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Topoclimatic conditions in the vicinity of the *Arctowski* Station (King George Island, Antarctica) during the summer season of 2006/2007

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Abstract: This paper describes the spatial differentiation of topoclimatic conditions in the vicinity of the *Arctowski* Station (King George Island, Antarctica) during the summer season of the 2006/2007. The measurement stations were located in the Point Thomas oasis as well as on the Ecology Glacier and Warszawa Icefield. The paper analyses meteorological elements such as air temperature, air humidity (eight sites) and wind direction and velocity (three sites). Significant topoclimatic diversities resulting from denivelation, exposure, ground properties and local air circulation were recorded in the study area.

Key words: Antarctica, *Arctowski* Station, meteorological conditions, topoclimate.

Introduction

Meteorological conditions on the King George Island (South Shetlands, Antarctica) show significant spatial differentiation due to large-scale denivelation, slope aspect, diverse ground properties and local air circulation (Marsz and Rakusa-Suszczewski 1987; Kejna 1999; Marsz and Styszyńska 2000; Kejna and Lagun 2004).

Topoclimatic research in the vicinity of the *Arctowski* Station was limited until recently. In the summer of 1979 there were two measurement stations on the Sphinx Glacier close to the *Arctowski* Station (Piasecki 1988). In the years 1979–1981, Moczydłowski (1986) studied the influence of a colony of penguins on meteorological conditions. In 1987, Schroeder and others (1995) studied the influence of microclimate on the functions of lichens *Usnea antarctica*. In the summer of 1991, glaciological and meteorological research was carried out by Bintanija (1995) on the Ecology Glacier. In 1995, Kruszewski (2000) analysed air temperature lapse-rate in the area using the measurements at the Point Thomas. The research carried out in 1996 had the widest range. It considered the topoclimatic spatial differentiation of the Site of Special Scientific Interest No. 8, and included the measurements of the ground temperature, air temperature and humidity as well as precipitation and snow cover (Kejna 1999a, b, 2000; Kejna and Láska 1997, 1999a, b). In the summer of 1997/1998, Braun *et al.* (2001) carried out both meteorological and glaciological research on the Arctowski Icefield, and, in 1998, Zwolska (2001) studied ground thermal conditions in the valley adjacent to the Jardine Peak.

Study area and research methods

Topoclimatic research in the vicinity of the *Arctowski* Station was undertaken during the 31st Antarctic Expedition of the Polish Academy of Sciences between 19 December 2006 and 17 February 2007. The study included three different areas: the Point Thomas oasis, where the *Arctowski* Station is located, and the Ecol-

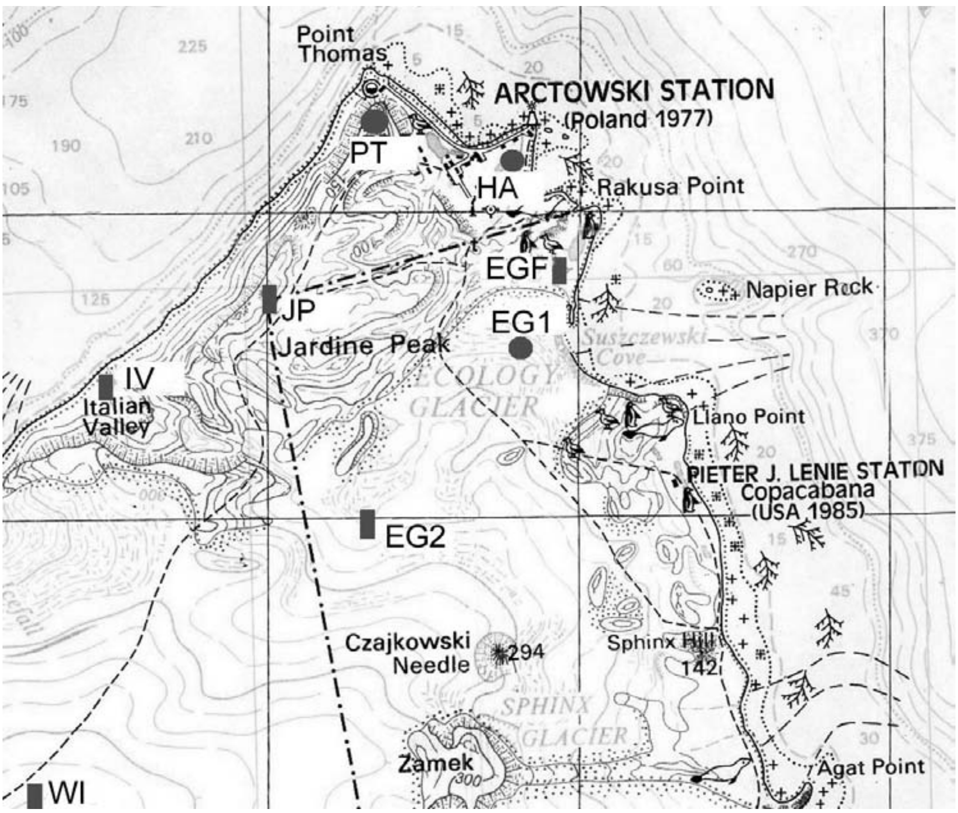

Fig. 1. Meteorological stands in the vicinity of the *Arctowski* Station in summer season 2006–2007. Part of the map: Admiralty Bay, King George Island (Battke 1990); ● – automatic weather station, ■ – electronic termohigrograph.

Table 1

Meteorological stands in the vicinity of the *Arctowski* Station in summer season 2006–2007

Stand	Symbol	Latitude	Logitude	m a.s.l.
Arctowski Station	HA	58°28’097”S	62°09’557”W	3
Italian Valley	IV	58°31’052”S	62°10’312”W	10
Ecology Glacier–forefield	EGF	58°27’750”S	62°10’101”W	5
Point Thomas	PT	58°28’097”S	62°09’557”W	173
Jardine Peak	JP	58°29’903”S	62°10’044”W	280
Ecology Glacier 1	EG1	58°28’382”S	62°10’359”W	78
Ecology Glacier 2	EG2	58°29’037”S	62°10’766”W	170
Warszawa Icefield	WI	58°32’376”S	62°11’832”W	463

ogy Glacier and the Warszawa Icefield. The Point Thomas oasis is surrounded by the glaciers which spread from the Warszawa Icefield, and, from the west, it is protected by the Arctowski Icefield which lies at 707 m a.s.l. (Braun *et al.* 2001).

Five measurement stations were located in the Point Thomas oasis (Table 1, Fig. 1):

HA – *Arctowski* Station – measurements by the automatic weather station included: air pressure (3 m a.s.l.), wind direction and velocity at 10 m a.g.l., and employing air temperature and air humidity with a sensing device placed in a radiation shield at 2 m a.g.l. Sunshine duration was measured with a Cambell-Stocke’s heliograph, and cloudiness was observed three times a day (8 am, 2 pm and 8 pm zonal time); precipitation was measured by a Hellmann rain gauge (at 8 am zonal time);

IV – Italian Valley – air temperature and relative humidity were measured at 2 m a.g.l. by an electronic recording device placed in a radiation shield at the station on the bank of the Ezcurra Inlet, at 10 m a.s.l.;

EGF – the forefield of the Ecology Glacier – an electronic device for recording air temperature and humidity was placed in a meteorological screen located on the ground moraine, 411 m from the snout of the Ecology Glacier;

PT – Point Thomas – an automatic weather station Wireless Vantage Pro (Davis Instruments) installed on the top of Point Thomas at 173 m a.s.l. recorded atmospheric pressure, wind direction and velocity as well as air temperature and humidity;

JP – Jardine Peak – an electronic device for recording air temperature and humidity was placed in a meteorological screen at 280 m a.s.l.

