PREFACE.

In the present paper the monthly mean values of upper air temperatures, pressures and humidities at Tromsø are worked out from the balloon soundings made by the German occupation air forces in Northern Norway. The soundings were made practically every day from May 5th 1941 until October 31st 1944 at 0230 hrs GMT. In the last 14 months of this period soundings were also made at 1400 hrs GMT. Altogether 1636 radiosondeascents were made during the period. For the computation of the monthly means and normals, only morning soundings (0230 hrs) have been taken into account. The afternoon soundings (1400 hrs) have been compared with the morning soundings, chiefly to get some idea of the value of the radiation error.

I wish to express my sincere thanks to the former Director of *Vervarslinga for Nord-Norge, Tromsø, Mr. P. Thrane* (now the head of a branch of Meteorologisk Institutt, Oslo) for his interest in this work. Thanks are also expressed to Messrs. *Egil Lindberg, Hans M. Hansen* and *Henry Johnsen* at *Vervarslinga for Nord-Norge*, for the valuable help in working out the Tables, and to Messrs. *Magnus Rasmussen* and *Knut Knaus* at *Vervarslinga på Vestlandet*, for the drawing of the diagrams.

Vervarslinga for Nord-Norge, Tromsø/

Vervarslinga på Vestlandet, Bergen.

April 1948.

Harald Johansen

MEAN UPPER AIR DATA OBTAINED FROM SOUNDINGS AT TROMSØ DURING THE YEARS 1941—44

BY

HARALD JOHANSEN

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1. THE TEMPERATURE.

The monthly mean values of temperature were determined by the method of differences (1), that is, by totalling the sums of the differences of temperature between corresponding pairs of successive standard levels and dividing this total by the corresponding number of observations. The quotient was taken to be the mean difference of temperature between the two levels. Table I (see p. 16) gives the total number of observations for each month (n), the simple arithmetical mean values of temperature (T) and the mean values determined by the method of differences (T_d). Table I shows that only a few of the soundings failed to reach into the stratosphere. Thus, there is no difference between T and T_d in the troposphere. In the stratosphere, on the other hand, the difference between T and T_d increases with height. From fig. I it will be seen that the differences are most pronounced in winter, whereas the differences are very slight in summer. This, of course, is due to the rapid decrease in number of observations with height in winter. The monthly mean temperatures, corrected by the method of differences, show a regular annual variation. A smoothing of the annual temperature curve by means of harmonic analysis, therefore, has been regarded as unnecessary. Instead of harmonic analysis, a smoothing, by means of the simple form $(A_n + 2A_{n+1} + A_{n+2}) : 4$, has been found sufficient. The monthly mean values found in this way are given in Table II and in figs. 2—3. The following annual variation of the temperature has been found:

a. At the surface the minimum temperature occurs in January—February and shifts towards the month of March at the lower levels of the

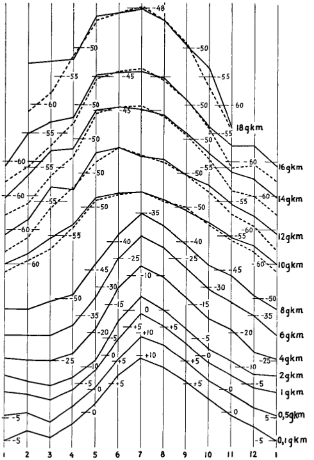

Fig. 1. Showing the annual variation of the temperature Full lines give the arithmetic mean values. Broken lines give the mean values corrected by means of the method of differences.

troposphere (2 gkms). At the higher levels of the troposphere the minimum temperature shifts back to February. When passing into the stratosphere, a rapid shifting from February to December—January is found.

b. At the surface the maximum temperature occurs in the end of July and lags a little behind throughout the troposphere. When, however, the next step upwards into the stratosphere is taken, we find a complete change, because the maximum temperature has moved back to the end of June. Thus, in the stratosphere the minimum as well as the maximum temperatures occur at the time of the solstices.

In the stratosphere the variation of the temperature with height shows a slight decrease in winter (from — 60.1° C at 10 gkms to — 62.1° C at 16 gkms) and a gradual increase in summer (from — 48.1° C at 11 gkms to — 41.6° C at 23 gkms). The annual mean temperatures are nearly constant at all stratospheric levels up to 16 gkms (varying from — 53.0 to — 53.6° C).

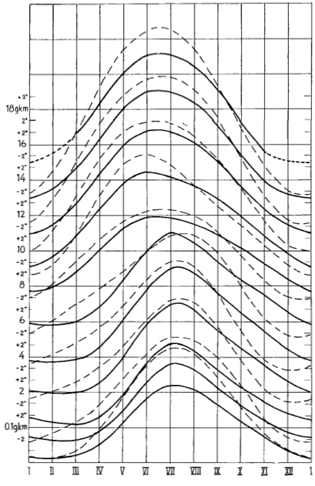

Fig. 2. Showing the annual variation of upper air temperatures over Tromsø (full lines) and over Abisko (broken lines).

As the soundings at Abisko (2) have been of great importance to our knowledge of the polar atmosphere, a comparison between the soundings at Tromsø (69° 39' N, 18° 57' E) and Abisko (68° 12' N, 18° 50' E) will be of interest. Fig. 2 shows the annual temperature variations at Abisko (broken lines) and at Tromsø (full lines). The temperature maxima occur at the same time in both places, but the minima show some differences in the troposphere owing to the great difference in climatic conditions at the two places. At all levels of the stratosphere the extreme temperatures occur simultaneously coinciding with the solstices. In the annual ranges of temperature at each level, however, great discrepancies appear, as will be seen from Table III.

The differences at the lower levels of the troposphere are due to the difference in climatic conditions at the stations. The differences diminish with height and practically disappear at 4 gkms. At 10 gkms the characteristic minimum in the annual range is well pronounced both at Abisko and at Tromsø. From this level and upwards into the stratosphere we find increasing differences in the annual temperature ranges. Thus, at 18 gkms the amplitude at Abisko is 9.0° C greater than at Tromsø. This disagreement at the higher levels of the stratosphere seems to be due partly to the exceptionally high stratospheric summer temperatures at Abisko. These temperatures have been a subject of much doubt, and *Väisälä* (3) has suggested that they may be due to radiation error in the Abisko-soundings. *Väisälä* has examined the Abisko-soundings at different altitudes of the sun and has shown that there seems to be an increase of the stratospheric temperatures with the increasing altitude of the sun. Thus, when the sun's altitude is 40° the temperature seems to exceed the night temperature by 5 degrees at 12—17 gkms.

The mean summer temperatures at Abisko, Tromsø and Spitsbergen (4) at 12—18 gkms, have been computed and the following values found: Spitsbergen — 43.4°, Tromsø — 44.7°, Abisko — 39.7° C. The temperature difference between

TABLE III

Annual range of temperatures at Abisko and at Tromsø.

(The difference between the warmest and the coldest month.)

Height gkm	0.1	1	2	4	6	8	10	12	14	16	18 gkms
Abisko	21 3	18.7	17.9	17.0	18.3	17.1	15.0	20.4	22.0	24.7	27.8°C
Tromsø..........	12.4	12.9	13.7	15.2	15.8	15.6	12 4	16.0	17.4	17.8	18.8°C

Tromsø and Spitsbergen is only 1.3° C and indicates that the increase of the temperature of the stratosphere towards the pole in summer is not so great as it has been supposed. The difference between Abisko and Tromsø is 5° C. This is in accordance with the value found by *Väisälä*.

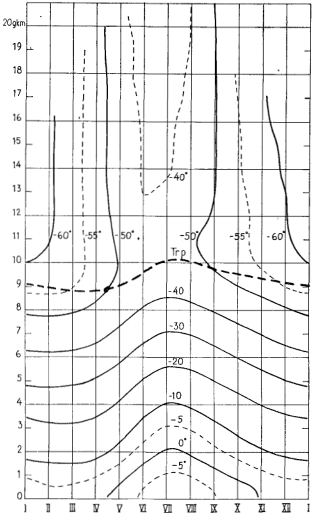

Fig. 3 Isopleths of upper air temperature over Tromsø together with the variation of the tropopause (heavy broken lines).

It is difficult to decide whether the soundings at Tromsø are affected by radiation error at higher stratospheric levels. However, at the levels 12—17 gkms the error seems to be insignificant. Thus, at 12—17 gkms the temperature difference between the soundings at 1400 hrs and 0230 hrs GMT is only 0.9° C for the period May—July.

In order to find out to what extent the upper air temperatures are representative and in accordance with the climatological mean values, the monthly mean values at the surface (obtained from the soundings) have been compared with the climatological temperature normals of Tromsø (5) as shown in fig. 4. In summer the temperature curve for 1941—44 gives a temperature about 2° C lower than the normal temperature. Now, the curve for 1941—44 refers to soundings at 0230 hrs and the normal curve is based on the mean temperature of the day. An examination of the mean difference between the mean temperature of the day and the temperature at 02—03 hrs gives about 2° C in summer and about 0° C in winter. Taking this into consideration, a fairly good agreement exists between the two curves.

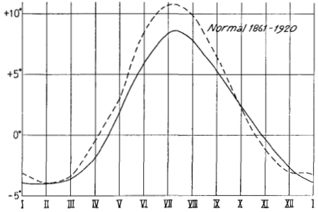

Fig. 4. The monthly mean values of temperature (full line) compared to the climatological temperature normals (broken line).

