POLISH POLAR RESEARCH
vol. 28, no. 2, pp. 123–136, 2007

Variations in weather on the East and West coasts of South Spitsbergen, Svalbard

Wojciech MACIEJOWSKI and Adam MICHNIEWSKI

Instytut Geografii i Gospodarki Przestrzennej, Uniwersytet Jagielloński, Gronostajowa 7, 30-387 Kraków, Poland
<w.maciejowski@geo.uj.edu.pl> <a.michniewski@geo.uj.edu.pl>

Abstract: This paper describes the weather conditions on the NE coast of Sørkappland (South Spitsbergen) during August 2005, and considers them in the context of the general synoptic situation over the North Atlantic. A comparison of local climates features for the East and West coast of southern Spitsbergen shows that the general atmospheric circulation and direct solar radiation in summer are the decisive factors affecting weather on the East coast. Foehn effects were observed during the study period. In the East, these were triggered by the westerly cyclonic situation and, in the West, by the easterly. The differences in the intensity of foehn effects may be explained by a specific relief of the Sørkappland peninsula.

Key words: Arctic, Spitsbergen, air temperature, air humidity, foehn effects.

Introduction

Despite decades of research, our knowledge of polar climatic system is still limited (Przybylak 1996). Previous work on the climates of Spitsbergen (Niedźwiedź 1993; Ferdynus 1997; Nowosielski 2004) has emphasised their great variability and their control by sea currents. The warm West Spitsbergen Current (Fig. 1) impinges on the western shores of the island and a high positive thermal anomaly is demonstrable here (Hisdal 1985). Several settlements and scientific stations are established here, which is why meteorological studies have previously been concentrated in the western part of the island. By contrast, the eastern part of Spitsbergen is dominated by the cold East Spitsbergen Current (Fig. 1). Most of this area is ice-covered and the climate is harsh. It is also much less accessible, whether overland, across the mountains of the Spitsbergen interior, or from the sea, which for most of the year is covered with pack-ice.

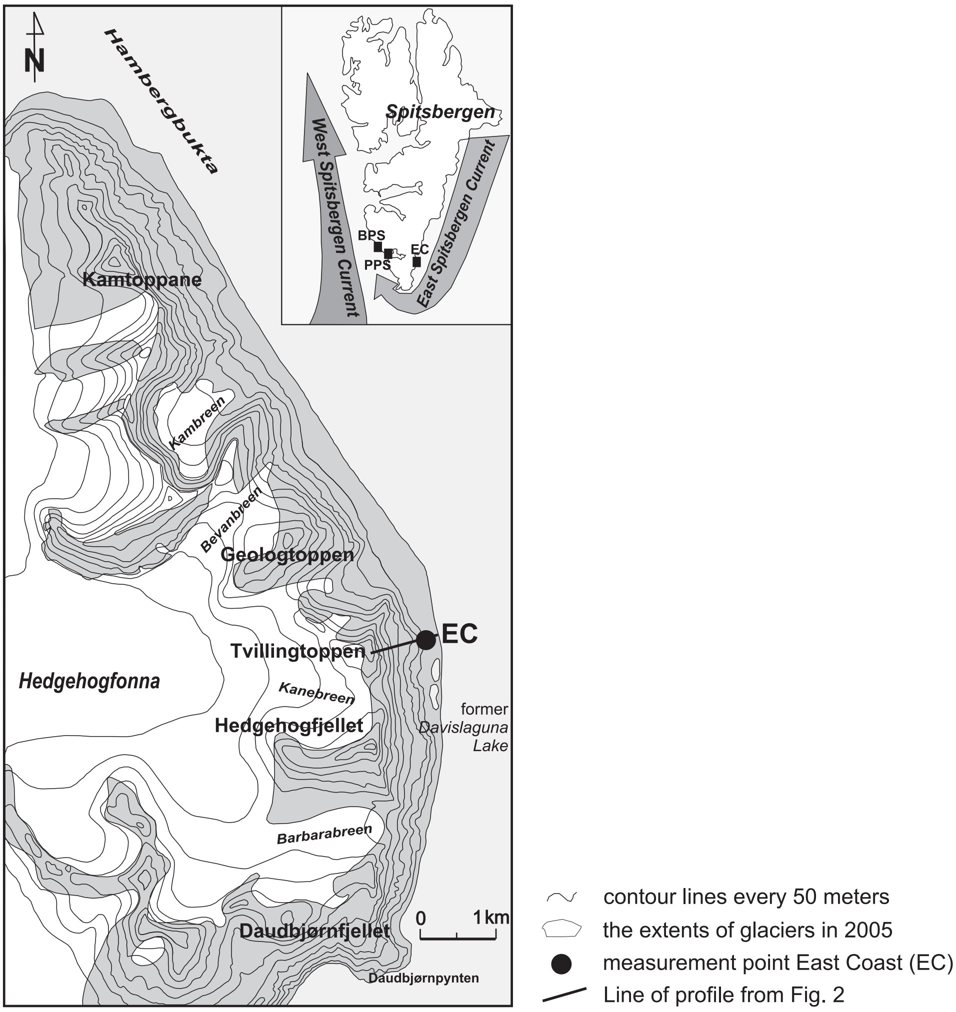

Fig. 1. East Coast measurement point location on Sørkappland. Abbreviations on the Spitsbergen contour map: BPS – *Baranowski* Polar Station, PPS – Polish Polar Station, EC – East Coast.

