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COMPARISON BETWEEN THE RESULTS OBTAINED WITH THE KEW MK IIB AND THE VAISALA RS 13 RADIO-SONDES UNDER OPERATIONAL CONDITIONS IN HONG KONG

BY

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Introduction

On January 1, 1969 the Vaisala RS 13 type of radiosonde was brought into use on routine upper-air soundings in Hong Kong replacing the Kew MK IIB type which had been in use in the Colony since 1949. In order to determine whether the change in sonde type would result in a discontinuity in the statistics of temperature, geopotential and relative humidity at standard pressure levels it was decided to carry out trial ascents with both types of sonde flown on the same balloon. One series was flown in January 1969 and a second in June 1969. The latter series was continued into July until the available supply of Kew sondes was exhausted.

2. Conditions for the trials

The balloon released each day for the routine 00 GMT ascent carried a target which was tracked by a Decca WF 2 windfinding radar and the Kew sonde was suspended below this target in the manner normal for operations with the sonde. The Vaisala sonde was attached below the Kew sonde on a cord 25 m. in length. Records from each sonde were made in exactly the same way as for routine ascents with these sondes but special care was taken to ensure that:

(a) the timing for each record was derived from the same clock,

(b) the timing of the radar observations was also controlled by this clock,

(c) the ranging circuits of the windfinding radar were set up as accurately as possible and the levelling of the equipment and its zeroing checked, and

(d) the recording equipment for each radiosonde was calibrated before and after each ascent.

3. Computation of the results of the trial

Computations were carried out on the recorded data in accordance with normal operational procedures. This included a check on the agreement between the height derived from the pressure, temperature and relative humidity record obtained from each sonde separately and the radar height at the same instant when the balloon was at about the 200 mb level. If the height obtained from either radiosonde differed by more than about 200 m* from the radar height the corresponding radiosonde pressures were discarded and replaced by values derived from radar heights and the radiosonde temperatures. This was also in conformity with standard routine practice. During the January trial period when radar observations were available, the pressure readings on the ascents accepted for comparison were amended on three occasions for the Kew sonde but those from the Vaisala sonde required no amendment. Unfortunately, during the June/July trials no radar observations were available so that this amendment procedure could not be used. In accordance with usual routine practice lag and radiation corrections were applied to the temperatures derived from the Kew sonde while radiation corrections only were applied to those from the Vaisala sonde.

* The actual figure used varied from ascent to ascent being based on the actual elevation and slant range to the sonde and assumed probable errors in the radar parameters.

From the aerogram for each ascent in January the temperatures at 25 pressure levels between 1000 mb and 20 mb inclusive were found for each sonde. The differences in temperature (Kew sonde value minus Vaisala sonde value) were also found for these levels. These latter figures were used to estirate the differences in temperature which would appear in statistics published by the Royal Observatory as a result of the change of sonde type. In this paper, the derived differences were called temperature differences at indicated pressure levels. This was to distinguish them from the temperature differences obtained at the same level and environment used later in the paper and which were called temperature differences at the same (true) temperature. Means and population variances* were estimated for the month for

(1) the Kew sonde temperatures

(2) the Vaisala sonde temperatures and

(3) their differences

for each of the selected pressure levels. A similar process was carried out on the derived geopotential and on the relative humidity except that, in the case of the latter, only 12 pressure levels between 1000 mb and 250 mb inclusive were used. The whole process was repeated for the ascents made in June and again for those made in July. The results for June and July were later combined and the process repeated for the combination. Tables I (1-6) show the final results of these computations for the January series and for the combined June/July series.

4. Discussion of the results - Temperature

The methods of computation took into account the corrections necessary to the temperature sensor indications for the effects of lag in the sensor and its warming by solar radiation to the extent to which they were applied in routine practice. The differences in temperature at the pressure levels selected should thus have reflected the residual differences caused by errors in sensor accuracy, correction procedure and the effect of indicated pressure differences. If the true temperature at pressure P was T and the pressure and temperature errors in indicating these conditions were $\triangle P_k$ and $\triangle T_k$ for the Kew sonde and $\triangle P_v$ and $\triangle T_v$ for the Vaisala sonde then the difference in the temperature allocated to pressure P by each sonde was, (neglecting squares of the errors)

$$(T + \triangle T_k) - (T + \triangle T_v) - \frac{\triangle T}{\triangle P} \left[(P + \triangle P_k) - (P + \triangle P_v) \right]$$

or

$$\triangle T_k - \triangle T_v - \frac{\triangle T}{\triangle P} (\triangle P_k - \triangle P_v) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \mathrm{I}$$

where $\frac{\triangle T}{\triangle P}$ was the rate of change of temperature with pressure and was normally positive in the troposphere.