Three measurement stations were installed in the glaciated area along the line between the Ecology Glacier and Warszawa Icefield:

EG1 – in the snout section of the Ecology Glacier (78 m a.s.l.) – an automatic weather station Wireless Vantage Pro2+ (Davis Instruments) was installed at 2 m a.g.l.; this recorded atmospheric pressure, wind direction and velocity, air temperature and humidity and total sunshine duration and ultraviolet radiation;

EG2 – on the Ecology Glacier (170 m a.s.l.) an electronic device was placed on an ablation pole at 2 m a.g.l. (at the end of the ablation season this was at 2.8 m a.g.l.); in a radiation shield for measuring air temperature and humidity **WI** – on the Warszawa Icefield (463 m a.s.l.) an electronic device in a radiation shield for measuring air temperature and humidity was placed on an ablation pole at 2 m a.g.l.

Measurements at all the stations were taken at 10-minute intervals according to the zonal meaning time. The *Arctowski* Station measurements were actually taken every three seconds, but for this paper's needs, the 10-minute interval data were used.

Weather conditions during the summer season of 2006/2007

The analysed period had variable weather conditions (Table 2, Fig. 2). The average level of cloudiness, 6.4 (scale 0–8), was significant. There was only one clear day (19 January 2007), 17 partly cloudy days (cloudiness from 2 to 6) and 44

Table 2

Mean values of meteorological elements in the vicinity of the *Arctowski* Station in the period 19.12.2006–17.01.2007

Element	Stand	19–20 Dec	21–31 Dec	1–10 Jan	11–20 Jan	21–31 Jan	1–10 Feb	11–17 Feb	19.12–17.02
Cloudiness (0–8)	HA	8.0	7.4	6.2	5.2	6.1	6.8	6.0	6.4
Sunshine duration (h/day)	HA	.	2.5	4.7	5.2	4.5	2.7	4.9	3.9
Solar Radiation ($MJ \cdot m^{-2} \cdot day$)	HA	10.18	15.95	19.01	17.14	16.64	12.76	14.90	15.94
	EG1[1]	–	13.55	16.59	18.23	16.84	13.00	13.53	15.29
UV (MED/day)	EG2	1.02	1.78	2.18	2.00	1.95	1.39	1.29	1.74
Air pressure (hPa)	HA	986.2	986.3	986.1	984.7	999.0	987.4	991.4	989.1
Wind velocity (m/s)	HA	5.0	4.2	4.8	6.1	4.7	5.1	5.1	5.0
	PT	6.9	4.5	3.4	4.4	3.6	5.1	2.5	4.1
	EG1	4.5	4.5	4.4	6.2	4.4	4.6	5.0	4.8
Air temperature (°C)	HA	1.0	1.7	2.2	2.4	3.6	2.3	3.3	2.5
	IV	0.9	1.6	2.0	2.0	3.2	2.1	2.9	2.2
	EGF	0.8	1.4	2.0	2.0	3.2	1.7	2.7	2.1
	PT	-0.1	0.7	1.0	1.2	2.7	0.8	2.3	1.4
	JP	-0.8	-0.3	0.4	0.1	2.4	-0.1	1.1	0.6
	EG1	0.3	1.0	1.6	1.4	2.7	1.2	2.3	1.6
	EG2	-0.2	0.4	0.8	1.0	2.2	0.8	1.6	1.1
	WI	-1.6	-1.5	-1.3	-1.3	0.3	-1.4	-0.2	-1.0
Relative air humidity (%)	HA	86	77	74	77	82	77	74	77
	IV	88	80	76	81	84	79	75	80
	EGF	88	79	76	79	85	82	78	80
	PT	89	82	77	82	84	86	78	82
	JP	89	85	81	89	86	91	87	86
	EG1	91	85	83	87	90	87	85	86
	EG2	97	91	89	93	91	93	92	92
	WI	97	97	95	100	95	100	99	97

1 – Data from Ecology Glacier (EG1), lack of the data in the period 25.12.2006–7.01.2007

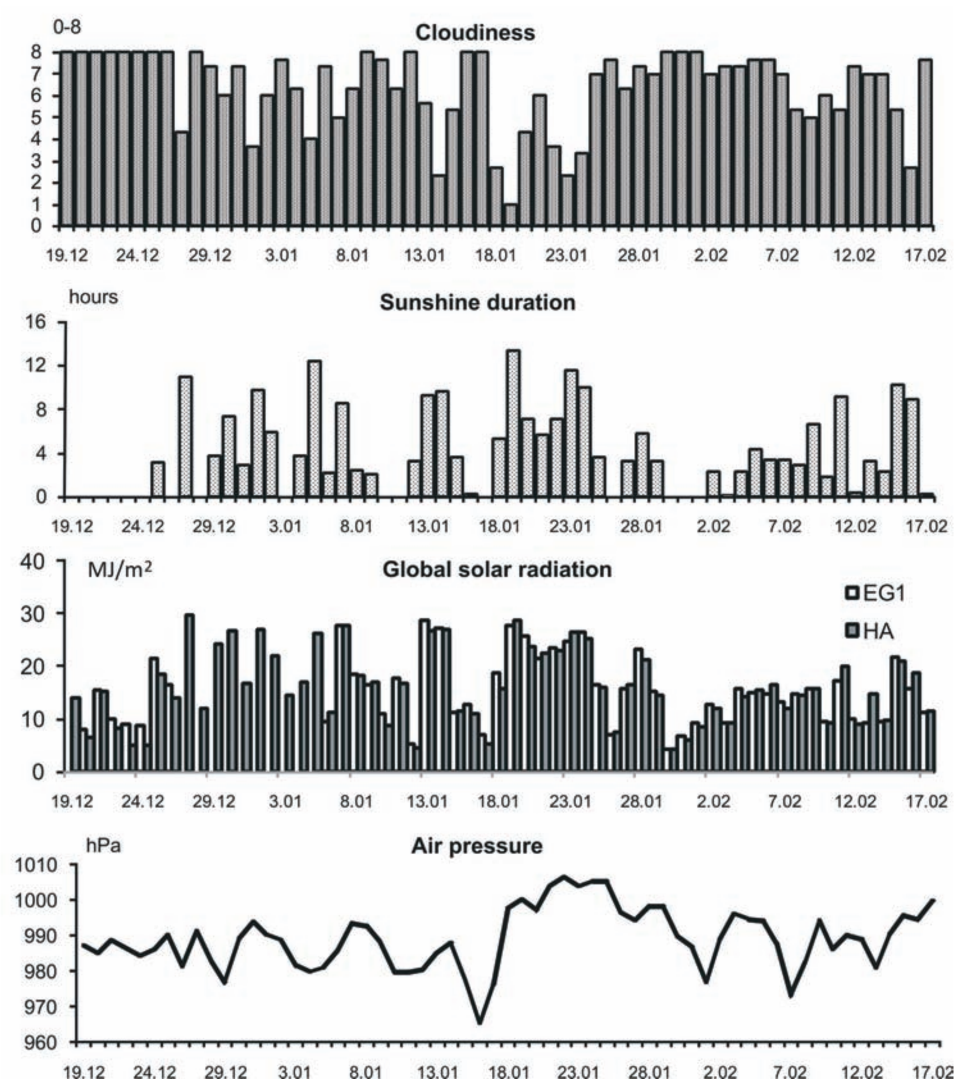

Fig. 2. Course of selected meteorological elements at the *Arctowski* Station in the period 19.12.2006– 17.01.2007.

overcast days (C >6,0), including 16 days of total cloudiness. The level of cloudiness in the studied period was slightly lower than the mean multi-annual value (Marsz and Styszyńska 2000). Low level clouds (*St*, *Ns* and *Sc*) dominated in the studied period, but there were also *Ac* and *As* clouds observed, and high level clouds (*Ci*, *Cc* and *Cs*). The weather resulting in intensive insolation also produced *Cu* clouds, especially above the ice domes surrounding the area. Local orographic clouds, such as föhn wall – and wave – clouds of *Ac len* and *Sc len* types were also recorded. The SW advection brought a "föhn window" to the cloudiness, which is typical for the vicinity of the *Arctowski* Station (Marsz and Styszyńska 2000).

