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SEASONAL PECULIARITIES OF THE TEMPERATURE AND ATMOSPHERIC CIRCULATION REGIMES IN THE ARCTIC AND ANTARCTIC

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FOREWORD

The present paper by Professor Pogosian is of topical interest in view of the greatly increased attention which has been given in recent years to the meteorology of the Arctic and Antarctic regions. It is published with the approval of the president of the WMO Commission for Aerology who has stated that it will be considered by the coming third session of the commission as a working document. The agenda for that session will include questions relating to the meteorology of the polar regions.

The paper was written in Russian, but to facilitate its study by those meteorologists who do not read Russian, the Permanent Representative of the USSR with the World Meteorological Organization has consented to its publication in English. Summaries of the paper are given in the three other official languagesof the Organization - French, Russian and Spanish.

The World Meteorological Organization is indebted to the director of the Canadian Meteorological Service for translation of the paper from the original Russian.

(D.A. Davies)
Secretary-General

SEASONAL PECULIARITIES OF THE TEMPERATURE AND ATMOSPHERIC CIRCULATION REGIMES IN THE ARCTIC AND ANTARCTIC

Summary

The similarities and differences in the meteorological conditions in the extreme latitudes of the two hemispheres are demonstrated by a comparison of the temperatures, winds and other parameters of the Arctic and Antarctic.

The common features are governed by the seasonal radiation conditions and the differences by the character of the underlying surface, on which the formation of the tropospheric temperature field depends. This explains the greater intensity of the inter-latitude exchanges of air between the middle latitudes and the central areas of the Arctic; it also explains the heat advection towards the North Pole area, and the comparatively weak exchange of air in the Antarctic and heat advection towards the central areas of Antarctica.

CARACTERISTIQUES SAISONNIERES DES REGIMES DE LA TEMPERATURE ET DE LA CIRCULATION ATMOSPHERIQUE DANS L'ARCTIQUE ET L'ANTARCTIQUE

Résumé

Les similitudes et les différences des conditions météorologiques existant aux latitudes extrêmes des deux hémisphères ressortent d'une comparaison entre les températures, les vents et autres paramètres de l'Arctique et de l'Antarctique.

Les traits communs résultent des conditions saisonnières du rayonnement, et les différences de la physionomie de la surface sous-jacente, dont dépend la formation du champ de la température troposphérique. C'est pourquoi l'intensité des échanges de masses d'air entre les latitudes moyennes et les parties centrales de l'Arctique est plus forte; pour la même raison, il existe une advection thermique vers la région du pôle nord, et des échanges relativement faibles de masses d'air dans l'Antarctique ainsi qu'une advection thermique vers les parties centrales de cette dernière région.

СЕЗОННЫЕ ОСОБЕННОСТИ РЕЖИМА ТЕМПЕРАТУРЫ И АТМОСФЕРНОЙ ЦИРКУЛЯЦИИ В АНТАРКТИКЕ И АРКТИКЕ

Резюме

Путем сопоставления температуры, ветра и других показателей в Арктике и Антарктике, показаны общность и различия метеорологического режима в высоких широтах обоих полушарий. Общие черты обусловлены сезонными радиационными чловиями, различия – характером подстилающей поверхности, от которой зависит формирование поля температуры тропосферы. Этим определяется более интенсивный междуширотный воздухообмен между средними широтами и центральными районами Арктики и адвекция тепла в район северного полюса, как и сравнительно слабый воздухообмен в Антарктике и адвекция тепла в центральные районы Антарктиды.

PECULIARIDADES ESTACIONALES DE LOS REGIMENES DE TEMPERATURA Y DE CIRCULACION ATMOSFERICA EN EL ARTICO Y EN EL ANTARTICO

Resumen

Las semejanzas y las diferencias de las condiciones meteorológicas en las latitudes extremas de los hemisferios se demuestran comparando las temperaturas, los vientos y otros parámetros del Artico y del Antártico.

Las características comunes se rigen por las condiciones estacionales de radiación y las diferencias por el carácter de la superficie subyacente, de la que depende la formación del campo de temperatura troposférica. Esto explica la gran intensidad de los intercambios interlatitudes de aire entre las latitudes medias y las zonas centrales del Artico; también explica la entrada de calor hacia la zona del Polo Norte, y el intercambio de aire comparativamente reducido en el Antártico, así como la entrada de calor hacia las zonas centrales del Antártico.

SEASONAL PECULIARITIES OF THE TEMPERATURE AND ATMOSPHERIC CIRCULATION REGIMES IN THE ARCTIC AND ANTARCTIC

The International Geophysical Year opened new possibilities for the study of atmospheric processes on a truly global extent. Owing to the establishment of new meteorological, aerological and other related forms of observations, the meteorological regime and, in particular, the atmospheric circulation of both hemispheres may now be studied with greater success than ever before. Particularly valuable is the wide complex of observations taken in the framework of IGY on the sixth continent which has hitherto been difficult of access; for the first time, it is possible to study the atmospheric processes in Antarctica in conjunction with those in the middle and low latitudes of the southern hemisphere.

In the present paper an attempt is made to establish some characteristic features of the vertical distribution of temperature and wind in different seasons and to determine some peculiarities of the atmospheric circulation over the Antarctic. The results are compared with the temperature and wind regimes of the Arctic for the purpose of revealing similarities and differences in these regimes caused by physical-geographical conditions.

Our studies have revealed that many common features exist, side by side with essential differences, in the vertical distribution of temperature and wind over the central regions of the Arctic and Antarctic. The common features are governed by the seasonal variation of radiation conditions, the differences by the character of the underlying surface and, consequently, by the intensity of heat advection.

