# THE AURORA Programme

## THE CLIMATE OF HALLEY - ANTARCTICA

INGER HANSSEN-BAUER

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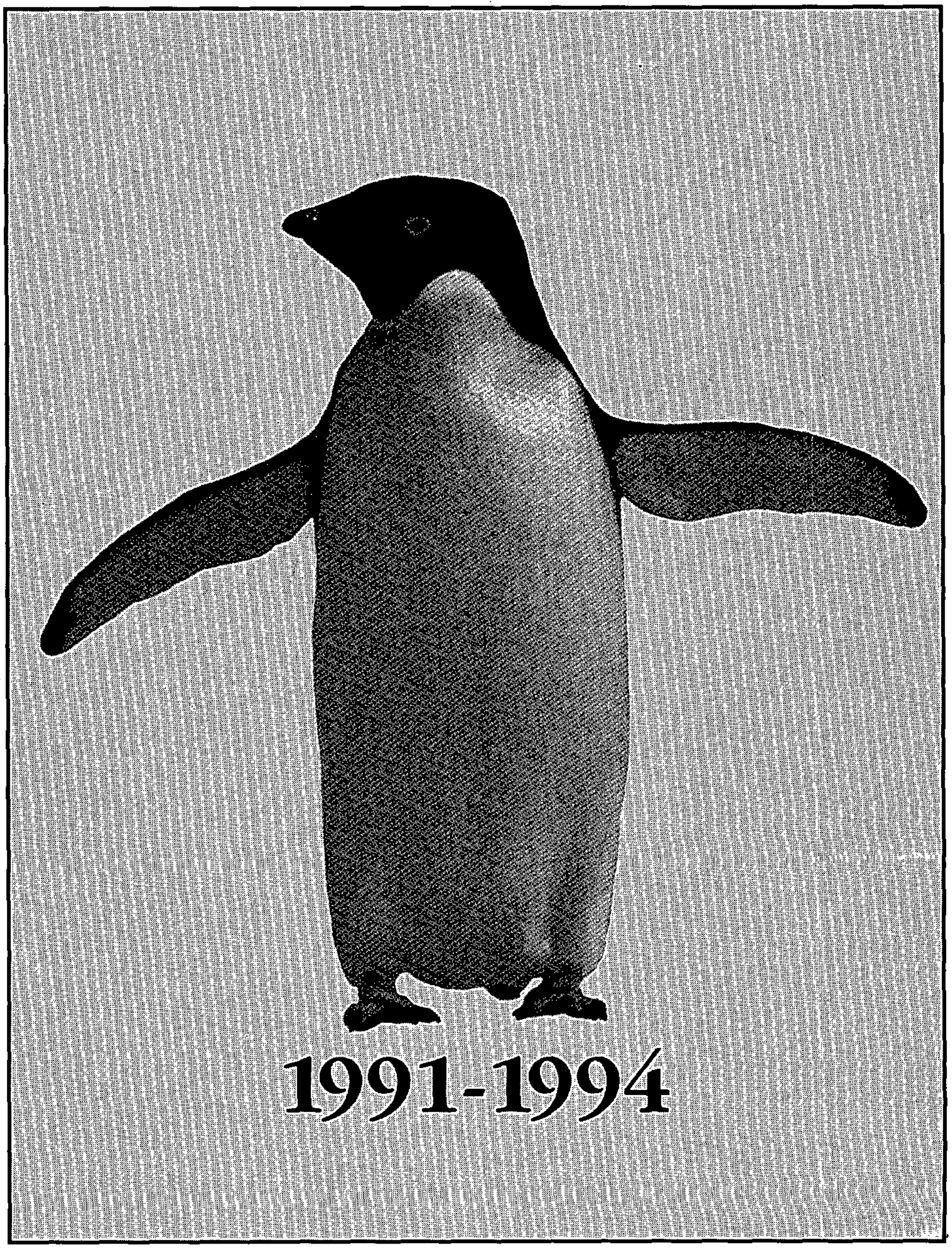

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THE CLIMATE OF HALLEY - ANTARCTICA

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SAMMENDRAG

General climate statistics of the Halley station in Antarctica is presented. Meteorological data from the Halley station were kindly made available by British Antarctic Survey. Climate statistics are based on 8 observations a day during the period 1957-1989.

UNDERSKRIFT

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# THE CLIMATE OF HALLEY - ANTARCTICA

by

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# 1. INTRODUCTION

## 1.1 Background.

This report is written as a part of the Aurora Programme (Kristensen 1991). Among the Antarctic climatological stations which have operated for at least 20 years, Halley is the one that is closest to the investigation area of the Aurora Programme (figure 1). Halley has therefore been chosen as a reference climatological station for the programme, and the climatology which is presented in this report will later be used as a reference to the climatology of the Filchner ice shelf.

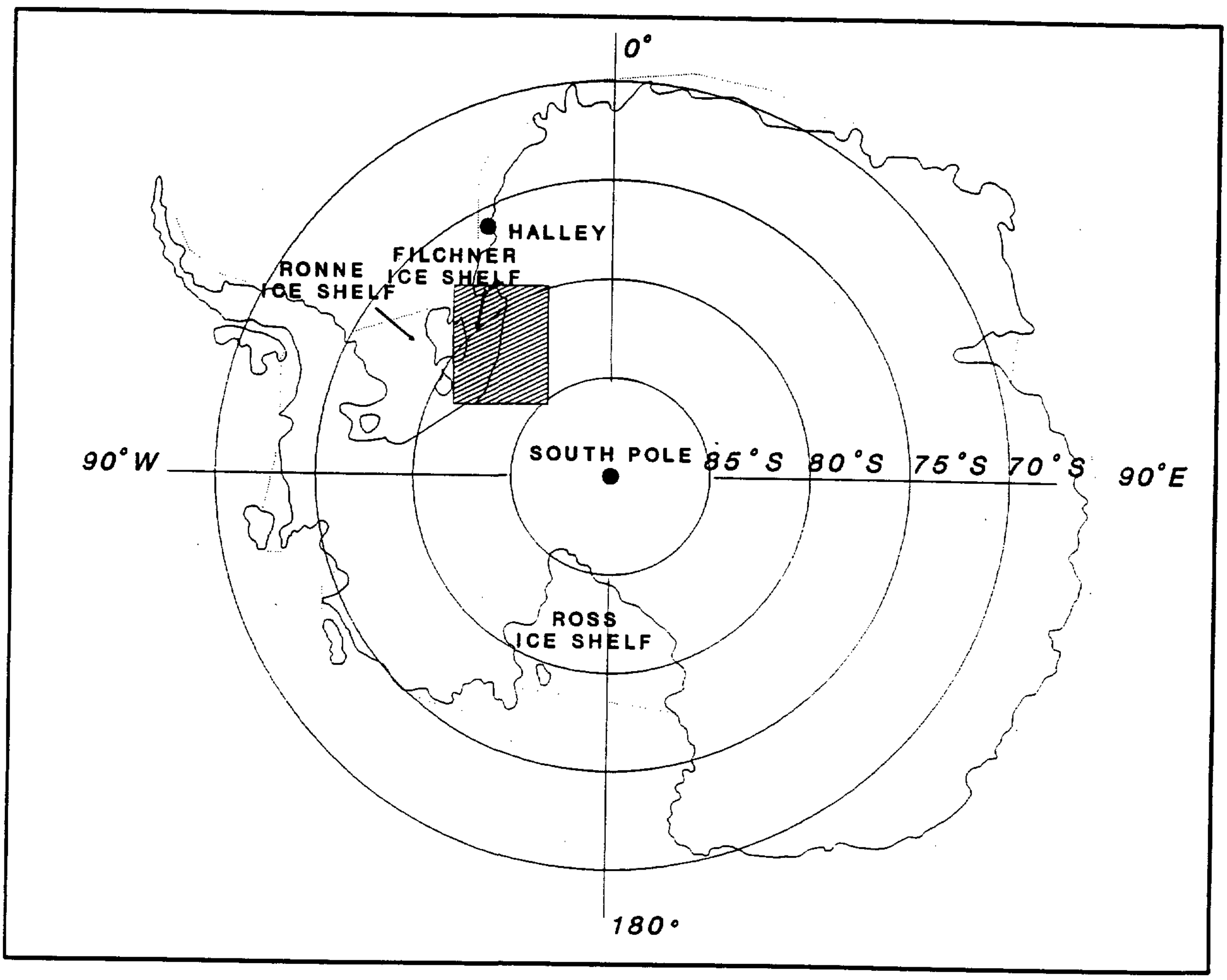



Figure 1. Map of Antarctica. The investigation area of the Aurora Programme is hatched.

## 1.2 The Halley climatological records.

The Halley Station is run by British Antarctic Survey (BAS). Halley is situated on drifting ice 75°36'S and 26°41'W (Antarctic Research Committee 1991). Elevation above sea level is about 30 m.

Climate data from Halley for the period 1957-1989 were kindly made available by Dr. J.C. King, Section Head for the Meteorology, Ice and Climate Division at BAS.

The data set consists of 8 observations a day (00, 03, 06, 09, 12, 15, 18 and 21 GMT) of cloud cover (N), height of lowest cloudbase (h), wind direction (dd) and speed (ff), visibility (VV), weather codes(ww, W1, W2), sea level pressure ($P_0$), air temperature (T) and relative humidity (RH).

Precipitation has not been measured at Halley, because of the problems involved with measuring solid precipitation under windy conditions. For the period 1973-1989, however, measurements of net snow accumulation/ablation are available for most months.

## 1.3 Data quality and treatment of errors.

The observations and measurements at Halley seem generally to be of high quality, and only two non-missing values were corrected in the original dataset. This was done because obviously faulty temperatures (+9.2°C at 27.11 1964 03 GMT and 0°C at 21.08 1984 06 GMT) would, if they were accepted, be the highest temperatures ever measured in November and August respectively. For temperature, no other obvious errors were detected, and it is unlikely that uncorrected errors in the dataset has significantly influenced the statistical results shown in table 1. The same is true for all other parameters except relative humidity.

Records of relative humidity are probably not reliable under drifting snow conditions and in periods with extremely low temperatures. This may have a minor influence on the mean values of relative humidity given in table 1.

## 1.4 Missing records and values.

**Missing records.**
Several records were missing in the Halley series during the period 1985 - 1988, mainly because of problems with a semi-automatic weather station. These gaps in the BAS computer database are currently being filled using manually-observed data (J. King, pers. com.). In the present work, however, single missing records were interpolated, while series of successive missing records were left missing. In 1985 (230 missing records) and 1987 (25 m.r.) the missing records were not successive, and they were thus interpolated. In 1986 (882 m.r.) and 1987 (265 m.r.) on the other hand, mainly whole months are missing. For the monthly statistics shown in table 1, this creates no problems. To avoid systematic errors in the annual values in table 1, these are computed as weighted mean values (or sums) of the tabulated monthly values, rather than mean values (or sums) computed directly from the data series.

The only figures in the present report which may be seriously affected by the missing monthly values in 1986 and 1988 are the time series shown in chapter 3. The "observed" mean temperature or cloud cover is not shown in the figures for periods which contain one or more missing months. Filter values are nevertheless computed by giving the missing period zero weight, while the neighbouring periods get the same relative weights as usual.

**Missing relative humidity.**
During 1961-1968, relative humidity was missing in 1-8% of the records each year. Vapour pressure was recorded, and relative humidity is currently being recomputed. For the present work, however, these values were not available, and as most of the missing values occurred in series of several successive missing values, they were not interpolated. The frequency of missing relative humidity is nevertheless small, and the influence on the mean values in table 1 is therefore small.

**Missing weathercodes.**
The World Meteorological Organization practice changed in 1982, and weathercodes ww 01-03 were no longer reported as part of the SYNOP message. From this year, it is therefore impossible to distinguish between fair weather and missing observations. To be able to include data from the last years in the statistical analysis, it has been assumed that ww is missing only when the full record is missing. In all non-missing records, it is assumed that ww is 01-03 whenever the code is missing. This assumption will be wrong on occasions when the record is non-missing, but ww has not been observed. Comparisons of frequency distributions of ww for 1957-1981 and 1982-1989 shows, however, no major discrepancies. This indicates that the assumption is good.

## 2. THE CLIMATE OF HALLEY

### 2.1 Univariate climate statistics.

Table 1 shows monthly and annual mean values and frequency distributions of a number of parameters from the Halley climatological records. The table is based on data from the period 1957-1989.

