78°40'58.6"	78°40'55.7"	78°40'59.1"	78°41'9.36"
Longitude (°E)	16°22'45.8"	16°23'53.3"	16°24'59.3"	16°27'30.4"
Altitude (m a.s.l.)	612	395	223	4
Photo				

At the beginning, two different weather types were identified: (i) sunny and calm, (ii) cloudy and windy. The reason of that procedure are the significant differences in values of particular meteorological components (*e.g.*, air temperature, air humidity, net radiation) during distinguished types (Paszyński *et al*. 1999). Therefore, in the next part of the study, only days with the above-mentioned weather types during July–August 2016 were taken into consideration.

The criterion for a sunny and calm weather was an average daily wind speed ≤ 3 m/s and an average cloudiness ≤ 4 octas. As a result, only 4 days met the criterion for this type of weather (Table 2). For the cloudy and windy weather, the criterion was an average wind speed > 3 m/s and an average cloudiness ≥ 7 octas. As in the previous case, only four days met this criterion as well (Table 2).

Based on the reanalysis of the data (NCEP/NCAR; Kalnay *et al*. 2006) for daily sea level pressure (SLP), 500 hPa geopotential height (z500), and 850 hPa air temperature (T850), composite maps of the synoptic situations and their anomalies for the 30W–60E/70N–85N for the whole measurement period, as well as for the specific weather types, were created. The anomalies were calculated by subtracting values (SLP, T850 and z500) of the chosen day from the same date long period mean values (1966–2015). The research results obtained concerning atmospheric circulation were then compared with the circulation types proposed for Spitsbergen by Niedźwiedź (2003, 2017). Next, for days with the above-mentioned weather types, basic statistics for temperature and humidity, as well as for differences between measurement points were calculated. For dataset, the analysis of the probability density distribution statistics were made.

Table 2

Days with weather types taken into consideration in this study.

Type of weather	Criterions	Days meeting the criteria
sunny and calm	• average daily wind speed ≤ 3 m/s • average cloudiness of ≤ 4 octas	10 July 2016 26 July 2016 27 July 2016 2 August 2016
cloudy and windy	• average wind speed of > 3 m/s • average cloudiness ≥ 7 octas	19 July 2016 8 August 2016 14 August 2016 26 August 2016

Results and interpretation

Synoptic weather conditions during the study period. — The mean daily distribution of sea level pressure (SLP), geopotential height of 500 hPa, and 850 hPa air temperature (T850) that prevail around the Svalbard archipelago during July–August are presented on the Fig. 2. Atmospheric pressure at sea level is characterised by a slight variation from 1010.5 hPa in the north to over 1012 hPa in the southeast. The altitude of the 500 hPa geopotential is from 5460 m above sea level in the north to 5560 m above sea level in the southeast. Similarly, the air temperature at an altitude of 850 hPa is also increases from -0.5°C in the north to more than 2.5°C in the southeast of the study area. Anomalies in the values of the described meteorological elements for the period July–August 2016 in relation to mean values from the multiannual period (1990–2010) are presented in of Fig. 2. It is noted that atmospheric pressure at sea level over the study area was lower than the mean value by approximately 2.5 hPa, while the 500 hPa geopotential height was approximately 20 m lower. Meanwhile, the 850 hPa air temperature was close to the mean.

Considering the classification of the circulation types designed by Niedźwiedź (2017), cyclonic circulation types appeared most frequently in the analysed period, occurring in almost 65% of days. In turn, anticyclonic circulation types occurred at a frequency of 34%. In comparison with the 1951–2000 reference period, there were significantly more days with cyclonic circulation types than anticyclonic types (Table 3) between July 9–August 31, 2016. In the reference period, there were 47% of days with cyclonic types and almost 50% with anticyclonic types.

Table 3

Frequency (in %) of atmospheric circulation types over Spitsbergen according to Niedźwiedź (2017) during the study period (A) and in the July–August 1951–2000 period (B). Anticyclonic situations: Na — North (direction of air masses advection, geostrophic wind), NEa — North–East, Ea — East; SEa — South–East; Sa — South; SWa — South–West; Wa — West; NW — North–West; central anticyclone situation (high center); Ka — anticyclonic wedge or ridge of high pressure. Cyclonic situations: Nc — North; NEc — North–East; Ec — East; SEc — South–East; Sc — South; SWc — South–West; Wc — West; NWc — North–West; Cc — central cyclonic, center of low; Bc — through of low-pressure (different directions of air flow and frontal system in the axis of through). x — unclassified situations or pressure column.

period	Na	NEa	Ea	SEa	Sa	SWa	Wa	NWa	Ca	Ka	Nc
A	9.4	1.9	1.9	0.0	0.0	7.5	3.8	0.0	1.9	7.5	3.8
B	2.4	2.3	6.3	5.5	2.7	4.4	3.7	2.6	1.9	15.1	4.4

period	NEc	Ec	SEc	Sc	SWc	Wc	NWc	Cc	Bc	x	sum
A	3.8	9.4	0.0	0.0	5.7	11.3	7.5	5.7	17.0	1.9	100
B	3.9	5.2	4.6	4.0	6.3	5.3	4.1	3.6	8.3	3.9	100