Owing to radiation conditions in the central Arctic and Antarctic, the air temperature in the upper troposphere of both Pole regions is lower all year round than in the respective middle latitudes; but in the lower troposphere this is true only during the colder half of the year. Moreover, the Antarctic troposphere is all year round, on the average, 10 - 12°C colder than that of the Arctic. The same holds true for the Antarctic stratosphere but only in winter and partly so in the transitional seasons.

The vertical distribution of temperature over drifting ice-floe stations "NP-4" and "NP-7"* in the Arctic and over station Amundsen-Scott at the South Pole are compared in Table 1. In winter, as can be seen from Table 1, the difference between Arctic and Antarctic mean temperatures is 12 to 18°C near the Antarctic ice shield, i.e., at the 650- to 600-mb pressure level, decreasing to 6 to 7°C in the upper troposphere and increasing again to 10 to 12°C in the stratosphere.

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* NP stands for North Pole.

In summer, these temperature differences are nearly of the same order in the troposphere but approach zero above the 200-mb level.

Table 1 contains also the vertical distribution of temperature over NP-7 in the Arctic in July 1958 after the radiosonde data were corrected for the radiation error of radiosondes. According to these data the lower stratosphere was 1 to 4°C colder in 1958 than in preceding years. If the temperature difference between stations Amundsen-Scott and NP-7 in summer is determined from July of the 1958 data, the equalization of Arctic and Antarctic temperatures occurs at the 200-mb level and the sign of that temperature difference becomes reversed at the 100-mb level, i.e., at the 100-mb level and above the Arctic becomes colder than the Antarctic. It is very likely that still lower temperatures are characteristic of the Arctic stratosphere and that the most probable cause of this phenomena lies in the somewhat greater warming of the ozone layer over the Antarctic due to the absorption of greater amounts of radiation reflected from the Antarctic ice shield than from the Arctic ice (Wexler). However, the final solution of this problem is possible only after the accumulation of more reliable observational data.

Beside this special phenomenon, quite considerable differences undoubtedly exist between the Arctic and Antarctic tropospheric temperatures all year around and between stratospheric temperatures in winter. Let us examine the factors which most probably cause these differences.

In [1] dealing with the results of studies of the character of inter-latitudinal exchange in the northern and southern hemispheres, it was shown that the inter-latitudinal exchange in the northern hemisphere occurs on a much larger scale than in the southern hemisphere [1]. Judging by the mean structure of the tropospheric temperature and pressure fields, warm air advection in the northern hemisphere from low to high latitudes prevails along some meridians and cold air advection from high to low latitudes along other meridians. Owing to the distribution of continents and oceans in the northern hemisphere and, consequently, to the different rates of warming and cooling of the air above them, the exchange between high and low latitudes of the northern hemisphere is more intense in winter than in summer and fall.

The inter-latitudinal exchange over the southern hemisphere occurs on a comparatively smaller scale. Although meridional upper-flow patterns and even the development of cut-off lows and blocking highs is observed there, the inter-latitudinal exchange is, in contrast to the northern hemisphere, more localized and occurs on a smaller scale because of the uniformity of the underlying surface between latitudes 35 and 65°S. This smaller scale inter-latitudinal exchange is realized most frequently by cyclonic and anticyclonic activity. The intense exchange between low and high latitudes occurs during the realization of those meridional deformations in the upper temperature and pressure fields which lead to the "blocking" of pressure systems.

The nearly zonal isotherm pattern of the underlying surface and the presence of a huge continent, surrounding the South Pole somewhat asymmetrically, do not favour vigorous inter-latitudinal exchange in high latitudes of the southern hemisphere. The conditions are reversed in the northern hemisphere.

Table 1

MEAN TEMPERATURES OF AND DIFFERENCES BETWEEN
STATIONS NP-4 + NP-7 AND AMUNDSEN-SCOTT IN WINTER (a) AND SUMMER (b), IN °C

(a)														
Pressure in mb	1000	900	850	800	700	650	600	500	400	300	200	100	50	30
Mean temperature over NP-4 and NP-7 in winter (January 1957 and 1958)	-28.5	-22.6	-21.4	-22.2	-24.9	-27.6	-30.8	-38.3	-47.7	-58.2	-64.0	-68.2	-	-
Mean temperature over Amundsen-Scott station in winter (July-August 1957)	-	-	-	-	-	-46.2	-43.7	-44.7	-54.2	-65.6	-74.4	-80.5	-	-
Difference	-	-	-	-	-	18.6	12.9	6.4	6.5	7.4	10.4	12.3	-	-
(b)														
Mean temperature over NP-4 and NP-7 in July of 1956 and 1957	-	-0.2	-1.2	-2.6	-6.8	-9.7	-13.1	-21.0	-31.5	-42.5	-39.2	-36.8	-	-
Mean temperature over NP-7 in July of 1958	-	(-0.2)	(-1.0)	(-2.7)	(-8.0)	(-11.0)	(-14.2)	(-21.7)	(-31.8)	(-44.1)	(-43.0)	(-40.8)	(-39.8)	(-40.1)
Mean temperature over Amundsen-Scott station (Dec. 1957 to Jan. 1958)	-	-	-	-	-	-26.0	-28.8	-35.2	-43.6	-50.7	-43.6	-37.8	-35.9	-
Difference	-	-	-	-	-	16.3	15.7	14.2	12.1	8.2	4.4	1.0	-	-

Alternation of meridionally-extended continents, absence of land mass around the North Pole and free access of warm Atlantic waters toward the Pole, contribute to an intense inter-latitudinal exchange even in high latitudes of the northern hemisphere [2].

The graphs in Figure 1, representing the variation of mean monthly temperature with height in winter and summer at stations : NP-4, NP-7, Amundsen-Scott, Sovetskaya, Vostok and Byrd, demonstrate also the character of the vertical temperature distribution in the Arctic and Antarctic. The curve of the vertical temperature distribution over Yakutsk has been included for comparison.