Sunshine duration reached 238.4 hrs, *i.e.* is 3.9 hrs of sunshine a day on average (Table 2). The longest sunshine duration was recorded on 19 January 2007 (13.4 hrs). However, days of short sunshine duration or lack of sunshine (17 days) dominated. The average level of solar radiation at the *Arctowski* Station was 15.94 MJ/m^2 and 15.29 MJ/m^2 for the Ecology Glacier (Table 2), the daily sums ranging from 4.19 MJ/m^2 at HA and 4.29 at EG1(30 January 2007) to 29.64 MJ/m^2 at HA (17 December 2006) and 28.76 MJ/m^2 (13 January 2007) at EG1. These values are similar to the extreme daily sums (from 3.3 to 33.3 MJ·m^{-2}) recorded for the summer seasons of 1995 and 1996 (Prošek *et al.* 1996; Kejna and Láska 1997). Atmospheric pressure varied considerably from day to day. The mean value throughout the entire measurement period of time was 989.1 hPa, ranging from 965.4 hPa on 16 January to 1006.4 hPa on 22 January 2007.

Spatial differentiation of topoclimatic conditions

Wind direction and velocity. — Wind direction and velocity in the vicinity of the *Arctowski* Station is strongly dependent on the development of the barometric situation in the area of the South Shetlands and the influence of local factors, mainly orography of the King George Island (Marsz and Styszyńska 2000). Föhn winds are a very frequent phenomenon there, which is the result of movement of air masses over the hills. While the pseudo-föhn winds are the consequence of gravitational run-off of air masses along the glaciers (Zubek 1980; Piasecki 1988). Tunnel phenomena are observed in narrow bays and fiords, and along narrow mountain valleys.

At the *Arctowski* Station WSW (18.8%) and W winds (10.8%) predominated; this follows the dominant pattern of advection from the western sector of the area, together with the ESE (10.9%) and SE winds (9.9%) from the Admiralty Bay (Fig. 3). The frequency of these winds is similar to the mean frequency over a longer period of observation (Marsz and Styszyńska 2000). At the Point Thomas, however, SW winds dominate (36.7%), as is the case at Ezcurra Inlet, and are typically tunnel winds. Domination of winds from this direction had also been revealed in earlier studies (Kowalewski and Wielbińska 1983) and in model studies of the surfacial sea currents in the Ezcurra Inlet (Robakiewicz and Rakusa-Suszczewski 1999). NW winds are also common at Point Thomas (NW 14.2%, NNW 14.0%). SE winds, however, so frequent in the lower-lying *Arctowski* Station, were much less common here.

The wind regime at the Ecology Glacier is quite different. In the lower part of the glacier, katabatic winds from the south-western sector, *i.e.* in parallel to the course of the glacier, prevail. This air flows from the Warszawa Icefield down the Ecology

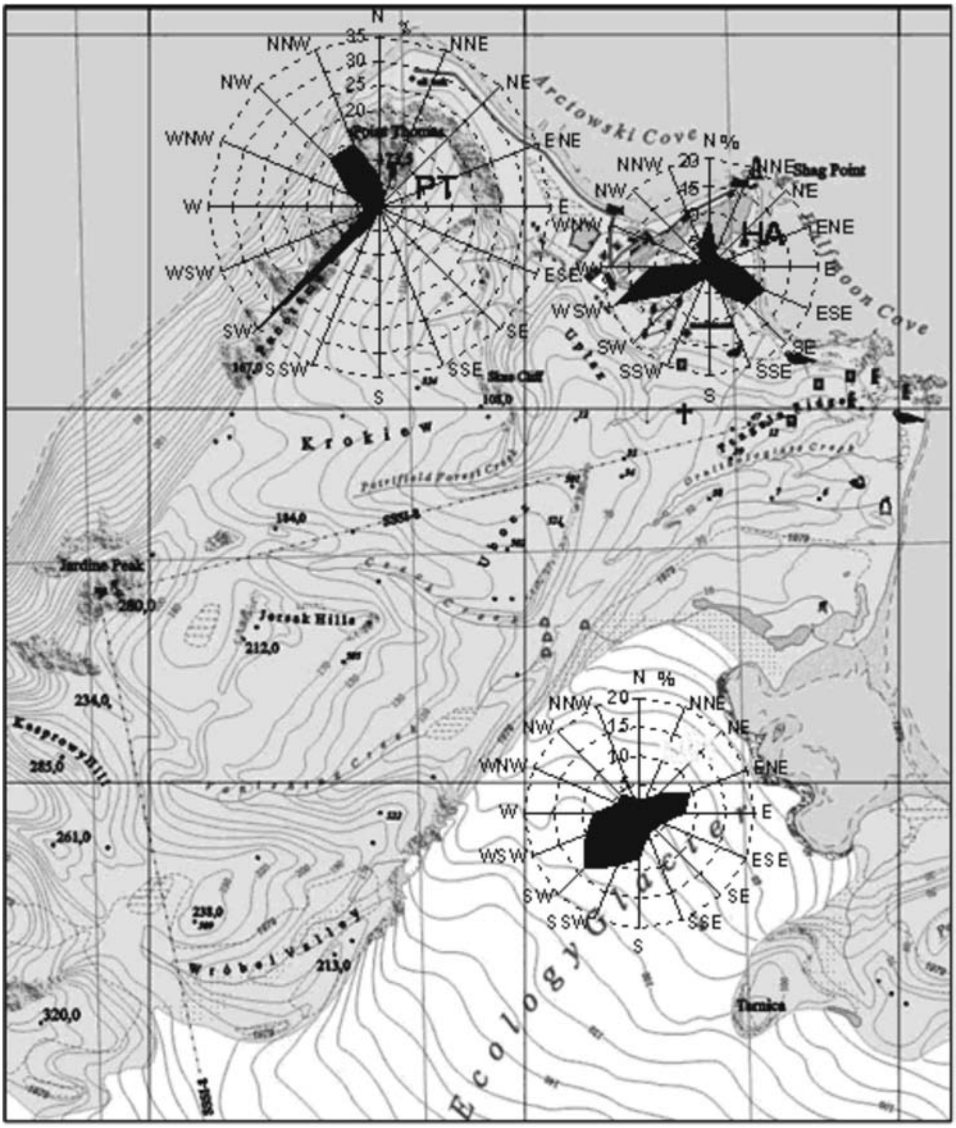

Fig. 3. Frequency of wind directions in the vicinity of *Arctowski* Station in the period 19.12.2006–17.01.2007. Part of the "Topographic map of the SSSI No. 8, King George Island" (Pudełko 2003).

Glacier slope (glacier breeze), which forms a tunnel surrounded by hills. The SSW, SW and WSW winds comprise 33.8% of total wind flow. The winds of this type are very frequent during anticyclonic weather (Styszyńska 1990). On the Ecology Glacier, especially at its snout (EG1), the winds from Admiralty Bay are also common (ENE 9.3%). The frequency of calm at all the stations was insignificant: 0.1% at the *Arctowski* Station, 0.7% on the Ecology Glacier and 3.2% at Point Thomas.

Wind velocity also shows significant variation. At the *Arctowski* Station, the mean wind velocity was 5.0 m/s, whereas at Point Thomas, 4.1 m/s. Values of wind velocity lower than that at the *Arctowski* Station were determinated in the Ezcurra Inlet, which concurs with studies of Krajewski (1986). In the glaciated area, the wind velocity on the Ecology Glacier was 4.8 m/s. However these results cannot be compared, as both measurements were taken at different height above the ground. Owing an irregular hypsometry, in the higher parts of the glacier dome, the wind velocity is diverse. In the summer season of 1997/1998 the mean wind velocity on the Arctowski Icefield was 6.0 m/s (Braun *et al.* 2001).

At the *Arctowski* Station, the largest mean values of wind velocity were recorded in respect of WSW winds (6.9 m/s), *i.e.* those parallel with the course of the Ezcurra Inlet, in which the tunnel effect is visible (Styszyńska 1990; Marsz and Styszyńska 2000), and at the SSE winds (6.7 m/s), *i.e.* those along the axis of Admiralty Bay. However at Point Thomas, the strongest winds were recorded in the northern wind sector (NW 9.1 m/s, N 8.9). These are the winds which descend from above the Arctowski Icefield together with those the SW (7.0 m/s), *i.e.* the direction parallel with the axis of the Ezcurra Inlet. On the Ecology Glacier the strongest winds also follow the course of this glacier (SW 13.7 m/s, ENE 9.3 m/s).