Since the purpose of the investigation was to determine the effect on upper air statistics of the change in sonde type, a "Students t" test was carried out to ensure that the Kew sonde results at the standard pressure levels between 850 mb to 50 mb inclusive could have been members of a normal population derived in the five years 1964 - 1968. This period

* In this study all population variances were unbiased estimates and standard deviations were obtained as the positive square root of these variances.

was chosen since the computing technique used for the Kew sonde results in these trials was first introduced in 1964. The test was necessary to ensure that the results of the trial had not been biased by the use of a batch of radiosondes with systematic errors peculiar to the batch. These "t" tests, carried out separately for the results in January and in June, showed that the mean temperature for the month, taken as a measure of the characteristic of the month at the particular pressure level, could have been a member of the same normal population as the means from the previous five years. It was therefore assumed that no unusual bias had been introduced into the Kew results used in this investigation.

Corresponding "t" tests for the July results were not carried out as these trials were confined to the first nine days of the month and could not give a valid estimate of the monthly mean. Based on the results of the comparisons for January and June, and because the Kew sondes used in July were from the same batch as those used in June, it was concluded that results for July would also be member of the population derived from the previous five years. The results from June and July were then associated to form the second independent trial. No similar check for the Vaisala sonde was possible because no prior results were available.

In this way two estimates of temperature differences to be expected at the various pressure levels were obtained. If corrections and correction procedures were correct then all the known seasonal factors had been removed from the results, except for the seasonal variation in the temperature at a given pressure level. The differences obtained should thus have reflected differences in the temperature and pressure sensor accuracies, both of these being independent of the season. It followed that the estimates from the trials should have been samples drawn from the same population if the temperature sensor error varied slowly with the indicated temperature. Application of "t" tests to these two estimates of the temperature difference at each pressure level (Table II) showed that the hypothesis that they are drawn from the same normal population was by no means substantiated at the 175, 150, 125, 100 and 90 mb levels and consequently that there was possibly a real variation in the differences at these levels. No purely seasonal correction was applied to the pressure readings of either sonde so one would have expected ΔP_K and ΔP_V to be independent of the season. An investigation of the temperature difference in the same environment at temperatures between -60°C and -80°C (the temperatures prevailing at the pressure levels mentioned above during the trials) was indicated.

<u>Additional investigation - Temperature</u>

The temperature given by each type of sonde flown on the same balloon at the same height above the surface and therefore at the same true temperature was found after all the corrections usual in routine practice had been applied. The difference (Kew sonde value minus Vaisala sonde value) was then computed at each selected height. For convenience, the height of the Vaisala sonde at every second minute from the time of release was chosen. The corresponding time at which the Kew sonde temperature was read off was determined from the rate of ascent of the balloon and the length of the suspension between the Kew and Vaisala sondes. This assumed that the two sondes remained vertically separated by the length of the suspension between them. Visual observation showed that the

Vaisala sonde swung through only a small angle from the vertical. In Table III are given mean values of $\Delta T/\Delta p$ at standard pressure levels for January and June and the approximate metre equivalent of 1 mb at these levels. The maximum possible error in the differences between the Kew and Vaisala temperature readings caused by the approximation that the sondes remained separated by the length of the 25 m. cord is given in the bottom two lines of Table III. These figures assumed that the Vaisala sonde was at the same level as the Kew sonde. Since the amplitude of the angle through which the Vaisala sonde oscillated was quite small the actual error was very much smaller than the figures quoted. From the differences in temperature obtained, the effects of pressure and air density on the indicated temperature had been removed. The results were analysed against the temperature as indicated by the Kew sonde, grouping being in intervals of five degree Celsius. Estimates of the mean difference and population variance at the mid point of the temperature intervals were obtained from the two trials separately and are given in Table IV. Application of "t" tests to these results showed that in each temperature interval they could belong to the same normal population except in the intervals from -75°C to -80° and from 10 to 15°C.

The winter monsoon in Hong Kong, the presence of which was reflected in the January results, was characterised by a persistent inversion with the temperatures at the inversion near 10 to 15°C. There was no such persistent inversion associated with the summer regime. It followed that the January results would contain occasions in the temperature ranges near 10°C - 15°C when the temperature was decreasing with pressure while the corresponding temperature intervals in the June/July results would not. This suggested that the results near 12½°C on the two trials were not compatible for this season. A similar argument would apply to the levels near the tropopause if the numbers of cases of reversal of sign of the temperature gradient with pressure differed in the two trials. The differences in the indicated temperature ranges from 10°C to 20°C and -55°C to -85°C were therefore analysed into cases where the temperature was decreasing with pressure at the height of the observation and those where the temperature was decreasing with pressure. The results of this are shown in columns 4 to 7 and 10 to 13 in Table IV. "t" tests showed that the two trials gave results which were not incompatible when the temperature gradient had the same sign in each case. The results from both trials were therefore used to obtain final estimates of the differences which would be obtained when the temperature was increasing with pressure and these were given in column 14 of Table IV. The corresponding results for the intervals over which temperatures decreasing with pressure were observed were given in column 16. In assessing the results it must be remembered that Vaisala temperature calibration was carried out only to about -65°C and the curve extrapolated while the Kew sonde was calibrated to about -85°C.