The geographical coordinates and the height above sea level of stations represented in Figure 1 are given in Table 2.

Table 2

GEOGRAPHICAL COORDINATES AND THE HEIGHT ABOVE SEA LEVEL OF STATIONS INVOLVED

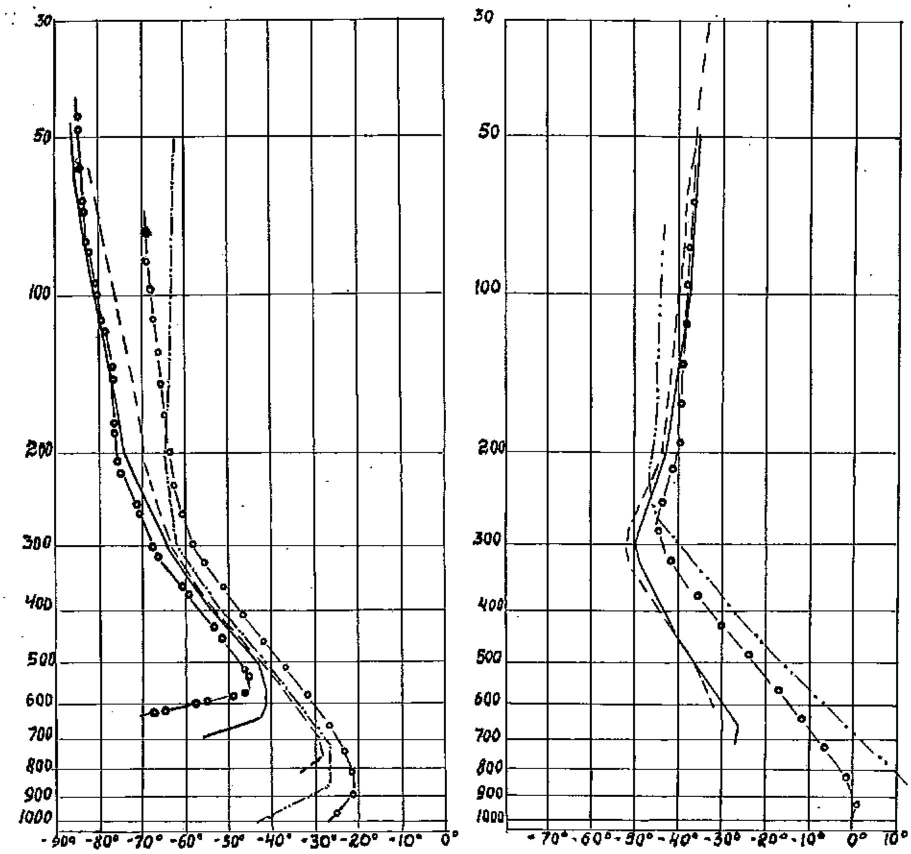
Name of Station	Period	Latitude	Longitude	Height above sea level in m*
NP-4	January 1957	87.7 - 86.0°N	11.2 - 6.9°E	-
NP-7	July 1957	83.8 - 85.1°N	166.9 - 173.6°W	-
NP-7	January 1958	85.8 - 85.7°N	166.6 - 156.6°W	-
NP-7	July 1958	87.1 - 87.5°N	135.3 - 120.1°W	-
Amundsen-Scott	-	90°S	00°00'	2750
Sovetskaya	-	78°24'S	87°35'E	3700
Vostok	-	78°27'S	106°52'E	3420
Byrd	-	80°00'S	120°00'W	1515
Yakutsk	-	62°05'N	129°45'E	103

* The height data of Antarctic stations are approximate.

It follows from Figure 1 that in winter the lowest temperatures are observed at the stations Sovetskaya and Vostok situated at a comparatively high elevation in the interior of the Antarctic continent. In correspondence with the geographical location of Antarctic stations involved, the mean surface temperature in July 1958 was -69.6°C at Sovetskaya, -65.2°C at Vostok and only -56.7° at Amundsen-Scott. These differences disappear rapidly with height. The lowest temperatures so far observed at Antarctic stations are -74.4°C at Amundsen-Scott on 18 September 1957 and -87.4°C at Vostok, 12° north of the

Figure 1

DISTRIBUTION OF MEAN TEMPERATURE WITH HEIGHT IN THE ARCTIC AND ANTARCTIC IN WINTER AND SUMMER



Winter Summer

(a) Winter

————————	Mean temperature, July and August, 1957, at Amundsen-Scott
— — — — —	Mean temperature, July 1957, at Byrd
— oo — oo —	Mean temperature, July 1957, at Sovetskaya
— o — o —	Mean temperature, January 1957 and 1958, at NP-4 and NP-7
— •• — •• —	Mean temperature, January 1958, at Yakutsk;

(b) Summer

————————	Mean temperature, Dec. 1957 and Jan. 1958, at Amundsen-Scott
— — — — —	Mean temperature, January 1958, at Vostok
— o — o — o	Mean temperature, July 1957, at NP-7
— •• — •• —	Mean July temperature at Yakutsk.

former, on 25 August 1958. The latter is the record low temperature for the entire globe. Unusually low temperatures of -81°C and lower were also observed at Sovetskaya in June to August 1958.

Very low temperatures at the earth's surface are usually the result of radiational cooling on calm and clear days within an anticyclone. Since the air over the Antarctic continent is essentially dry because of very low temperatures, it really does not matter for the development of low temperature whether the pressure field is cyclonic or anticyclonic. The main factor here is the calm condition of the air maintained by small horizontal pressure gradients. It should be pointed out that on days with and without extremely low temperatures at the ice surface, the temperature at 1 km above the station level was -40 to -50°C; in other words, the radiational cooling is limited usually to the first one-km layer.