During the studied period, wind velocities reached 33.3 m/s at the *Arctowski* Station (11 February 2007) and 25.0 m/s on both the Ecology Glacier (10 February 2007) and at Point Thomas (7 February 2007). Gale force winds at the *Arctowski* Station result from the baric gradient and the specific orography of the region and turbulence which makes the winds more gusty (Marsz and Styszyńska 2000). Air masses which move from the western side of the island above the Arctowski Icefield fall to the leeward side along the Ezcurra Inlet. Next, after passing the Point Thomas massif they turn to the SE, in an irregular flow, towards the wider Admiralty Bay. Thus, the *Arctowski* Station often experiences whirlwinds with a diameter of about 20 m; accordingly high wind velocities and significant wind gusts are recorded. At a wind velocity of *c.* about 10 m/s, the gusts can be as much as 3 times stronger, but the winds of even higher velocity are less gusty (Kowalski 1985). The air flow from the SE over the waters of the Admiralty Bay shows a more laminar character (Nowosielski 1980; Kejna and Láska 1997).

The relationship between the measurement stations on individual days change and are depended on wind direction. For instance, the NW winds are weakest at the *Arctowski* Station (3.9 m/s), whereas on the Ecology Glacier mean wind velocity is 6.9 m/s, and at Point Thomas 9.1 m/s. However, if the wind blows from the SW, its velocity on the Ecology Glacier is 13.7 m/s, whereas it is 7.0 m/s at Point Thomas and 5.3 m/s the wind-sheltered *Arctowski* Station.

In the daily course, the highest wind velocities were recorded during the day at all the stations; the evening and night winds were much weaker (Fig. 4). Higher wind velocities during the day are presumably the result of growing thermo-barometric gradients between the glaciers, the sea and the rocky surface of the oases.

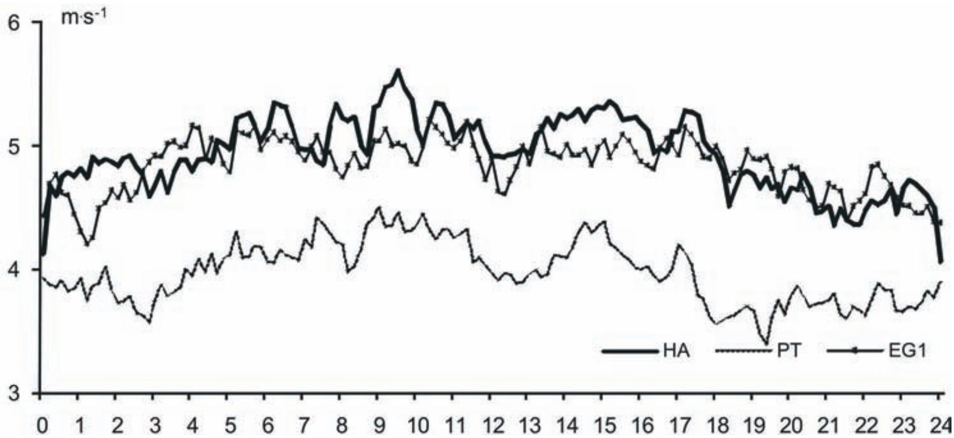

Fig. 4. Mean daily course of wind velocity of *Arctowski* Station (HA), Point Thomas (PT) and Ecology Glacier (EG1) in the period 19.12.2006–17.01.2007.

Air temperature. — Air temperatures in the *Arctowski* Station area show significant temporal variability in the form of several-day-long-phases (Fig. 5). Marsz and Styszyńska (2000) calculated that 29–35 such waves may develop annually. They are conditioned by the type of air mass and the direction they come from. The highest air temperatures are recorded in respect of the NW winds; during the summer season they are 1.5–2.0°C higher than average (Styszyńska 1999). In winter these differences can be as much as to 4°C (Wielbińska and Skrzypczak 1988). However, those air masses of SE advection are cooler (Kejna 1996).

Spatial differentiation of the air temperatures in the vicinity of the *Arctowski* Station is significantly influenced by altitude, the terrain characteristics, degree of exposure and local air circulation. The highest mean temperatures in the study period were recorded at the *Arctowski* Station (2.5°C) – Table 2. The mean temperature in the Italian Valley was lower (2.2°C) owing to a much higher shade factor and the cooler air masses descending the Ezcurra Inlet. Much lower temperatures, however, were recorded on the forefield of the Ecology Glacier (EGF 2.1°C) which was often affected by katabatic winds.

Growing altitude lowers air temperature to 1.4°C at Point Thomas (PT – 173 m a.s.l.) and 0.6°C on Jardine Peak (JP – 280 m a.s.l.). Temperature lapse-rate in the relation to the *Arctowski* Station, though, is 0.66°C/100 m for PT, 0.70°C/100 m for JP, and 0.78°C/100 m between the JP and the PT. During individual days these vertical gradients can be much steeper, such as on 2 February 2007 (up to 1.36°C/100 m between the PT and the *Arctowski* Station), and on 25 December 2007 (1.18°C/100 m between the JP and the *Arctowski* Station). However, inversions are common in the region, *e.g.* on 27 December 2006, it was -0.32°C/100 m between the PT and the *Arctowski* Station, and, on 25 January 2007 it was -0,55°C/100 m between the JP and the *Arctowski* Station.

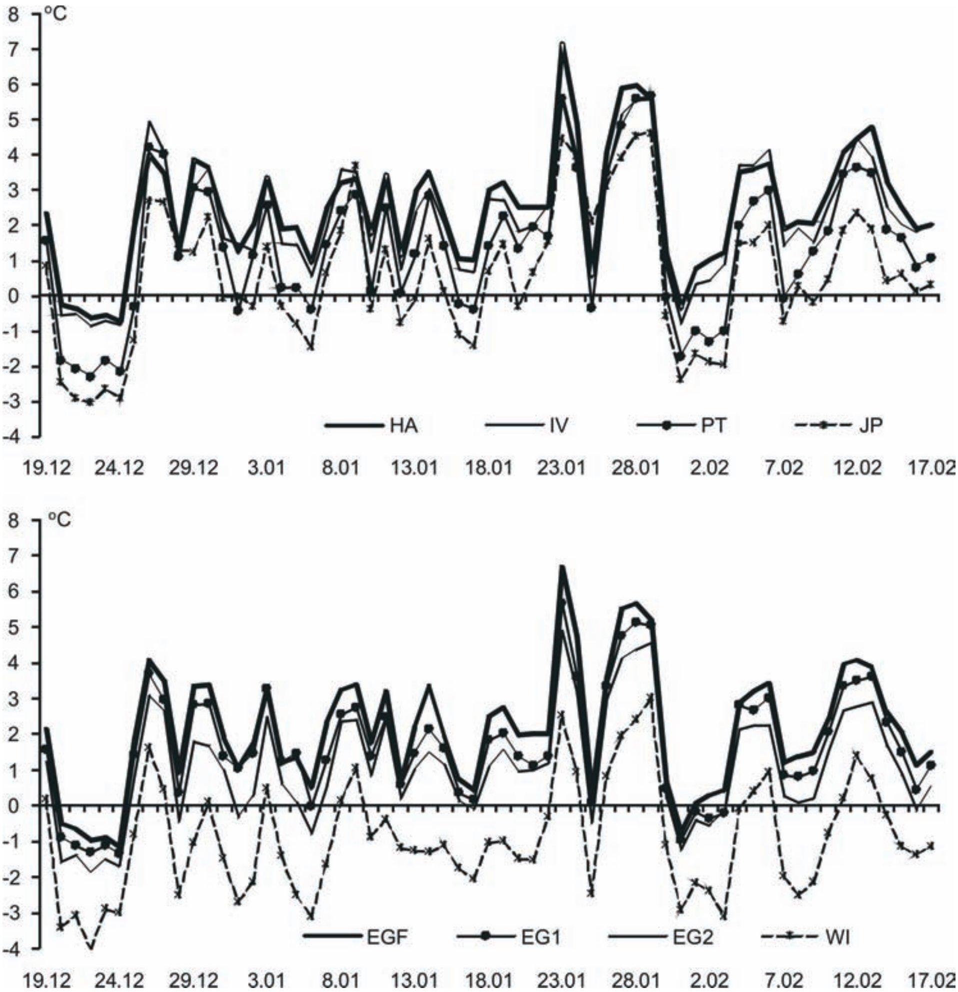

Fig. 5. Course of air temperature in the vicinity of *Arctowski* Station in the period 19.12.2006–17.01.2007.

