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A CLIMATOLOGY OF THE STRATOSPHERE OVER NORTH-WEST EUROPE

BY

R. A. HAMILTON, O.B.E., M.A., F.R.S.E., B. D. MASON, B.Sc. and G. C. BRIDGE

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A CLIMATOLOGY OF THE STRATOSPHERE OVER NORTH-WEST EUROPE

SUMMARY

The results of over 200 meteorological rocket soundings made from West Geirinish, Outer Hebrides, during the period 1964–72 are discussed. A statistical analysis of monthly data, comprising temperatures and zonal and meridional wind components at various stratospheric levels, is systematically presented, and some comparison is made with similar data from Fort Churchill (58°N) and Fort Greely (64°N). Correlations between temperatures and winds show the tendency for vertical motion during a period of strongest zonal winds, while the highest temperatures in the middle and upper stratospheric levels appear to coincide with the maximum southerly wind components. Data from Vologograd and Heiss Island in the U.S.S.R. are also given to enable an assessment to be made of mean temperature and circulation patterns during the winter months in the region 48°N–80°N and 145°W–58°E.

Stratospheric warmings are discussed in some detail, with vertical motion being regarded as the prime mechanism for the large temperature fluctuations which occur.

Simultaneous temperature and wind data from a three-station network are presented and an attempt is made to determine the synoptic scale of events whilst temperature–wind-shear relationships derived from these data show good agreement with theoretical values for observations made from locations in close proximity. Finally the diurnal variation is discussed, with due consideration being given to the difficulty of obtaining accurate day-time temperature values because of radiation errors.

1 – INTRODUCTION

This memoir is mainly concerned with the results of over 200 meteorological rocket soundings made from the Royal Artillery Range in the Outer Hebrides, Scotland, during the years 1964–72. The rocket launcher is situated near mean sea level at latitude 57°21' N, longitude 07°24' W near the village of West Geirinish on the island of South Uist. All soundings have been made using the SKUA I or SKUA II rocket.

The SKUA is a solid-propellant end-burning rocket of about 2.5 m in length and has a detachable boost motor. The main motor has a burn time of approximately 32 seconds, taking the rocket to about 16 km, from where it coasts to apogee, the height of which is dependent on the launcher elevation. Normally apogee is in the region of 68 km for a SKUA I and 85 km for a SKUA II, these heights being attained about 135 and 148 seconds after launch respectively. At apogee a small charge separates the nose cone and ejects the sonde and parachute.

The parachute is 5 m in diameter with alternately metallized panels and is tracked by a Cossor 353 10-cm radar. The radar is normally locked on to the parachute within a few seconds of ejection, and experience has shown that 95 per cent of the forward velocity of the parachute is lost in less than 45 seconds after ejection for SKUA I, and 100 seconds for SKUA II; in both cases it is accepted that the parachute is moving with the wind at those intervals after ejection, normally at a height of about 64 km. Recordings of slant range, elevation and azimuth are made at 15-second intervals when the parachute is above 40 km, and at 30-second intervals below 40 km, with corrections for the earth's curvature being applied. The parachute fall-speed varies from about 150 m/s at 64 km, to 30 m/s at 40 km and 10 m/s at 20 km. For data obtained before 1969 the mean wind in each interval of 15 or 30 seconds was calculated and attributed to the mean height of the layer, the winds at whole-kilometre levels being obtained by interpolation and the application of a certain amount of smoothing. Since 1969 the wind determinations have been performed by computer which, from the basic radar data, calculates the position of the parachute at whole-kilometre levels and the mean wind in the 2-km layer centred at the whole-kilometre level.

The SKUA sonde has been described by Almond[1]*and has remained virtually unchanged during eight years of operation. The sensor is fundamentally a sensitive resistance thermometer, consisting of nearly 8 m of spiralized tungsten-wire of 13 μm diameter, with supporting telemetry, and transmitting in the 27.5 to 28 MHz range. The signal is received by standard radiosonde receiving equipment which yields a graph of temperature versus time. The corrections to be applied for the dynamic heating of the falling sonde have been determined by experiments in the low-density wind-tunnel of the National Physical Laboratory, where estimates were also made of the small corrections for cooling by infra-red radiation. These corrections are a function of the fall-speed and the values for normal fall-speeds are shown in Table I. In addition the correction to be applied for normally incident solar radiation was determined but in practice the

TABLE I – CORRECTIONS FOR DYNAMIC HEATING AND INFRA-RED COOLING OF A SONDE DESCENDING AT NORMAL FALL-SPEED

Pressure	Height†	Fall-speed	Dynamic heating correction	Infra-red radiation correction
mb	*km*	*m/s*	*degrees Celsius*	
0.11	61	128	−11.3	0.9
0.21	56	97	− 6.3	0.5
0.43	50.5	68	− 2.5	0.3
0.67	47	54	− 2.0	0.2
1.33	42	37	− 1.4	0.1
2.00	39.5	30	− 0.9	0.1
2.67	37.5	25	− 0.6	0.1
4.00	35	21	− 0.5	0.1

† Height values are based on the U.S. Standard Atmosphere 1966 for 60°N January (cold).

heating will depend on the solar elevation, the amount of shading by the parachute and sensor mounting, and the albedo of the clouds and global surface below, which can only be estimated. As a consequence of this source of error, it is the practice of the British Meteorological Office to launch rockets only at night. Launching generally takes place just after sunset at a height of 70 km, but delays up to midnight sometimes occur; thus the soundings analysed in this memoir may be regarded as having been made close to, but after, sunset. The Appendix is an index of meteorological soundings which made some measurements of wind or temperature above 40 km whilst the monthly total of soundings, excluding a few made during daylight, are given in Table II. In the earlier years soundings were made during all seasons, but after 1967 the main effort was directed towards the study of stratospheric warmings during the winter months. It will be noted in the Appendix that the height range over which temperatures were recorded is sometimes greater than that for wind; this arises when the signal from the sonde is received before the radar locks on to the parachute. If the subsequent descent of the parachute is normal and the height–time curve extrapolated backwards passes reasonably close to the expected rocket apogee, then it is used to calculate the height of the temperature measurements.

* The superscript figures refer to the Bibliography on page 34.

TABLE II – MONTHLY TOTAL OF SOUNDINGS

	1964	1965	1966	1967	1968	1969	1970	1971	1972
Jan.	3	6	–	–	11	7	11	10	5
Feb.	2	5	9	4	15	–	–	8	–
Mar.	–	4	4	5	–	–	–	–	–
Apr.	–	3	2	10	–	–	–	–	–
May	–	–	–	–	–	–	–	–	–
June	–	–	–	9	–	–	–	–	–
July	–	–	–	8	–	–	–	–	–
Aug.	–	–	–	–	–	–	–	–	–
Sept.	–	2	1	–	–	–	–	–	–
Oct.	–	–	10	–	–	–	–	–	–
Nov.	–	1	12	–	–	2	2	–	–
Dec.	–	–	2	9	5	11	4	7	–

Thermodynamic data

Heights of geopotential surfaces have been obtained by integration of the equation

$$\mathrm{d}\log p = \frac{-g}{RT}\,\mathrm{d}z$$

where:

p is the atmospheric pressure in mb,
z is the geometric height in metres,
T is the temperature in K,
$g = 9.8166\,(1 - 3.143 \times 10^{-7} z)\ \mathrm{ms}^{-2}$,
and $R = 287.05\ \mathrm{Jkg}^{-1}\mathrm{K}^{-1}$.

The lower boundary conditions are obtained by interpolation, from a series of 50-mb synoptic charts, of the geopotential height of the 50-mb surface at West Geirinish at the time of launch; the estimated error in winter being 20 m. The mean difference between the temperature measured by the rocketsonde at the 50-mb level and the temperature estimated from the 50-mb synoptic chart, based on midnight radiosonde measurements, during the 1971–72 winter was 0.7 degC, with a root-mean-square value of 1.0 degC.

Meteorological satellites

In April 1970 the NIMBUS 4 satellite was launched carrying a selective chopper radiometer. This made possible the remote measurement of the weighted mean temperature of four layers in the stratosphere centred at pressure levels of about 100, 50, 15 and 2 mb and, combined with radiosonde data, enabled constant pressure level charts to be drawn on a global scale up to a pressure level of 1 mb. In view of this vast increase in the frequency and area of soundings there seems little point in attempting to study the stratospheric circulation by means of a small number of rocket soundings, and accordingly no attempt has been made to do so. However, the height discrimination of the satellite sounding is poor, and rocket soundings are likely to be required for many years to come for studies of the detailed temperature and wind profile in the stratosphere, gravity waves, tides, and the progress of a warming event. Rocket soundings will be made in conjunction with satellite soundings and indeed this was the case in the 1971–72 winter rocket campaign at West Geirinish, however, satellite data gave no indication of a stratospheric warming anywhere in the northern hemisphere, and the rocket campaign was terminated at the end of January 1972.

2 – STATISTICAL ANALYSIS

Table III gives mean data for each month in which three or more rocket soundings were made. The data are evaluated at 2-km intervals and show mean temperatures (T) and mean zonal (u) and meridional (v) wind components with their respective standard deviations; values have not been calculated for heights at which less than three measurements were made during the month. The number of measurements (N) made at each height is also given.

In order to indicate the very large range of temperatures and winds which occur when the stratopause is at a low level, the percentage frequency of occurrence of temperature and the two wind components, during December, January and February, has been calculated over given ranges. The percentage values are given in Tables IV to VI, where N is again the number of observations.

Individual monthly means for the winter months of December, January and February are entered at 5-km intervals in Table VII where, for purposes of comparison, similar data for Fort Churchill (58°44' N, 93°49' W) and Fort Greely (64°00' N, 145°44' W) (derived from the World Data Center A *Data reports* [2] high altitude meteorological data) are also given. The mean value entered in these tables is the average of the means for each year, and the standard deviation is that of the yearly mean. Maximum and minimum values are the extremes measured during the whole period. It should be noted that soundings at Fort Churchill and Fort Greely are generally made at local times near midday, although considerable departures from these times are not infrequent. Because of this variation in time and the high standard deviation of the components from the calculated mean, no attempt has been made to correct for diurnal variation when making comparisons with West Geirinish.

Table VIII gives the correlation coefficient between the temperatures at different 5-km levels for 68 soundings made at West Geirinish during December, January and February 1967–72, for which data were available at all heights between 20 and 60 km. Correlations between layers less than 10 km apart are not shown.

A coefficient of 0.31 is significant at the 1-per-cent level and the most significant value is the negative correlation between levels of about 50 and 25 km, indicating a tendency for the lower stratosphere to become cold when the stratopause is warm. In the upper stratosphere there is appreciable correlation between the temperatures of layers 10 km apart, with no correlation between temperatures in the lower mesophere (60 km) and the upper stratosphere (50 km).

Correlations have also been calculated between temperature and wind components at the same levels and the results are given in Table IX the sample of soundings being almost the same as for Table VIII and with the same level of significance. The generally positive and significant correlation between the wind components confirms the overall tendency at all levels for westerly components to be associated with southerly components. The high values of

TABLE III – MONTHLY MEANS AND STANDARD DEVIATIONS OF TEMPERATURE AND ZONAL AND MERIDIONAL WINDS FOR WEST GEIRINISH

January 1964

Height *km*	*T* °C	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62								
60								
58								
56								
54	Insufficient data available			86	20	−9	17	3
52				88	18	−6	21	3
50				90	16	−2	25	3
48				96	6	1	21	3
46				101	3	4	19	3
44				103	10	5	13	3
42				102	15	1	7	3
40				93	8	2	3	3
38				83	2	1	2	3
36				76	3	−1	1	3
34				72	2	−2	6	3
32				68	4	−1	10	3
30				64	4	−1	16	3
28				56	2	−1	15	3
26				47	5	−2	14	3
24				40	4	−3	13	3
22				32	6	−2	10	3
20				25	8	−2	7	3

January 1965

Height *km*	*T* °C	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62	−17	13	4					
60	−14	15	5					
58	−21	11	5	89	26	24	11	4
56	−19	8	5	86	29	16	11	6
54	−17	9	5	85	33	13	13	6
52	−13	12	5	87	33	9	13	6
50	− 8	12	5	88	27	6	19	6
48	−14	9	5	82	21	12	16	6
46	−18	9	5	71	19	10	5	6
44	−19	8	5	69	17	9	3	6
42	−27	7	5	68	16	4	11	6
40	−27	7	5	65	13	5	8	6
38	−34	9	5	71	15	7	7	6
36	−38	7	5	70	10	7	12	6
34	−49	8	5	72	11	6	11	6
32	−59	8	5	68	15	5	11	6
30	−67	6	5	64	16	5	10	6
28	−71	6	5	61	14	1	11	6
26	−75	6	5	57	14	−3	11	6
24	−77	4	5	47	12	−5	10	6
22	−76	5	5	39	12	−5	10	6
20	−74	5	5	30	10	−3	11	6

February 1965

Height *km*	*T* °C	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62								
60	−21	7	4					
58	−15	8	4					
56	−12	2	4					
54	− 9	6	4					
52	− 7	6	4	36	14	− 8	15	4
50	−11	4	4	60	29	− 2	18	5
48	−14	8	4	53	26	− 4	15	5
46	−11	10	4	57	23	− 1	16	5
44	−13	14	4	59	26	2	17	5
42	−23	11	4	55	22	− 1	14	5
40	−34	11	4	52	17	− 3	11	5
38	−36	8	4	52	24	− 9	12	5
36	−42	7	4	48	15	−11	13	5
34	−47	4	4	46	11	−15	14	5
32	−55	7	4	47	13	−16	15	5
30	−65	2	4	41	15	−12	15	5
28	−69	6	4	37	15	−12	17	5
26	−67	3	3	31	15	−13	14	5
24	−67	2	3	26	15	−13	11	5
22	−66	3	3	22	14	−13	11	5
20	−68	5	3	17	12	−13	10	5

March 1965

Height *km*	*T* °C	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64	−17	4	4					
62	−16	4	4					
60	−18	3	4					
58	−17	5	4	58	5	6	9	3
56	−12	2	4	55	6	13	10	3
54	−10	2	4	52	5	8	12	4
52	−10	3	4	54	3	7	6	4
50	−11	4	4	57	6	5	5	4
48	− 7	2	4	50	6	6	5	4
46	− 8	5	4	45	6	6	4	4
44	−13	3	4	46	12	3	4	4
42	−21	6	4	44	13	−1	6	4
40	−28	11	4	38	9	−3	11	4
38	−37	7	4	37	13	−3	11	4
36	−46	8	4	29	14	−2	13	4
34	−46	13	4	23	16	−3	15	4
32	−54	5	4	26	23	−4	11	4
30	−56	4	4	19	18	0	11	4
28	−56	3	4	16	14	1	10	4
26	−59	3	4	15	12	−2	8	4
24	−60	6	4	14	9	−3	8	4
22	−59	6	4	13	6	−4	7	4
20	−60	11	4	10	4	−5	8	4

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE III – *continued*

April 1965

Height km	*T* °C	*SD* degC	*N*	*u* metres/second	*SD* metres/second	*v* metres/second	*SD* metres/second	*N*
64								
62	−27	3	3					
60	−22	4	3					
58	−13	5	3					
56	− 9	5	3					
54	− 5	6	3					
52	− 2	6	3	6	5	−5	3	3
50	− 1	7	3	10	5	−9	4	3
48	− 2	6	3	9	5	−6	4	3
46	− 5	7	3	9	6	−3	2	3
44	− 6	7	3	9	7	−1	3	3
42	−15	9	3	5	7	0	5	3
40	−21	8	3	5	8	2	8	3
38	−24	9	3	6	9	6	7	3
36	−30	6	3	6	12	1	6	3
34	−36	5	3	9	14	1	8	3
32	−40	7	3	7	17	−1	10	3
30	−47	3	3	4	15	−3	11	3
28	−52	3	3	5	14	−3	10	3
26	−55	1	3	4	11	−4	10	3
24	−57	2	3	2	9	−5	9	3
22	−58	3	3	3	7	−7	9	3
20	−56	3	3	4	3	−8	7	3