6. Additional investigation - Pressure

An investigation similar to that carried out on the temperature results in the previous section was made using the observed pressure values at the same height above the surface. Differences should have been independent of season and temperature so the results were analysed against the pressure indicated by the Kew sonde. The intervals for the analysis were chosen by first meaning the June/July values of the indicated pressure at each even minute from the start of the ascent. The interval levels were then chosen to be centred on the value of each successive two minute mean. In this way most of the results in the June/July trial were grouped exactly as if all the pressures at each even minute had been used. The January results were then analysed into the same pressure intervals. A "t" test was then applied to the values of mean and population variance of the differences obtained in each pressure interval from the two trials. This showed that the pressure differences obtained in each pressure interval could belong to the same normal population. Accordingly, a new estimate of the mean difference and population variance was made from the results of both trials together with the 90% fiducial limits for each pressure level. This gave the values shown in the first four columns of Table V.

7. Estimated temperature differences at indicated pressure levels

In Table VI estimates of the temperature difference between the sondes at indicated standard pressure levels were made using equation I. The temperature and pressure differences obtained from observations at the same height already established for each trial were used for this. The table showed that the contribution of the difference in indicated pressure to the temperature difference at a specified pressure level was small compared with that from the difference between the temperature sensors up to the tropopause. It was, however, important at levels in the stratosphere up to 30 mb.

Comparison of these calculated temperature differences with the actual observed differences at given indicated pressure levels (Tables I.1 and I.4 transposed to columns 5 and 9 of Table VI), showed that agreement between the results for January was better than that between results in June/July. Although the samples used to compute the separate differences was smaller than that used in obtaining the figures in Tables I.1 and I.4 and this critical selection may have had some effect, it appeared that the practice of systematic comparison of radar and radiosonde derived heights at even a single level (200 mb) in January had reduced the number of gross errors. The temperature difference to be expected in routine soundings is represented by column 10 in Table VI which is the mean of figures in columns 4 and 8 of the same table.

8. Consistency of Vaisala-sonde observations

The lag coefficient for the Kew sonde was treated as constant so the variation in the applied lag correction at a given level varied only with the seasonal variation of the lapse rate of temperature at that level. This was small in the upper troposphere. There was no separate lag correction applied to the Vaisala sonde.* The radiation corrections for both sondes were dependent on the solar angle at the time of the ascent. This ranged from 15° to 25° on ascents in January and from 25° to 35° on ascents in June and July. Radiation corrections for the Kew sonde were derived from theoretical calculations. Those for the Vaisala sonde were based on comparisons between ascents in sunlight and those in darkness. From January 1st 1969 radiosonde ascents were made in Hong Kong at 12 G.M.T. as well as at 00 G.M.T. It was thus possible to compare the results from the two daily ascents, on both of which Vaisala sondes were flown, to check whether the radiation corrections applied to the Vaisala sonde were adequate. The temperature at each standard pressure level on a 00 G.M.T. ascent was compared with the mean of the temperatures at the same standard pressure level on ascents 12 hours before and 12 hours after it and the difference (Temperature at 00Z minus mean temperature from ascents 12 hours before and 12 hours after) found.

* This lag correction is 0.3°C to 0.5°C in the troposphere if the lapse rate is dry adiabatic but is ignored in routine operation with the Vaisala sonde.

Care was taken to exclude sequences where the temperature change at a given level fluctuated widely from one 12 G.M.T. ascent to the next so that interpolation errors were reduced. The ascents were all carefully scrutinised and where large changes in temperature occurred from one ascent to another, confirmation was sought by comparison of the 850, 700, 500, 300 and 200 mb temperatures from other stations over southern China made at the same synoptic hour e.g. those at Canton. In this way, gross errors were minimised. "t" tests showed that the three sets of differences from the January, June and July trials were not incompatible. Accordingly all three sets were used to give final differences independent of season. The results of the investigation were given in Table VII. This showed that the corrections applied to the Vaisala sonde had eliminated the day/night differences in general. The levels 100 mb to 80 mb included those where the tropopause was most frequently found in Hong Kong and the large mean difference at 90 mb was probably due to the influence of errors in the indicated pressure from one sounding to the next combined with real variations at the tropopause with resultant interpolation errors. Temperatures at these levels were also obtained from parts of the Vaisala temperature calibration charts that had been extrapolated i.e. where temperatures were less than about -65°C. Since the reduction of day time soundings to equivalent night time soundings is the basis of the Vaisala correction system, it is clear that this had been achieved in the Vaisala results of the trial periods. It should be noted that the non-application of lag correction to the results could only affect this conclusion if the rates of ascent of the sondes varied widely and this was not so. This form of checking was carried out broadly on the Payerne (1956) results by Vaisala (3). However, the lowest temperatures used were about -60°C and within the calibration of the sondes. Hence extrapolation errors may be the main cause of the difference at 100 to 80 mb in this study.