On the Ecology Glacier, air temperature lowers with increasing altitude from 1.6°C at 78 m a.s.l. (EG1) to 1.1°C at 170 m a.s.l. (EG2), to -1,0°C on the Warszawa Icefield (WI – 463 m a.s.l.). At higher altitudes, temperature falls more than this during the summer season of 1997/1998, it was -3.8°C on the Arctowski Icefield (619 m a.s.l.) – Braun *et al.* (2001). Mean temperature lapse-rate at the snout of the Ecology Glacier (between EG1 and EGF) is close to normal and is 0.62°C/100 m. However, the phenomena of inversion and non-adiabatic gradient of the air are also recorded. For instance, on 14 January 2007, after 9.6 h of sunshine and solar radiation (27.2 $MJ \cdot m^{-2}$), the temperature lapse-rate between the EG1 and EGF was 1.64°C/100 m.

The mean air temperature value of the daily maxima were highest on the coast (HA and the IV had 4.6°C, whereas the EGF 4.4°C). Increased altitude increases these mean values both in the non-glaciated area (PT 3.8°C and JP 3.3°C), and on the Ecology Glacier (EG1, 3.7°C; EG2, 3.2°C and WI, 1.1°C). However the mean air temperature values of the daily minima were above zero only at HA (0.6°C) and IV (0.2°C), whereas for the other stations, they were below zero -0.1°C (EGF), -0.5°C (PT), -1.5°C (JP), -0.3°C (EG1), -0.9°C (EG2), and -2.6°C(WI). The highest air temperatures were recorded on 28 January 2007; at the *Arctowski* Station it was 10.4°C, on the forefield of the Ecology Glacier (10.1°C), whereas the other stations recorded from 8 to 10°C. The only place where a highest temperature on a different day was recorded the Warszawa Icefield (24 January 2007, 5.4°C). The lowest air temperatures reached from -1.3°C at the *Arctowski* Station and -2.0°C in the Italian Valley to -3.0°C on the Ecology Glacier forefield. Mountain tops recorded even lower temperatures (PT, -3.4°C; JP, -4.6°C), whereas the Ecology Glacier it ranged from -3.4°C (EG1), to -5.1°C (EG2) and to -6.0°C on the Warszawa Icefield.

The daily course of air temperatures refers to the temperatures of the ground, which in turn relates to the solar radiation balance. The solar radiation balance for the *Arctowski* Station is symmetrical in relation to solar noon. The highest values are recorded when the Sun is at its highest (Prošek *et al.* 2000). The daily course of temperatures, however, is asymmetrical, the highest value being recorded in the afternoon (Kejna 1999a; Marsz and Styszyńska 2000). At the seacoast (HA, WI and EGF), the highest temperatures are recorded mainly in the late afternoon, while the stations located at higher altitudes, both in the mountains (PT and JP) and on the glaciated area (EG2 and WI) recorded the highest temperatures earlier, *e.g.* for the WI at 13:00 hrs (Fig. 6). This is clearly associated with the thermal properties of the ground. Minimum air temperatures in a diurnal cycle are associated with the end-of-the-night cooling, *i.e.* when the radiation balance stops being negative. Owing to diversity in the terrain properties, the minimum air temperatures are not recorded at the simultaneously time at all the stations. For instance, the Italian Valley recordings were 1–2 hours later. On the mountain peaks (PT and JP), temperature drops at about 1–2 hours and stays almost unchanged until sunrise. Diurnal air temperature courses are often disturbed by non-periodical factors, especially by advection of various air masses (Kejna 1999a; Marsz and Styszyńska 2000).

In respect of the considering diurnal course of temperatures, the differences between the stations located in the Point Thomas oasis grow in the afternoon and at night, while these differences in the morning and before the noon are much smaller (Fig. 6). The situation is diverse on the forefield of the Ecology Glacier, where the differences between the EGF and the glaciated area grow during the day owing to more intense heating above the morainic and sandy ground. However the snow and ice covered Ecology Glacier and the Warszawa Icefield record similar values during both day and night for all their stations (EG1, EG2 and WI).

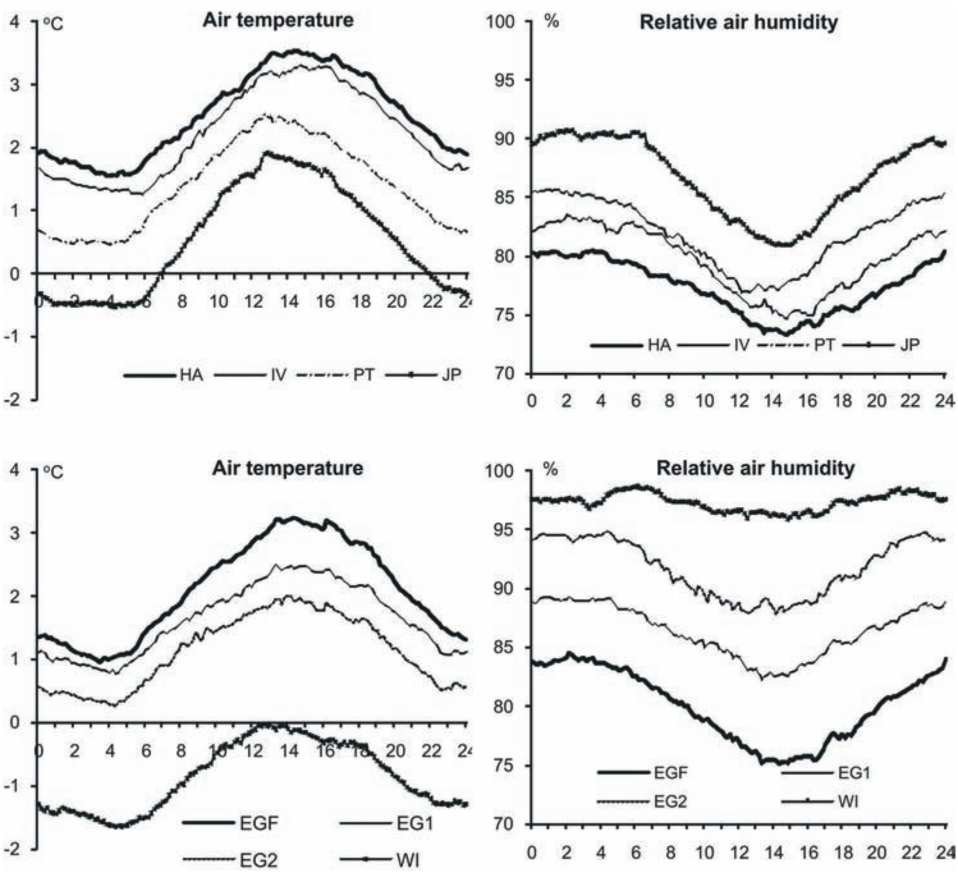

Fig. 6. Mean daily course of air temperature and relative air humidity in the vicinity of *H. Arctowski* Station in the period 19.12.2006–17.01.2007.

Diurnal amplitudes, calculated from the mean air temperature courses, are largest in respect of increasing altitude: from 2.0°C at the seacoast (HA) to 2.1°C on the Point Thomas and 2.4°C on the Jardine Peak. High amplitudes are also recorded at the forefield of the Ecology Glacier (2.3°C), while the lowest are recorded in the glaciated area (1.6–1.8°C).