2. THE TROPOPAUSE.

In the cases when the vertical temperature gradient decreases gradually, the height of the tropopause has been taken at the point where the temperature gradient diminishes to 0.2° C/100 m, provided that it does not exceed this value in any subsequent layer. In cases where multiple tropopauses have been observed, the height of the tropopause has been given as the average height of the multiple tropopauses. Table IV gives the mean monthly heights, temperatures and potential temperatures of the tropopause. The annual variation of these elements is shown in fig. 5, together with the variation of the temperature at 10 gkms.

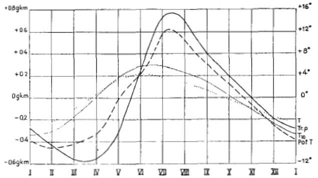

Fig 5. Showing the annual variation of the height of the tropopause (Tr.p.), temperature of the tropopause (*T*), potential temperature of the tropopause (Pot. *T*) and temperature at the level of 10 gkms.

The annual variation of the tropopause is similar to that of the temperatures in the troposphere. Thus, the highest and the lowest tropopause occurs in July—August and March—April respectively. The mean annual range of the height of the tropopause is 1.3 gkms. In this connection it may be mentioned that the absolute highest and lowest tropopause found over Tromsø is 14270 gm (Sept. 1943) and 6430 gm (May 1941) respectively. The annual mean temperature of the tropopause is — 54.8° C and thus lower than the annual mean temperature at any level in the stratosphere. Fig. 5 shows that the height of the tropopause has an annual variation almost parallel to the annual variation of the potential temperature in the tropopause. This, of course, is due to the circumstance that a certain tropopause is characterized by its potential temperature, which varies only a little from day to day (6.7). The temperature of the tropopause shows an annual variation similar to that of the temperature at the level of 10 gkms, but with a smaller annual range.

3. THE VERTICAL TEMPERATURE GRADIENT.

The monthly mean vertical temperature gradients are given in Table V. The seasonal variation can be summarized as follows: The layer 0.1—0.5 gkms has great stability at all seasons, with a temperature inversion in January, but otherwise no distinct annual variation. A distinct annual variation first occurs at 2—3 gkms with the maximum of the vertical temperature gradient in winter and the minimum in summer. The difference in the lapse rate between winter and summer vanishes with height, thus at the level of 6—7 gkms no regular annual variation can be found. The lapse rate between 7 and 9 gkms shows an annual variation converse to that at lower levels. In the stratosphere above 11 gkms the lapse rate is slightly negative in summer and slightly positive in winter. The maximum vertical temperature gradients occur in a layer just below the tropopause, therefore, the layer of the maximum lapse rate shows the same annual variation as the tropopause.

The variation of the vertical temperature gradients at 1—3 gkms are very interesting. Fig. 6 illustrates the deviations of lapse rate at different levels from the mean lapse rate between the surface and 4 gkms. A minimum in the monthly mean lapse rate is particularly pronounced in spring and autumn, but cannot be seen to exist in the annual mean. *A. Wagner* (8) has drawn attention to these

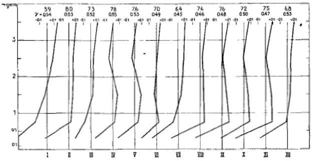

Fig. 6. Illustrating the deviations of lapse rate at the different levels from the mean lapse rate between the surface and 4 gkms Upper numbers at the top of the diagram give the mean monthly cloud amount (scale 0—10).

peculiarities in vertical temperature gradients at some european stations and he supposed that these variations were connected with condensation processes in the atmosphere. In fig. 6 mean monthly cloud amounts have been computed and are given at the top of the diagram (scale 0—10). With the exception of February, deviations from the mean lapse rates are associated with considerable anomalies in cloud amount. Thus, the minimum in the vertical temperature gradient in spring and autumn are associated with great cloud amount, and vice versa.

4. THE PRESSURE.

Table VI gives the monthly normal pressures at standard heights. The annual variation of pressure is illustrated in fig. 7. Apart from some irregularities at the surface and up to 2 gkms, the smoothed pressure curves coincide very well with the curves based on monthly arithmetic mean

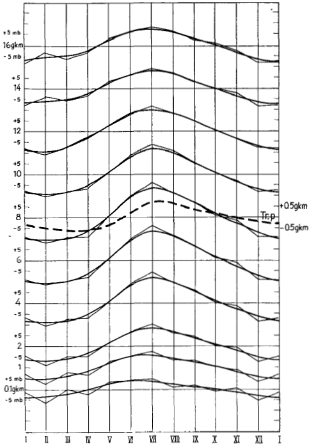

Fig. 7. The annual variation of pressure. Light full lines are the monthly arithmetic mean values; and the heavy full lines are the smoothed values.

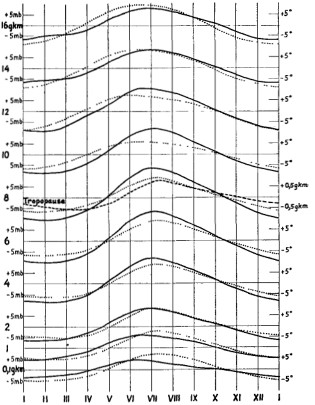

Fig. 8. Showing the annual variation of pressure (heavy full lines) in relation to the annual variation of temperature (dotted lines).

values. The surface pressure is highest in the month of June and lowest in the month of January. At middle and higher tropospheric levels the seasonal variation of pressure is characterized by maximum in July and minimum in February. The minimum shifts backwards to January in the stratosphere and the maximum seems to shift backwards to the month of June at higher stratospheric levels (above 16 gkms). The annual variation of pressure increases from 8.0 mb at the surface to 24.1 mb at 7—8 gkms after which it decreases to 12.1 mb at 16 gkms.

Fig. 8 shows the annual variation of pressure in relation to the annual variation of temperature. In the coupling of these elements a close association can be stated at middle and higher tropospheric levels and at higher stratospheric levels. The curves of temperature, pressure and tropopause are seen to be assymetrical in the troposphere, as the rise from winter to summer is of shorter duration than the fall from summer to winter.

In a paper by *J. Namias* (9), the normal annual variation in heigth and temperature of the 700 mb

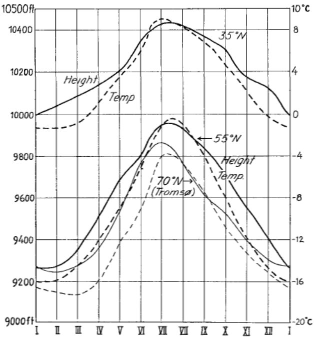

Fig. 9 Normal annual variations in height and temperature of the 700-mb surface at 35° N and 55° N (after *Namias*) together with corresponding values of the 700 mb surface at Tromsø

surface at 35° N and 55° N is given. The values are averages from longitude 0° westwards to 180.° These values, together with corresponding values of the 700 mb surface at Tromsø are reproduced in fig. 9. The parallelism of height and temperature of the 700 mb surface is striking. Furthermore, fig. 9 shows that there must be a pronounced annual variation of the west-to-east geostrophic component of wind speed between latitudes 35° N and 55° N (varying from 6 m/s in summer to 11 m/s in winter). Between 55° N and 70° N the meridional pressure and temperature gradients are small and without any pronounced annual variation. The values at Tromsø are, of course, not directly comparable with the values which are averaged from longitude 0° westwards to 180°, therefore, corresponding values at the Swedish station Gøteborg—Torslanda (59° 42' N, 11° 47' E) have been computed for the years 1940—43 (10). The values found in that way are given in Table VII, which also gives the meridional pressure gradient and the corresponding values of the west-to-east component of the geostrophic wind speed between Gøteborg and Tromsø.

Fig. 10 shows the vertical distribution of the zonal wind velocities. In the troposphere these are seen to be only slightly stronger in winter than in summer. The vertical distribution with height shows increasing zonal wind velocities from the surface up to 7—8 gkms, diminishing to zero at the level of about 12—13 gkms. At the level of 14 gkms the zonal circulation shows an east-to-west component of the geostrophic wind in summer as well as in winter. In addition, the zonal wind velocities between latitude 60° and 70° N have been computed by means of data from »Klimatologie der freien Atmosphäre« (8) and are reproduced in fig. 10 as dotted lines. A comparison between the values of the zonal wind speed found in these different ways, shows, especially in winter, great disagreements. Thus in winter, the zonal wind velocities, calculated by means of soundings at Tromsø and Gøteborg, show much smaller values than the values which, hitherto, have been regarded as reasonable.

5. THE HUMIDITY.

A. The Relative Humidity.

The relative humidity has been measured by means of the hair hygrometer. The monthly mean values of the relative and the specific humidities at the standard levels up to 5 gkms are given in Table VIII together with the number of observations. The variation of the relative humidity with height is shown in fig. 11 A and B together with the following European stations: Utti (11), Kjeller (12), Soesterberg — de Kooij (8), Reykjavik (13), Abisko (Riksgränsen), Pajala and Gøteborg — Torslanda (10). The annual mean values of the relative humidity at Tromsø increase slightly from the surface

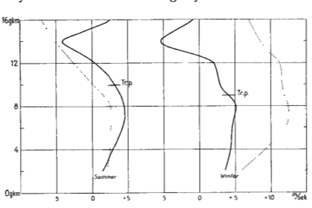

Fig. 10. Showing the vertical distribution of the zonal wind velocities. Dotted lines are the values computed by means of data from »Klimatologie der freien Atmosphäre« (8).

upwards to about 1 gkm, and then decrease above this level. Furthermore, the decrease of the relative humidity is seen to be less in winter than in summer.