February 1966

Height km	*T* °C	*SD* degC	*N*	*u* metres/second	*SD* metres/second	*v* metres/second	*SD* metres/second	*N*
64	−30	9	4					
62	−31	12	8					
60	−26	11	8	16	28	0	18	6
58	−26	9	8	31	27	5	19	8
56	−23	8	8	33	27	1	15	9
54	−17	7	8	37	25	2	14	9
52	−15	9	8	41	21	3	14	9
50	−11	7	8	45	20	1	11	9
48	−11	8	8	45	18	0	7	9
46	−15	9	8	43	17	−3	9	9
44	−15	7	8	41	17	−2	10	9
42	−17	7	8	40	16	−2	15	9
40	−19	5	8	40	16	−1	15	9
38	−26	11	8	38	19	−1	15	9
36	−27	11	8	39	18	−2	12	9
34	−32	12	8	42	21	−1	14	9
32	−41	9	8	44	25	−4	16	9
30	−51	6	8	40	20	−1	14	9
28	−60	4	8	38	20	−2	12	9
26	−64	6	8	37	18	−1	12	9
24	−66	7	8	33	17	1	13	9
22	−68	6	8	30	15	1	13	9
20	−67	5	8	27	12	3	12	9

March 1966

Height km	*T* °C	*SD* degC	*N*	*u* metres/second	*SD* metres/second	*v* metres/second	*SD* metres/second	*N*
64	−31	2	4					
62	−26	1	4					
60	−23	2	4					
58	−18	5	4	9	9	−1	9	4
56	−13	5	4	14	14	−1	6	4
54	− 8	5	4	18	17	−2	3	4
52	− 5	8	4	19	17	−4	4	4
50	− 5	5	4	23	16	0	4	4
48	− 2	2	4	24	20	2	8	4
46	− 5	2	4	25	22	3	7	4
44	− 7	5	4	23	21	7	5	4
42	−13	6	4	20	18	9	4	4
40	−25	5	4	15	11	11	6	4
38	−31	5	4	22	8	8	6	4
36	−40	3	4	19	11	8	6	4
34	−48	2	4	12	13	8	11	4
32	−53	1	4	15	12	8	9	4
30	−57	4	4	18	9	6	9	4
28	−59	7	4	15	8	9	7	4
26	−62	7	4	15	9	5	11	4
24	−60	5	4	13	5	5	9	4
22	−62	5	4	13	5	3	8	4
20	−58	4	3	13	6	1	8	4

October 1966

Height km	*T* °C	*SD* degC	*N*	*u* metres/second	*SD* metres/second	*v* metres/second	*SD* metres/second	*N*
64	−30	8	7					
62	−32	4	7					
60	−29	6	7	67	18	− 5	14	7
58	−26	3	7	68	17	−10	24	8
56	−19	4	7	64	16	− 9	25	8
54	−16	4	7	64	13	− 6	26	8
52	−13	7	7	65	12	− 3	16	9
50	− 9	4	7	61	12	− 3	9	9
48	− 9	7	7	56	12	− 5	6	9
46	−13	6	7	52	11	− 7	7	9
44	−19	4	7	47	9	− 7	6	10
42	−26	5	7	41	10	− 5	8	10
40	−37	6	7	35	9	− 6	6	10
38	−40	4	7	31	10	− 7	6	10
36	−45	4	7	28	12	− 7	6	10
34	−50	5	7	23	11	− 8	5	10
32	−53	3	7	21	13	− 7	7	10
30	−56	4	7	15	12	− 6	5	10
28	−59	4	7	12	11	− 5	3	10
26	−58	4	7	9	9	− 3	3	10
24	−58	4	7	8	7	− 2	3	10
22	−58	5	6	6	6	− 2	3	10
20	−58	4	6	5	5	− 2	3	10

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE III – *continued*

November 1966

Height km	*T* °C	*SD* degC	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64	−14	4	5					
62	−15	10	7					
60	−13	4	7					
58	−13	4	9	54	17	−10	25	7
56	−11	5	10	69	17	−15	16	9
54	−12	9	10	76	13	− 7	20	11
52	−16	7	10	77	14	− 4	13	12
50	−16	10	10	75	12	− 1	10	12
48	−18	10	10	70	6	− 1	10	12
46	−26	5	10	67	10	0	8	12
44	−33	3	10	63	9	− 3	6	12
42	−39	3	10	57	7	− 3	7	12
40	−46	5	10	51	7	− 2	8	12
38	−52	5	10	45	7	− 1	6	12
36	−59	5	10	40	7	− 2	5	12
34	−64	5	10	38	9	− 2	7	12
32	−69	4	10	35	8	0	7	12
30	−70	5	10	30	6	0	10	12
28	−71	4	10	25	4	0	8	12
26	−70	4	10	21	7	0	9	12
24	−68	4	10	16	6	0	9	12
22	−66	5	10	13	7	0	7	12
20	−63	4	10	9	5	− 1	7	12

February 1967

Height km	*T* °C	*SD* degC	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64	−25	3	3					
62	−19	2	3	27	17	−11	11	3
60	−15	4	3	36	16	−24	13	3
58	−16	5	4	41	16	−32	15	3
56	−16	6	4	47	24	−25	21	4
54	−17	9	4	49	25	−15	26	4
52	−11	9	4	49	22	−16	30	4
50	−11	9	4	55	16	−21	32	4
48	−11	6	4	59	14	−23	34	4
46	−17	7	4	60	13	−26	32	4
44	−19	2	4	62	13	−23	27	4
42	−25	3	4	63	12	−18	26	4
40	−35	4	4	59	13	−15	27	4
38	−39	10	4	45	17	−23	26	4
36	−40	10	4	53	9	−21	24	4
34	−55	8	4	58	7	−16	20	4
32	−61	9	4	59	7	−12	16	4
30	−65	8	4	56	5	− 9	13	4
28	−67	5	4	54	5	− 6	14	4
26	−68	3	4	49	8	− 5	12	4
24	−67	5	4	46	9	− 3	8	4
22	−66	4	4	41	7	− 1	8	4
20	−64	4	4	37	9	1	7	4

March 1967

Height km	*T* °C	*SD* degC	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62	−18	3	4					
60	−11	4	4	19	13	5	9	4
58	−13	4	4	17	13	−1	5	5
56	− 7	5	4	21	12	−5	7	5
54	− 5	3	4	26	9	−6	10	5
52	− 4	5	4	33	11	−4	9	5
50	− 2	6	4	35	11	1	10	5
48	− 3	6	4	34	11	2	7	5
46	− 5	4	4	36	8	3	9	5
44	−11	2	4	36	8	2	11	5
42	−17	1	4	36	8	3	12	5
40	−29	3	4	41	9	0	12	5
38	−31	4	4	38	9	0	11	5
36	−42	3	4	38	8	−2	13	5
34	−47	2	4	33	6	−3	11	5
32	−49	3	4	33	6	−4	12	5
30	−55	1	4	33	6	−3	8	5
28	−57	4	4	33	6	−1	7	5
26	−59	2	4	31	6	2	6	5
24	−57	2	4	26	7	1	6	5
22	−56	2	4	25	3	−2	7	5
20	−56	3	4	23	4	−2	6	5

April 1967

Height km	*T* °C	*SD* degC	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64	−22	7	5					
62	−17	5	7					
60	−12	4	9					
58	− 9	4	10	11	7	− 8	7	4
56	− 6	4	10	14	16	− 7	8	10
54	− 3	3	10	16	16	− 7	6	10
52	− 1	3	10	17	18	− 4	6	10
50	− 3	3	10	17	18	− 5	5	10
48	− 3	3	10	12	17	− 3	7	10
46	− 4	4	10	9	17	− 5	6	10
44	− 9	2	10	10	17	− 7	6	10
42	−15	3	10	8	15	− 9	5	10
40	−23	5	10	9	17	− 7	5	10
38	−32	4	10	5	21	− 6	6	10
36	−39	5	10	3	21	−11	9	10
34	−47	4	10	5	18	−10	7	10
32	−52	4	10	4	18	− 9	9	10
30	−56	3	10	6	15	−10	9	10
28	−57	3	10	7	13	− 9	8	10
26	−57	2	10	6	12	− 8	7	10
24	−57	3	10	6	10	− 6	6	10
22	−56	3	10	6	10	− 5	5	10
20	−56	3	10	8	11	− 6	3	10

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE III – *continued*

June 1967

Height	T	SD	N	u	SD	v	SD	N
km	°C	degC		metres/second				
64	−25	5	6					
62	−19	5	7	−32	2	−11	3	3
60	−13	4	7	−34	7	− 9	3	6
58	− 7	3	8	−29	6	− 8	3	7
56	− 3	3	8	−29	8	− 8	5	8
54	1	2	9	−27	6	− 6	4	8
52	3	3	9	−27	5	− 4	3	9
50	3	3	9	−26	5	− 5	5	9
48	4	2	9	−25	7	− 5	6	9
46	2	2	9	−24	5	− 6	3	9
44	0	1	9	−23	4	− 5	5	9
42	− 3	3	9	−19	2	− 4	3	9
40	−10	2	9	−17	3	− 3	3	9
38	−17	2	9	−16	3	− 2	2	9
36	−23	2	9	−14	2	− 1	2	9
34	−28	1	9	−14	3	1	2	9
32	−34	1	9	−13	2	2	2	9
30	−38	2	9	−13	2	1	2	9
28	−42	1	9	−11	3	0	1	9
26	−45	1	9	−10	2	0	2	9
24	−47	1	9	− 8	3	0	2	9
22	−49	1	9	− 6	2	0	1	9
20	−51	1	9	− 2	2	0	3	9

July 1967

Height	T	SD	N	u	SD	v	SD	N
km	°C	degC		metres/second				
64	−25	4	4	−56	4	−10	5	5
62	−21	2	5	−47	3	−10	1	6
60	−14	3	6	−41	6	− 7	3	7
58	− 9	2	7	−39	3	− 7	3	7
56	− 5	2	7	−38	5	− 8	4	7
54	− 1	2	7	−31	3	− 7	3	8
52	2	3	7	−27	3	− 6	3	8
50	4	1	7	−27	3	− 3	3	8
48	7	3	7	−27	1	− 4	2	8
46	6	2	7	−24	2	− 4	1	8
44	2	2	7	−23	2	− 4	3	8
42	− 6	2	7	−21	2	− 3	3	8
40	−11	2	7	−18	3	− 3	2	8
38	−17	1	7	−15	2	− 1	2	8
36	−22	1	7	−14	2	− 2	2	8
34	−27	1	7	−13	2	− 1	3	8
32	−32	1	7	−10	1	0	1	8
30	−37	1	7	−11	2	2	1	8
28	−40	1	7	−10	1	1	1	8
26	−43	1	7	− 9	1	1	1	8
24	−45	1	7	− 7	1	− 1	1	8
22	−47	1	7	− 4	1	0	1	8
20	−49	1	7	− 1	1	1	2	8

December 1967

Height	T	SD	N	u	SD	v	SD	N
km	°C	degC		metres/second				
64	−31	23	4					
62	−29	18	6					
60	−21	19	7	78	39	33	29	3
58	−23	16	7	78	40	19	18	6
56	−21	14	7	81	55	20	22	7
54	−16	13	7	88	57	24	28	7
52	−11	11	8	76	71	25	23	8
50	− 4	12	8	78	75	26	21	8
48	− 3	14	8	81	78	23	21	8
46	0	16	8	92	77	11	21	9
44	0	20	8	87	71	11	20	9
42	− 5	21	8	79	63	11	16	9
40	−11	21	8	68	57	10	15	9
38	−19	21	8	59	49	5	14	9
36	−27	19	8	53	48	1	15	9
34	−36	15	8	50	43	−2	15	9
32	−47	15	8	43	36	−5	15	9
30	−56	16	8	36	29	−5	14	9
28	−64	15	8	31	21	−4	12	9
26	−67	13	8	28	18	−4	12	9
24	−69	13	8	22	14	−6	12	9
22	−69	14	8	21	12	−7	11	9
20	−67	12	8	18	9	−8	10	9

January 1968

Height	T	SD	N	u	SD	v	SD	N
km	°C	degC		metres/second				
64	−39	13	4					
62	−40	14	7	56	40	− 2	11	3
60	−39	11	8	60	43	− 4	11	5
58	−39	5	8	72	46	2	9	7
56	−38	3	8	66	43	1	5	7
54	−37	4	8	51	43	5	7	8
52	−38	4	8	43	38	6	7	8
50	−37	5	8	41	39	5	8	10
48	−39	7	8	38	40	0	11	10
46	−40	6	9	26	35	− 3	6	10
44	−42	4	9	19	31	− 3	4	10
42	−46	5	9	13	28	− 6	5	10
40	−45	5	9	8	28	− 6	5	10
38	−49	8	9	7	24	− 7	11	10
36	−51	10	9	3	18	− 7	14	10
34	−52	11	9	0	14	−10	9	10
32	−53	11	9	2	13	− 9	12	10
30	−53	11	9	2	14	− 9	12	10
28	−53	9	9	3	15	− 9	11	10
26	−52	8	9	2	12	− 7	9	10
24	−53	6	9	4	9	− 5	8	10
22	−56	5	9	4	8	− 4	7	10
20	−56	5	9	4	6	− 5	6	10

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE III – *continued*

February 1968

Height km	T °C	SD degC	N	u metres/second	SD	v	SD	N
64	−21	6	5					
62	−19	9	10					
60	−17	9	13	86	11	26	6	3
58	−15	7	14	81	20	23	21	8
56	−11	9	14	92	21	7	26	10
54	−11	8	15	92	17	3	16	14
52	−11	9	15	93	14	3	16	14
50	−14	7	15	91	12	4	14	14
48	−16	10	15	84	14	5	9	14
46	−20	12	15	76	13	2	5	14
44	−27	11	15	67	14	−5	6	14
42	−37	11	15	61	13	−3	7	14
40	−45	8	15	54	13	−5	5	14
38	−53	7	15	47	14	−5	4	14
36	−60	4	15	39	12	−6	6	14
34	−64	4	15	33	12	−7	6	14
32	−67	4	15	28	12	−7	5	14
30	−69	4	15	28	11	−7	7	14
28	−69	5	15	23	10	−8	6	14
26	−68	4	15	19	12	−8	5	14
24	−67	5	15	16	10	−7	5	14
22	−65	5	15	15	9	−7	4	14
20	−63	5	15	12	9	−8	6	14

December 1968

Height km	T °C	SD degC	N	u metres/second	SD	v	SD	N
64								
62								
60	−27	6	4					
58	−27	6	4	85	46	11	7	3
56	−21	7	4	112	62	12	17	5
54	−17	9	4	116	66	16	22	5
52	−13	12	4	110	62	29	25	5
50	− 8	10	4	106	53	25	25	5
48	− 6	13	4	100	43	25	18	5
46	− 3	15	4	93	36	22	8	5
44	− 5	19	4	87	25	21	13	5
42	− 9	26	4	81	16	24	10	5
40	−19	19	4	73	11	24	17	5
38	−34	13	4	64	10	22	15	5
36	−43	11	4	56	9	17	20	5
34	−52	12	4	50	11	12	20	5
32	−61	9	4	37	16	2	14	5
30	−65	8	4	31	15	− 5	16	5
28	−67	5	4	26	12	− 6	8	5
26	−67	2	4	19	11	− 8	5	5
24	−67	3	4	14	10	− 9	4	5
22	−65	4	4	10	10	−10	6	5
20	−64	5	4	7	6	−11	8	5

