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Mean air temperatures at definite wind directions at Arctowski Station, King George Island, West Antarctica

ABSTRACT: Observations from 1978—81, 1983 and 1985 collected at the Polish Polar Arctowski Station (King George Island, South Shetland Islands) were used to calculate frequencies of wind directions in 30° sectors and mean air temperatures observed at each wind direction. Results reveal that all over the year the warmest air masses flow onto the South Shetland Islands from the northwest while the coolest ones from the southeast and east.

Key words: Antarctica, South Shetland Islands, wind direction, air temperature.

Introduction

In the circumantarctic Southern Ocean a distinct zonality of air temperature is connected with strong meridional thermal gradients. Air temperature rises northwards, in summer from about 0°C at continent coasts to about 10°C near latitude 50°, and in winter from about −20°C at coasts to +2°C at the same latitude. This zonality is however disturbed by symmetry of the Antarctic continent in relation to the South Pole. These disturbances are best noted in the South American sector of the circumantarctic zone where the Antarctic Peninsula protrudes far north into the ocean. In mid-summer air temperature in the Weddell Sea is as low as −6°C. In latitude of 50° in the Atlantic part of the Southern Ocean it retains the value of 7°C whereas in the Pacific sector it reaches 12°C at the same latitude. In winter a local meridional gradient is still larger. In the Weddell Sea air temperature falls to −30°C, retaining positive values (+2°C to +3°C) in latitudes of 50° in the Atlantic sector of the Southern Ocean and 6°C to 7°C in the Pacific sector (Dolgin and Pietrov 1977, Treshnikov and Salnikov

1985). South Shetland Islands lying off the western coast of the Antarctic Peninsula, are influenced both by the cool Weddell Sea and by the warmer air from above the Atlantic and Pacific sectors of the Southern Ocean, depending on direction of air flow. These influences should be reflected in relations of air temperature and wind direction at the Arctowski Station.

Data and method

Calculations were based on standard meterological wind and temperature measurements performed 8 times a day. Frequencies of wind direction and variability of air temperature were computed, using data from 5 years (1978—81 and 1983). Closer relations between temperature and wind direction were found by adding the data from 1985. Frequency distribution of wind directions in 30° sectors and air temperatures, coexisting with these wind directions, were described. Calculations were made separately for the periods which can be approximated to seasons of a year in considered zone. Thus December, January and February are accepted for summer, March, April and May for autumn, and so on. Each mean air temperature was averaged from a different number of data, dependent on accompanied varying frequency of wind directions.

Frequency of wind directions

Arctowski Station is located at latitude 62° at southern margin of the zone with strong westerly winds, only 2—3° to the north from the axis of the southern lowest pressure trough (Newton et al. 1972, Stepko and Wielbińska 1981). South of this trough a subantarctic zone with prevailing easterly winds extends (Treshnikov and Solnikov 1985). Broad frontier of both these interacting zones is marked by a very strong cyclonal activity, resulting in great variability of wind direction.

During 5 years of full standard meterological observations (1978—81 and 1983) these interaction resulted in a presented distribution of wind directions (Table 1, Fig. 1). Southwesterly directions 210° and 240° were the most frequent throughout a year (about 14% each). Northwesterly directions 300° and 330° were second frequent (7 and nearly 10% respectively). Share of westerly directions was comparatively low (only somewhat over 6%). The last value depends probably on permanent air flow over the station and is forced by its nearest surroundings, being not an attribute of circulation in this zone. All other wind directions occurred with frequencies from 4 to 7%.