The cause of the vertical temperature distribution over the central parts of the Arctic and Antarctic, shown in Figure 1, must be sought in the different intensities of heat advection from middle latitudes.

Unfortunately, the existing aerological network is still inadequate for a quantitative computation of heat advection either to the Arctic or the Antarctic. For that reason indirect methods have to be applied for the verification of the hypothesis suggested. It is well-known that the regions of intense advection are characterized by large wind speeds. Moreover, the variability of wind speed and direction may be used as a guide in estimating the intensity of advection. Also, the temperature itself varies over wide limits in the regions of intense advection. Conversely, in those parts of the globe where weak advection prevails, the temperature and wind vary on a relatively smaller scale.

In accordance with radiation conditions, the temperature in the central Arctic and Antarctic, with the exception of that in the summer stratosphere, may rise only on account of heat advection from middle latitudes. The curves of vertical distribution of temperature and wind at different latitudes of both hemispheres indicate that heat advection weakens as one goes from middle latitudes to the central Arctic and Antarctic. However, this phenomenon is more pronounced in the Antarctic than in the Arctic.

The occurrence frequency of temperature for a number of Arctic and Antarctic stations in 1958 is given in Table 3 in 5°C intervals. As can be seen from this table, the observed temperatures at all levels, particularly at the 100-, 50- and 30-mb pressure levels over NP-7, were within the limits of -35 to -80°C and that the temperature range increases with increasing height. The highest occurrence frequency of temperature in a 10°C interval, expressed in percentages in the last column of Table 3, varies from 46 to 73% at NP-7 in the Arctic. A different temperature frequency exists over the Antarctic. Here the occurrence of temperature is confined mainly to 2 to 3 adjacent 5°C intervals instead of 6 to 10 at NP-7 in the Arctic, and also the percentage of highest temperature frequency in a 10°C interval is considerably higher than at NP-7. It is interesting to note that, while the temperature at NP-7 in January varied between -45 to -80°C at the 200-mb level and between -40 to -80°C at the 50-mb level, the maximum temperature over Amundsen-Scott and Sovetskaya

T a b l e 3

THE FREQUENCY OF AIR TEMPERATURES IN 5 AND 10°C INTERVALS IN WINTER

P	Number of cases	Mean monthly temperature	-20 to -25	-25 to -30	-30 to -35	-35 to -40	-40 to -45	-45 to -50	-50 to -55	-55 to -60	-60 to -65	-65 to -70	-70 to -75	-75 to -80	-80 to -85	-85 to -90	Highest frequency of temperature in a 10°C interval
Station NP-7, January, 1958																	
Surface	28	-30.0	6	9	4	7	2	-	-	-	-	-	-	-	-	-	54
300 mb	31	-58.7	-	-	-	-	-	1	6	12	11	1	-	-	-	-	74
200 mb	31	-62.7	-	-	-	-	-	2	3	3	12	7	3	1	-	-	61
100 mb	30	-64.9	-	-	-	-	-	4	3	-	1	11	11	-	-	-	73
50 mb	24	-65.7	-	-	-	-	3	1	1	1	2	5	4	7	-	-	46
30 mb	17	-64.5	-	-	-	1	2	1	1	1	1	2	2	6	-	-	47
Station Amundsen - Scott, July, 1958																	
Surface	14	-56.7	-	-	-	-	-	3	5	2	1	3	-	-	-	-	57
300 mb	22	-65.6	-	-	-	-	-	-	-	-	10	12	-	-	-	-	100
200 mb	22	-73.9	-	-	-	-	-	-	-	-	-	1	15	5	1	-	91
100 mb	21	-81.3	-	-	-	-	-	-	-	-	-	-	-	5	16	-	100
50 mb	5	-88.3	-	-	-	-	-	-	-	-	-	-	-	-	1	4	100
30 mb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Station Sovetskaya, July, 1958																	
Surface	31	-69.6	-	-	-	-	-	-	4	2	1	9	7	5	3	-	52
300 mb	23	-65.1	-	-	-	-	-	-	-	1	10	11	1	-	-	-	91
200 mb	23	-75.4	-	-	-	-	-	-	-	-	-	-	11	12	-	-	100
100 mb	19	-81.8	-	-	-	-	-	-	-	-	-	-	-	5	12	2	89
50 mb	5	-84.0	-	-	-	-	-	-	-	-	-	-	-	-	4	1	100
30 mb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Station Vostok, July, 1958																	
Surface	20	-65.2	-	-	-	-	-	-	-	5	6	6	3	-	-	-	60
300 mb	8	-64.0	-	-	-	-	-	-	-	1	3	4	-	-	-	-	88
200 mb	8	-76.4	-	-	-	-	-	-	-	-	-	-	4	3	1	-	88
100 mb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50 mb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30 mb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Station Byrd, July, 1958																	
Surface	7	-32.1	2	1	3	-	1	-	-	-	-	-	-	-	-	-	57
300 mb	17	-65.0	-	-	-	-	-	-	-	-	-	7	10	-	-	-	100
200 mb	17	-70.7	-	-	-	-	-	-	-	-	-	1	6	9	1	-	88
100 mb	16	-77.6	-	-	-	-	-	-	-	-	-	-	1	3	5	7	75
50 mb	4	-86.5	-	-	-	-	-	-	-	-	-	-	-	-	-	4	100
30 mb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

in the Antarctic in July never rose above -65°C at the 200-mb and above -80° at the 50-mb level.

