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Climatic conditions of the north-western part of Oscar II Land (Spitsbergen) in the period between 1975 and 2000

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Abstract: The paper describes climatic conditions of the north-western part of Oscar II Land (Spitsbergen) based on meteorological data from 1975 to 2000, which were taken from Ny Ålesund and Kaffiöyra-Heggodden stations. The changes in annual courses of main climatic elements are investigated. However, the authors focused mainly on the analysis of summer climate, because most of the field work is conducted at this time of the year. Aside from the standard climatic analysis, the influence of atmospheric circulation on selected meteorological elements was also investigated. The climate of the north-western part of Oscar II Land was compared with the climates of the remaining areas of the western coast of Spitsbergen. It was found that the climate of the studied area differs considerably from the climate of the central-inner and southern parts of the western coast of Spitsbergen (areas represented by the Svalbard Lufthavn and Hornsund stations respectively). The differences in climatic elements, however, are not stable throughout the year and in particular seasons and months can even change signs. Thus, any generalisation of results obtained based on seasonal data is inadmissible. It was also found that the wind conditions of the Kaffiöyra region are more representative of the north-western part of Oscar II Land than are the wind conditions of the Ny Ålesund region.

Key words: Arctic, Spitsbergen, Oscar II Land (Kaffiöyra), climate.

Introduction

The aim of this study is to present the climatic conditions of tundra in the north-western part of Oscar II Land (the area from St. Jonsfjorden to Kongsfjorden) in the last 26 years of the 20th century and to compare them to the climate of the remaining part of the western coast of Spitsbergen. As most field research in polar areas is conducted during the summer period, we present the summer season in more detail. The climate of Oscar II Land has been characterised using meteorological data from the Kaffiöyra-Heggodden station (operated by the Nicolaus Copernicus

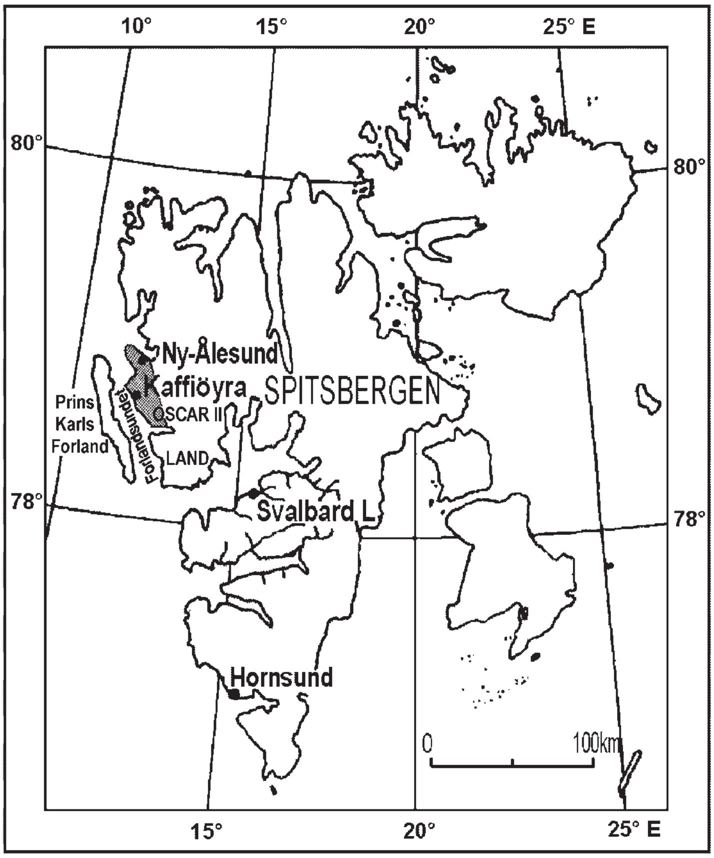

Fig. 1. Location of research area (in grey) and meteorological stations used in the study.

University, Institute of Geography and active only during some summer seasons) and from Ny Ålesund (an all-year round station which is part of the Norwegian meteorological network). The climate of the central-inner and southern parts of the western coast of Spitsbergen, however, is represented in this study by data from the Svalbard Lufthavn and Hornsund stations respectively (Fig. 1). The Svalbard Lufthavn station is situated in a fjord (Isfjorden) a long way from the open sea. As a result, the climate here is more continental than, for example, at Isfjord Radio, a very well known meteorological station located close to the open sea. The latter station would have been better for the present analysis, but was closed in 1976.

The standard meteorological observations at the Kaffiöyra-Heggodden station were performed in the period between 1975 and 2000 in the following summer seasons: 1975, 1977, 1978, 1979, 1980, 1982, 1985, 1989, 1997, 1998, 1999, and 2000. The meteorological station was run each summer by the Toruń Polar Expeditions and was located at the foot of a terminal moraine of the Aavatsmark Glacier at a height of 11.5 m a.s.l., and at a distance of approximately 200 m from the

Forland Strait. The meteorological observations were performed four times every 24 hours (at 00.00, 06.00, 12.00 and 18.00 hours GMT, *i.e.* 01.00, 07.00, 13.00 and 19.00 LMT). They included the measurements of air temperature and humidity (at a height of 2.0 m a.g.l.), wind direction and velocity (2.0 m a.g.l.), atmospheric precipitation (1.0 m a.g.l.) as well as visual observations of the degree and type of cloudiness, horizontal visibility and atmospheric phenomena. Moreover, using the Campbell-Stokes universal heliograph, sunshine duration was registered.

For the purposes of this study, meteorological data (*in extenso*) from the period 1975–1989 were taken from *Meteorological Observations on Oscar II Land (Spitsbergen) and in Bunger's Oasis (Antarctica)* (Wójcik *et al.* 1997). For another four seasons (1997–2000) research by Araźny (1999, 2002), Kejna (2002), and Przybylak and Szczeblewska (2002a) was used. Detailed characteristics of meteorological conditions in Kaffiöyra during the Toruń Polar Expeditions in the summer seasons 1975–2000 have been presented in the following publications: Leszkiewicz 1977; Wójcik 1982; Wójcik and Marciniak 1983; Marciniak and Przybylak 1983; Marciniak and Przybylak 1991; Wójcik and Przybylak 1991; Kejna and Dzieniszewski 1993; Marciniak *et al.* 1993; Araźny 1999, 2002; Kejna 2002; Przybylak and Szczeblewska 2002a.

The meteorological data from the Norwegian stations have been provided by the Norwegian Meteorological Institute in Oslo, and the data for Hornsund were taken from the "Hornsund" Meteorological Yearbook, using research conducted by the Maritime Department of the Institute of Meteorology and Water Management (IMGW) in Gdynia. In order to make a credible comparison of weather conditions present in all the stations, the results were presented for the common period (July 21st – August 31st) out of the above mentioned 12 summer seasons. Additionally, calculations were made for four ten-/eleven-day periods, *i.e.* 21.07–31.07, 1.08–10.08, 11.08–20.08, and 21.08–31.08. The characteristics of the tundra climate of the northern part of Oscar II Land in the remaining part of the year were ascertained on the basis of data from the Ny Ålesund station.

Of particular use in carrying out this study were climate studies published for the area of Kaffiöyra (Przybylak and Szczeblewska 2002b; Przybylak *et al.* 2004) and for the whole of Spitsbergen (including Ny Ålesund, located approximately 30 km north of the meteorological station Kaffiöyra-Heggodden) (*e.g.* Steffensen 1969, 1982; Marciniak and Przybylak 1985; Hanssen-Bauer *et al*. 1990; Przybylak 1992a, b; Førland *et al.* 1997; Ørbæk *et al.* 1999).