Table 1

Annual variation of frequency (in %) of wind direction at the Arctowski Station in 1978—1983

Direction	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Year
180° (S)	5,9	4,4	3,3	2,8	3,3	3,4	3,8	2,4	4,0	4,2	5,7	6,8	3,9
210°	11,8	14,8	12,1	16,9	13,0	10,4	10,3	9,3	11,0	21,0	14,5	16,5	13,6
240°	10,9	15,4	16,5	16,7	17,7	14,9	15,9	10,5	17,2	17,3	11,3	11,9	14,7
270° (W)	5,8	5,6	4,9	7,1	6,0	10,3	7,7	7,1	8,1	6,2	4,9	4,9	6,3
300°	5,4	8,1	7,4	10,9	5,5	6,6	6,9	10,5	7,7	8,5	6,1	5,2	7,0
330°	8.1	10.0	9.5	9,7	13,7	9.7	8,3	13,1	7,6	6,8	9,9	11,2	9,6
360° (N)	3,7	4.7	9.0	5.9	5,6	6,3	7,7	8,5	7,6	4,0	5,0	6,3	6,1
30°	5,3	2,9	5,1	3,1	6,1	3,6	3,4	3,4	4,0	4,9	4,1	4,9	4,3
60°	6,3	2,7	2,8	1,7	4,5	4,8	5,2	3,9	5,1	4,7	6,9	4,9	4,3
90° (E)	5,2	6,8	5,7	5,9	6,7	6,0	8,1	6,6	4,8	7,1	9,2	9,6	6,6
120°	5,8	6,4	5,4	7,4	9,1	7,3	7,5	8,9	8,4	6,9	4,7	6,9	6,7
150°	5,7	3,8	6,6	4,0	5,9	7,9	6,3	5,6	4,8	3,7	6,0	6,4	5,5
Calm	20,6	14,6	14,1	7,8	5,2	8,8	7,9	9,3	8,9	7,5	11,2	7,7	10,3

Analysis of yearly variation of wind direction frequencies confirmed the predominance of southwesterly winds. February was the only month when northwesterly directions prevailed. During some months the share of easterly and southeasterly winds reached nearly 10%. Frequency of calm weather was also popular (10.3%). Share of calms was the most frequent in winter: in July it reached 20.6% and in August nearly 15%.

This analysis is based as already mentioned, on data from 5 years only (Table 1) and thus, may not reflect mean conditions. Looking through observations from some particular periods (Cygan 1981, Wielbińska and Stanisławczyk *unpubl.*), a frequency of easterly air flow over South Shetland Islands seems to be on the average greater than shown by data from presented period. The same could be judged when comparing characteristic features of atmospheric circulation in some particular years in this area

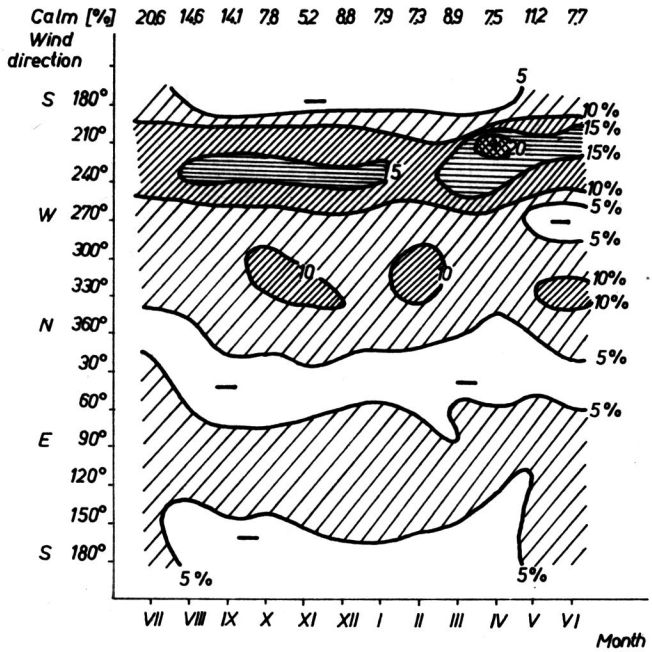


Fig. 1. Annual variation of frequency (per cent) of wind directions at the Arctowski Station in 1978—1983

(Wielbińska and Stanisławczyk *unpubl.*) and if comparing climatological data from nearby stations *e.g.* Bellingshausen (Dolgin and Petrov 1977).

