Andrzej Gluza
Krzysztof Siwek

3. Weather conditions

Since 1986 the north-western Wedel Jarlsberg Land is a study area of several meteorological and climatological projects carried out by researchers from Lublin. The main purpose of research was to identify the climatic conditions of the southern Bellsund, particularly the Calypsostranda, in various time scales.

The main characteristics of the climate along the outer Bellsund are controlled by processes related to atmospheric circulation (circulation types, advection patterns, air masses) and the interaction between the following environments: maritime (vicinity of the extensive water system of the Bellsund), glacial (Scottbreen and Renardbreen), land – area free from permanent snow and ice cover, and additionally the mountain massifs (Bohlinryggen and Wijkanderberget). The rich relief of the land intensifies local disruptions in the circulation of air masses, which in turn modifies the general characteristics of atmospheric circulation (Gluza & Piasecki 1989). The climate and topoclimate of the southern Bellsund are mostly affected by the following three systems (Piasecki & Gluza 1988):

- fjord systems – Van Keulenfjorden – Bellsund (for eastern circulation types),
- fjord and glacier system – Recherchebreen and fjord together with the Chamberlindalen (for southern circulation types),
- systems of valleys in the western coast of southern Bellsund: Lognedalen, Dyrstaddalen, Tjørndalen (for western and eastern circulation types).

The result of the impact of these factors is responsible for the unique spatial variability of meteorological elements in terms of both large and smaller geographical units, e.g. the development of local anemo-orographic systems that have not been researched sufficiently yet. The influence of these systems was impermanent and invariably related to a given type of atmospheric circulation. This also led to variability of meteorological phenomena, which emphasised local differences. The aforementioned situation is evidenced by the spatial diversity of Calypsostranda topoclimate (Gluza & Piasecki 1988; Siwek & Paczos 1990).

Another group of factors that affect the climatic conditions of Svalbard are astronomical factors. They are responsible for supplying solar energy to the Earth's surface during the polar day, which is further affected by the state of the cloud cover and cloud types.

An important part in the Arctic's radiation balance is played by three types of active surfaces: land, ice and water, which is markedly visible in the summer seasons. The average reflection coefficient during that time is 10% for water, 15-25% for tundra and 55-65% for thawing ice (Gluza & Siwek 2005; Siwek *et al.* 2004). Other crucial factor includes the vertical heat exchange in the ground and water environment, as well as the turbulent and convective air exchange related to the processes of warming and cooling of the soil.

Research aims, materials and methods

During the first expedition in 1986 the researchers established a meteorological station on a flat marine terrace at the level of 23 m a.s.l., approximately 200 m from the coast (φ=77°33'29.5''N and λ=14°30'46.6''E) (Photo 3.1). Vegetation cover in the study area was in the form of spotted tundra, with low species diversity, consisting of moss patches, lichens, saxifrages and polar willows (Święs 1988ab). Observations were conducted every three hours for a period of twenty four hours. The following meteorological elements were measured:

- atmospheric pressure,
- air relative humidity and temperature (current, maximum, minimum),
- sum of precipitation,
- potential evaporation,
- wind speed and direction,
- cloudiness and cloud types,
- intensity of total radiation and reflected radiation,
- sunshine duration,
- ground temperature at: 2, 5, 10, 20, 50 cm.

Additionally, using automatic recorders, researchers gathered information about atmospheric pressure, temperature and relative humidity of the air. In order to find out more about bio-climatic conditions, Hill's katathermometer was used to determine the air cooling power (Gluza 1988c).

Apart from the base station a network of permanent measuring points was established: in areas with specific relief features – by installing automatic recorders measuring relative air humidity and temperature, and in selected vegetation/soil environments – by installing stations measuring soil temperature and air temperature at the level of 5 cm above soil surface. In terms of works dealing with thermal air currents and the dynamics of permafrost active layer, soil temperature measurements were taken in boreholes at the depth of 50, 100, 150 and 200 cm (Repelewska-Pękalowa *et al.* 1987a, 1988; Gluza *et al.* 1988; Repelewska-Pękalowa & Gluza 1988ab). In the years 1989-1990 topoclimatic measurements were carried out along selected transects on Calypsostranda. During later expeditions the topoclimatic studies covered the whole area of Calypsostranda, beach and Scottbreen forefield (Gluza & Piasecki 1989; Piasecki & Rodzik 1988; Rodzik & Ryżyk 1987; Rodzik 1989; Łanczont 1988ab; Rodzik 1989; Siwek & Paczos 1990; Siwek 1991). In years 1986-1988 observations were carried out every three hours according to UTC time, and starting from 1989 – every six hours. During certain expeditions only 3 measurements per day were taken.

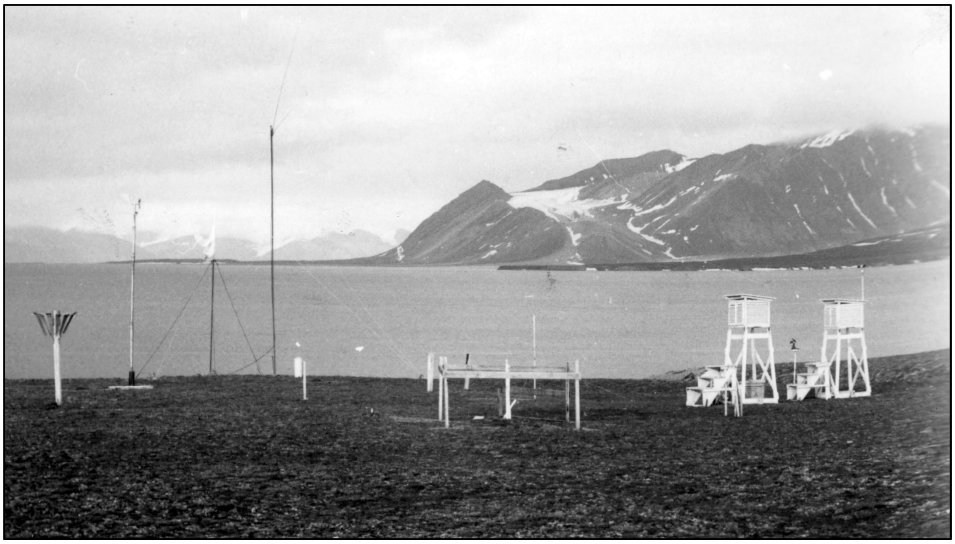

Photo 3.1. Calypsobyen – meteorological station in 1987 (Photo A. Gluza).