Fig. 11 A shows the yearly mean values of relative humidities at Tromsø together with the values found at Utti, Kjeller, Soesterberg — de Kooij and Reykjavik. The values at Tromsø are seen to be much higher than the values at the other stations. Now, the latter values are based upon airplane ascents and, therefore, not directly comparable with the sounding results at Tromsø. *A. Nyberg* (14) has made a comparison between the relative humidities measured by means of soundings- and airplane-ascents respectively, and has stated that the two methods give practically the same results. Therefore, the disagreement must be due to other circumstances. Thus, unfavourable weather situations and extensive vertical cloud systems may be a hindrance to the airplane ascents, and the means of the relative humidity based upon those ascents are likely to be lower than the means based upon soundings. A comparison between the values at Tromsø and at the sounding stations Abisko (Riksgränsen), Pajala and Gøteborg are shown in fig. 11 B. First, the differences are seen to be smaller than the differences between Tromsø and the airplane stations. Furthermore, the values at Abisko (situated only one degree of lat. to the south of Tromsø) seem to confirm the high relative humidities measured at Tromsø.

The annual variation of the relative humidity is shown in fig. 12. At the surface the highest rel. hum. occurs in the month of August, but the annual

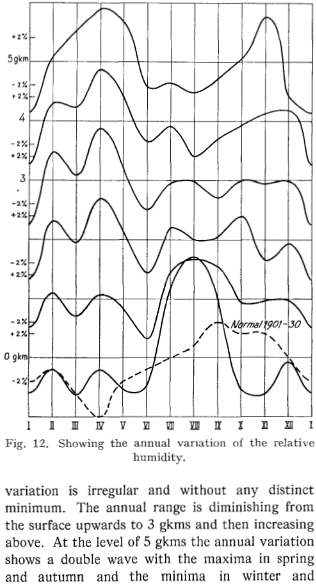

Fig. 12. Showing the annual variation of the relative humidity.

variation is irregular and without any distinct minimum. The annual range is diminishing from the surface upwards to 3 gkms and then increasing above. At the level of 5 gkms the annual variation shows a double wave with the maxima in spring and autumn and the minima in winter and summer.

A comparison between the standard climatological values of the relative humidities at Tromsø (15) and the values obtained by means of this material, is of no great interest, because the normal values refer to the daily mean values, whereas the sounding values give the mean relative humidities at 0430 hrs. Using the vapour pressures instead of the rel. hum., a fairly good agreement is found, as shown in fig. 13.

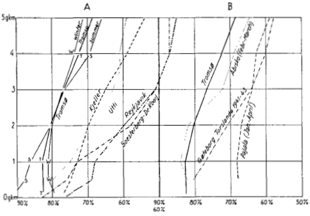

Fig. 11. The variation of the relative humidity with height: A, compared to airplane ascents, B, compared to radiosonde ascents.

B. The Specific Humidity.

Like the rel. hum., the spec. hum. increases from the surface upwards to 0.5—1 gkm and decreases above. Fig. 14 shows the annual variation of the spec. hum. The annual variation of the spec.

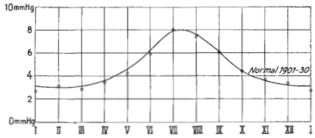

Fig. 13. The monthly mean values of the vapour pressure compared to the standard climatological values (full line).

hum. is similar to that of the temperature, with the extremes of the spec. hum. and the extremes of the temperature occurring at the same time. The most noteable feature about the spec. hum. is that the amount at 4—5 gkms is practically the same at Tromsø as at Kjeller in Southern Norway (12). Compared to Kjeller, the isopleth diagrams show a most remarkable resemblance, thus, in either case, the vertical gradient of the spec. hum. is small in winter and large in summer. The distribution of the spec. hum. shown in fig. 14, is usually explained by the stable stratification in winter and the prevailing convective type in summer. Thus, the lapse rate at Kjeller shows a stable type (0.56°/100 m) in winter and a convective type (0.62—0.65°/100 m) in summer. The converse has been found at Tromsø (0.62°/100 m in winter and 0.54°/100 m in summer). Even so, there is no difference in the vertical distribution of the spec.

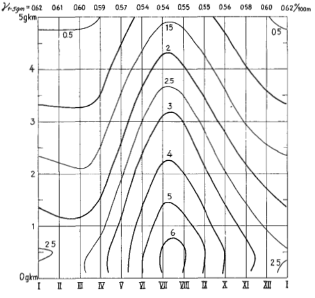

Fig. 14. Isopleths of specific humidity. Numbers at the top of the diagram give the mean monthly lapse rate values between 1 and 5 gkms.

hum. at Tromsø and at Kjeller. This seems to indicate that the distribution of the spec. hum. with height, is mainly of an advective nature.

6. THE POTENTIAL EQUIVALENT TEMPERATURE AND THE POTENTIAL TEMPERATURE.

Table IX gives the monthly normal potential temperatures and the potential equivalent temperatures at standard heights over Tromsø. The pot. equivalent temperatures are given at the standard levels up to 5 gkms and the pot. temperatures are given at the levels above. The mean monthly pot. equivalent temperatures rise progressively from the surface up to 5 gkms showing thereby that convective instability is completely absent. However, the increase of the potential equivalent temperature with height has an annual variation with its maximum in the month of November and its minimum in July. Fig. 15 shows the corresponding

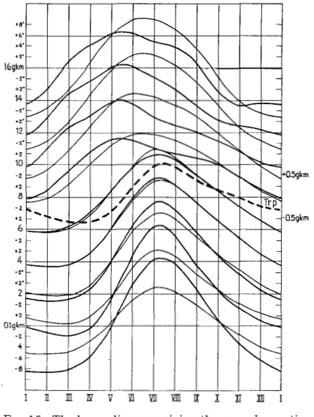

Fig. 15. The heavy lines are giving the annual variation of the potential equivalent temperature (0—5 gkms) and the potential temperatures (above 5 gkms) The light lines indicate the annual variation of upper air temperatures.

curves of the annual variation. The annual variation of the potential equivalent temperature is seen to be similar to that of the temperature. The difference between the annual range of the pot. equivalent temperature and the temperature is 8.7° C at the surface and diminishes to 1.5° C at 5 kgms. The curves above 5 gkms refer to the potential temperatures and show an annual variation which exactly corresponds to the annual variation of the temperature in the upper troposphere. When passing upwards into the stratosphere, the monthly mean maximum of the potential temperature moves back to the month of May and the minimum seems to shift backwards towards the month of January.

7. COMPARISON BETWEEN THE MORNING AND THE AFTERNOON SOUNDINGS.

As mentioned above, sounding ascents were made twice a day from September 1st 1943 until October 31st 1944. The soundings were made at about 03.30 hrs and 15.00 hrs M.E.T. The morning and afternoon values of the temperature and the humidity at the standard levels have been compared every day, and the seasonal mean differences between the afternoon and morning values are given in the Tables X and XI, which show the following results.

A. The Relative Humidity.

In summer, spring and autumn the morning values of the rel. hum. are higher than the afternoon values. In winter the morning values are slightly lower than the afternoon values. The difference between the two series of values diminishes with height and is insignificant above 2 gkms.

B. The Specific Humidity.

The difference between the afternoon and morning values is positive at all seasons and varies from zero in winter to 0.52 gr/kgr in summer. The difference vanishes at about 1 gkm in summer and at about 0.5 gkms during the other seasons.

C. THE TEMPERATURES.

The seasonal mean temperature differences between the afternoon and the morning soundings (ΔT) are given in Table XII, which also gives the seasonal mean equivalent temperature differences (ΔQ_E) up to 5 gkms and the potential temperature differences (ΔQ) above 5 gkms. Besides, the variation with height of the seasonal mean values of ΔT, ΔQ_E and ΔQ are shown in fig. 16. The variation of ΔT is interesting as it may give some idea of the radiation error.

In the stratosphere the radiation error always appears at daytime and disappears at night, therefore, the determination of the radiation error is carried out by comparing soundings made at daytime with those made at night. *Väisälä* (3) has shown that the radiation error depends on the height angle of the sun. In winter the height angle of the sun is negative in Tromsø both at the morning and the afternoon soundings, and it has its maximum in summer where the height angle in June is about 38° at the afternoon soundings and about 9° in the morning. Considering each season separately, the following results are found.

(*a*) *Summer* (June, July, August). From fig. 16 and Table XI it is seen that ΔT decreases from 3.5° C at the surface to 1.0° C at 1 gkm, and varies about 1° C above. As this result is based upon 92 observations at the surface decreasing to 36 observations at 16 gkms, it must be regarded as reliable up to 16 gkms. Above 17 gkms ΔT is based upon only one observation, and must, therefore, be regarded as less reliable. Furthermore, the variation of the potential temperature difference at these levels seems to indicate that the radiation is overcompensated by other processes in the stratosphere.

(*b*) *Autumn* (September, October, November). The mean temperature difference between the afternoon and the morning soundings is 1.6° C at the surface decreasing to 0.3° C at 1 gkm. From 1 km up to 12 gkms ΔT varies between — 0.5° C and + 0.7° C, and increases above 12 gkms to 3.0° C at 19 gkm. This result is based upon 144 numbers of observations at the surface decreasing to 17 observations at 16 gkms. Although there are few observations above 17 gkms, the increase of ΔT at these levels seems to be real.