Therefore, due to a great variability of prevailing wind directions, the area should be considered for located within the area under changing influence both of strong westerly and slightly weaker easterly air flow.

Range of variability of air temperature

During the same 5 years air temperatures at the station varied from −24.4°C in August to 16.4°C in January (Table 2). These extreme values were measured at standard synoptic hours. Absolute minimum and maximum temperatures were somewhat lower and higher, respectively.

Annual variation of frequency distribution of the whole population of temperatures is illustrated by percentiles *i.e.* probability of occurrence of 5, 25, 50, 77 and 95% (Table 2, Fig. 2). The curve of 5% probability

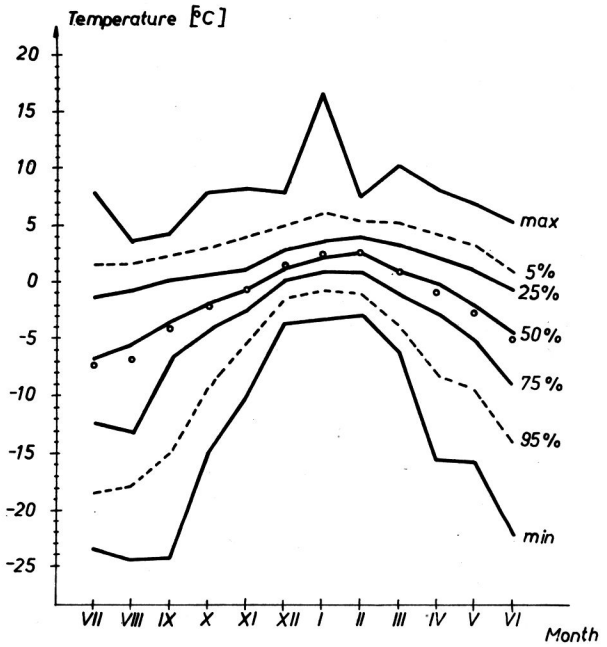


Fig. 2. Variation of temperature values at the Arctowski Station in 1978—1983 (from measurements at synoptic hours only): maximum and minimum temperature and percentiles of 5, 25, 50, 75 and 95% of occurrence probability. Circles denote monthly means

means that higher temperatures in the described month occurred in 5% and lower ones in 95% of cases. Similarly, the curve of 25% probability means that in the given month higher temperatures occurred in 25% and lower ones in 75% of cases.

When observation series is long enough, the 50% probability can be identified with a mean temperature. In case of only several observation years the set of data may be somewhat too short from a climatological point of view to reflect well the mean values. Nevertheless, differences between mean monthly air temperatures and 50% probability (Fig. 2) are negligible for the 5 years in question.

Table 2

Probability of occurrence (percentiles) and extreme air temperatures (from observations at synoptic hours only) at the Arctowski Station in 1978—1983

month	highest value			percentiles					lowest value		
	°C	year	day	5%	25%	50%	75%	95%	°C	year	day
Jan	16,4	79	20	5,9	3,5	2,2	0,9	−0,7	−3,3	80	23
Feb	7,4	80	24	5,3	3,9	2,4	0,8	−1,0	−3,0	80	27
Mar	10,3	79	24	5,1	3,1	0,9	−1,1	−3,9	−6,1	81	14
Apr	8,1	81	08	4,0	1,9	−0,1	−2,9	−8,2	−15,4	80	17
May	6,7	80	01	3,3	0,8	−2,3	−5,3	−9,4	−15,6	80	27
Jun	5,3	83	16	1,9	−0,9	−4,4	−8,7	−13,9	−21,9	80	08
Jul	7,7	81	04	1,4	−1,4	−6,9	−12,5	−18,4	−23,6	78	26
Aug	3,4	83	27	1,5	−0,8	−5,5	−13,3	−17,8	−24,4	78	10
Sep	4,1	80	27	2,2	0,1	−3,4	−6,9	−14,9	−24,2	80	23
Oct	7,8	81	28	2,7	0,5	−1,8	−4,3	−9,3	−14,7	81	03
Nov	8,2	79	25	3,7	1,1	−0,7	−2,6	−5,4	−10,2	81	09
Dec	7,7	79	23	4,7	2,8	1,3	0,1	−1,5	−3,9	80	01