January 1969

Height km	T °C	SD degC	N	u metres/second	SD	v	SD	N
64								
62								
60	−38	4	3					
58	−33	4	4					
56	−26	6	4	112	17	55	17	3
54	−23	3	4	118	17	42	13	4
52	−17	2	4	124	26	34	12	6
50	−14	4	4	129	30	41	12	6
48	−12	7	5	122	27	35	15	6
46	−10	9	6	117	23	41	16	6
44	− 9	13	6	110	18	33	16	6
42	−11	17	6	106	16	33	14	6
40	−13	19	6	100	14	30	12	6
38	−25	17	6	90	11	30	18	7
36	−33	12	6	80	8	23	13	7
34	−44	11	6	67	6	13	11	7
32	−52	9	7	56	7	9	9	7
30	−60	7	7	48	8	6	7	7
28	−65	5	7	42	7	2	8	7
26	−69	5	7	36	6	−1	6	8
24	−71	4	7	29	4	−2	7	8
22	−71	3	7	23	3	−1	5	8
20	−68	2	5	18	3	0	3	3

December 1969

Height km	T °C	SD degC	N	u metres/second	SD	v	SD	N
64								
62	−26	14	3					
60	−25	9	6	78	31	20	25	5
58	−17	8	8	89	39	17	27	6
56	−12	8	8	97	34	13	19	7
54	− 6	11	9	109	47	14	16	7
52	− 4	6	9	112	45	27	24	9
50	− 3	8	9	121	43	24	20	10
48	− 5	11	9	121	36	27	23	10
46	− 5	14	9	114	33	27	36	10
44	−11	19	9	112	28	27	34	10
42	−16	21	10	106	24	25	29	10
40	−25	22	10	97	21	22	21	10
38	−32	22	10	93	19	15	17	10
36	−41	18	10	78	16	11	12	10
34	−52	12	10	65	13	7	7	11
32	−63	7	10	54	8	0	2	11
30	−72	5	10	46	6	− 3	4	11
28	−75	3	10	39	5	− 6	6	11
26	−78	3	10	34	6	− 8	6	11
24	−78	3	10	29	7	− 9	7	11
22	−77	3	10	25	8	−10	7	11
20	−74	5	9					

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE III – *continued*

January 1970

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62	−38	11	4	−6	20	34	27	3
60	−37	8	5	8	30	39	25	3
58	−32	8	6	29	31	25	16	6
56	−24	7	6	32	28	26	18	6
54	−16	6	6	45	38	20	11	7
52	−11	7	6	41	34	21	15	7
50	− 7	7	6	49	34	21	17	7
48	− 4	4	6	50	28	21	16	7
46	0	9	7	51	24	21	19	7
44	6	14	8	44	24	22	16	7
42	8	13	9	45	22	23	13	7
40	3	11	10	44	16	23	20	7
38	−10	18	11	39	20	26	17	7
36	−18	19	11	38	15	21	17	8
34	−27	21	11	34	17	14	18	10
32	−39	17	11	31	16	9	13	10
30	−51	10	11	24	16	3	11	11
28	−58	7	11	23	16	0	11	11
26	−65	6	11	21	14	−1	11	11
24	−70	5	11	21	13	−3	12	11
22	−71	3	11	21	12	−3	10	11
20	−70	2	11	20	11	−6	9	9

December 1970

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62								
60	−22	17	3	98	10	20	25	3
58	−17	9	4	115	10	17	17	4
56	−13	8	4	121	17	29	17	4
54	−10	7	4	125	27	21	18	4
52	− 9	3	4	135	31	21	37	4
50	−11	6	4	138	36	23	35	4
48	−13	9	4	138	36	18	31	4
46	−16	15	4	140	38	23	32	4
44	−19	23	4	129	44	29	26	4
42	−25	22	4	120	43	19	31	4
40	−31	22	4	111	44	17	28	4
38	−43	20	4	97	31	8	24	4
36	−52	15	4	81	22	8	19	4
34	−59	12	4	67	15	3	9	4
32	−65	10	4	57	10	−3	10	4
30	−70	7	4	49	11	−4	9	4
28	−74	5	4	42	6	−4	6	4
26	−76	6	4	36	5	−5	6	4
24	−76	6	4	31	1	−6	4	4
22	−75	6	4	26	2	−7	5	4
20	−71	6	4					

January 1971

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62	−37	12	4					
60	−33	7	8	44	45	−10	43	7
58	−30	7	8	47	41	− 7	40	8
56	−26	7	9	50	41	− 1	39	8
54	−23	8	9	47	36	2	32	9
52	−20	9	9	47	34	1	31	9
50	−20	11	9	45	26	4	29	9
48	−21	14	9	39	27	2	22	9
46	−25	17	10	39	34	5	20	10
44	−26	19	10	31	35	6	22	10
42	−27	21	10	23	34	3	29	10
40	−30	21	10	22	34	2	29	10
38	−35	18	10	21	32	3	24	10
36	−40	13	10	20	31	− 5	18	10
34	−49	6	10	16	28	−10	17	10
32	−54	6	10	14	26	−12	15	10
30	−55	6	10	11	21	−11	12	10
28	−57	7	10	11	17	−10	9	10
26	−57	7	10	9	13	− 9	8	10
24	−57	7	10	10	10	− 8	8	10
22	−57	7	10	9	8	− 6	8	10
20	−55	7	10	10	8	− 4	5	6

February 1971

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62								
60	−28	6	3					
58	−30	6	4	105	12	4	24	7
56	−27	7	7	105	13	1	24	7
54	−25	6	7	101	12	−1	20	7
52	−26	4	8	92	7	2	15	8
50	−26	3	8	90	5	1	10	8
48	−27	3	8	82	8	3	10	8
46	−30	4	8	72	9	0	6	8
44	−36	6	8	60	6	−3	5	8
42	−42	6	8	54	6	−5	5	8
40	−47	3	8	43	10	−3	4	8
38	−53	2	8	37	9	−4	4	8
36	−59	4	8	29	9	−5	3	8
34	−61	5	8	23	5	−7	3	8
32	−63	3	8	18	5	−7	3	8
30	−64	2	8	15	4	−7	7	8
28	−66	3	8	12	6	−6	4	8
26	−63	3	8	11	5	−5	4	8
24	−62	3	8	10	5	−7	5	8
22	−62	3	8	8	5	−7	4	8
20	−61	3	8	10	3	−7	4	7

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE III – *continued*

December 1971

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64	−19	9	3					
62	−17	11	3					
60	−17	12	5					
58	−14	6	6	61	16	− 9	26	4
56	−11	13	6	75	24	2	30	6
54	−17	12	7	81	20	− 3	31	7
52	−19	10	7	83	31	−10	25	7
50	−19	7	7	93	30	−10	18	7
48	−24	9	7	97	25	−17	13	7
46	−27	8	7	103	18	−10	13	7
44	−34	7	7	98	24	− 9	13	7
42	−41	7	7	95	21	−17	11	7
40	−48	7	7	92	25	−13	7	7
38	−53	5	7	83	23	− 8	4	7
36	−58	5	7	73	24	− 7	2	7
34	−64	6	7	64	25	− 8	8	7
32	−69	6	7	57	20	− 6	8	7
30	−71	7	7	49	21	− 2	9	7
28	−71	9	7	44	14	− 5	13	7
26	−72	7	7	34	13	− 3	10	7
24	−69	5	7	28	11	− 2	9	7
22	−68	4	7	22	7	− 1	7	7
20	−65	3	7	14	6	− 1	7	5

January 1972

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62								
60								
58								
56	−30	8	3					
54	−27	5	4					
52	−25	7	5					
50	−27	5	5					
48	−32	13	5	87	35	−12	17	4
46	−36	11	5	82	38	− 6	15	5
44	−37	12	5	87	33	4	13	5
42	−33	11	5	80	25	4	8	5
40	−33	13	5	74	19	7	10	5
38	−38	8	5	68	16	3	12	5
36	−48	5	5	66	17	7	18	5
34	−52	7	5	60	17	11	16	5
32	−59	7	5	52	20	16	20	5
30	−61	8	5	49	16	13	21	5
28	−65	9	5	45	15	13	17	4
26	−63	10	5	38	14	10	17	5
24	−62	9	5	34	13	8	13	5
22	−60	10	5	29	12	5	10	5
20	−60	7	5	19	8	5	9	4

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

TABLE IV – FREQUENCY DISTRIBUTIONS OF TEMPERATURE AT WEST GEIRINISH DURING DECEMBER, JANUARY AND FEBRUARY

	Height *km*	Range (degrees Celsius) –90– –81	–80– –71	–70– –61	–60– –51	–50– –41	–40– –31	–30– –21	–20– –11	–10– – 1	0– 9	10– 19	20– 29	N*
		per cent												
December	60	–	–	–	–	8	24	32	16	8	8	4	–	25
	55	–	–	–	–	–	10	19	32	29	10	–	–	31
	50	–	–	–	–	–	–	16	25	31	22	6	–	32
	45	–	–	–	–	3	19	16	16	19	9	9	9	32
	40	–	–	3	15	12	21	18	6	6	9	3	6	33
	35	–	6	15	39	9	12	12	0	6	–	–	–	33
	30	3	45	36	9	0	3	3	–	–	–	–	–	33
	25	12	52	24	9	3	–	–	–	–	–	–	–	33
	20	9	38	38	12	3	–	–	–	–	–	–	–	32
January	60	–	–	–	3	23	30	27	3	10	3	–	–	30
	55	–	–	–	–	6	34	26	31	3	–	–	–	35
	50	–	–	–	–	5	22	24	19	22	5	3	–	37
	45	–	–	–	3	23	15	17	7	20	13	0	3	40
	40	–	–	–	–	34	17	10	10	10	10	10	–	41
	35	–	–	7	22	32	17	15	0	2	0	2	2	41
	30	–	9	21	50	9	5	5	–	–	–	–	–	42
	25	5	24	36	24	12	–	–	–	–	–	–	–	42
	20	–	20	35	33	13	–	–	–	–	–	–	–	40
February	60	–	–	–	–	–	23	26	39	10	3	–	–	31
	55	–	–	–	–	–	5	19	41	30	3	3	–	37
	50	–	–	–	–	–	–	28	44	23	5	–	–	39
	45	–	–	–	–	5	15	36	28	15	–	–	–	39
	40	–	–	–	15	39	18	15	10	3	–	–	–	39
	35	–	–	33	33	10	10	10	0	3	–	–	–	39
	30	–	13	64	10	13	–	–	–	–	–	–	–	39
	25	–	21	69	10	–	–	–	–	–	–	–	–	39
	20	–	13	61	26	–	–	–	–	–	–	–	–	38

* *N* = number of observations

TABLE V – FREQUENCY DISTRIBUTION OF THE ZONAL WIND COMPONENT AT WEST GEIRINISH DURING DECEMBER, JANUARY AND FEBRUARY

Range (m/s)

	Height *km*	−39– −20	−19– 0	1– 20	21– 40	41– 60	61– 80	81– 100	101– 120	121– 140	141– 160	161– 180	181– 200	N*
								per cent						
December	60	–	–	7	20	0	13	27	33	–	–	–	–	15
	55	–	–	7	10	0	10	27	13	17	10	0	7	30
	50	3	3	3	9	0	6	15	15	18	15	15	–	34
	45	3	3	0	0	9	11	17	14	23	11	9	–	35
	40	6	0	0	0	11	31	14	20	14	0	3	–	35
	35	6	0	0	9	29	23	31	3	–	–	–	–	35
	30	–	6	6	28	44	17	–	–	–	–	–	–	36
	25	–	–	22	72	6	–	–	–	–	–	–	–	36
	20	–	4	63	33	–	–	–	–	–	–	–	–	24
January	60	–	17	11	17	22	6	17	6	6	–	–	–	18
	55	–	8	8	11	25	11	8	17	11	–	–	–	36
	50	–	5	19	5	19	16	12	12	9	2	2	–	43
	45	–	13	9	15	13	21	11	11	6	2	–	–	47
	40	4	9	17	11	19	17	13	9	2	–	–	–	47
	35	2	14	20	16	12	25	12	–	–	–	–	–	51
	30	–	19	23	19	23	15	2	–	–	–	–	–	53
	25	–	13	31	35	20	2	–	–	–	–	–	–	55
	20	–	7	53	37	2	–	–	–	–	–	–	–	43
February	60	–	14	14	7	29	14	21	–	–	–	–	–	14
	55	–	3	12	3	21	15	21	24	3	–	–	–	34
	50	–	–	3	10	23	15	43	7	–	–	–	–	40
	45	–	–	3	15	25	45	13	–	–	–	–	–	40
	40	–	–	5	23	47	25	–	–	–	–	–	–	40
	35	–	–	15	45	27	13	–	–	–	–	–	–	40
	30	–	–	35	33	25	7	–	–	–	–	–	–	40
	25	–	–	53	25	23	–	–	–	–	–	–	–	40
	20	–	5	54	36	5	–	–	–	–	–	–	–	39

* *N* = number of observations

TABLE VI – FREQUENCY DISTRIBUTIONS OF THE MERIDIONAL WIND COMPONENT AT WEST GEIRINISH DURING DECEMBER, JANUARY AND FEBRUARY

		Range (m/s)									
		−79– −60	−59– −40	−39– −20	−19– 0	1– 20	21– 40	41– 60	61– 80	81– 100	
	Height *km*				*per cent*						*N**
December	60	–	–	7	33	13	33	0	13	–	15
	55	–	3	7	27	20	20	20	3	–	30
	50	–	–	6	24	29	21	18	3	–	34
	45	–	–	6	29	23	34	0	3	6	35
	40	–	–	9	31	34	20	6	6	–	35
	35	–	–	3	60	14	23	–	–	–	35
	30	–	–	6	64	31	–	–	–	–	36
	25	–	–	3	75	22	–	–	–	–	36
	20	–	–	8	67	25	–	–	–	–	24
January	60	6	6	6	28	22	17	11	6	–	18
	55	3	0	6	25	42	17	3	6	–	36
	50	–	2	7	21	49	5	14	2	–	43
	45	–	–	2	30	49	11	6	2	–	47
	40	–	–	2	51	23	15	6	0	2	47
	35	–	–	10	43	29	16	2	–	–	51
	30	–	–	9	51	34	6	–	–	–	53
	25	–	–	7	64	25	4	–	–	–	55
	20	–	–	5	70	26	–	–	–	–	43
February	60	–	–	21	14	43	21	–	–	–	14
	55	–	6	6	47	29	12	–	–	–	34
	50	3	3	5	43	45	3	–	–	–	40
	45	3	3	0	75	17	3	–	–	–	40
	40	–	3	5	67	25	–	–	–	–	40
	35	–	3	7	73	17	–	–	–	–	40
	30	–	–	10	65	23	3	–	–	–	40
	25	–	–	3	75	23	–	–	–	–	40
	20	–	–	8	69	21	3	–	–	–	39

* *N* = number of observations

TABLE VII – MONTHLY MEANS AND EXTREMES OF TEMPERATURE, ZONAL AND MERIDIONAL WIND FOR WEST GEIRINISH, FORT CHURCHILL AND FORT GREELY

DECEMBER

West Geirinish

Height	Temperature							Extremes		Zonal wind							Extremes		Meridional wind							Extremes		Height
	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	Height
km	*degrees Celsius*									*metres/second*									*metres/second*									*km*
60	−21	−27	−25	−22	−17	−24	3	4	−70	78	(58)	78	98	(49)	72	9	117	14	33	(17)	20	20	(−17)	15	6	68	−26	60
55	−19	−19	−10	−11	−15	−21	4	9	−40	85	115	104	124	77	101	18	185	6	24	16	15	33	− 3	15	12	78	−52	55
50	− 4	− 8	− 3	−11	−19	− 9	6	12	−27	78	106	121	138	93	107	21	175	−32	26	25	24	23	−10	17	14	79	−31	50
45	0	− 3	− 9	−17	−29	−15	11	29	−44	90	89	114	137	100	106	18	178	−26	9	22	28	30	− 9	16	15	97	−36	45
40	−11	−19	−25	−31	−48	−27	13	25	−61	68	73	97	111	92	88	16	178	−24	10	24	22	17	−13	12	13	66	−25	40
35	−31	−50	−47	−55	−61	−49	10	− 4	−73	52	53	71	74	67	63	9	102	−26	0	14	9	7	− 7	6	7	37	−21	35
30	−56	−65	−72	−70	−71	−67	6	−27	−84	36	31	46	49	49	48	7	79	−13	−5	− 5	− 3	−4	− 2	− 4	1	17	−25	30
25	−69	−67	−78	−76	−70	−72	4	−49	−84	23	16	32	34	28	27	7	48	2	−6	− 9	− 9	−7	− 1	− 6	3	14	−26	25
20	−67	−64	−74	−71	−65	−68	4	−50	−83	18	7	(13)	(25)	14	15	5	30	0	−8	−11	(−15)	(−7)	− 1	− 8	4	10	−23	20

