NORSK POLARINSTITUTT
SKRIFTER NR. 136

ERIK WISHMAN

A COMPARISON BETWEEN THE GENERAL CIRCULATION OVER THE SVALBARD AREA AND THE WEATHER CONDITIONS AT ISFJORD RADIO

NORSK POLARINSTITUTT
OSLO 1966

DET KONGELIGE DEPARTEMENT FOR INDUSTRI OG HÅNDVERK

NORSK POLARINSTITUTT
Middelthuns gate 27 b, Oslo 3, Norway

Short account of the publications of Norsk Polarinstitutt

The two series, Norsk Polarinstitutt — SKRIFTER and Norsk Polarinstitutt — MEDDELELSER, were taken over from the institution Norges Svalbard- og Ishavs-undersøkelser (NSIU), which was incorporated in Norsk Polarinstitutt when this was founded in 1948. A third series, Norsk Polarinstitutt — ÅRBOK, is published with one volume per year.

SKRIFTER includes scientific papers, published in English, French or German. MEDDELELSER comprises shorter papers, often being reprints from other publications. They generally have a more popular form and are mostly published in Norwegian.

SKRIFTER has previously been published under various titles:

Nos. 1—11. Resultater av De norske statsunderstøttede Spitsbergen-ekspeditioner.
No. 12. Skrifter om Svalbard og Nordishavet.
Nos. 13—81. Skrifter om Svalbard og Ishavet.
» 82—89. Norges Svalbard- og Ishavs-undersøkelser. Skrifter.
» 90— . Norsk Polarinstitutt Skrifter.

In addition a special series is published: NORWEGIAN—BRITISH—SWEDISH ANTARCTIC EXPEDITION, 1949—52. SCIENTIFIC RESULTS. This series will comprise six volumes, four of which are now completed.

Hydrographic and topographic surveys make an important part of the work carried out by Norsk Polarinstitutt. A list of the published charts and maps is printed on p. 3 and 4 of this cover.

A complete list of publications, charts and maps is obtainable on request.

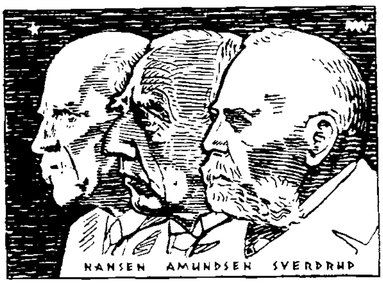
ÅRBØKER

Årbok 1960. 1962. Kr. 15.00.
Årbok 1961. 1962. Kr. 24.00.
Årbok 1962. 1963. Kr. 28.00.
Årbok 1963. 1965. Kr. 35.00.
Årbok 1964. 1966. Kr. 30.00.

NORSK POLARINSTITUTT
SKRIFTER NR. 136

ERIK WISHMAN

A COMPARISON BETWEEN THE GENERAL CIRCULATION OVER THE SVALBARD AREA AND THE WEATHER CONDITIONS AT ISFJORD RADIO



NORSK POLARINSTITUTT
OSLO 1966

PUBLISHED BY NORSK POLARINSTITUTT
On sale only through our distributor
UNIVERSITETSFORLAGET
Postboks 307 — Blindern, Oslo 3

Contents

Abstract

The mean annual variation of the surface wind in the Svalbard area for the 5-year period 1955—59 is illustrated by means of the wind observations from Isfjord Radio on Vestspitsbergen. The wind conditions are further described by means of frequency distributions of lows and highs, and by the motion of individual cyclones in the area in the extreme seasons. The corresponding changes in the various weather elements observed at Isfjord Radio is discussed. Finally, for the period 1957—60, the mean annual variation of the 1000/500 mb thickness over Vestspitsbergen is compared with the corresponding variation of cloud amount and precipitation. The results show that there exists a good correspondence between the annual change of the weather conditions on Vestspitsbergen, and the varying distributions of the low tropospheric air masses and frontal systems in the course of the year.

Introduction

The general horizontal air-circulation on the Northern Hemisphere, as seen e. g. on the monthly mean pressure charts for different levels, has a typical annual course. Using monthly mean zonal wind components as indices, NAMIAS (1947) has described these annual variations for the main wind belts. The seasonal variation of the mean index must be due to a corresponding change in intensity, frequency, and movement of the lows and highs. The works by REED and KUNKEL (1960) and KEEGAN (1958), which deal especially with the arctic regions, show that in the mean the areas of greatest cyclone frequency shift from summer to winter.

In the present paper the annual variation of the surface wind regime in the Svalbard area is described, based upon monthly means of the 5-year period 1 Jan. 1955—31 Dec. 1959. Special attention is given to the corresponding changes in the weather conditions on Vestspitsbergen.

Weather observations from the Svalbard area are sparse, as is the case with most arctic regions. We have here primarily used the observations from Isfjord Radio (78° 04′ N, 13° 38′ E). The observations are taken from the Norsk Meteorologisk Årbok (1955—60). In addition, the weather maps drawn at Ververslinga for Nord-Norge, Tromsø, were utilized. In some cases it was found necessary to re-analyze the maps. The last part, which relates the mean change of the weather at Vestspitsbergen with air mass exchange in the lower troposphere, is restricted to the period 1 Sept. 1957—31 Aug. 1960, when upper air data from Isfjord Radio were available.

The lack of observations in the Svalbard area makes a detailed analysis of the different phenomena impossible. The aim of the present work is only to reveal certain characteristic features, and it is to be hoped that it may serve as useful background information both for the forecaster and for those who might want to do more work on the climatology.

The Svalbard area

By the Svalbard area we here mean the sector extending from the North Pole to 70° N between eastern Greenland and Novaya Zemlya. The area is of about the same order of magnitude as the synoptic weather-systems generally appearing in these regions. The weather observations from Isfjord Radio, which is sited near the center of the area, will therefore generally reflect the effect from weather-systems appearing within the area, assuming that the observations from the station are not significantly influenced by local particularities.

Fig. 1 gives a survey of the area. The mean positions of the ice limits for the extreme months April and August have been inserted. They refer to the period 1929—39, and are taken from the publication by OMDAL (1953). Information

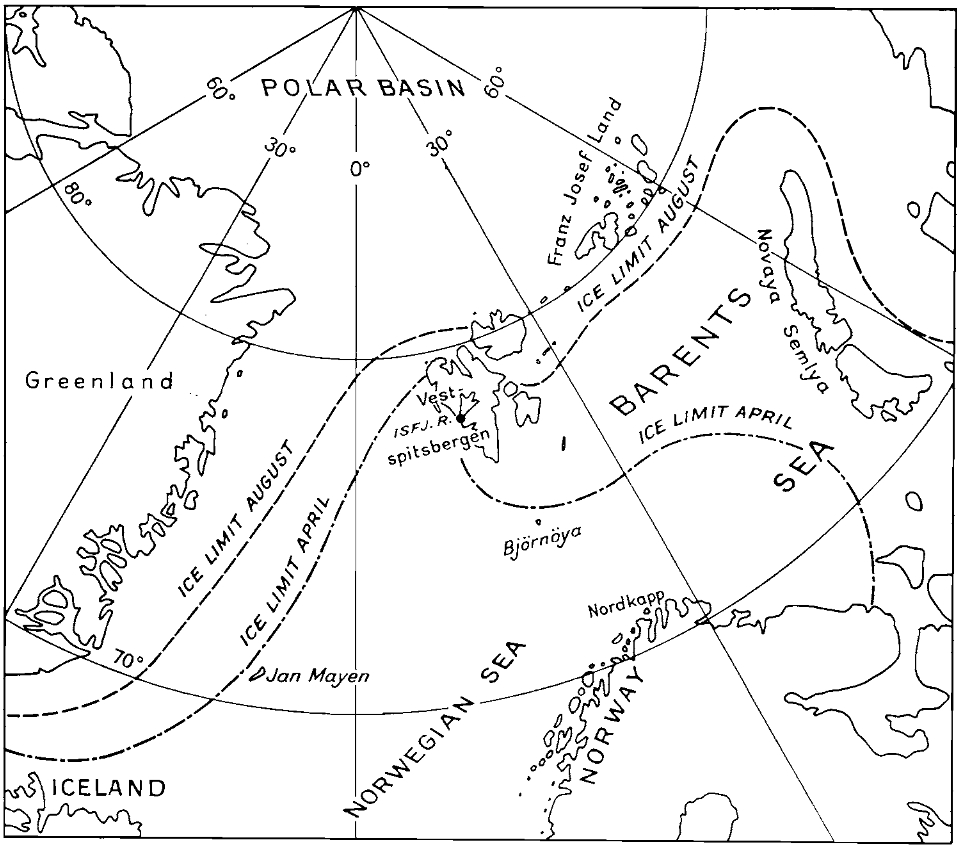


Fig. 1. The Svalbard area. Mean ice limits for April and August after OMDAL *(1953).*

about the extension of the ice for the period 1955—59 has unfortunately not been available, but mean limits will hardly differ significantly for the two periods.

The nature of the Svalbard area deviates fundamentally from the other parts of the Arctic, as it forms the most important break in the continental barrier which otherwise embraces the Polar Basin. Relatively warm ocean currents from the Atlantic penetrate into the Arctic, where they encounter the drifting ice along a curved line, which has its northermost position near the northwest point of Vestspitsbergen. The islands themselves lie in the border area of the ice masses with the open seas to the south. To the west an ice-free bay is formed between the East Greenland ice and Vestspitsbergen. This outstanding feature must influence the atmospheric circulation at Vestspitsbergen. As regards the general circulation of the whole area, the opposition between the ice-covered ocean and the open seas is favourable for the formation or intensification of cyclones over the ice-free waters, at least in the cold season. A preference for cyclones to develop or to be maintained in the southern parts of the Svalbard area is therefore to be expected (Petterssen 1950).

Also of importance for the general circulation is the fact that the area is situated east of the Greenland plateau, which generally means on the lee side in relation to the general tropospheric circulation. This will favour the formation of cyclonic vorticity off the coast of eastern Greenland, and contribute to cyclone development in the Svalbard area.

As a whole, the area is plain. Certainly, Svalbard and Franz Josef Land are mountainous, but they represent a small part of the area and are therefore generally expected to be of secondary importance as far as influences on large scale weather-systems are concerned. The islands are not supposed to act as appreciable hindrances for the movements of the individual lows and highs.