(*c*) *Winter* (December, January, February). At this time of the year the height angle of the sun is negative in the month of December and slightly positive at midday in January—February. Therefore, in this case it should be expected that the values of T should be relatively small. Table XI

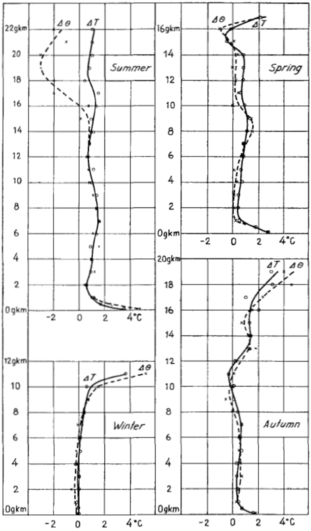

Fig. 16. Representing the seasonal mean temperature differences (full lines) and potential temperature differences (broken lines) between the afternoon and the morning soundings.

and fig. 16 confirms this, as the values of ΔT varies about zero from the surface up to 10 gkms. The number of observations varies from 85 at the surface to 25 at 10 gkms. The sudden rise in ΔT from 0.6° C at 10 gkms to + 3.7° C at 11 gkm is based on 5 observations only. A closer examination of each of these cases indicates that the increase in ΔT above 10 gkms is of an advective nature. Thus, the soundings on December 13th 1943 and on January 19th 1944 show a considerable decrease of the temperature in the troposphere and a corresponding increase of the temperature in the stratosphere, together with a depression of the tropopause. Disregarding these observations, no increase in ΔT can be found in winter.

(*d*) *Spring*. (March, April, May). ΔT decreases from 2.6° C at the surface to 0.5° C at 1 gkm, and varies between 0.4° C and 1.3° C up to 14 gkms. The negative values of ΔT at 15 and 16 gkms are probably not caused by the radiation error of the instrument. A close examination of the seven pairs of soundings at the level of 15—16 gkms shows that in several cases there has been a cooling of the stratosphere during the day. This cooling was especially pronounced on April 22nd 1944 and was accompanied by variation of the height of the tropopause. If these soundings are disregarded, the value of ΔT increases slowly from 0.8° C at the level of 14 gkms to about 3° C at the level of 17 gkms.

The variation of ΔT with height can be summed up as follows:

At the surface ΔT varies from 0° 3 in winter to 3.5° C in summer. This diurnal variation of the temperature disappears at the level of about 1 gkms. The variation of ΔT with height shows that the temperature difference between the afternoon and the morning soundings is mostly below 1° C from the level of 1 gkm up to the level of 13—14 gkms. From these levels and upwards ΔT very likely increases with height and reaches the value of about 3° C at the level of 19 gkms.

In a paper by *M. Tommila* and *N. Raunio* (4), dealing with radiosonde ascents at Spitsbergen, the temperature difference between daytime soundings and night soundings has been determined in summer. The values of ΔT at Spitsbergen and at Tromsø are given in Table XII. The order of magnitude of ΔT as well as the variation of ΔT with height agrees very well in both places. Thus, the slight minimum value of ΔT at 3 gkms as well as the pronounced maximum value at 6—12 gkms appears in both places.

In the paper by *Tommila* and *Raunio* just mentioned, it has been shown that the rate of ascent has a minimum at the levels of 6—12 gkms and increases above. As the value of the radiation error depends on the ventilation, it is likely that the maximum of ΔT occurring at the levels of 6—12 gkms, is caused by the decrease in the rate of ascent at the same levels.

TABLES

TABLE I

Mean monthly and annual temperatures

(n) Number of observations
(T) Arithmetic mean values of temperature (° c)
(T_d) Mean values determined by the method of differences (° c)

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
0.1	T	— 5,0	— 3,3	— 4,5	— 2,1	1,5	6,5	9,6	8,0	5,4	2,3	— 0,5	— 2,5	1,2	14,6
	T_d														
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
0.5	T	— 4,6	— 4,1	— 5,7	— 3,0	0,3	5,4	9,3	7,8	5,0	1,6	— 0,7	— 3,1	0,7	15.0
	T_d														
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
1	T	— 6,5	— 6,9	— 7,9	— 6,1	— 2,6	2,8	7,4	5,2	2,1	— 1,3	— 3,5	— 5,7	— 1,9	15.3
	T_d														
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
2	T	—11,6	—12,7	—13,4	—12,0	— 8,8	— 1,8	2,5	0,1	— 3,3	— 6,9	— 9,0	—11,4	— 7,4	15.9
	T_d														
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
3	T	—17,8	—18,6	—19,0	—17,8	—13,8	— 6,8	— 2,8	— 4,8	— 8,2	—11,9	—13,8	—17,2	—12,7	16.2
	T_d														
	n	92	82	74	90	120	120	116	123	104	124	87	91	1223	
4	T	—24,6	—24,9	—25,1	—23,8	—19,4	—12,2	— 8,2	—10,2	—13,8	—17,6	—19,4	—23,4	—18,6	16.9
	T_d		—24,9											—18,6	16.9
	n	92	82	72	89	120	120	116	123	104	124	87	90	1219	
5	T	—31,6	—31,5	31,6	—30,0	—25,3	—18,3	—14,3	—16,4	—20,0	—24,0	—26,1	—30,2	—24,9	17.3
	T_d		—31,5	—31,4	—30,1								—30,2	—24,9	17.3
	n	90	79	71	88	118	119	116	121	102	123	86	90	1203	
6	T	—38,5	—38,6	—38,6	—36,8	—31,8	—24,9	—20,9	—23,0	—26,7	—30,4	—32,6	—37,0	—31,7	17.7
	T_d	—38,6	—38,5	—38,5	—36,9	—31,9	—24,9		—23,0	—26,7	—30,4	—32,7	—37,0	—31,7	17.7
	n	89	77	65	87	110	119	114	120	101	123	86	84	1175	
7	T	—45,4	—45,5	—44,6	—43,4	—38,4	—31,5	—27,7	—30,0	—33,6	—37,2	—39,6	—43,7	—38,4	17.8
	T_d	—45,4	—45,4	—45,0	—43,5	—38,6	—31,5	—27,8	—30,2	—33,5	—37,2	—39,7	—43,6	—38,3	17.6
	n	87	75	61	85	107	119	110	120	98	120	79	82	1143	
8	T	—51,9	—52,0	—50,5	—49,3	—43,8	—38,5	—35,0	—37,3	—40,5	—44,2	—46,0	—49,6	—44,9	17.0
	T_d	—51,9	—51,7	—51,2	—49,3	—44,2	—38,5	—35,0	—37,5	—40,4	—44,3	—46,6	—49,6	—45,0	16.9
	n	75	58	55	75	103	115	109	115	97	116	69	69	1056	
9	T	—57,0	—56,3	—54,5	—52,8	—47,1	—44,3	—42,1	—44,1	—46,7	—49,8	—52,0	—54,4	—50,1	14.9
	T_d	—57,8	—56,6	—55,5	—53,1	—47,6	—44,3	—42,1	—44,4	—46,6	—50,2	—52,7	—55,0	—50,5	15.7
	n	59	41	41	63	101	113	108	113	91	108	59	56	953	
10	T	—60,0	—58,2	—55,3	—53,0	—48,2	—47,4	—47,2	—48,6	—50,4	—52,7	—55,2	—56,7	—52,7	12.8
	T_d	—61,4	—59,6	—57,2	—53,5	—48,7	—47,5	—47,2	—49,0	—50,0	—53,1	—55,7	—57,8	—53,4	14.2
	n	27	24	30	47	96	112	105	109	80	88	37	39	794	
11	T	—60,7	—57,9	—54,2	—53,1	—47,2	—47,3	—48,4	—49,1	—50,9	—52,3	—56,1	—57,6	—52,9	13.4
	T_d	—62,5	—60,7	—56,5	—53,4	—47,6	—47,3	—48,4	—49,6	—50,7	—53,4	—57,1	—58,9	—53,6	15.2
	n	13	17	22	40	91	109	100	100	73	72	21	28	686	
12	T	—60,8	—58,2	—52,4	—52,8	—45,8	—45,5	—47,0	—47,5	—50,3	—52,1	—55,4	—57,6	—52,1	15.3
	T_d	—63,7	—61,2	—56,0	—53,5	—46,3	—45,4	—46,9	—48,0	—50,1	—53,3	—57,2	—59,4	—53,4	18.3
	n	13	11	19	39	84	107	98	96	61	63	12	22	625	
13	T	—59,8	—56,9	—52,4	—52,6	—45,2	—44,4	—45,5	—46,1	—49,7	—52,4	—55,6	—57,2	—51,5	15.4
	T_d	—62,7	—61,5	—56,3	—53,4	—45,6	—44,4	—45,3	—46,6	—49,7	—53,6	—58,4	—59,5	—53,1	18.3

TABLE I (*continued*)