Fort Churchill

Height	Temperature							Extremes		Zonal wind							Extremes		Meridional wind							Extremes		Height
	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	Height
km	*degrees Celsius*									*metres/second*									*metres/second*									*km*
60	−	(−10)	− 5	1	1	− 4	3	23	−17	−	−	94	28	51	58	27	116	−32	−	−	− 2	−32	−11	−15	13	28	− 73	60
55	−10	−13	−10	− 6	− 3	− 8	3	10	−23	(37)	39	69	50	60	51	11	128	−59	(−6)	1	1	−26	− 1	− 6	11	53	− 94	55
50	− 4	−20	−13	−13	− 6	−11	6	28	−32	32	34	62	44	64	47	13	109	−68	−1	0	−12	−38	− 5	−14	14	57	−109	50
45	−12	−37	−34	−31	−18	−26	10	16	−51	40	25	51	54	68	48	14	115	−28	11	−13	−23	−35	− 7	−13	15	38	−121	45
40	−25	−49	−52	−44	−37	−41	10	− 4	−65	43	11	32	43	61	38	16	101	−43	13	−18	−34	−33	− 8	−16	17	71	−106	40
35	−35	−54	−61	−55	−57	−54	9	9	−68	37	3	18	36	51	29	17	83	−28	15	−19	−38	−27	−13	−16	18	81	− 80	35
30	−47	−53	−61	−59	−62	−56	6	−20	−66	32	−1	12	32	43	24	16	73	−19	4	−13	−33	−13	−15	−14	12	58	− 56	30
25	−60	−53	−55	−56	−60	−57	3	−44	−65	21	−1	8	24	36	18	13	63	−16	−10	− 9	−21	−11	−14	−13	4	19	− 45	25

Fort Greely

Height	Temperature							Extremes		Zonal wind							Extremes		Meridional wind							Extremes		Height
	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	1967	1968	1969	1970	1971	Mean	*SD*	Max.	Min.	Height
km	*degrees Celsius*									*metres/second*									*metres/second*									
60	− 2	(−17)	−	(−11)	(−28)	−15	−	12	−29	−	−	−	9	−	−	−	(23)	(−28)	−	−	−	−13	−	−	−	(7)	(−24)	60
55	− 1	−	−	− 7	−12	− 7	5	26	−40	22	−10	−	27	30	17	17	86	−67	−11	−34	−	−19	21	−11	20	34	−107	55
50	−13	(−26)	−	− 8	−31	−19	10	3	−52	37	− 4	−	34	29	24	16	94	−59	11	−47	−	−44	−15	−24	24	60	−136	50
45	−29	(−30)	−	−19	−48	−31	12	−13	−62	34	− 2	−	47	58	34	23	84	−80	−11	−44	−	−55	−40	−37	16	48	−139	45
40	−49	(−36)	−	−37	−53	−44	7	−19	−62	44	− 2	−	56	69	41	27	92	−35	−26	−36	−	−53	−49	−41	11	19	−110	40
35	−54	(−45)	−	−49	−48	−49	3	−24	−74	49	− 3	11	53	62	34	26	90	−30	−28	−20	−9	−38	−27	−24	10	27	− 84	35
30	−57	−44	−	−59	−49	−50	6	−33	−64	47	− 2	9	39	51	29	21	84	−12	−26	− 9	−2	−21	−17	−15	9	16	− 44	30
25	−59	−47	−	(−56)	(−55)	−54	−	−36	−72	40	3	4	37	(41)	25	18	56	− 5	−11	− 4	4	− 7	(−24)	− 8	5	17	− 29	25
20	(−56)	−49	−	(−44)	−	−50	−	(−41)	(−65)	31	7	−	(31)	−	23	−	43	2	−11	− 3	−	(3)	−	− 4	−	10	− 15	20

Note: Entries in brackets are based on less than three observations. *SD* = standard deviation.

TABLE VII – *continued*

JANUARY

West Geirinish

Temperature (degrees Celsius)

Height km	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.
60	−14	−39	−38	−40	−33	–	−33	10	4	−54
55	−17	−37	−24	−20	−23	−29	−25	7	−10	−44
50	− 8	−37	−14	− 7	−20	−27	−19	11	12	−47
45	−15	−40	− 9	2	−25	−38	−21	15	20	−53
40	−27	−45	−13	3	−30	−33	−25	15	17	−58
35	−42	−52	−39	−21	−45	−50	−41	10	21	−68
30	−67	−52	−60	−51	−55	−61	−58	5	−27	−74
25	−78	−52	−71	−67	−58	−63	−65	9	−41	−83
20	−74	−56	−68	−70	−55	−60	−64	7	−46	−79

Zonal wind (metres/second)

Height km	1964	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	(63)	60	–	8	44	–	44	22	130	−18
55	(83)	86	55	111	45	49	–	62	24	135	−13
50	90	88	41	129	49	45	(85)	75	30	172	−12
45	104	69	23	111	51	36	86	69	31	147	−14
40	93	65	8	100	44	22	74	58	32	125	−31
35	74	73	2	75	34	18	64	49	28	95	−20
30	64	64	2	48	24	11	49	37	23	95	−16
25	43	51	2	33	21	9	36	28	17	74	−15
20	25	30	4	18	20	10	19	18	8	49	− 3

Meridional wind (metres/second)

1964	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.	Height km
–	(17)	−4	–	39	−10	–	11	19	70	−80	60
(0)	14	4	39	21	0	–	19	14	68	−68	55
−2	6	5	41	21	4	(−19)	8	17	78	−40	50
6	11	−2	35	24	4	− 2	11	13	61	−22	45
2	5	−6	30	23	2	7	9	12	87	−24	40
−2	8	−9	18	17	− 8	7	4	10	41	−27	35
−1	5	−9	6	3	−11	13	1	8	36	−27	30
−2	−5	−6	−1	− 2	− 9	9	−2	5	21	−29	25
−2	−3	−5	0	− 6	− 4	5	−3	3	14	−21	20

Fort Churchill

Temperature (degrees Celsius)

Height km	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	−26	− 9	−21	–	–	−19	7	0	−37
55	−10	−23	− 9	−23	–	–	−16	7	5	−46
50	−21	−22	−17	−24	–	− 9	−21	5	10	−48
45	−28	−21	−29	−27	–	−25	−26	3	19	−57
40	−39	−21	−47	−29	–	−35	−34	9	32	−63
35	−50	−21	−55	−43	–	−38	−42	12	− 7	−63
30	−56	−35	−59	−51	–	−51	−50	8	−27	−65
25	−57	−51	−59	−50	–	−52	−54	4	−37	−63

Zonal wind (metres/second)

Height km	1964	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	–	–	–	− 9	–	–	− 9	–	(77)	(−49)
55	–	(49)	26	139	15	–	–	57	49	184	−38
50	–	21	22	125	6	–	27	40	43	196	−40
45	–	25	11	105	− 5	–	41	35	38	163	−51
40	–	26	4	66	−10	–	47	27	28	107	−47
35	–	32	0	35	−23	–	48	23	26	72	−54
30	–	32	−2	18	−22	–	53	16	26	67	−45
25	–	33	0	11	−13	–	53	21	24	65	−24

Meridional wind (metres/second)

1964	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.	Height km
–	–	–	–	− 6	–	–	− 6	–	(12)	(−46)	60
–	(5)	−10	13	8	–	–	4	9	44	−54	55
–	−20	1	16	9	–	−27	− 4	17	51	−91	50
–	−25	10	11	3	–	−25	− 2	16	37	−94	45
–	−43	24	2	− 6	–	−37	−12	25	36	−74	40
–	−44	28	− 2	−12	–	−41	−14	27	49	−74	35
–	−35	26	− 4	−14	–	−40	−13	24	47	−67	30
–	−30	10	0	− 9	–	−38	−17	18	53	−50	25

Fort Greely

Temperature (degrees Celsius)

Height km	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	(−19)	− 3	−10	−24	(−25)	−16	9	7	−38
55	(−11)	−22	−13	−27	−25	−16	−19	5	− 1	−37
50	−12	−24	−29	−37	−24	−21	−25	8	− 3	−48
45	−34	−28	−43	−46	−27	−33	−35	7	− 6	−59
40	−47	−41	−52	−47	−33	−35	−43	7	−15	−65
35	−55	−42	−56	−50	−36	−42	−47	7	−16	−67
30	−53	−44	−54	−49	−40	−47	−48	5	−21	−66
25	(−57)	−54	−54	−47	−45	−50	−51	4	−35	−61
20	(−52)	−55	−51	−47	−45	–	−50	4	−37	−60

Zonal wind (metres/second)

Height km	1964	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	0	–	−17	− 9	−38	(20)	−11	14	44	−101
55	27	13	40	22	−20	13	25	17	17	73	−74
50	32	25	39	20	−13	13	55	24	20	78	−72
45	39	35	24	15	−15	−1	57	22	23	67	−67
40	47	30	12	11	−18	−7	48	17	24	86	−80
35	50	36	9	4	−19	−8	55	18	27	85	−65
30	45	34	9	0	−16	−7	31	16	21	71	−47
25	41	25	11	2	− 7	−5	36	15	18	67	−35
20	29	17	19	4	− 2	1	–	11	11	41	−18

Meridional wind (metres/second)

1964	1965	1968	1969	1970	1971	1972	Mean	*SD*	Extremes Max.	Extremes Min.	Height km
–	−21	–	−68	11	11	(19)	−10	32	85	−82	60
−39	−18	15	−38	39	− 9	11	− 5	25	119	−112	55
−35	−29	14	−39	25	− 7	−36	−15	24	129	−160	50
−42	−31	10	−34	10	−16	−32	−19	20	125	−129	45
−41	−30	0	−24	11	−11	−11	−18	17	75	−91	40
−33	−25	− 3	−17	11	−11	−14	−13	13	56	−84	35
−24	−16	− 8	− 9	6	− 9	−15	−11	9	25	−64	30
−13	− 6	−15	− 3	5	−11	−10	− 7	6	16	−44	25
− 2	0	−11	− 2	3	−10	–	− 4	5	13	−26	20

Note: Entries in brackets are based on less than three observations. *SD* = standard deviation.

TABLE VII – *continued*

FEBRUARY

West Geirinish

Temperature (degrees Celsius)

Height km	1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.
60	–21	–26	–15	–17	–28	–21	5	0	–40
55	– 8	–20	–13	–10	–26	–15	7	18	–34
50	–11	–11	–11	–14	–26	–15	6	2	–30
45	–13	–14	–20	–23	–33	–21	7	– 1	–42
40	–34	–19	–35	–45	–47	–36	10	–10	–55
35	–45	–27	–49	–63	–60	–49	13	– 3	–69
30	–65	–51	–65	–69	–64	–61	6	–42	–76
25	–67	–66	–68	–67	–62	–66	2	–53	–73
20	–68	–67	–64	–63	–61	–65	3	–55	–75

Zonal wind (metres/second)

Height km	1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	16	36	86	(85)	56	29	99	–16
55	(33)	35	49	92	105	63	29	129	–10
50	60	45	55	91	90	68	19	112	7
45	59	41	61	71	67	60	10	94	21
40	52	40	59	54	43	50	7	80	14
35	45	40	59	34	25	41	11	64	10
30	41	40	56	28	15	36	14	64	5
25	28	36	48	17	10	28	13	59	1
20	17	27	37	12	10	21	10	50	0

Meridional wind (metres/second)

1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.	Height km
–	0	–24	26	(25)	9	20	32	–35	60
(–18)	2	–19	6	–2	– 6	9	38	–57	55
– 2	1	–21	4	1	– 3	9	22	–60	50
1	–2	–26	–4	–2	– 7	10	31	–63	45
– 3	–1	–15	–5	–3	– 5	5	19	–57	40
–12	–3	–18	–9	–5	–10	5	10	–42	35
–12	–1	– 9	–7	–7	– 7	4	21	–27	30
–13	2	– 5	–8	–5	– 6	5	17	–24	25
–13	3	1	–8	–7	– 5	6	24	–23	20

Fort Churchill

Temperature (degrees Celsius)

Height km	1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	– 4	–	– 1	–16	– 7	7	16	–25
55	–	– 2	–13	– 8	–19	–11	6	13	–28
50	–	0	–12	–17	–25	–13	9	23	–30
45	–	–11	–15	–30	–33	–22	9	14	–43
40	–	–32	–25	–46	–47	–37	9	– 5	–52
35	–	–45	–34	–60	–56	–49	10	–25	–62
30	–	–55	–42	–63	–58	–55	8	–37	–67
25	–	–57	–47	–62	–57	–56	5	–44	–66

Zonal wind (metres/second)

Height km	1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.
60	–	–	–	–	90	90	–	(102)	(78)
55	30	(33)	2	53	89	41	32	110	–18
50	22	28	1	75	79	41	31	120	–20
45	36	22	–3	65	52	34	24	86	–45
40	39	5	3	46	34	25	18	65	–37
35	36	2	9	31	20	20	13	50	–25
30	33	5	11	21	10	16	10	41	–17
25	34	9	12	18	7	16	10	47	–20

Meridional wind (metres/second)

1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.	Height km
–	–	–	–	3	3	–	(15)	(0)	60
–13	(9)	–18	–1	0	– 6	8	29	–40	55
– 9	0	–34	8	0	–12	15	39	–81	50
–22	2	–37	–1	2	–11	16	51	–75	45
–28	–10	–32	2	0	–17	14	23	–65	40
–18	–23	–25	–2	1	–13	11	13	–47	35
–19	–29	–18	0	–1	–17	11	20	–47	30
–11	–21	–15	–2	–3	–10	7	17	–32	25

Fort Greely

Temperature (degrees Celsius)

Height km	1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.
60	(–13)	–14	(–21)	–	(–1)	–12	–	12	–27
55	(–15)	–19	–18	–	–13	–16	3	20	–35
50	–13	–25	–18	(–22)	–20	–20	4	– 3	–50
45	–10	–34	–29	(–43)	–27	–29	9	– 7	–53
40	–15	–38	–36	(–49)	–47	–37	12	–10	–54
35	–28	–40	–40	(–57)	–55	–44	10	–19	–62
30	–35	–43	–45	(–62)	–58	–49	8	–34	–62
25	–43	–45	–49	(–61)	–53	–50	4	–36	–68
20	–45	–47	–49	(–58)	–51	–50	2	–43	–66

Zonal wind (metres/second)

Height km	1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.
60	–11	–	(3)	69	(52)	28	–	62	–54
55	0	–23	17	66	68	32	36	76	–79
50	5	–15	19	55	65	26	30	73	–80
45	10	–15	23	43	44	21	22	59	–33
40	16	–12	26	35	27	18	16	50	–30
35	18	–13	29	23	13	14	15	54	–30
30	25	– 5	29	21	11	16	12	50	–20
25	21	2	25	15	8	14	8	47	–15
20	19	6	24	16	7	14	7	45	–10

Meridional wind (metres/second)

1965	1966	1967	1968	1971	Mean	*SD*	Extremes Max.	Extremes Min.	Height km
–15	–	(3)	4	(–23)	– 8	–	17	– 70	60
–24	–17	– 3	–27	– 7	–16	9	35	–102	55
–30	–29	– 3	–14	–11	–17	11	40	–108	50
–32	–31	–14	– 9	–11	–19	10	39	–126	45
–27	–31	–11	– 1	– 6	–15	12	23	– 97	40
–23	–25	–12	– 4	– 1	–13	10	20	– 53	35
–16	–15	–10	– 3	– 2	– 9	6	14	– 42	30
–10	– 9	– 6	0	1	– 6	5	10	– 33	25
– 4	– 6	– 1	2	1	– 2	3	10	– 22	20

Note: Entries in brackets are based on less than three observations. *SD* = standard deviation.

correlation between temperature and the meridional component in the middle and upper stratosphere show that high temperatures are associated with southerly components, suggesting that advection may be of some importance. In the lower mesosphere, however, correlation is small; this is due perhaps to a reversal in the latitudinal gradient of temperature indicated by the general decrease in the zonal wind above the stratosphere.