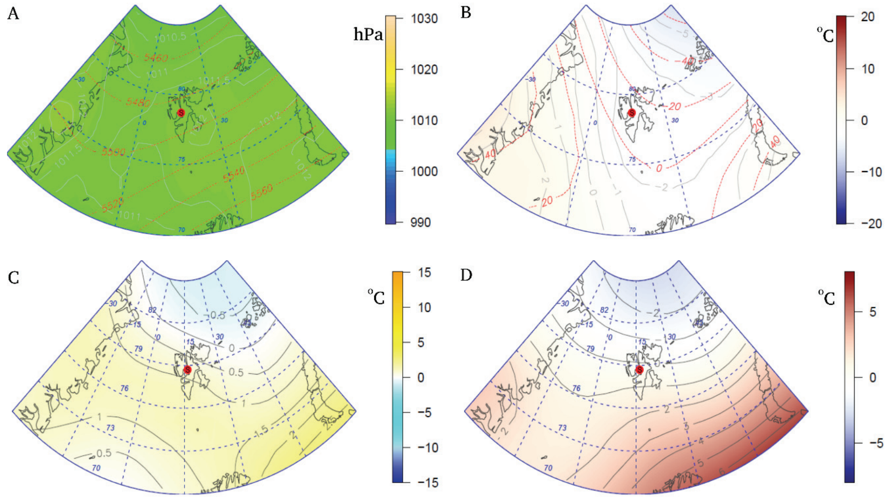


Fig. 2. The average daily distribution of (**A**) sea level pressure (grey solid line) and 500 hPa geopotential height (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (**C**) and its anomalies (**D**) for the June–July 2016 period.

Comparing the thermal conditions of the examined period near the Adam Mickiewicz University Polar Station (study area) with the mean values of the 1980–2010 period from the meteorological station in Longyearbyen (located closest to the study area), the period 9–31 of July 2016 at point p4 (seashore) was characterised by a mean temperature of 8.8°C, which was 2.3°C higher than the mean taken for comparison (Kendzierski 2017). On the other hand, the mean August temperatures at p4 and at the Svalbard Lufthavn station were the same and amounted to 5.6°C. For the period 9–31 of July, the mean temperature of the individual measurement points was as follows: p4: 8.8°C, p3: 7.6°C, p2: 6.6°C and p1: 5.1°C. In turn, in August, these values were lower, *i.e*. p4: 5.6°C, p3: 3.9°C, p2: 2.6°C and p1: 0.4°C.

Synoptic weather conditions on sunny and calm days. — On days with sunny and calm weather, the area under examination was directly affected by an anticyclonic system or was on the edge of it. According to the calendar of the Niedźwiedź circulation types (2017), the following circulation types occurred during these days: Ec (10 of July 2016), Ca (26–27 of July), and Ka (2 of August 2016).

On 10 of July, the temperature at an altitude of 850 hPa was higher than the mean value by approximately 4°C, while the level of 500 hPa geopotential was higher by 100 m than the mean. On the remaining days with the type of weather analysed, the thermal conditions at an altitude of 850 hPa were slightly cooler than the mean values, while the location of the 500 hPa geopotential was slightly higher than the mean value (Figs. 3–6).

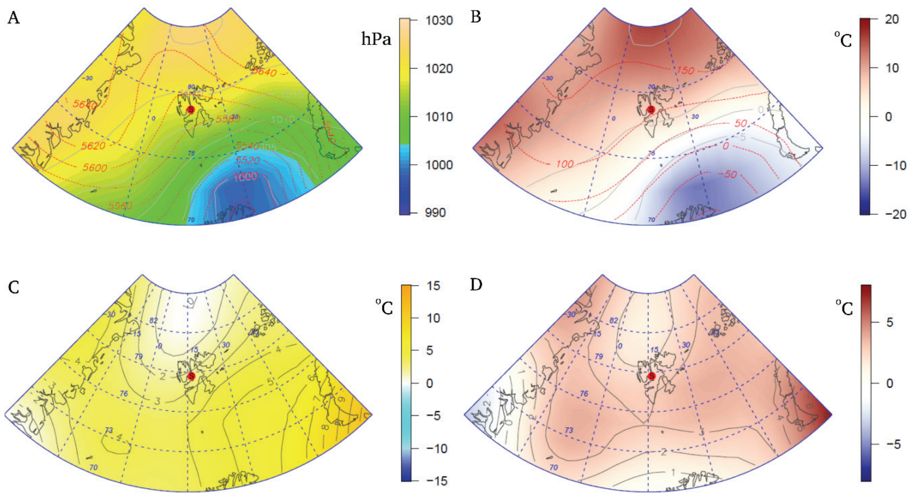


Fig. 3. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for July 10, 2016.

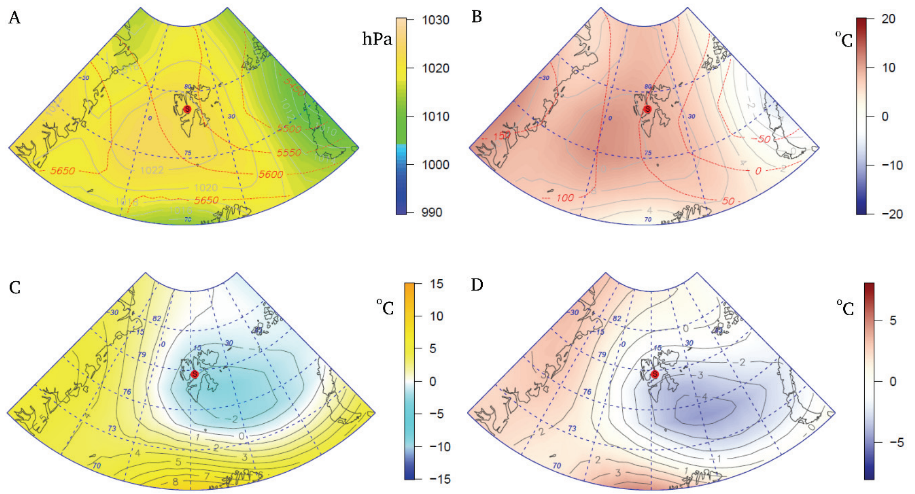


Fig. 4. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for July 26, 2016.