The climate of the north-western part of Oscar II Land

Here we present the annual course of the selected meteorological elements based on mean long-term daily and monthly data for the Ny Ålesund station. However, the detailed characteristics of the summer climate were ascertained on the ba-

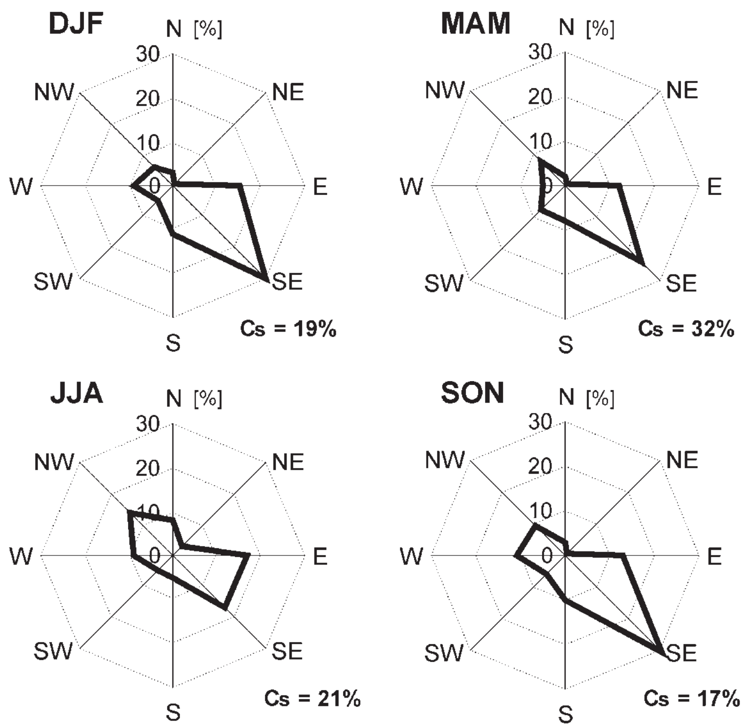

Fig. 2. Frequency of wind directions (%) and periods of calm (Cs) in Ny Ålesund in the period 1975–1989 (Hanssen-Bauer *et al.* 1990).

sis of data from the Kaffiöyra-Heggodden station, which is located in a more central position in the north-western part of Oscar II Land. This is why we believe the data from that station are more appropriate for establishing the characteristics of the climate of that area. It is worth noting that the meteorological data from both stations correlate well with each other (with the exception of data for wind, which are affected by the local topography).

Annual course.—During the year Ny Ålesund is dominated by SE and E winds. Their share is particularly considerable in winter and autumn: 30% and 15% in winter and 31% and 13% in autumn respectively (Fig. 2). In the summer, however, apart from the aforementioned wind directions (which have a frequency of 17% in both cases), NW winds are also frequent (14%). These prevailing wind directions are compatible with the course of Kongsfjorden and the courses of valleys which are filled with the Kongsvegen and Kronebreen glaciers. The strongest winds are noted in autumn and particularly in winter; during these seasons they are the result of an intensive cyclonic circulation (see Serreze *et al.* 1993). Their mean velocity (V) at the height of 2 m a.g.l. is 2.8 and 3.2 m/s respectively (Table 1). The windiest month is January (3.4 m/s) (particularly for the first three weeks) (Fig. 3), and the calmest months are June and July (1.9 m/s each). The mean annual wind

Table 1

Climatic conditions in Ny Ålesund (NA) in comparison with Svalbard Lufthavn (NA-SL*) and Hornsund (NA-H**), 1975–2000

Element	Station	J	F	M	A	M	J	J	A	S	O	N	D	Year
V [m/s]	NA	3.4	2.9	2.8	2.3	2.0	1.9	1.9	2.0	2.2	2.9	3.3	3.3	2.6
	NA-SL	–0.9	–0.9	–0.7	–0.7	–0.9	–1.3	–1.6	–1.1	–0.9	–1.0	–1.1	–1.0	–1.0
	NA-H	–1.6	–2.2	–2.2	–2.0	–1.4	–0.8	–1.0	–1.0	–1.0	–1.0	–1.1	–1.3	–1.4
C [0–10]	NA	5.2	5.7	6.0	5.7	6.5	7.7	7.8	8.0	7.6	7.1	6.2	5.2	6.6
	NA-SL	–0.4	–0.1	0.1	0.1	0.0	0.2	0.4	0.2	–0.1	–0.1	–0.2	–0.5	0.0
	NA-H	–1.1	–0.9	–0.6	–0.8	–0.8	–0.3	–0.2	0.0	–0.5	–0.2	–0.7	–0.8	–0.6
SS*** [h]	NA	.	0.0	77.1	280.9	287.5	205.5	180.3	133.0	74.0	0.6	.	.	1238.8
	NA-H	.	–2.4	–10.5	65.2	79.1	36.7	16.2	18.0	3.3	–24.6	.	.	180.9
Tmax abs [°C]	NA	5.1	4.7	5.0	5.5	8.0	11.2	17.3	18.3	12.3	8.6	7.4	5.8	18.3
	NA-SL	–1.6	–1.2	–1.3	0.0	–2.6	–3.1	–4.0	0.2	–2.9	–0.3	0.8	–1.4	–3.0
	NA-H	0.6	1.3	1.8	1.4	2.4	–0.1	3.9	6.3	1.9	1.0	2.7	1.4	4.9
Tmax [°C]	NA	–10.0	–10.1	–9.0	–6.7	–0.6	3.8	7.0	6.1	2.2	–2.9	–5.5	–8.8	–2.9
	NA-SL	0.8	1.1	0.7	0.8	0.5	–0.8	–1.9	–1.2	–0.6	–0.2	0.4	0.4	0.0
	NA-H	–1.3	–1.6	–1.7	–0.6	0.2	0.3	0.6	0.2	–0.8	–1.4	–1.0	–0.9	–0.7
Ti [°C]	NA	–13.5	–14.2	–12.8	–10.4	–3.5	1.7	4.9	4.0	0.0	–5.6	–8.5	–12.1	–5.8
	NA-SL	1.2	1.2	0.8	0.9	0.2	–0.6	–1.3	–1.0	–0.6	–0.3	0.4	0.5	0.1
	NA-H	–1.7	–2.5	–2.4	–1.3	–0.3	0.1	0.6	0.1	–1.2	–2.0	–1.5	–1.2	–1.1
Tmin [°C]	NA	–17.6	–18.3	–16.8	–14.2	–6.0	0.3	3.4	2.6	–2.0	–8.4	–11.9	–15.7	–8.7
	NA-SL	1.0	1.1	0.7	0.8	–0.4	–0.5	–1.1	–0.9	–0.9	–0.7	0.0	0.1	–0.1
	NA-H	–2.4	–3.3	–3.3	–1.9	–0.5	0.3	1.0	0.4	–1.5	–2.6	–2.1	–1.8	–1.5
Tmin abs [°C]	NA	–36.6	–41.1	–42.2	–34.0	–19.1	–8.5	–1.4	–5.5	–15.0	–20.6	–27.2	–34.3	–42.2
	NA-SL	2.2	2.6	4.1	5.1	2.6	–0.1	–0.7	–1.6	–2.4	0.2	6.0	1.3	4.1
	NA-H	–0.7	–7.5	–8.0	–3.3	0.4	–1.1	–0.4	–0.6	–3.8	0.2	1.7	–2.2	–6.3
f [%]	NA	73.3	77.3	76.6	75.0	78.1	83.1	85.6	83.8	81.2	74.4	72.2	72.1	77.7
	NA-SL	0.1	3.3	3.0	3.0	5.3	10.7	11.2	8.6	6.4	2.1	0.0	0.2	4.5
	NA-H	–3.4	–1.2	–1.3	–1.8	–0.8	0.4	–0.5	–1.4	–1.7	–1.6	–3.8	–2.8	–1.6
P [mm]	NA	31.9	37.3	45.9	26.0	18.3	17.3	24.7	39.4	49.3	32.3	40.2	37.4	400.0
	NA-SL	17.7	18.2	25.2	14.7	11.4	7.4	9.8	13.6	26.8	19.5	23.0	19.8	207.1
	NA-H	2.2	9.1	15.3	3.3	–1.4	–16.2	–15.6	–12.4	–15.0	–12.3	5.0	5.9	–32.1

Key: SL* (1976–2000), H** (1979–2000),***1993–2000, V – wind velocity at 2m a.g.l.; C – cloud cover; SS – sunshine duration; $T_{max\ abs}$ – absolute maximum temperature, T_{max} – maximum daily temperature, T_i – mean daily temperature, T_{min} – minimum daily temperature, $T_{min\ abs}$ – absolute minimum temperature, f – relative humidity; P – atmospheric precipitation.

velocity in the period 1975–2000 was 2.6 m/s (Table 1). The greatest drop in wind velocity is observed in March, and the greatest increase is in September (Fig. 3).