Relation between air temperature and wind direction

Quantitative reflection of thermal features of described atmospheric circulation can be found in relation between direction of air flow and air temperature. For this purpose air temperatures coexisting with winds from particular directions, were selected and averaged. Calculations were performed within 30° sectors. Presented results (Table 3) are also supplemented with a number of cases of relevant wind direction at mean temperatures. The same relations are also illustrated (Fig. 3a—3d). Mean temperature for each season is indicated by a dashed line. Similar wind roses and similar asymetry of „temperature roses" are found to be characteristic for all seasons, though they differ a little in magnitude of deviations.

In spring (September-November) mean air temperature was −1.9°C. Mean temperature at northwesterly winds (300° and 330°) was equal +0.5°C. At all the other wind directions mean temperatures remained below 0°C, with the lowest value of −4.5°C at easterly and southeasterly winds (90° and 120°). Deviations of air temperatures at particular wind directions from seasonal means (Table 4) vary in spring from +2.4°C at northwesterly winds (300°) to −2.6°C at southeasterly (120°) ones.

In summer (December-February) mean air temperature was equal +2.2°C. Mean temperatures at winds from particular directions were also above

Table 3

Mean temperatures $\bar{T}$ (in °C) at particular wind directions in 1978—1981, 1983 and 1985; n — number of observations

Direction	Jun — Aug		Sep — Nov		Dec — Feb		Mar — May	
	n	$\bar{T}$	n	$\bar{T}$	n	$\bar{T}$	n	$\bar{T}$
180° (S)	216	−7,0	125	−2,5	148	1,5	185	−1,2
210°	576	−4,6	549	−2,1	347	1,9	634	0,0
240°	671	−4,4	812	−1,4	657	2,4	618	0,1
270° (W)	277	−2,7	278	−0,6	406	2,8	266	0,5
300°	266	−1,0	312	0,5	292	3,6	295	1,8
330°	441	−1,5	491	0,2	441	3,4	387	1,1
360° (N)	215	−2,9	341	−0,6	337	3,0	249	1,2
30°	179	−4,9	189	−1,2	159	2,9	221	−0,7
60°	179	−8,4	129	−2,0	168	1,3	246	−3,8
90° (E)	276	−10,8	246	−4,4	306	1,0	346	−4,3
120°	272	−10,0	279	−4,5	258	0,7	315	−3,3
150°	216	−8,8	226	−3,8	277	0,9	228	−1,9
Calm	605	−10,0	386	−5,1	404	1,9	395	−2,6
Sum n	4389		4363		4300		4385	
$\bar{T}$		−5,8		−1,9		2,2		−0,9

0°C. Highest values were reached at northwesterly winds. Thus deiations from means varied from +1.4°C to −1.5°C and did not cause a marked asymetry of temperature distribution (Fig. 3b).

Table 4

Deviations (in °C) of mean air temperatures at particular wind directions from mean seasonal temperatures. Observations from 1978—1981, 1983 and 1985

Direction	Deviations			
	Jun — Aug	Sep — Nov	Dec — Feb	Mar — May
180 (S)	−1,2	−0,6	−0,7	−0,3
210°	1,2	−0,2	−0,3	0,9
240°	1,4	0,5	0,2	1,0
270° (W)	3,1	1,3	0,6	1,4
300°	4,8	2,4	1,4	2,7
330°	4,3	2,1	1,2	2,0
360° (N)	2,9	1,3	0,8	2,1
30°	0,9	0,7	0,7	0,2
60°	−2,6	−0,1	−0,9	−2,9
90° (E)	−5,0	−2,5	−1,2	−3,4
120°	−4,2	−2,6	−1,5	−2,4
150°	−3,0	−1,9	−1,3	−1,0
Calm	−4,2	−3,2	−0,3	−1,7