## Table 1. CLIMATE STATISTICS FOR HALLEY - ANTARCTICA 1957-1989

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SEA LEVEL PRESSURE, mb** | | | | | | | | | | | | | |
| Monthly mean | 993.1 | 991.1 | 987.5 | 988.1 | 990.8 | 991.4 | 988.9 | 988.2 | 985.7 | 984.5 | 986.6 | 992.1 | 989.0 |
| **AIR TEMPEARTURE, C** | | | | | | | | | | | | | |
| Monthly/annual mean | -4.6 | -9.7 | -16.1 | -20.3 | -24.3 | -26.7 | -28.6 | -28.1 | -26.2 | -19.7 | -11.7 | -5.2 | -18.5 |
| Highest monthly mean | -3.0 | -7.6 | -10.3 | -14.7 | -16.3 | -20.8 | -22.7 | -19.9 | -16.7 | -14.0 | -9.1 | -3.5 | |
| Lowest monthly mean | -6.7 | -12.3 | -21.6 | -25.0 | -32.1 | -32.6 | -34.2 | -36.8 | -33.4 | -24.5 | -16.0 | -8.2 | |
| Standard deviation | 3.0 | 4.8 | 6.4 | 7.8 | 8.5 | 8.2 | 8.2 | 8.3 | 8.0 | 6.8 | 4.9 | 3.1 | |
| Mean daily max. | -2.4 | -6.7 | -12.6 | -16.6 | -20.5 | -22.7 | -24.6 | -24.1 | -22.4 | -16.2 | -8.9 | -3.1 | |
| Mean monthly max. | 0.7 | -1.3 | -4.6 | -6.1 | -7.9 | -10.1 | -12.0 | -12.8 | -11.2 | -7.0 | -3.2 | 0.2 | |
| Absolute max. | 6.0 | 0.6 | -1.5 | -0.7 | -1.4 | -3.6 | -5.9 | -4.6 | -3.9 | -2.7 | 1.8 | 3.9 | |
| Mean daily min. | -7.2 | -13.2 | -19.9 | -24.3 | -28.4 | -31.0 | -32.8 | -32.4 | -30.4 | -23.7 | -15.1 | -7.9 | |
| Mean monthly min. | -15.0 | -23.9 | -31.8 | -38.3 | -41.1 | -43.8 | -46.3 | -45.0 | -44.2 | -36.0 | -25.5 | -15.2 | |
| Absolute min. | -20.8 | -29.3 | -40.7 | -49.7 | -48.4 | -52.2 | -54.9 | -51.5 | -50.5 | -45.3 | -32.3 | -20.9 | |
| <u>Mean number of days with:</u> | | | | | | | | | | | | | |
| Daily min.T < -10 C | 6 | 19 | 29 | 29 | 30 | 30 | 31 | 31 | 30 | 30 | 24 | 8 | 297 |
| Daily min.T < -20 C | 0 | 4 | 15 | 22 | 26 | 27 | 29 | 28 | 26 | 22 | 6 | 0 | 204 |
| Daily min.T < -30 C | - | - | 2 | 7 | 14 | 17 | 20 | 20 | 16 | 6 | 0 | - | 102 |
| Daily min.T < -40 C | - | - | 0 | 1 | 2 | 4 | 6 | 6 | 3 | 0 | - | - | 22 |
| Daily min.T < -50 C | - | - | - | - | - | 0 | 0 | 0 | 0 | - | - | - | 1 |
| Daily max.T > 0 C | 3 | 0 | - | - | - | - | - | - | - | - | 0 | 2 | 5 |
| Daily max.T > -10 C | 31 | 23 | 10 | 5 | 3 | 1 | 1 | 1 | 1 | 5 | 20 | 31 | 133 |
| Daily max.T > -20 C | 31 | 28 | 29 | 20 | 15 | 11 | 9 | 9 | 11 | 23 | 30 | 31 | 246 |
| Daily max.T > -30 C | 31 | 28 | 31 | 30 | 27 | 25 | 24 | 24 | 26 | 31 | 30 | 31 | 338 |
| **RELATIVE HUMIDITY, %** | | | | | | | | | | | | | |
| Monthly/annual mean | 86 | 84 | 82 | 82 | 79 | 79 | 77 | 78 | 79 | 81 | 84 | 85 | 81 |
| **CLOUD COVER, OCTAS** | | | | | | | | | | | | | |
| Monthly/annual mean | 6.0 | 6.0 | 5.6 | 5.6 | 4.9 | 4.5 | 4.6 | 5.1 | 5.4 | 5.8 | 5.8 | 5.8 | 5.4 |
| <u>Mean monthly number of:</u> | | | | | | | | | | | | | |
| clear days (N<1.34) | 1 | 2 | 2 | 2 | 4 | 5 | 5 | 3 | 3 | 2 | 2 | 1 | 32 |
| overcast days (N>6.66) | 16 | 15 | 14 | 13 | 10 | 8 | 9 | 11 | 12 | 14 | 15 | 15 | 152 |
| <u>Percentage frequencies of:</u> | | | | | | | | | | | | | |
| Lowest cloud height: | | | | | | | | | | | | | |
| < 100 ft | 2.3 | 3.4 | 6.2 | 9.8 | 8.9 | 7.6 | 8.8 | 8.7 | 9.4 | 9.2 | 5.7 | 1.9 | 6.8 |
| < 400 ft | 4.4 | 5.7 | 7.7 | 11.2 | 9.8 | 8.2 | 9.6 | 9.7 | 11.5 | 11.4 | 7.3 | 3.8 | 8.4 |
| <1000 ft | 20.7 | 20.6 | 21.0 | 21.1 | 16.5 | 13.1 | 13.9 | 15.3 | 17.6 | 21.0 | 19.9 | 21.3 | 18.5 |
| **FOG, SNOWFALL AND VISIBILITY** | | | | | | | | | | | | | |
| <u>Percentage frequencies of:</u> | | | | | | | | | | | | | |
| Fog | 1.8 | 1.3 | 2.4 | 4.0 | 2.7 | 2.2 | 2.0 | 3.0 | 3.7 | 3.1 | 1.5 | 1.3 | 2.4 |
| Drifting snow | 9.2 | 14.8 | 19.9 | 19.7 | 19.6 | 18.1 | 19.9 | 20.0 | 21.7 | 22.8 | 20.0 | 12.3 | 18.2 |
| Snowfall | 19.6 | 23.2 | 23.2 | 28.1 | 21.6 | 24.8 | 23.0 | 22.2 | 23.9 | 21.7 | 22.9 | 16.5 | 22.6 |
| Horizontal visibility: | | | | | | | | | | | | | |
| < 50 m | 0.2 | 0.1 | 1.2 | 2.4 | 2.5 | 2.8 | 3.3 | 3.9 | 4.5 | 4.2 | 1.8 | 0.2 | 2.3 |
| < 200 m | 1.6 | 2.1 | 5.8 | 8.6 | 7.8 | 7.8 | 8.2 | 10.3 | 11.7 | 11.4 | 6.2 | 1.6 | 6.9 |
| < 1 km | 6.5 | 9.8 | 17.7 | 23.2 | 19.9 | 18.7 | 19.4 | 22.8 | 26.4 | 23.4 | 15.5 | 6.8 | 17.5 |
| < 10 km | 20.4 | 27.7 | 33.7 | 45.4 | 41.4 | 39.1 | 37.8 | 41.3 | 43.6 | 38.1 | 28.6 | 17.3 | 34.5 |
| **WIND SPEED , KNOTS** | | | | | | | | | | | | | |
| Monthly mean | 10.5 | 11.6 | 13.7 | 14.2 | 13.6 | 13.4 | 13.9 | 14.8 | 14.7 | 14.7 | 12.8 | 10.7 | 13.2 |
| <u>Monthly frequencies (%) of wind strength (Beaufort):</u> | | | | | | | | | | | | | |
| 0 (calm) | 5.7 | 4.6 | 3.2 | 3.6 | 3.4 | 2.9 | 3.2 | 2.9 | 3.3 | 3.0 | 3.9 | 4.4 | 3.7 |
| 1-2 (light breeze) | 23.4 | 20.4 | 16.6 | 18.3 | 19.9 | 20.9 | 17.9 | 16.7 | 15.7 | 17.0 | 20.1 | 24.3 | 19.3 |
| 3-5 (gentle-fresh b.) | 63.9 | 65.4 | 62.7 | 57.8 | 58.5 | 59.0 | 60.2 | 59.6 | 59.6 | 58.7 | 60.2 | 63.5 | 60.7 |
| 6-8 (strong b.-gale) | 6.8 | 9.5 | 16.6 | 18.7 | 16.3 | 15.3 | 16.6 | 17.3 | 19.1 | 19.1 | 15.3 | 7.6 | 14.9 |
| 9-11(stong gale-storm) | 0.2 | 0.1 | 0.9 | 1.6 | 2.0 | 1.8 | 2.1 | 3.5 | 2.3 | 2.2 | 0.5 | 0.1 | 1.5 |
| 12 (hurricane) | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | - | 0.0 | 0.0 | - | 0.0 |

Daily extreme temperatures were not included in the data-set received from BAS. In the statistical analyses, daily maximum and minimum temperatures were therefore substituted by the highest and lowest of the 8 daily observed temperatures respectively. The "maximum" temperatures in table 1 may therefore be somewhat too low, while the "minimum" temperatures may be a bit too high. Consequently, the frequencies of maximum temperatures above given values and minimum temperatures below given values may be slightly underestimated.

Typical numbers of "clear" and "overcast" days and frequencies of fog and snowfall are given in table 1. Clear days are here defined as days when average cloud cover is below 1.34, and overcast days are days when average cloud cover is above 6.66. Frequency of fog is defined as frequency of weather code ww 40-45. Frequency of snowfall is defined as ww 70-79 or 85-86, which, in addition to regular snowfall, includes both ice needles and single snow crystals, as well as snow showers.

Monthly frequencies of wind force (Beaufort) in given intervals are also given in table 1. The relation between the Beaufort number and the wind speed is given i table 2.

Table 2. **Wind speed equivalents**

| Beaufort number | Description | Wind speed equivalent at height 10 m above the ground. | |
|---|---|---|---|
| | | Knots | m/s |
| 0 | Calm | < 1 | 0 - 0.2 |
| 1 | Light air | 1 - 3 | 0.3 - 1.5 |
| 2 | Light breeze | 4 - 6 | 1.6 - 3.3 |
| 3 | Gentle breeze | 7 -10 | 3.4 - 5.4 |
| 4 | Moderate breeze | 11 -16 | 5.5 - 7.9 |
| 5 | Fresh breeze | 17 -21 | 8.0 -10.7 |
| 6 | Strong breeze | 22 -27 | 10.8 -13.8 |
| 7 | Near gale | 28 -33 | 13.9 -17.1 |
| 8 | Gale | 34 -40 | 17.2 -20.7 |
| 9 | Strong gale | 41 -47 | 20.8 -24.4 |
| 10 | Storm | 48 -55 | 24.5 -28.4 |
| 11 | Violent storm | 56 -63 | 28.5 -32.6 |
| 12 | Hurricane | 64 and over | 32.7 and over |

## 2.2 Temperature.

Some mean and extreme temperature values from table 1 are shown in figure 2. The figure shows that January has the highest mean temperature at Halley, while July has the lowest mean temperature. The differences between December and January and between July and August are small, however, and August has the lowest mean temperature over the period 1956-1967 (Schwerdtfeger 1970).

Typical diurnal temperature cycle for each month is shown in figure 3. From May through August there is no diurnal cycle, as the sun is below the horizon most of the time. For the other months, typical diurnal temperature amplitude is between 0.5 and 4.5°C. The amplitude is typically at maximum in October and November, in spite of the fact that the sun is above the horizon most of the time in November.