Since 1999 meteorological measurements were carried out with the use of automatic stations, recording the results every 10 minutes (Fig. 3.1; Photos 3.2 and 3.3AB). These stations measured the following:

- temperature and relative humidity of air at the altitude of 200 cm above soil surface with the use of an integrated temperature and air humidity sensor manufactured by VAISALA,
- air temperature at the altitude of 5 cm above soil surface,
- active layer temperature (thermometer on the soil surface),
- soil temperature at the depth of 5, 10, 20, and 50 cm,
- sum of precipitation,
- wind direction and speed,
- total radiation and UV radiation (A+B),
- atmospheric pressure.

The stations also recorded the state of the cloud cover, cloud types and atmospheric phenomena (four times a day: at 00:00, 06:00, 12:00, and 18:00 UTC) and once a day (at 06:00 UTC) took measurements of precipitation and potential evaporation.

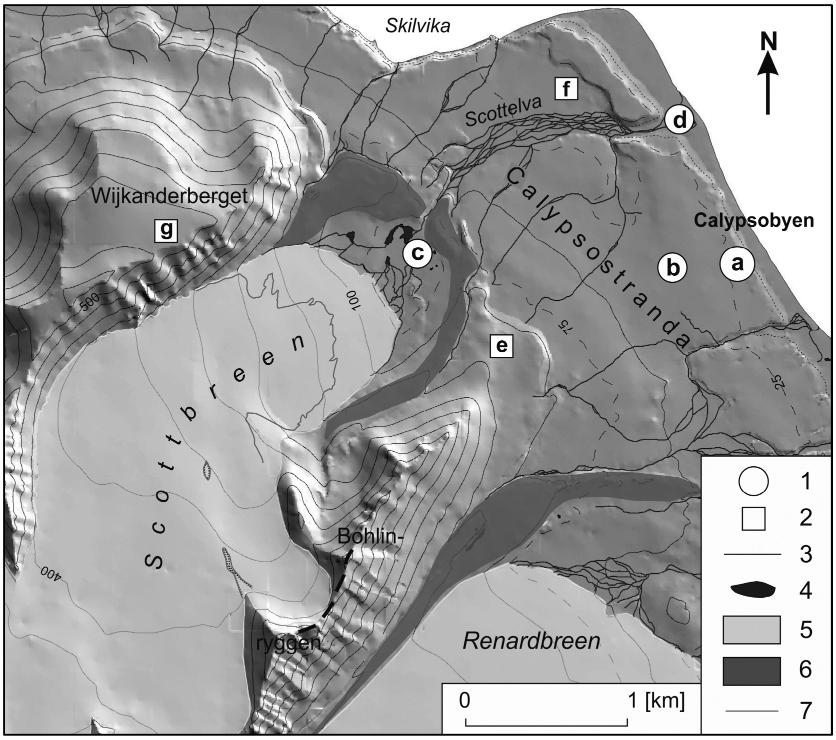

Fig. 3.1. Location of automatic meteorological stations and meteorological points in Calypsobyen region (background: DEM, Zagórski 2002): 1- meteorological station: a- Calypsobyen, main station; b- Calypsostranda; c- Scottbreen forefield; d- Scottelva mouth; 2- meteorological points: e- Bohlinryggen; f- Skilvika; g- Wijkanderberget; 3- rivers; 4- lake; 5- glaciers in 1990; 6- moraine ridge; 7- position of the Scottbreen front in 2006.

Photo 3.2. Calypsobyen - automatic meteorological stations in 2011 (Photo K. Siwek).