Cloud cover (C) is lowest in December and January (at only 52%); in the period from February to April it is slightly higher, though not exceeding 60% on average (Table 1 and Fig. 3). In May cloud cover increases rapidly and from June it fluctuates between 77% and 80%. This rate of cloud cover is maintained until the end of September, reaching its maximum in August (80%). A considerable constant drop in cloud cover is observed in October and November.

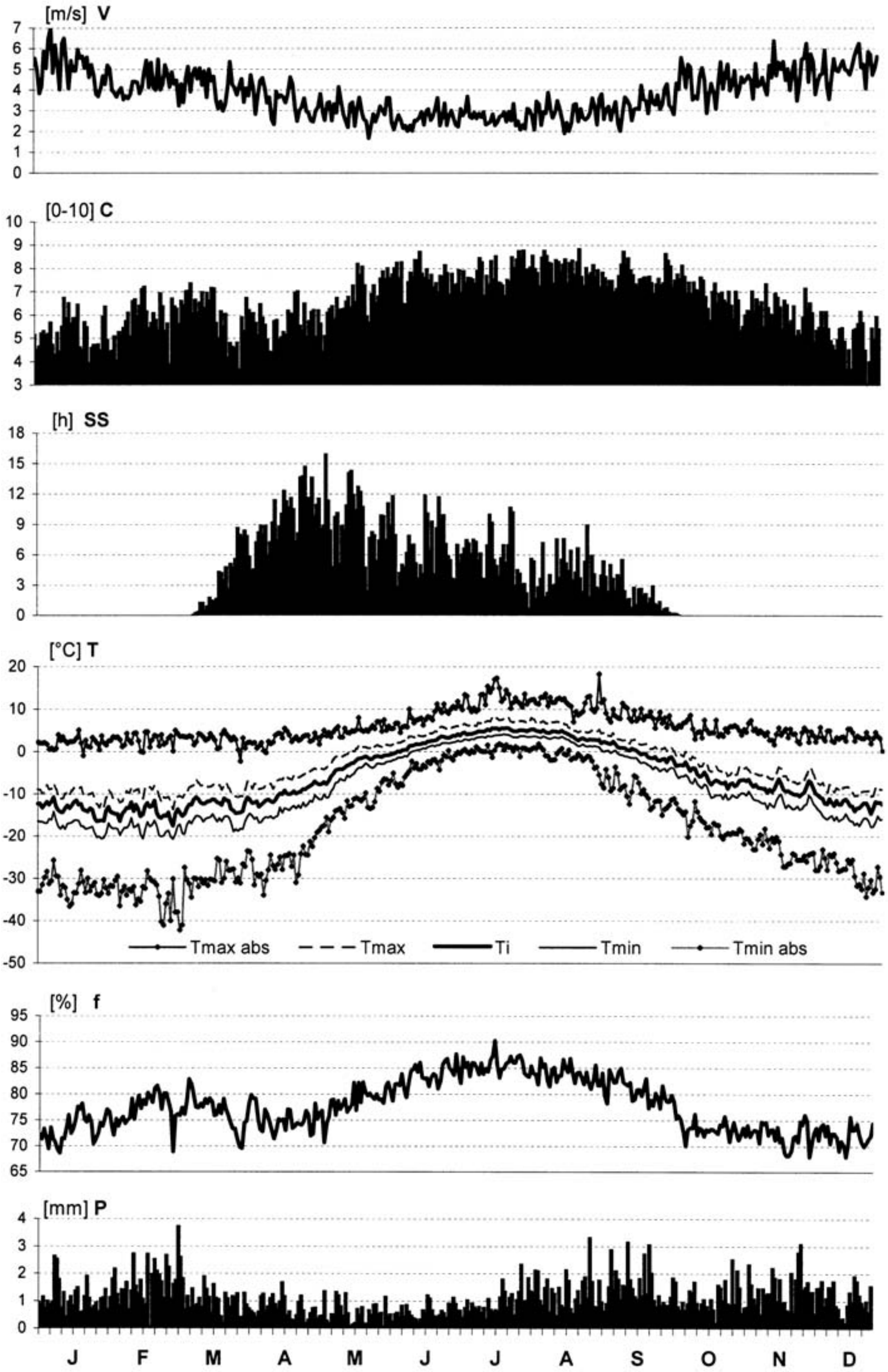

Fig. 3. Mean annual courses of selected meteorological elements in Ny Ålesund during the period 1975–2000 according to daily values. Key to abbreviations as in Table 1.

The magnitude of sunshine duration (SS) is not only the function of cloud cover, but also of the length of the day, which is subject to the greatest changes in the Polar Regions. The mean annual sum of sunshine duration in the years 1993–2000 (Kaldewey Station) was 1238.8 hours. The greatest monthly sums were noted in May (287.5 hours) and April (280.9 hours). However, relative sunshine duration is greater in April (45.4%) than in May (38.6%). The increase in cloud cover in the summer season, which was discussed earlier, results in sums of sunshine duration in that season being 1.5–2 times lower than in spring (Table 1).

The mean air temperature in Ny Ålesund in the period 1975–2000 was –5.8°C (Table 1). July was the warmest month (4.9°C), and February the coldest (–14.2°C). With the exception of absolute maximum air temperatures ($T_{max\ abs}$) in summer and absolute minimum air temperatures ($T_{min\ abs}$) in winter, this pattern was characteristic of other thermal variables which were analysed.

In the 26-year study period, the period with negative mean long-term 24-hour air temperatures (T_i) in Ny Ålesund begins in the beginning of the second half of September and ends in the first five days of June, *i.e.* it lasts approximately nine months (Fig. 3). The lowest temperatures are observed at the turn of February and March. That period is clearly visible on the $T_{min\ abs}$ graph. In the years 1975–2000 the lowest air temperature (–42.2°C) occurred on March 3, 1986. From the beginning of December till the end of the third week of April mean long-term daily temperatures are generally at the same level and always lower than –10°C. A majority of $T_{min\ abs}$ are lower than –30°C, while $T_{max\ abs}$ are higher than 0°C. It is also in that period that the greatest variability of all the analysed air temperature variables is noted (Fig. 3). Along with a considerable increase in sun height over the horizon and the arrival of the polar day (April 18th) air temperature increases quickly and its changeability gradually decreases. The highest long-term mean values for T_i in the annual cycle occur in the second half of July. The highest daily values for $T_{max\ abs}$ are also most often recorded in that period, though the highest air temperature (18.3°C) in Ny Ålesund in the 26-year study period was recorded on August 31st, 1997. On that day the highest air temperature was also recorded at Kaffiöyra (Araźny 2002).

Low air temperatures occurring in the north-western part of Oscar II Land cause relative air humidity (f) to be high. On average it is highest in July (85.6%), and lowest in December (72.1%) with an annual mean of 77.7% (Table 1). Aside from a clear summer maximum (considerably above 80%) one can also observe a secondary maximum (75–80%) occurring in February and March (Fig. 3). Aside from a primary minimum in November and December, a secondary minimum in April is also clearly visible.