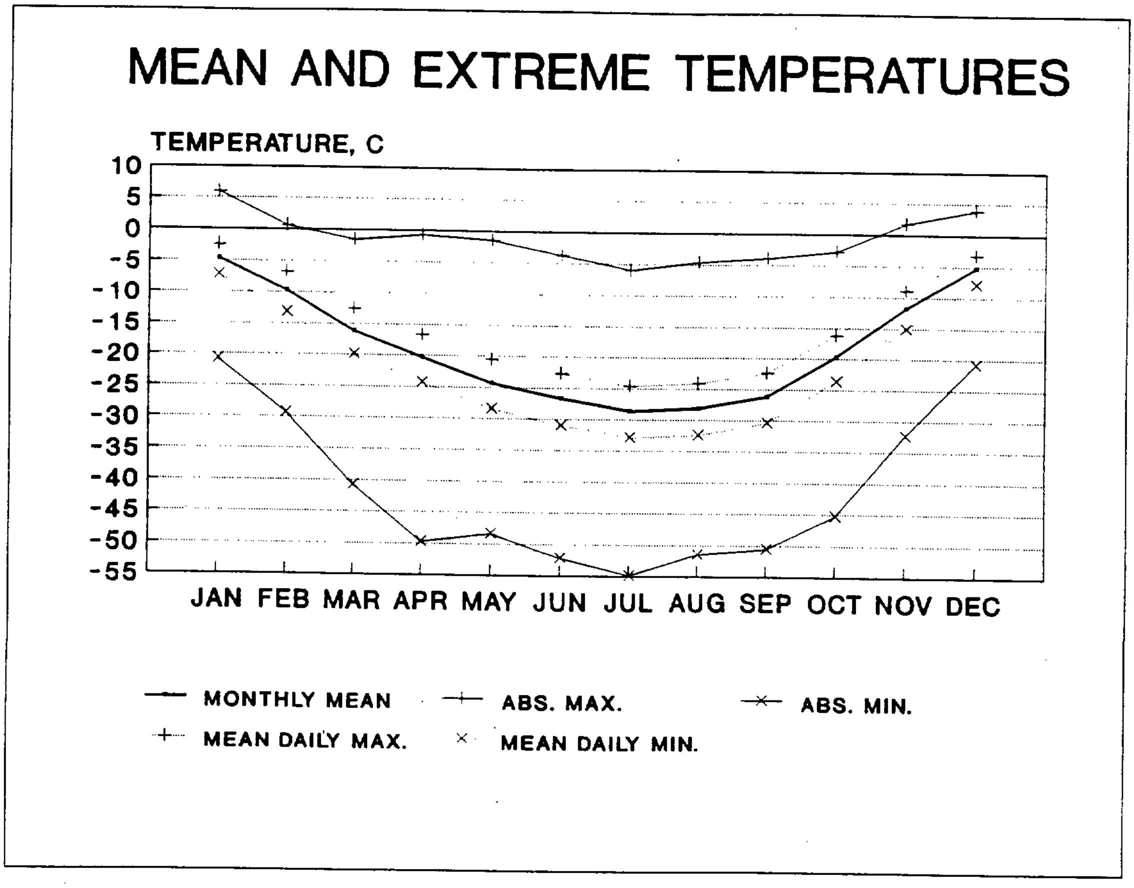
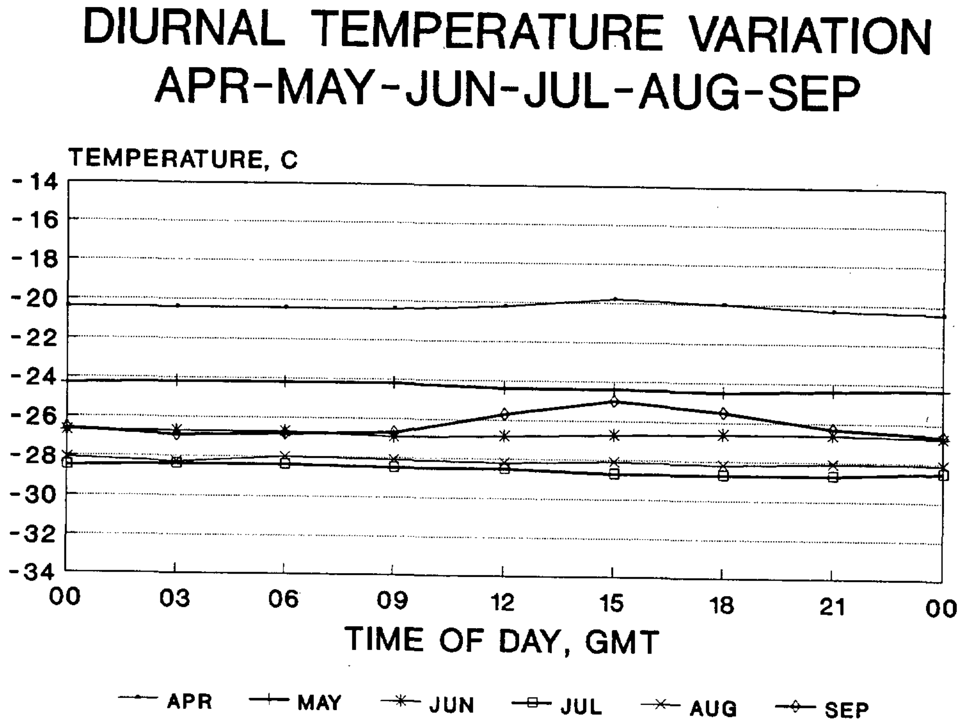



Figure 2. Monthly mean and extreme temperatures at Halley.



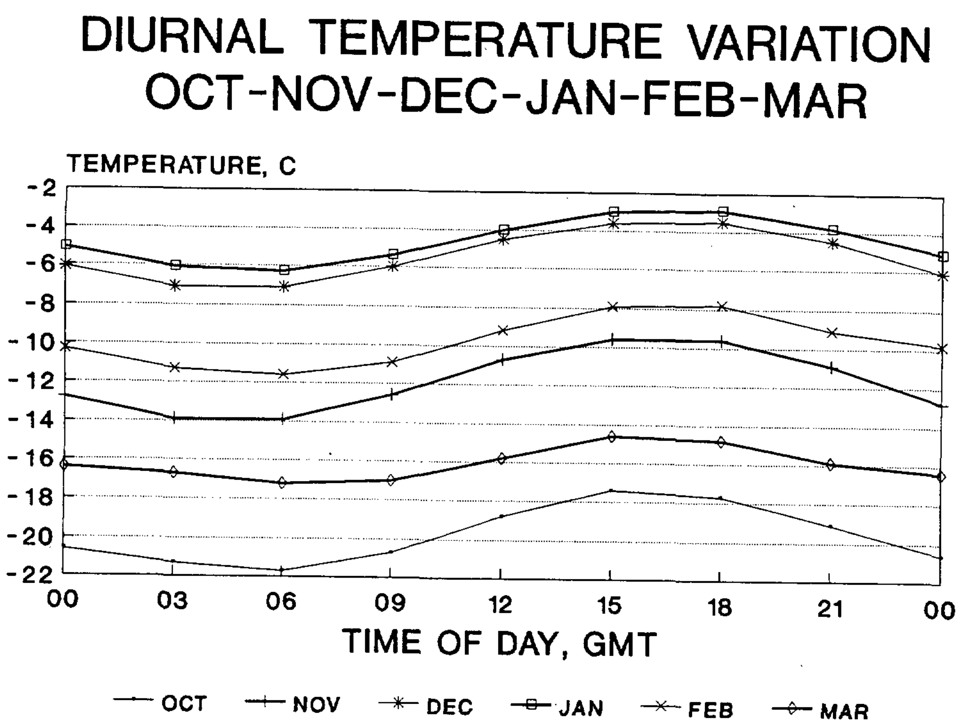




Figure 3. Mean diurnal temperature amplitude for each month.

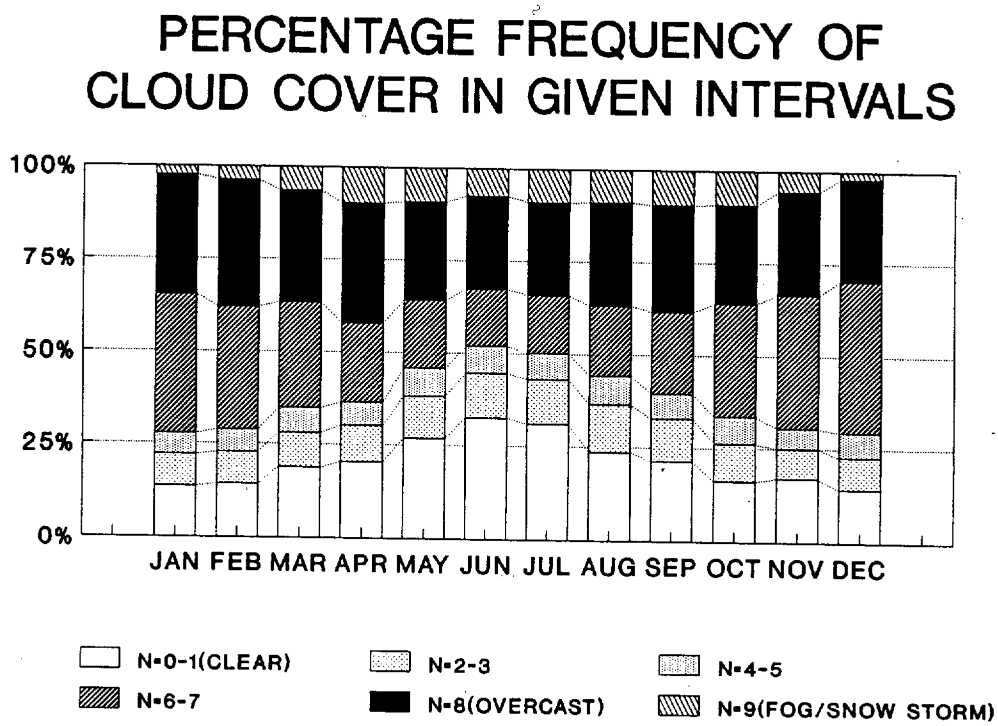
## 2.3 Cloud cover.

Both average cloud cover and number of overcast and clear days show that cloudiness is at a maximum during summer an at a minimum during winter (table 1). This is also illustrated by figure 4a, which shows monthly percentage of the records with cloud cover (N) in different groups. During the summer months (Dec-Jan-Feb), the percentage of N=0-1 (i.e. 0-1/8) normally lies between 10 and 15%, while it is 25-35% during the winter months (Jun-Aug). The percentage of N=8 (overcast) is more stable during the year, and varies only between 25% (June) and 35% (February). The code N=9 is used when it is impossible to see the sky. At Halley, the reasons for this may be fog, drifting or blowing snow and/or heavy snowfall. The percentage of N=9 is lowest during the summer, when average wind speed and frequency of drifting snow both are at a minimum.

Figure 4b shows mean temperature for the different cloud cover groups for each month. There is a clear tendency for increasing temperature with increasing cloud cover for all months. During summer, the temperature average for the N=0-1 group is only 2-5 °C lower than the N=8 group. During winter, however, the difference is nearly 10 °C. The N=9 group is warmer than the overcast group during winter, probably because N=9 frequently is combined with relatively high windspeeds, which tend to break down inversions.

The upper part of figure 5 shows frequencies of cloud cover groups in January and July as a function of time of day. In January, there is no diurnal variation of cloud cover. In July, however, there is a tendency for lower frequencies of clear sky around local noon than during night. This is difficult to explain physically, as the sun is below the horizon all the time. It might reflect a systematic observational error, as the sky will be somewhat lighter around noon than the rest of the day, thus making detection of small amounts of clouds easier.

a)




b)

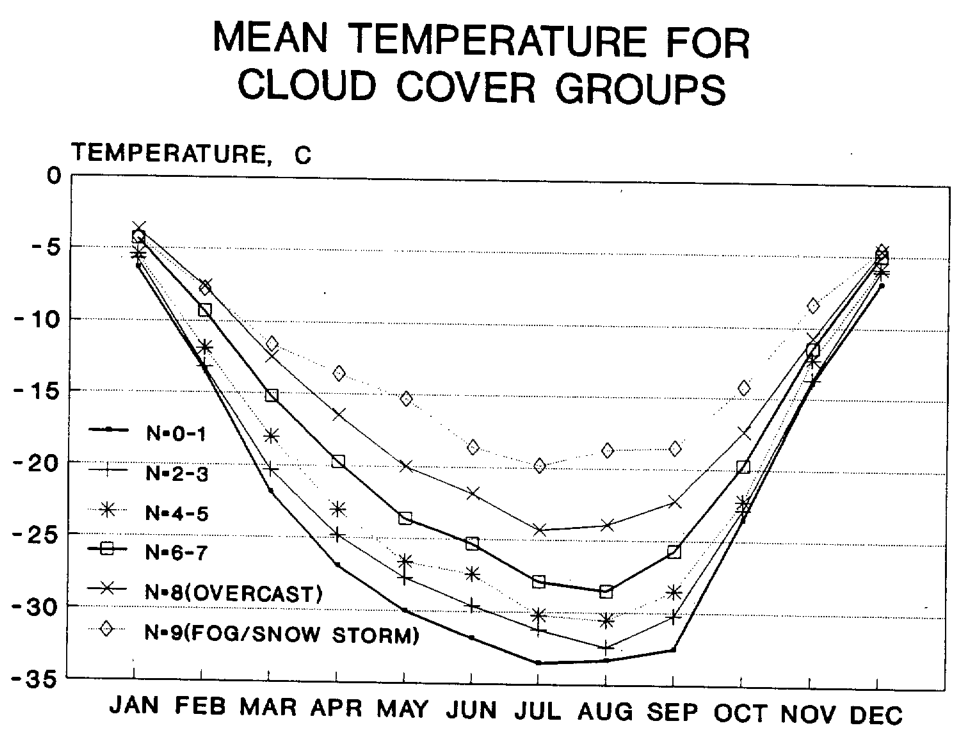



Figure 4. Monthly percentage frequency (a) and mean temperature (b) for groups with different cloud coverage N.