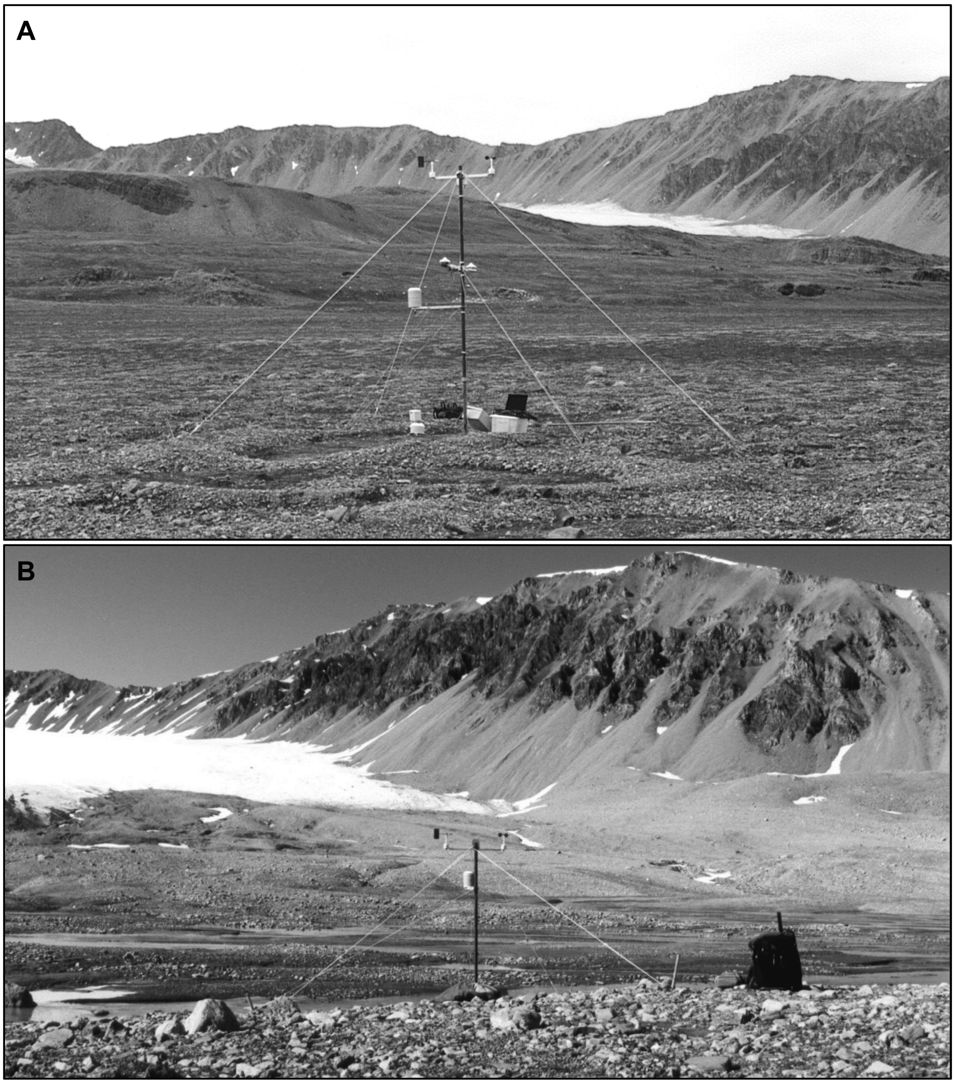

Photo 3.3. Automatic meteorological stations: A- Calypsostranda (Photo S. Bartoszewski 2002), B- Scottbreen forefield (Photo K. Siwek 2011).

In the course of expeditions meteorological observations were commenced and concluded at different times. As a result, the length of respective observation periods is different and depends on the duration of observations. The longest measurement period was 92 days (in 1988), and the shortest – only 30 days (in 2000). The earliest measurement commencement date was 14th June, 1987 and the latest date for concluding observations was 30th September, 1988. There were any expeditions organised in 1997, 2003 and 2004.

In order to determine the climatic conditions in the area of Bellsund during the summer seasons collected data from 15 expeditions (organised between 1986-2006) were compared, in the longest common period, which was 47 days, i.e. 09.07 – 24.08.

Average diurnal values were calculated for 4 dates and any incomplete sets of data were supplemented with information from the Hornsund station, after accounting for the comments included in methodical analyses (e.g. Gluza & Siwek 2002; Gluza *et al.* 2003, 2004).

Climatic conditions of the Bellsund region

Circulation-related factors have a decisive impact on the weather patterns during the summer seasons in Calypsobyen. Important part is also played by such factors as: types of air masses, radiational warming and cooling processes and local circulation systems. During studied seasons, out of all the circulation types defined by Niedźwiedź (2001), the most common ones were: Ka (16%) and Bc (10%). The least common (<2%) were anticyclonic circulation types with advection of air masses from the direction of NW and S. Cyclonic types occurred more often (51%) than anticyclonic ones (47%) (Gluza & Siwek 2012a).

Solar radiation influences both the course of respective meteorological elements as well as the intensity of physical and chemical processes occurring in the area (Gluza & Siwek 2005). The average sum of total radiation during the summer season in Calypsobyen in between 2006 and 2008 was 710 $MJ \cdot m^{-2}$; radiation values varied strongly between individual seasons. Monthly sums of total solar radiation in Calypsobyen are similar to the values recorded in other areas of Spitsbergen, although data from 2006 proves that certain differences might occur due to local factors. Similarly to total values calculated for the whole summer seasons, also diurnal total values showed much diversity throughout the years. The extreme values ranged between 4.9-29.7 $MJ \cdot m^{-2}$ in July and 2.5-18.1 $MJ \cdot m^{-2}$ in August.

The diurnal pattern of total solar radiation values is symmetrical, with the peak values occurring around noon and correlates to the temperature of air and soil. The highest correlation coefficient exists between the sum of total solar radiation and the soil surface temperature or soil temperature to the depth of 10 cm; the coefficient value is a little bit lower in case of air temperature (5 and 200 cm above soil surface). During every season the researchers also found a strong relation between the state of the cloud cover and the total solar radiation values. The correlation between solar radiation and relative air humidity varied throughout the years.

An important factor that affects the radiation balance, and as a result also local climatic conditions, is reflection coefficient of active surface. Albedo measurements at the Calypsobyen station began during the first expeditions (1986-1990) with the use of a solarimeter manufactured by Kipp&Zonen with a spectral range of 305-2800 nm (0.3-2.8 μm). The researchers studied the diversity of the reflection coefficients of Calypsostranda surface during the summer seasons. These were patrol-type studies, conducted along the transect that crosses the most characteristic ecosystems of Calypsostranda (Gluza & Siwek 2005). The following factors were taken into account during measurements: substratum and landform type, land cover (beach: sand, gravel; tundra: mosses and lichens, stones; structural soil of different activity phases) and its hydration, degree of surface contamination (percentage of coverage) with aeolian material and surface inclination. Studies were conducted on six specific days, in different weather and at different angles of sun rays. The average albedo for tundra during the research period was 15.5% and changed depending on the soil type and state of cloud cover between 11% and 21%, approximately. The highest albedo values (>20%) were recorded for structural soil and the beach, the lowest value (approx. 10%) was found at the bottom of a dry landlocked hollow, covered with dark and moist aeolian sediment. One notable fact is high (almost two-times) difference in albedo values between areas of standing water depending on the state of cloud cover.