Air humidity. — Owing to dominance of fresh maritime masses, the air in the *Arctowski* Station region shows a significant level of saturation with the water vapour (Marsz and Styszyńska 2000). During the study period, mean relative humidity at the *Arctowski* Station was 77%. The values for the Italian Valley and the Ecology Glacier forefield were slightly higher (80% in both cases) – Table 2. Increasing altitude and falling temperature bring an increase in relative air humidity, *e.g.* PT, 82%; JP and EG1 86%; EG2 92% and WI 97%.

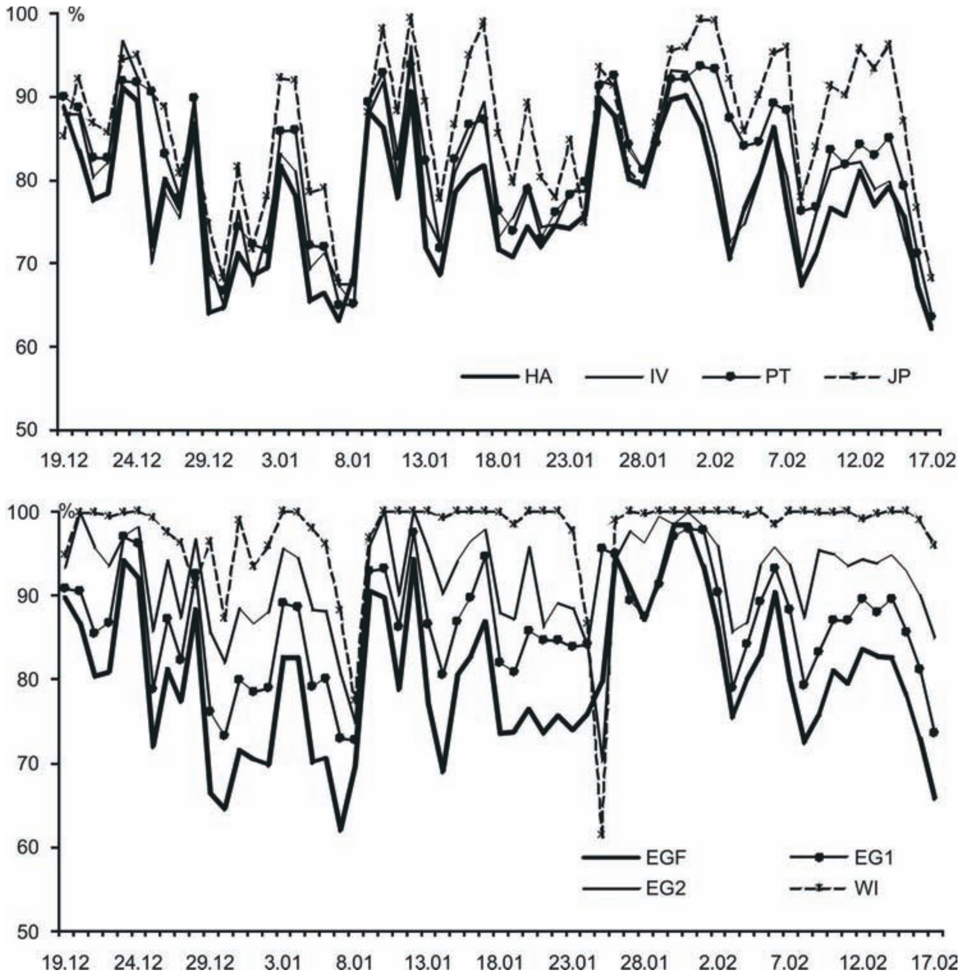

Fig. 7. Course of relative air humidity in the vicinity of *Arctowski* Station in the period 19.12.2006–17.01.2007.

The course of the relative humidity shows extended periods of reduced values (Fig. 7). The lowest mean daily values of relative humidity were 60–70%. A relatively low humidity was associated with föhn processes and the influx of cool, relatively dry continental air masses during the advection from E, S and SW directions (Marsz and Styszyńska 2000).

The daily course of air relative humidity at all the stations shows lowest values around noon and higer level of saturation with water vapour at night (Fig. 6). In the Arctowski oasis greater differences between the stations are recorded at night, rather than during the day, in contrast to the glaciated area, especially on the Warszawa Icefield, where, during most of the study period, relative humidity oscillated to 100%.

Differentiation of topoclimatic conditions during various weather situations

Topoclimatic diversity increases during the insolation and radiation weather. During cloudy weather, however, the factor which most influences diversity, solar radiation, is limited significantly (Fig. 9). Thus, a few cases of diverse weather conditions – different cloudiness and variable directions of advection of air masses – were selected to compare temperature and air humidity courses at all the stations.

On 19 January 2007, sunny weather, which favours development of föhn winds, was recorded at the *Arctowski* Station . The day was clear (mean daily cloud cover of Cu was 1.0), sunny (13.4 hrs) and had large solar radiation income (daily total of 28.84 MJ·m^2 at HA and 27.8 MJ·m^2 at EG1). The northern wind was weak and moderate; between 10 am and 1 pm it changed into south-eastern, and then to western with the velocity of over 10 m/s. It was a typical föhn wind, which is often recorded in the *Arctowski* Station vicinity (*e.g.* Piasecki 1988; Styszyńska 1990), especially if air masses cross the ice domes of Arctowski (NW, N and NE) and Warszawa (W and SW). Air temperature then increases by 2.0°C to 2.25°C in the case of the Arctowski Icefield, and from 1.0°C to 1.75°C in the case of the Warszawa Icefield. Relative air humidity decreases by about 18% and 8–11% respectively (Marsz and Styszyńska 2000). Föhn winds relate to a long sunshine duration and a high level of solar radiation due to the formation of a "föhn window", which develops above the *Arctowski* Station on the leeward side of the hills (Marsz and Styszyńska 2000). On the day in question the diurnal course of temperatures at all the stations showed a significant amplitude; the maximum ranged from 8.8°C at 14:00–15:00 hrs at the *Arctowski* Station to 1.8°C at the Warszawa Icefield. The lowest temperatures were recorded between 3:00 and 4:00 hrs, and ranged from 0.5°C (HA) to -3.0°C (WI). Daily range of air temperatures was largest at the snout of the Ecology Glacier (EGF, 9.2°C), while the lowest at the WI (4.8°C). The range of temperatures between the stations increased during the maximum influx of solar radiation. Relative humidity on that day showed a diverse course; a minimum was recorded in the afternoon when the values of the parameter dropped to 41% for the *Arctowski* Station , 43% for the EG1 and 44% for the IV. The Warszawa Icefield also then recorded a significant decrease in relative humidity (86%).

These elements took a quite different course on the cloudy day of 17 January 2007 (cloudiness 8.0, lack of sunshine and solar energy: 5.20 MJ·m^2 at HA and 7.10 MJ·m^2 at EG1). The courses of both temperature and relative humidity were similar. Thus, with the limited influx of solar radiation, the advection factor may cover up the normal diurnal rhythm (Kejna 1999a).