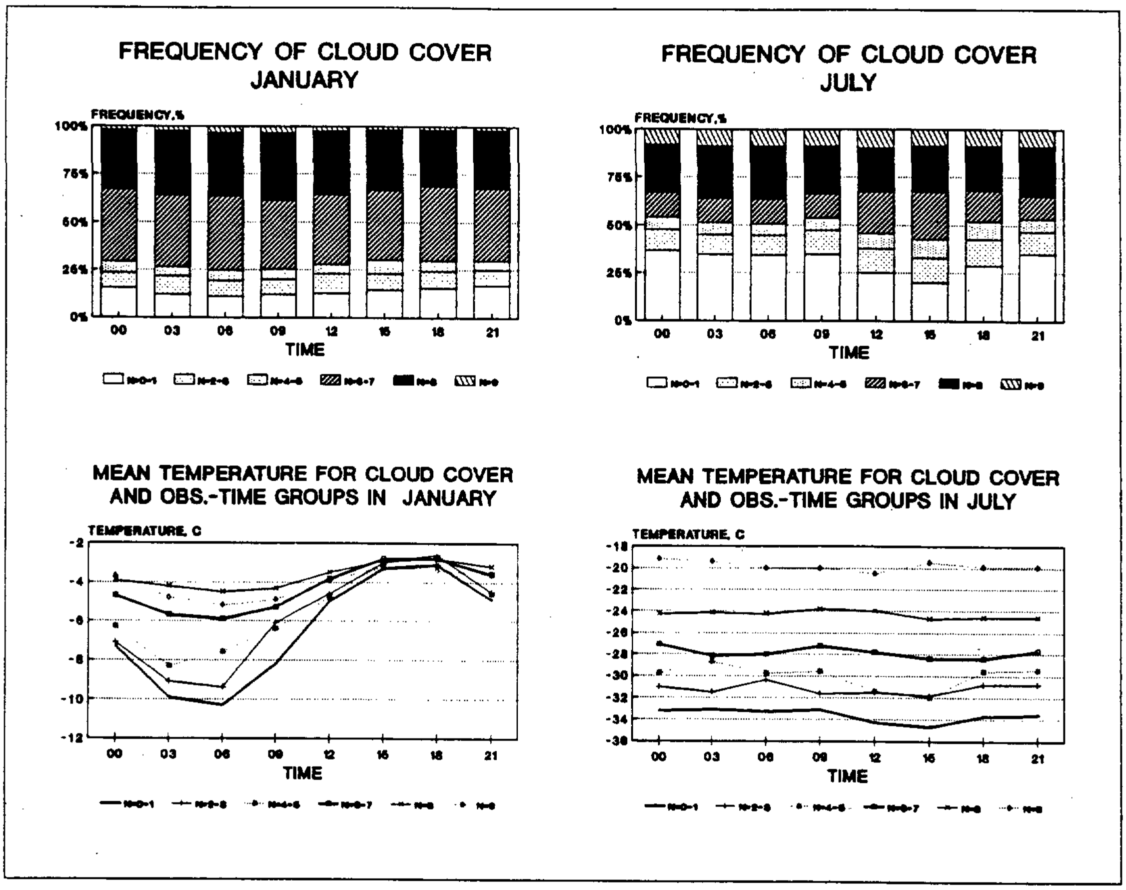



Figure 5. Diurnal variation of frequency and mean temperature of cloud cover groups in January and July.

The lower part of figure 5 shows the mean temperatures for cloud cover groups at different observational times for January and July. In January, the day temperature shows little variation with cloud cover, while the night temperature on average is 6°C lower when N=0-1 than when N=8. In July the average temperature under clear sky conditions lies 9-10°C below the average temperature when the sky is overcast all day.

Note, however, that the mean temperature for clear sky conditions is 1-2°C lower around noon than at night in July. This might indicate that the noon clear-sky group is "purer" than the clear sky groups the rest of the day, thus supporting the theory of a systematic observational error.

## 2.4 Fog and visibility.

The frequencies of horizontal visibility below given distances are presented for all months in table 1 and in figure 6a. The frequency of reduced visibility is at a minimum during summer (Dec-Jan-Feb), while the highest frequencies are found in spring (September) and fall (April). Table 1 shows that the frequency of fog has a similar annual cycle. The fog frequencies are, however, only 1/4 - 1/10 of the frequencies of visibility below 1 km. Thus drifting snow and/or heavy snowfall must be the reasons for reduced visibility in many cases.

A cross tabulation of visibility and weather code shows that drifting snow and/or snowfall may explain the reduced horizontal visibility on all occasions when no fog is reported.

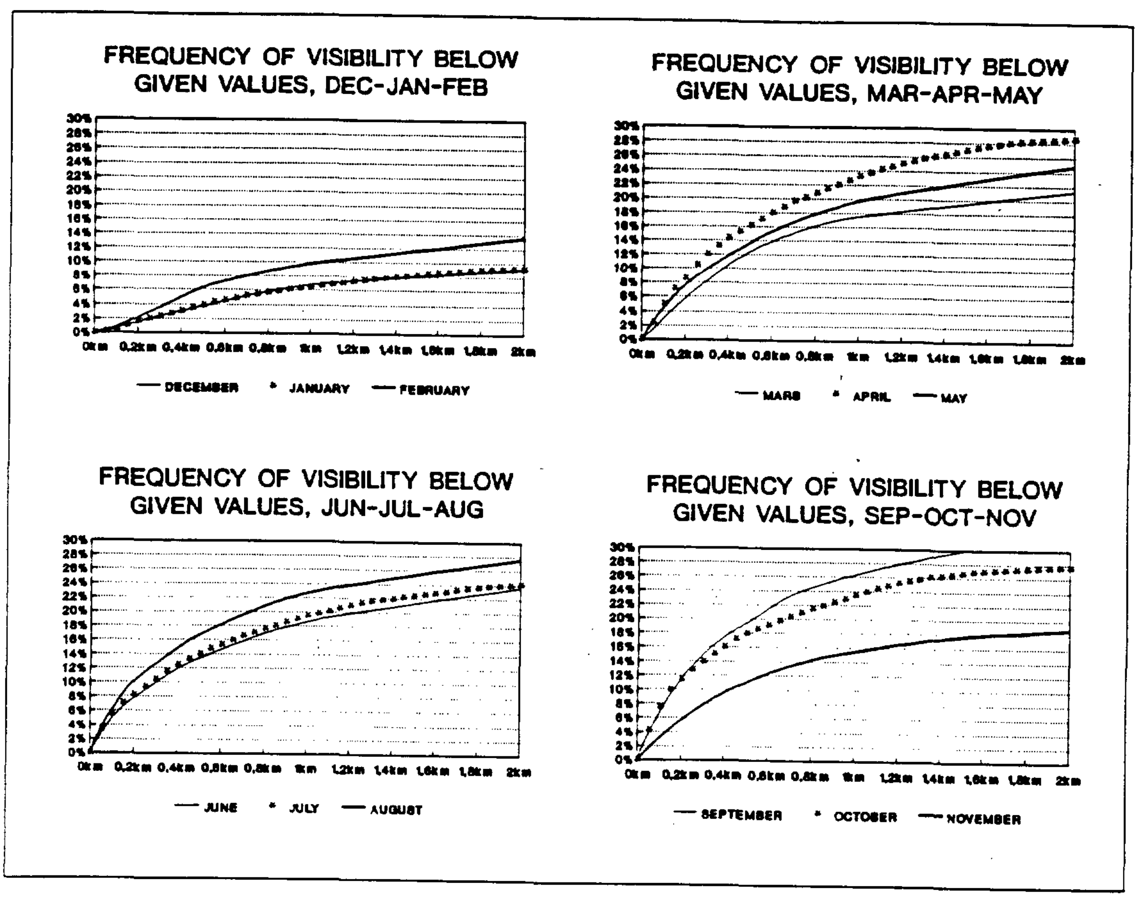



Figure 6a. Frequencies of visibility below distances from 0 to 2 km. for all months.

Figure 6b shows the monthly frequencies of visibility below 1 km subdivided into weathercodes. It should be noted that observation of snowfall has priority before fog and drifting snow in the ww code. Combinations of snowfall and fog, and of snowfall and drifting snow, are therefore registrered as snowfall in figure 6b, even though the reason for the reduced visibility may be fog or drifting snow respectively.

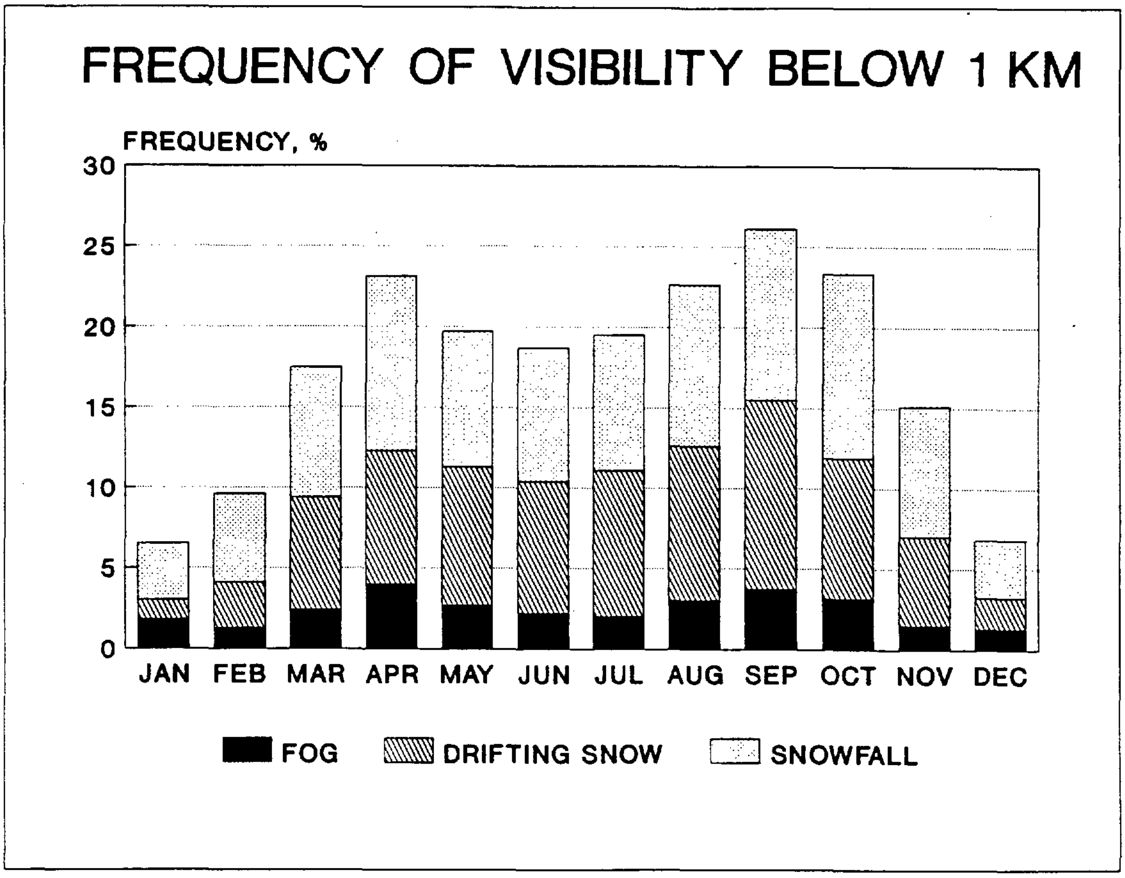



Figure 6b. Monthly frequencies of visibility below 1 km combined with: ww=40-45 (fog), ww=36-39 (drifting snow) and ww=70-79 or 85-86 (snowfall).

Table 3a and b show, for each month, number and duration of instances with visibility below 200 m and 1 km respectively. Table 3a shows for instance that September on average had 5.97 instances of visibility below 200 m. Of theese, 0.97 or 16% lasted for more than 1 day, while 0.27 or 5% lasted for more than 2 days. The duration of instances with visibility below 200 m was never greater than 4 days.