Reflection coefficient differences between surfaces of Scottbreen in the summer seasons were also studied by conducting patrol measurements along the ablation profile, which covers the whole height profile of the glacier (Siwek *et al.* 2004). The following factors were taken into account during measurements: type and hydration of substratum (snow, firn, glacial ice, superimposed ice), degree of surface contamination with moraine or aeolian material, glacier slope surface inclination and degree of cracking, angle of sun rays (at different times of day) and various weather types. Different surfaces of Scottbreen have shown very different values of albedo and temporary variations resulting from the type of weather and time of day. The lowest values (15–25%) were seen at the glacier head areas that were either covered with superimposed ice which included numerous water-filled cryoconite melt-holes or were contaminated with moraine and aeolian material. Higher values (40–60%) were found in supraglacial river valleys and in areas covered with slush deposits. The highest albedo values (60-85%) were recorded on firn fields with deposits of post-winter snow, often crystallised, or fresh wind-blown snow. Reflection coefficient exceeded the value of 88% immediately after snowfalls that supplied fresh, clean snow. These changes in albedo values were strongly dependent on the physical characteristics of the glacier surface. In most parts of the glacier changes were mostly affected by meteorological conditions that modified the glacier surface, e.g. presence of fresh snow, hydration of upper snow layer, washing of surface due to heavy rainfall. On the glacier head the reflection coefficient decreased during the summer seasons due to the disappearance of a thin layer of post-winter snow that uncovered surface contamination with moraine and aeolian material. In central part of the glacier albedo values changed further depending on the water content in the snow and on the glacier surface. The coefficient was additionally modified due to the creation of superimposed ice free from mineral contaminants.

The average air temperature in Calypsobyen during the study period was 5.1°C (Table 3.1). The warmest was the 2002 season with its average temperature of 6.3°C, and the coldest was the 1987 one with 4.3°C. The lowest average diurnal temperature value of 0.2°C was recorded on 11th August, 1994 and the highest (10.2°C) on 13th July, 2002.

The average general state of the cloud cover for the common period was 6.6 (on a scale of 0-8) (Table 3.1). The curve of average cloudiness values throughout the whole period of 1986-2006 is very even. The values only change by 1.8 degrees (scale of 0-8). The most 'sunny' season was 1993 (5.6), and on average the most cloudy one was 2005 (7.4). The general cloudiness of the sky was mostly affected by the state of the low-stage clouds cover (*Stratus* and *Stratocumulus*). During the whole period of study there have never been a cloudless day (N=0); also, there were only 18 sunny days (N≤2/8) – most of which (4) occurred in 1993. On the other hand, the number of cloudy days (N≥7/8) was 537; out of which the most – i.e. 47 – were recorded in 1994. Completely overcast sky (N=8/8) occurred on 91 days; most of these – 16 – happened in 2002.

The average wind speed in Calypsobyen throughout the years was 4.3 $m \cdot s^{-1}$. The highest average value (6.7 $m \cdot s^{-1}$)was recorded in 2005, the lowest – in 1995 (2.7 $m \cdot s^{-1}$). The highest average diurnal wind speed (21.0 $m \cdot s^{-1}$) was noted on 12th August 1993 – it was related to specific circulation conducive to the occurrence of foehn winds. In two cases an average diurnal wind speed of 0.0 m/s (14th July, 1992 and 21st July, 1995) was recorded. There were also 28 days with an average wind speed of ≥10.0 $m \cdot s^{-1}$, including 3 days (all in 1993) with an average wind speed value of ≥15.0 $m \cdot s^{-1}$ (Table 3.1).

The most unstable factor throughout the period of study turned out to be the precipitation level (Table 3.1). The highest precipitation value (82.3 mm) was noted in the season of 1994, the lowest (10.0 mm) – in 1998. The highest diurnal precipitation value of 36.3 mm was recorded on 10th August, 1993. The average level of precipitation for all studied seasons was 34.6 mm. There were 238 days recorded with a precipitation value ≥0.1 mm (most of these, i.e. 28, in the summer season of 1994) including 113 days with a precipitation value ≥1.0 mm (the season of 1994 had the highest number of such days – 14). Moreover, there were 29 days with a level of precipitation ≥5.0 mm (most in 1994 – 8) and 9 days with a precipitation value ≥10.0 mm.

Structure of weather types

In order to fully characterize the climate of a given area it is necessary to provide information about how many days occurred within a given period in a given area that were characterised by a specific weather state: e.g. ones that at the same time had high air temperature, low air humidity, low cloudiness, no precipitation, etc. As such, an important source of information about the climate of a given place or area is knowledge concerning the number of days with a specific weather situation and the recurrence of such days.

In order to identify weather patterns occurring in Calypsobyen during the summer seasons the Ferdynus (2007) classification of weather states for polar regions was applied. According to his approach the basic classification unit is the type of weather that groups together all days that were similar in terms of air temperature, cloudiness, precipitation and wind speed. A weather class is characterised by an identical description of three features: cloudiness, precipitation and wind speed. When identifying the weather regime the basic data integration units are: a single day (date) as well as the average and extreme values of meteorological elements.

During the studied seasons the area of Calypsobyen was characterised by a relative homogeneity of weather groups (Gluza & Siwek 2007, 2012b). Only two weather groups were recorded – T7 (moderately warm; 0.0° < average temperature < 4.9°C; minimum temperature ≥0°C) and T8 (warm; 5.0° < average temperature < 9.9°C; minimum temperature. ≥0°C). Most often (21.3% of cases) the researchers noted the weather type marked 8301, i.e. warm, no frost, with average diurnal temperature between 5.0°C and 9.9°C, and minimum temperature ≥0°C, cloudy or overcast sky, no precipitation or trace values of precipitation, and light breeze (wind speed average between 1.6 and 7.9 $m \cdot s^{-1}$ and wind speed maximum<11 $m \cdot s^{-1}$). The second most common weather type (9.8%) was the one marked 7311, i.e. moderately warm, no frost, with average diurnal temperature ranging from 0.0°C to 4.9°C, and minimum temperature. ≥0°C, cloudy or overcast sky, with precipitation and light breeze (wind speed average between 1.6 and 7.9 $m \cdot s^{-1}$ and wind speed max <11 $m \cdot s^{-1}$). It is worth noting that a significant proportion of weather types recorded throughout the period of study included types characterised by no precipitation or trace values of precipitation. These comprised between 50% up to even 80% of all weather types occurring in given studied summer season. A combination of these weather types with the types that are characterised by strong winds might have a significant impact on the environment, e.g. over-drying of tundra. During each of the studied summer seasons weather was characterised by either weak winds or a combination of weak wind periods and temporary occurrences of stronger winds, regardless of the thermal air currents, state of the cloud cover or precipitation. This seems to be a unique feature of the summer seasons on the SW coast of Spitsbergen (Gluza & Siwek 2012b).