This work had two main objectives. The first was to determine the weather conditions on the north-eastern coast of Sørkappland, north of the former Davislaguna Lake represented by the East Coast measurement site, later referred to as the EC. The second was to compare the weather conditions on East and West coasts of southern Spitsbergen. The West coast is represented by the well-established measurement sites at Hornsund (Polish Polar Station – PPS; φ = 77°01'N, λ = 15°33'E, h_s = 10.0 m a.s.l.) and *Baranowski* Polar Station (BPS; φ = 77°04'20"N, λ = 15°11'30"E, h_s = 18.0 m a.s.l.).

The East Coast study area

The EC measurement point (φ = 76°58’46”N, λ = 17°16’28”E) was established in the easternmost part of Sørkappland, at the foot of the Tvillingtoppen mountain Massif (530 m a.s.l.), approximately 500 m NW of the former Davislaguna Lake, at altitude 47 m a.s.l. (Fig. 1). It is located on a slightly inclined (3–6°) convex slope with NE exposure, on one side limited by the foot of the Tvillingtoppen mountain Massif, and on the other by a high and steep cliff dropping to the Barents Sea (Fig. 2). Multi-fraction moraine deposits occur in that area and cover dead ice which is remain of a larger glacier from the Little Ice Age period (Fig. 3). It is also close to Hedgehogfjellet (608 m a.s.l.) and Geologtoppen (570 m a.s.l.) mountain massifs, which in the east, as at Tvillingtoppen, are inclined almost vertically, bordering the narrow coastal accumulation plain. In the west, they smoothly merge with Hedgehogfonna glacier. This area is one of the many in Spitsbergen where, since 1900s, rapid glacier recession has been observed more or less (Jania 1988; Ziaja 1997). In the first half of 20^{th} century, nearby glaciers (Coryellbreen, Bevanbreen, Kambreen) had tongues running into the Barents Sea. Today they terminate far inland, away from seashore (Ziaja and Ostafin 2005). There is very little vegetation in the area.

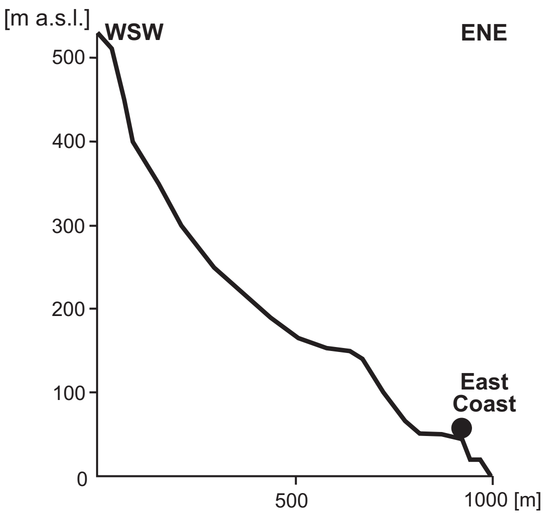

Fig. 2. East Coast measurement point location compared to the relief of the Tvillingtoppen Massif. Refer to Fig. 1 for the position of this profile.

Methods

The EC meteorological measurements (a Väisäla electronic thermohygrometer, an extreme-temperature thermometers and a manually operated cup anemometer) and observations were carried out at three standard climatological ob-

Fig. 3. Panoramic view from the East Coast measurement point on the moraine and the Tvillingtoppen Massif area.

servation times: 06:00, 12:00 and 18:00 UTC (Coordinated Universal Time) between August 7 and 21, 2005. Extreme-temperature thermometers were put in a roofed stone cage 1.5 m above ground level. Visual observations of cloudiness, cloud genera and wind direction were carried out during the measurements. These measurements were compared with those recorded simultaneously at the Hornsund and the Baranowski Polar Stations (Fig. 1). The PPS is located at the outlet of the Hornsund Fiord, and the BPS close to the frontal moraine of the Werenskiold Glacier. By using the synoptic maps (available from the Wetterzentrale website), the three sets of data were related to the general circulation conditions then prevailing over the North Atlantic.