Representativeness of the observations from Isfjord Radio

The winds observed at Isfjord Radio should be representative for every direction, thereby being able to point out the directions to the principal pressure systems at any time. With respect to the other weather elements, they should be representative for the greatest possible part of Vestspitsbergen.

Below, a qualitative description is given of some features concerning the nature around the station, which may influence the representativeness of the observations.

Isfjord Radio is a coastal station sited on the southern bank of Isfjorden, at the mouth of the fjord (see Fig. 2). Its height above sea level is about 10 meters. Isfjorden spreads deep into the central parts of Vestspitsbergen, like a great basin. The main direction of the fjord is SW—NE, but it branches into several fjord-arms towards N and S. Near the mouth it is 12 km wide, which is narrower than the inner parts of the fjord. The land around is mountainous, cut

Fig. 2. Outline map of Svalbard. In addition to Isfjord Radio, the positions of some old stations mentioned in the text are indicated. Concerning the names of these stations, we have kept to those used in BIRKELAND *and* FØYN *(1932).*

through with deep valleys which to a large extent are filled up with glaciers. North of the station, the mountains on the other side of the fjord are about 15 km away. In the NE direction the distance to the mainland varies up to 70 km, depending on the breadth of the fjord. The shore, upon which the station is sited, is an open plain extending southwards. Towards the E the shore meets with a north-south orientated mountain range with tops reaching 500 to 900 m. At a distance of about 5 km south of the station the shore is at its narrowest, about 2 km. From here it broadens, because the mountain range curves towards the southeast. In the sector from south to north-northwest is the sea, sometimes separated from the shore by an icebelt a few km wide, especially in late winter. According to verbal information from the chief telegraphist, who has lived at the station for 5 years, Isfjorden is generally frozen from December to May, apart from the outermost 10 km, where wind and sea often breaks it up.

It is thus seen that the horizon is broken by the mountain range in the southeast sector, between the directions 100 to 150 degrees, and to a less extent also to the east and to the north. Otherwise the area around the station is plain.

From the above, it can be seen that the conditions are favourable for cold airmasses from inland to stream towards the warmer, open sea off the west coast. Because of the nature of this circulation, this effect will, on an average, be greatest in the coldest season. Isfjorden forms a natural outlet for the offshore winds, which will be sligthly increased because of orographic convergence of the streamlines towards the mouth.

From this it follows that the air currents from the quadrant north to east will be somewhat favourized by local conditions. Winds from south-easterly directions are least representative, as the station to a large extent is sheltered against winds from this sector. Fall winds from southeast do not seem to be essential, as there is no height-plateau in the mountains where extensive cold air masses can be produced.

Annual variation of the wind regime

The main features of the annual variation of the wind regime in the Svalbard area will in the following be illustrated by a) annual change of the surface winds at Isfjord Radio, b) frequency of cyclones and anticyclones at different seasons, c) cyclone tracks in the Svalbard area in January and July.

a) Annual variation of the surface wind at Isfjord Radio

Figs. 3 a—b show the mean wind for each month, based upon observations at 1200 GMT. The wind force is given in Beaufort, and the individual observations were referred to the nearest direction divisible by 3 (i. e. to one of the 12 directions 30°, 60°, ... , 330°, 360°) for the calculation of the monthly mean components in the main directions east-west and north-south. $\overline{V_R}$ is the monthly mean wind vector, V_R its scalar value, and V_S is the mean monthly wind force independent of direction. The constancy of the wind, $q = V_R/V_S \cdot 100$, is also given in the diagram. It is a measure of the variability of the wind in the respective months. U, the zonal component of the monthly mean wind vectors (Fig. 3 b), is supposed to be a good indication of the zonal index in the Svalbard area. Fig. 3 c shows the monthly mean pressure difference $P_I — P_B$ at 1200 GMT in the 5-year period, between Isfjord Radio and Bjørnøya. (The latter is situated halfway between Nordkapp in northern Norway and Sørkapp at Vestspitsbergen, at 74°31′ N and 19°01′ E [Fig. 1].) It is seen that the yearly variation in the

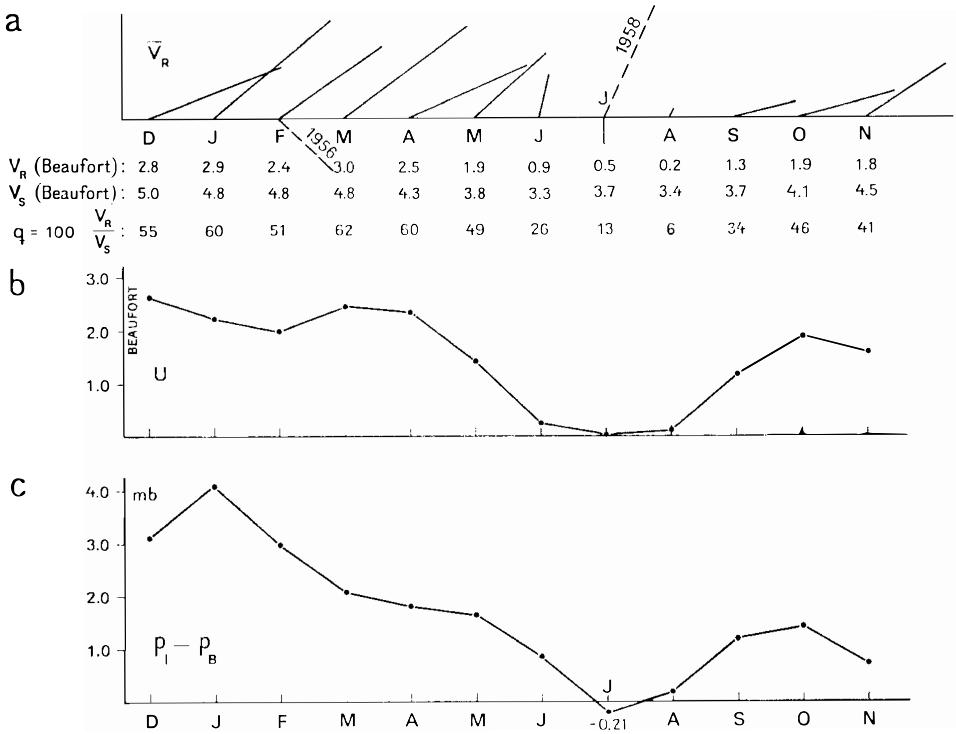


Fig. 3. a) Monthly mean wind vectors at Isfjord Radio for 1200 GMT (1955—59). Vectors of the "abnormal" months February 1956 and July 1958 inserted. V_R is the scalar value of the mean wind vector $\overline{V}_R$ for the respective months; V_S is the mean wind speed. (Beaufort wind scale.) q is the constancy.

b) Annual cycle of the zonal component U of $\overline{V}_R$.

c) Mean monthly pressure differences (mb) between Isfjord Radio and Bjørnøya for 1200 GMT (1955—59).

zonal index corresponds fairly well with the mean pressure difference P_I — P_B, showing that the wind observations at Isfjord Radio approximate the gradient wind and is able to reflect the pressure distribution of a great part of the Svalbard area. Table 1 shows the frequency of the different wind directions observed at 1200 GMT.

Fig. 3 together with Table 1 points out some main features concerning the nature of the annual variation of the surface wind in the Svalbard area. Primarily, it seems possible to divide the year into seasons with comparatively uniform wind conditions. Of longest duration is the period December—April, with the highest constancy, and with pronounced easterly and northerly components. The high constancy in this period is due to the high frequency of northeasterly winds, compared with the rest of the year (Table 1). The period December-April will in the following be referred to as the winter-period.

July forms the opposite extreme with its southerly mean wind vector. This month is supposed to be representative of the main characteristics of the summer-period. The constancy is rather low in July, although higher than in August. As

Table 1.
Percentage frequency of wind directions at Isfjord Radio (1200 GMT, 1955—59).

Direction	02—10	11—13	14—22	23—01	Calms
Dec.	71	2	18	7	2
Jan.	70	1	14	15	1
Feb.	66	4	17	11	2
March	77	0	11	10	2
April	75	1	17	5	2
May	63	0	21	12	5
June	42	1	23	32	3
July	26	1	45	28	0
Aug.	37	0	34	28	0
Sep.	52	2	28	14	4
Oct.	65	2	25	6	2
Nov.	61	2	17	18	2

seen from Table 1, this is due to the uniform scattering of wind direction in August, in contrast to July, which has a pronounced surplus of southerly winds, typical for this month. The spring-period includes May with a marked decrease in constancy compared with the preceding months, though still with a much higher value than in the summer-period. According to Table 1, the decrease in constancy in spring, expresses an increase of the frequency of the southerly winds at the expense of the northeasterly winds.

The autumn-period is of longer duration than spring, and forms a kind of compromise between the winter and the summer conditions. The period lasts at least from September through October and November. For instance, it is seen from Table 1 that the frequency of southerly winds is still rather high in this period, while the frequency of northeasterly winds has not yet reached the winter values. The long duration of the autumn-period gives the annual variation of the wind its typical asymmetric form. It may be mentioned that this feature corresponds qualitatively with that found by NAMIAS for the seasonsal change of the wind in the Northern Hemisphere from 0° to 180° W between 70° and 55° N (NAMIAS 1947).

Fig. 3 further indicates that the air circulation in the Svalbard area changes from a zonal type in the colder part of the year to a more meridional type in the middle of the summer, as seen e. g. from the variation in the zonal component of the mean wind vector. From Table 1 the shift in circulation type is seen by the change in frequencies for the different windsectors, from a surplus of northeasterly winds in the winter season to southerly winds in the summer season. In the transition periods, spring and autumn, there seems to be a more pronounced alternation between zonal and meridional circulation types.

The change-over from one circulation type to the other is also revealed by the annual change of the mean pressure difference $P_I — P_B$ between Isfjord Radio and Bjørnøya. This change agrees well with the features revealed by the mean pressure maps recently published by GOMMEL (1963) and O'CONNOR (1961).