The influence of advection on both temperature and relative humidity course was also obvious on 22 December 2006, when the lowest air temperatures of the entire study period were recorded (Fig. 9). At night temperature dropped to -1.4°C at

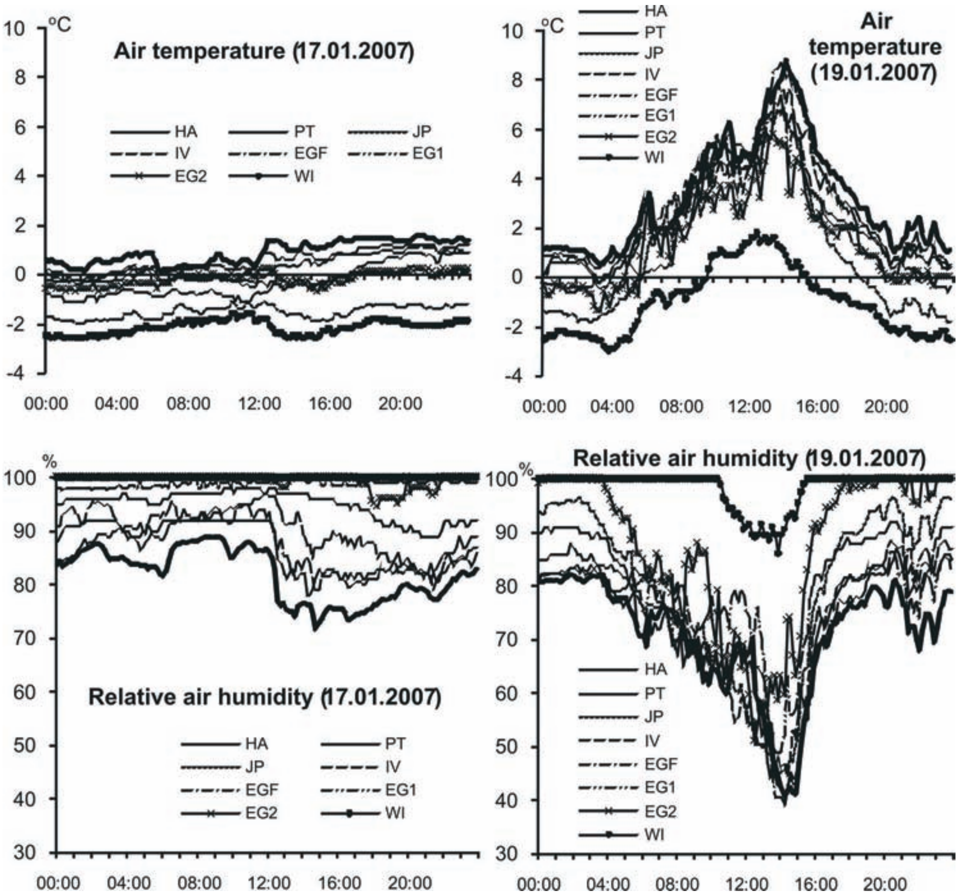

Fig. 8. Course of relative air humidity in the vicinity of *Arctowski* Station in the days: 17th and 19th January 2007.

the *Arctowski* Station and decreased further with the increasing altitude (JP, -4.0°C; WI, -5.2°C). During the day air temperature slightly increased; at all the stations except that at *Arctowski* Station; however, it remained below zero throughout. Such a significant cooling was undoubtedly caused by eastern and south-eastern advection, which brings cold and dry air masses to the South Shetlands from above the Weddell Sea (Braun *et al.* 2001). On the day in question, cloudiness was total and the ground received only 10.1 MJ·m^{-2} of solar radiation. Initially, relative air humidity ranged from 65–75% on the seacoast (HA, IV, EGF) to 80–90% at JP and EG2 and 95–100% at WI. In the afternoon, the change in the wind direction from E to SE owing relative humidity increased significantly.

Diverse conditions, especially those related to the humidity ones, are recorded during fog. In the morning of 25 January 2007 fog and low *St* clouds were recorded; in the afternoon, however, the fog dispersed. At the coastal lowlands diurnal maxi-

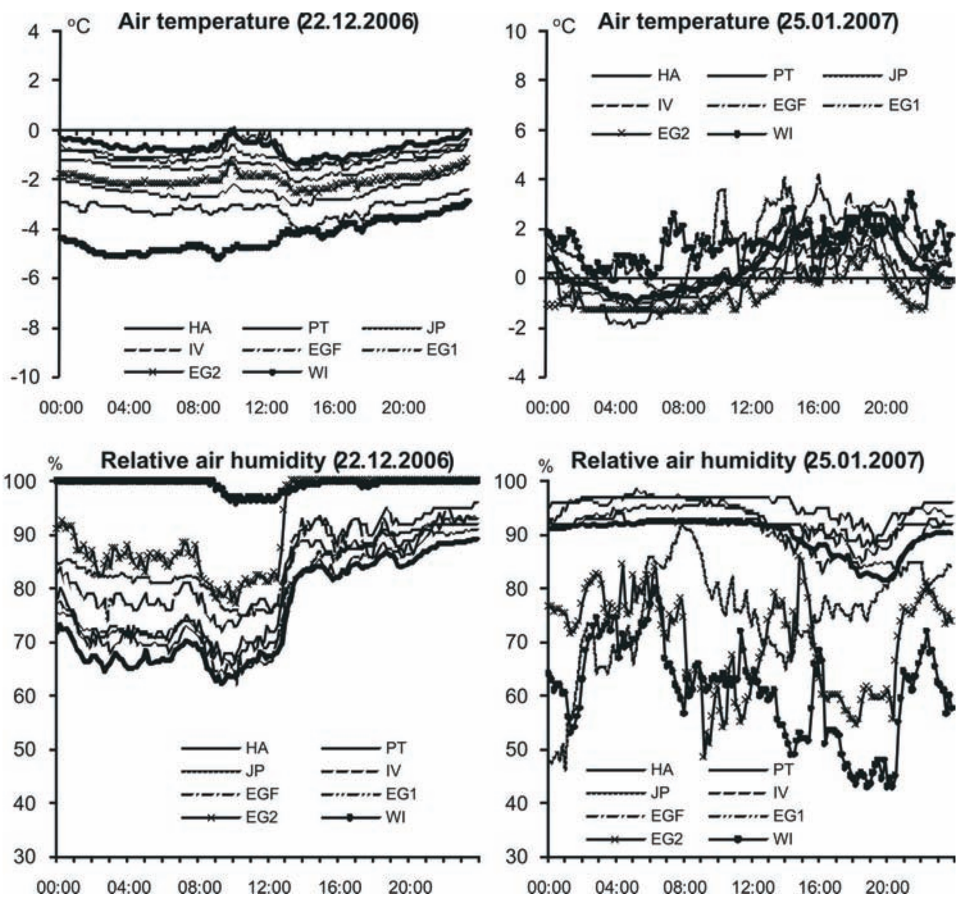

Fig. 9. Course of relative air humidity in the vicinity of *Arctowski* Station in the days: 22nd December 2006 and 25th January 2007.

mum of temperature occurred in the late afternoon. During fog, the stations located at higher altitudes (WI, JP) registered temperatures 2–3°C higher than those on the seacoasts. Such an inversion was probably associated with the lack of clouds at these stations as well as an intensive solar radiation. This notion is supported by an analysis of the relative humidity course, which, during most of the day and night, was 90–100% on the seacoast lowlands, while at the Warszawa Icefield, Jardine Peak and the Ecology Glacier it was much lower (as much as 40% for WI).

Concluding remarks

The research carried out in the summer of 2006/2007 demonstrated a significant diversity of topoclimatic conditions in the *Arctowski* Station vicinity.

Wind direction at the three stations corresponds closely with the local relief. The prevailing winds at the *Arctowski* Station include those from the NW, SW and SE sectors. The most frequent winds at Point Thomas are associated with the course of the Ezcurra Inlet. On the Ecology Glacier, the dominant winds are katabatic, blowing along this glacier from the Warszawa Icefield. Katabatic winds are also characteristic for other glaciers in the area (Zubek 1980); they are recorded, for instance, on the Sphinx Glacier, where they show pseudo-föhn character (Piasecki 1988). Owing to orography the wind velocity is also diverse, this favours a velocity increase by tunneling effects, as well as föhn winds and local calm areas. Owing to its location at the mouth of the Ezcurra Inlet the strongest wind was recorded at the *Arctowski* Station. Strong winds also blow along the glacial tongues, *i.e.* on the Ecology Glacier. The weakest winds, however, were recorded at Point Thomas. The variability between the stations appears to depend on the wind direction. Considering the diurnal course, the highest wind velocities at all stations are recorded around noon this being the time thermal and pressure lapse-rates increase above variable terrain (land, maritime and glacial).