Weather conditions in the observation period against long-term averages

While carrying out observations at the EC point, atmospheric circulation changed three times. Between August 7 and 12, 2005, the island was within the influence reach of a high-pressure area which moved to over the Barents Sea from Greenland and North Atlantic. This resulted in rapid and relatively high changes of all meteorological elements. During this period, there was a preva-

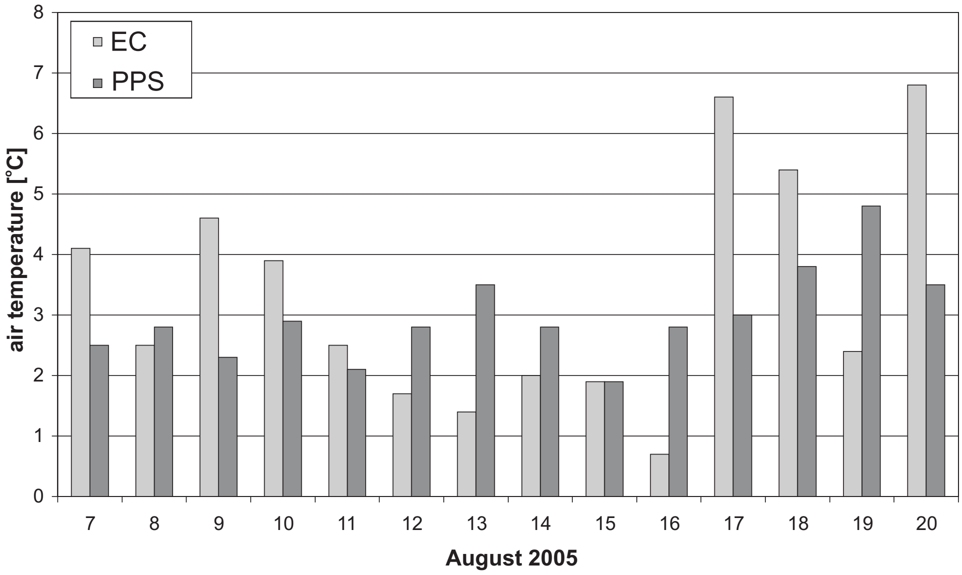

Fig. 4. Daily air temperature ranges at East Coast measurement point, and Polish Polar Station between August 7 and 21, 2005.

lence of weak winds with velocities 2–4 ms^{-1} from N and NE and frequent calm periods. Relatively high air temperature during the initial period (8.1°C) later fell to 3.2°C. The daily temperature ranges were reduced from approximately 4°C to less than 2°C (Fig. 4), mostly due to a gradual maximum temperature fall which resulted from an increased cloud cover (Fig. 5a). Relative humidity remained within 80–90%, dropping below 70% only twice, during bright intervals (Fig. 5b). There was much variability in the diurnal cloud cover; lower-level clouds prevailed but clouds at all levels were noted. Occasional hydrometeors occurred in the form of mists and haze. Much drizzle and rainfall occurred at the end of this period (Table 1).

During the second period, between August 13 and 16, 2005, an active low formed over North Atlantic between the Scandinavian Peninsula and Greenland, and high-pressure centres occurred at the North Pole (Fig. 6a). This brought air from E and SE to Spitsbergen. A considerable increase of average wind velocities was observed at the EC point, gusts reaching 15–16 ms^{-1} (Fig. 7). When the air flow was from NE, the temperature never exceeded 5°C, and, owing to a general fall in the maximum temperature, daily ranges were very low (maximum 2°C). Air humidity was generally high, at around 90% (Fig. 5). Total sky cover with low-level and Nimbostratus clouds predominated. Heavy rainfall occured in this period, and visibility was often limited by frequent mist and haze.

During the third period between August 17 and 21, Spitsbergen was in a low pressure zone. Several low-pressure centres moved in moving quickly from the

Table 1

Selected results of meteorological observations carried out at the East Coast point between August 7 and 21, 2005. Symbol definitions: h – hour, T – air temperature, f – relative humidity of air, d – wind direction, V – wind velocity, C – cloudiness, CT – circulation type: Ka – wedge of high pressure, SWa – south-westerly antycyclonic situation, Ea – easterly antycyclonic situation, Ec – easterly cyclonic situation, Sc – southerly cyclonic situation, Cc – center of low pressure, Wc – westerly cyclonic situation, SWc – south-westerly cyclonic situation

Day	**h** [UTC]	**T** [°C]	**f** [%]	**d**	**V** [m/s]	**C** [0–8]	**CT**
7.08	6	8.1	66	NNE	2	6	Ka
	12	7.5	75	NE	1	8	
	18	4.5	84	E	2	8	
8.08	6	3.8	89	N	3	8	Ka
	12	3.8	86	N	4	8	
	18	3.7	79	C	0	7	
9.08	6	4.6	78	C	0	8	SWa
	12	7.4	75	C	0	4	
	18	5.3	86	C	0	5	
10.08	6	4.0	85	N	2	8	Ka
	12	4.8	87	NE	3	8	
	18	5.3	67	ENE	1	7	
11.08	6	3.5	83	NE	3	8	Ka
	12	4.3	84	S	3	7	
	18	3.5	94	S	4	8	
12.08	6	3.6	78	NE	1	8	Ea
	12	3.3	88	N	4	8	
	18	3.2	89	NE	5	8	
13.08	6	3.2	94	NNE	5	8	Ec
	12	3.6	95	NE	9	8	
	18	3.6	89	NE	10	7	
14.08	6	3.1	92	NE	11	8	Ec
	12	4.3	84	NE	10	5	
	18	4.0	83	NE	5	6	
15.08	6	2.9	94	NE	13	8	Ec
	12	2.6	95	NE	9	8	
	18	2.6	94	ENE	6	8	
16.08	6	2.4	94	NE	5	8	Ec
	12	2.0	89	NE	5	8	
	18	2.1	94	NE	4	8	
17.08	6	2.9	85	S	1	4	Ka
	12	4.8	79	C	0	2	
	18	3.0	86	C	0	2	