Since the radiation conditions in the lower troposphere of the Arctic and Antarctic are approximately similar, the comparatively high Arctic temperatures may be considered to be the result of a more intense inter-latitudinal exchange. Against this, the small range of the temperature variation and low temperature itself in the Antarctic indicate an inter-latitudinal exchange on a more modest scale.

We would like to point out that during the first twenty days of January 1958, the area of intense cold in the upper layers of the central Arctic was situated more or less symmetrically around the Pole and the jet streams in the stratosphere encircled the northern hemisphere nearly along the Arctic circle. In the last part of January, a strong warming occurred in the central Arctic as a result of increased inter-latitudinal exchange. High temperatures of the order of -41 to -45°C were observed in the upper levels of the central Arctic during these days. In consequence of this warming, the area of intense cold at the upper levels shifted to the European and West Siberian sector of the Arctic whereas over the Canadian sector of the Arctic, in which inter-latitudinal exchange occurred, temperature rose simultaneously with the central Arctic.

Such temperature variations in the central Arctic are quite frequent. According to Table 3, this is not the case in central Antarctica. Although Table 3 is composed of data of one to two winter months of 1958, the observations taken in 1957 support our general conclusion. Also according to these data the inter-diurnal variability of temperature in the Arctic is considerably greater than in the Antarctic.

The differences between maximum and minimum temperatures at upper levels over both Poles in the winter months of 1957 are given in Table 4.

According to Table 4, the indicated differences are considerably greater in the Arctic than in Antarctica. At the 400-mb pressure level these differences are but half as large in the extreme south as in the extreme north. This also points to a less intense inter-latitudinal exchange in Antarctica and consequently to the comparatively smaller heat advection there. Actually, when the temperature at the 500-mb level over the North Pole region in January rises, every now and then, up to -21 to -23°C from the usual -40 to -45°C, it is mainly due to warm air advection there. Although descending motions may play a certain part in the temperature rise, heat advection is to be held as a main factor in this temperature rise [3].

Different wind regimes over central Antarctica and the Arctic also point to different intensities of the inter-latitudinal exchange and heat advection in these regions. According to observations, weak winds are characteristic of central Antarctica. Even in mid-winter, strong winds are relatively rare deep in Antarctica. Contrary to this, upper winds in the central Arctic are characterized by great speeds and inter-diurnal variability. Winds speeds and directions over NP-7 in the Arctic, Amundsen-Scott, Sovetskaya and Byrd in Antarctica are compared in Table 5. According to this table, the wind speed

Table 4

DIFFERENCES BETWEEN MAXIMUM AND MINIMUM TEMPERATURES AT UPPER LEVELS OF THE ARCTIC AND ANTARCTIC IN WINTER

Isobaric surfaces	1000	900	850	800	700	600	500	400	300	200	100	50
Arctic : NP-4, January 1957 (87.7 to 86.0°N. 11.2 to 6.9°E)												
Difference	37.1	29.7	27.4	23.2	18.5	15.6	14.3	16.3	12.8	13.2	13.1	-
Number of cases	20	30	31	31	31	31	31	31	31	30	21	-
NP-6, January 1958 (78.8 to 78.9°N, 161.7 to 164.2°E)												
Difference	28.8	22.7	21.6	21.3	13.3	9.0	22.0	24.6	36.0	33.0	-	-
Number of cases	28	29	29	29	29	29	29	28	15	8	-	-
Antarctica : Amundsen-Scott, July 1957												
Difference	-	-	-	-	-	-	18.8	8.0	6.8	13.7	5.0	5.6
Number of cases	-	-	-	-	-	-	4	9	9	9	6	3
Amundsen-Scott, August 1957												
Difference	-	-	-	-	-	-	11.4	12.7	7.4	8.7	12.8	5.3
Number of cases	-	-	-	-	-	-	6	18	18	18	17	11
Byrd, July 1957												
Difference	-	-	-	-	-	20.0	12.3	10.6	9.7	12.1	13.8	7.0
Number of cases	-	-	-	-	-	18	18	18	18	16	14	11

in the stratosphere over NP-7 in January 1958 varied over wider limits than over the Antarctic stations mentioned. For instance, the observed wind speeds over NP-7 were from weak to 90 km/h at the 200-mb level and from 31 to 150 km/h at the 50-mb level. The wind speed at 200 mb over Amundsen-Scott in July 1958 did not exceed 90 km/h whereas only wind speeds below 30 km/h occurred at the 50-mb level. Comparable speeds were also observed over Sovetskaya. Only over Byrd, which is situated not far from the coast, did the wind speed vary over wider limits. However, even here the wind speed at the 200 mb level exceeded 90 km/h only in two cases out of 16.

An analogous wind regime in the Arctic and Antarctic was also observed in 1957. It is sufficient to compare frequencies of wind speeds at Mirnyi and Amundsen-Scott in July 1957 with those at Murmansk and NP-4 for the period from December 1956 to January 1957. The latter stations lie approximately at the same latitude as the former. The corresponding frequencies are tabulated in Table 6.

It follows from the latter table that the differences in wind speed distribution at the 200 to 100 mb level between Murmansk and NP-4 are not as great as between Mirnyi and Amundsen-Scott. While wind speeds at the 200- and 100-mb levels over Mirnyi vary with equal frequencies in the interval from weak wind up to 200 and more km/h, this variation range is considerably narrower over the South Pole where the winds become prevailingly weak.

It follows from the previous discussion that well-developed upper-frontal systems and cyclonic and anticyclonic activity, i.e., the inter-latitudinal exchange and heat advection, are considerably weaker over the South Pole than over the North Pole.

As concerns the wind direction at NP-7 (Table 5), west and north winds occur with nearly equal frequency in the surface layers whereas west winds prevail at upper levels.