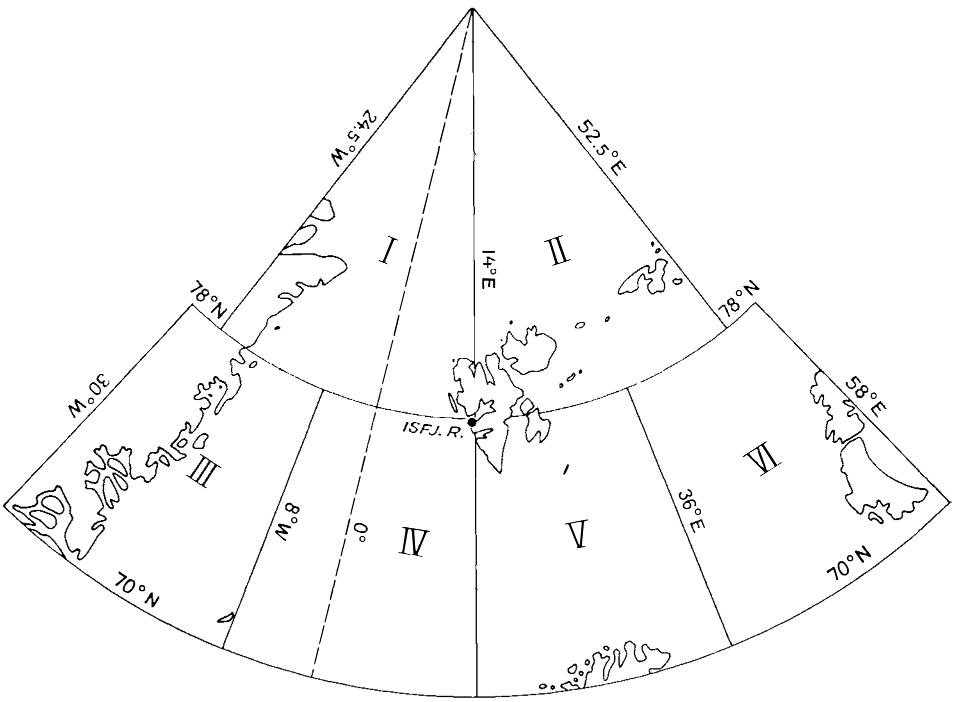


Fig. 4. The Svalbard area with the 6 equal areas I, II, III, IV, V, VI.

The discussion above applies to mean conditions. From one year to the next there may be great differences. February 1956 and July 1958 are inserted on Fig. 3a as examples of such long-lasting deviations in wind conditions. Further references will be made to these months later.

b) Frequency distribution of pressure centers in the Svalbard area

To make a survey of the frequency distribution, the Svalbard area was divided into 6 equal areas (in the following called I, II, III, IV, V and VI), lying on each side of latitude 78° N and longitude 14° E, which cross each other approximately at Isfjord Radio (see Fig. 4). The number of days when cyclones and anticyclones, according to the weather maps for 1200 GMT, were situated within the individual areas, were counted for January, May, July, and October. The cyclones counted also include troughs without distinct centers, when it otherwise was a dominating feature within the area considered. The center was then chosen at the trough line where the isallobaric gradient was greatest. Some of the cyclones were quasi-stationary lows connected to cold tropospheric cores, but the majority of the cyclones were of the migratory type, connected to extended tropospheric frontal zones. The anticyclones were counted when the point of highest pressure was definable within the area. In some cases the pressure center was sited on the border line between two areas. It was then considered as belonging to the area towards which it was moving at that time. Two centers in the same area hardly ever occurred, but was then counted as one center.

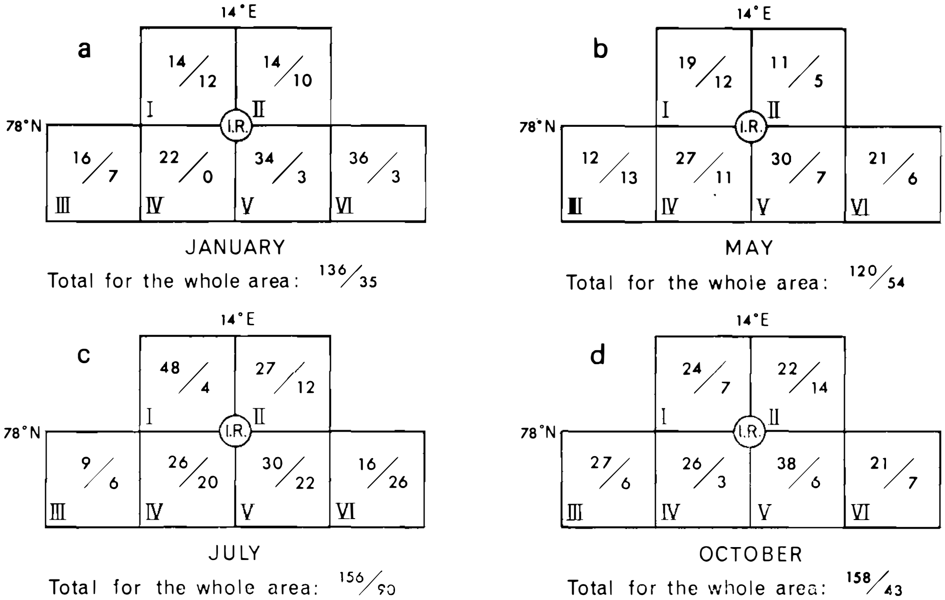


Fig. 5 a—d. Number of days in 1955—59 with cyclones (above skew line) and anticyclones (below skew line) for selected months and equal areas (cf. Fig. 4).

The numbers for areas I and II are somewhat doubtful, partly because of the scattered observations in the area, and partly because the maps used before September 1957 did not include areas north of 85° N.

Fig. 5 a—d gives a schematic view of the 6 areas for the four selected months, with the frequency of cyclones and anticyclones inserted above and below the skew line respectively. The total number of days with cyclones and anticyclones for the whole area is also inserted.

We see that in *January* (Fig. 5 a) the frequency of cyclones, and also the proportion between cyclone and anticyclone frequency in all southerly areas are greater than in the north. It is particularly high in the southerly and southeasterly part of the area. Thus the areas of prevailing cyclonic circulation, broadly speaking, coincide with the ice free areas of the northern part of the Norwegian Sea and the southern Barents Sea. This is what could be expected after PETTERSSEN (1950).

In *July* (Fig. 5 c) we meet to some extent conditions opposite to those of January: The proportion of cyclone frequency to anticyclone frequency now is at its greatest in the northern part of the Svalbard area. At the same time the frequency of anticyclones has increased pronouncedly relative to the frequency of cyclones in the southern and southeastern part of the area, which was characterized by a great cyclonic frequency in January. The frequency of anticyclones reaches its highest value in the Barents Sea area, where it exceeds that of cyclones by a considerable amount.

The cyclones seem to be more zonally distributed in January than in July.

May (Fig. 5 b) resembles January with respect to the different frequency of cyclones in north and south, but the increase of anticyclone frequency in the southern part, relative to January, at the same time has a certain relationship with July.

October (Fig. 5 d) resembles January with respect to the low frequency of anticyclones relative to cyclones in the southern part. On the other hand, it resembles July with its relative high frequency of cyclones in the northern part.

The frequency of cyclones and anticyclones, and their areal distribution for the four selected months, shown in Fig. 5, corresponds well with the frequency of the different wind directions of Table 1, p. 11, for the same months. The frequency distribution of the wind directions does not change much within each season, and accordingly, it is expected that the frequency distribution of pressure centers shown above applies to the respective seasons.

Referring to the whole area, the cyclone frequency is in the mean greatest in July and October with about 31 cyclones per month. That is one cyclone a day as an average. In May the mean number of cyclones, 14, was the lowest in the four months. The corresponding number for april was found to be 15. The proportion between cyclone and anticyclone frequency for the whole area varies between 1.7 in July and 3.7 in January. The latter number may be compared with the corresponding proportion 2 : 1, found by KEEGAN (1958) for the Northern Hemisphere north of 60° N.

It should be emphasized that in individual months the frequency distribution of cyclones and anticyclones may deviate considerably from that shown in Fig. 5. As examples are shown the conditions in February 1956 and July 1958 (Fig. 6, a and b) (cf. the mean wind vectors for same months inserted on Fig. 3 a, p. 10). A qualitative comparison with Fig. 5 a shows that in February 1956 the cyclone frequency is more equally distributed in northern and southern areas than would be expected from the foregoing description for January. So far, February 1956 resembles more midsummer conditions. However, the high frequency of anticyclones in area IV, V and VI, which is supposed to be a typical summer characteristic, is completely lacking in February 1956. Referring to ANDREWS (1956), the ground level circulation of February 1956 was characterized by a considerable displacement towards northwest of the Siberian anticyclone, with a corresponding displacement of the cyclone activity towards the western and northern part of the Svalbard area. The anticyclonic steering centers were restricted to the continent.

In the same way, July 1958, with its large frequency of cyclones in area V, deviates from what otherwise could be expected for this month according to the previous description. There is a certain formal resemblance with mean winter conditions, although the maximum area is of a smaller extent. The deviation from the average conditions was due to a quasi-stationary tropospheric cold trough with a corresponding low at the surface, covering the southern and eastern part of the Svalbard area at least half of the month (DUNN 1958), thus replacing the "normal" summer maximum of anticyclone frequency in the Barents Sea.

The areal distribution of cyclones and anticyclones for July for the 5-year period has much in common with that shown by REED and KUNKEL (1960) for

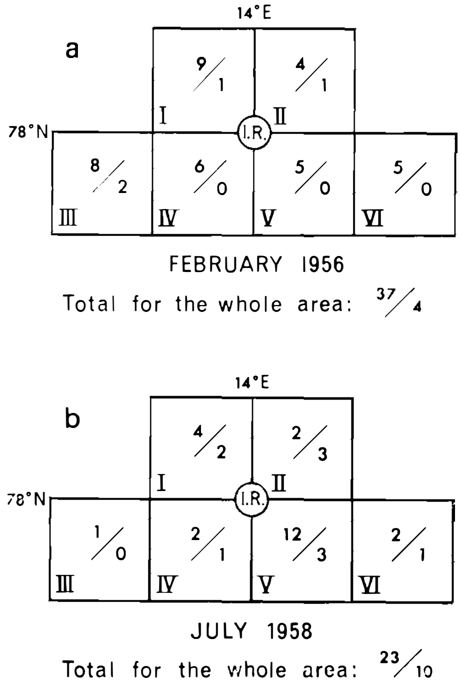


Fig. 6. Number of days with cyclones (above skew line) and anticyclones (below skew line) within equal areas for the "abnormal" months February 1956 and July 1958 (cf. Figs. 5 a and c).

the months June—September (1952—56) for the arctic regions. Their work shows a marked maximum area of cyclone frequency in the Canadian and East-Siberian sector of the Polar Basin, extending across the North Pole towards the northern part of the Svalbard area, where the cyclone frequency, according to Fig. 5 c, is greatest. There is also good correspondance with respect to the high frequency of anticyclones in the Barents Sea shown on Fig. 5 c.