The prevailing influence of cyclonic situations in the Norwegian Arctic, particularly in the winter half of the year, leads to this region having a maximum precipitation level in autumn and winter, unlike more continental areas. Moreover they contribute to a considerable increase in total annual precipitation, which in Ny Ålesund in the period 1975–2000 was 400.0 mm. Analyzing Table 1 and Fig. 3, one can clearly see the occurrence of three maximums in March, September, and November. Mean totals of monthly precipitation in those months were 45.9, 49.3, and 40.2 mm respectively. Approximately half of these amounts of precipitation were recorded in the period from April to July, when the influence of anticyclonic situations increases considerably, the frequency of which in May is even greater than cyclonic situations (see Fig. 3 in Przybylak 1992a). Mean daily totals of precipitation usually do not exceed 1mm. In the cool period of the year (with the exception of spring) these totals are higher, and often fluctuate between 1 and 2 mm. The highest mean precipitation total (3.7 mm) was noted on March 12th. The absolute highest daily precipitation total occurred on December 1st, 1993 and was 57.0 mm.

Summer season (July 21st – August 31st). — The location of Kaffiöyra over the long and narrow Forland Strait, between the high mountain ranges of Prince Charles Island (in the west) and Oscar II Land (in the east) considerably modifies the direction of the in-flow of air masses. These land forms of considerable height, running along the SSE-NNW nozzle-shaped axis, direct the stream of air flowing in the boundary layer of the troposphere, into the area of the Kaffiöyra Plain and the Forland Strait. They form “a channel” of sorts for the ground-level wind streams, which consequently, depending on the synoptic situation, result in a marked predominance of directions from the northern and southern sectors.

In the common 42-day period investigated in this study, winds from the directions compatible with the axis of the Forland Strait (SSE-NNW) occurred during 33.5% of observations, and including neighbouring directions (N, NW, S, SE) they accounted for as much as 74.6% (Fig. 4). The most frequently observed winds were from the SSE (19.1%), NNW (14.4%), S (11.5%), NW (11.2%) and SE (10.8%). By far the most seldom were the winds from the directions perpendicular to the orographic barriers, and this is why winds from the ENE-E-ESE sector were recorded sporadically (2.9%) and WSW-W-WNW (5.7%). In the period between July 21st to August 31st, periods of calm occurred on average during 4% of fixed-time observations (Przybylak *et al.* 2004).

Mean daily wind velocity from 12 seasons was 4.4 m/s (Table 2). In the study period, the last five days of July were the windiest (5.8 m/s), during two days of which the mean wind velocity was 6.7 m/s (Fig. 5). Mean below-average velocities occurred most often in the second half of August. The distribution of wind velocities according to their directions in the period from July 21st to August 31st shows a regularity, with the most frequent directions being characterised by the greatest velocities and the least frequent by the lowest velocities (Fig. 4). Confirmation of this regularity is that of the 16 directions, only for the four most frequent ones was the mean velocity higher than the long-term mean, and thus the greatest velocity accompanied the following directions: SE (5.6 m/s), SSE (5.5 m/s), NNW (5.1 m/s) and S (5.0 m/s). The exceptions to this are the following directions: N (3.4 m/s) and NW (4.0 m/s). The smallest velocities recorded were for the following wind direc-

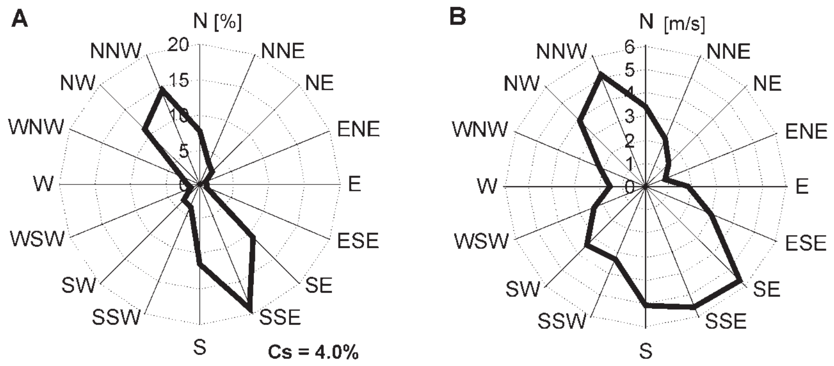

Fig. 4. A. Frequency of wind directions (%) and periods of calm (Cs) and B mean wind velocities (m/s) according to direction on the Kaffiöyra Plain in the summer season (July 21st – August 31st), 1975–2000

tions ENE (0.9 m/s), NE (1.4 m/s), and W (1.5 m/s). The mean long-term fixed-hour wind velocity was greatest in the afternoon hours (4.8 m/s), while nights showed the most stable atmosphere (4.0 m/s).

Due to quite intensive cyclonic activity during summer (see Serreze *et al.* 1993), along with melting of the snow and ice, and the vicinity of the open ocean, Spitsbergen is characterised by high cloud-cover rates with high year-to-year stability. The mean cloud cover in Kaffiöyra in the common period of observations July 21st to August 31st reached 8.4, on a scale of 0–10 (Table 2). In that period long-term mean values for cloud cover were characterised by low day-to-day variability (Fig. 5). The lowest mean cloud cover (8.2) was noted in from the third week of July onwards, when the first five days were partly cloudy ($2 \leq C \leq 8$). The greatest number of cloudy days occurred in the first ten days of August, when only one partly cloudy day was recorded. The longest, continuous period of cloudy weather lasted 11 days (July 26th to August 5th).

High cloud cover determines the occurrence of low sunshine duration totals (SS) in Kaffiöyra. In the common period of observations in the 12 years under investigation mean recorded sunshine duration was 164.9 hours *i.e.* 16.7% of the total possible sunshine duration (Table 2). The sunniest period was from 21st to 31st July (56.6 hours), and the first ten-day mean of August was the least sunny (34.7 hours). In the common period of observations (42 days), the greatest mean diurnal SS occurred on July 25 (7.9 hours) while the lowest was on August 1st (0.7 hours) (Fig. 5).

The mean long-term daily air temperature was 4.6°C (Table 2). In the period between July 21st and August 31st, the last eleven days of July turned out to be the warmest (5.3°C) (Fig. 5). However, in connection with the end of the polar summer and the progressively lower position of the sun over the horizon, the long-term coolest was the last eleven days of August (3.3°C). The mean daily temperatures during the common period of observations were characterised by small day-to-day variability, showing a clear downward trend. The warmest period with a tempera-

Table 2

Mean values of selected meteorological elements on the Kaffiöyra Plain in the summer seasons (July 21st – August 31st), 1975–2000

Element	1975	1977*	1978	1979	1980	1982	1985	1989	1997**	1998	1999	2000	1975–2000
V [m/s]	4.3	3.2	4.6	5.0	5.5	4.2	3.2	5.0	5.4	4.0	3.8	4.6	4.4
C [0–10]	8.7	8.7	8.8	7.3	9.1	8.8	7.2	8.3	8.4	9.1	8.9	7.2	8.4
SS [h]	112.9	147.6	119.9	281.9	90.9	91.3	309.5	203.0	165.0	93.5	150.1	213.3	164.9
SS [%]	11.2	15.9	12.1	29.0	9.1	9.2	32.2	20.5	16.8	9.5	15.2	21.6	16.7
$T_{max\ abs}$ [°C]	11.5	13.5	10.0	18.9	12.5	10.4	16.0	11.5	10.8	14.0	10.3	8.8	18.9
T_{max} [°C]	6.7	7.0	6.3	6.6	5.6	4.8	6.9	5.5	5.4	7.6	6.4	5.9	6.2
T_i [°C]	4.9	5.0	4.7	4.5	4.1	3.3	5.4	4.0	4.2	6.3	4.9	3.9	4.6
T_{min} [°C]	3.3	3.5	3.1	2.5	2.6	1.8	4.0	2.7	2.7	5.0	3.5	2.2	3.1
$T_{min\ abs}$ [°C]	1.4	0.6	0.7	–0.5	–0.8	–4.2	0.9	–3.6	–0.2	1.8	0.0	–3.6	–4.2
e [hPa]	7.8	7.8	7.7	7.6	7.3	6.8	8.1	7.4	7.5	8.7	7.3	7.2	7.6
f [%]	90	89	89	89	88	88	89	90	90	91	85	88	89
Δe [hPa]	0.9	1.0	0.9	0.9	0.9	1.0	1.0	0.8	0.8	0.9	1.3	1.0	1.0
P [mm]	66.5	44.4	44.2	17.7	108.0	54.5	13.9	27.0	122.5	16.0	58.4	29.1	50.2