At the 100-mb level over the South Pole the wind direction is prevailingly between 136 and 045° of the compass, over Byrd from W and partially from N. Unfortunately, the wind record of Sovetskaya is too short for comparison. However, even this short record indicates the prevalence of E winds near the ground with a sharp drop in their frequency at the 300-mb level.

The inter-diurnal temperature variation in the stratosphere decreases considerably in summer. Already at the 100-mb level over NP-4 and NP-7 in July as well as over stations Amundsen-Scott, Vostok and Byrd in January, the difference, daily maximum - daily minimum, remains below 5 to 7°C. In other words, the stratospheric temperature regime over the Arctic and Antarctic is nearly the same (Figure 1). It is true that at the 300- and 200-mb levels this difference is considerably larger over the North Pole (12 - 17°C) than over the South Pole (5 to 9°C). Wind distribution complies with the vertical temperature distribution at both Poles. Below 200 mb over Antarctic stations the wind speed frequently exceeds 60 km/h and over NP-7 90 km/h. However, above the 100-mb level at both Poles the wind speed decreases sharply and rather seldom exceeds the 10 to 30 km/h interval. The prevailing westerly winds at 18 - 22 km

Table 6

FREQUENCY OF WIND SPEED AT MURMANSK AND NP-4 IN DECEMBER TO JANUARY 1956/1957

AND AT MIRNYI AND AMUNDSEN-SCOTT IN JULY 1957

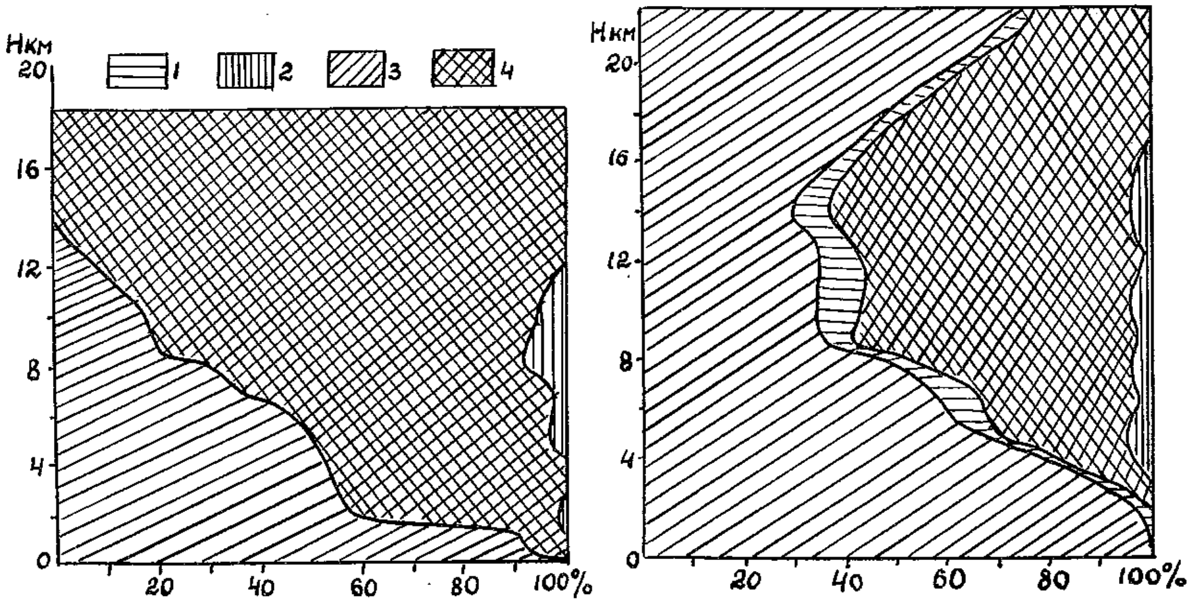
P	Number of cases	Wind speed in km/h							P	Number of cases	Wind speed in km/h						
		0-30	31-60	61-90	91-120	121-150	151-200	>200			0-30	31-60	61-90	91-120	121-150	151-200	>200
					Murmansk									NP-4			
300	26	5	11	8	2	-	-	-	300	29	4	10	9	3	2	1	-
200	21	2	12	5	-	2	-	-	200	30	5	12	3	6	4	-	-
100	9	2	4	2	-	1	-	-	100	20	4	7	7	1	1	-	-
50	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-
					Mirnyi									Amundsen-Scott			
300	29	8	9	1	6	2	1	2	300	11	6	5	-	-	-	-	-
200	26	6	4	6	5	-	4	1	200	7	5	1	-	1	-	-	-
150	23	5	5	4	3	2	3	1	150	4	3	1	-	-	-	-	-
100	13	2	2	4	1	1	1	2	100	2	2	-	-	-	-	-	-
50	2	-	-	-	2	-	-	-	50	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-

height usually change to easterly above and spread over nearly the entire southern hemisphere. In the stratosphere of the northern hemisphere westerly winds prevail in winter. The change of seasons in both hemispheres is accompanied by the change of wind direction in corresponding stratospheres.

The frequency of the zonal component of wind over Mirnyi in 1956, as compiled by G.M. Tauber [4] from Leonov's data, is presented in Figure 2. As can be seen, the westerly component at Mirnyi in winter (July) becomes prevalent above 2 - 3 km. The easterly component so characteristic at the surface disappears completely at a height of 13 - 14 km.

Figure 2

FREQUENCY OF ZONAL AND MERIDIONAL COMPONENTS OF UPPER WINDS AT MIRNYI IN 1956



July 1956 December 1956

1 - The southerly component

2 - The northerly component

3 - The easterly component

4 - The westerly component

In summer (December) conditions are reversed. The easterly component prevails up to 7 - 8 km, the westerly in the upper troposphere and lower stratosphere up to 16 to 17 km. Above that height, particularly above 20 km, the easterly component becomes the basic characteristic of wind direction. Analogous seasonal distribution of wind direction seems to be the case also at other Antarctic coastal stations.