Table 3a. **Duration of instances with visibility < 200 m.**

Average monthly numbers of instances with duration above the given values.
Numbers in brackets: Instances in % of all instances with visibility < 200 m.

| MONTH: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DURATION | | | | | | | | | | | | |
| > 0 hours | 1.31 (100%) | 2.06 (100%) | 4.36 (100%) | 5.00 (100%) | 4.15 (100%) | 3.91 (100%) | 4.25 (100%) | 4.66 (100%) | 5.97 (100%) | 5.64 (100%) | 3.67 (100%) | 1.38 (100%) |
| > 3 hours | 0.81 (62%) | 1.06 (51%) | 2.76 (63%) | 3.24 (65%) | 2.97 (72%) | 2.72 (70%) | 3.03 (71%) | 3.47 (74%) | 4.09 (69%) | 4.09 (73%) | 2.06 (56%) | 0.91 (66%) |
| > 6 hours | 0.47 (36%) | 0.64 (31%) | 2.03 (47%) | 2.39 (48%) | 2.27 (55%) | 2.22 (57%) | 2.53 (60%) | 2.88 (62%) | 3.27 (55%) | 3.27 (58%) | 1.67 (45%) | 0.41 (30%) |
| > 9 hours | 0.28 (21%) | 0.48 (24%) | 1.58 (36%) | 1.91 (38%) | 1.88 (45%) | 1.72 (44%) | 1.97 (46%) | 2.50 (54%) | 2.64 (44%) | 2.64 (47%) | 1.24 (33%) | 0.25 (18%) |
| >12 hours | 0.22 (17%) | 0.24 (12%) | 1.12 (26%) | 1.45 (29%) | 1.42 (34%) | 1.34 (34%) | 1.72 (40%) | 2.00 (43%) | 2.21 (37%) | 2.18 (39%) | 1.12 (31%) | 0.25 (18%) |
| >15 hours | 0.19 (15%) | 0.15 ( 7%) | 0.79 (18%) | 1.30 (26%) | 1.15 (28%) | 1.13 (29%) | 1.34 (32%) | 1.69 (36%) | 1.73 (29%) | 1.85 (33%) | 0.94 (25%) | 0.22 (16%) |
| >18 hours | 0.19 (15%) | 0.12 ( 6%) | 0.58 (13%) | 1.06 (21%) | 0.85 (20%) | 0.94 (24%) | 1.16 (27%) | 1.44 (31%) | 1.42 (24%) | 1.39 (25%) | 0.76 (21%) | 0.13 ( 9%) |
| >21 hours | 0.09 ( 7%) | 0.06 ( 3%) | 0.30 ( 7%) | 0.73 (15%) | 0.67 (16%) | 0.72 (18%) | 1.13 (26%) | 1.16 (25%) | 1.21 (20%) | 1.09 (19%) | 0.61 (17%) | 0.13 ( 9%) |
| > 1 day | 0.09 ( 7%) | 0.03 ( 1%) | 0.21 ( 5%) | 0.58 (12%) | 0.55 (13%) | 0.63 (16%) | 0.78 (18%) | 0.91 (19%) | 0.97 (16%) | 0.91 (16%) | 0.48 (13%) | 0.09 ( 7%) |
| >30 hours | 0.09 ( 7%) | 0.03 ( 1%) | 0.18 ( 4%) | 0.45 ( 9%) | 0.45 (11%) | 0.38 (10%) | 0.56 (13%) | 0.69 (15%) | 0.70 (12%) | 0.55 (10%) | 0.33 ( 9%) | 0.09 ( 7%) |
| >36 hours | 0.09 ( 7%) | - - | 0.09 ( 2%) | 0.30 ( 6%) | 0.36 ( 9%) | 0.31 ( 8%) | 0.38 ( 9%) | 0.47 (10%) | 0.45 ( 8%) | 0.36 ( 6%) | 0.21 ( 6%) | 0.03 ( 2%) |
| >42 hours | 0.03 ( 2%) | - - | - - | 0.21 ( 4%) | 0.27 ( 7%) | 0.28 ( 7%) | 0.22 ( 5%) | 0.38 ( 8%) | 0.30 ( 5%) | 0.30 ( 5%) | 0.15 ( 4%) | - - |
| > 2 days | 0.03 ( 2%) | - - | - - | 0.15 ( 3%) | 0.24 ( 6%) | 0.25 ( 6%) | 0.16 ( 4%) | 0.38 ( 8%) | 0.27 ( 5%) | 0.21 ( 4%) | 0.12 ( 3%) | - - |
| >54 hours | 0.03 ( 2%) | - - | - - | 0.12 ( 2%) | 0.12 ( 3%) | 0.22 ( 6%) | 0.06 ( 1%) | 0.22 ( 5%) | 0.18 ( 3%) | 0.18 ( 3%) | 0.09 ( 2%) | - - |
| >60 hours | 0.03 ( 2%) | - - | - - | 0.09 ( 2%) | 0.03 ( 1%) | 0.13 ( 3%) | - - | 0.19 ( 4%) | 0.09 ( 2%) | 0.15 ( 3%) | 0.06 ( 2%) | - - |
| >66 hours | - - | - - | - - | 0.03 ( 1%) | - - | 0.13 ( 3%) | - - | 0.13 ( 3%) | - - | 0.09 ( 2%) | 0.06 ( 2%) | - - |
| > 3 days | - - | - - | - - | - - | - - | 0.06 ( 2%) | - - | 0.06 ( 1%) | - - | 0.06 ( 1%) | 0.06 ( 2%) | - - |
| >78 hours | - - | - - | - - | - - | - - | - - | - - | 0.03 ( 1%) | - - | 0.06 ( 1%) | - - | - - |
| >84 hours | - - | - - | - - | - - | - - | - - | - - | 0.03 ( 1%) | - - | 0.06 ( 1%) | - - | - - |
| >90 hours | - - | - - | - - | - - | - - | - - | - | 0.03 ( 1%) | - - | 0.06 ( 1%) | - - | - - |
| > 4 days | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - |

# Table 3b. **Duration of instances with visibility < 1 km.**

Average monthly numbers of instances with duration above the given values.
Numbers in brackets: Instances in % of all instances with visibility < 1 km.

| MONTH: DURATION | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| > 0 hours | 6.31 (100%) | 7.88 (100%) | 11.18 (100%) | 12.50 (100%) | 10.61 (100%) | 9.42 (100%) | 10.56 (100%) | 11.44 (100%) | 13.00 (100%) | 12.67 (100%) | 7.91 (100%) | 5.88 (100%) |
| > 3 hours | 2.88 (46%) | 3.76 (48%) | 6.52 (58%) | 8.36 (67%) | 6.82 (64%) | 5.61 (59%) | 6.19 (59%) | 7.34 (64%) | 8.52 (66%) | 7.79 (61%) | 4.91 (62%) | 2.94 (50%) |
| > 6 hours | 1.94 (31%) | 2.64 (33%) | 4.73 (42%) | 5.85 (47%) | 5.24 (49%) | 4.27 (45%) | 4.94 (47%) | 5.09 (45%) | 6.48 (50%) | 6.00 (47%) | 3.67 (46%) | 1.84 (31%) |
| > 9 hours | 1.28 (20%) | 1.91 (24%) | 3.88 (35%) | 4.30 (34%) | 3.94 (37%) | 3.58 (38%) | 3.94 (37%) | 4.19 (37%) | 5.15 (40%) | 4.85 (38%) | 3.00 (38%) | 1.41 (24%) |
| > 12 hours | 0.94 (15%) | 1.48 (19%) | 3.21 (29%) | 3.67 (29%) | 3.27 (31%) | 3.03 (32%) | 3.34 (32%) | 3.28 (29%) | 4.15 (32%) | 4.06 (32%) | 2.39 (30%) | 1.06 (18%) |
| > 15 hours | 0.78 (12%) | 1.03 (13%) | 2.85 (25%) | 3.09 (25%) | 2.70 (25%) | 2.48 (26%) | 2.81 (27%) | 2.88 (25%) | 3.30 (25%) | 3.27 (26%) | 2.03 (26%) | 0.84 (14%) |
| > 18 hours | 0.50 ( 8%) | 0.76 (10%) | 2.27 (20%) | 2.58 (21%) | 2.39 (23%) | 2.18 (23%) | 2.38 (22%) | 2.56 (22%) | 2.88 (22%) | 2.85 (22%) | 1.67 (21%) | 0.63 (11%) |
| > 21 hours | 0.44 ( 7%) | 0.55 ( 7%) | 1.82 (16%) | 2.27 (18%) | 1.97 (19%) | 1.85 (20%) | 2.13 (20%) | 2.22 (19%) | 2.52 (19%) | 2.48 (20%) | 1.39 (18%) | 0.44 ( 7%) |
| > 1 day | 0.38 ( 6%) | 0.39 ( 5%) | 1.45 (13%) | 2.06 (17%) | 1.73 (16%) | 1.61 (17%) | 1.88 (18%) | 1.94 (17%) | 2.33 (18%) | 2.06 (16%) | 1.18 (15%) | 0.34 ( 6%) |
| > 30 hours | 0.22 ( 3%) | 0.18 ( 2%) | 0.94 ( 8%) | 1.33 (11%) | 1.12 (11%) | 1.15 (12%) | 1.50 (14%) | 1.56 (14%) | 1.76 (14%) | 1.39 (11%) | 1.00 (13%) | 0.25 ( 4%) |
| > 36 hours | 0.16 ( 2%) | 0.15 ( 2%) | 0.61 ( 5%) | 1.15 ( 9%) | 0.88 ( 8%) | 0.91 (10%) | 1.06 (10%) | 1.25 (11%) | 1.27 (10%) | 1.09 ( 9%) | 0.79 (10%) | 0.16 ( 3%) |
| > 42 hours | 0.13 ( 2%) | 0.09 ( 1%) | 0.39 ( 4%) | 0.70 ( 6%) | 0.61 ( 6%) | 0.67 ( 7%) | 0.81 ( 8%) | 1.03 ( 9%) | 1.00 ( 8%) | 0.88 ( 7%) | 0.61 ( 8%) | 0.13 ( 2%) |
| > 2 days | 0.03 ( 0%) | 0.03 ( 0%) | 0.27 ( 2%) | 0.55 ( 4%) | 0.61 ( 6%) | 0.58 ( 6%) | 0.66 ( 6%) | 0.78 ( 7%) | 0.82 ( 6%) | 0.52 ( 4%) | 0.42 ( 5%) | 0.09 ( 2%) |
| > 54 hours | 0.03 ( 0%) | 0.03 ( 0%) | 0.21 ( 2%) | 0.36 ( 3%) | 0.52 ( 5%) | 0.48 ( 5%) | 0.44 ( 4%) | 0.75 ( 7%) | 0.55 ( 4%) | 0.42 ( 3%) | 0.39 ( 5%) | 0.09 ( 2%) |
| > 60 hours | 0.03 ( 0%) | 0.03 ( 0%) | 0.12 ( 1%) | 0.27 ( 2%) | 0.36 ( 3%) | 0.39 ( 4%) | 0.28 ( 3%) | 0.66 ( 6%) | 0.39 ( 3%) | 0.33 ( 3%) | 0.24 ( 3%) | 0.06 ( 1%) |
| > 66 hours | 0.03 ( 0%) | 0.03 ( 0%) | 0.12 ( 1%) | 0.21 ( 2%) | 0.30 ( 3%) | 0.27 ( 3%) | 0.19 ( 2%) | 0.56 ( 5%) | 0.24 ( 2%) | 0.27 ( 2%) | 0.15 ( 2%) | 0.06 ( 1%) |
| > 3 days | - | - | 0.06 ( 1%) | 0.12 ( 1%) | 0.18 ( 2%) | 0.21 ( 2%) | 0.16 ( 1%) | 0.41 ( 4%) | 0.18 ( 1%) | 0.21 ( 2%) | 0.12 ( 2%) | 0.03 ( 1%) |
| > 78 hours | - | - | 0.03 ( 0%) | 0.06 ( 0%) | 0.18 ( 2%) | 0.12 ( 1%) | 0.06 ( 1%) | 0.41 ( 4%) | 0.12 ( 1%) | 0.12 ( 1%) | 0.09 ( 1%) | 0.03 ( 1%) |
| > 84 hours | - | - | - | 0.06 ( 0%) | 0.09 ( 1%) | 0.06 ( 1%) | 0.03 ( 0%) | 0.25 ( 2%) | 0.12 ( 1%) | 0.09 ( 1%) | 0.09 ( 1%) | 0.03 ( 1%) |
| > 90 hours | - | - | - | 0.03 ( 0%) | 0.09 ( 1%) | 0.06 ( 1%) | 0.03 ( 0% | 0.19 ( 2%) | 0.09 ( 1%) | 0.09 ( 1%) | 0.09 ( 1%) | - |
| > 4 days | - | - | - | 0.03 ( 0%) | 0.03 ( 0%) | - | 0.03 ( 0%) | 0.19 ( 2%) | 0.09 ( 1%) | 0.06 ( 0%) | 0.09 ( 1%) | - |
| >102 hours | - | - | - | 0.03 ( 0%) | - | - | - | 0.16 ( 1%) | 0.09 ( 1%) | 0.06 ( 0%) | 0.06 ( 1%) | - |
| >108 hours | - | - | - | 0.03 ( 0%) | - | - | - | 0.03 ( 0%) | 0.09 ( 1%) | 0.06 ( 0%) | 0.06 ( 1%) | - |
| >114 hours | - | - | - | 0.03 ( 0%) | - | - | - | - | 0.06 ( 0%) | 0.06 ( 0%) | 0.03 ( 0%) | - |
| > 5 days | - | - | - | 0.03 ( 0%) | - | - | - | - | 0.03 ( 0%) | - | - | - |
| >126 hours | - | - | - | - | - | - | - | - | 0.03 ( 0%) | - | - | - |
| >132 hours | - | - | - | - | - | - | - | - | 0.03 ( 0%) | - | - | - |
| >138 hours | - | - | - | - | - | - | - | - | - | - | - | - |
| > 6 days | - | - | - | - | - | - | - | - | - | - | - | - |

## 2.5 Snowfall and drifting snow.

Monthly frequencies of drifting snow (ww=36-39) and snowfall (ww=70-79 or 85-86) are shown in table 1. The drifting snow percentages are also shown in figure 7, subdivided by visibility. Because of the priority rules for ww (see section 2.4), the given percentages of drifting snow do not include situations when drifting snow and precipitation occur at the same time.

Frequencies of snowfall are shown in figure 8, subdivided by type of snowfall. A distinction is made between ww=70-75 (snow), ww=76-79 (ice needles, single snow crystals) and ww=85-86 (snow showers).