Table 1 – *continued.*

Day	**h** [UTC]	**T** [°C]	**f** [%]	**d**	**V** [m/s]	**C** [0–8]	**CT**
18.08	6	4.7	79	NE	1	6	Sc
	12	6.6	80	NE	1	7	
	18	4.9	80	C	0	5	
19.08	6	3.5	91	NE	3	8	Cc
	12	3.4	95	NE	4	8	
	18	2.8	95	C	0	8	
20.08	6	5.9	59	W	10	6	Wc
	12	5.6	62	SE	5	7	
	18	5.6	74	C	0	6	
21.08	6	5.3	79	C	0	7	SWc
	12	6.8	75	S	5	8	

North Atlantic and northern Scandinavia areas to NE (Fig. 6b, c), which brought about very variable weather conditions. In that days, many fronts were moving over the island area. Initially, weak north-eastern winds or calms were experienced in this period. Later in this period (August 20 and 21; Fig. 6d), observations indicated temporary velocity increase in respect of winds from westerly and southerly directions, 10 and 5 ms^{-1} respectively. Air temperatures was very variable (Table 1). During bright intervals, air temperatures increased quickly during windless weather, reaching up to 8°C.

On August 20, a foehn-type westerly wind, reaching 10 ms^{-1} led to an air temperature rise to 8.4°C (the highest during observation period). Daily air temperature ranges were high, in excess of 5–6°C, resulting from a fall in the daily minimum temperature values (1.6°C – lowest value observed on August 20), primarily from a considerable increase in the maximum values.

On August 17 and 18, the relative humidity of air hovered around 80%, and the cloud cover fell to 2/8 (Fig. 5); concomitantly, medium- and high-level clouds were evident. On August 19, there was a total sky cover with Nimbostratus and Stratus clouds and, during intense rainfall and misty weather, the humidity exceeded 90% (Fig. 5b). On August 20 and 21, changes in air-mass advection direction brought about considerable relative humidity reduction (even to <60%) and cloud cover fluctuations; clouds were observed at all levels.

An atmospheric circulation which is very rare for that season of the year was observed on Spitsbergen in August, 2005. Usually, during the polar day, anticyclonic systems (49.4%) slightly prevail over cyclonic systems (45.5%) (Malik 2005), and normally, during August, there is a rough balance between high and low pressure situations (Niedźwiedź 2003). However, in the study period, cyclonic conditions were dominant (23 days), easterly and south-easterly cyclonic systems being most frequent (9 days) (Niedźwiedź 2007). In Hornsund, that usually results