To a large extent the results above also agree with KLEIN's 40-year mean (KLEIN 1957), as far as the frequencies in the southern part of the area are concerned. For the northern districts, however, KLEIN's results differ considerably. This is due to the fact that the data of KLEIN, as he himself admits, are hardly representative for the arctic regions.

c) The cyclone tracks in the Svalbard area

In the following only the tracks of the extreme months January and July will be shown, as they are expected to represent the greatest contrasts. From what has been shown earlier, it is likely that January and July are representative for the respective seasons they belong to, and that the other seasons on an average will be a compromise between them, also with respect to the cyclone tracks.

Generally the tracks may be divided into four groups, according to the direction in which they are moving, namely:

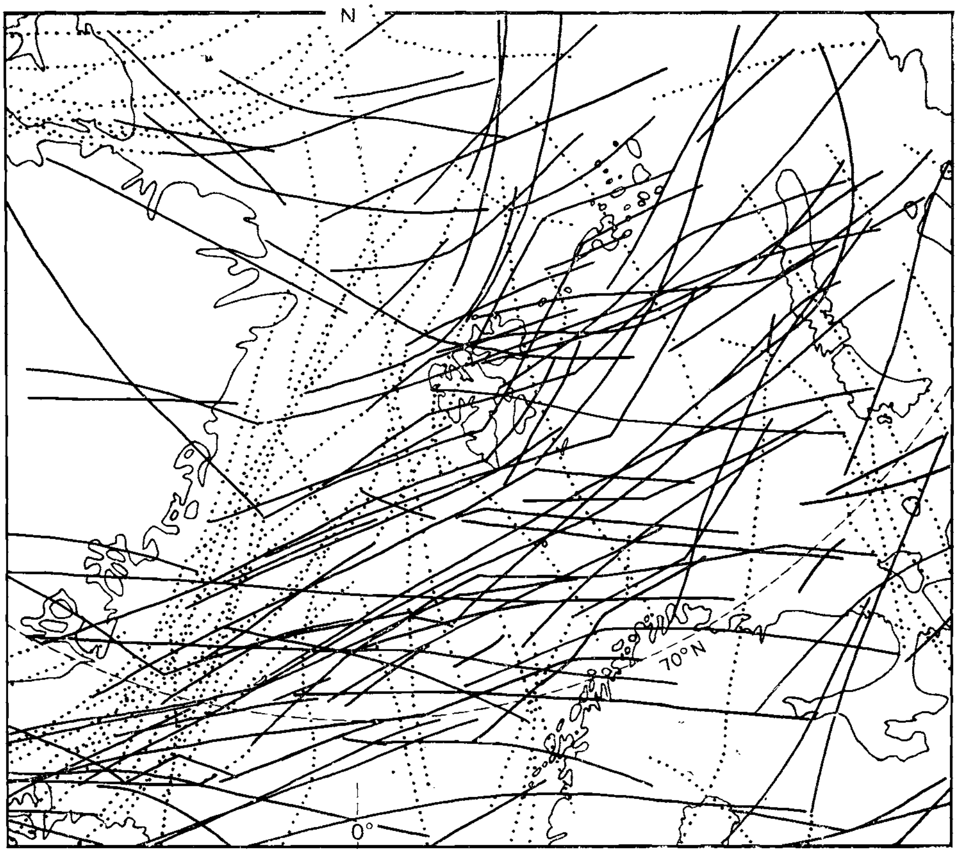


Fig. 7 a. Cyclone tracks in the Svalbard area. January 1955—59. Dotted lines: Meridional tracks. Full lines: Zonal tracks.

1) Zonal	tracks directed	E-wards	within	the	sector	045—135°
2) Meridional	»	N-wards	»	»	»	315—045°
3) Zonal	»	W-wards	»	»	»	225—315°
4) Meridional	»	S-wards	»	»	»	135—225°

Figs. 7 a and 7 b show the tracks for 5 January and 5 July months. Zonal E-ward directed tracks (in the following referred to as zonal tracks) have been drawn with full lines, and northward directed tracks (in the following referred to as meridional tracks) have been drawn with points. Zonal and meridional tracks mentioned under 3) and 4) were very rare, and have been omitted on the figures.

The characteristic features may be summarized as follows:

January

1) Meridional tracks mainly concentrated between eastern Greenland and about 10° W. Most of these cyclones originate in the area Iceland — eastern Greenland and curve anticyclonically between 75 and 85° N. East of 5° E meridional tracks are rare, though a certain concentration in the south-eastern

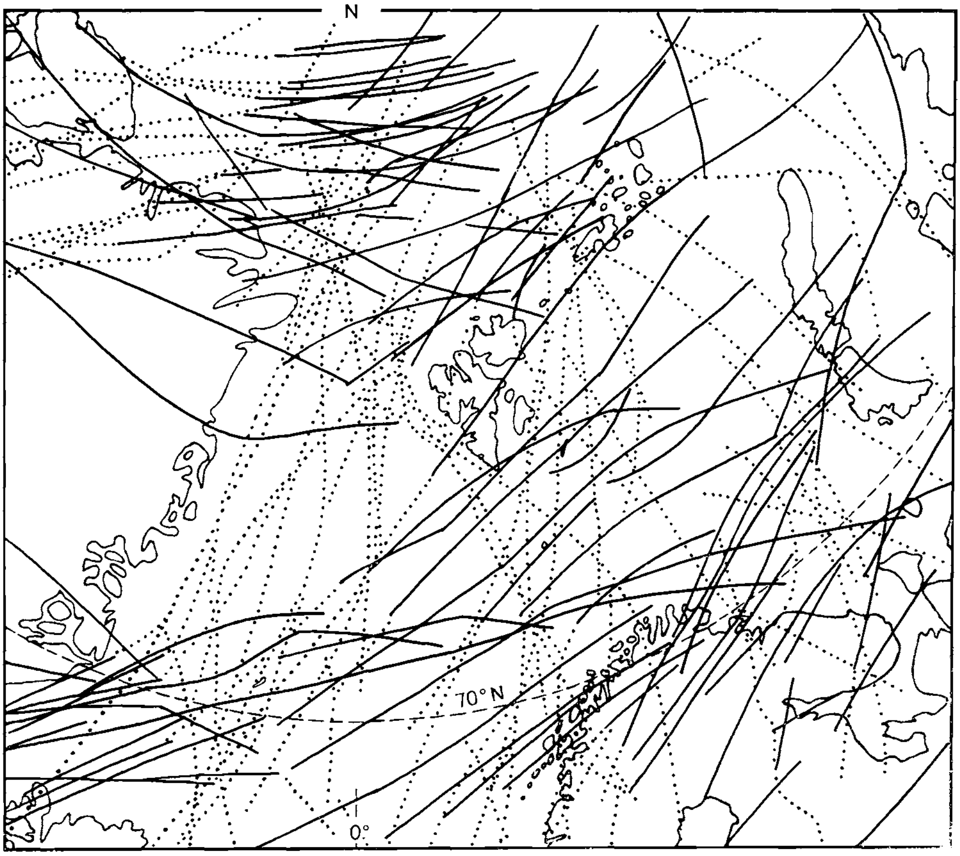


Fig. 7 b. Cyclone tracks in the Svalbard area. July 1955—59. Dotted lines: Meridional tracks. Full lines: Zonal tracks.

part of the Barents Sea of cyclones originating in European Russia are discernible.

2) Cyclones with zonal tracks between northern Norway and Spitsbergen most often originate near Iceland. A few of them are new formations of lows near eastern Greenland, due to disturbances which have passed the Greenland plateau from west.
3) Relatively few tracks without any predominating direction north of about 85° N.

July

1) Frequent meridional tracks scattered all over the area and with origin as well from the ocean areas as from the continent south of 70° N.
2) Zonal tracks in the southern part of the area. They are fewer in number than in January, and the cyclones originate both in the Iceland area, in the Norwegian Sea, and in European Russia. Some cyclones can be traced back to the areas west of Greenland.
3) The concentration of tracks north of 83° N. These tracks are partly zonal, due to cyclones from the areas west of Greenland, and partly meridional, due to cyclones which can be traced back to the Norwegian Sea and Scandinavia.

Common features for the two extreme months are primarily that the lows in most cases originate outside the Svalbard area. As would be expected, zonal and meridional tracks directed eastwards and northwards, respectively, completely dominate in both months compared with southward and westward directed tracks.

The total number of cyclonic tracks within the area is about the same for both January and July, with a monthly mean of about 20 tracks.

Among marked differences between cyclone tracks in January and July may be mentioned the apparently greater tendency in January for the cyclones to curve eastwards, especially in the areas between northern Norway and Spitsbergen. Furthermore, in January the place of origin of the cyclones seems generally to be the semi-permanent Icelandic low. In July, on the other hand, the meridional tracks are more pronounced, and, as already mentioned, the cyclones originate both in the oceanic and continental areas south of 70° N. The cyclones often reach the Polar Basin, where their tracks, north of about 80° N, are crossed by the earlier mentioned zonal tracks in this area. This increase in number of cyclones in the northernmost part of the Svalbard area in July, due to the intrusion of cyclones from south and west, is perhaps the most marked and interesting difference from January.