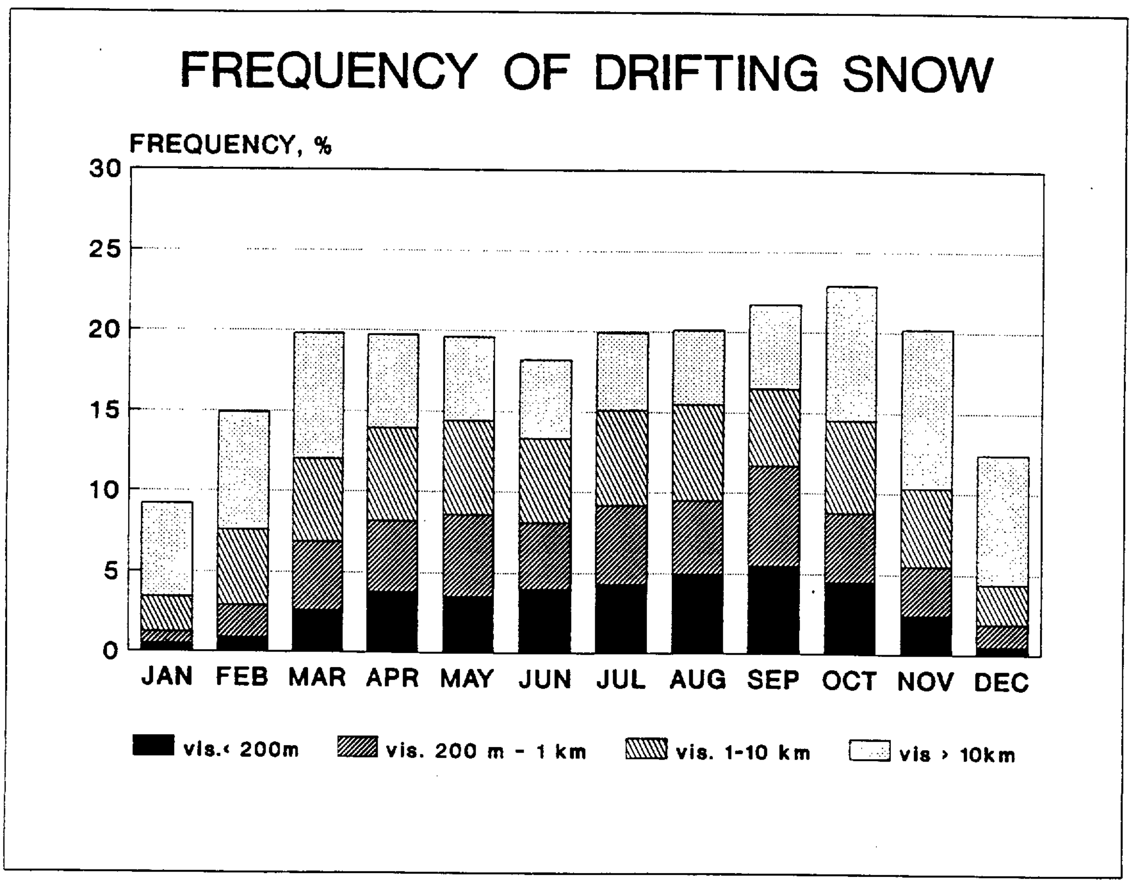



Figure 7. Monthly frequencies of drifting snow without precipitation (ww=36-39), subdivided by visibility.

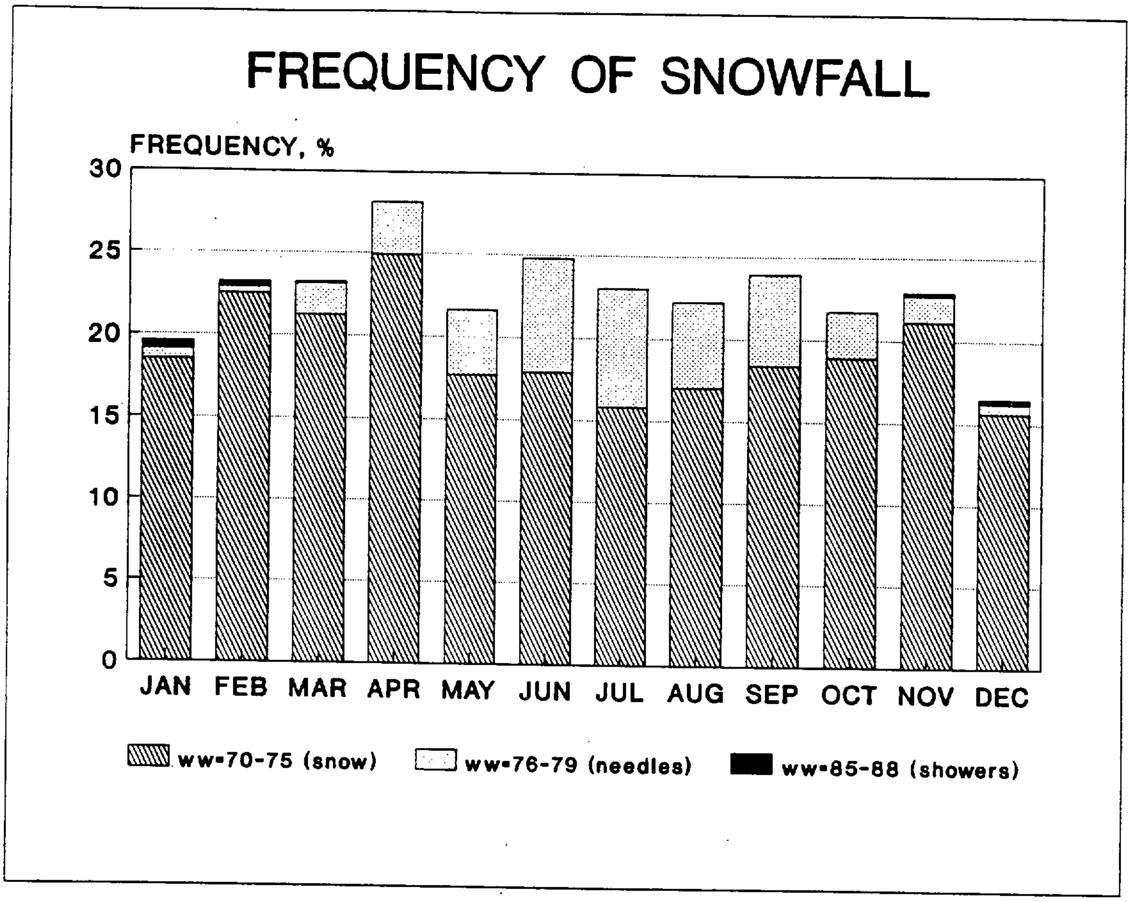



Figure 8. Monthly frequencies of snowfall, subdivided by type of precipitation.

## 2.6 Wind.

Mean wind speed and frequencies of wind above force 5 shows that August, September and October are the windiest months, while summer (Dec-Jan-Feb) is the least windy season at Halley (table 1). The wind roses in figure 9 show that the frequencies of different wind directions vary only slightly during the year, and easterly winds are the most frequent in all seasons.

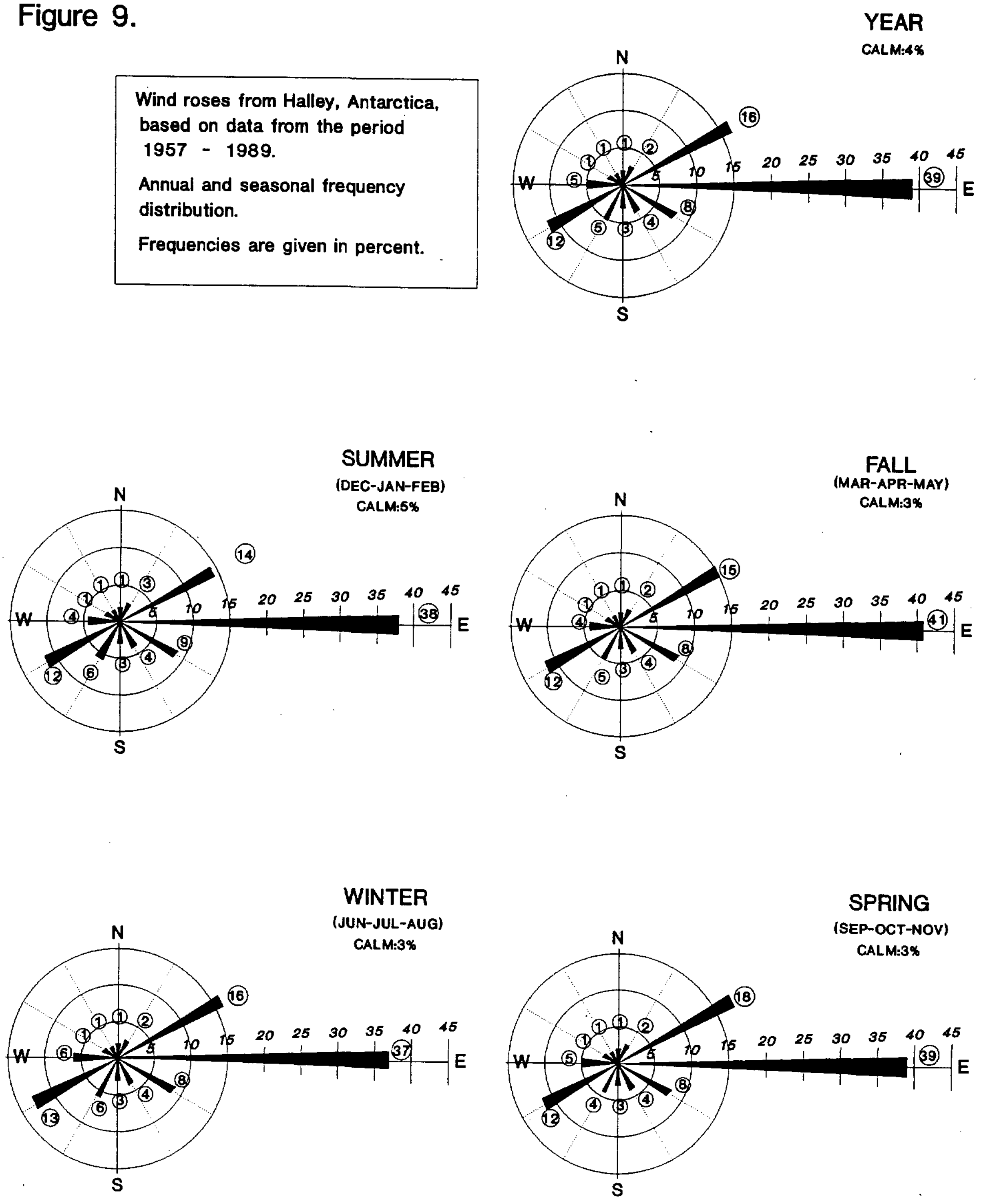
Figure 10 a-b shows frequency distributions of wind force and direction for all months. The relative frequency of easterly winds generally increases with increasing wind force, and the wind direction was E or ENE in more than 95% of the cases with wind force 9-11 (strong gale-violent storm).

Figure 9.

Wind roses from Halley, Antarctica, based on data from the period 1957 - 1989.

Annual and seasonal frequency distribution.

Frequencies are given in percent.



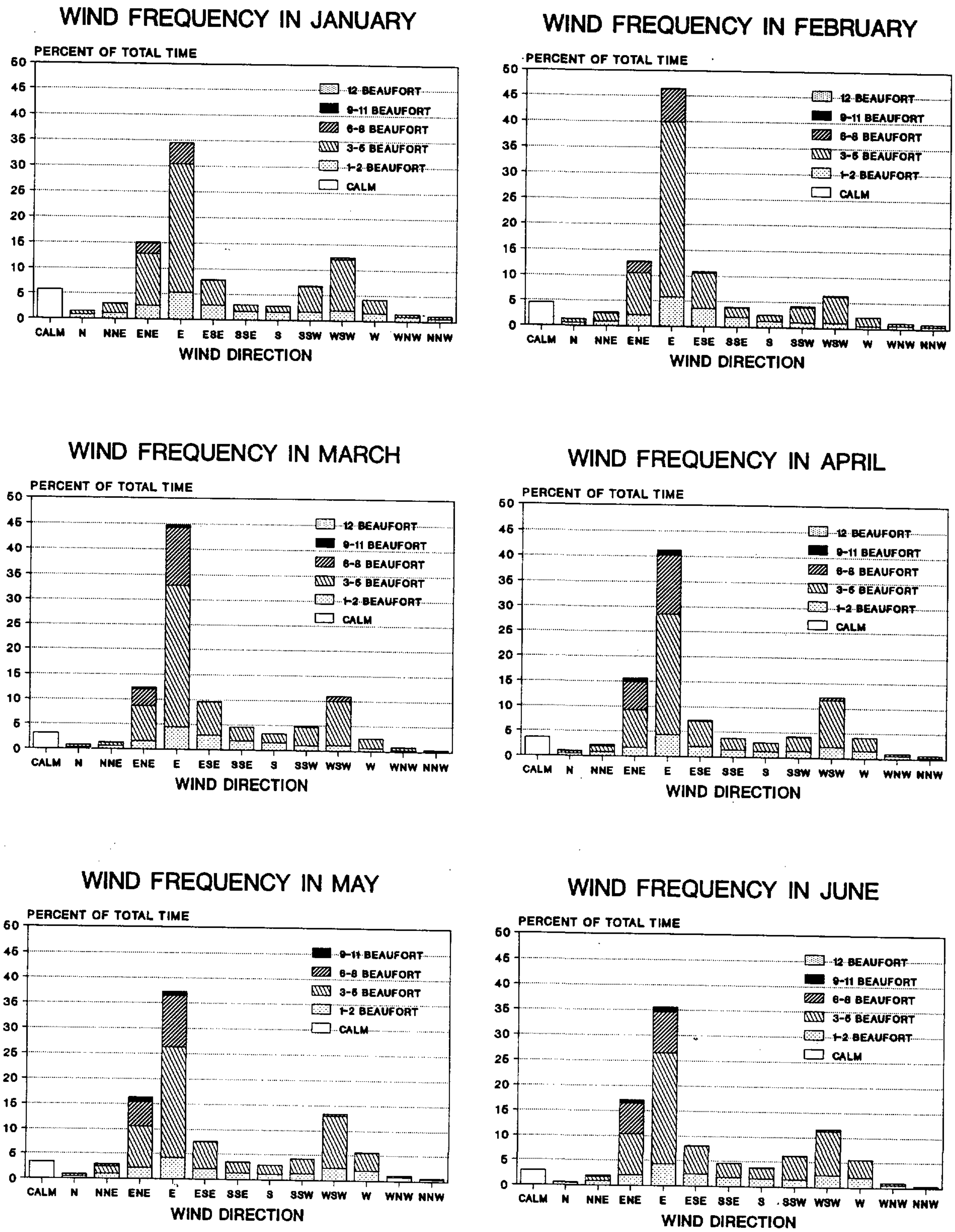



Figure 10a. Frequency distribution of wind speed and direction.