A

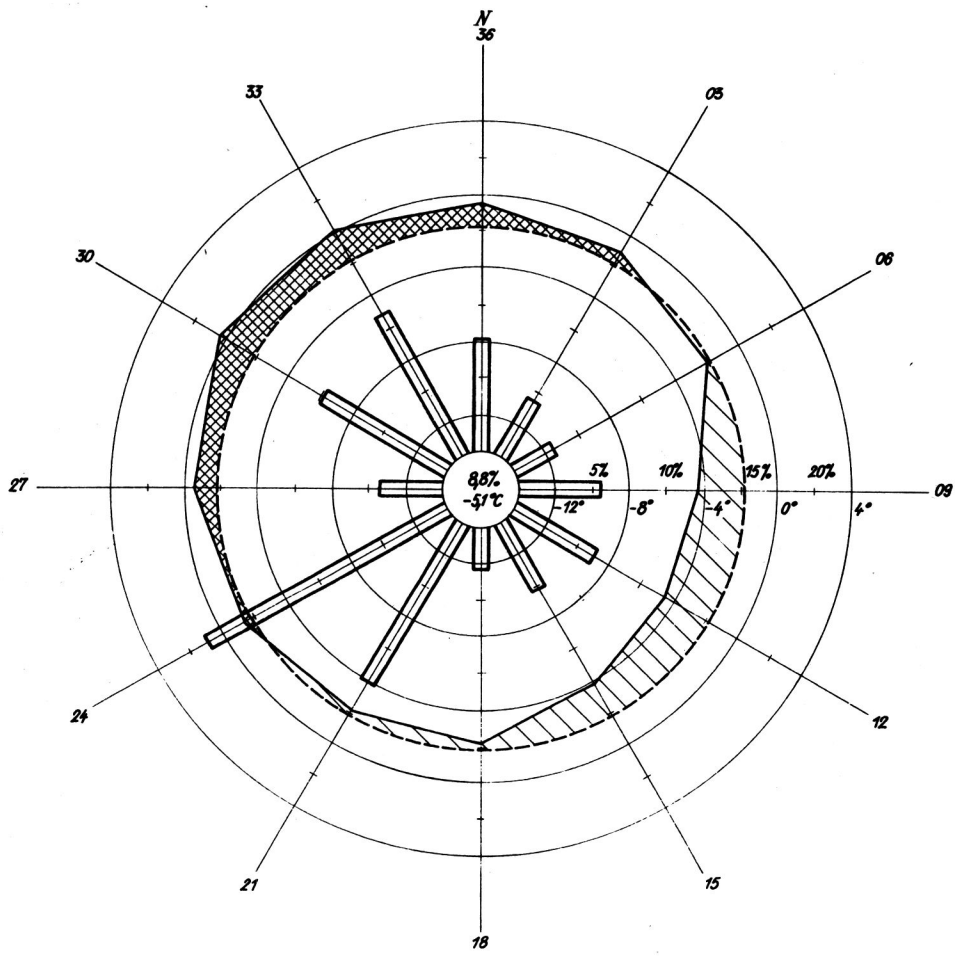
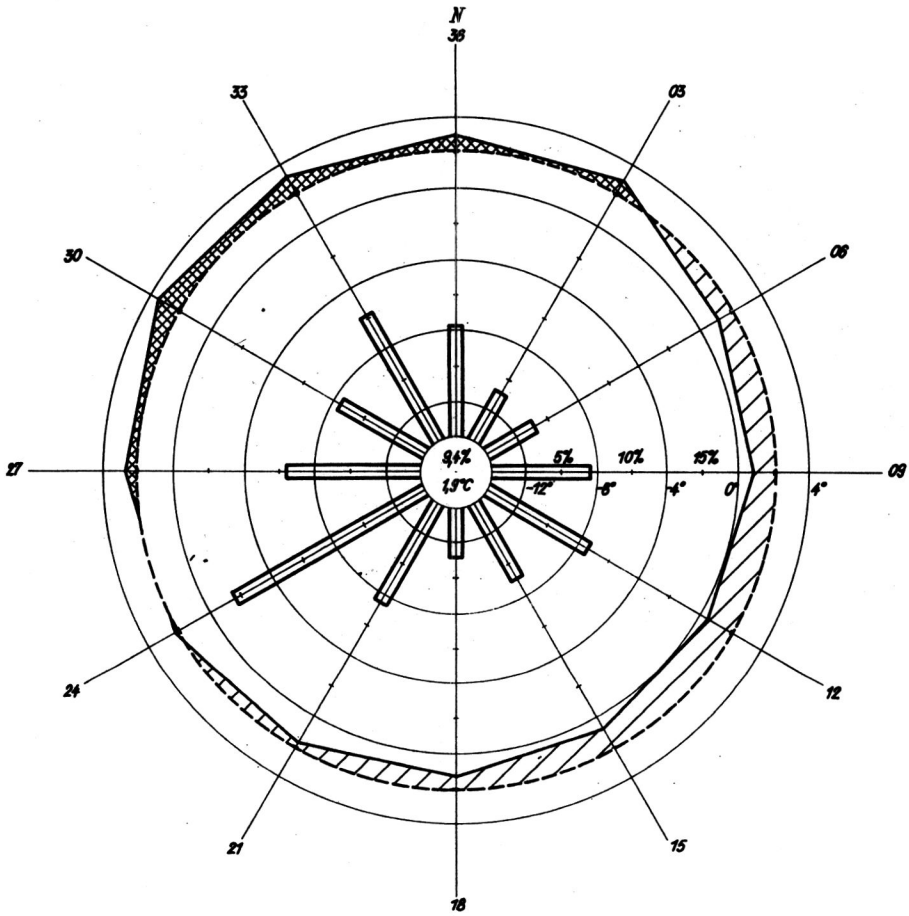