Other indirect evidence supports also our thesis on the governing role of advection.

If the frequency of migratory cyclones over the northern and southern hemispheres are studied, significant differences between them can be established. In the Arctic sector, bounded by Greenland, the North Pole and Taimyr, the frequency of migratory cyclones is incomparably greater than in any Antarctic sector, not to mention the South Pole region itself [2, 5, 6]. However, this difference is not the heart of the matter. As a result of large-scale meridional deformations in the temperature and pressure field of the northern hemisphere, cyclone families frequently penetrate into the Arctic from the Atlantic. If this process lasts for some time, an advective temperature rise of a magnitude never observed in central Antarctica takes place in the Arctic sector outlined above. In winter the temperatures in the Arctic rise quite frequently to -10 to -5°C and in individual cases to -5 - 0°C [7]. This is also verified by Figure 3, representing the annual variation of upper-air temperatures at Barentsburg at 78°N. Large differences between the maximum temperatures of the Antarctic and Arctic are also observed during the remaining seasons of the year.

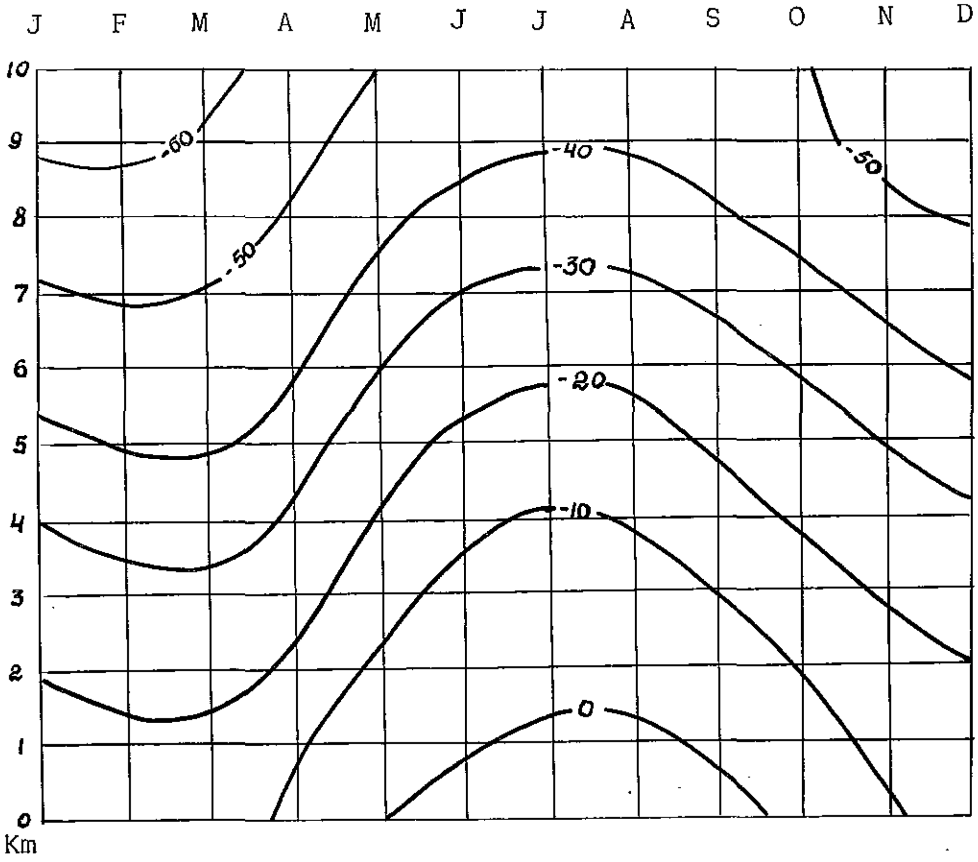
Differences in the distribution of the maximum and minimum temperatures and upper-wind speeds, as well as in the characteristics of the atmospheric circulation, are the result of different physical-geographical conditions in the extreme north and south of the Earth.

The boundary of drift and pack is located at different distances from the North and South Poles. The North Pole is situated close to the open waters of the Atlantic and Barents Sea, approximately at a distance of 1000 km from the drift ice boundary at Spitzbergen.

The situation is different in the Antarctic. Here, owing to the vast ice-covered Antarctic continent, the mean boundary of drift ice is located, on the average, at a distance of 2000 km in summer and of 3000 km in winter from the South Pole. This difference in the distribution of ice around the North and South Poles has a different cooling effect on air masses moving from middle latitudes towards the Poles. In accordance with the distance of the ice boundary, the cooling of air masses is considerably greater over the vast ice surface of the Antarctic than in the Arctic and, in particular, in the Atlantic-European sector of the latter. Intense cooling of warmer air masses advected to the Antarctic from middle latitudes is also responsible for comparatively small horizontal temperature gradients and, consequently, for low wind velocities here, which, as was established earlier, are particularly small over central Antarctica. On the other hand, small wind velocities here are indications of a poor inter-latitudinal exchange in central Antarctica, although the latter is fairly intense in middle latitudes of the southern hemisphere.

Figure 3

ANNUAL VARIATION OF UPPER-AIR TEMPERATURE AT BARENTSBURG



It has been demonstrated by a number of examples in [8] that in the case of strong meridional deformations in middle-latitude temperature and pressure fields, a strong inter-latitudinal exchange usually extends to the periphery of Antarctica. The interior regions of Antarctica appear to be outside of the strong inter-latitudinal exchange. This is indicated also by a sharp decline in the inter-diurnal variability of temperature in central Antarctica as compared to its periphery.