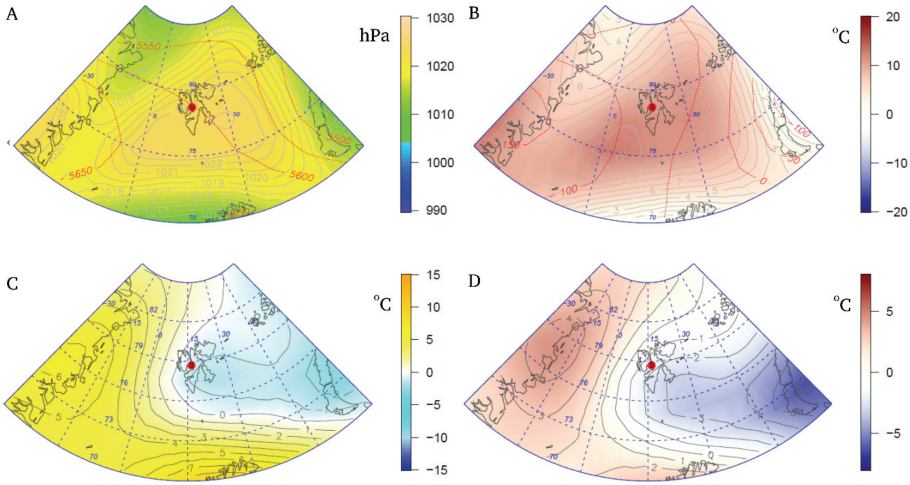


Fig. 5. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for 27 of July, 2016.

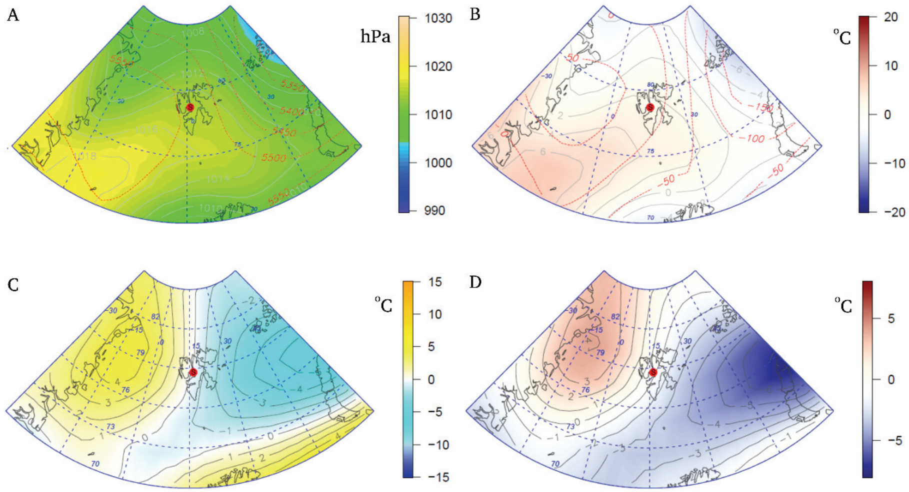


Fig. 6. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for 2 of August, 2016.

Synoptic weather conditions on cloudy and windy days. — During cloudy and windy weather, the area under examination was under the direct influence of a low-pressure system (19 of July 2016, 8 of August 2016), a low-pressure trough (14 of August 2016) or on the western edge of a low-pressure system

(26 of August 2016). On these days, circulation types Cc, Cc, Wc, Nc occurred consecutively (Niedźwiedź 2017).

All these days with cloudy and windy days were characterised by reduced atmospheric pressure from 4 to 8 hPa in relation to the average conditions, and a lower from 25 to 150 gpm than average height for the 500 hPa geopotential (Figs. 7–10).

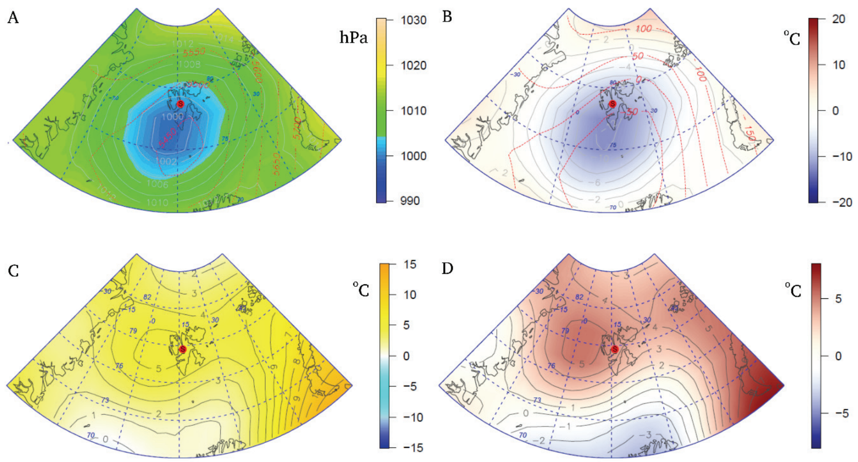


Fig. 7. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for 19 of July 2016.

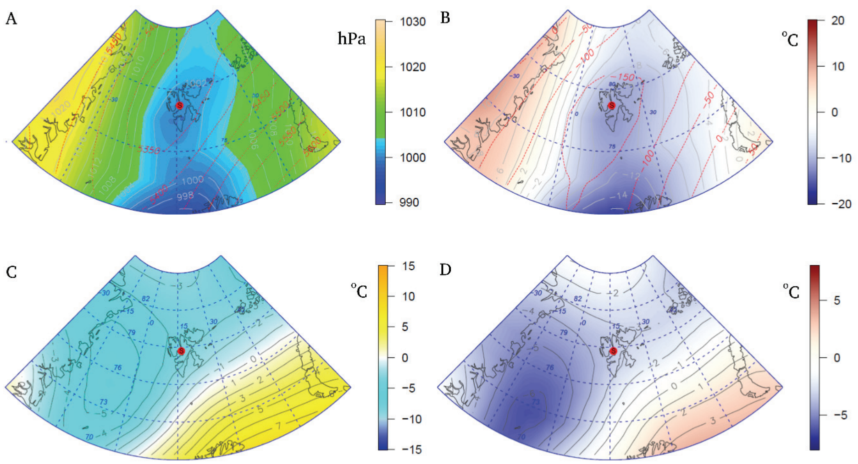


Fig. 8. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for 8 of August, 2016.