Fig. 3
For explanations *see*: D

B



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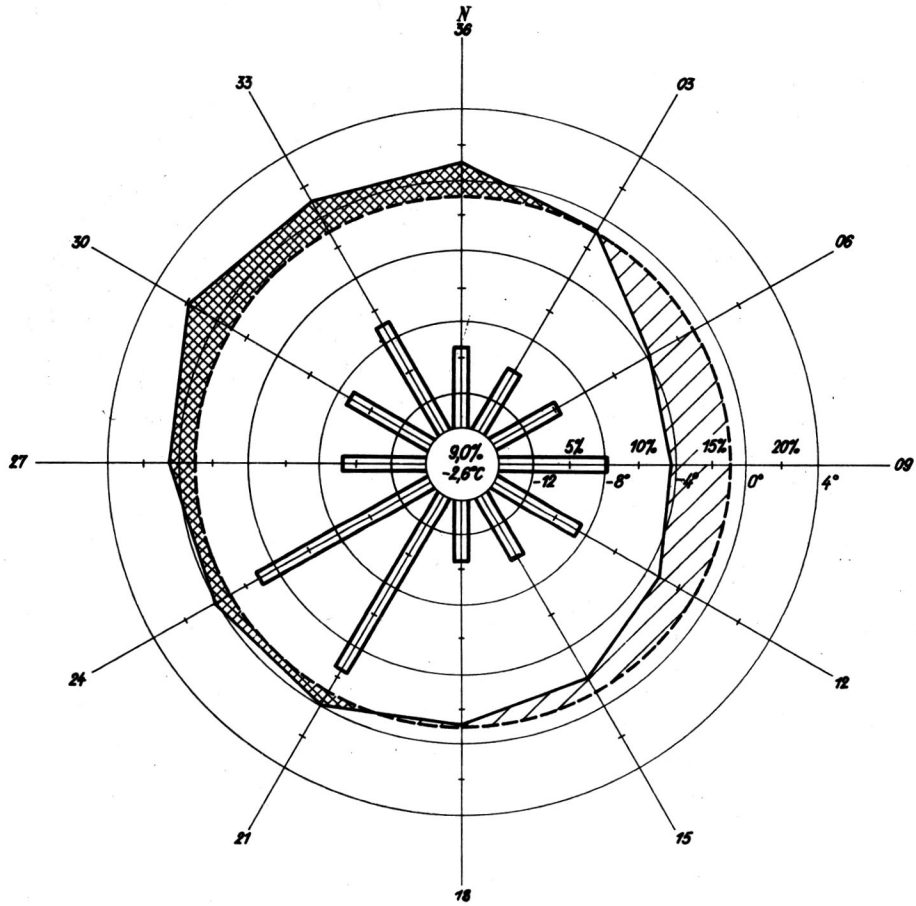