The significant correlation between T and u at stratopause levels suggests that descent and dynamic heating are associated with periods of high winds, while the negative correlation below 34 km indicates the simultaneous ascent of air in the middle and lower stratosphere.

TABLE VIII – CORRELATION COEFFICIENTS BETWEEN TEMPERATURES AT DIFFERENT HEIGHTS

Height km	60	55	50	45	40	35	30	25	20
60			−0.02	−0.16	−0.39	−0.47	−0.54	−0.31	−0.14
55				0.27	−0.06	−0.24	−0.56	−0.54	−0.47
50					0.57	0.35	−0.25	−0.63	−0.60
45						0.54	−0.07	−0.52	−0.55
40							0.24	−0.30	−0.36
35								−0.05	−0.19
30									−0.37

TABLE IX – CORRELATION COEFFICIENT BETWEEN TEMPERATURE, ZONAL AND MERIDIONAL COMPONENTS AT DIFFERENT LEVELS

	Height (km)							
Parameters	55	50	45	40	35	30	25	20
T, u	0.11	0.30	0.39	0.25	0.08	−0.40	−0.70	(−0.67)
T, v	0.04	0.39	0.45	0.58	0.49	0.19	0.06	(0.25)
u, v	0.28	0.34	0.34	0.38	0.41	0.33	0.29	

A comparison of monthly mean values of temperature, and the zonal and meridional wind components at five high-latitude stations for the winter months is given in Table X but the period and number of observations is not identical for all stations. For Fort Greely the means are those given in the World Data Center A *Data reports,*[2] for the years 1961–68 and for Fort Churchill they have been calculated, from data contained in the same publication, for those months in which soundings were made at West Geirinish. Data for Ostrov Heiss (80°37' N, 58°03' E) and Volgograd (48°41' N, 44°21' E) have been extracted from Logvinov[3] and relate to the period 1957–64.

The tables indicate that, during these winter months, the north European stratosphere below 30 km is generally colder than that over Canada, but above this level the situation is reversed with a lower stratopause and a tighter temperature gradient existing over Europe. At all levels the zonal winds at 60°N increase eastwards from Fort Greely to West Geirinish but at the much higher latitude of Ostrov Heiss they are weaker, particularly in December. The meridional winds are northerly over Canada, mainly southerly in the vicinity of West Geirinish

TABLE X – MONTHLY MEAN VALUES OF TEMPERATURE, ZONAL AND MERIDIONAL WIND FOR DECEMBER, JANUARY AND FEBRUARY AT FIVE HIGH-LATITUDE STATIONS

	Temperature					Zonal wind					Meridional wind				
Height	Fort Greely	Fort Churchill	West Geirinish	Ostrov Heiss	Volgograd	Fort Greely	Fort Churchill	West Geirinish	Ostrov Heiss	Volgograd	Fort Greely	Fort Churchill	West Geirinish	Ostrov Heiss	Volgograd
km	*degrees Celsius*					*metres/second*					*metres/second*				
DECEMBER															
60	– 6	– 2	–22	–	–	26	50	75	–	–	–20	–16	17	–	–
55	– 1	– 8	–14	–	–	24	57	98	–	–	–22	– 4	15	–	–
50	–13	–11	– 8	–11	–18	26	52	105	9	60	–16.	–10	17	31	–1
45	–31	–27	–11	–17	–23	25	50	104	9	75	–18	–14	15	34	–2
40	–51	–42	–26	–35	–32	26	39	87	10	82	–23	–17	12	30	–2
35	–58	–54	–47	–56	–41	25	29	63	–9	76	–16	–19	4	19	–3
30	–56	–57	–67	–70	–50	23	24	42	–7	52	–12	–16	–4	7	–3
25	–52	–56	–73	–77	–60	16	18	27	–8	32	– 3	–14	–6	–1	–4
20	–50	–	–69	–73	–63	12	–	15	–8	17	– 1	–	–8	–3.	–5
JANUARY															
60	–24	–19	–33	–	–	0	–	45	–	–	–25	–	4	–	–
55	–15	–19	–25	–	–	22	49	65	–	35	–18	7	12	–	–
50	–21	–19	–20	–12	–10	27	45	67	21	50	–21	2	11	51	– 3
45	–31	–26	–22	–18	–11	28	37	59	24	62	–26	0	10	62	– 2
40	–39	–32	–26	–29	–19	26	24	48	20	69	–27	–5	8	71	– 3
35	–44	–40	–42	–37	–28	32	12	40	0	65	–24	–8	3	71	– 6
30	–47	–49	–57	–49	–41	30	8	30	– 8	48	–19	–8	–1	40	– 8
25	–49	–53	–63	–63	–57	26	8	23	–11	28	–13	–7	–3	21	–10
20	–51	–	–62	–70	–62	21	–	16	–12	15	– 5	–	–3	11	– 9
FEBRUARY															
60	–15	– 7	–21	–	–	8	–	45	–	–	– 8	–	4	–	–
55	–18	– 9	–15	–	–	13	50	71	–	18	–16	– 4	–1	–	–
50	–20	–12	–15	–12	0	14	46	73	27	27	–19	– 5	–1	28	5
45	–28	–21	–22	–14	– 4	15	37	61	25	35	–21	– 8	–5	26	7
40	–35	–37	–38	–26	–27	13	25	49	21	40	–19	–11	–4	20	1
35	–40	–49	–52	–36	–45	12	18	37	12	40	–17	–13	–8	13	– 3
30	–44	–56	–63	–49	–54	15	14	33	4	32	–12	–13	–6	10	– 7
25	–47	–57	–66	–63	–61	13	14	24	2	19	– 6	–11	–5	5	–11
20	–48	–	–64	–67	–62	15	–	18	2	10	– 2	–	–4	0	–11

and stronger southerly at Ostrov Heiss, indicating, in the mean, the presence of an Atlantic trough, except at very low levels in the stratosphere.

3 – STRATOSPHERIC WARMINGS

Figure 1 shows height–time cross-sections of the temperature between 20 and 65 km above West Geirinish for December, January and February for the five winters 1967/68 to 1971/72. Figure 2 shows similar cross-sections of the zonal winds, and Figure 3 of the meridional winds. A dot indicates the date on which the rocket soundings were made.

These diagrams show clearly the marked variability of the atmosphere, especially at the higher levels both over a period of several days and from one year to the next. In 1967/68 the zonal winds were westerly at all levels in early December reaching a maximum of over 100 m/s at about 52 km, somewhat below the stratopause which was at 60 km with a temperature just over 0°C. As the month progressed the height of the stratopause and of the maximum zonal wind gradually decreased, so that by mid month, winds of about 175 m/s and temperatures above 10°C occurred at about 45 km. At the same time temperatures below 30 km fell to below –80°C.

In the next few days dramatic changes took place – the stratopause fell to 43 km with a temperature of +40°C on 21 December while the zonal winds became light then easterly. Thereafter temperatures rose slowly in the lower levels and fell at higher levels, thus, by mid January there was little variation of temperature with height, and winds in the lower levels were generally light. At high levels, however, westerly winds began to increase and spread downwards with the temperature structure becoming normal once more. A second warming appeared late in February with temperatures below 30 km of less than –70°C, and stratopause temperatures above 0°C.

Figure 4 shows the vertical temperature profiles for 7 December, 21 December 1967 and 1 January 1968. These profiles are fairly typical of the early-warming, height-of-warming, and post-warming period at West Geirinish. In the early-warming period, the minimum temperature was –70°C at 29 km, with a normal stratopause at 50 km, and a first indication of a warming at high levels with a temperature of +11°C at 60 km. At the height of the warming there was a temperature difference of 126 degC through the 19-km layer from the low minimum of –86°C at 24 km to the maximum of +40°C at 43 km. A high lapse rate occurred above the stratopause, with temperatures falling 81 degC between 43 and 60 km. The profile for 1 January shows clearly the post-warming thermal structure, with a much warmer low stratosphere and cooler middle and high stratosphere, resulting in a small temperature difference between 30 and 55 km.

The winter most similar to 1967/68 was 1970/71: temperatures higher than 0°C occurred above 50 km on 13 December, and again on 29 December, after an unfortunate period when no successful soundings were made. A warming appeared to be in progress during this period and temperatures at 25 km fell to below –80°C, then, in the next few days, temperatures exceeding 16°C and winds exceeding 190 m/s occurred at about 44 km. Thereafter the atmosphere became nearly isothermal, winds became light with a period of easterly components, then westerlies once again spread downwards from higher levels.

It was only in these two winters that the change from 'warming' to isothermal atmosphere occurred. There appears to be a strong tendency for a warming to take place in the second half of December at the time of strong westerly winds at the stratopause level, however, in both winters of 1968/69 and 1969/70 the stratopause temperatures fluctuated but remained high through-