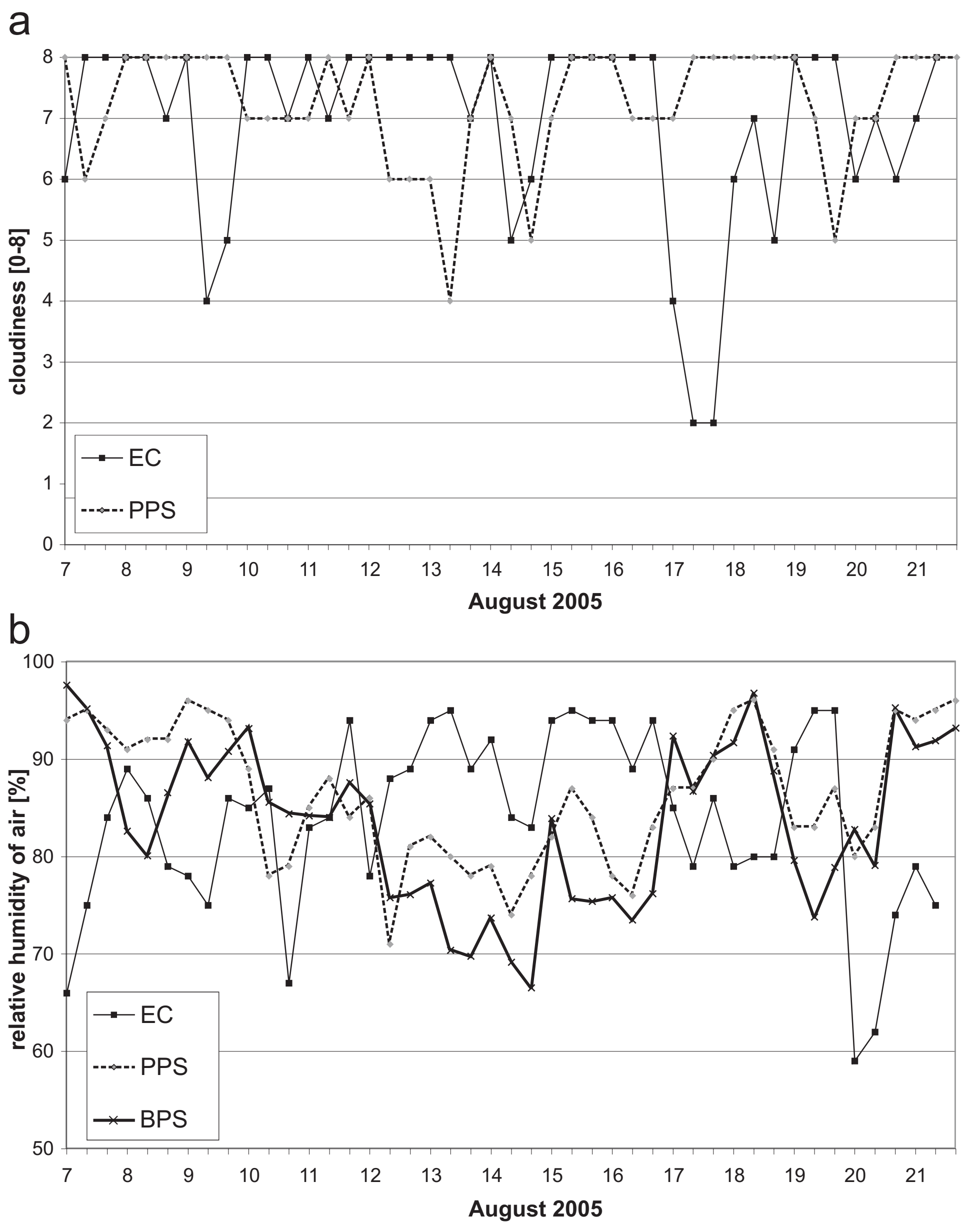

Fig. 5. Cloudiness at East Coast measurement point and Polish Polar Station (**a**), and relative humidity of air at East Coast measurement point, Polish Polar Station and *Baranowski* Polar Station (**b**) between August 7 and 21, 2005.

in relatively warm weather with a strong winds, often with accompanying rainfall (Malik 2005). This atmospheric circulation is rather more typical of the Polar night than August and was strikingly different from the long-term average (Table 2).

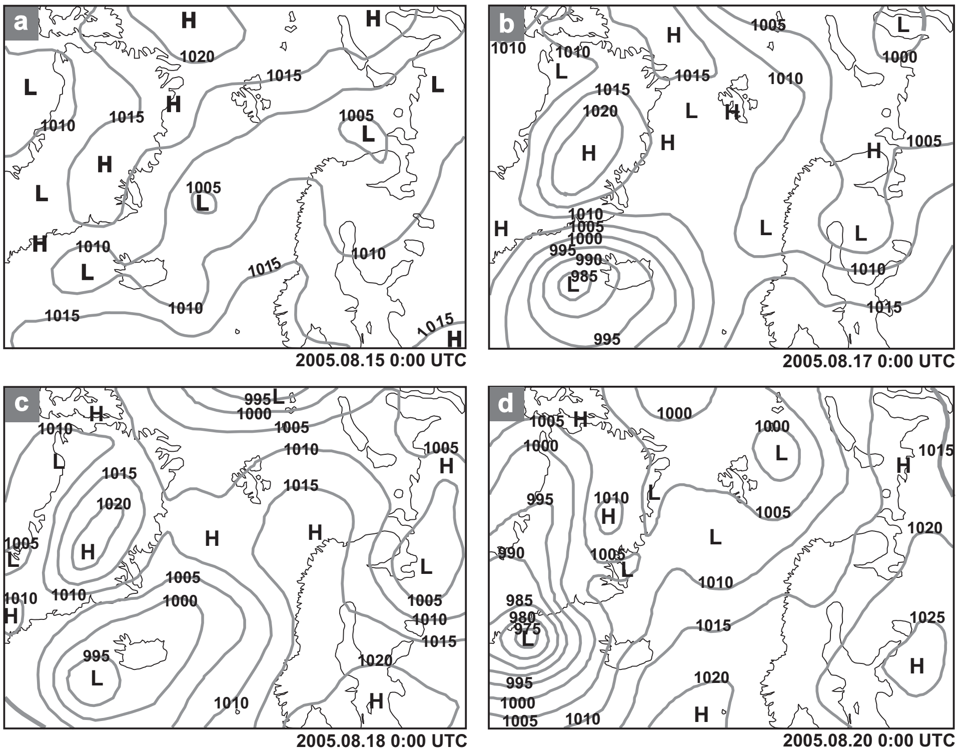

Fig. 6. Pressure field maps for August 15 (**a**), August 17 (**b**), August 18 (**c**) and August 20 (**d**).