Bio-climatic conditions

Due to the fact that the human body is homoeothermic in our opinion it is important to familiarise oneself with the bio-climatic conditions occurring in a given area. This knowledge could be useful to members of research expeditions living in the area but can also be applied in practice on a wider scale due to the significant increase of persons travelling or planning to stay in the polar regions. The climate of polar regions is determined by harsh bio-climatic conditions which often pose a threat to human health and life.

Studies of bioclimatic conditions of the Bellsund region began during the first expeditions (1986-1990) with the use of Hill's kata-thermometer (H), which measures the air cooling power (kata-thermometric cooling). Additionally, researchers calculated the equivalent temperature (Te) and effective temperature (NTE) values.

In the area of Calypsobyen the average diurnal value of H during the studied summer seasons was 1259 $W \cdot m^{-2}$, ranging from 780 to 2060 $W \cdot m^{-2}$. Throughout said seasons no days were noted with an average cooling value of less than 420.0 $W \cdot m^{-2}$, i.e. there were no 'hot' or 'sweltering' days. In terms of mean diurnal cooling values the most common results (about 60%) were within the range of 840.1-1260.0 and 1260.1-1680.0 $W \cdot m^{-2}$ (i.e. 'cool' and 'cold' days). When it comes to the extreme values: the lowest air cooling quantity 417 $W \cdot m^{-2}$ (experienced as 'hot') was recorded on 11th July, 1988 at 06:00 UTC. The highest value of over 2400 $W \cdot m^{-2}$ ('extremely cold and windy') was noted twice on the night of 19th July, 1986.

In terms of terminal values of equivalent temperature most recorded days were 'cold' (Te<18°). There were no days with a 'comfort zone', or days experienced as 'slightly sultry' or 'sultry' (Te>32°), and in terms of effective temperature the most common values were within the range of -5.0°>NTE >-9.9°, i.e. 'cold' (Gluza1988a).

In the years of 1999-2006, thanks to the data collected from automatic stations, the bio-climate of the Bellsund region was evaluated based on three generally used indicators of thermal sensibility: air cooling power (H); wind chill index (WCI) and wind chill temperature (WCT). In order to assess these conditions researchers used comprehensive indicators that present the interactions between various meteorological elements in the form of empirical formulas. 10 minute intervals used in the analysis made it possible to record the occurrence, even transient, of unfavourable bio-meteorological conditions that might result in injury to uncovered body parts, e.g. frostbite of the ear, nose or cheeks (Gluza & Siwek 2009).

The average value of H during the summer seasons was 1285 $W \cdot m^{-2}$ and varied between 245 and 2730 $W \cdot m^{-2}$. Most common (64%) were cases of 'cold' and 'cool' conditions; sporadically, the study recorded conditions experienced as 'hot', 'mild' and 'extremely cold and windy'. The proportion of cases with 'optimal' thermal conditions for a physically fit human being (420-840 $W \cdot m^{-2}$) was only 13.3%.

The average WCI value during the summer seasons was 823 $W \cdot m^{-2}$ and individual values ranged from 315 to 1245 $W \cdot m^{-2}$. During the analysed period Calypsobyen noted only three out of the 8 categories of thermal sensations. In general, the conditions were experienced as 'cool' – this included 64% of all measurements. Thermal sensations defined as 'comfortable' were only noted occasionally.

Mean value of wind chill temperature (WCT) in the summer seasons was 3.3°C. Due to the fact that the measurement period only covered the summer seasons, the values of wind chill temperature ranged from -4.7 to 17.5°C. As a result, the researchers only noted cases in which the threat posed by meteorological conditions was either 'very small' (56%) or 'small' (44%). Similar values were recorded at other stations in western Spitsbergen.

The diurnal curve of air cooling power (H) and WCT values, averaged for the whole summer season, shows a clear pattern, with the highest values being recorded around noon and the lowest – between 01:00 and 03:00. The diurnal curve of the wind chill index (WCI) is even.

Throughout the studied summer seasons only small differences in average values of the aforementioned indicators were found. On the other hand, there was much diversity in the frequency of occurrence of specific thermal sensations during individual months of a given summer season.

Comparing weather conditions in Calypsobyen to other sites in Spitsbergen

To learn more about the diversity of meteorological conditions during summers seasons on the western coast of Spitsbergen recorded values of selected meteorological elements were compared with data from other weather stations (Brăzdil *et al.* 1991; Gluza *et al.* 2004; Kejna *et al.* 2000; Przybylak *et al.* 2006, 2007). This comparison was most comprehensive with regard to the Calypsobyen and Hornsund stations, which are located at extreme opposites of Wedel Jarlsberg Land (Fig. 3.2). The analysis took into account data on the following: average diurnal air temperature values [°C] measured at the level of 200 cm, general state of the cloud cover, wind speed [$m \cdot s^{-1}$] and diurnal precipitation value [mm]. Conducted comparative analysis was based on the frequency of differences (Calypsobyen – Hornsund) between respective meteorological elements in terms of directions and types of circulation on Spitsbergen according to Niedźwiedź (2001).