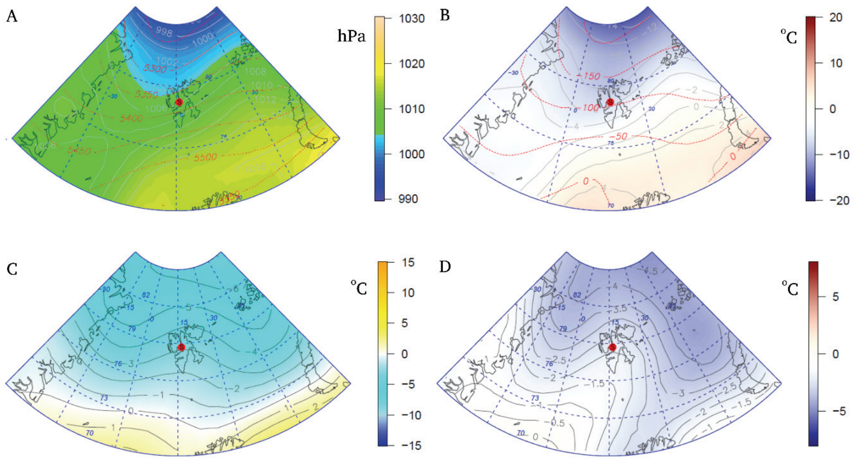


Fig. 9. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for 14 of August, 2016.

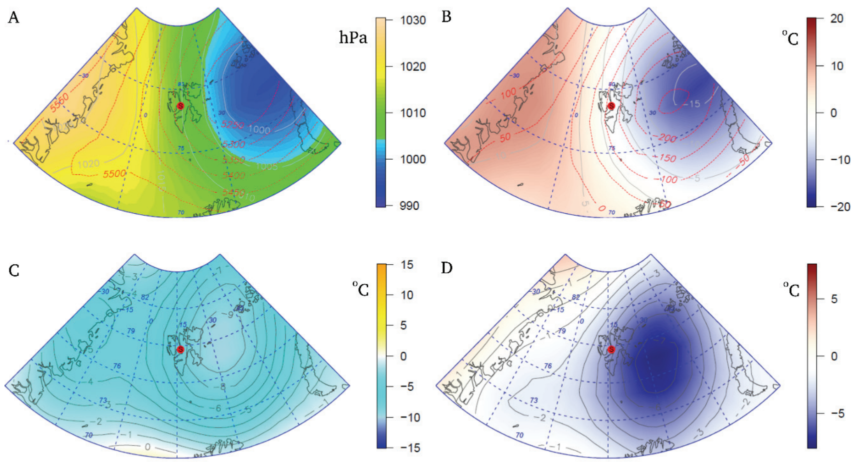


Fig. 10. The average daily distribution of (**A**) sea level pressure (grey solid line) and geopotential height of 500 hPa (red dotted line), their anomalies (**B**), air temperature at an altitude of 850 hPa (grey solid line) (**C**) and its anomalies (**D**) for August 26, 2016.

Synoptic weather conditions on cloudy and windy days. — During cloudy and windy weather, the examined area was under the direct influence of a low-pressure system (19 of July, 2016; 8 of August, 2016), a low-pressure trough (14 of August, 2016) or on the western edge of a low-pressure system (26 of August 2016). On these days, circulation types Cc, Cc, Wc, and Nc occurred consecutively (Niedźwiedź 2017).

All these days with sunny and windy weather conditions were characterised by reduced atmospheric pressure from 4 to 8 hPa in relation to average conditions, and a lower-than-average height for the 500 hPa geopotential (Figs. 7–10).

Air temperature in the study period. — Taking into account all measurement points, the air temperature over the study period varied from -5.2°C to 13.1°C, showing a clear daily cycle. In the air temperature variation, the differentiation between measuring stations resulting from their different altitudes above sea level was clearly marked (Fig. 11A, Table 3). This dependence is shown by the probability density distribution statistics presented in Figs. 11B and 11C. The analysis carried out unequivocally indicates statistically significant differences between the air temperature median values, occurring at the individual points (Fig. 11C; the ranges determined by the notches do not overlap; Chambers *et al*. 1983). As expected, the lowest air temperature values were recorded at p1, and the highest at p4. The mean air temperature gradient for all days was 0.72°C/100 m, on days with sunny and calm weather it was 0.63°C/100 m, while on cloudy and windy days it was 0.8°C/100 m.

In the analysed temperature datasets obtained for the individual points, the minimum, maximum, 25th percentile, median, and 75th percentile values decreased with increasing altitude above sea level (Figs. 11B–11C). Descriptive statistics for data from the individual points are presented in Table 4. The increasing values of the temperature standard deviation (T_{sd}) with the rising altitude of the measurement points above sea level are noteworthy.

Table 4

Air-temperature statistics for individual measurement points fin Petuniabikta in the period from 9th of July to 4th of September 2016. T_{max} – maximum air temperature, T_{min} – minimum air temperature, T_{avg} – mean air temperature, T_{sd} – standard deviation of air temperature data.
Petuniabukta, Svalbard, period from 9 July to 4 of September, 2016.