As a result of cooling of air masses over both Polar regions, cold air pools and low pressure areas develop in their tropospheres. Their intensification and extension into the stratosphere in winter brings about the development of the westerly jet stream near the southern polar circle. In summer, contrary to the winter, high pressure and an easterly stratospheric jet develop above the tropospheric cold air as a result of warming of air in the ozone layer.

Two decades ago Arctic explorers refuted the idea of a stationary Arctic anticyclone. At the present, nobody questions the equiprobability of cyclonic and anticyclonic activity in the Arctic.

With respect to Antarctic circulations, no such unified viewpoint exists as yet, mainly because of the lesser meteorological study of the Antarctic. Besides, the Antarctic ice shield makes the latter much more complex than in the Arctic.

It is known that, in the north, the pressure systems may migrate to all Arctic sectors and may, unimpeded, move across the North Pole itself. The motion of pressure systems in the Antarctic is much more complex. Here, the migratory cyclones and anticyclones, encountering the elevated ice-covered continent having a mean height up to 3 km, become deformed in the lower one-third of the troposphere. It is only above that height that the air currents may freely move across the Antarctic continent in any direction. Depending upon circulation processes of the southern hemisphere, the upper-flow patterns over different Antarctic sectors may have cyclonic or anticyclonic curvature. Due to the sparse observational network in the interior of Antarctica, it is impossible to follow the displacement of pressure systems there. Nevertheless, it is not difficult to arrive at the conclusion that their motions cannot be similar to those in the Arctic. Let us determine by analysis which pressure systems are likely to move across Antarctica.

Developing pressure systems with concentric isobar patterns, having a small vertical extent, become deformed while striking the elevated Antarctic continent. Only their upper-frontal zones with the corresponding wind fields above the ice shield remain undeformed. High cold lows and warm highs, being of a stationary nature, cannot move across Antarctica. Evidently cyclones and anticyclones in their most intense stage of development, i.e., when they are still characterized by a concentric isobar (contour) system in the mid-troposphere, are capable of penetrating deep into the interior of Antarctica. However, in proportion to their progress toward the interior, the concentric form of isobars (contours) must gradually disappear due to the cooling of participating air masses and deformations in their temperature and pressure fields. Evidently, even in such exceptional cases, pressure systems may penetrate only into the borderlands of Antarctica. It is not accidental that, in attempts to plot the tracks of pressure systems in Antarctica, this can more readily be done only in its peripheral regions.

By virtue of differences in the physical-geographical conditions between the northern and southern polar regions, differences exist also in the structure of the seasonal temperature and pressure fields.

Owing to the small scale of the inter-latitudinal exchange at high latitudes of the southern hemisphere, the symmetrical distribution of the ice masses with respect to the centre of the continent and the intense cooling of air masses arriving here from middle latitudes, a pool of cold develops over Antarctica. An analogous pool of cold is known to exist also in the Arctic. The difference between these pools of cold is that in winter the Arctic pool of cold between North America and Asia has an elongated form due to the non-uniform cooling of air over adjacent continents and to the localized intense inter-latitudinal exchange in the Arctic sector referred to earlier. In the extreme south, the isotherms outline the Antarctic continent more conspicuously and the seasonal pool of cold has a more concentric form.

The upper pressure fields are also different. In the Arctic, the upper pressure field coincides, in general, with the temperature field. In the Antarctic, frequently-occurring deep cyclones around Antarctica leave noticeable marks in the mid-tropospheric pressure field. Since deep cyclones are frequent in the coastal areas of Antarctica, the horizontal pressure gradient is directed from central Antarctica to surrounding oceans. This is verified by the prevailing east component of wind in the lower half of the troposphere at Mirnyi (Figure 2). Depending upon the motion of cyclones over Antarctica the winds here, as elsewhere, undergo corresponding changes. However, a relative high pressure area over the Antarctic continent appears in the seasonal pressure charts for the 500- and 700-mb levels. The mean monthly contour maps for the 500- and 700-mb levels, constructed by V. Rastorguev and H. Al'vares [9] verify the validity of the latter statement.

Since the pool of cold air in the lower layers is situated over central Antarctica and the horizontal temperature gradient is directed from the periphery of the continent to its centre, the relative high pressure area over central Antarctica weakens continuously with height and becomes a cold low in the lower stratosphere. However, even at the 300-mb level a weak high pressure belt running across the continent is still recognizable in individual months.

As regards the so-called "stationary Antarctic high" expected to develop as the result of cooling of air over a continental ice shield, the following may be said. The relative high pressure area over Antarctica appearing in the mean monthly pressure charts is caused not so much by the radiation conditions as by the frequent cyclonic activity in the periphery of the Antarctic continent. Inter-diurnal variations of the form of the high pressure are related to the general circulation patterns for the southern hemisphere [10]. This is also true in summer with the only exception that a high pressure area, and the east to west advection caused by it, develops in the Antarctic stratosphere due to the warming of air in the ozone layer. As a result of this and of the non-symmetrical form of the Antarctic continent with respect to the Pole, the cyclones coming from the north have a free access to the Ross Sea, Bellinghausen Sea and Weddel Sea where they usually become occluded. Blocking of these cyclones can be traced up to 10 - 15 km. Above these heights cyclones frequently enter in winter into the system of the Antarctic upper cold low.

The intensification of upper-frontal zones and cyclonic activity in the Antarctic occurs during the meridional transformations in the temperature and pressure field caused by warm air advection from the north. At the same time intense outbreaks of cold air take place into the middle latitudes of the southern hemisphere.

Since both the cyclonic and anticyclonic forms of circulation are probable in the Antarctic, considerable pressure variations may be experienced within intervals of a few days.

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