Key: * – July 21st – August 28th; ** – July 28th – August 31st; e – water vapour pressure; e – saturation deficit. Remaining abbreviations as in Table 1.

ture of ≥ 5.5°C lasted from July 21st to July 27th, reaching its maximum (6.1°C) on July 22nd (Fig. 5). At the turn of July and August a slight cooling was recorded in Kaffiöyra which lasted approximately one week. The lowest values for T_i (4.2°C) were recorded on July 31st and August 1st. Subsequently, until about mid-August, T_i rose and remained above 5.0°C. The greatest amplitude of the mean daily temperature (11.7°C) in the study period was recorded on August 16th. T_i changed on that day from 2.2°C (1977) to 13.9°C (1979). An evident drop in T_i (> 1°C) occurs in the period between 15th and 25th August (Fig. 5). In the last eleven days of August, mean values of T_i are in the range of 3.0–3.9°C, with the exception of the coolest day of the season (2.8°C).

Long-term courses of mean daily T_{min} and T_{max} in the study period are similar to mean courses of T_i (Fig. 5). Mean daily values for T_{min} in the period between July 21st and August 31st changed from 1.1°C (August 29th) to 4.6°C (July 21st and 22nd) with the mean for the whole period being 3.1°C. Up to August 18th above-average long-term temperatures persisted and in the last eleven days of the month, oscillated around 1.7°C. The range of fluctuations of mean T_{max} was between 4.3°C (August 26th) to 8.5°C (July 23rd). The graph illustrating averaged daily T_{max} values for the seasons 1975–2000, shows a greater day-to-day variability than T_i and T_{min} (Fig. 5). The highest mean daily T_{max} (> 7.0°C) occurred in the first week of the study period; however from August 22nd they did not exceed 5.0°C, with the eleven-day (21–31 August) mean being 4.7°C.

A characteristic feature of the climate of Kaffiöyra, as well as the whole of Spitsbergen, is a high level of moisture content in the air, largely the result of (a)

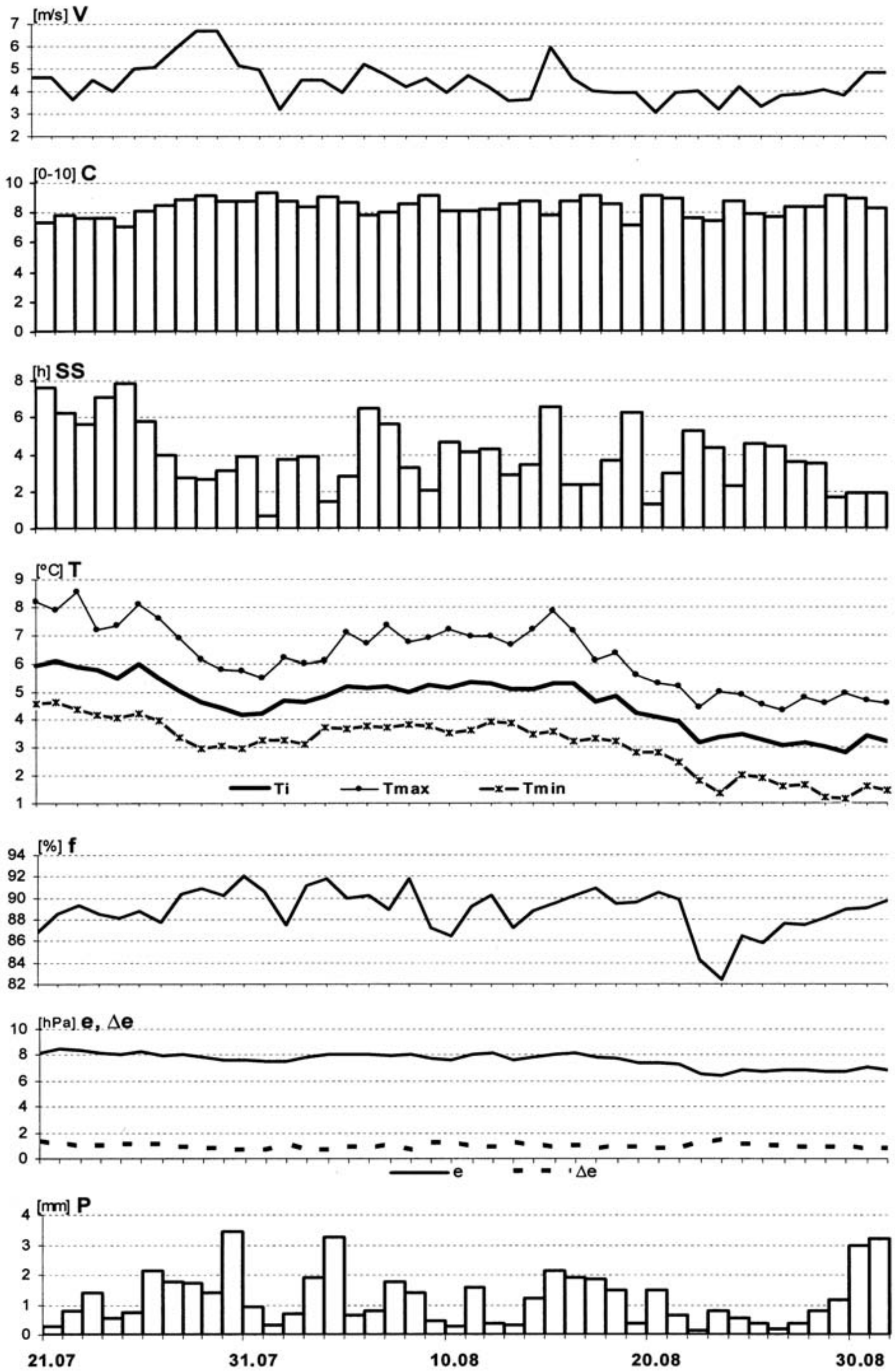

Fig. 5. Course of meteorological elements on the Kaffiöyra Plain in the summer season (July 21st – August 31st), 1975–2000. Remaining abbreviations as in Tables 1 and 2.

very intensive cyclonic activity bringing humid air masses from moderate latitudes, (b) low temperatures, and (c) the vicinity of the sea.

In the summer season mean long-term daily water vapour pressure (e) changed from 6.4 hPa (August 23rd) to 8.5 hPa (July 22nd), with a period mean of 7.6 hPa (Table 2). The highest values for water vapour pressure were noted in the first six days of the study period, *i.e.* from July 21st to July 26th (≥ 8.0 hPa) (Fig. 5). The aforementioned period of decreased temperature recorded at the turn of July and August also caused a decrease in water vapour pressure values to 7.5–7.8 hPa. From August 22nd, mean, long-term daily water vapour pressure values dropped below 7.0 hPa (except for August 30th).

The mean long-term values of relative humidity calculated for the common period was 89% (Table 2). Its course in the study period does not display great day-to-day variation (Fig. 5). The most distinct period with decreased relative humidity (< 87%), lasted just four days (August 22nd – 25th). During that time (on August 23rd) the lowest (82%) mean daily value was noted in the summer season. On July 31st and August 4th and 8th the highest values were recorded (92%). The ten-/eleven-day means of relative humidity varied little – from 87% in the last eleven days of August to 90% in the preceding two ten-day periods of that month.