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D

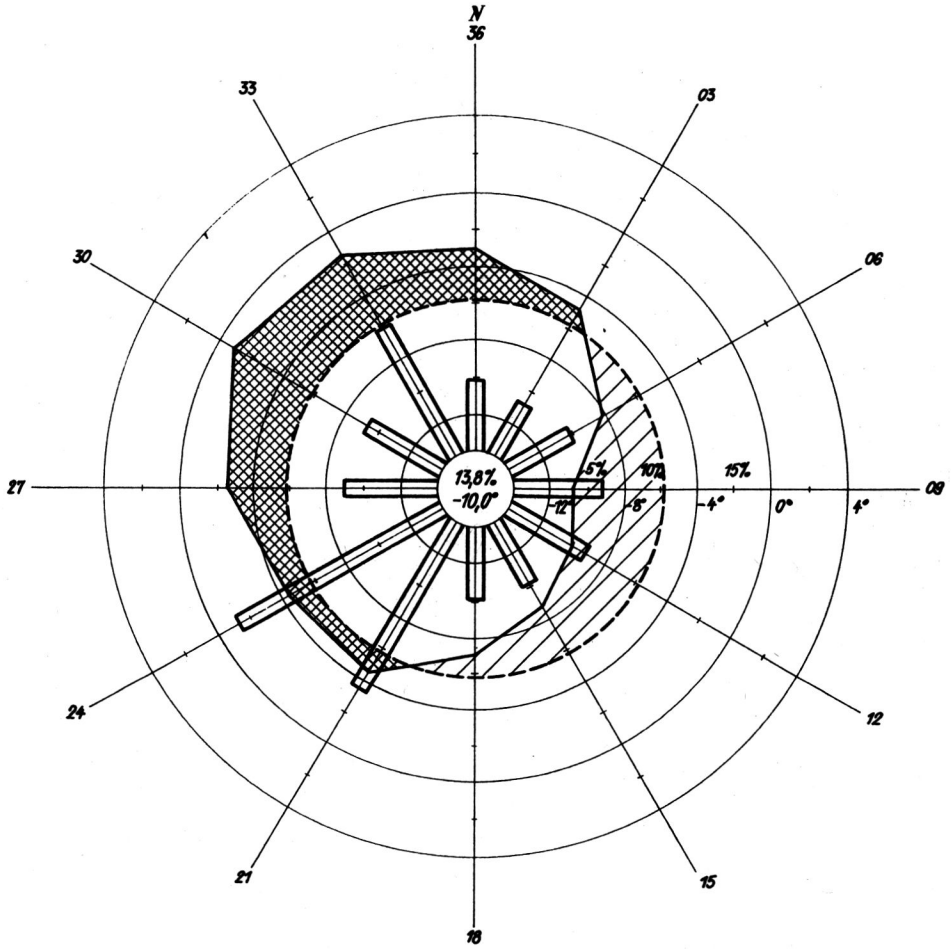

Fig. 3. Relation between air temperature and wind direction at the Arctowski Station. Data from 1978—1981, 1983 and 1985. Numbers in circles indicate frequency (in %) of calms and their mean temperatures. Horizontal lines mean frequency (per cent) of wind direction (in %), hachured area-positive deviation from mean seasonal temperature, and oblique lines — negative deviation from mean seasonal temperature. A — September-November, B — December-February, C — March-May, D — June-August