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	10	7	15	36	73	105	90	93	52	49	10	15	555	
14	T	—60,4	—56,4	—52,0	—52,3	—44,8	—44,3	—44,7	—45,7	—49,0	—52,6	—55,9	—57,1	—51,3	16.1
	T_d	—63,4	—61,3	—56,4	—53,0	—45,4	—44,3	—44,2	—46,1	—49,4	—53,8	—59,1	—60,0	—53,0	19.1
	n	8	6	14	35	68	100	88	87	47	35	8	11	507	
15	T	—61,0	—54,5	—52,5	—52,3	—44,6	—44,2	—44,3	—45,6	—48,8	—52,3	—56,1	—57,9	—51,2	16.8
	T_d	—63,5	—61,1	—56,6	—52,9	—45,4	—44,3	—43,8	—45,9	—49,4	—53,7	—59,8	—60,1	—53,1	19.7
	n	3	4	14	30	63	95	84	83	35	25	7	6	449	
16	T	—60,9	—55,1	—53,0	—52,2	—44,6	—44,2	—44,0	—45,3	—49,2	—53,9	—57,2	—57,1	—51,4	16.9
	T_d	—63,5	—60,9	—57,1	—53,1	—45,3	—44,1	—43,6	—45,7	—49,4	—54,4	—61,1	—60,6	—53,2	19.9
	n		3	9	23	36	69	55	51	20	13	3	4	286	
17	T		—52,8	—51,6	—52,6	—44,3	—44,0	—43,5	—45,2	—49,6	—53,0	—58,1	—56,6		
	T_d		—60,9	—57,4	—53,0	—45,3	—43,8	—43,2	—45,3	—49,3	—54,7	—62,7	—61,0		
	n		3	5	16	32	60	48	40	15	7	1	2	229	
18	T		—53,0	—52,2	—52,1	—44,2	—43,7	—43,0	—45,1	—49,7	—53,6	—64,2	—52,0		
	T_d		—61,1	—57,7	—53,2	—45,0	—43,6	—42,7	—45,1	—49,5	—55,1	—64,6	—59,6		
	n		3	4	12	25	44	41	29	12	4			174	
19	T		—53,2	—52,2	—49,9	—43,9	—43,5	—42,7	—44,8	—50,1	—57,8				
	T_d		—61,3	—58,2	—51,9	—44,8	—43,3	—42,3	—44,7	—49,6	—55,4				
	n			1	10	20	40	32	22	3	2			130	
20	T			—53,1	—49,4	—43,7	—43,0	—42,2	—44,9	—51,7	—58,6				
	T_d			—58,5	—51,6	—44,7	—42,9	—41,8	—44,8	—49,8	—55,3				
	n				3	17	32	24	17	2	1			96	
21	T				—50,6	—43,2	—42,5	—41,8	—44,8	—53,3	—58,2				
	T_d				—50,9	—44,6	—42,3	—41,1	—44,5	—51,1	—55,0				
	n				1	11	19	21	10					62	
22	T				—51,2	—42,6	—42,1	—41,2	—44,4						
	T_d				—50,6	—44,5	—42,0	—40,6	—44,2						
	n				1	4	6	7	7					25	
23	T				—51,0	—40,7	—42,8	—40,0	—44,4						
	T_d				—50,4	—43,6	—41,8	—40,2	—44,2						
	n					1		5	5					11	
24	T					—39,9		—40,9	—44,9						
	T_d					—44,0		—40,2	—44,0						
	n							1	1					2	
25	T							—40,5	—46,5						
	T_d							—40,3	—44,0						

TABLE II

Mean monthly temperatures (° C)

smothed by means of $(A_n + 2A_{n+1} + A_{n+2}) : 4$

Heights G km	January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
0.1	− 3,9	− 4,0	− 3,6	− 1,8	1,9	6,0	8,4	7,8	5,3	2,4	− 0,3	− 2,6	1,2	12,4
0.5	− 4,1	− 4,6	− 4,1	− 2,8	0,7	5,1	7,4	7,8	4,9	1,9	− 0,8	− 2,9	0,7	12,4
1	− 6,4	− 7,0	− 7,2	− 5,7	− 2,1	2,6	5,7	5,0	2,0	− 1,0	− 3,5	− 5,6	− 1,9	12,9
2	−11,8	−12,4	−12,9	−11,6	− 7,9	− 2,5	0,8	− 0,2	− 3,6	− 6,5	− 9,1	−10,9	− 7,4	13,7
3	−17,9	−18,5	−18,6	−17,1	−13,1	− 7,6	− 4,3	− 5,2	− 8,3	−11,5	−14,2	−16,5	−12,7	14,3
4	−24,4	−24,9	−24,7	−23,0	−18,7	−13,0	− 9,7	−10,6	−13,9	−17,1	−20,0	−22,7	−18,6	15,2
5	−31,2	−31,5	−31,1	−29,2	−24,8	−19,1	−15,8	−16,8	−20,1	−23,5	−26,6	−29,5	−24,9	15,7
6	−38,2	−38,5	−38,1	−36,1	−31,4	−26,2	−22,7	−23,4	−26,7	−30,1	−33,2	−36,3	−31,7	15,8
7	−45,0	−45,3	−44,7	−42,7	−38,1	−32,4	−29,3	−30,4	−33,6	−36,9	−40,1	−43,1	−38,3	16,0
8	−51,3	−51,6	−50,9	−48,5	−44,1	−39,1	−36,0	−37,6	−40,7	−43,9	−46,3	−49,4	−45,0	15,6
9	−56,3	−56,6	−55,2	−52,1	−48,2	−44,6	−43,2	−44,4	−46,5	−50,0	−52,7	−55,1	−50,5	13,4
10	−60,1	−59,5	−56,9	−53,2	−49,6	−47,7	−47,7	−48,8	−50,5	−53,0	−55,6	−58,2	−53,4	12,4
11	−61,2	−60,1	−56,8	−52,7	−49,0	−47,7	−48,4	−49,6	−51,1	−53,7	−56,6	−59,4	−53,6	13,5
12	−62,0	−60,5	−56,7	−52,3	−47,9	−46,0	−46,8	−48,3	−50,4	−53,5	−56,8	−59,9	−53,4	16,0
13	−61,6	−60,5	−56,9	−52,2	−47,3	−44,9	−45,4	−47,1	−49,9	−53,8	−57,5	−60,0	−53,1	16,7
14	−62,0	−60,6	−56,8	−52,0	−47,0	−44,6	−44,7	−46,5	−49,7	−54,0	−58,0	−60,6	−53,0	17,4
15	−62,1	−60,6	−56,8	−52,0	−47,0	−44,5	−44,5	−46,3	−49,6	−54,2	−58,4	−60,9	−53,1	17,6
16	−62,1	−60,6	−57,1	−52,2	−47,0	−44,3	−44,3	−46,1	−49,7	−54,8	−59,3	−61,5	−53,2	17,8
17			−57,2	−52,2	−46,9	−44,0	−43,9	−45,8	−49,7	−55,4	−60,3			
18			−57,7	−52,3	−46,7	−43,7	−43,5	−45,6	−49,8	−56,1	−61,0			
19			−57,7	−51,7	−46,2	−43,4	−43,2	−45,3	−49,8					
20				−51,6	−46,0	−43,1	−42,8	−45,3	−49,9					
21					−45,6	−42,6	−42,3	−45,3	−50,4					
22					−45,4	−42,3	−41,9							
23					−44,9	−41,9	−41,6							

TABLE IV

Mean monthly and annual heights, temperatures and potential temperatures of the tropopause.

	January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
n..............	61	53	51	76	105	114	107	100	83	109	58	63	980	
Heights (G km) ..	9,24	8,85	8,80	8,87	8,88	9,65	10,28	10,15	9,66	9,55	9,46	8,98	9,36	1,48
Temp. (°C)	—60,3	—59,4	—56,8	—54,7	—50,6	—50,1	—51,1	—51,8	—53,4	—55,0	—56,9	—58,0	—54,8	10,2
Pot. temp. (°C) ..	38,1	34,2	36,7	38,7	43,6	52,6	58,4	56,3	50,0	47,4	44,6	38,2	44,9	24,2

Smothed by means of $(A_n + 2A_{n+1} + A_{n+2}) : 4$

	January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
Heights	9,08	8,93	8,80	8,81	9,05	9,61	10,09	10,06	9,76	9,56	9,36	9,17	9,36	1,29
Temp.	—59,5	—59,0	—56,9	—54,2	—51,5	—50,5	—51,0	—52,0	—53,4	—55,1	—56,7	—58,3	—54,8	9,0
Pot. temp.	37,2	35,8	36,6	39,4	44,6	51,8	56,4	55,3	50,9	47,4	43,7	39,8	44,9	20,6

TABLE V

Mean monthly vertical temperature gradients (° C/100 gm).