It goes without saying that there is a certain correspondence between the frequency distribution of low pressure centers, discussed earlier, and the distribution of the cyclone tracks. Thus the January frequency maximum in the southern parts, shown on Fig. 5 a, is obviously connected with the greater concentration of cyclone tracks here than in the northern part. On the other hand, there seems to be a discrepancy between the increasing frequency of cyclones towards the eastern sectors and the decreasing density of tracks in the same direction. The cause of this may be that the cyclones which move eastwards have a tendency to stagnate in the Barents Sea at this time of the year. Some meridionally moving cyclones originating in Russia also move into the Barents Sea, contributing to the cyclone frequency maximum in this area in January.

The July distribution of cyclonic frequency (Fig. 5 c), which seemed to be of a more meridional character, corresponds well to the greater frequency of meridional tracks in this month, leading to the occurrence of lows in the northern part which have been counted in the southern part 24 hrs. earlier. The high frequency of cyclones in the northern part in July is related to the crossing of cyclone tracks in this area, the cyclones originating both west and east of Greenland. These arctic cyclone tracks are in many cases connected with an anticyclone in the Barents Sea (and the semi-permanent Greenland high), as the anticyclones act as "steering centers" for peripheral disturbances to the north and northwest.

February 1956 and July 1958 are examples of extreme deviations from the main features described above (provided that the general pattern of the tracks for January applies to February too). The tracks in February 1956 were pronouncedly meridional and concentrated in the western part of the Svalbard area. Most of the cyclones curved anticyclonically north of Spitsbergen, steered by the displaced Siberian anticyclone.

The cyclone tracks in July 1958 revealed a variegated picture with all directions represented, also westward and southward directed tracks. In the northern part of the Svalbard area, cyclone tracks did not appear with the pronounced high frequency typical for the other July months. This is in agreement with the low frequency of highs in the Barents Sea this month (see Fig. 6 b).

The pronounced zonal movements of the cyclones in January corresponds well with KEEGAN's results for the 5 winters he investigated (KEEGAN 1958). There is also a pretty good correspondence with the tracks shown by KLEIN (1957) for this area in January.

On the other hand, the July characteristics described above deviate from the results of KLEIN, except that the zonal tracks, which dominate the cold season, become of secondary importance and have an increasing northerly component.

As the movement of the cyclone is connected with the air currents throughout the troposphere, the different characteristics of the two months must be reflected, for instance, by the streamlines on the mean 500 mb map. Referring to the mean 500 mb map of GOMMEL (1963), we find that there is a strong westerly air stream over the Svalbard area in January and a weaker southwesterly air stream in July.

Finally, we may say a few words about the annual variation of the extension of the sea ice in the area considered. It is a well-known fact that the movement of the ice does not only depend on the ocean currents, but to a considerable extent also on the surface winds. In this connection the increasing cyclonic activity in the southern part of the Svalbard area towards winter, and the corresponding increase of the frequency and strength of the northeasterly winds in the northern part, must be of importance for the southerly expansion of the ice during the cold season. Similarly, the withdrawal of the ice during the summer is probably partly due to the increasing frequency of southerly winds at the expence of the northeasterly winds, in connection with the change to a more meridional circulation.

Annual variation of some weather elements at Isfjord Radio

It is a well-known fact that there is a certain correspondance between the surface wind and other weather elements. All data for the weather elements discussed here refer to Isfjord Radio (1955—59) and have been taken from the Norsk Meteorologisk Årbok (1956—1960).

Cloud amount and precipitation

Fig. 8 illustrates the percentage frequency (f_0) for each month based upon the observations at 0600 and 1800 GMT of cloud amount equal to or less than 3/8 ($N \leqq 3/8$). The rest of the material then comprises cases when $N > 3/8$, the relative frequency of which will be referred to as f. The group $N = 9/8$ (i. e. sky not visible on account of fog, snowdrift etc.) will as an exception include cases with $N \leqq 3/8$. However, this cannot noticeably influence the mean values. No distinction has been made between types of clouds. Generally, however,

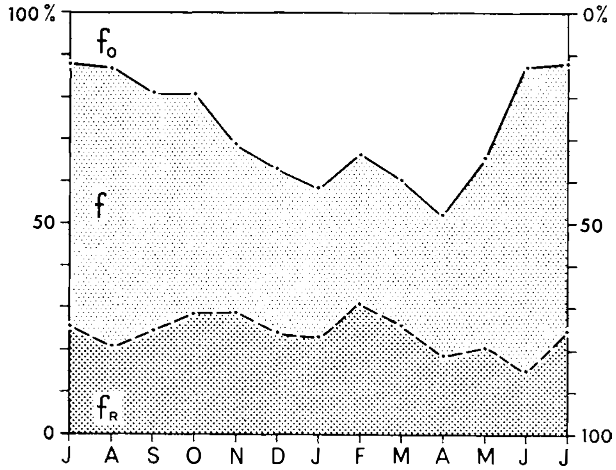


Fig. 8. Percentage frequencies for Isfjord Radio (1955—59) of cloud amount ≦ 3/8 (f_0, scale to the right), of cloud amount > 3/8 (f, scale to the left), and of precipitation (f_R, scale to the left).

clouds in the Svalbard area belong to the low and medium types. Also, the relative frequency of observations of precipitation of any kind (f_R) is shown in the diagram. It is believed that the group N > 3/8 contains practically all cases of precipitation.

Considering Fig. 8, it is, in the first place, obvious that the variation between high values of f_0 in the cold season and low values in midsummer agrees with what could be expected for an arctic station (Birkeland and Føyn 1932, Petersen 1935, Sverdrup 1935). The highest value of f_0 is reached in April. This may be compared with the duration of sunshine measured during the "Maud" expedition, showing the highest values, both as a per cent of maximum duration and as an absolute value, in March—April (Sverdrup 1935). Secondly, we notice that the annual variation of f_0 (resp. f) has a similar asymmetric form as that previously described for the surface wind. Thus the period of highest values of f_0 falls within December—April, earlier referred to as the "winter-period".

In broad outline, the precipitation frequency increases slightly during summer and autumn (Fig. 8). In spring it has a weak minimum, coinciding with the high vaue of f_0. The annual variation of the precipitation frequency for Isfjord Radio thus has a similar form to that found for west Greenland coastal stations (Petersen 1935). February has the highest frequency, coinciding with the secondary minimum of f_0. Further reference will be made to this feature later.

The low value of f_0 in summer is closely associated with the more meridional circulation type in this season, characterized by relatively high frequency of northerly moving cyclones and a northward extension of warmer and moister air masses. The cooling of the northward moving air masses favours the formation of low clouds of the stratus and stratocumulus type. The high number of cyclones in the northern part of the area in midsummer, will also carry moist air masses towards Vestspitsbergen, and contribute to the typical large summer cloud amount at Isfjord Radio.

In autumn f_0 is still rather low. This is in agreement with the tendency of the summer circulation to continue in the autumn. Besides, the ice in September and October is still situated near its northern extreme. Furthermore, the cyclone frequency in the Svalbard area seems to be greatest in the autumn (Fig. 5).

Towards winter the value of f_0 increases distinctly.

This corresponds to the decreasing frequency of meridional circulation types, and the shift of the areas of highest cyclone frequency towards the south. Colder and drier air masses from the Polar Basin now more often reach Svalbard as northerly and northeasterly winds. As far as the west coast is concerned, the dissolving effect of subsidence on clouds is favoured by the orography. These effects are most pronounced in late winter, and the climate is of a continental character at this time of the year. The ice-masses have now reached their southernmost position and almost enclose the islands.

The description above refers to the mean conditions. Sometimes, of course, the frontal zone may be displaced comparatively far north also in the winter season. The meridional circulation thus established, causes warmer and moister air masses to penetrate northwards over Svalbard. February 1956 is an example of a particularly long-lasting period with circulation of this type. Also in February 1959 the mean frontal zone was displaced rather far north, but had an approximately zonal direction and was situated south of Isfjorden. Those two Februaries are responsible for the maximum precipitation frequency and the corresponding minimum of f_0 shown in Fig. 8.

Fog and relative humidity

The percentage frequency of fog occurrence at Isfjord Radio in the 5-year period was based upon observations at 0600, 1200, and 1800 GMT, and is shown in Fig. 9. The total number of observations was 83. The monthly means of the relative humidity are also inserted in the figure. They are, according to the Norsk Meteorologisk Årbok (1956—1960), evaluated with respect to ice for temperatures below 0°C.

The figure shows a rather flat winter minimum of fog frequency. In fact, within the seven months November—May (35 individual months) only 12 cases with fog were observed. None of them occurred in January and April. In the period June—October a pronounced maximum occurs in midsummer (July). In broad outline, this annual variation is in qualitative agreement with corresponding data from arctic coastal regions and from the Polar Basin.

Table 2 shows the frequency of fog in relation to winds for the two periods November—May and June—October. These two periods were distinguished in order to obtain approximately homogeneous material within the period June—October with respect to fog type. For this period it appears that most of the observations of fog occur together with winds in the sector 170—220°, with a displacement of the frequency maximum towards the western sectors. This indicates that the fog is of the advection type with its origin over the sea areas to the south and west of the station.

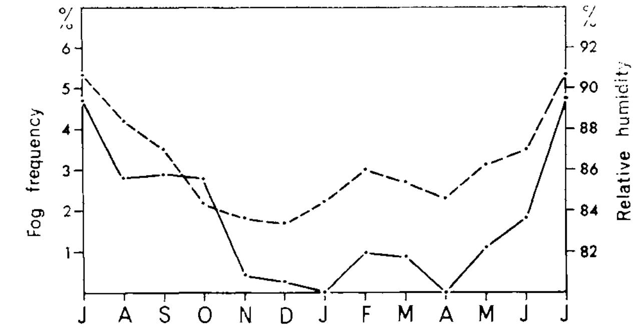


Fig. 9. Percentage frequency of fog (full line) and mean monthly relative humidity (broken line) at Isfjord Radio (1955—59).

Table 2.

Number of observations of fog in relation to the wind at Isfjord Radio.

a) June—October 1955—59.

Wind direct.	00	03	06	09	12	15	18	21	24	27	30	33	36	Total
Wind force (Beaufort)														
0	4	·	·	·	·	·	·	·	·	·	·	·	·	4
1	·	·	·	·	·	·	3	2	·	·	1	·	1	7
2	·	·	·	·	·	·	3	3	1	2	·	·	2	11
3	·	1	·	·	·	·	8	4	·	1	3	·	·	17
4	·	1	·	·	·	·	13	3	1	·	·	·	1	19
5	·	·	·	1	·	1	7	·	·	·	·	·	·	9
6	·	·	·	·	·	1	1	·	·	·	·	·	·	2
7	·	·	·	·	·	·	1	·	·	·	·	·	·	1
8	·	·	·	·	·	·	1	·	·	·	·	·	·	1
Total	4	2	0	1	0	2	37	12	2	3	4	0	4	71

b) November—May 1955—59.