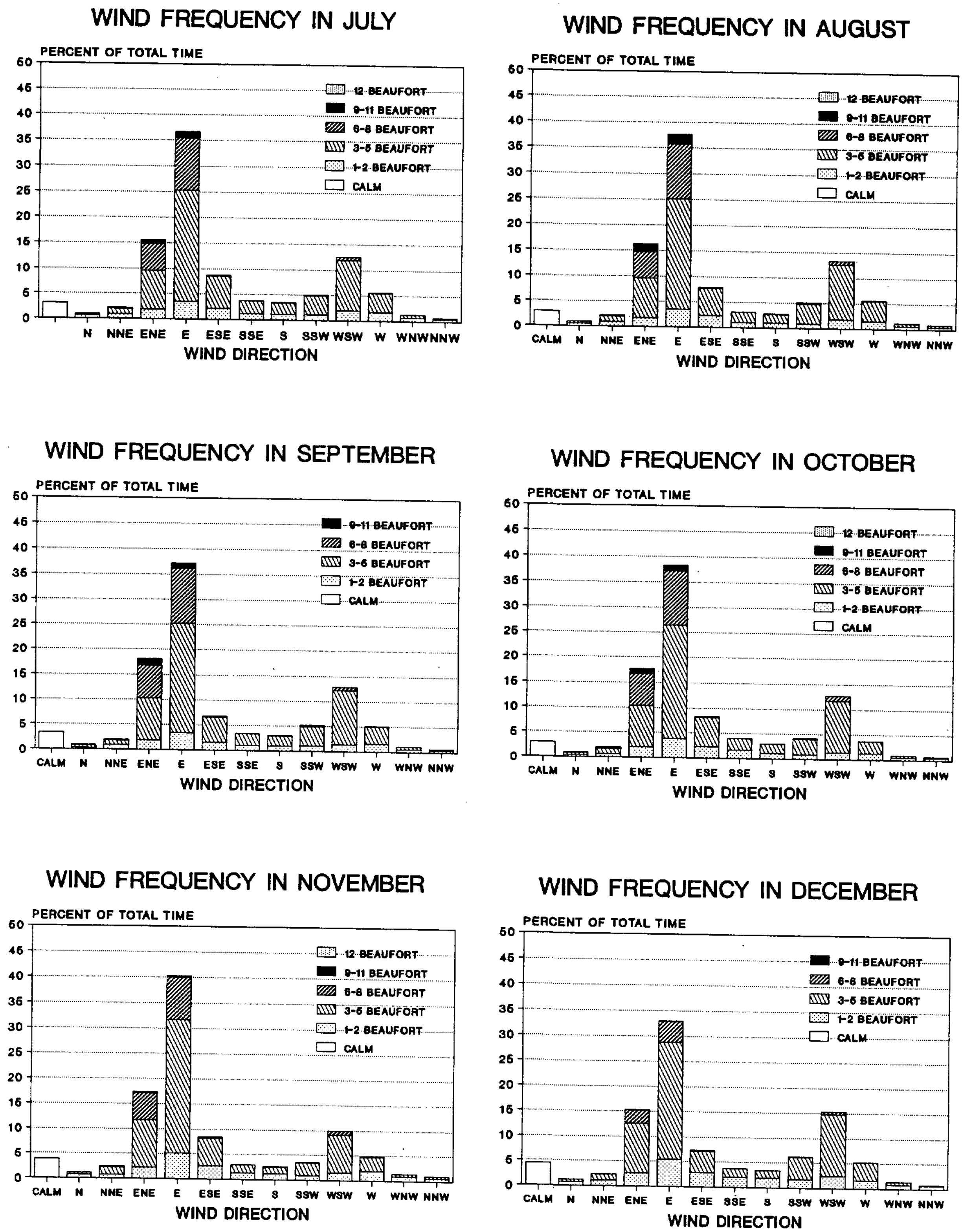



Figure 10b. Frequency distribution of wind speed and direction.

This is, however, not the case for the strongest winds observed at Halley. The frequencies of wind force 9-11 and of wind force 12 (hurricane) from different directions on an annual basis are shown in figure 11. The figure shows that hurricane from W-WSW and hurricane from ENE-E has occured with the same frequency. The W-WSW hurricanes occurred mainly in January through March, while the ENE-E hurricanes occurred mainly during the southern winter and spring.

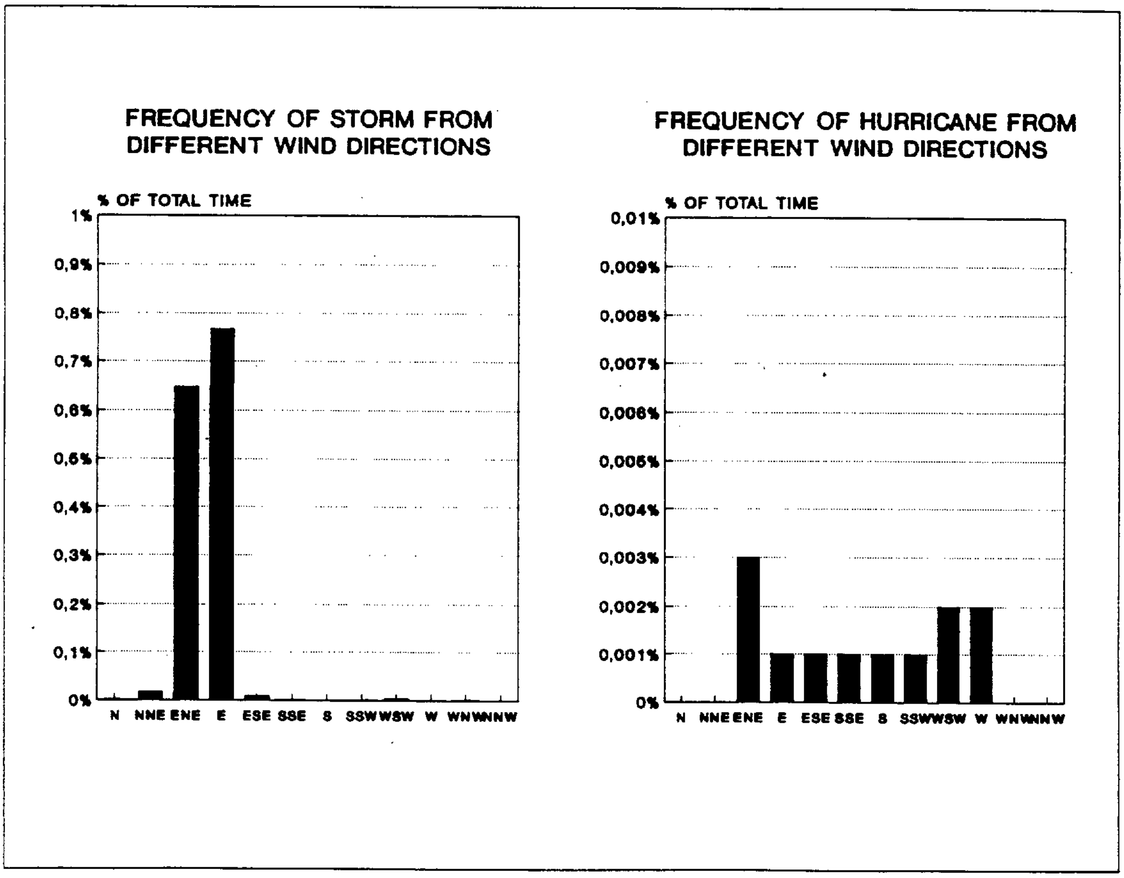



Figure 11. Frequencies of wind force 9-11 (strong gale-storm-violent storm) and 12 (hurricane) for different wind directions.

## 2.7 Snow accumulation.

Monthly totals of net accumulation/ablation have been measured at Halley during the period 1973-1989. Figure 12 shows mean monthly totals (in mm water equivalent) for January through December based on this period. All months have positive values (i.e. accumulation) on average, but negative single values have occurred for all months except March, June and August. There is no apparent association between mean frequency of snowfall (figure 8) and mean net accumulation (figure 12).

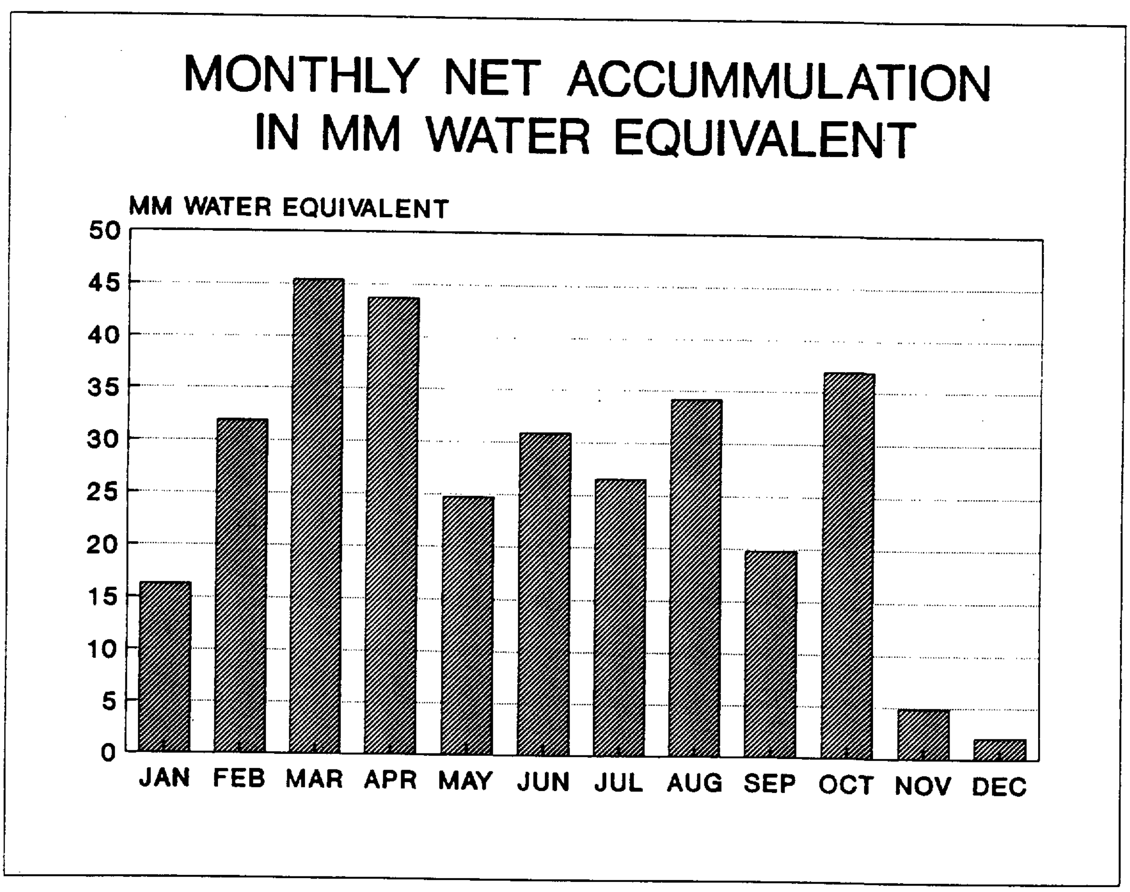



Figure 12. Monthly mean values of net snow accumulation (in mm water equivalent) based on data from the period 1973-1989.