Heights G km	January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
0.1—0.5	—0,10	0,20	0,30	0,23	0,30	0,28	0,08	0,05	0,10	0,18	0,05	0,15	0,15	0,40
0.5—1	0,38	0,56	0,44	0,62	0,58	0,52	0,38	0,52	0,58	0,58	0,56	0,52	0,52	0,24
1—2	0,51	0,58	0,55	0,59	0,62	0,46	0,49	0,51	0,54	0,56	0,55	0,57	0,54	0,16
2—3	0,62	0,59	0,56	0,58	0,50	0,50	0,53	0,49	0,49	0,50	0,48	0,58	0,54	0,14
3—4	0,68	0,63	0,61	0,60	0,56	0,54	0,54	0,54	0,56	0,57	0,56	0,62	0,58	0,14
4—5	*0,70*	0,66	0,63	0,63	0,59	0,61	0,61	0,62	0,62	0,64	0,67	*0,68*	0,64	0,11
5—6	*0,70*	*0,70*	*0,71*	*0,68*	0,66	0,66	0,66	0,66	0,67	0,64	0,66	*0,68*	0,67	0,07
6—7	0,68	0,69	0,65	0,66	*0,67*	0,66	0,69	0,72	0,68	0,68	*0,70*	0,66	0,68	0,07
7—8	0,65	0,63	0,62	0,58	0,56	*0,70*	*0,72*	*0,73*	*0,69*	*0,71*	0,69	0,60	0,66	0,15
8—9	0,59	0,49	0,43	0,38	0,34	0,58	0,69	0,69	0,62	0,59	0,61	0,54	0,55	0,35
9—10	0,36	0,30	0,17	0,04	0,11	0,32	0,49	0,46	0,34	0,29	0,30	0,28	0,29	0,38
10—11	0,11	0,11	—0,07	—0,01	—0,11	—0,02	0,12	0,06	0,07	0,03	0,14	0,11	0,05	0,25
11—12	0,12	0,05	—0,05	0,01	—0,13	—0,19	—0,15	—0,16	—0,06	—0,01	0,01	0,05	—0,04	0,31
12—13	—0,10	0,03	0,03	—0,01	—0,07	—0,10	—0,16	—0,14	—0,04	0,03	0,12	0,01	—0,03	0,26
13—14	0,07	—0,02	0,01	—0,04	—0,02	—0,01	—0,11	—0,05	—0,03	0,02	0,07	0,05	—0,01	0,18
14—15	0,01	—0,02	0,02	—0,01	0,00	0,00	—0,04	—0,02	0,00	—0,01	0,07	0,01	0,00	0,11
15—16	0,00	—0,02	0,05	0,02	—0,01	—0,02	—0,02	—0,02	0,00	0,07	0,13	0,05	0,02	0,15
16—17		0,00	0,03	—0,01	0,00	—0,03	—0,04	—0,04	—0,01	0,03	0,16	0,04		
17—18		0,02	0,03	0,02	—0,03	—0,02	—0,05	—0,02	0,02	0,04	0,19	—0,14		
18—19		0,02	0,05	—0,13	—0,02	—0,03	—0,04	—0,04	0,01	0,03				
19—20			0,03	—0,03	—0,01	—0,04	—0,05	0,01	0,02	—0,01				

TABLE VI

Mean monthly and annual pressures (mb).

(n) No of observations.
(P) Arithmetic mean values
(P') Smoothed values.

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
0.1	P	994,9	989,9	996,3	994,0	999,9	1000,9	1001,3	997,5	998,3	995,6	997,1	991,1	996,4	9,8
	P'	992,7	992,7	994,1	996,0	998,7	1000,7	1000,2	998,6	997,4	996,7	995,7	993,5	996,4	8,0
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
0.5	P	945,7	941,2	946,4	945,4	951,3	952,7	954,0	950,0	950,8	947,3	947,8	942,7	948,0	12,8
	P'	943,9	943,6	944,9	947,1	950,2	952,7	952,7	951,2	949,7	948,3	946,4	944,7	948,0	9,1
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
1	P	885,6	881,2	886,3	885,3	891,7	894,4	896,2	892,3	892,1	889,0	887,7	882,4	888,7	15,0
	P'	883,7	883,6	884,8	887,2	890,8	894,2	894,8	893,2	891,4	889,5	886,7	884,5	888,7	11,2
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
2	P	776,2	772,1	776,0	776,0	783,1	787,7	791,2	787,0	785,3	781,2	780,0	773,7	780,8	19,1
	P'	774,6	774,1	775,0	777,8	782,5	787,6	789,3	787,6	784,7	781,9	779,2	775,9	780,8	15,2
	n	92	83	74	90	120	120	116	123	104	124	87	91	1224	
3	P	678,0	674,2	677,4	677,9	685,6	692,4	696,4	691,8	689,4	683,9	682,7	676,2	683,8	22,2
	P'	676,0	675,9	676,7	679,7	685,4	691,7	694,3	692,4	688,6	685,0	681,4	678,3	683,8	18,4
	n	92	82	74	90	120	120	116	123	104	124	87	91	1223	
4	P	590,3	586,8	589,4	590,4	597,9	606,5	611,6	606,7	603,4	597,6	595,8	588,8	597,1	24,8
	P'	589,1	588,4	589,0	592,0	598,2	605,6	609,1	607,1	602,8	598,6	594,4	590,9	597,1	21,3
	n	92	82	72	89	120	120	116	123	104	124	87	90	1219	
5	P	513,0	508,7	511,0	512,6	520,8	529,4	535,5	530,8	526,4	520,7	518,9	511,2	519,9	26,8
	P'	511,5	510,4	510,8	514,3	520,9	528,8	532,8	530,9	526,1	521,7	517,4	513,6	519,9	22,4
	n	90	79	71	88	118	119	116	121	102	123	86	90	1203	
6	P	442,3	439,7	441,6	443,2	451,9	461,2	467,2	462,5	458,2	452,1	450,0	442,2	451,0	27,5
	P'	441,6	440,8	441,5	445,0	452,1	460,4	464,5	462,6	457,8	453,1	448,6	444,2	451,0	23,7
	n	89	77	65	87	110	119	114	120	101	123	86	84	1175	
7	P	380,4	378,3	380,2	381,6	390,3	399,8	406,1	401,4	396,6	390,6	387,9	380,6	389,5	27,8
	P'	379,9	379,3	380,1	383,4	390,5	399,0	403,4	401,4	396,3	391,4	386,8	382,4	389,5	24,1
	n	87	75	61	85	107	119	110	120	98	120	79	82	1143	
8	P	326,3	323,8	326,1	327,3	336,5	345,8	351,8	347,0	342,6	336,7	334,3	326,3	335,4	28,0
	P'	325,7	325,0	325,8	329,3	336,0	345,0	349,1	347,1	342,2	337,6	332,9	328,3	335,4	24,1
	n	75	58	55	75	103	115	109	115	97	116	69	69	1056	
9	P	279,9	277,9	279,5	280,6	289,0	297,6	303,1	299,9	294,2	289,2	286,4	280 1	288,1	25,2
	P'	279,5	278,8	279,4	282,6	289,1	296,8	300,9	299,3	294,4	289,8	285,5	281,6	288,1	22,1
	n	59	41	41	63	101	113	108	113	91	108	59	56	953	
10	P	239,3	237,0	238,9	240,3	248,3	256,0	260,8	258,2	252,4	247,9	244,2	239,1	246,9	23,8
	P'	238,7	238,1	238,8	242,0	248,2	255,3	258,9	257,4	252,7	248,1	243,9	240,4	246,9	20,8
	n	27	24	30	47	96	112	105	109	80	88	37	39	794	
11	P	203,0	200,4	202,9	206,0	212,7	219,1	223,4	220,1	216,0	211,7	208,2	203,2	210,6	23,0
	P'	202,4	201,7	203,1	206,9	212,4	218,6	221,5	219,9	216,0	211,9	207,8	204,4	210,6	19,8
12	n	13	17	22	40	91	109	100	100	73	72	21	28	686	
	P	173,2	170,5	173,9	177,9	184,2	189,4	192,9	189,9	186,3	182,0	177,7	173,6	181,0	22,4
	P'	172,6	172,0	174,1	178,5	183,9	190,0	191,3	189,8	186,1	182,0	177,8	174,5	181,0	19,3

TABLE VI (*continued*)

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	13	11	19	39	84	107	98	96	61	63	12	22	625	
13	P	148,4	148,8	149,4	153,3	159,3	163,7	166,6	164,4	160,0	156,8	153,1	148,6	156,0	18,2
	P'	148,6	148,9	150,2	153,8	158,9	163,3	165,3	163,9	160,3	156,7	152,9	149,7	156,0	16,7
	n	10	7	15	36	73	105	90	93	52	49	10	15	555	
14	P	126,3	130,1	127,3	130,7	137,5	140,8	143,1	141,5	137,2	134,0	131,6	125,9	133,8	17,2
	P'	127,2	128,5	128,9	131,6	136,6	140,6	142,1	140,8	137,5	134,2	130,8	127,4	133,8	14,9
	n	8	6	14	35	68	100	88	87	47	35	8	11	507	
15	P	106,1	110,7	107,6	110,7	117,1	120,3	122,2	120,5	116,5	114,9	111,5	106,0	113,7	16,2
	P'	107,2	108,8	109,2	111,5	116,3	120,0	121,3	119,9	117,1	114,5	111,0	107,4	113,7	14,1
	n	3	4	14	30	63	95	84	83	35	25	7	6	449	
16	P	88,3	96,5	91,2	94,0	99,5	102,3	104,1	102,3	98,8	96,2	92,4	91,8	96,5	15,8
	P'	91,2	93,1	93,2	94,8	98,8	102,1	103,2	101,9	99,0	95,9	93,2	91,1	96,5	12,1
	n		3	9	23	36	69	55	51	20	13	3	4	286	
17	P		81,3	77,9	80,5	85,8	88,2	89,6	88,1	84,7	82,8	80,3	79,5		
	P'			79,4	81,2	85,1	87,9	88,9	87,6	85,1	82,7	80,7			
	n		3	5	16	32	60	48	40	15	7	1	2	229	
18	P		68,7	66,8	69,5	74,5	76,4	77,6	76,2	72,5	71,7	68,0	69,5		
	P'			67,9	70,1	73,7	76,5	77,9	76,1	73,2	71,0	69,3			
	n		3	4	12	25	44	41	29	12	4			174	
19	P		57,3	57,0	60,0	64,1	65,8	66,7	65,9	61,8	61.0				
	P'			57,8	60,3	63,5	65,6	66,3	65,1	62,6					
	n			1	10	20	40	32	22	3	2			130	
20	P			48,0	51,2	55,2	56,7	57,9	57,4	55,0	51,5				
	P'				51,4	54,6	56,6	57,5	56,9	54,7					
	n				3	17	32	24	17	2	1			96	
21	P				43,3	48,1	48,9	49,6	49,2	45,5	43,0				
	P'					47,1	48,9	49,3	48,4	45,8					
	n				1	11	19	21	10					62	
22	P				37,0	41,0	41,8	42,3	42,0						
	P'					40,2	41,7	42,1							
	n				1	4	7	7	7					26	
23	P				31,0	34,8	36,7	36,7	35,6						
	P'														
	n					1	5	5	5					16	
23	P					31,0	30,6	30,6	29,8						
	P'														
	n						1	1	1					3	
25	P						26,0	26,0	25,0						
	P'														