Measurement points	T_{max} [°C]	T_{min} [°C]	T_{avg} [°C]	T_{sd} [°C]
p1	11.1	-5.2	2.7	3.2
p2	12.7	-3.4	4.3	3.1
p3	12.0	-2.0	5.5	2.8
p4	13.1	0.4	7.0	2.5

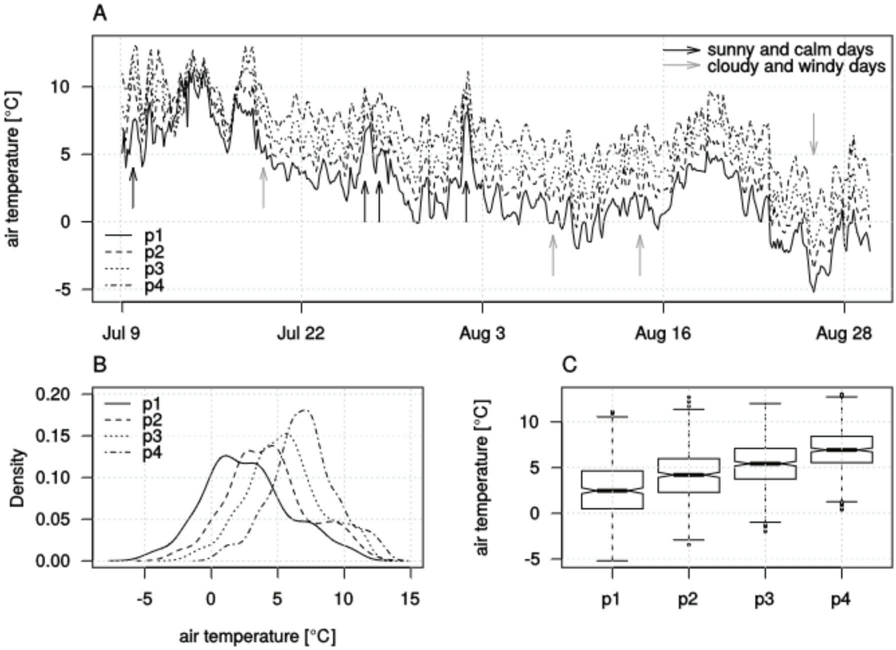


Fig. 11. Air temperature variation at measurement points (**A**) in the study area (p1–p4 marked on the Figure 1A), density plot (**B**), and box-and-whisker plot (**C**) for data from measurement points, Petuniabukta, Svalbard, for period 9 July to 4 September 2016. On the boxplot, the middle values denote medians, the box extends to the Q1 (first quartile) and Q3 (third quartile), and the whiskers show the range (99.3%): the upper whisker shows Q3+1.5*IQR (the interquartile range), the lower shows Q1−1.5*IQR. The notches extend to +/-1.58 IQR/sqrt(n) and the dots represent outliers.

Although only four days were taken for analysis with the weather types highlighted, the differences in thermal conditions during these days are fairly obvious. During sunny and calm days, the air temperature is higher by several degrees than that recorded during non-radiative weather at each point for both medium and minimum values. Considering the differences between the median of air temperature at the individual points, it can be stated that these differences are statistically significant between p1 and p2, between p3 and p4, and between p1 and p4. There are no statistically significant differences between p2 and p3.

The air temperature range in windy and cloudy weather conditions is larger than that in calm and clear weather conditions (Fig. 12). This dependency is visible at every measurement point. On the analysed days, the differences between medians of air temperature at individual points are statistically significant only for points not directly adjacent to each other, which indicates a smaller impact of altitude above sea level on the temperature level than on days with calm and clear weather.

On days with radiative weather, the density distribution for the probability of occurrence of a certain temperature value indicates the highest probability of occurrence for a temperature from the middle part of their range, while in non-radiative weather the density graphs are more flattened, meaning that the temperature values from almost the whole range at a given measurement point occur with a similar probability.

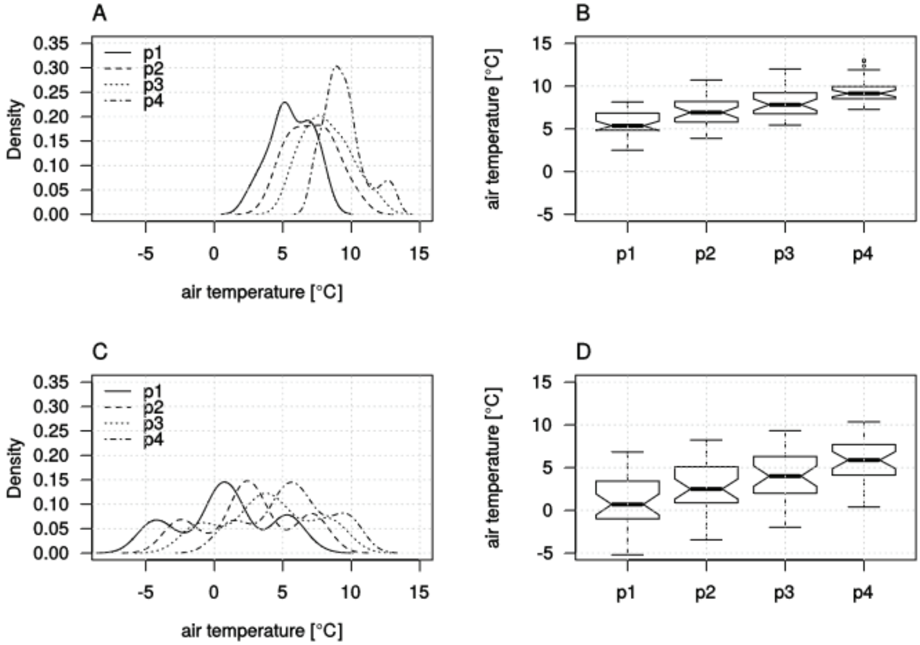


Fig. 12. Density plots for air temperature data (**A**, **C**) and box-and-whisker plots (**B**, **D**) on measurement p1–p4 in transect shown on Fig. 1 for sunny and clear (**A**, **B**) as well as cloudy and windy (**C**, **D**) days, Petuniabukta, Svalbard. For a detailed description of boxplots, see Fig. 11.