Table 2

Selected long-term mean climatic characteristics for August at the Polish Polar Station Hornsund (Source: author's compilation based on Araźny 2003, Niedźwiedź 2003, Nowosielski 2004 and Owczarek 2005)

weather element	value	time period
air temperature [°C]	+4.0	1983–2000
annual precipitation [mm]	50.3	1978–2002
barometric pressure [hPa]	1009.0	1991–2000
relative humidity of air [%]	85.0	1971–2000

Weather diversity on the East and West coasts of South Spitsbergen in various types of atmospheric circulation

Meteorological measurements at the EC were carried out in a meaningful period, characterised by a large variability of circulation conditions. They caused the occurrence of several phenomena. The explanation of them may help in a better

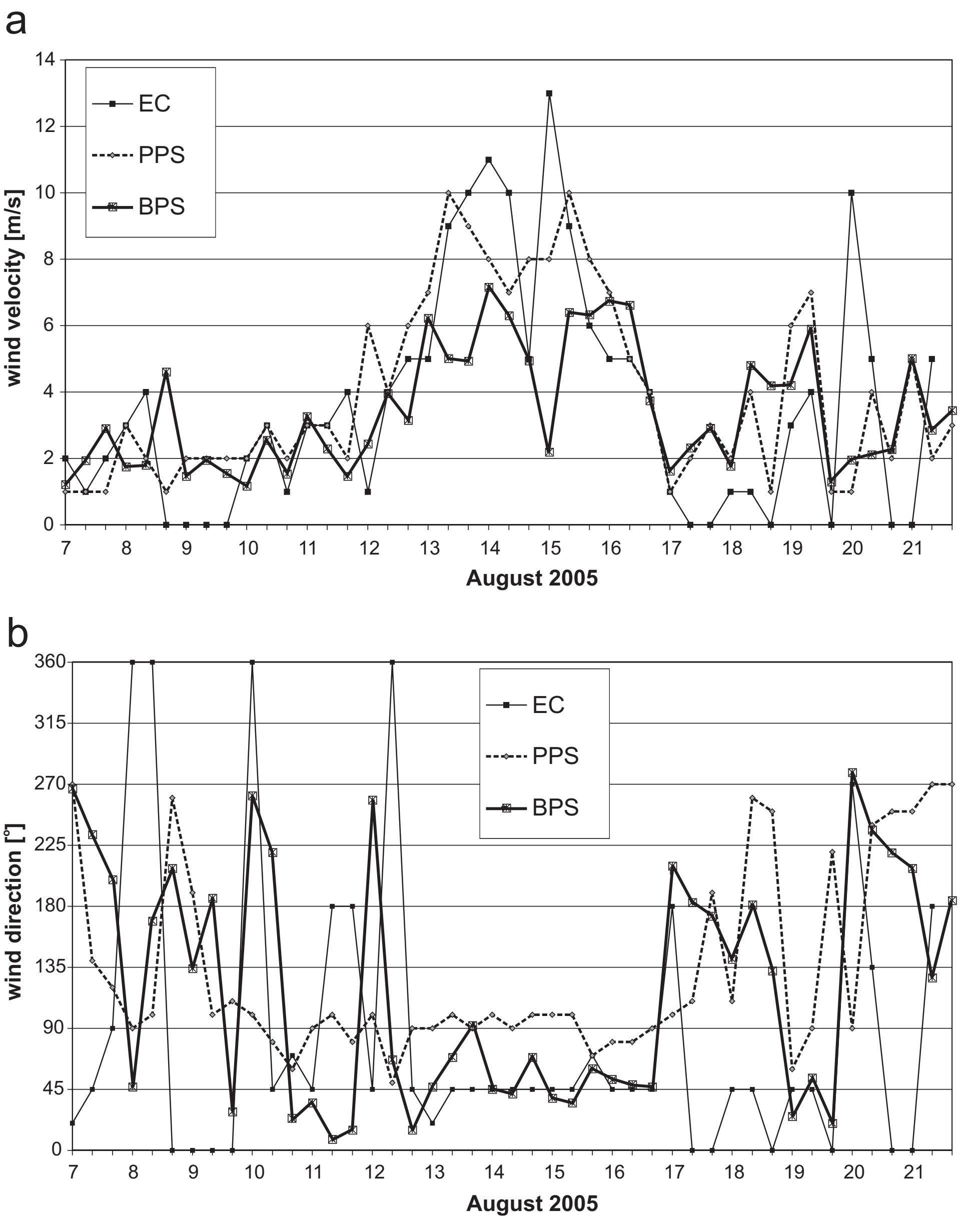

Fig. 7. Wind velocity (**a**) and direction (**b**) at East Coast measurement point, Polish Polar Station and *Baranowski* Polar Station between August 7 and 21, 2005.

understanding of the influence of local weather-forming factors. In order to present them, data from the EC point were compared with that from the PPS and the BPS.