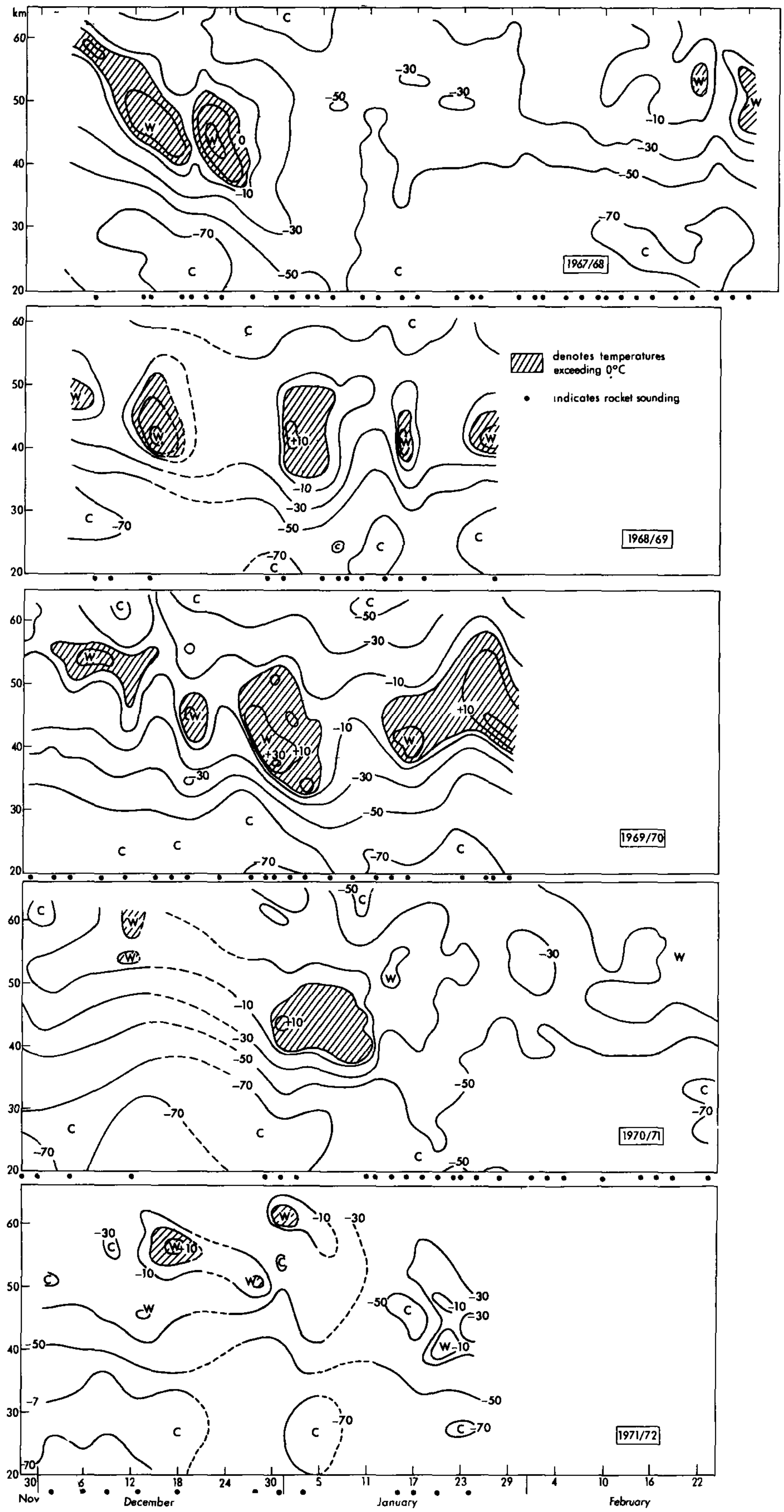

FIGURE 1. HEIGHT–TIME CROSS-SECTIONS OF TEMPERATURE (°C) AT WEST GEIRINISH FOR THE FIVE WINTERS BETWEEN 1967 AND 1972

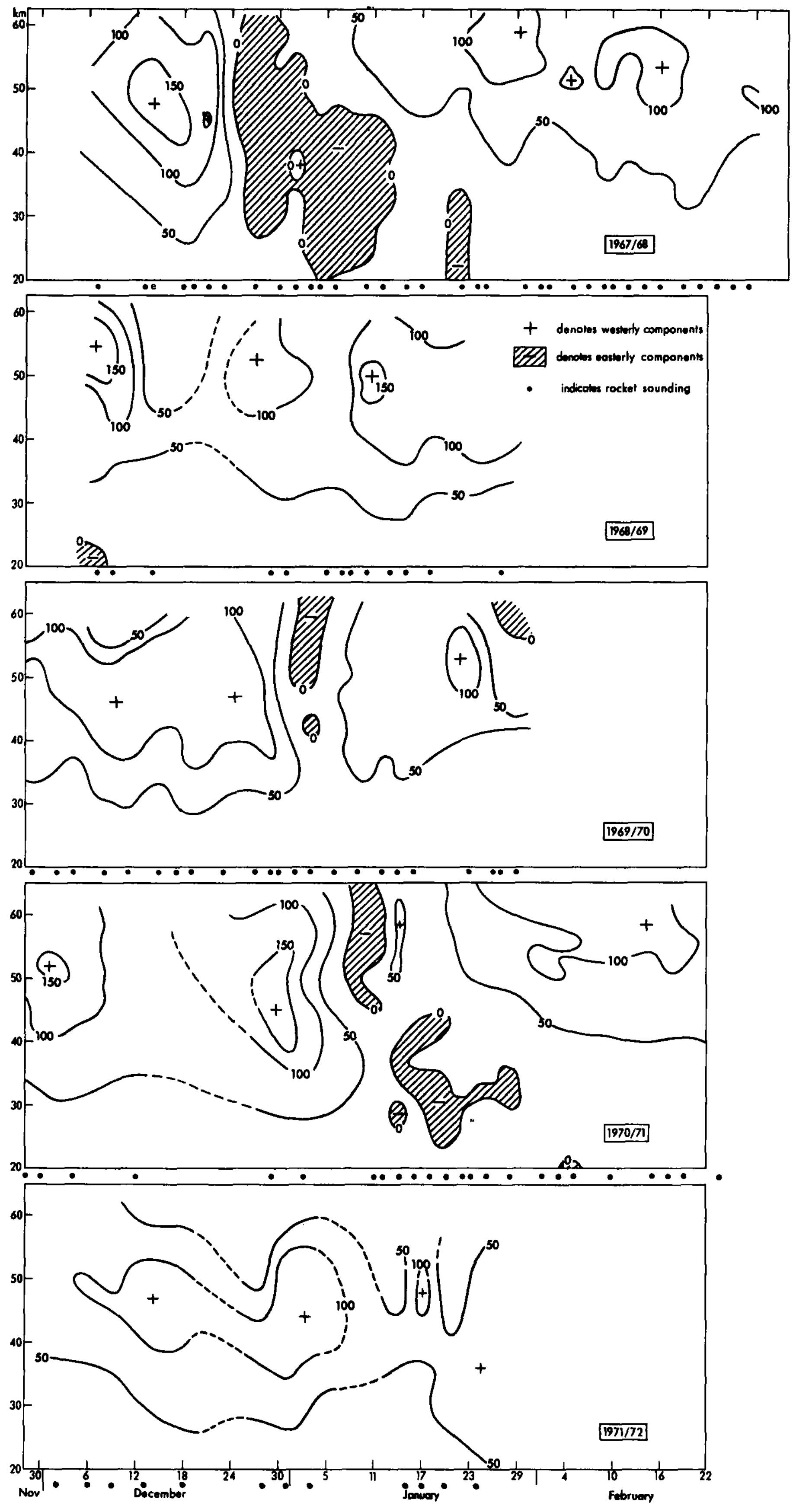

FIGURE 2. HEIGHT–TIME CROSS-SECTIONS OF ZONAL WIND (m/s) AT WEST GEIRINISH FOR THE FIVE WINTERS BETWEEN 1967 AND 1972

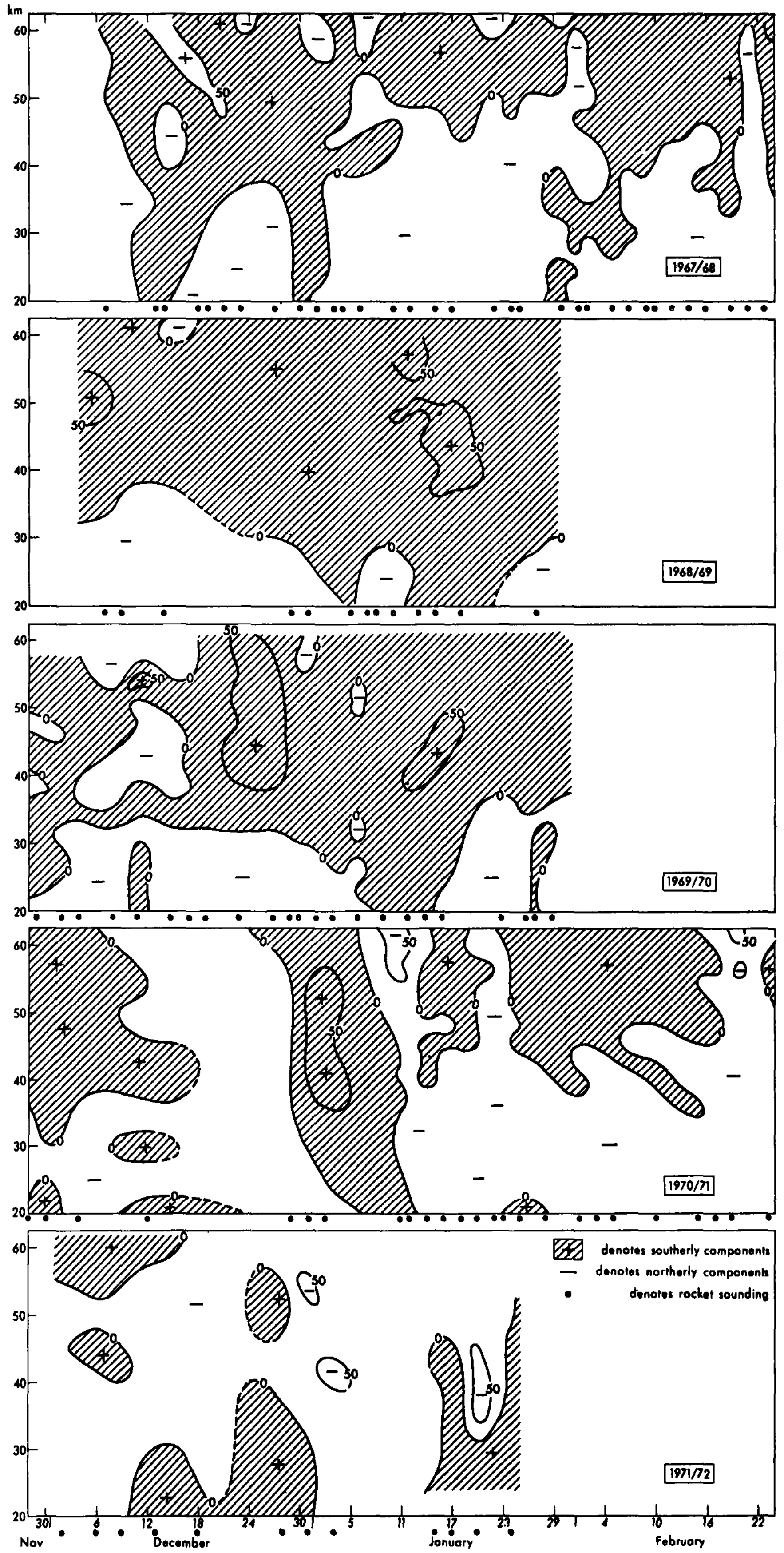

FIGURE 3. HEIGHT–TIME CROSS-SECTIONS OF MERIDIONAL WIND (m/s) AT WEST GEIRINISH FOR THE FIVE WINTERS BETWEEN 1967 AND 1972

TABLE XI – MEANS AND STANDARD DEVIATIONS OF TEMPERATURE, ZONAL AND MERIDIONAL WIND COMPONENTS FOR JANUARY 1970 AT WEST GEIRINISH AND KIRUNA

Kiruna

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62	−37	8	6	64	29	44	27	6
60	−32	8	7	68	26	43	28	9
58	−26	7	8	72	24	45	27	9
56	−21	8	8	65	23	37	42	10
54	−18	8	9	62	19	35	42	11
52	−14	9	9	56	16	39	43	11
50	−11	9	9	52	15	38	36	11
48	− 8	10	9	46	17	38	31	11
46	− 5	12	9	44	19	38	33	11
44	− 6	13	9	39	20	38	29	11
42	−10	10	10	34	19	39	27	12
40	−16	6	10	25	20	36	26	12
38	−21	6	10	14	25	32	23	12
36	−28	8	10	6	28	25	18	12
34	−34	10	10	−2	28	18	15	12
32	−40	8	10	−6	23	9	13	12
30	−48	8	10	−9	21	4	11	12
28	−52	6	10	−9	17	1	10	12
26	−58	6	10	−7	16	−3	11	12
24	−63	5	10	−7	14	−6	8	12
22	−67	5	10	−3	14	−7	9	12
20	−67	8	4	−1	14	−7	9	11

West Geirinish

Height km	T °C	SD degC	N	u	SD	v	SD	N
				metres/second				
64								
62	−38	11	4	−6	20	34	27	3
60	−37	8	5	8	30	39	25	3
58	−32	8	6	29	31	25	16	6
56	−24	7	6	32	28	26	18	6
54	−16	6	6	45	38	20	11	7
52	−11	7	6	41	34	21	15	7
50	− 7	7	6	49	34	21	17	7
48	− 4	4	6	50	28	21	16	7
46	0	9	7	51	24	21	19	7
44	6	14	8	44	24	22	16	7
42	8	13	9	45	22	23	13	7
40	3	11	10	44	16	23	20	7
38	−10	18	11	39	20	26	17	7
36	−18	19	11	38	15	21	17	8
34	−27	21	11	34	17	14	18	10
32	−39	17	11	31	16	9	13	10
30	−51	10	11	24	16	3	11	11
28	−58	7	11	23	16	0	11	11
26	−65	6	11	21	14	−1	11	11
24	−70	5	11	21	13	−3	12	11
22	−71	3	11	21	12	−3	10	11
20	−70	2	11	20	11	−6	9	9

Note:

Height = height of observation   *N* = total number of observations
T = mean temperature   *u* = mean zonal wind
SD = standard deviation   *v* = mean meridional wind

out January. Below 30 km temperatures remained low and winds westerly during this period, though easterlies occurred at high levels after the intense warming at the very end of December 1969. In all years temperatures fluctuated at levels above the stratopause, and there appears to be a tendency for a cold period to occur at 60 km about a week after a marked stratospheric warming, probably associated with the easterly zonal wind.

Cross-sections of the meridional wind showed zero or small northerly flow below 35 km, but marked fluctuations of both negative and positive values above. Largest values (75 m/s) occurred at the time and level of maximum warming. These winds were always southerly and their magnitude indicated a backing in the flow preceding the event.

These diagrams show without doubt that vigorous disturbances occur at all levels in the stratosphere, and the variability of conditions is a consequence of the variation of the intensity and tracks of these disturbances within the main circulation system. The large temperature changes must be due to vertical motion, the very low temperatures in the lower stratosphere being a result of rising air in the trough normally occurring over the Atlantic sector, while the very high temperatures near stratopause levels must be due to the rapid descent of air in the vigorous systems at these levels.

4 – NORTH-WEST EUROPEAN NETWORK

In January 1970, soundings were made concurrently at West Geirinish and at ESRANGE, Kiruna, Sweden (67°49' N, 20°20' E). Further soundings were also carried out from these two stations in January

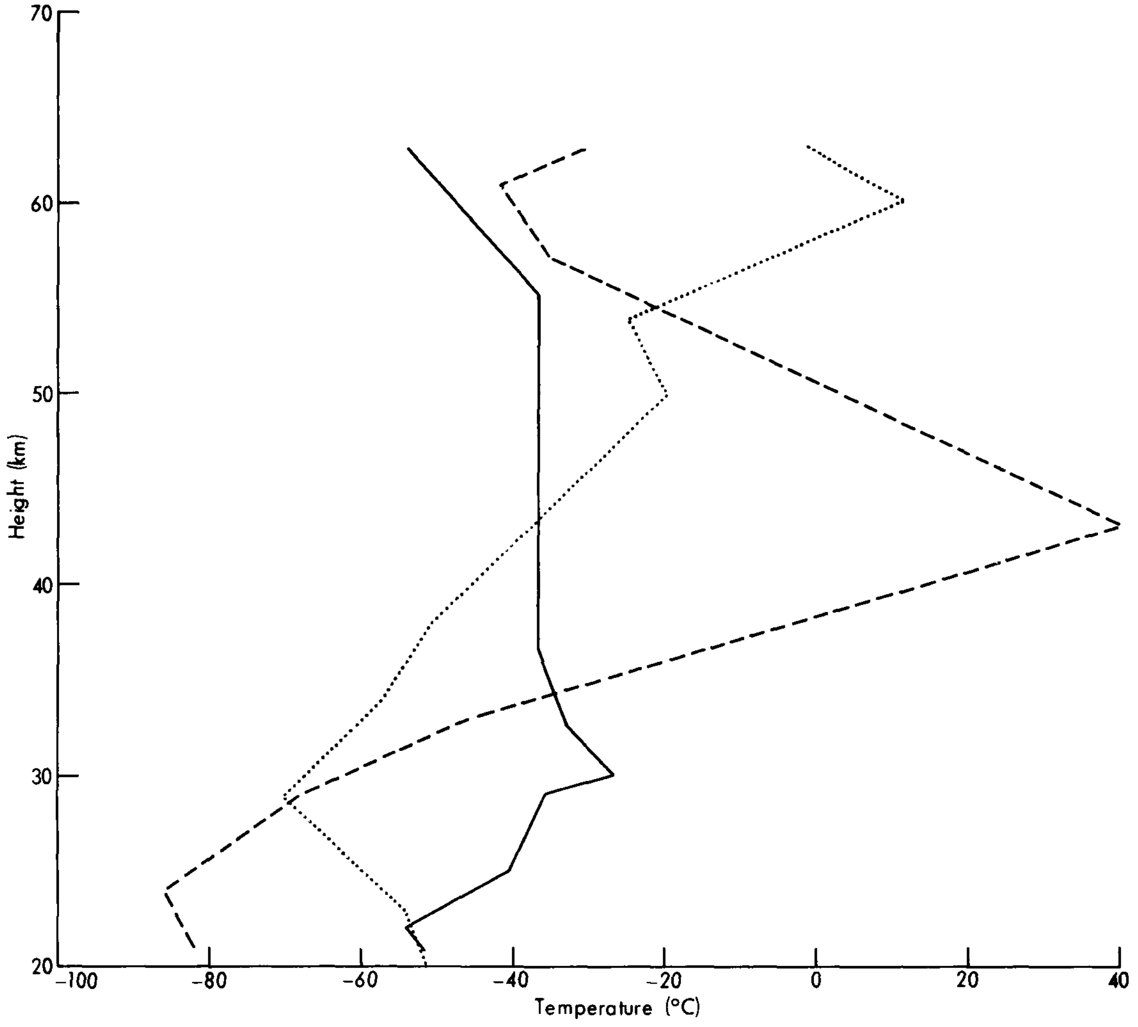

FIGURE 4. VARIATION OF TEMPERATURE WITH HEIGHT AT WEST GEIRINISH DURING THE EARLY-WARMING, HEIGHT-OF-WARMING AND POST-WARMING PERIODS IN THE WINTER OF 1967/68

·············· 7 Dec. 1967 — — — — 21 Dec. 1967 ———————— 1 Jan. 1968

and February 1971 and with the addition of observations from Aberporth (52°08' N, 4°34' W) a three-station rocketsonde network was created. This second series of soundings took place from 14 January to 12 February and during this period 12 soundings were made at West Geirinish, 6 at Aberporth and 13 at Kiruna, where observations were made by the University College of London. The same rocketsonde equipment was used at all three stations and the aim of the network was to obtain a greater understanding of the dynamics of stratospheric warmings, but unfortunately very little activity occurred during the period of observation.

Mean values of temperature and wind components for each station, during both series of soundings are given in Tables XI and XII and the corresponding height–time cross-sections in Figures 5 and 6.

January 1970 (West Geirinish and Kiruna)

The temperatures at low and high levels were very similar at both stations but stratopause temperatures were approximately 20 degC higher at West Geirinish; however, during a warming which occurred at the end of the period, stratopause temperatures reached 35°C at West Geirinish and 16°C at Kiruna. During the early part of the month zonal winds at West Geirinish were light, with easterlies above the stratopause, but thereafter westerly components re-established themselves at higher levels and values exceeding 100 m/s were recorded before the peak of the warming. At Kiruna the zonal component remained light throughout the month. Meridional winds were predominately northerly at Kiruna at the beginning of the period, but later were mainly southerly at both stations, becoming strong at times and exceeding 100 m/s at the stratopause level over Kiruna, although at lower levels they remained light or northerly.

January–February 1971 (Aberporth, West Geirinish and Kiruna)

The highest stratopause temperature occurred on the first day of the period at West Geirinish, at the end of a warming, but temperatures then fell rapidly and, after 15 January, all stratopause temperatures were between −20°C and −30°C at Aberporth and West Geirinish but some 10 degC lower at Kiruna. Below 30 km temperatures were higher than normal for this time of year for all three locations, thus there was little variation of temperature with height, especially at Kiruna, and the day-to-day variation was quite small. The wind flow pattern was more interesting. Easterly components prevailed over Kiruna between 30 and 45 km at the beginning of the period, but by the end of January there had been a gradual return to a westerly pattern at all levels – a sequence of events similar to those which have been experienced at West Geirinish after a warming, suggesting that a warming may have occurred at Kiruna shortly before the commencement of the soundings. West Geirinish experienced light zonal winds, sometimes easterly at middle levels, until late January when westerly flow was re-established at all levels; from then onwards there was a gradual increase in strength to about 100 m/s above 50 km. The pattern at Aberporth was similar but the winds were somewhat stronger. Meridional winds at both British stations were almost identical in the mean, with weak northerlies below 45 km and southerlies above; while at Kiruna northerly components predominated up to 45 km at the start of the period before a return, at the end of January, to the more normal régime as experienced at West Geirinish and Aberporth.