Figure 13 shows the mean daily air temperature trends, with the weather types highlighted. Attention is drawn to the clear daily cycle, depending on sun elevation angle on days with clear and calm weather type. The maximum air temperature occurs during the afternoon hours, while the minimum air temperature occurs during hours with the lowest position of the sun just above the horizon (hours 0–5 UTC). On the other hand, during cloudy and windy weather, the daily cycle is significantly less pronounced. On days with radiative weather, there is a smaller vertical air temperature gradient (averaging 0.63°C/100 m) compared to non-radiative weather (for which the gradient was 0.8°C/100 m). For this reason, a smaller thermal differentiation at the measurement points is observed during a 24 hour period for days with radiative weather. Attention is also drawn to the clear impact of fjord waters on the daily temperature of point p4 (located near the beach). In this case, during radiative weather, the temperature increase from 4°C at night to around noon is milder than at the other three measurement points, while its decrease after 15 UTC is slower (apart from the point located at the top of the hill; p1).

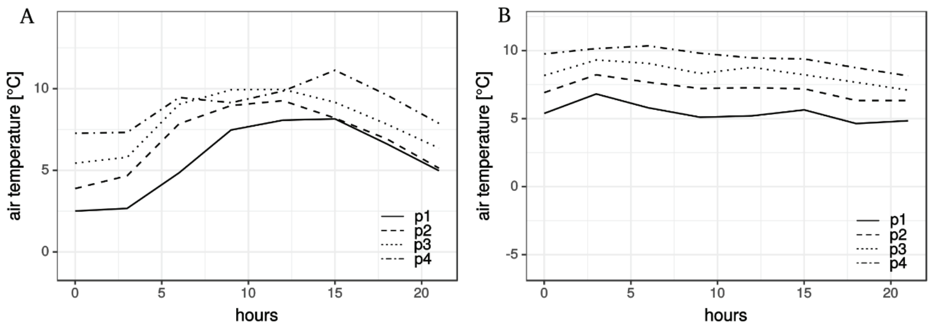


Fig. 13. Daily course of the mean hourly air temperature for days with calm and clear weather (**A**) and windy and cloudy weather (**B**), Petuniabukta, Svalbard.

Relative humidity. — Taking into account the results of measurements at all measuring points throughout the entire study period, it is noted that the relative humidity ranged from 46% to 100% (Fig. 14A; Table 5). The density distribution and basic statistics from datasets obtained for the individual stations indicate that the most humid spot is the first point situated at the highest altitude (600 m a.s.l.). As the altitude decreases, the relative humidity decreases. At p1, the average humidity was above 90%, and at p4 it was below 80% (Fig. 14B). It is also noted that the distribution of moisture density at the highest measuring point is bimodal, right-angled, and as the altitude above sea level decreases, the shapes of density curves increasingly approach the normal distribution. This indicates a significant impact of increase in altitude on the more frequent occurrence of very high humidity values of > 90% (Fig. 14B, C). Differences between the medians of relative humidity for all points are statistically significant (Fig. 14C; Chambers *et al*. 1983).

The analysis of the probability density distribution of the relative humidity indicates that during calm and clear days, the range of these values is much wider (40%–100%) than during sunny and windy days (60%–100%). In addition, it is noted that on days with calm and clear weather, humidity of approximately 70% to 90% is likely to occur at all measuring stations (Fig. 15A). On the other hand, during days with clear and windy weather, there is a clear differentiation between the points in this respect. At the lowest point (p4), the most likely values are around 80% which grow as the altitude of the points increases, reaching about 95% for the highest one (p1; see Fig. 15C).

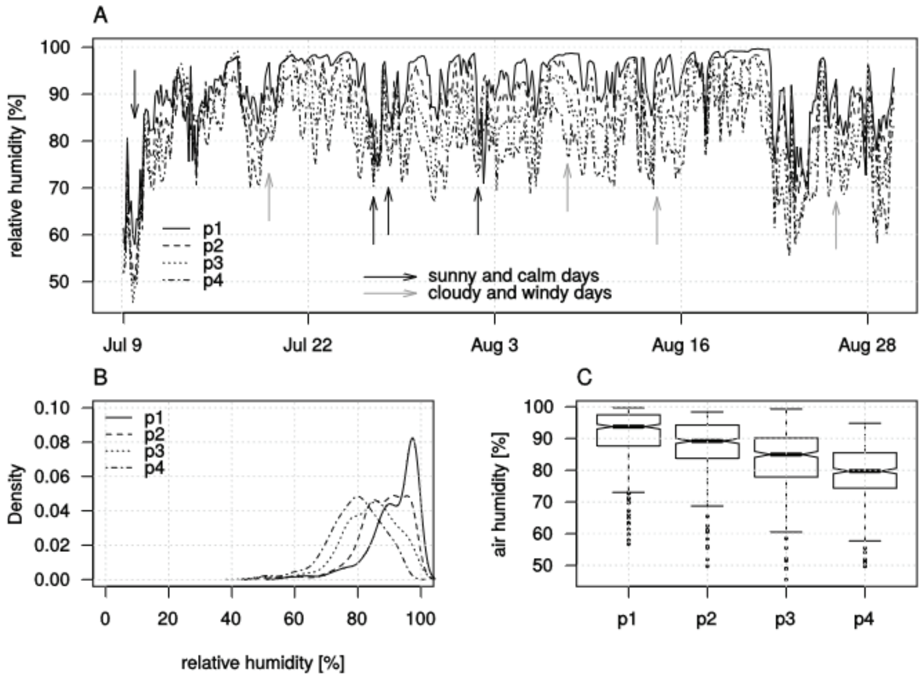


Fig. 14. Variation of relative humidity on measurement p1–p4 shown on Fig. 1 – (**A**), density plot (**B**), and box-and-whisker plot (**C**) for data from measurement p1–p4, Petuniabukta, Svalbard, for the period from 9 July–4 September, 2016. For a detailed description of boxplots, see Fig. 11.