TABLE VII

Heights (gkm)		2	4	6	8	10	12	14	16
Summer	Tromsø	788.2	607.3	462.5	347.1	257.2	190.4	141.2	102.4
(Ju, Ju, Au)	Gøteborg	790.6	611.4	467.2	351.3	259.5	190.6	139.6	103.1
Winter	Tromsø	774.9	589.5	442.2	326 3	239.1	173.0	127.7	91.8
(De, Ja, Fe)	Gøteborg	781.7	595.9	447.5	331.2	241.0	174.0	125.7	91.6
Corresponding values of meridional pressure gradients (mb/degree of lat.)									
Summer		0.20	0.34	0 40	0.35	0.19	0.02	—0.13	0.06
Winter		0.57	0.54	0.44	0.40	0.16	0.08	—0.17	—0.02
Corresponding values of zonal wind speed (m/s)									
Summer		1.4	2.9	4.3	4.5	3.2	0.5	—4.1	2 5
Winter		3.6	4.4	4.6	5.2	2.9	2.1	—5.4	—0.9

TABLE VIII

Mean monthly and annual humidities.

(n) No. of observations.
(U) Relative humidity (per cent)
(S) Specific humidity (grams per kilogram)
(S') Smoothed values of S

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	92	83	73	74	120	120	116	123	104	123	87	91	1206	
0.1	U	79,5	81,6	79,3	81,6	79,8	80,0	88,4	91,0	87,3	79,8	79,4	82,2	82,5	11,5
	S	2,21	2,56	2,34	2,40	3,43	4,87	6,63	6,12	4,93	3,72	3,07	2,74	3,75	4,42
	S'	2,43	2,42	2,41	2,64	3,53	4,95	6,06	5,95	4,93	3,86	3,15	2,69	3,75	3,65
	n	91	83	73	74	120	118	114	122	104	123	86	89	1197	
0.5	U	79,5	82,8	81,0	82,8	80,8	78,6	86,9	87,8	86,0	81,5	81,6	81,2	82,5	9,2
	S	2,39	2,60	2,36	2,44	3,39	4,71	6,87	6,22	5,12	3,79	3,12	2,77	3,82	4,51
	S'	2,54	2,49	2,44	2,66	3,48	4,92	6,17	6,11	5,06	3,96	3,20	2,76	3,82	3,73
	n	91	83	73	74	120	118	114	122	104	123	86	88	1196	
	U	80,3	83,2	81,1	83,1	81,8	79,2	84,9	86,1	85,4	82,4	82,5	82,6	82,7	6,9
	S	2,23	2,25	2,02	2,12	3,03	4,24	6,27	5,31	4,37	3,28	2,73	2,45	3,36	4,25
	S'	2,29	2,16	2,10	2,32	3,10	4,44	5,52	5,32	4,33	3,42	2,80	2,46	3,36	3,42
	n	90	83	73	74	120	118	113	121	103	123	86	87	1191	
	U	76,9	81,9	80,0	83,7	81,0	77,4	81,3	80,3	80,5	82,3	78,5	80,0	80,3	6,8
	S	1,64	1,66	1,50	1,54	2,25	3,33	4,85	3,97	3,16	2,52	2,04	1,74	2,52	3,35
	S'	1,67	1,61	1,55	1,71	2,34	3,44	4,25	3,99	3,20	2,56	2,09	1,79	2,52	2,70
	n	88	83	73	73	119	117	113	121	103	123	84	87	1184	
	U	72,9	79,1	77,1	81,1	77,8	74,2	76,5	76,6	75,2	76,7	76,4	76,6	76,7	6,2
	S	1,06	1,20	1,08	1,09	1,64	2,55	3,46	3,00	2,33	1,85	1,39	1,24	1,82	2,40
	S'	1,14	1,13	1,11	1,22	1,75	2,55	3,12	2,95	2,38	1,86	1,47	1,24	1,82	2,01
	n	87	80	73	73	119	116	113	121	102	123	82	83	1172	
	U	68,7	73,9	73,6	76,8	74,4	70,7	72,0	69,4	70,9	72,0	73,0	73,3	72,4	8,1
	S	0,67	0,76	0,71	0,73	1,15	1,82	2,48	2,04	1,63	1,31	0,97	0,83	1,26	1,81
	S'	0,73	0,72	0,73	0,83	1,21	1,82	2,20	2,05	1,65	1,30	1,02	0,82	1,26	1,48
	n	82	76	64	64	110	109	109	111	96	117	80	72	1090	
	U	64,2	69,0	71,2	73,0	71,9	66,4	66,7	65,9	67,2	68,8	72,3	65,6	68,5	8,8
	S	0,38	0,46	0,42	0,42	0,76	1,15	1,58	1,34	1,09	0,85	0,68	0,50	0,80	1,20
	S'	0,43	0,43	0,43	0,50	0,77	1,16	1,41	1,34	1,09	0,87	0,68	0,51	0,80	0,98

TABLE IX

Mean monthly and annual potential temperatures and potential equivalent temperatures.

(n) No. of observations.

(*Q*) Potential temperature

(Q_E) Potential equivalent temperature.

(Q' Q'_E) Smoothed values of Q and Q_E

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	92	83	73	90	120	120	116	123	104	123	87	91	1222	
0.1	Q_E	1,3	4,0	2,2	5,3	10,4	19,1	26,4	24,	18,5	12,3	7,7	5,6	11,5	25,1
	Q_E	3,1	2,9	3,4	5,8	11,3	19,3	24,0	23,2	18,4	12,7	8,3	5,1	11,5	21,1
	n	91	83	73	89	120	118	114	122	104	123	86	89	1212	
0.5	Q_E	6,0	7,6	5,3	8,3	12,9	21,2	30,8	27,7	22,0	15,6	11,5	8,9	14,8	25,5
	Q'_E	7,1	6,6	6,6	8,7	13,8	21,5	27,6	27,3	21,8	16,2	11,9	8,8	14,8	21,0
	n	91	83	73	89	120	118	114	122	104	123	86	88	1211	
1	Q_E	9,2	9,3	7,1	9,8	14,6	24,2	33,0	28,3	23,1	16,9	13,3	11,0	16,6	25,9
	Q'_E	9,8	8,7	8,3	10,3	15,8	24,0	29,6	28,2	22,9	17,6	13,6	11,1	16,6	21,3
	n	90	83	73	88	120	118	114	121	104	123	86	87	1207	
2	Q_E	12,9	12,0	10,8	11,6	16,7	26,3	35,0	30,2	23,9	19,6	16,3	13,8	19,1	24,2
	Q'_E	12,9	11,9	11,3	12,7	17,8	26,1	31,6	29,8	24,4	19,9	16,5	14,2	19,1	20,3
	n	88	83	73	88	119	118	114	121	104	123	84	86	1201	
3	Q_E	16,0	15,3	14,5	16,1	20,8	30,3	36,8	33,3	28,1	23,3	20,0	17,0	22,6	22,3
	Q'_E	16,1	15,3	15,1	16,9	22,0	29,6	34,3	32,9	28,2	23,7	20,1	17,5	22,6	19,2
	n	87	80	73	88	119	118	114	121	103	123	83	85	1194	
4	Q_E	18,5	18,7	17,9	19,9	24,9	33,8	38,7	36,2	31,3	26,8	23,6	20,4	25,9	20,8
	Q'_E	19,0	18,5	19,1	20,7	25,9	32,8	36,9	35,6	31,4	27,1	23,6	20,7	25,9	18,4
	n	82	76	65	79	111	111	114	111	79	117	82	72	1099	
5	Q_E	31,3	21,9	21,1	23,1	28,3	36,5	39,9	38,9	34,8	30,3	27,3	24,4	29,0	18,8
	Q'_E	22,2	21,6	21,8	23,9	29,1	35,3	38,8	38,1	34,7	30,7	27,6	24,4	29,0	17,2
	n	90	79	72	88	118	119	116	121	102	124	86	90	1203	
6	Q	23,7	24,3	23,6	26,1	30,5	37,8	41,9	39,8	35,8	31,8	30,1	25,9	30,9	18,3
	Q'	24,4	24,0	24,4	26,6	31,2	37,0	40,4	39,2	35,8	32,4	29,5	26,4	30,9	16,4
	n	89	78	66	89	110	119	114	120	101	123	86	84	1177	
7	Q	27,9	27,8	28,4	31,5	34,4	41,5	45,5	43,2	39,6	36,3	33,7	30,0	35,0	17,7
	Q'	28,4	28,0	29,0	31,5	35,5	40,7	43,9	42,9	37,7	36,5	33,4	30,4	35,0	15,9
	n	86	74	61	85	107	119	110	120	98	120	79	82	1141	
8	Q	32,6	33,2	34,2	35,8	41,0	45,6	49,0	46,9	43,8	40,6	38,4	35,3	39,7	16,4
	Q'	33,4	33,3	34,4	36,7	40,9	45,3	47,6	46,7	43,8	40,9	38,2	35,4	39,7	14,3
	n	75	57	56	76	103	115	110	115	97	117	69	68	1058	
9	Q	39,1	40,5	42,4	44,8	50,2	51,5	53,0	51,4	49,3	46,5	44,8	42,8	46,4	13,9
	Q'	40,4	40,6	42,5	45,6	49,2	51,6	52,2	51,3	49,1	46,8	44,7	42,4	46,4	11,8
	n	58	42	42	63	101	113	108	113	92	107	60	56	955	
10	Q	48,6	52,1	56,5	59,0	63,3	61,7	59,8	59,1	58,8	57,0	54,4	53,8	57,0	14,7
	Q'	50,8	52,3	56,0	59,4	61,8	61,6	60,1	59,2	58,4	56,8	54,9	52,6	57,0	11,1
	n	27	26	30	48	96	112	106	109	81	87	41	38	801	
11	Q	64,1	69,2	73,7	73,3	80,3	77,3	73,0	73,5	72,0	72,7	68,3	69,2	72,4	16,2
	Q'	66,6	69,0	72,5	75,1	77,8	77,0	76,7	73,0	72,6	71,4	69,6	67,7	72,4	11,2