The range of air temperature is determined significantly by altitude, exposure, shading, the type and properties of the ground and local air circulation. In the study period the highest temperatures were recorded on the coastal lowland adjacent to the *Arctowski* Station. This is the result of a favourable slope aspect of the surrounding hills and the föhn effects, predominantly the reduced level of cloudiness above the station, a property of a "föhn window" (Marsz and Styszyńska 2000). Consequently, the highest diurnal maximum of air temperature was recorded there. The lower temperatures at the Italian Valley result mainly from the largest shading of the area. Owing temperatures at the marginal zone of the Ecology Glacier (EGF) are even lower frequent advection of cool air masses from the interior of the island. With respect to the summer of 1996 (Kejna 2000), the temperature difference between the *Arctowski* Station and marginal zone of the Ecology Glacier (EGF) increased from 0.2 to 0.4°C.

Both in the oasis and on the glaciated area air temperatures reduce with altitude. Recorded mean vertical gradients between Point Thomas and the *Arctowski* Station (0.66°C/100 m) are greater than in the summer of 1994/1995, when they reached 0.53°C (Kruszewski 2000). On the higher levels (between JP and PT) the vertical temperature gradient is even larger, amounting to 0.78°C/100 m. These higher lapse-rates reflect the frequent föhn processes which take place on the leeward side of King George Island. During individual types of weather, lapse-rates may be even higher. During summer, when the tops are insolated (Kruszewski 2000) and the coastal lowlands experience fogs or low cloud cover, inversions were also recorded. The gratest temperature lapse-rate over the glaciated areas was recorded at the contact zone between the glacier and its marginal zone (between EG1 and EGF 0.62°C/100 m). In the summer of 1979, Piasecki (1988) recorded a temperature lapse-rate of 0.92°C/100 m on the nearby Sphinx Glacier. These differences increase when insolation is intensive, the result of significant heating of the morainic ground, whereas the temperatures above the glacial surface remain low (ablation takes place at 0°C). The influence of solar radiation on the snow-glacial-cover surface is limited by its high albedo; that of the snow on the Arctowski Icefield for example is 81.1–86.5% (Braun *et al.* 2001). In the higher parts of the Ecology Glacier and the Warszawa Icefield, the air temperature drop is from 0.66 to 0.72°C/100 m. Similar values of the lapse-rate (0.71°C/100 m) are recorded on the Arctowski Icefield (Braun *et al.* 2001).

During the day, the relations between the research stations change due to the diverse thermal properties of the ground. The distribution of radiation balance, symmetrical in respect to noon (Prošek *et al.* 2000), gives a distinct asymmetry in the course of temperature, with a maximum in late afternoon (Kejna 1999a; Marsz and Styszyńska 2000); the asymmetry was also recorded at the forefield of the Sphinx Glacier (Piasecki 1988). This phenomenon is more typical of the seacoast; by contrast to the stations located in the mountains and in the glaciated area, the maximum is recorded earlier. Minimum air temperature is recorded at sunrise, but at the shaded stations it may be later. In the non-glaciated areas, the diurnal course shows larger temperature ranges in the afternoon and at night, whereas at the forefield of the Ecology Glacier, the temperature range increases during the day owing to intensified heating of the air above the morainic-outwash ground. The relationship between the Ecology Glacier and the Warszawa Icefield (EG1, EG2 and WI) follows a similar diurnal pattern. Diurnal ranges of temperature increase at higher altitude and at the glacial snout. In the glaciated area, they are significantly lower.

Analysis of tree ring clustering carried out for 8 air temperature parameters at separate stations showed that the most similar thermal conditions occur at the stands HA and IV. The second group comprises the stands EGF and PT, and the conditions at the stands on Ecology Glacier (EG1 and EG2) are similar to these. Quite different conditions occur on the Jardine Peak (JP) and Warszawa Icefield (WI) see Fig. 10. The basic factors controlling thermal conditions in the region of the *Arctowski* Station are the ground type (non-glaciated or glacial) and the height above sea level.

Relative air humidity in the *Arctowski* Station region is high due to a large share of maritime air masses (Marsz and Styszyńska 2000). Mean relative humidity on the seacoast (HA, IV, EGF) ranged from 77 to 80% and increased with the altitude to 86% on the JP and 97% on the Warszawa Icefield. On the Arctowski Icefield, air is almost saturated with water vapour (98%) – Braun *et al.* (2001). The course of the relative humidity is influenced significantly by föhn winds, during which humidity reduce to 40–50%. Föhn winds are common place; on the Sphinx Glacier they make up 64% of winds. A lower relative air humidity is also noted when dry continental air masses inflow from the sector between E and S to SW (Marsz and Styszyńska 2000). The diurnal course of relative humidity is diverse in respect of air temperature. Non-glaciated areas produce greater differences in air saturation at night, whereas the glaciers, during the day. The analysis of tree ring

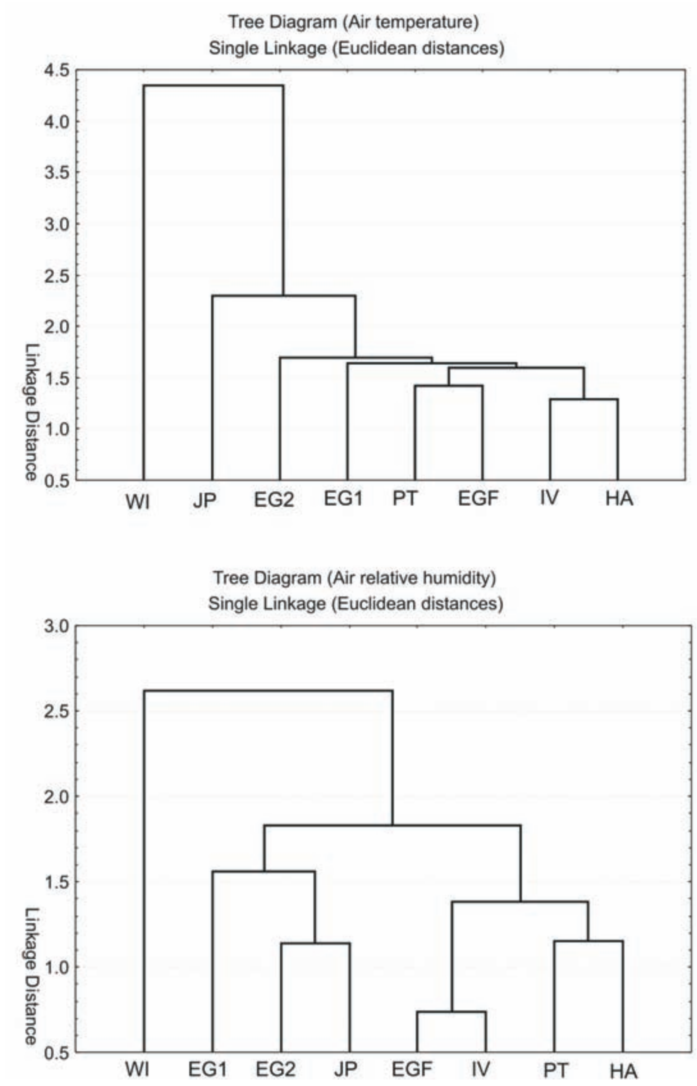

Fig. 10. Connection graph (tree ring clustering analysis) of the meteorological stands for air temperature and relative air humidity, summer 2006–2007.

clustering carried out for 4 air humidity parameters showed that stands EGF and IV, and HA and PT were all similar (Fig. 10). The second group contains EG1, EG2 and JP, whereas the greatest contrast in humidity conditions occurs on the Warszawa Icefield (WI).

Both topoclimatic and microclimatic diversity also influence the geosystem in the region of the Admiralty Bay (Tatur 1996; Rakusa-Suszczewski 2003). During significant increases in air temperature in the Antarctic Peninsula region (King 1994; Ackley *et al.* 1996; Domack *et al.* 2003) and on King George Island (Kejna

2003; Kejna and Lagun 2004) intensive deglaciation is observed (Kejna *et al.* 1998; Batke *et al.* 2001; Birkenmajer 2002). An increase of temperature by 1°C on the Ecology Glacier intensifies ablation by 15% (Bintanja 1995). Hydrological, geomorphological and soil processes are also transformed. The areas freed from ice undergo intensive plant succession (Olech and Massalski 2001), and changes in animal population (*e.g.* Rakusa-Suszczewski 2003).

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