Table 5

Relative humidity statistics for individual measurement points for the whole research period. H_{max} – maximum relative humidity, H_{min} – minimum relative humidity, H_{avg} – mean relative humidity, H_{sd} – standard deviation of relative humidity data, Petuniabukta, Svalbard, for the period from 9 of July to 4 of September 2016.

Measurement points	H_{max} [%]	H_{min} [%]	H_{avg} [%]	H_{sd} [%]
p1	100	57	91	7.9
p2	98	50	88	8.2
p3	99	46	84	9.1
p4	95	50	79	8.6

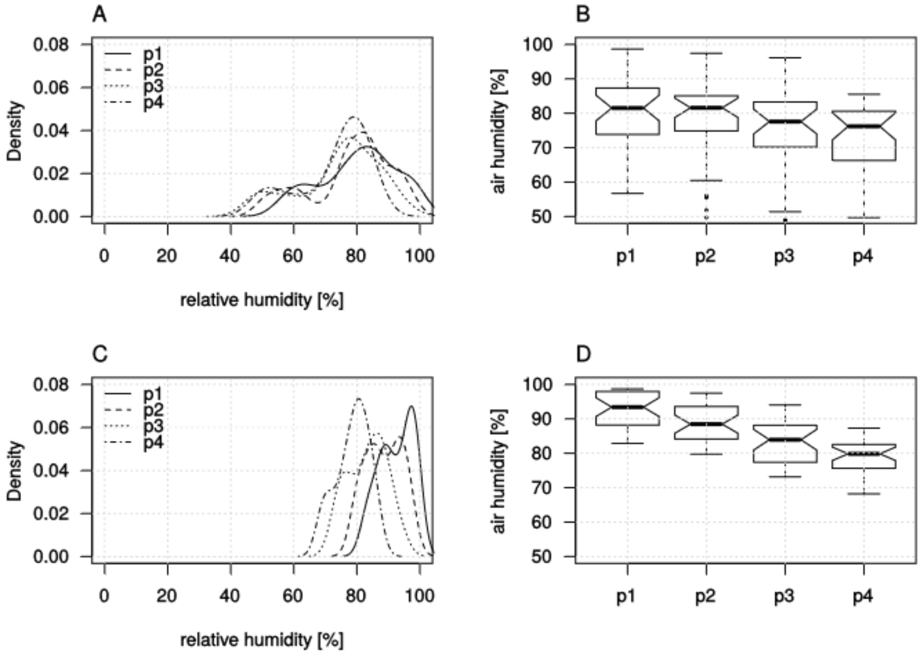


Fig. 15. Density plots (**A**, **C**) and box-and-whisker plot of relative humidity (**B**, **D**) on measurement p1–p4 in transect located in the research area, shown on Fig. 2 for calm and clear (**A**, **B**) and cloudy and windy (**C**, **D**) weather days, Petuniabukta, Svalbard. For a detailed description of boxplots, see Fig. 2.

Figure 16 shows the average daily courses of relative humidity for the selected types of weather. A clear daily cycle of the analysed elements, strongly associated with the previously examined air temperature course, can be noticed. On sunny and calm days, the highest humidity occurs during the lowest position of the sun just above the horizon (hours 0–5 UTC), with the lowest humidity during midday hours. Differences in humidity between the indicated times of day were about 10% of the relative humidity at the individual points of measurement. On the other hand, during cloudy and windy weather, the observed daily cycle is less pronounced, with the differences between the maximum and minimum values reaching about 5%.

The average relative humidity gradient (decreasing with altitude) in the study period is about 1.5%/100 m. In both weather types, an increase in humidity with altitude is also observed; however, it is higher on days with cloudy and windy weather. The differentiation between all measuring stations is very clear, while the increase in humidity with altitude is approximately 1.9%/100 m. During clear and calm weather, the differences between the points are smaller, especially in the afternoon when the differences can disappear altogether, particularly between p4 and p3 (Fig. 16).

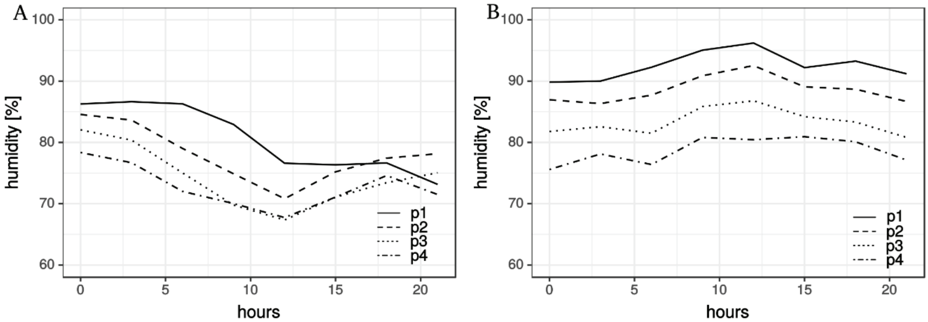


Fig. 16. Daily course of mean hourly relative humidity (%) for sunny and calm days (**A**) and windy and cloudy weather (**B**), Petuniabukta, Svalbard.