# 3. TIME SERIES

## 3.1 Temperature.

Time series of mean annual and seasonal temperature for the period 1957-1989 are shown in figure 13. The figure shows observed values as well as values computed from Gauss filters with standard deviations of 1 and 3 years respectively. The temperature pattern is largely the same as Raper et al. (1984) found for Antarctica.

On an annual basis, the temperature level in the early 1960's was about 1 °C lower than the level in the 1980's. Figure 13 shows that this is mainly due to higher winter temperatures during the last decennium than during the first part of the series. The winter temperature level, however, was at a minimum in the early 1970's, while annual temperature showed an increasing trend from the early 1960's to the late 1970's.

The summer temperature shows a weak increasing trend through most of the period, while the spring and fall temperatures generally increased during the first part of the series and decreased during later years. The fall temperature was at a maximum in the last part of the 1970's, while the highest spring temperatures occurred almost 10 years earlier.

## 3.2 Temperature and cloud cover.

Figure 14 shows time series of mean monthly cloud cover and temperature in January (a) and July (b). There is apparently no connection between cloud cover and temperature in January. In July, on the other hand, mean cloud cover and temperature are obviously correlated.

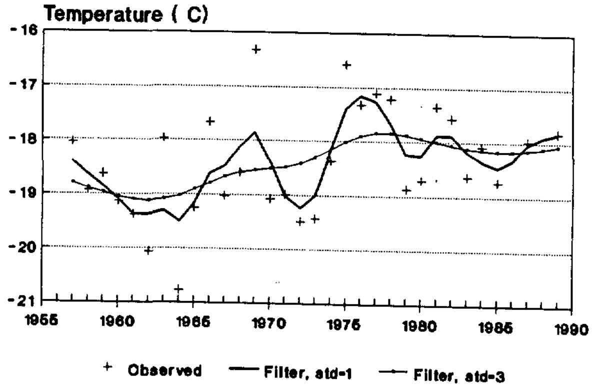
# Figure 13.

Temperature series from Halley, Antarctica, for the period 1957-1989.

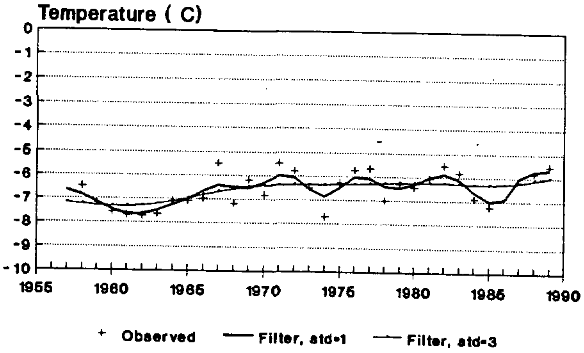
Annual and seasonal mean values.

The figure shows observed mean values and values computed from Gauss filters with standard deviations of 1 and 3 years.

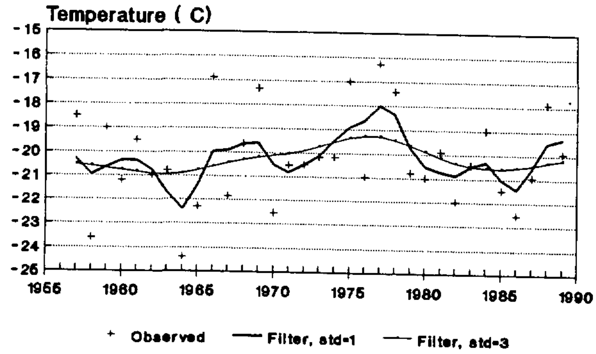
## ANNUAL MEAN TEMPERATURE



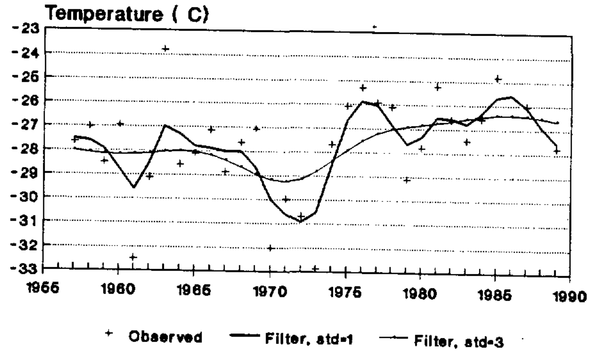

## MEAN SUMMER TEMPERATURE
(DEC-JAN-FEB)



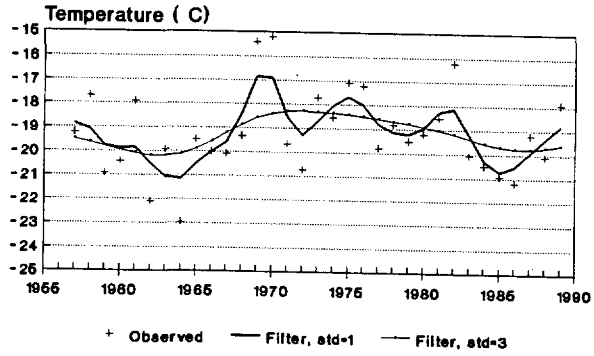

## MEAN FALL TEMPERATURE
(MAR-APR-MAY)



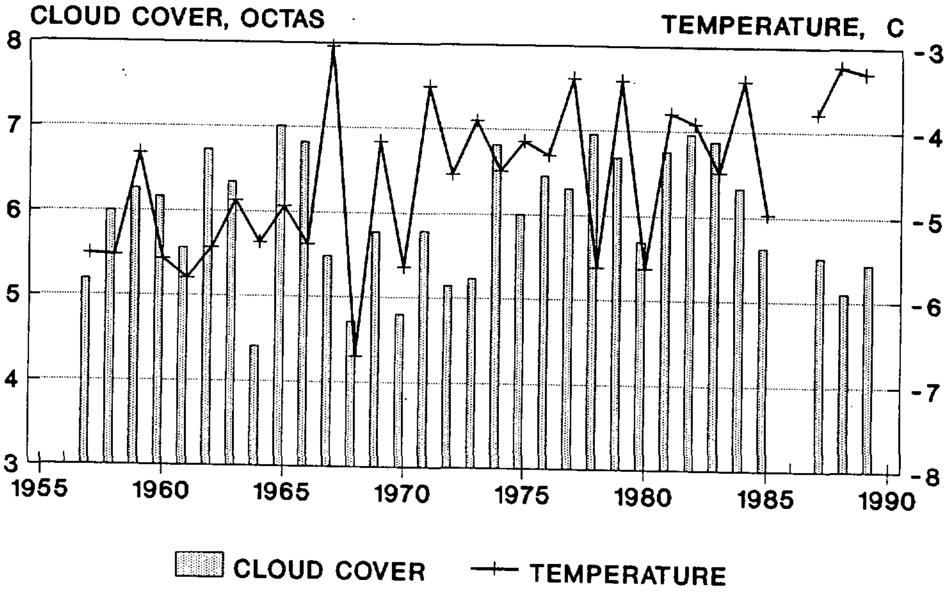

## MEAN WINTER TEMPERATURE
(JUN-JUL-AUG)




## MEAN SPRING TEMPERATURE
(SEPT-OCT-NOV)



## a) MEAN CLOUD COVER AND TEMPERATURE IN JANUARY 1957-1989




## b) MEAN CLOUD COVER AND TEMPERATURE IN JULY 1957-1989

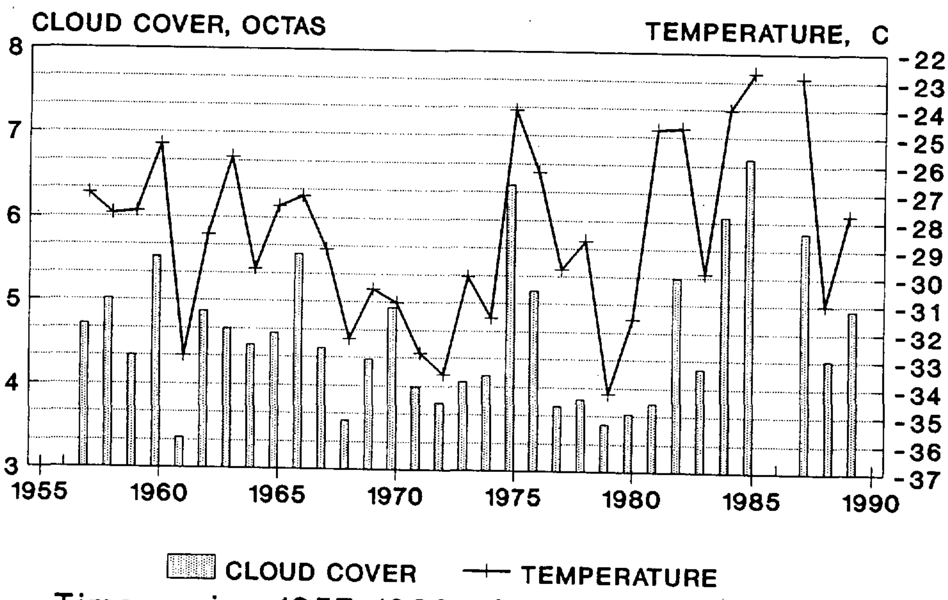



Figure 14. Time series 1957-1989 of mean cloud cover and temperature in January (a) and July (b).

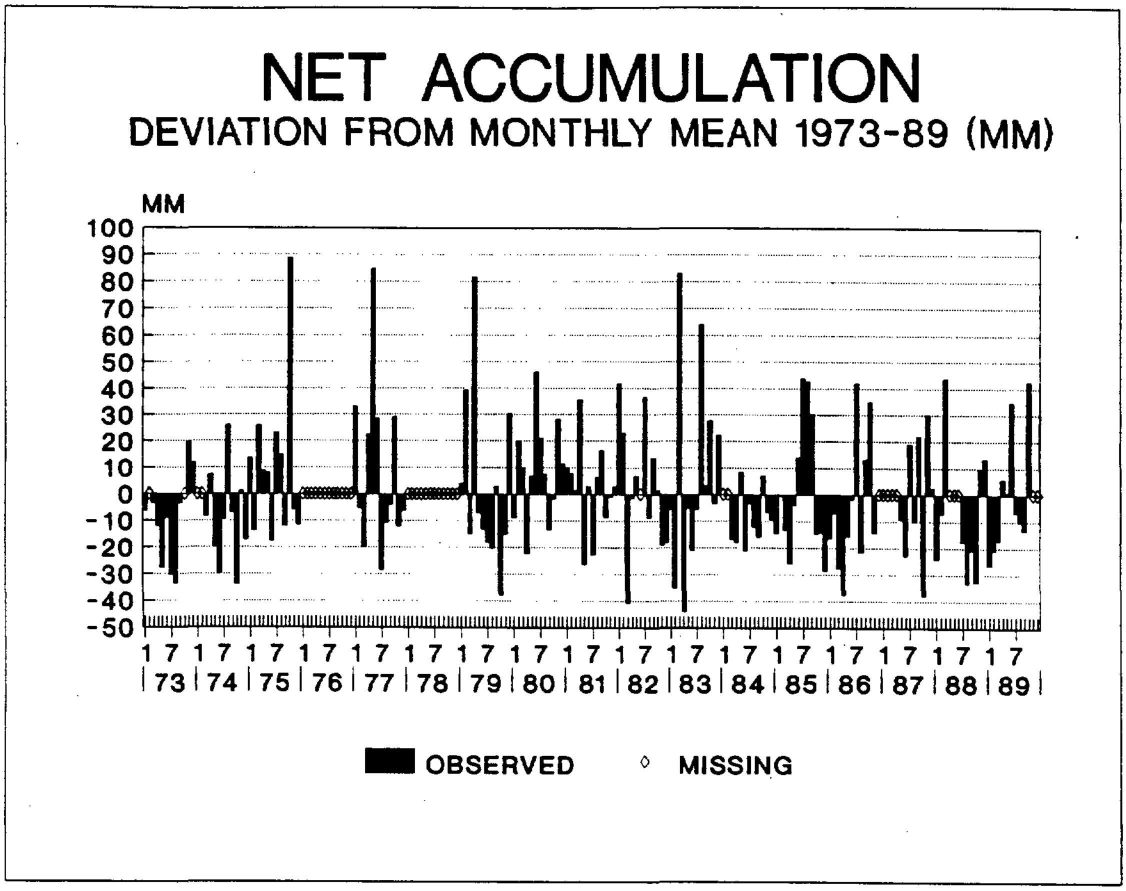



Figure 15. Monthly totals of net accumulation for Halley in deviation from the mean value for the respective month (figure 12). Values are expressed as mm of water equivalent.

## 3.3 Net snow accumulation.

Figure 15 shows time series 1973-1989 of monthly totals of net accumulation for Halley, in deviation from the mean values shown in figure 12. There is no obvious trend in the snow accumulation at Halley during this period.

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