The air temperature in Calypsobyen is on average 0.6°C higher than in Hornsund, which confirms the results of previous studies showing that thermal conditions are more favourable in central parts of the island. This interrelation occurs with nearly all directions of circulation. The biggest temperature differences (>1°C) occur in the case of circulation from the S and SW, more specifically in the case of Sa circulation type (1.9°C). The smallest differences (0.1-0.2°C) were noted in the case of following circulation types: Nc, SEa, SEc, NWa. Only in the case of NWc circulation Calypsobyen was colder than Hornsund (by 0.3°C). The reason is the fact that location of Calypsobyen station allows for free influx of cold air masses from the north-west. In Hornsund, during this type of circulation, the air masses are transformed due to passing through an orographic barrier.

The average general cloudiness of the sky [0–8] was similar at both analysed stations, the mean difference was 0.1. Itis because of the fact that sky over Spitsbergen is very cloudy in the summer. On average, maximum diurnal differences did not exceed 1. Calypsobyen is 'brighter' in the case of circulation from the northern sector, while Hornsund – in the case of southern and western circulations. Only in the case of NWa circulation Calypsobyen is 'brighter' than Hornsund. The biggest differences *in minus* occur with the SWc circulation type (0.5). In general, there were no differences with cyclonic circulation types and in the case of anti-cyclonic types the average difference value was 0.3. The majority of positive differences occur with the following directions: NW, N and NE. In the case of other circulation directions the differences are mostly negative.

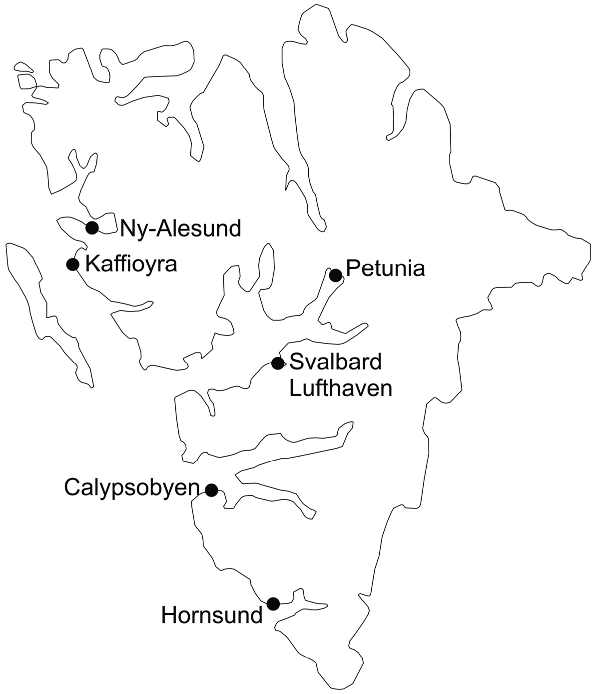

Fig. 3.2. Location of meteorological stations on Spitsbergen.

When it comes to average wind speed, just as in the case of cloudiness, no significant variations were discovered, as the mean difference was 0.1 m/s. In the area of Hornsund the winds are stronger with eastern directions of circulation. In such circumstances average differences exceed 2 $m \cdot s^{-1}$. In the area of Calypsobyen winds are stronger with circulations from the SW – in such cases the differences reach up to 1.8 $m \cdot s^{-1}$. Other factors that play an important part/role in the wind speed differences between analysed stations, depending on the direction of circulation, include the locations of the two stations and the orographic relief of their surroundings. An analysis of circulation types shows that the biggest negative differences (i.e. when higher wind speed values were recorded in Hornsund) occur with the following types: Ec (2.4 $m \cdot s^{-1}$) and Ea (2.1 $m \cdot s^{-1}$). Calypsobyen experienced higher winds in the case of the following circulations: NWa (2.2 $m \cdot s^{-1}$), SWa (1.8 $m \cdot s^{-1}$) and SWc (1.8 $m \cdot s^{-1}$). Only the Ca circulation type led to no differences between average wind speed values.

Diurnal total precipitation values in Hornsund were, on average, higher by 0.8 mm than in Calypsobyen. This pattern holds true to basically all circulation types.

The largest differences (approx. 4 mm) occur with southern and south-western circulation. Precipitation values from Calypsobyen are higher only with northern and eastern circulation directions, or in the case of a high pressure wedge over Spitsbergen (Ka), but even then the differences are marginal (0.1-0.2 mm). The collected results of the comparative analysis of precipitation values confirm the pattern that precipitation is higher in open sea coastal areas than within the archipelago (Przybylak *et al.* 2006). The frequency of differences in precipitation is not the same as in the case of previously described meteorological elements. Most positive differences occur only with the northern circulation direction. In terms of circulation types, the biggest differences in average values occur with cyclonic types (1.3 mm in favour of Hornsund), and in the case of anticyclonic types – Hornsund was more 'wet' by only 0.2 mm. The largest differences in precipitation occurred with SWc circulation (4.7 mm) and Sc circulation (4.3 mm). Calypsobyen sees higher precipitation values in the case of the following circulation types: Nc (0.3 mm), NEa (0.2 mm), Ea (0.2 mm), Ka (0.1 mm) and Ca (0.1 mm). With circulation types from the direction of NW researchers found no differences between results from both stations.

In general, the biggest differences in the values of analysed meteorological elements between the stations at Calypsobyen and Hornsund exist during influx of air from the SW.

The comparison of western coast weather diversity was based on the data from the summer seasons of 2005-2006. The researchers compared the meteorological conditions observed at 4 Polish polar stations: Hornsund, Calypsobyen, Petuniabukta and Kaffiøyra, and 2 Norwegian stations: Ny Ålesund and Svalbard Lufthavn (Przybylak *et al.* 2006, 2007) (Fig. 3.1).

It was concluded that spatial differences between most of the analysed meteorological elements on the western coast of Spitsbergen were quite significant. Said differences are clearly higher (with the exception of wind speed) during the first part of the summer season (until the first decade of August). Records from respective stations vary from day to day depending on the synoptic situation; nevertheless it is evident that the results depend to a lesser extent on the geographical latitude but rather on the fact that when moving away from the coast the character of the climate becomes increasingly continental.