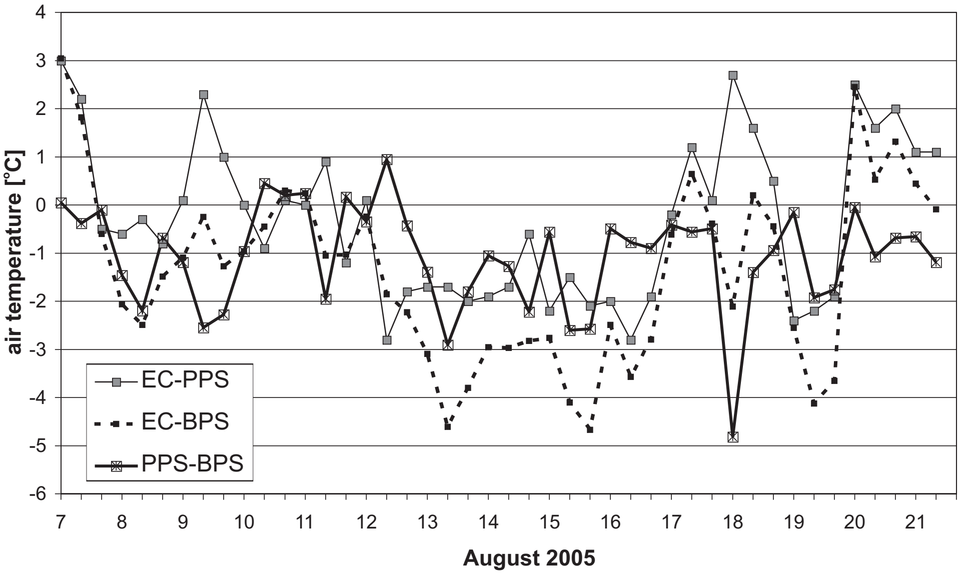

Fig. 8. Air temperature differences between East Coast measurement point and Polish Polar Station and *Baranowski* Polar Station between August 7 and 21, 2005.

In the analysed period, foehn effects occurred twice. On the west coast, at the PPS and the BPS they took place between August 13 and 16, particularly on the two last days. The easterly cyclonic situation made a mass of humid, cool air move over Spitsbergen, which resulted in rainfall and drizzle on the east coast, with heavy rainfall noted continually on August 15 and 16 (Fig. 6a). Based on synoptic maps and the noted wind velocity, pressure gradients on those days were evaluated at 2–3 hPa/100km. It was accompanied by a constant temperature decrease and full cloud cover. On the other side of the southern Spitsbergen mountain barrier, an increase in temperature was observed. The differences reached above 4°C (Fig. 8). Air relative humidity on the eastern side oscillated around 90%, while on the western side of the peninsula it was between 70 and 85% (Fig. 7). What is interesting is the fact that the foehn effect was much more visible at the BPS point than at the PPS in Hornsund. It was possibly due to the north-easterly direction of wind. In that case, air reached Hornsund having crossed a relatively narrow and not high mountain barrier, culminating at 720 m a.s.l., whereas to reach the front of the Werenskiold glacier, it had to cross a barrier of more than 1000 m a.s.l., extending over the area of 100 km. That resulted in relative humidity *c*. 10% lower and temperature even 2°C higher at the BPS point. Differences in wind velocity on the western coast may be explained by a tunnel effect in the Hornsund fiord, hence at its outlet higher wind speeds were recorded, and the fiord's course influenced a change in its direction.

Another foehn development took place on the east coast of Sørkappland on August 20, in a westerly cyclonic situation (Fig. 6d). Despite a small pressure gradient, estimated at 0.5–0.8 hPa/100 km, a strong, northerly wind was observed at the EC point, with gusts reaching 18 ms^{-1} (Fig. 7). This was accompanied by a large decrease in relative humidity (to 60%), a decrease in cloudiness and a change in the type of cloud from layered to non-layered. Overnight, the temperature on the eastern coast of Sørkappland increased by 0.3°C, and on the west coast, it decreased by 2.0–2.5°C. The diurnal amplitude of temperature at the EC point was twice as large as on the west coast. However, the thermal difference between the PPS and the BPS in that period was insignificant, being less than 1°C (Fig. 8). The difference in wind direction at the stations was puzzling. At the EC point and the BPS, a westerly wind was observed, whereas, at the PPS it was easterly. Presumably, with such weak winds in the west of the peninsula, some local factor must have modified the wind direction.

An unusual situation occurred on August 17 (Fig. 6b) when southern Spitsbergen was under the influence of a high pressure ridge. Such a circulation is more typical of a polar day (Malik 2005). The meteorological elements were evidently similar at all three stations. Any differences noted were related to the degree of cloudiness. At the EC point, the day was among the clearest, with cloudiness 2/8–4/8 (Fig. 5a), whereas, in the west, total cloudiness prevailed with only momentary breaks in the cloud cover, owing to a large supply of solar energy, the maximum temperature was more than 5°C and the amplitude twice that at the BPS and the PPS.