The mean long-term saturation deficit (Δe) during the study period was 1.0 hPa (Table 2), and the day-to-day course of Δe based on long-term data shows only minimal changes (Fig. 5): its mean daily values fluctuated from 0.6 hPa (July 31st) to 1.4 hPa (August 23rd).

Precipitation in Spitsbergen is not high, in spite of extensive cloud cover. Low contents of water vapour in the air, the stability of air masses, and the related predominance of stratus and stratocumulus clouds are not conducive to high levels of atmospheric precipitation (Wójcik and Przybylak 1991). The long-term mean precipitation total measured in the period between July 21st and August 31st was 50.2 mm (Table 2), which means that mean relative amount of precipitation was 1.2 mm per 24 hours. Mean daily precipitation totals varied from 0.2 mm (August 22nd and 26th) to 3.6 mm (August 4th). From Fig. 5 it may be seen that precipitation was characterised by a high irregularity of coverage. The greatest mean long-term ten-/eleven-day precipitation totals were calculated for those periods in which there was precipitation in every season, *i.e.* in the last eleven days of July (15.2 mm) and the second ten-day period of August (12.8 mm). The last eleven-day period of August was the driest (10.7 mm), and in two seasons (1975 and 1985) this period saw no precipitation.

The characterisation of the atmospheric circulation for the Kaffiöyra Plain was drawn up using a circulation-type calendar for the years 1975–2000, derived from Niedźwiedź (pers. comm.). He identified 20 types of circulation, taking into consideration types of baric patterns and the direction of air advection, as well as one particular circulation type – marked "x" – representing a col and other situations that defied classification. The types of circulation which were identified and de-

Table 3

Relative frequency (%) of occurrence of types of atmospheric circulation over Spitsbergen in the period July 21st – August 31st, 1975–2000 (Przybylak *et al.* 2004)

Types of circulation	1975	1977*	1978	1979	1980	1982	1985	1989	1997	1998	1999	2000	1975–2000
NW_a+N_a+NE_a	7.1	10.3	2.4	9.5	2.4	7.1	2.4	9.5	2.4	0.0	7.1	7.1	5.6
E_a+SE_a	9.5	12.8	26.2	16.7	2.4	2.4	40.5	4.8	2.4	35.7	9.5	7.1	14.2
S_a+SW_a+W_a	14.3	7.7	11.9	7.1	19.0	4.8	0.0	7.1	19.0	7.1	0.0	0.0	8.2
C_a+K_a	16.7	10.3	21.4	7.1	14.3	19.0	23.8	23.8	11.9	31.0	19.0	14.3	17.8
NW_c+N_c+NE_c	2.4	2.6	4.8	23.8	14.3	9.5	7.1	14.3	11.9	4.8	26.2	16.7	11.6
E_c+SE_c	9.5	20.5	2.4	14.3	4.8	21.4	14.3	7.1	11.9	14.3	7.1	14.3	11.8
S_c+SW_c+W_c	26.2	23.1	23.8	21.4	31.0	21.4	4.8	16.7	35.7	0.0	9.5	16.7	19.2
C_c+B_c	11.9	10.3	7.1	0.0	11.9	14.3	7.1	11.9	4.8	4.8	14.3	21.4	10.0
X	2.4	2.6	0.0	0.0	0.0	0.0	0.0	4.8	0.0	2.4	7.1	2.4	1.8
Anticyclonic	47.6	41.0	61.9	40.5	38.1	33.3	66.7	45.2	35.7	73.8	35.7	28.6	45.7
Cyclonic	50.0	56.4	38.1	59.5	61.9	66.7	33.3	50.0	64.3	23.8	57.1	69.0	52.5

*– 21.07–28.08

scribed are to be found in works by Niedźwiedź (1993, 1997) and Nordli *et al.* (2000) and elsewhere. In this study, due to the limited occurrence of certain types of circulation, circulation types were merged according to the methodology described by Przybylak (1992a, b). As a result their number was reduced to six types with distinct direction of advection, and one type (x) representing a col and other unclassified situations.

The frequency of occurrence of types of baric patterns in the Kaffiöyra Plain during the period from July 21st to August 31st displays considerable variation between summers (Table 3). During the summer seasons analysed we notice, on average, a prevailing occurrence of lows (52.5%) over highs (45.7%). In any given summer, the share of cyclonic circulation in shaping the weather and the climate of Spitsbergen varied from 23.8% (1998) and 33.3% (1985) to 66.7% (1982) and 69.0% (2000). The frequency of occurrence of high-pressure systems in the aforementioned summer seasons was 73.8%, 66.7%, 33.3% and 28.6% respectively. The most accurately approximated proportions to long-term mean frequencies of occurrence of synoptic types were noted in the seasons of 1975 and 1989 (Przybylak *et al.* 2004).

In the 12 studied summers with the greatest average frequency, the following types of cyclonic circulation pattern occurred: Sc+SWc+Wc (19.2%), Ca+Ka (17.8%), and Ea+SEa (14.2%). The circulation patterns which had the lowest frequency were types NWa+Na+NEa (5.6%) and Sa+SWa+Wa (8.2%). In many summers, dominance of one type of circulation became evident, not necessarily the most frequent in the long-term (Table 3). In five of them Sc+SWc+Wc was the most frequent type of circulation. For example, 1997 was characterised by the greatest frequency of this type (35.7%), while in 1998 it did not occur at all. Ea+SEa type circulation was the most frequent in three seasons: 1985 (40.5%), 1998 (35.7%), and 1978 (26.2%). The summers of 1998 (31.0%) and 1985 and 1989 (23.8%) were marked by the major occurrence of the Ca+Ka synoptic situation.

In the study period (1975–2000), the most frequent directions were S+SW+W (27.4%); however their share in a given season was characterised by considerable changeability from 54.9% and 50.0% (1997 and 1980) to just 4.8% and 9.5% (1985 and 1999) (Table 3). The directions E+SE occurred with almost the same frequency (26.0%) though in some seasons their share reached 54.8% (1985) and 50.0% (1998). The situations with northern-sector air mass advection (NW+N+NE) were the least frequent (17.2%). Only in 1979 and 1999 did their frequency exceed 30%. For single inflow directions, south-eastern advection (SEc+SEa – 13.3%) was recorded as the most frequent, as well as eastern advection (Ec+Ea – 12.6%) and the synoptic situation Ka (15.5%).

To estimate the influence of atmospheric circulation on particular meteorological elements, appropriate statistical calculations were made. The results are illustrated in Fig. 6, presented in the form of anomalies in relation to long-term means.

Comparison of the climate of NW Oscar II Land with other areas of the west coast of Spitsbergen

Annual course. — Wind directions on the western coast of Spitsbergen are to a considerable degree modified by the local topography, and thus for the stations analysed here they differ significantly from one another, particularly in the summer. In the cool period of the year during the 1975–1989 period, there was a similar frequency of wind directions in Ny Ålesund and Svalbard Lufthavn, where SE winds dominated, followed by E winds (Hanssen-Bauer *et al.* 1990). In Hornsund, however, this configuration was reversed. Easterly winds were clearly the most frequent in the years 1978–1995 (approximately 30–35%), followed by SE winds (approximately 15%) (see Fig. 2, Kierzkowski 1996). The mean wind velocity in Ny Ålesund (2.6 m/s) is considerably lower than in Svalbard Lufthavn (3.6 m/s) and in Hornsund (4.0 m/s) (Table 1). However, as was subsequently demonstrated by data from Kaffiöyra (Table 4), the Ny Ålesund station is not representative for Oscar II Land as a whole, if we take into consideration this meteorological element. The biggest differences between stations occurred in the summer (Svalbard Lufthavn) and in the spring (Hornsund).