The presented results confirm the conclusions derived from previous studies regarding the influence of circulation factors on spatial differences between selected meteorological elements. Data analysis shows that the direction of circulation is of significant importance as it affects the value of differences between respective meteorological elements. On the other hand, in certain cases (wind speed, precipitation) local factors are decisive, including the orographic relief and the location of the measuring point.

Streszczenie

Warunki pogodowe

Średnie warunki pogodowe rejonu Bellsundu w sezonie letnim określono na podstawie danych ze stacji meteorologicznej, zlokalizowanej na wysokości 23 m n.p.m., na wysokiej terasie morskiej w Calypsobyen – 200 m od brzegu. Porównano dane uzyskane z 15 wypraw (z lat 1986-2006), dla najdłuższego wspólnego okresu, od 9 lipca do 24 sierpnia, liczącego 47 dni. Najczęściej występowały wówczas typy cyrkulacji Ka (16%) oraz Bc (10%). Najmniej (<2%) było typów antycyklonalnych o adwekcji mas powietrza z NW i S.

Średnia temperatura powietrza w Calypsobyen wyniosła w tym okresie 5,1°C (tabela 3.1). Najcieplejszy był sezon 2002 (6,3°C), zaś najchłodniejszy – 1987 (4,3°C). Najniższa średnia dobowa temperatura (0,2°C) wystąpiła 11 sierpnia 1994, zaś najwyższa (10,2°C) – 13 lipca 2002. Średnie zachmurzenie ogólne, w skali 0-8, wynosiło 6,6; najbardziej pogodny (5,6) był sezon 1993, zaś najbardziej pochmurny (7,4) – 2005. Nie zanotowano żadnego dnia bezchmurnego (N=0); wystąpiło zaś tylko 18 dni pogodnych (N≤2/8) – najwięcej (4) w 1993 roku. Dni pochmurnych (N≥7/8) było aż 537; najwięcej (47) – w roku 1994. Dni z zachmurzeniem całkowitym (N=8/8) było 91; najwięcej (16) – w 2002 roku. Średnia prędkość wiatru w wynosiła 4,3 m/s: najwyższa (6,7 m/s) charakteryzowała sezon 2005, zaś najniższa (2,7 m/s) – 1995. Najwyższą średnią dobową prędkość wiatru (21,0 m/s) zanotowano podczas fenu 12 sierpnia 1993. Wystąpiły dwa dni bezwietrzne oraz 28 dni ze średnią prędkością wiatru ≥0,0 m/s, w tym 3 dni (w 1993 roku) ze średnią ≥15,0 m/s.

W badanym okresie średnia suma opadu atmosferycznego wyniosła 34,6 mm: najwyższą (82,3 mm) zanotowano w sezonie 1994, najniższą (10,0 mm) – w roku 1998 (tab. 1). Najwyższą sumę dobową opadu (36,3 mm) zanotowano 10 sierpnia 1993. Wystąpiło 238 dni z opadem ≥0,1 mm, w tym 113 dni z opadem ≥1,0 mm, 29 dni z opadem ≥5,0 mm oraz 9 dni z opadem ≥10,0 mm. Najwięcej takich dni wystąpiło w sezonie 1994, odpowiednio: 28, 14 i 8.

Średnia suma promieniowania całkowitego w sezonie letnim, w latach 2006-2008 wynosiła 710 MJ/m^2, zaś średnie albedo tundry wyniosło 15,5% i zmieniało się w zależności od warunków od 11% do 21%. Najwyższe albedo (>20%) miały grunty strukturalne oraz plaża, natomiast najniższe (ok. 10%) – dno suchego zagłębienia z ciemnymi osadami eolicznymi. Na Scottbreen najmniejsze (15–25%) albedo zmierzono na czole lodowca, zaś nieco wyższe (40–60%) stwierdzono w korytach rzek supraglacjalnych oraz w strefie papki śnieżno-wodnej. Najwyższe albedo zmierzono na polu firnowym: dla śniegu zleżałego wynosiło ono 60-85%, zaś dla śniegu świeżego wzrastało powyżej 88%.

Określono warunki bioklimatyczne w sezonie letnim w Calypsobyen na podstawie: wielkości ochładzającej powietrza (H), wskaźnika ochładzania wiatrem (WCI) i temperatury ochładzania wiatrem (WCT). Średnia wartość H wynosiła 1285 W/m^2 i zmieniała się od 245 do 2730 W/m^2. Najczęściej (64%) notowano przypadki „zimno" i „chłodno". Przypadków z „optymalnymi' warunkami termicznymi dla człowieka aktywnego fizycznie (420-840 W/m^2) zanotowano tylko 13,3%. Średnia wartość WCI w sezonach letnich wyniosła 823 W/m^2 i zmieniała się od 315 do 1245 W/m^2. Najczęściej występowały warunki określane jako „chłodne", które obejmowały 64% wszystkich pomiarów. Średnia wartość WCT w sezonach letnich wynosiła 3,3°C. Wartości temperatury ochładzania wiatrem zmieniały się w sezonie letnim od -4,7 do 17,5°C.

Wystąpiły tylko przypadki, w których zagrożenie warunkami meteorologicznymi określane jest jako „bardzo małe" (56%) i „małe" (44%).

W porównaniu ze stacją w Hornsundzie temperatura powietrza w Calypsobyen jest średnio o 0.6°C wyższa, średnie ogólne zachmurzenie nieba oraz średnia prędkość wiatru są podobne, natomiast dobowe sumy opadu atmosferycznego w Hornsundzie są wyższe średnio o 0.8 mm niż w Calypsobyen. Rejon Calypsobyen cechował się względną jednorodnością grup pogód. Wystąpiły tylko 2 grupy pogód – T7 (umiarkowanie ciepłe) i T8 (ciepłe). Najczęściej notowano dni z typem pogody oznaczonym symbolem 8301 (21.3%) i 7311 (9,8%). Znaczny odsetek, od 50% do 80% dni okresu letniego, to typy pogód bez opadu lub ze śladem opadu.