On August 18 (Fig. 6c), during a southerly cyclonic situation over Spitsbergen, with a pressure gradient estimated at 0.8–1 hPa/100 km, significant differences between the stations were noted, particularly with regards to cloudiness, air temperature and humidity. The eastern part of the South Spitsbergen experienced reduced cloud cover and lower humidity relative to the west. Considerably lower temperatures were recorded at the PPS relative to the other stations (Fig. 8). The differences reached almost 5°C and were the highest of the study period. Unfortunately, solely on the basis of the meteorological data available, we find it difficult to draw conclusions concerning the cause of such differences only on the basis of the collected meteorological data. Perhaps the underlying reason for this state of affairs is the nearby oceanic circulation, the influence of which was not considered in this work.

Conclusions

However, from this knowledge, it is possible to calculate the local influences on weather variations, the air circulation during August 2005 was certainly atypical and this was undoubtedly the reason for the very variable weather conditions at the three compared stations. During the foehn events, the meteorological differences, observed between the stations of the west coast, were only-too-obvious. In respect of the inflow of air from NE, the strongest foehn effects were observed at the *Baranowski* Polar Station; presumably, these reflect the influence of a higher and wider mountain barrier which had to be crossed by the air flow. The air, which reached the Polish Polar Station at Hornsund, had crossed a considerably narrower and lower barrier; that induced much weaker foehn effects, and part of this was doubtless due to a tunnel effect caused by the course and relief of the fiord. With such a circulation, the eastern part of the island became exposed to considerable and long-lasting rainfall. By contrast, at the East Coast point, foehn effects were observed during the westerly cyclonic circulation. We conclude that, on the west coast of South Spitsbergen, the weather conditions controlled by the general circulation were to a large extent modified by other factors (relief of terrain and oceanic circulation). This was particularly evident when considering wind distribution. With weakening winds, relief of terrain came progressively into play and wind direction might depended largely on this factor, whereas with increase in wind velocity, the circulation factor became dominant.

Acknowledgements. — Field research was completed during the Jagiellonian University expedition as a part PBZ-KBN-108/P04/2004 ordered project *Structure, evolution and dynamic of lithosphere, cryosphere and biosphere in the European Arctic and Antarctic*, managed by the Institute of Geophysics of the Polish Academy of Sciences. We thank employees of Polish Polar Station at Hornsund and the *Baranowski* Polar Station of Wroclaw University for providing access to meteorological data.

References

ARAŹNY A. 2003. Annual course of relative air humidity in the Norwegian Arctic from 1971 to 2000. *Problemy Klimatologii Polarnej* 13: 107–115.

FERDYNUS J. 1997. *Main characteristics of the ocean climate of a subpolar zone of the North Atlantic Ocean on the basis of states of weather structures*. Wydawnictwo Uczelniane Wyższej Szkoły Morskiej, Gdynia: 140 pp. (in Polish).

HISDAL V. 1985. *Geography of Svalbard*. Norsk Polarinstitutt, Oslo: 81 pp.

JANIA J. 1988. Dynamiczne procesy glacjalne na południowym Spitsbergenie (w świetle badań fotointerpretacyjnych i fotogrametrycznych. *Prace Naukowe Uniwersytetu Śląskiego w Katowicach* 955, Katowice: 260 pp. (in Polish).

MALIK P. 2005. Circulation reasons of weather types frequency in Hornsund in the period 1991–2000. *Problemy Klimatologii Polarnej* 15: 91–102.

NIEDŹWIEDŹ T. 1993. Long-term variability of the atmospheric circulation over Spitsbergen and its influence on the air temperature. *Polish Polar Studies*, 20th Polar Symposium, Lublin: 17–30.

NIEDŹWIEDŹ T. 2003. Contemporary variability of atmospheric circulation, temperature and precipitation in Spitsbergen. *Problemy Klimatologii Polarnej* 13: 79–92.

NIEDŹWIEDŹ T. 2007. Kalendarz typów cyrkulacji nad Spitsbergenem (zbiór komputerowy w Katedrze Klimatologii, Wydział Nauk o Ziemi Uniwersytetu Śląskiego, Sosnowiec). (in Polish).

NOWOSIELSKI L. 2004. Climate of Spitsbergen. *Gazeta Obserwatora IMGW* LIII, 2, Warszawa: 14–17. (in Polish).

OWCZAREK M. 2005. Biometeorological stimuli due to air pressure over the Polish Station in Hornsund area, 1991–2000. *Problemy Klimatologii Polarnej* 15: 143–153.

PRZYBYLAK R. 1996. *Variability of air temperature and precipitation over the period of instrumental observations in the Arctic*. Wydawnictwo Uniwersytetu Mikołaja Kopernika, Toruń: 280 pp. (in Polish).

WETTERZENTRALE, *www.wetterzentrale.de*

ZIAJA W. 1997. Deglaciation of Sørkappland (Spitsbergen) in the 20th century. *Polish Polar Studies*, 24th Polar Symposium, Warszawa: 233–236.

ZIAJA W. and OSTAFIN K. 2005. Landscape dynamics in the land pass between Sørkapp Land and the rest of Spitsbergen. *Polish Polar Studies*, 31th Polar Symposium, Kielce: 218–225. (in Polish).

Received 7 December 2006
Accepted 29 May 2007