The temperature–wind shear relationship

The wind shear at a point is related to the horizontal temperature gradient by the equations

$$\frac{\partial u}{\partial z} = -\frac{gz}{fT} \cdot \frac{\partial T}{\partial y}$$

and

$$\frac{\partial v}{\partial z} = \frac{gz}{fT} \cdot \frac{\partial T}{\partial x} ,$$

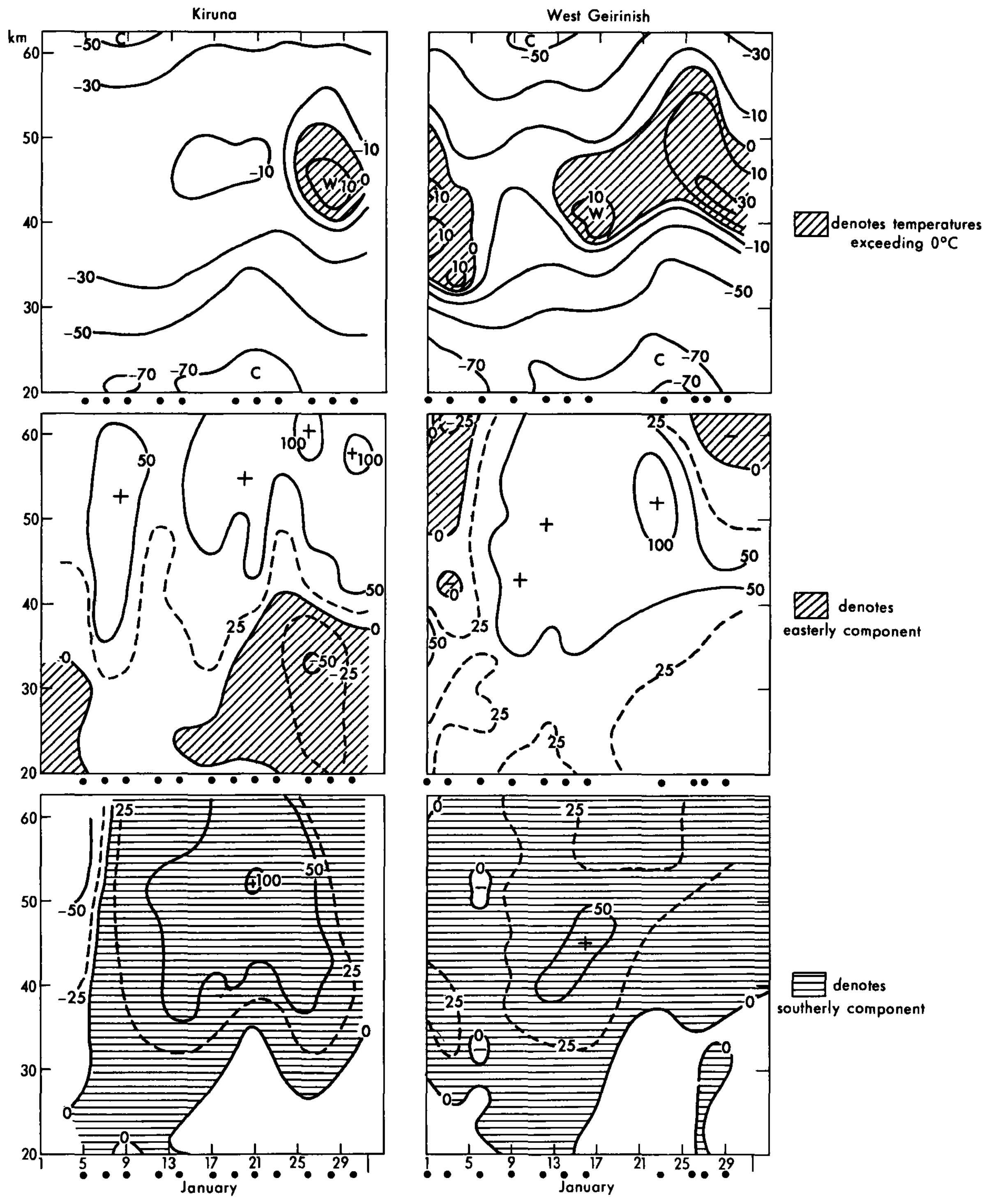

FIGURE 5. HEIGHT–TIME CROSS-SECTIONS OF TEMPERATURE (°C), ZONAL AND MERIDIONAL WIND (m/s) FOR JANUARY 1970

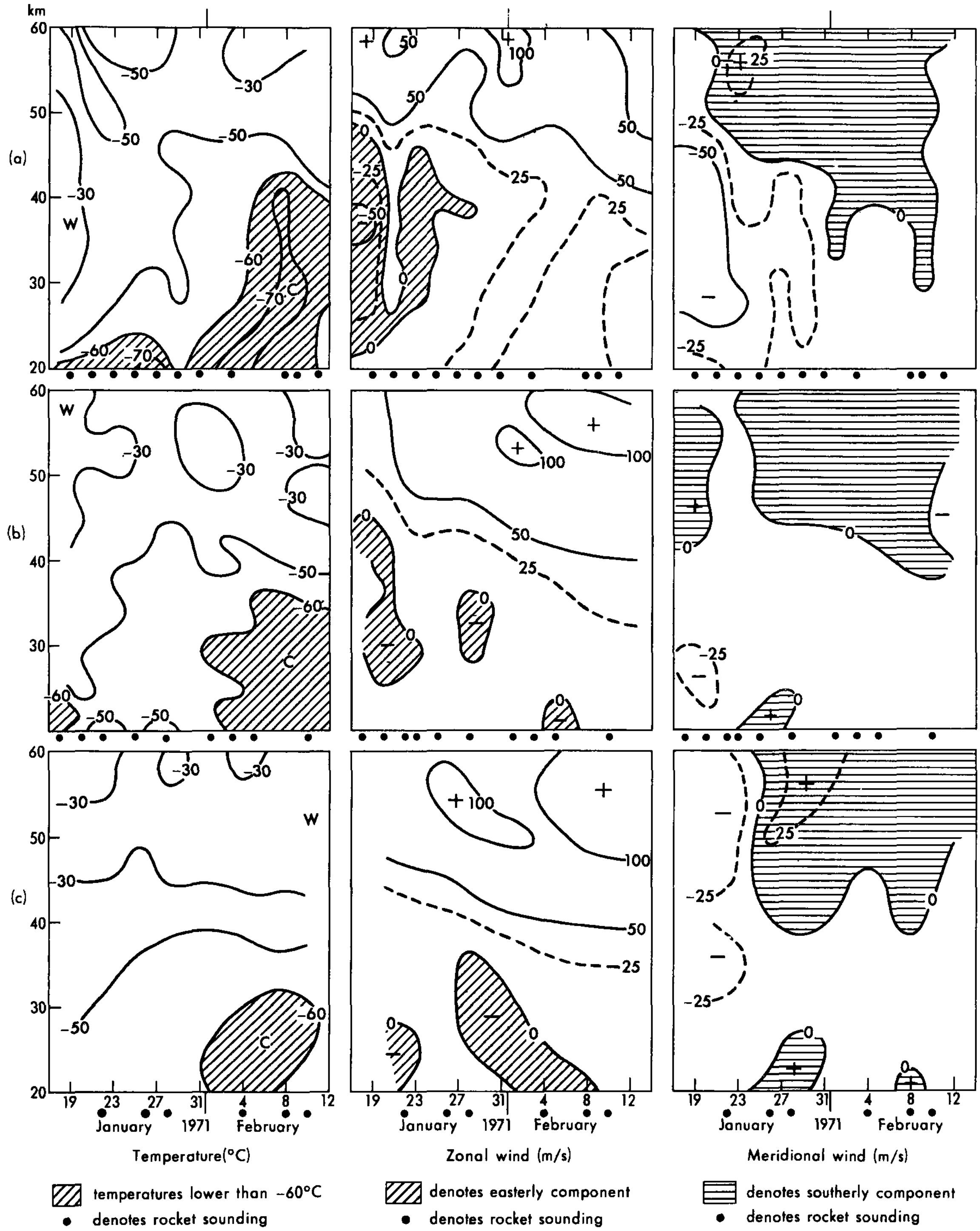

FIGURE 6. HEIGHT–TIME CROSS-SECTIONS OF TEMPERATURE (°C), ZONAL AND MERIDIONAL WIND (m/s) FOR JANUARY 1971 AT (a) KIRUNA, (b) WEST GEIRINISH AND (c) ABERPORTH

TABLE XII – MEANS AND STANDARD DEVIATIONS OF TEMPERATURE, ZONAL AND MERIDIONAL WIND COMPONENTS FOR THE PERIOD 14 JANUARY–12 FEBRUARY 1971 AT WEST GEIRINISH, ABERPORTH AND KIRUNA

Kiruna

Height *km*	*T* °*C*	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62								
60	−39	9	4	88	20	9	10	4
58	−37	7	5	73	21	9	10	6
56	−38	7	5	68	21	7	10	6
54	−39	8	6	59	22	12	23	11
52	−40	8	6	53	23	13	24	11
50	−41	8	7	49	27	14	27	11
48	−41	9	7	40	24	7	24	11
46	−43	9	7	30	25	− 1	23	11
44	−46	11	8	23	27	− 7	26	12
42	−48	12	8	13	33	− 7	29	12
40	−51	15	8	6	27	− 8	23	12
38	−50	16	8	5	30	−11	20	12
36	−52	14	10	1	26	−20	21	12
34	−51	14	10	4	24	−27	24	13
32	−52	13	10	6	23	−25	24	13
30	−52	14	10	12	19	−30	27	13
28	−54	12	10	16	19	−39	34	13
26	−55	11	10	18	15	−36	34	13
24	−58	8	10	21	13	−29	26	13
22	−62	6	10	19	9	−22	13	13
20	−66	5	10	21	6	−19	11	13

Aberporth

Height *km*	*T* °*C*	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62								
60	−33	3	3	82	13	0	19	3
58	−29	5	5	103	14	3	18	6
56	−27	3	6	102	13	1	14	6
54	−25	3	6	101	15	1	15	6
52	−23	2	6	97	16	3	17	6
50	−23	2	6	90	15	5	17	6
48	−25	4	6	81	17	5	17	6
46	−26	3	6	68	14	4	15	6
44	−31	4	6	57	14	1	7	6
42	−37	3	6	43	16	− 2	5	6
40	−41	3	6	35	16	− 1	8	6
38	−47	2	6	25	14	− 7	7	6
36	−50	3	6	18	12	− 8	5	6
34	−52	5	6	15	9	−12	10	6
32	−55	5	6	9	10	−11	8	6
30	−57	3	6	6	7	− 9	5	6
28	−59	4	6	3	4	− 7	4	6
26	−59	4	6	2	4	− 6	5	6
24	−59	4	6	1	3	− 5	7	6
22	−58	4	6	2	6	− 4	7	6
20	−56	5	6	5	7	− 3	7	6

West Geirinish

Height *km*	*T* °*C*	*SD* *degC*	*N*	*u*	*SD*	*v*	*SD*	*N*
				metres/second				
64								
62								
60	−31	6	7	63	28	11	21	6
58	−30	7	8	77	28	8	23	9
56	−27	6	10	78	27	9	10	9
54	−25	7	10	71	28	3	16	10
52	−24	8	10	69	24	3	19	10
50	−26	8	10	65	25	2	10	10
48	−28	8	10	55	25	3	13	10
46	−33	8	11	46	21	2	8	11
44	−38	10	11	35	20	− 2	7	11
42	−41	9	11	25	21	− 5	9	11
40	−45	7	11	17	16	− 7	9	11
38	−49	6	11	15	14	− 7	6	11
36	−50	8	11	11	11	−10	6	11
34	−52	7	11	7	11	−13	5	11
32	−55	6	11	6	10	−13	7	11
30	−56	6	11	5	9	−14	7	11
28	−57	6	11	6	6	−11	6	11
26	−56	4	12	5	5	−11	8	12
24	−57	4	12	8	6	−12	7	12
22	−57	6	12	9	6	− 9	7	12
20	−55	6	12	10	6	− 6	5	8

Note:

Height = height of observation
T = mean temperature
SD = standard deviation
N = total number of observations
u = mean zonal wind
v = mean meridional wind

therefore the temperature difference, ΔT, between two stations a distance Δs apart is:

$$\Delta T = \frac{\partial T}{\partial s} . \Delta s = \frac{fT}{gz} . \Delta s \left(\frac{\partial u}{\partial z} \cos\alpha - \frac{\partial v}{\partial z} \sin\alpha \right) ,$$

where f is the Coriolis parameter, T is the mean temperature of the layer, g is the acceleration due to gravity, z is the thickness of the layer and α is the azimuth, measured from true north, of the line between the stations. This equation has been used to calculate the theoretical difference of mean temperature; ΔT_{th}, in a given layer between two stations and this has been compared with the observed temperature difference, ΔT_{ob}.

Calculations have been performed for two pairs of stations, West Geirinish–Aberporth and West Geirinish–Kiruna and values of T, u and v, have been extracted from the cross-sections in Figure 6 at heights of 30, 38, 46 and 54 km for 22, 25, 28 January, and 4 and 10 February. For each pair of stations and for each 8-km layer the shear of both wind components has been taken as the mean of the shear at each station. In Figure 7 are plotted the values of ΔT_{th} and ΔT_{ob} for each pair of stations and for three different layers. Agreement of the two curves over the shorter base line (600 km) between West Geirinish and Aberporth is reasonably good on most days and for each layer. As would be expected the agreement over the longer separation is rather poor although observed trends are generally indicated by the theoretical curve, except at the higher level.

5 – DIURNAL CHANGES DURING THE SUMMER

During June and July 1967 four afternoon soundings were made at West Geirinish near 1500 GMT, in addition to night-time (near midnight) soundings, to investigate diurnal variation during the summer. The four afternoon soundings have been paired with the nearest midnight sounding.

Winds

The mean values of the afternoon and midnight winds and their differences, together with the individual differences for the four pairs, are given in Table XIII for each wind component. It can be seen that up to a height of about 40 km the diurnal variation is small, whereas above this height the range from afternoon to midnight increases and reaches a value of about 13 m/s for each component. The changes in the meridional component are similar to those measured in four pairs of soundings (near noon and midnight) made at Fort Churchill (58°44' N) in August 1965, June 1966 and August 1966 when the differences, day minus night, increased from small values around 40 km to 16 m/s at 55 km, with southerly winds by day and northerly winds by night. These Fort Churchill soundings showed however, no appreciable systematic day-to-night change in the zonal wind but both these samples of four pairs of soundings are too small to be of real statistical significance. A further series of summer soundings at White Sands Missile Range (32°23' N) have been analysed by Beyers *et alii*[4] and it was found that the amplitude of the diurnal variation of the zonal wind increased from about 4 m/s at 40 km to about 13 m/s at 60 km, the hour of maximum increasing smoothly from about 1300 local time (LT) at 60 km to 0100 LT at 45 km, and 1000 LT at 40 km. These day-to-night changes in the zonal wind are greater, but generally similar to those shown in Table XIII.