TABLE IX (continued)

Heights G km		January	February	March	April	May	June	July	August	September	October	November	December	Year	Range
	n	14	18	22	40	93	109	100	100	73	71	23	29	692	
12	Q	80,9	85,9	93,1	89,4	97,6	95,5	90,4	91,8	88,7	88,5	85,4	84,4	89,3	16,7
	Q'	83,0	86,4	90,4	92,4	95,0	94,7	92,0	90,7	89,4	87,8	85,9	83,8	89,3	12,0
	n	14	11	19	39	84	107	98	97	61	63	14	23	630	
13	Q	98,9	102,5	109,8	103,6	114,3	112,8	109,3	109,7	106,5	104,0	99,8	100,3	105,8	13,9
	Q'	100,1	103,4	106,4	107,8	111,2	112,3	110,3	108,8	106,7	103,6	101,0	99,8	105,8	12,5
	n	10	7	15	36	73	105	90	93	52	48	11	15	555	
14	Q	116,1	119,9	129,3	124,7	133,7	130,6	128,3	127,6	122,8	120,8	119,0	120,7	124,5	17,6
	Q'	118,2	121,3	125,8	128,1	130,7	130,8	128,7	126,6	123,5	120,9	119,9	119,1	124,5	12,6
	n	8	6	14	35	69	100	88	87	47	35	8	10	507	
15	Q	133,9	144,0	148,1	144,6	151,5	149,4	147,2	147,1	144,7	138,5	136,0	139,3	143,7	17,6
	Q'	137,8	142,5	146,2	147,2	149,2	149,2	147,7	146,5	143,8	139,4	137,5	137,1	143,7	12,1
	n	3	4	14	30	63	94	84	82	38	25	7	7	451	
16	Q	155,0	156,8	167,2	164,8	171,5	169,1	167,2	167,4	164,9	157,2	154,1	158,1	162,8	17,4
	Q'	156,2	158,9	164,0	167,1	169,2	169,2	167,7	166,7	163,6	158,4	155,9	156,3	162,8	13,0
	n		4	8	23	35	69	55	53	20	13	5	4	289	
17	Q		176,0	191,6	184,4	191,2	189,5	188,6	187,0	184,7	179,1	172,2	176,0		
	Q'														
	n		3	5	16	32	61	48	41	15	7	1	2	231	
18	Q		208,7	212,4	206,8	211,0	209,7	210,0	207,2	205,6	196,3	182,0	204,5		
	Q'														
	n		3	3	12	25	44	41	29	11	4			172	
19	Q		228,7	229,7	232,4	232,9	231,1	232,0	228,4	226,0	210,3				
	Q'														
	n			1	10	20	40	32	24	3	2			132	
20	Q			254,0	258,1	255,8	254,3	255,0	251,1	245,0	231,5				
	Q'														
	n				3	17	32	24	17	2	1			96	
21	Q				276,7	278,5	277,5	277,3	271,2	268,5	260,0				
	Q'														
	n				1	11	19	21	10					62	
22	Q				300,0	307,0	304,3	305,3	297,7						
	Q'														
	n				1	4	6	7	7					25	
23	Q				331,0	337,5	336,5	331,6	325,3						
	Q'														
	n				1		5	5						11	
24	Q				361,0		361,0	355,0							
	Q'														
	n						1	1						2	
25	Q						394,0	382,0							
	Q'														

TABLE X

Mean differences between the afternoon and the morning soundings.

(n) No. of observations.

(ΔR) Differences of the relative humidities.

(ΔS) » » » specific »

Heights G km	Spring			Summer			Autumn			Winter		
	n	ΔR	ΔS	n	ΔR	ΔS	n	ΔR	ΔS	n	ΔR	ΔS
0,1	87	— 7,2	0,27	92	—11,3	0,52	143	— 4,8	0,13	85	2,2	0,06
0,5	86	— 6,4	0,00	86	— 7,5	0,22	143	— 5,1	—0,10	85	— 0,4	0,01
1	86	— 5,3	—0,15	86	— 6,2	0,06	142	— 3,7	—0,10	85	— 0,4	—0,02
2	86	— 5,4	—0,10	86	— 4,2	—0,04	141	— 1,0	0,05	85	0,4	0,00
3	85	— 3,7	—0,01	84	— 0,7	0,17	140	1,2	0,14	85	0,0	—0,02
4	85	— 5,5	—0,01	82	1,1	0,16	139	— 1,1	0,10	84	0,2	—0,03
5	85	— 3,8	—0,02	80	— 1,4	0,09	139	— 2,3	0,00	84	— 0,3	—0,02

TABLE XI

Mean differences between the afternoon and the morning soundings.

(n) No. of observations.

(ΔT) Differences of the temperatures.

(ΔQ_E) » » » potential equivalent temperatures (0—5 gkm).

(ΔQ) » » » » temperatures (above 5 gkms).

Heights G km	Spring			Summer			Autumn			Winter		
	n	ΔT	ΔQ_E ΔQ	n	ΔT	ΔQ_E ΔQ	n	ΔT	ΔQ_E ΔQ	n	ΔT	ΔQ_E ΔQ
0.1	88	2.6	2.8	92	3.5	4.8	144	1.6	+ 1.8	85	0.0	— 0 2
0.5	88	1.8	1.7	92	1.7	2.5	144	0.7	+ 0.7	85	0.0	— 0.2
1	88	0.5	0.2	92	1.0	1.2	144	0.5	+ 0.3	85	— 0.2	— 0.3
2	88	0.4	0.1	92	0.6	+ 0.4	144	0.4	+ 0.5	85	0.0	— 0.6
3	88	0.4	0.1	92	0.9	+ 1.2	144	0.3	+ 0.7	85	0 0	0.0
4	88	0.7	0.3	92	1.0	+ 1.1	144	0.3	+ 0.6	85	— 0.3	— 0.1
5	88	0.6	0.1	92	0.9	+ 1.6	144	0.7	+ 0.5	84	0.1	— 0.2
6	85	0.8	0.7	88	1.4	1.1	138	0.6	0.5	80	0.1	0.1
7	77	0.8	0.8	85	1.6	1.6	135	0.8	0.7	76	0.2	— 0.1
8	71	1.1	1.5	79	1.4	1.4	130	0.4	0.0	71	0.5	0.4
9	63	1.3	1.4	75	1.4	1.1	122	0.1	— 0.5	48	0.7	0.7
10	41	0.9	0.0	72	1.0	0.8	105	0.1	0.0	25	0.6	1.5
11	28	0.6	0.4	64	1.1	0.7	66	— 0.3	0.1	5	3.7	5.2
12	24	0.8	0.2	56	0.7	0.6	56	0.2	0.3			
13	19	0.8	0.0	50	0.8	0.8	44	1.3	1.4			
14	10	0.8	0.4	42	1.1	0.8	31	1.4	1.2			
15	7	— 0.5	0.1	40	0.9	0.1	25	1.3	0.7			
16	7	— 0.2	— 1.0	36	1.3	0 7	17	2.0	1.5			
17	1	2.1	3.0	2	1.5	— 2.0	5	1.0	2.3			
18				1	0.4	— 2.0	3	3.1	4.6			
19				1	0.8	— 3.0	1	3.0	4.0			
20				1	1.0	— 3.0						

TABLE XII

Heights G km	Tromsø		Spitsbergen	
	n	ΔT_0 C	n	ΔT_0 C
0	92	3.5	9	1.1
1	92	1.0	9	—0.9
2	92	0.6	9	—0.2
3	92	0.9	9	0.8
4	92	1.0	9	0.6
5	92	0.9	9	0.9
6	88	1.4	9	1.2
7	85	1.6	9	2.1
8	79	1.4	9	2.2
9	75	1.4	9	0.7
10	72	1.0	9	1.2
11	64	1.1	9	0.5
12	56	0.7	9	1.2
13	50	0.8	9	1.4
14	52	1.1	9	1.6
15	40	0.9	8	1.7
16	36	1.3	8	2.0
17	2	1.5	8	2.5
18	1	(0.4)	7	2.4
19	1	(0.8)	5	2.9
20	1	(1.0)	3	3.2

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