Objaśnienia

Ryciny

Ryc. 3.1. Lokalizacja automatycznych stacji i punktów meteorologicznych w rejonie Calypsobyen (podkład: DEM, Zagórski 2002): 1- stacje meteorologiczne: a- Calypsobyen (stacja główna), b- Calypsostranda, c- przedpole Scottbreen, d- ujście Scottelvy; 2- punkty meteorologiczne: e- Bohlinryggen, f- Skilvika, g- Wijkanderberget; 3- rzeki; 4- jeziora; 5- powierzchnia lodowców w 1990 r.; 6- wały morenowe, 7- zasięg czoła Scottbreen w 2006 r.

Ryc. 3.2. Lokalizacja stacji meteorologicznych na Spitsbergenie.

Fotografie

Fot. 3.1. Calypsobyen – stacja meteorologiczna w 1987 roku (fot. A. Gluza).

Fot. 3.2. Calypsobyen – automatyczna stacja meteorologiczna w 2011 roku (fot. K. Siwek).

Fot. 3.3. Automatyczne stacje meteorologiczne: A- Calypsostranda (fot. S. Bartoszewski 2002), B- przedpole Scottbreen (fot. K. Siwek 2011).

Tabele

Tabela 3.1. Wartości wybranych elementów meteorologicznych oraz liczba dni w Calypsobyen w typowych w sezonach letnich (9 lipca - 24 sierpnia).

Table 3.1. The values of selected meteorological elements and the number of days in a typical Calypsobyen in summer seasons (9th July – 24th August).

	1986	1987	1988	1989	1991	1992	1993	1994	1995	1998	1999	2001	2002	2005	2006	Min	Max
Ti [°C]	4.9	4.3	5.1	5.0	5.7	5.0	4.9	4.4	5.3	6.0	4.7	5.3	6.3	4.8	5.1	4.3	6.3
Tmin [°C]	2.9	1.2	2.6	2.5	2.4	2.9	2.0	0.2	1.2	3.7	2.5	2.5	4.2	2.8	3.0	0.2	4.2
Tmax [°C]	7.2	8.7	8.4	7.1	8.4	7.4	9.2	7.9	9.3	9.2	7.8	8.5	10.2	6.4	7.8	6.4	10.2
N [0-8]	7.3	6.6	6.4	6.6	6.1	6.0	5.6	7.4	6.5	6.2	6.4	6.8	6.7	7.4	7.0	5.6	7.4
Nmin [0-8]	4.6	1.5	0.1	1.4	0.8	2.6	0.5	6.2	1.1	1.6	2.0	1.2	0.8	4.6	2.2	0.1	6.2
Nmax [0-8]	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
N=0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N≤2	0	2	2	2	1	0	4	0	1	2	1	1	2	0	0	0	4
N≥7	44	39	35	35	32	26	21	47	35	32	33	38	37	44	39	21	47
N=8	5	2	1	7	4	1	9	8	8	7	4	3	16	10	6	1	16
V [$m \cdot s^{-1}$]	4.2	5.2	3.7	3.7	4.4	4.3	5.7	4.1	2.7	4.3	4.0	3.2	4.0	6.7	3.8	2.7	6.7
Vmin [$m \cdot s^{-1}$]	1.0	0.5	0.9	0.8	1.0	0.0	0.7	0.8	0.0	0.6	0.4	0.8	1.2	2.6	1.2	0.0	2.6
Vmax [$m \cdot s^{-1}$]	10.6	14.2	12.4	8.5	9.6	11.7	21.0	10.5	8.0	11.6	11.5	9.0	9.0	11.7	7.6	7.6	21.0
V=0,0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1
V≥10,0	1	4	2	0	0	1	6	1	0	4	3	0	0	6	0	0	6
V≥15,0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
P [mm]	34.9	31.7	14.8	26.9	29.4	26.7	61.7	82.3	34.2	10.0	23.8	16.7	44.8	54.5	27.0	10.0	82.3
Pmax [mm]	11.0	5.6	6.4	14.2	9.0	8.2	36.3	12.7	14.0	3.5	6.9	3.1	8.5	14.2	4.7	3.1	36.3
P>0,0	15	21	10	11	12	16	11	28	16	4	17	19	15	22	21	4	28
P≥1,0	9	8	4	6	6	7	5	14	8	3	7	8	11	10	7	3	14
P≥5,0	2	3	1	1	2	1	3	8	1	0	1	0	3	3	0	0	8
P≥10,0	1	0	0	1	0	0	2	2	1	0	0	0	0	2	0	0	2

P - sum of precipitation [mm]; Pmax - maximum daily precipitation [mm]; P>0,0 – number of days the daily precipitation >0,0 mm; P≥1,0 – number of days the daily precipitation ≥1,0 mm; P≥5,0 – number of days the daily precipitation 5,0 mm; P≥10,0 – number of days the daily precipitation ≥10,0 mm; Ti – mean air temperature [°C]; Tmin – minimum mean daily air temperature [°C]; Tmax – maximum mean daily air temperature [°C]; V - Wind velocity [$m \cdot s^{-1}$]; Vmin – minimum mean daily wind velocity [$m \cdot s^{-1}$]; Vmax – maximum mean daily wind velocity [$m \cdot s^{-1}$]; N – cloud cover [0-8]; Nmin – minimum mean daily cloud cover [0-8]; Nmax – maximum mean daily cloud cover [0-8]; N=0 - number of days the mean daily cloud cover =0/8, N≤2 - number of days the mean daily cloud cover ≤2/8; N≥7 - number of days the mean daily cloud cover ≥7/8; N=8 - number of days the mean daily cloud cover =8/8.