As far as cloud cover is concerned, no considerable differences were reported between the Ny Ålesund and Svalbard Lufthavn stations. Cloud cover in the north-western part of Oscar II Land is slightly greater in the summer, and less in the winter, though mean annual values are the same. The southern part of Spitsbergen had greater cloud cover in all seasons and months (with the exception of August) in the years 1975–2000 (on average by 0.6 annually) (Table 1). The biggest differences occurred in the winter and the smallest in the summer.

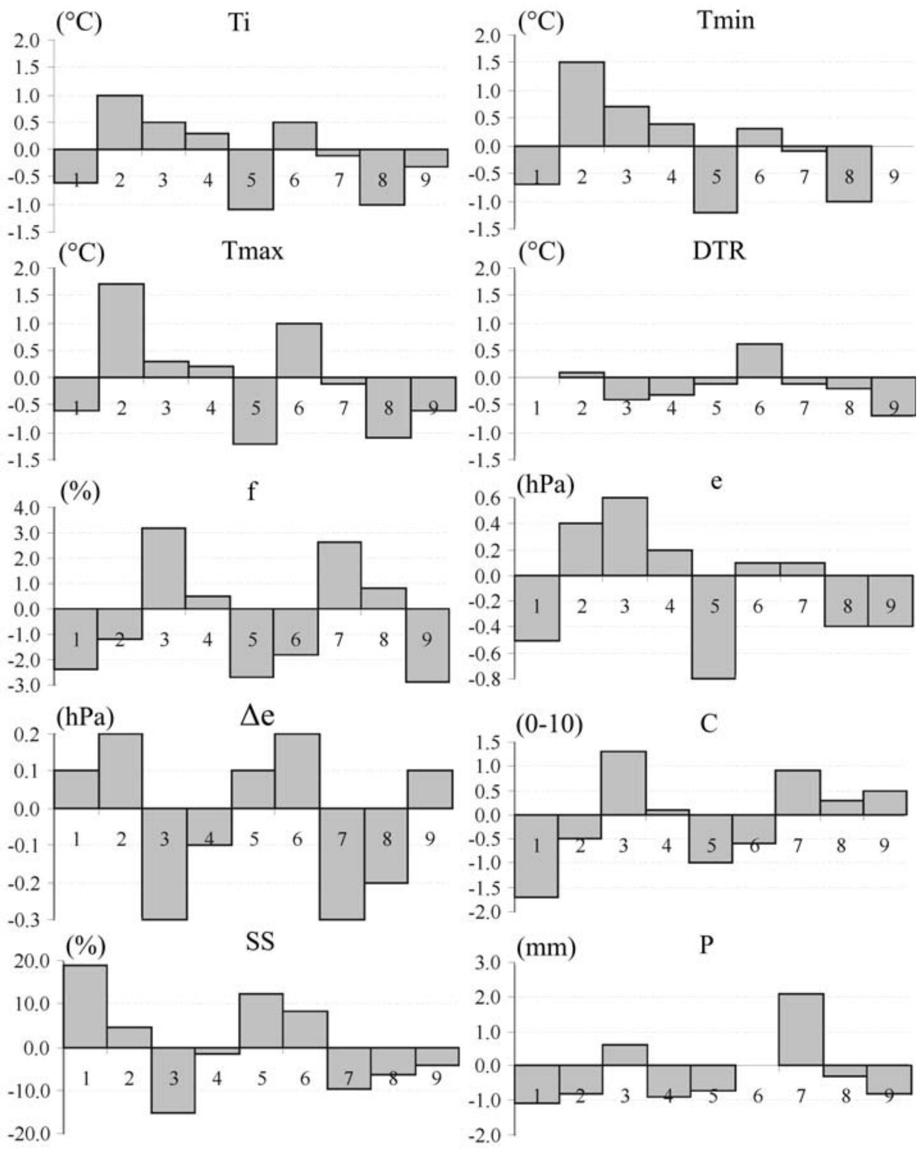

Fig. 6. Mean anomalies of selected meteorological elements for particular types of circulation in the Kaffiöyra Plain in the period July 21st – August 31st, 1975–2000 (Przybylak *et al.* 2004). Types of circulation: 1 NWa+Na+NEa ; 2 Ea+SEa ; 3 Sa+SWa+Wa ; 4 Ca+Ka ; 5 NWc+Nc+NEc ; 6 Ec+SEc ; 7 Sc+SWc+Wc ; 8 Cc+Bc ; 9 X. Remaining abbreviations as in Tables 1 and 2.

Comparing the recorded sunshine duration during the year, it is greater in Ny Ålesund than in Hornsund by over 180 hours. This is not the result of solar conditions but rather of the fact that the horizon is obscured to a considerable degree from the northern side in Hornsund, which reduces the registered intake time of direct solar radiation.

Table 4

Ten-/eleven-day means and seasonal means from the whole summer season (July 21st – August 31st) of values from selected meteorological elements in Spitsbergen, 1975–2000

Element	Period	Ny Ålesund	Kaffiöyra	Svalbard Luft.*	Hornsund**
T_{max} [°C]	21.07–31.07	7.0	7.2	9.2	6.4
	01.08–10.08	6.8	6.6	8.4	6.2
	11.08–20.08	6.5	6.6	8.1	6.3
	21.08–31.08	4.6	4.7	5.4	4.8
	21.07–31.08	**6.2**	**6.2**	**7.7**	**5.9**
T_i [°C]	21.07–31.07	5.0	5.3	6.4	4.2
	01.08–10.08	4.6	4.9	6.0	4.2
	11.08–20.08	4.5	4.9	5.6	4.3
	21.08–31.08	2.7	3.3	3.3	3.0
	21.07–31.08	**4.2**	**4.6**	**5.3**	**3.9**
T_{min} [°C]	21.07–31.07	3.6	3.8	4.7	2.3
	01.08–10.08	3.1	3.6	4.5	2.3
	11.08–20.08	3.0	3.4	3.9	2.3
	21.08–31.08	1.1	1.7	1.8	1.3
	21.07–31.08	**2.7**	**3.1**	**3.7**	**2.1**
V [m/s]	21.07–31.07	2.0	5.1	3.6	2.5
	01.08–10.08	1.8	4.4	3.0	2.7
	11.08–20.08	1.8	4.1	2.9	3.1
	21.08–31.08	1.8	4.0	3.0	3.6
	21.07–31.08	**1.9**	**4.4**	**3.1**	**3.0**
C [0–10]	21.07–31.07	7.9	8.2	7.4	7.5
	01.08–10.08	7.9	8.6	7.8	8.5
	11.08–20.08	8.0	8.4	7.6	7.7
	21.08–31.08	7.8	8.3	7.7	8.0
	21.07–31.08	**7.9**	**8.4**	**7.6**	**7.9**
f [%]	21.07–31.07	87.7	89.2	74.4	86.1
	01.08–10.08	86.3	89.5	76.7	86.8
	11.08–20.08	86.5	89.5	77.1	86.2
	21.08–31.08	84.8	87.2	74.3	82.2
	21.07–31.08	**86.3**	**88.8**	**75.6**	**85.3**
P [mm]	21.07–31.07	13.7	15.2	6.8	14.1
	01.08–10.08	10.8	11.5	9.0	28.7
	11.08–20.08	12.6	12.8	6.2	15.5
	21.08–31.08	9.5	11.3	7.1	15.0
	21.07–31.08	**46.7**	**50.8**	**29.1**	**73.4**

Key: means calculated from 12 summer seasons (1975, 1977–1980, 1982, 1985, 1989, 1997–2000), * 1977–2000, **1978–2000.