Regarding temperature and air humidity and its relations with atmospheric circulation, the study results indicate that: in sunny and calm weather days, the research area was directly affected by an anticyclonic or the edge of anticyclonic system which occur on average at a frequency of 34%, while in cloudy and windy days, a low-pressure trough or the western edge of a low-pressure system dominated. That type of atmospheric circulations occurred in research period with frequency of about 64%.

Taking into consideration diurnal cycle of air temperature and humidity, the attention is drawn to the clear daily cycle associated with the location of the sun on days with clear and calm weather. During cloudy and windy weather the daily cycle is significantly less pronounced. Similar results were obtained by Ambrožová and Láska (2017) for the summer seasons of 2013–2015 in studies that were also carried out in the area of Petuniabukta and by Bednorz and Kolendowicz (2010) in the 2009 summer season for the Ebbadalen.

The differences between the median values for relative humidity for all measurement points are statistically significant. While the differences between the median of air temperature at the individual points are statistically significant between p1 and p2, between p3 and p4, and between p1 and p4. There are no statistically significant differences between p2 and p3.

The air temperature range during windy and cloudy weather conditions is broader than in calm and clear weather conditions at every measurement point. In clear and calm days the range is 0 to 10°C for p1 and 5 to 15°C for p4 while in cloudy and windy days it is -10 to 10°C and -2.5 to 12°C, respectively. The reason for that differentiation is not disturbed direct sun radiation and low turbulent mixing in atmospheric boundary layer during clear and calm weather resulting in higher temperature values.

The average vertical air temperature gradient for all days of the study period was 0.7°C/100 m, while on sunny and calm days it was around 0.6°C/100 m, while on cloudy and windy days around 0.8°C/100 m. This problem has been previously examined in a number of studies. The average air temperature gradient over the chosen measurement points in southern Spitsbergen was 0.5°C/100 m (Migała *et al*. 2008). An identical temperature gradient was reported in other areas of Spitsbergen by Wójcik *et al*. (1998); Araźny (1999), and Kejna (2001). Migała *et al*. (2008) pointed out that the mean vertical temperature gradient between the lower and upper part of the unglaciated valley near the Horsund station was lower by 0.05°C when compared with that of the glacier forefront and the glacier, *i.e*. 0.87°C/100 m (Migała *et al*. 2008). Bednorz and Kolendowicz (2010) emphasised that the temperature gradient is smaller for calm and clear days (0.56°C/100 m) than for cloudy and windy ones (0.94°C/100 m) in the Ebbadalen. Also, Przybylak (1992) and Niedźwiedź (2001, 2003, 2006) both pointed to the considerable impact of current weather type on the vertical temperature gradient.

The probability density distribution of the relative humidity indicates that during calm and clear weather type, their range is much broader (40%–100%) than during sunny and windy weather (60%–100%). In addition, it is noted that on days with calm and clear weather, humidity ranging from approximately 70%–90% is likely to occur at all measuring stations.

Mean vertical gradient of relative humidity is around 1.5%/100 m, and is higher on days with cloudy and windy weather (1.9%/100 m). Differentiation then between all measuring stations is very clear; the increase in humidity with altitude is about 1.9%/100 m. During clear and calm weather, the differences between the stations are smaller, especially in the afternoon hours. It was observed that an increase in altitude results in more frequent occurrence of very high air humidity values (above 90%).

Conclusions

The article presents the results of topoclimatic studies based on measurements of air temperature and humidity from July and August 2016 along the vertical profile over the western slope of Petuniabukta, which is located in central Spitsbergen. The analyses were carried out on the entire dataset from the research period as well as on selected days with different types of weather. Based on the adopted criteria, two types of weather were distinguished: (i) clear and calm, and (ii) as cloudy and windy.

Characterising the frequency of occurrence of specific types of atmospheric circulation (Niedźwiedź 2017) over Spitsbergen, it was established that when compared to the reference period (1951–2000), a greater number of days with cyclonic circulation types were observed in the study period than in average.

A comparison of the mean thermal conditions in the period from 9 of July to 31 of August, 2016, over the research area on the one hand, with the average thermal conditions (1950–2000) occurring at the nearest meteorological station in Svalbard Lufthavn on the other indicates a clearly warmer July (by 2.3°C) than the average at the indicated station. In turn, in August both the study area and the Svalbard Lufthavn station had very similar thermal conditions.

Characterising the days highlighted in the study with clear and calm weather, it should be noted that there was a higher temperature at an altitude of 850 hPa by approximately 4°C, as well as a higher location of the geopotential height of the 500 hPa by an average of about 100 gpm as compared to the mean value throughout the research period. On the other hand, on windy and cloudy days, a reduction in both atmospheric pressure and altitude of the 500 hPa geophysical potential was observed in relation to the average conditions. Observed phenomenon is a result of different thermal conditions in sunny and calm and windy and cloudy days. As stated in previous part of the study, sunny and calm days are warmer.

On days with clear and calm weather, the study area was directly affected by a high-pressure system or was on its edge, while during cloudy and windy weather the area under study was directly influenced by a low-pressure system, low-pressure trough or was on the western edge of a low pressure system.

The obtained research results indicate significant differences in the values of the meteorological elements in the selected types of weather. However, taking into account the small number of days with both weather types, the results obtained in this study should be treated with caution. It also indicates the need for further research within the scope described in the paper.

Acknowledgments. — The authors would like to thank for the participants of the 21rd Adam Mickiewicz University scientific expedition to Spitsbergen for their help in research conducting. Also, the authors would like to thank Tadeusz Niedźwiedź and Kamil Láska for their reviews and all helpful comments and remarks.

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Received 21 January 2018
Accepted 25 June 2018