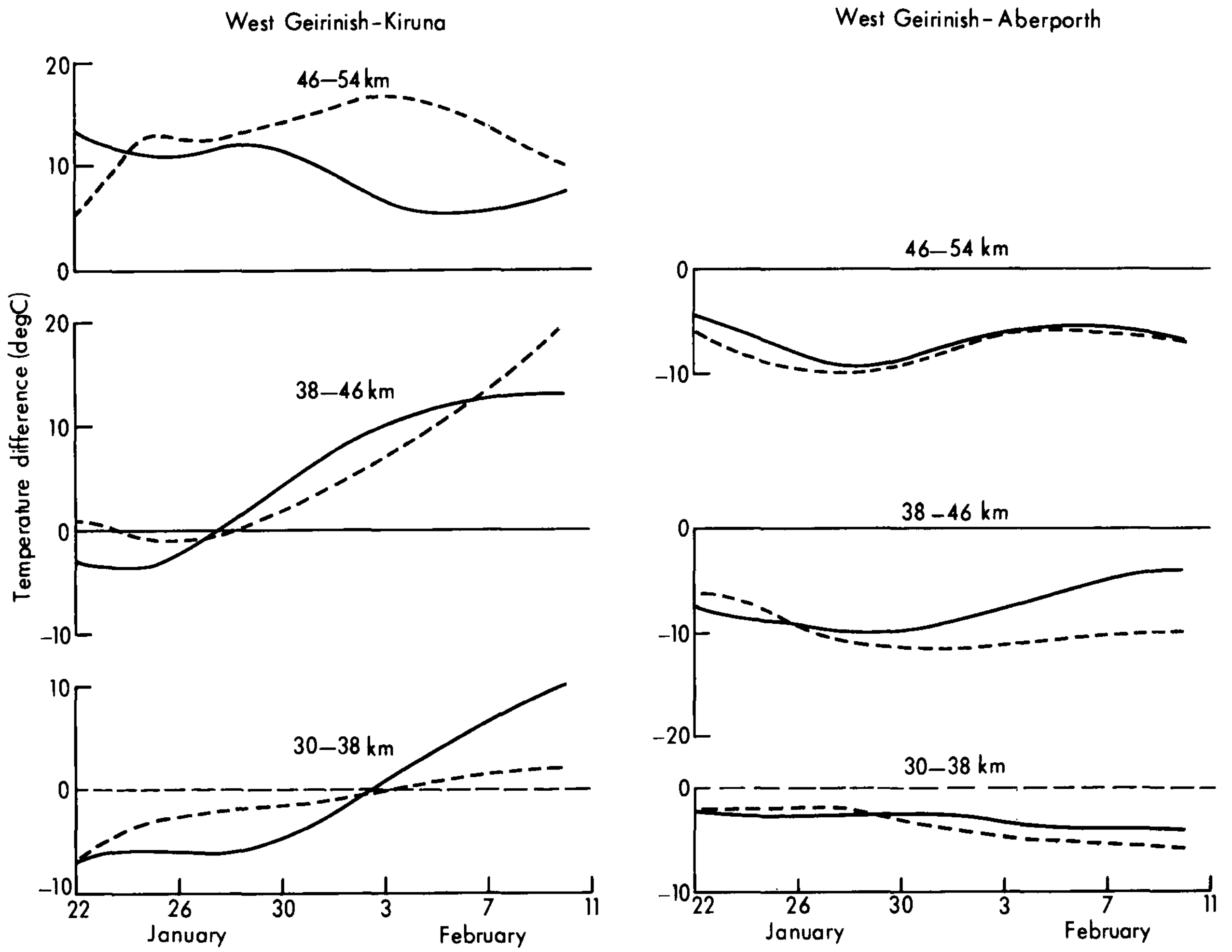

FIGURE 7. VARIATION OF OBSERVED AND CALCULATED MEAN TEMPERATURE DIFFERENCES BETWEEN WEST GEIRINISH AND KIRUNA, AND WEST GEIRINISH AND ABERPORTH, FOR THREE DIFFERENT LAYERS

——— ΔT_{ob} – – – – – ΔT_{th}

Temperature

The change of temperature from day to night can also be determined, but in this case there is the difficulty of eliminating the effect of solar radiation on the temperature element for the afternoon sounding. The temperature is recorded at intervals of one second, and an examination of the traces for the afternoon soundings shows that a significantly lower temperature is recorded at irregular intervals of about six seconds; these are interpreted as being measurements made when the temperature sensor was in the shadow of the parachute. This is confirmed by the fact that

TABLE XIII – VALUES OF THE AFTERNOON AND MIDNIGHT WINDS AND TEMPERATURES, AND THEIR DIFFERENCES, FOR JUNE AND JULY 1967

Zonal components

Height *km*	Mean afternoon wind	Mean midnight wind	Individual differences Pair A*	Pair B	Pair C	Pair D	Mean
			metres/second				
60	−24.5	−38.0	13	19	17	5	13.5
55	−24.0	−29.3	8	6	−1	8	5.3
50	−22.3	−27.7	1	3	14	4	5.5
45	−19.7	−22.7	3	4	2	3	3.0
40	−19.5	−17.3	−4	−6	1	0	−2.3
35	−13.5	−15.0	5	4	−4	1	1.5
30	−11.3	−13.7	2	−1	4	5	2.5
25	− 8.7	− 8.5	0	0	0	−1	0.3
20	− 4.5	− 2.5	−3	0	−4	−1	−2.0

Meridional components

Height *km*	Mean afternoon wind	Mean midnight wind	Individual differences Pair A	Pair B	Pair C	Pair D	Mean
			metres/second				
60	4.0	− 8.5	12	16	13	9	12.5
55	5.5	− 6.3	10	10	10	17	11.7
50	6.7	− 3.7	14	7	13	8	10.5
45	4.7	− 6.7	15	10	15	6	11.5
40	0.5	− 3.0	1	3	2	8	3.5
35	0.5	0.3	3	0	−2	0	0.3
30	0.5	0.7	0	1	0	−2	−0.3
25	1.7	0.0	1	2	1	3	1.7
20	− 0.3	− 0.3	−4	2	2	0	0.0

Temperatures

Height *km*	Mean afternoon temperature	Mean midnight temperature	Individual differences Pair A	Pair B	Pair C	Pair D	Mean
			degrees Celsius				
55	2.0	− 4.3	8	3	–	8	6.3
50	6.0	4.0	3	4	0	1	2.0
45	1.7	1.7	2	−4	−1	3	0.0
40	−10.7	−10.0	1	−1	−4	1	−0.7
35	−26.7	−26.3	−2	−1	1	0	−0.5
30	−38.7	−39.0	4	1	−1	−3	0.3
25	−46.3	−46.5	0	−1	2	0	0.3
20	−49.4	−51.0	4	1	0	1	1.5

*
Pair A 1431 1/6 and 2332 2/6
Pair B 1457 10/6 and 0020 10/6
Pair C 1503 14/6 and 0026 14/6
Pair D 1515 8/7 and 0010 8/7

the width of the trace from these lowest readings to the highest is, at all heights, approximately equal to the solar radiation correction as determined by the laboratory experiments. The air temperatures have therefore been determined by drawing an envelope of these minima and applying an albedo correction of 0.1 to 0.3 degC at 30 km, to 0.4 to 1.5 degC at 55 km, depending on the amount of cloud. The mean temperatures and the individual differences are shown in Table XIII. The mean profile suggests that between 32 and 45 km the air is colder by day than by night, but the differences are small and in view of the difficulty of eliminating entirely the effect of solar radiation and of estimating the albedo correction, these values may not be significant.

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APPENDIX – INDEX OF METEOROLOGICAL ROCKET SOUNDINGS AT WEST GEIRINISH

Date		Time	Height range over which data are available for temperature	wind
		GMT	km	
1964	15 January	1837	20–64	20–54
	17 January	2007	20–65	20–55
	23 January	2225	20–39	20–57
	5 February	1925	20–60	20–50
	12 February	1111	20–44	20–40
	13 February	2216	24–41	20–38
1965	11 January	2109	Nil	20–60
	15 January	2150	20–63	20–57
	18 January	2137	20–63	20–58
	20 January	1948	20–65	20–60
	26 January	1950	20–38	20–28
	28 January	1917	20–65	20–57
	30 January	1811	20–61	20–58
	11 February	2115	28–60	20–50
	15 February	2008	20–60	20–53
	18 February	1936	20–62	20–52
	20 February	1942	Nil	20–56
	23 February	1942	20–62	20–57
	1 March	2008	20–64	20–54
	18 March	2121	20–65	20–58
	19 March	2112	20–65	20–62
	23 March	2056	20–64	20–58
	7 April	0025	20–62	20–53
	13 April	2207	20–65	20–60
	15 April	1509	Nil	20–64
	22 April	2246	20–65	20–60
	23 September	2230	20–59	Nil
	26 September	2338	19–57	Nil
	2 November	2250	20–65	20–58
1966	8 February	2202	19–62	20–61
	10 February	2010	19–62	20–61
	12 February	2020	19–62	20–61
	14 February	2002	19–62	20–59
	18 February	2020	19–64	20–61
	21 February	2156	19–64	20–58
	23 February	1952	19–65	20–61
	26 February	2015	Nil	20–57
	28 February	2022	20–65	20–60
	2 March	2022	19–65	20–61
	4 March	1949	19–64	20–60
	7 March	2005	19–65	20–59
	9 March	2014	21–65	20–59
	18 April	1950	20–65	20–60
	21 April	2012	20–65	20–60
	27 September	2027	19–51	20–41
	3 October	1945	19–65	20–60
1966	6 October	1941	Nil	20–62
	10 October	1954	Nil	20–52
	14 October	1925	20–65	20–60
	17 October	1904	20–65	20–60
	19 October	1857	20–65	20–61
	22 October	1932	20–55	20–45
	25 October	2046	20–65	20–60
	27 October	1900	23–65	20–61
	29 October	1908	20–64	20–59
	1 November	2032	20–56	20–52
	3 November	2014	20–63	20–59
	5 November	2009	19–65	20–56
	7 November	1908	Nil	20–59
	9 November	1907	20–65	20–59
	11 November	1908	20–63	20–59
	14 November	1958	20–65	20–63
	17 November	1935	20–59	20–55
	19 November	1903	Nil	20–58
	21 November	1745	20–65	20–64
	23 November	1729	20–58	20–57
	25 November	1736	21–65	20–55
	3 December	2002	Nil	20–60
	5 December	1730	20–63	20–59
1967	17 February	1909	19–64	19–63
	21 February	2208	19–64	19–57
	23 February	1924	19–65	19–64
	25 February	1947	19–59	19–65
	8 March	2014	Nil	19–61
	16 March	1218	20–55	19–45
	18 March	1400	20–63	19–54
	23 March	2000	19–63	19–60
	25 March	2000	19–65	19–60
	29 March	2031	19–64	19–59
	31 March	2032	19–63	19–63
	1 April	2148	19–63	19–56
	6 April	2055	19–61	19–57
	7 April	2150	19–61	19–58
	8 April	2053	19–65	19–58
	10 April	2241	20–65	19–59
	11 April	2141	19–65	19–57
	12 April	2100	19–65	19–58
	14 April	2103	19–63	20–57
	15 April	2102	19–59	19–57
	21 April	2141	19–65	19–61
	1 June	1431	19–65	19–63
	2 June	2332	19–65	19–63
	4 June	2346	19–65	19–64

APPENDIX – INDEX OF METEOROLOGICAL ROCKET SOUNDINGS AT WEST GEIRINISH

Year	Date	Time GMT	Height range over which data are available for temperature km	wind km
1967	6 June	2358	19–55	19–52
	10 June	0020	19–65	19–61
	10 June	1457	19–65	19–63
	12 June	0025	19–65	19–62
	14 June	0026	19–65	19–61
	14 June	1503	19–54	19–63
	16 June	0029	19–65	19–61
	30 June	0037	19–59	19–57
	1 July	0021	19–61	19–63
	3 July	0022	19–58	19–55
	5 July	0023	19–65	19–61
	6 July	0024	19–65	19–65
	7 July	0023	19–65	19–65
	8 July	0010	19–65	19–65
	8 July	1515	19–62	19–59
	12 July	0011	19–63	19–64
	12 July	2355	Nil	19–64
	7 December	1728	20–64	20–59
	13 December	1858	20–63	20–60
	14 December	1740	Nil	20–46
	18 December	1719	19–59	20–58
	19 December	1718	20–65	20–58
	21 December	1731	20–65	20–61
	23 December	1724	20–65	20–62
	27 December	1743	20–53	20–52
	30 December	1753	20–62	20–57
1968	1 January	1724	20–63	20–60
	3 January	1742	Nil	20–55
	4 January	1728	20–65	20–63
	6 January	1727	20–65	20–63
	10 January	1732	20–62	20–59
	12 January	1815	20–34	20–24
	15 January	1802	20–46	20–36
	17 January	1800	20–60	20–50
	22 January	1824	20–65	20–61
	24 January	1805	Nil	20–50
	25 January	1809	20–63	20–59
	30 January	1811	20–65	20–63
	1 February	1823	20–65	20–57
	2 February	1828	20–63	20–59
	5 February	1830	20–63	20–55
	7 February	1836	20–62	20–58
	9 February	1833	20–59	20–56
	10 February	1829	20–65	20–61
	12 February	1831	20–60	20–54
	14 February	1853	20–60	20–60
1968	16 February	1858	20–54	20–54
	19 February	1904	20–65	20–60
	21 February	1909	20–65	20–59
	23 February	1909	20–65	20–58
	24 February	1910	19–63	20–58
	26 February	1927	19–62	20–59
	28 February	1820	19–62	20–57
	7 December	1820	19–62	20–57
	9 December	1728	19–65	20–61
	14 December	1818	19–61	20–60
	29 December	1725	20–60	20–58
	31 December	1458	20–57	20–57
1969	5 January	1642	Nil	20–54
	7 January	1849	21–58	22–53
	8 January	1833	20–32	21–27
	10 January	1755	20–49	20–53
	13 January	1801	20–61	21–61
	15 January	1848	20–61	21–56
	18 January	1748	19–64	19–59
	27 January	1858	21–47	21–38
	16 July	1509	20–64	20–60
	19 July	1340	20–57	20–54
	26 November	1910	20–50	20–49
	29 November	1743	20–60	20–56
	2 December	1830	21–58	22–60
	4 December	1817	20–58	20–53
	8 December	1754	20–60	21–51
	11 December	1800	20–61	21–60
	15 December	1755	20–64	21–56
	17 December	1753	20–43	21–34
	19 December	1735	20–62	21–60
	23 December	1720	20–61	21–61
	27 December	1736	20–55	21–52
	29 December	1847	Nil	21–61
	30 December	1745	19–63	20–59
1970	1 January	1821	20–42	20–34
	3 January	1755	20–63	20–64
	6 January	1756	19–64	20–58
	9 January	1747	20–61	21–62
	12 January	1752	20–62	21–59
	14 January	1844	19–46	19–36
	16 January	1755	19–58	20–58
	23 January	1932	19–39	19–55
	26 January	1800	19–44	20–35
	27 January	1815	19–41	20–31

APPENDIX – INDEX OF METEOROLOGICAL ROCKET SOUNDINGS AT WEST GEIRINISH

	Date	Time	Height range over which data are available for temperature	wind
		GMT	km	
1970	29 January	1814	19–63	20–62
	28 November	1931	19–60	20–61
	30 November	1734	20–61	21–59
	4 December	1801	20–59	20–59
	12 December	1855	20–60	21–61
	29 December	1750	19–60	20–60
	31 December	1742	20–60	21–62
1971	2 January	1821	19–60	20–60
	11 January	1806	20–65	21–65
	12 January	1800	19–63	20–60
	14 January	1844	19–62	20–61
	16 January	1749	20–61	21–63
	18 January	1816	19–36	20–26
	20 January	1757	19–64	21–60
	22 January	1755	19–60	20–59
	23 January	1933	20–56	20–55
	25 January	1820	20–61	21–60
	28 January	1907	19–47	20–46
	1 February	1848	19–57	20–62
	3 February	1825	19–60	20–59
	5 February	1859	20–58	21–59
	10 February	1839	20–60	20–61
	15 February	1912	20–53	20–53
	17 February	1904	20–57	20–59
	19 February	1930	19–60	20–59
	24 February	1732	Chaff trial	
	24 February	2102	19–57	20–58
	2 December	1850	19–65	20–61
	6 December	1820	20–60	20–55
	9 December	1810	19–55	20–59
	13 December	1754	20–64	20–58
	18 December	1819	20–58	21–55
	28 December	2130	20–61	20–57
	31 December	1758	Chaff trial	
	31 December	1905	19–65	20–64
1972	3 January	1805	19–64	20–57
	15 January	1804	19–53	20–47
	17 January	1801	19–54	20–48
	20 January	1809	20–61	20–53
	24 January	2006	20–56	21–48

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