Mean temperature of autumn (March-May) was equal −0.9°C. The warmest air was as usually, transported by northwesterly and northerly winds with mean temperatures of +1.8°C and +1.1°C, respectively. Most common southwesterly winds (210° and 240°C) brought temperatures of about 0°C. The coolest air flowing from the eastern sector (60° to 120°), had mean temperatures from −4.3°C to −3.3°C. Thus the maximum positive deviation from the seasonal mean was equal +2.7°C, and the negative one −3.4°C (Fig. 3c).

Greatest differentiation of thermal conditions was observed in winter (June-August) what resulted in a similar differentiation of the "temperature rose". Warmest air masses from the northwest (300° and 330°) had mean temperature equal −1.0°C and −1.5°C. The coolest easterly winds (90° and 120°) brought air with temperature below −10°C. Deviations from the seasonal mean were equal −5.8°C and varied from +4.8°C at a wind direction of 300° to −5.0°C at winds from the east (Fig. 3d). Mean temperatures calculated for calms had negative deviations from seasonal means. They varied from −0.3°C in summer to −4.2°C in winter.

Final remarks

The analysis of relations of air temperatures and wind directions at the Arctowski Station allows to draw the following conclusions:

— throughout a year warmest air is brought from northwesterly directions and coolest air from southeasterly and easterly directions; atmospheric situations which cause direct transport of warmest air masses from the north and of coolest ones directly from the south can be regarded as extremaly rare;

— warm air comes from the Pacific sector of the Southern Ocean; coolest air comes from the ice-covered Weddell Sea which is in its southern part strongly influenced by the antarctic easterly wind zone;

— wind directions of greatest thermal contrasts are diametrally different; they are separated by "thermally indifferent" directions; changes from thermally contrasted to thermally indifferent directions occur gradually.

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Streszczenie

Rozkład częstości i kierunków wiatru na stacji „Arctowski" w okresie 1978—1981 i 1983 przedstawiał we wszystkich porach roku obraz dość podobny: wiatry mające przewagę zachowywały ją na ogół w ciągu całego roku. Najczęściej występowały kierunki 210° i 240° (południowo-zachodnie), osiągając 14% częstości w skali rocznej. Następne co do liczności były wiatry północno-zachodnie (300° i 330°). Ich częstość wynosiła odpowiednio 7% i 10%. Częstości pozostałych kierunków wahały się od około 4% do ponad 6%. Stosunkowo liczne były też cisze, zwłaszcza zimą. W skali roku częstość ich przekraczała 10% (tabl. 1, fig. 2). W omawianym pięcioleciu, średnia temperatura okresu letniego (grudzień — luty) wynosiła 2,2°C. Jesienią (marzec — maj) spadła do −0,9°C a zimą do 5,8°C. Temperatura wiosny (wrzesień — listopad) była nieco wyższa od −°C (tabl. 2 i 3, fig. 2).

Przy uwzględnieniu dodatkowo danych z 1985 roku, obliczono średnią temperaturę powietrza przypadającą na poszczególne kierunki wiatru. Najcielplejsze okazały się masy powietrza przychodzące z północnego zachodu znad cieśniny Drake'a, przy kierunkach wiatru 300° i 330°. Wiosną były cieplejsze o ponad 2°C od średniej temperatury sezonu, latem — o koło półtora stopnia, jesienią o prawie 3°C a zimą o 5°C. Masy powietrza przynoszonego znad Morza Weddella, a więc z kierunków wschodnich i południowo-wschodnich (90° i 120°), były najchłodniejsze. Wiosną ich temperatury były niższe o 2,5°C od średniej sezonu, latem prawie o 1,5°C, jesienią o około 3°C a zimą o prawie 5°C (tabl. 3 i 4, fig. 3).

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