Wind direct.	00	03	06	09	12	15	18	21	24	27	30	33	36	Total
Wind force (Beaufort)														
0	·	·	·	·	·	·	·	·	·	·	·	·	·	0
1	·	·	·	·	·	·	·	1	·	·	·	·	·	1
2	·	·	1	·	·	·	·	·	·	·	·	·	·	1
3	·	·	·	·	·	·	1	1	·	·	·	·	·	2
4	·	·	·	·	·	·	·	·	·	·	·	·	·	0
5	·	·	·	·	·	·	1	·	·	1	·	·	·	2
6	·	1	·	1	·	·	·	·	·	·	·	·	·	2
7	·	1	·	·	·	·	1	·	·	·	·	·	·	2
8	·	·	2	·	·	·	·	·	·	·	·	·	·	2
Total	0	2	3	1	0	0	3	2	0	1	0	0	0	12

From the data of Table 2 it was found that when fog is observed, the mean wind force is 3.2 Beaufort in the period June—October. This is practically equal to the mean wind force given for the Grand Banks for periods with advection fog (PETTERSSEN 1956). The rapid fall of the number of fog cases for greater forces than about 5 Beaufort, obviously must be due to the increasing turbulent mixing of the air by increasing speeds, leading to dissolving of the fog.

As previously mentioned, the period November—May only contained 12 cases with fog observations. According to Table 2, they seem to group around the main wind directions northeast and south. Half of the fog cases occurred with wind forces exceeding 6 Beaufort, and none during calm conditions. Some of the cases which occurred with southerly winds, obviously were of the advection type. Among the other cases, at least two must have been arctic steam fogs which have formed over ice-free fjord mouth to the north of the station in connection with heavy land-winds with temperatures around -20°C.

Thus it may be concluded that, at least for the period June—October, the occurrence of fog at Isfjord Radio is closely related to the wind conditions. Two different origins of the fog may be mentioned. In the first place, the fog may be formed over the land by cooling of relative warm and moist air masses streaming from the sea. Secondly, it seems evident that advection fog to a great extent is formed over the sea south of Svalbard (WILLETT 1928). The possibility therefore exists that such fog, due to the increasing frequency of meridional circulation types towards the summer maximum, may drift toward the Svalbard islands with the southerly winds. The slow decrease of fog frequency in autumn is again supposed to be the result of a certain persistence of this circulation. In addition, it may be mentioned that in the late summer and autumn the ice limit is at its northernmost position, and so is also the northern limits of the sea fog. Evidently the conditions are exceptionally favourable for fog to occur at the coast of Vestspitsbergen at this time of the year.

On the other hand, in the period November—May other types of fog seem to occur with equal frequency, apparently being less dependent on the type of air circulation. Although the low number of cases for this period makes it impossible to draw general conclusions, it is fairly obvious that the low frequency is due to the rather rare occurrence of warm air advection from the south in this period.

As previously mentioned the fog frequencies for the 5-year period have a peak-formed maximum in July. In July 1958, however, fog did not occur at all at Isfjord Radio. The explanation must be sought in the abnormal wind conditions, described earlier, which existed in the Svalbard area in this month, with prevailing north and northeasterly dry air currents over Svalbard.

The annual variation of the relative humidity shows, as one would expect, in broad outline the same features as that of the fog frequency.

Temperature

The annual variation of the mean monthly temperature is shown on Fig. 10. Towards the winter the temperature in the mean falls more slowly than it rises

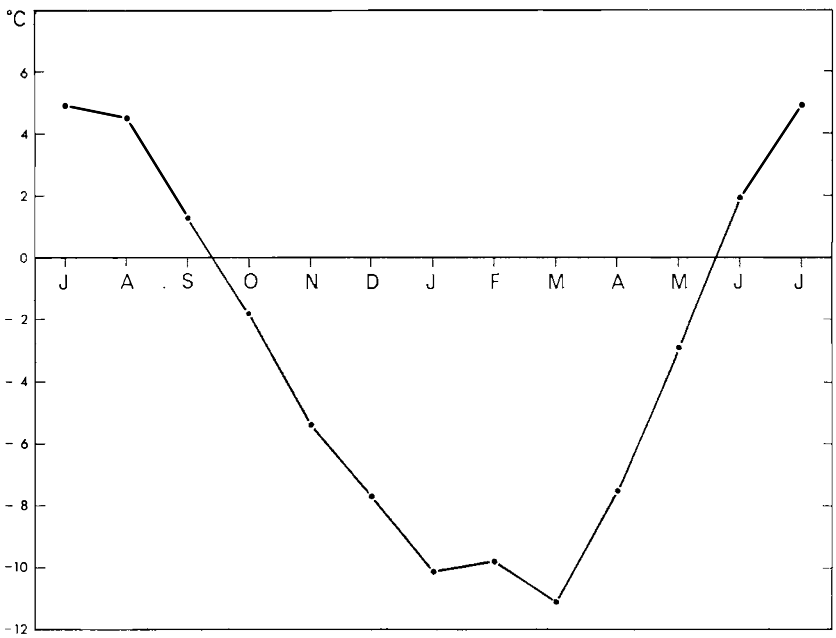


Fig. 10. Mean monthly temperatures at Isfjord Radio (1955—59).

towards summer. It has a coreless minimum in winter, although March is the coldest month. These features are typical for arctic coastal stations and for the Polar Basin.

The character of the annual temperature variation at Isfjord Radio is similar to that of the wind, and the coreless temperature minimum is probably connected to the cyclone activity, which is supposed to exist comparatively unchanged in the southern part of the Svalbard area throughout the winter period. This activity leads to a successive exchange of cold air masses from the north and warmer air masses from the south, keeping the mean temperature on Vestspitsbergen relatively constant. The temperature minimum in March, may, referring to WEXLER (1957—58), be connected with the ice extension, which at this time approaches its southernmost extreme. Later, in April, the rapid increase of solar radiation, associated with the relatively high frequency of clear skies, contributes to the rather rapid temperature increase.

In the autumn, on the contrary, the general temperature drop is partly counteracted by the tendency to a meridional circulation type, which to a certain degree is still present, bringing warm air masses from south towards Svalbard. This leads, as previously mentioned, also to a relatively great cloud-amount, which will counteract radiative cooling. In this season, when the ice is at its northernmost position, the climatic conditions in the Svalbard area are most oceanic.

Air masses and frontal systems, and the weather conditions at Isfjord Radio

Seasonal variation of the 500/1000 mb thickness

By use of the radiosonde data from Isfjord Radio it is possible to get an idea of the relation between the large scale tropospheric wave systems in the different seasons in the Svalbard area, and the mean weather conditions on Vestspitsbergen, as represented by the same station. The radiosonde-station on Isfjord Radio was established on 1 September 1957, and the statements below are based upon the 3-year period ending with 31 August 1960. Reference is, however, also made to the 5-year period previously described, assuming that the statements for that period also apply to the 3-year period. This seems justifiable, as the discussion refers to seasonal means which are not expected to vary fundamentally from one succession of years to another.

First a few remarks on the 3-year thickness means at 0000 and 1200 GMT for the four seasons. Winter has in the following been defined to comprise the months November—March (15 months in all), spring April—May (6 months) summer June—August (9 months), and autumn September—October (6 months). (Thus, for the upper air data, the seasonal periods differ from those applied in the foregoing for the surface observations. The reason is, that the upper air statistics were computed earlier, and initially independent of the surface statistics. However, the limits for the periods must be somewhat fluid, and in the mean, the possible differences which would arise from the deviation in periods can not be expected to have a decisive influence.) The mean thicknesses were: For winter 5118 GPM, for spring 5209 GPM, summer 5370 GPM, and autumn 5286 GPM. Thus the assymmetric annual variation found in the previous discussion for various weather elements also applies to the mean thickness: It decreases, on an average, more slowly towards winter than it increases towards summer. Furthermore, with respect to the mean temperature and moisture content in the lower troposphere, summer and autumn seems to be more related to each other than summer and spring. The rapid increase in thickness towards summer is connected with the general change to a more meridional circulation with a northward transport of warmer and moister air masses in the lower troposphere. As mentioned earlier, these conditions to a certain degree continue during autumn.

The standard deviations were: 113, 103, 74, and 89 GPM for winter, spring, summer, and autumn respectively. To a certain degree this reflects the greater mean contrast between arctic and temperate air masses in winter and spring than in summer and autumn.

Cloud amount and precipitation in relation to the 500/1000 mb thickness

The frequency of cloud amount $\overline{\overline{<}}$ 3/8 and of precipitation (f_0 and f_R respectively) for different classes of thickness deviations in the four seasons, has been found by comparing the individual deviations from the seasonal mean thicknesses at 0000 GMT with the observations of cloud amount and precipitation at 1800, 0000, and 0300 GMT. Similarly, the deviations at 1200 GMT were compared with the observations at 0600, 0900, 1200, and 1500 GMT (observations were not taken at 2100 GMT). Thereby weather observations are compared with sonde data which have been executed up to 6 hours after the ground level observations. Generally, however, the variations of thickness within a 6 hr interval are rather small. It was not distinguished between low, medium and high clouds. The total number of surface observations was for the winter seasons 3173, for the springs 1296, summers 1923, and autumns 1281. The deviations from the mean thicknesses in the respective seasons were grouped into class intervals of 20 GPM, and for each class the percentage frequency of observations of cloud amount $\leqq$ 3/8 and of precipitation was computed. The resulting diagrams are shown in Fig. 11 a—d.

The seasons are discussed separately.