Air temperature at Ny Ålesund is slightly higher (by 0.1°C) than at Svalbard Lufthavn and considerably lower (by 1.1°C) than at Hornsund (Table 1). There are, however, many changes in the annual course. In comparison with the central-inner part of the western coast, the north-western part of Oscar II Land is clearly warmer in the winter (on average by 1.0°C), and cooler in the summer (also by 1.0°C). The reverse is true when compared to the southern part of Spitsbergen. Ny Ålesund is warmer in the summer (on average by 0.6°C), and cooler in the remaining seasons, particularly in winter (by 1.9°C). Extreme temperature values ($T_{max\ abs}$ / $T_{min\ abs}$) were highest and lowest in the central-inner and southern parts of Spitsbergen respectively (reflecting the highest and lowest degrees of climate continentalisation) (Table 1).

As may be seen in Table 1, relative humidity is not particularly prone to changes on the western coast. Its highest values occur in the south and north (the differences in monthly averages do not, however, exceed 4%, and from May to July this figure drops to as low as 1%). As may be expected, the lowest relative humidity occurs in the central-inner part of the western coast of Spitsbergen, particularly in the summer when, on average, relative humidity there is lower than in Ny Ålesund by 10.2%.

The north-western part of Oscar II Land and the southern part of the western coast of Spitsbergen are privileged as far as amount of precipitation is concerned. However, annual totals are greater in the south, mainly due to more efficient precipitation in the period from June to October. In the remaining part of the year (with the exception of May) they are higher at Ny Ålesund. In both areas, precipitation is approximately twice as high as in the central part of Spitsbergen (Table 1), where the inflow of humid air masses from the southern sector is limited.

Summer season (July 21st – August 31st). — Climatic conditions in Kaffiöyra during the summer season (as discussed earlier) were compared with other areas located on the western coast of Spitsbergen. As expected, Table 4 and Fig. 7 show that the climate of the Ny Ålesund area is most similar (apart from wind velocity) to the climate of Kaffiöyra. Kaffiöyra is a little warmer, more humid and cloudier. However, wind velocity is twice as high here, which is probably the result of the free meridional transport of air currents. Additionally, the movement of air is intensified by the tunnel effect between the mountain ranges of the Spitsbergen interior and Prince Charles Island in the west (Fig. 1). However, such free-flowing air conditions do not exist in the Ny Ålesund station, located deep in Kongsfjorden and surrounded by mountains.

The central-inner part of the western coast of Spitsbergen (characterised by the biggest ratio of climate continentalisation) is clearly the warmest and driest in the summer season. Atmospheric precipitation is particularly low here, amounting to just 29.1 mm in the investigated season, while in the north-western part of Oscar II Land it approached approximately 50 mm (Table 4, Fig. 7). The southern part of Spitsbergen, represented by the station in Hornsund, is clearly cooler than Oscar II Land; it is also characterised by less cloud cover (particularly in comparison with Kaffiöyra) and lower air humidity. However, a characteristic feature of this part of Spitsbergen is high atmospheric precipitation (73.4 mm).

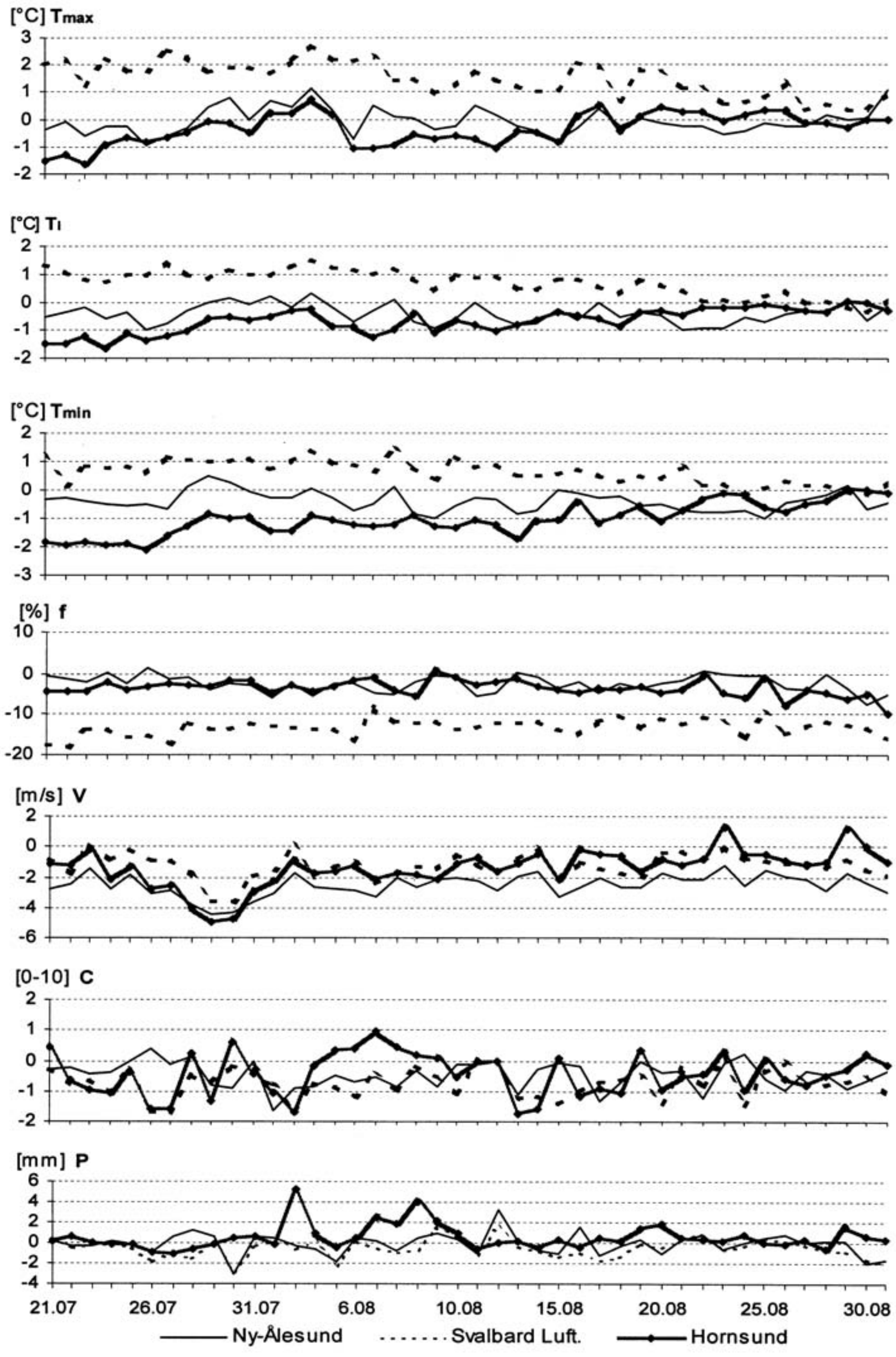

Fig. 7. Course of differences of mean values of selected meteorological elements in the summer season (July 21st – August 31st) between the Kaffiöyra-Heggodden station and other analysed Spitsbergen stations, 1975–2000. Abbreviations as in Table 1.

Conclusions

1. The climate of the tundra of the north-western part of Oscar II Land differs considerably from the climate of the other parts (central-inner and southern) of the western coast of Spitsbergen.

2. In these areas the calculated differences between mean monthly and seasonal values of the meteorological elements analysed change considerably during the annual cycle (including changes in sign), and particularly between summer and winter. Therefore mean annual characteristics may often be misleading. Similarly, it is not possible to draw conclusions for the year as a whole from the results achieved from data from a particular season (especially summer or winter).

3. The analysis conducted demonstrated that the Kaffiöyra-Heggodden station is a more representative meteorological station for the purposes of characterising the wind conditions of the tundra of the north-western part of Oscar II Land than is the Ny Ålesund station. The topographic location of the latter station contributes to a twofold reduction of wind velocity in comparison with the plains along the Forland Strait (including more frequent occurrences of periods of calm). As a result, the bioclimatic conditions are considerably milder for those working and holidaying in these areas. It is worth remembering to wear appropriate clothing for field work or to plan exposure time to hazardous weather conditions in the north-western part of Oscar II Land (Przybylak and Araźny 2005).

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