Winter. — For the winter months the percentage of occurrence of cloud amount $\leqq$ 3/8 was found to be 31, distributed according to the thickness as seen from Fig. 11 a. This figure reveals that the highest frequency of cloud amount $\leqq$ 3/8 is connected to the lowest thicknesses. Increasing thickness increases the chances for larger cloud amounts and precipitation to occur, and upon passing about 5300 GPM, cloud amount $\leqq$ 3/8 do not occur at all. Studying the weather maps, we find that clear or nearly clear skies are connected with a southward expansion of arctic air masses with a corresponding anticyclonic wind regime at the surface. Thus the dry and clear weather types on Vestspitsbergen is the effect of a cold anticyclone centered to the north, with the frontal zone displaced well to the south of the islands.

On the other hand, the results shown in Fig. 11 a indicate that warm tropospheric ridges, which in winter expand towards Svalbard between Greenland and Novaya Semlya, are always connected with increasing cloud amounts and often with precipitation, and hardly ever with clear skies. Scrutinity of the weather maps reveals that during the cold season Svalbard remains within or north of the frontal zone between the warm ridge and the cold polar vortex. In other words, warm anticyclones seem to be a rarity in the Svalbard area in winter, at least in the middle and northern part of the area. It should be recalled that, according to the earlier discussion of the surface wind and cyclonic activity, the cyclonic circulation prevailed in the southern part of the Svalbard area in winter. Frequently cyclones moved through the area in quasi-zonal tracks, corresponding to a mean east-west oriented frontal zone south of the Svalbard islands.

Spring. — The conditions in spring (Fig. 11 b) are to a large extent similar to those of the winter. It may be noted that the percentage frequency of cloud amounts $\leqq$ 3/8 is 29 % compared with 31 % in winter.

In addition, low thicknesses are again generally related to clear skies, and the sky becomes more cloudy with increasing thickness.

Summer. — In summer (Fig. 11 c) conditions differ markedly from those of the winter. Firstly, cases of cloud amounts $\leqq$ 3/8 have now decreased to 14 % of the total of observations. Moreover, clear or nearly clear skies now mostly occur together with the greatest thicknesses. This implies that "fair weather" in

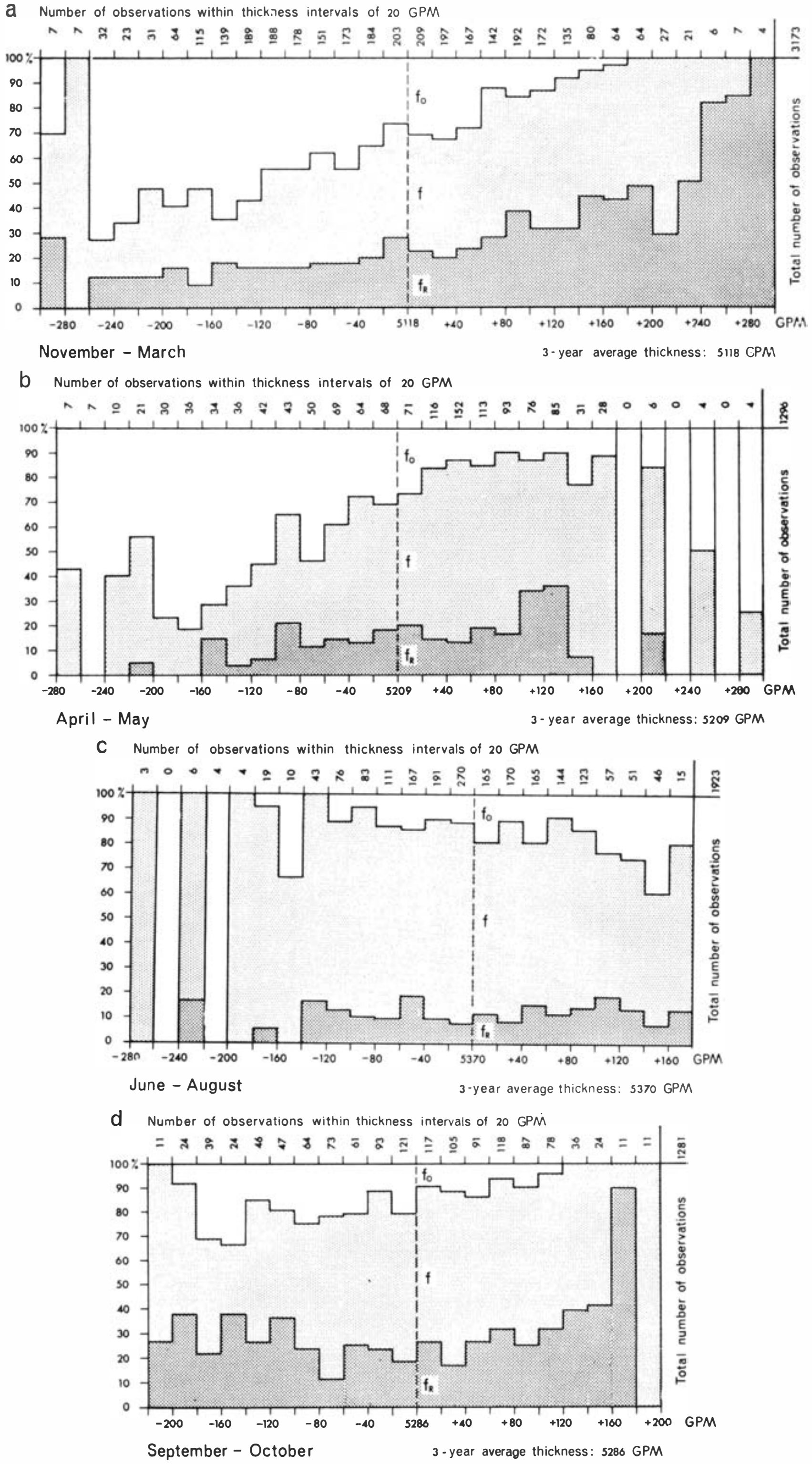


Fig. 11. Percentage frequency for different thicknesses of cloud amount $\leqq$ *3/8, of cloud amount > 3/8, and of precipitation (f_O, f, and f_R respectively) at Isfjord Radio (f_O is equal to 100 % minus the value read on the scale to the left). a) Winter, b) Spring, c) Summer, d) Autumn.*

summer is most often connected with the influence of a warm anticyclone. This agrees well with the high frequency of anticyclones in the southern and south-western parts of the Svalbard area shown earlier for July (Fig. 5 c). Thus, "fair weather" in Vestspitsbergen in summer is likely to be connected with the northward expansion of this warm anticyclone. At the same time the earlier mentioned frontal zone is established in the northernmost part of the Svalbard area.

Autumn. — The conditions in autumn are illustrated in Fig. 11 d. According to the mean thicknesses, autumn was found to be most similar to summer. This is also confirmed by the low percentage of cloud amounts $\lesseqqgtr$ 3/8, which equals that of the summer with 14 %. However, in autumn, as in winter, "fair weather" seems most frequently to occur in connection with cold anticyclones approaching from the north. Warm anticyclonic ridges seem no longer to be able to penetrate sufficiently far north for Vestspitsbergen to become markedly influenced by the subsidence south of the frontal zone (cf. the low frequency of anticyclones and the high frequency of cyclones in the southern part of the Svalbard area in October, Fig. 5 d). Studying the weather maps, we find that the frontal zone seems most often to be sited near or to the south of the islands, as in winter, but generally not at such a great distance as in the winter period.

Concluding remarks

Generally the cold tropospheric polar vortex expands southwards during autumn and winter, and the mean frontal zone takes a quasi-zonal position south of the Svalbard islands. The southernmost position is reached in late winter or early spring. During spring warm anticyclonic ridges are most frequently built up in the southern part of the Svalbard area, and this tendency reaches its highest stage in midsummer, when the tropospheric polar vortex has its smallest areal extension. These warm ridges in summer mostly originate from the Russian or Siberian part of the continent, and, accordingly, the cyclones frequently take a northward course. In some cases in the summer the Barents Sea anticyclone and the Greenland anticyclone emerge, and a frontal zone develops along the border areas between the warm anticyclone and the limited cold polar vortex, extending from the areas west of Greenland to the ocean north of Svalbard and Franz Josef Land. As far as can be judged from the annual variation of the weather elements and circulation indices, the increase of the polar vortex during the autumn is slower than the decrease of the vortex back to summer conditions.

Strictly speaking, the results presented above apply only to the 5-year period 1955—59, and, as far as the upper air data are concerned, to a 3-year period extending from 1957 to 1960. It has, however, been pointed out that the main features of the annual variation of the surface wind regime in the Svalbard area agree with results of investigations comprising older and longer periods (Gommel 1963, O'Connor 1961, Klein 1957, and others). Furthermore, the annual change of the other meteorological elements at Isfjord Radio, presented in this paper, and corresponding data from older weather stations at Vestspitsbergen, show in the main the same features (Quade Hook, Green Harbour, Advent Bay, Aksel Island) (BIRKELAND and FØYN 1932). It thus seems reasonable to conclude that the description given of the annual variation of the wind regime and its proposed connection to large scale processes in the lower troposphere, has a more general validity.

Acknowledgments

I wish to express my sincere thanks to Dr. REINHARD MOOK for his encouragement and interest in my work and for his valuable criticism and comments. I also wish to thank Mr. TOR SKIBELI at Vervarslinga for Nord-Norge for valuable examination of the manuscript.

Literature

ANDREWS, JAMES F., 1956: The weather and circulation of February 1956. *Monthly Weather Review.* **84**, (2). U. S. Weather Bureau, Washington D. C.

BIRKELAND, B. J. and N. J. FØYN, 1932: Klima von Nordwest-Europa und den Inseln von Island bis Franz Josef Land. In KÖPPEN und GEIGER, 1932: *Handbuch der Klimatologie.* **3**, (L), 32—38. Berlin.

DUNN, CARLOS R., 1958: The weather and circulation of July 1958. *Monthly Weather Review.* **86**, (7). U.S. Weather Bureau, Washington D. C.

GOMMEL, WILLIAM R., 1963: Mean distribution of 500-mb topography and sea level pressure in middle and high latitudes of the Northern Hemisphere during the 1950—59 decade, January and July. *J. Appl. Met.* **2**, (1). Boston.

KEEGAN, THOMAS J., 1958: Arctic synoptic activity in winter. *J. Met.* **15**, 513—521. Boston.

KLEIN, WILLIAM H., 1957: Principal tracks and mean frequencies of cyclones and anticyclones in the Northern Hemisphere. *Research Paper no. 40.* U.S. Weather Bureau, Washington D. C.

NAMIAS, J., 1947: *Extended forecasting by mean circulation methods.* U.S. Weather Bureau, Washington D. C.

Norsk Meteorologisk Årbok (1956—60), published by Det Norske Meteorologiske Institutt, Oslo.

O'CONNOR, JAMES F., 1961: Mean circulation pattern based on 12 years of recent northern hemispheric data. *Monthly Weather Review.* **89**, (7). U.S. Weather Bureau, Washington D. C.

OMDAL, KIRSTEN, 1953: Drivisen ved Svalbard 1924—1939. *Norsk Polarinstitutt Medd.* Nr. 72. Oslo.

PETERSEN, HELGE, 1935: Das Klima der Küsten von Grönland. In KÖPPEN und GEIGER, 1935: *Handbuch der Klimatologie.* **2**, (K). Berlin.

PETTERSSEN, SVERRE, 1950: Some aspects of the general circulation of the atmosphere. *Centenary proceeding of the Royal Meteorological Society.* 120—155. London.

— 1956: *Weather analysis and forecasting. Second edition.* **2**. *Weather, and weather systems.* 120—121. McGraw-Hill Book Co., New York.

REED, RICHARD J., and BRUCE A. KUNKEL, 1960: The arctic circulation in summer. *J. Met.* **17**, 489—506. Boston.

SVERDRUP, H. U., 1935: Übersicht über das Klima des Polarmeeres und des Kanadischen Archipels. In KÖPPEN und GEIGER, 1935: *Handbuch der Klimatologie.* **2**, (K). Berlin.

WEXLER, H., 1957—1958: The "kernlose" winter in Antarctica. *Geophysica.* **6**, 577—595. Helsinki.

WILLETT, H. C., 1928: Fog and haze, their causes, distribution, and forecasting. *Monthly Weather Review.* **56**, (11), 435—468. U.S. Weather Bureau, Washington D. C.

SKRIFTER

Skrifter Nr. 1—110, see cover of previous numbers of Skrifter.

Nr.

111. SVERDRUP, H. U.: *The Stress of the Wind on the Ice of the Polar Sea.* 1957. Kr. 2.00.
112. ORVIN, ANDERS K.: *Supplement I to the Place-names of Svalbard. Dealing with new Names 1935—55.* 1958. Kr. 13.00.
113. SOOT-RYEN, TRON: *Pelecypods from East-Greenland.* 1958. Kr. 4.00.
114. HOEL, ADOLF and WERNER WERENSKIOLD: *Glaciers and Snowfields in Norway.* 1962. Kr. 40.00.
115. GROOM, G. E. and M. M. SWEETING: *Valleys and Raised Beaches in Bünsow Land, Central Vestspitsbergen.* 1958. Kr. 3.00.
116. SVENDSEN, PER: *The Algal Vegetation of Spitsbergen.* 1959. Kr. 7.00.
117. HEINTZ, NATASCHA: *The Downtonian and Devonian Vertebrates of Spitsbergen. X. Two new Species of the Genus Pteraspis from the Wood Bay Series in Spitsbergen.* 1960. Kr. 3.00.
118. RODAHL, KÅRE: *Nutritional Requirements under Arctic Conditions.* 1960. Kr. 8.00.
119. RAPP, ANDERS: *Talus Slopes and Mountain Walls at Tempelfjorden, Spitsbergen.* 1960. Kr. 25.00.
120. ORVIN, ANDERS K.: *The Place-names of Jan Mayen.* 1960. Kr. 14.00.
121. CARSTENS, HARALD: *Cristobalite-Trachytes of Jan Mayen.* 1961. Kr. 3.00.
122. HOLLAND, MICHAEL FRANK WILLIAM: *The Geology of Certain Parts of Eastern Spitsbergen.* 1961. Kr. 12.00.
123. LUNDE, TORBJØRN: *On the Snow Accumulation in Dronning Maud Land.* 1961. Kr. 9.00.
124. RØNNING, OLAF I.: *Some New Contributions to the Flora of Svalbard.* 1961. Kr. 3.00.
125. MANUM, SVEIN: *Studies in the Tertiary Flora of Spitsbergen, with Notes on Tertiary Floras of Ellesmere Island, Greenland, and Iceland. A Palynological Investigation.* 1962. Kr. 26.00.
126. HOEL, ADOLF and JOHANNES NORVIK: *Glaciological Bibliography of Norway.* 1962. Kr. 30.00.
127. GOBBETT, DEREK JOHN: *Carboniferous and Permian Brachiopods of Svalbard.* 1963. Kr. 32.50.
128. WILSON, OVE: *Cooling Effect of an Antarctic Climate on Man.* 1963. Kr. 4.00.
129. LØVENSKIOLD, HERMAN L.: *Avifauna Svalbardensis.* 1964. Kr. 44.00.
130. LID, JOHANNES: *The Flora of Jan Mayen.* 1964. Kr. 14.00.
131. VINJE, TORGNY E.: *On the radiation balance and micrometeorological conditions at Norway Station, Antarctica.* 1964. Kr. 10.00.
132. VIGRAN, JORUNN OS: *Spores from Devonian deposits, Mimerdalen, Spitsbergen.* 1964. Kr. 8.00.
133. HISDAL, VIDAR: *On the tides at Norway Station and adjacent coastal areas of Antarctica.* 1965. Kr. 4.00.
134. RØNNING, OLAF I.: *Studies in Dryadion of Svalbard.* 1965. Kr. 12.00.
135. BUCHAN, S. H., A. CHALLINOR, W. B. HARLAND, and J. R. PARKER: *The Triassic Stratigraphy of Svalbard.* 1965. Kr. 15.00.
136. WISHMAN, ERIK: *A comparison between the general circulation over the Svalbard area and the weather conditions at Isfjord Radio.* 1966. Kr. 4.00.

CHARTS

				Kr.
501	Bjørnøya	1: 40,000	1932	10.00
502	Bjørnøyfarvatnet	1:350,000	1937	10.00
503	Frå Bellsund til Forlandsrevet med Isfjorden	1:200,000	1932	10.00
504	Frå Sørkapp til Bellsund	1:200,000	1934	10.00
505	Norge–Svalbard, northern sheet	1:750,000	1933	10.00
506	» » southern »	1:750,000	1933	10.00
507	Nordsvalbard	1:600,000	1934	10.00
508	Kongsfjorden og Krossfjorden	1:100,000	1934	10.00
509	Frå Storfjordrenna til Forlandsrevet med Isfjorden	1:350,000	1946	10.00
510	Frå Kapp Linné med Isfjorden til Sorgfjorden	1:350,000	1946	10.00
511	Østgrønland, fra Liverpool Kyst til Store Koldeweys Ø (rev. 1958)	1:600,000	1937	10.00
512	Jan Mayen	1:100,000	1955	10.00
513	Svalbard-Havner	various	1959	10.00
514	Barentshavet	1:2,000,000	1960	10.00
515	Svalbard–Grønland	1:2,000,000	1962	10.00

The charts are distributed by Norges Sjøkartverk, Stavanger.

MAPS

General, geographical, topographical, and technical maps:

				Kr.	
DRONNING MAUD LAND					
Giæverryggen	F 5	1:250,000	1962	5.55	
Borgmassivet	F 6	1:250,000	1962	5.55	
Kirwanveggen	F 7	1:250,000	1961	5.55	
Ahlmannryggen	G 5	1:250,000	1961	5.55	
Jutulstraumen	G 6	1:250,000	1961	5.55	
Neumayerskarvet	G 7	1:250,000	1961	5.55	
Jutulgryta	H 5	1:250,000	1961	5.55	
H. U. Sverdrupfjella	H 6	1:250,000	1961	5.55	
Mühlig-Hofmannfjella Sør	J 6	1:250,000	1962	5.55	
Filchnerfjella Sør	K 6	1:250,000	1962	5.55	
Glopeflya	L 6	1:250,000	1964	5.55	
Hoelfjella Sør	M 6	1:250,000	1964	5.55	
Sør-Rondane		1:250,000	1957	5.55	
GRØNLAND, Aust-Grønland					
Eirik Raudes Land frå Sofiasund til Youngsund		1:200,000	1932	2.20	
Claveringøya		1:100,000	1937		In one volume with index. Limited stock.
Geographical Society-øya		1:100,000	1937	30.00	
Jordan Hill		1:100,000	1937		
JAN MAYEN					
Jan Mayen		1:100,000	1955	2.20	Preliminary map.
Sør-Jan	Sheet 1	1: 50,000	1959	5.55	Also as supplement to Skrifter Nr. 120.
Nord-Jan	» 2	1: 50,000	1959	5.55	
SVALBARD					
Svalbard		1:2,000,000	1958	2.20	Latest edition.
Vestspitsbergen, southern part	Sheet 1	1:500,000	1964	10.00	
Vestspitsbergen, northern part	» 3	1:500,000	1964	10.00	
Kongsfjorden	A 7	1:100,000	1962	5.55	
Prins Karls Forland	A 8	1:100,000	1959	5.55	
Isfjorden	B 9	1:100,000	1955	5.55	
Van Mijenfjorden	B 10	1:100,000	1948	5.55	
Van Keulenfjorden	B 11	1:100,000	1952	5.55	
Torellbreen	B 12	1:100,000	1953	5.55	
Adventdalen	C 9	1:100,000	1950	5.55	
Markhambreen	C 12	1:100,000	1957	5.55	
Sørkapp	C 13	1:100,000	1947	5.55	
Adventfjorden–Braganzavågen		1:100,000	1941	2.20	
Hopen		1:100,000	1949	2.20	Preliminary map.
The Claims to Land in Svalbard		1: 50,000	1927	2.20	each. Nos. 1–33.
Bjørnøya		1: 25,000	1925	5.55	New ed. 1944 and 1955. Also as supplement to Skrifter Nr. 86.
Bjørnøya		1: 10,000	1925	....	6 sheets. Out of print.

The maps are distributed by Norges geografiske oppmåling, St. Olavs gt. 32, Oslo.

A.W. BRØGGERS BOKTRYKKERI A/S - OSLO

Norsk Polarinstitutt Skrifter Nr. 136. Erik Wishman: The general circulation over the Svalbard area.