9. Estimate of the absolute errors in the pressure indications of the sondes.

Since the ascents in the January trials were followed by 3 cm radar, an attempt was made to estimate the probable absolute errors in the pressure readings of the sondes. Each radiosonde ascent had already been scrutinised during the course of the calculation to estimate pressure and temperature difference between the sondes. A further filtering was made to eliminate those ascents which had previously been accepted for comparison of radiosonde results but upon which the radar observations were even slightly suspect. There was an automatic check on the ranging of the radar to prevent gross errors. An isolated ground echo has been recorded on a bearing of 238 deg. at a range of 32.02 km on the average over a period of almost 20 years with radars with wavelength near 10 cm as well as one with wavelength near 3 cm. It also corresponds with a feature on the map of small extent (measured radially along the bearing from the radar to the ground feature). This feature was recorded during the January trials at 32.02 km with standard deviation 10 m and, because of the method of ranging used on the wind-finding radar, ranges up to 40 km can be assumed to be set up to this accuracy.*

* Ranges are increased in 10 km steps and ranging in any decade is common to all. Thus the correctness of any range in a decade implies accuracy of the "steps" and ranging accuracy to the end of the decade is guaranteed by the common ranging.

With the probable error in a ranging determination at 50+ metres and elevation readings accurate to 0.1 degree, the probable error in each height determination (corrected for earth's curvature) was computed for each observation used in the comparison and was between 30 and 50 m over the whole field of observations used. The mean value was 40 m. The estimated mb equivalent of this probable error was:-

Pressure level (mb)	850	700	500	300	200	100	80
Probable error (mb)	4	3	3	2	2	1	1

Recordings for the sondes were evaluated to ½ of a scale unit in the case of the Kew sonde and to 1/10 of a scale unit for the Vaisala sonde the scale units being dissimilar. From the average sensitivity of the pressure curves one was led to expect probable errors in a pressure determination as follows, assuming no calibration errors:-

Pressure level (mb)	850	700	500	300	200	100	80
Kew (mb)	0.8	0.6	0.6	0.5	0.4	0.3	0.3
Vaisala (mb)	0.3	0.3	0.3	0.2	0.2	0.2	0.2

It was clear that the probable error in the difference between either radiosonde pressure value and those from the radar were predominantly those due to the probable errors in the radar observations. If calibrations were accurate to 1 mb in each case, then the probable error in the difference (Kew pressure minus Vaisala pressure) was estimated to be:-

Pressure level (mb)	850	700	500	300	200	100	80
Kew-Vaisala (mb)	1.3	1.3	1.3	1.1	1.1	1.1	1.1

The differences (Kew sonde pressure reading minus radar derived pressure) were obtained at every even minute on the selected ascents. These differences were analysed into the same pressure intervals as were used in the investigation discussed in Section 6 above. The mean and standard deviation for the differences in each interval were then obtained. A

\+ Some authorities give the probable ranging error with the WF 2 as 10 m. This is probably correct if a separate operator is used for ranging. In these trials a single operator was used for range, elevation and azimuth readings and range was only accurately adjusted in the last few moments before the end of a minute. The probable error in a ranging determination at a given time is larger than 10 m with this system and was estimated as having a probable error of 50 m.

similar analysis was carried out with the differences between the Vaisala sonde pressure readings and the radar derived pressures. The pressure differences between the two sondes using the same sample of ascents were also found. The latter was considered necessary as the sample used in this investigation was only part of that used previously in the investigation of the pressure differences between the sondes in Section 6. The results are shown in the final six columns of Table V.

"t" tests were carried out to find out whether the results in the various columns of means in Table V could belong to normal populations with means zero, the estimate of standard deviation being that corresponding to the observed mean being investigated and the 5% level being taken as significant. For example, the mean obtained in column 2 for the 565 mb level (-3.5) would be obtained from a normal population with mean zero and standard deviation 6.9 mb with less than 5% probability. All cases similar to this were underlined in the columns of means in the table.

Taking the results of columns 2 and 3 first of all, it was clear that considerable random errors had occurred in the results. This was shown by standard deviations in the differences obtained which were considerably larger than 1.1 to 1.3 mb which was to be expected. However the mean differences were taken as representative. They could not, in general, have belonged to a population with zero mean at each individual pressure level. The differences were maximum at pressure levels near the tropopause and in the lower stratosphere.

The results from the smaller sample of ascents selected for comparison with radar results showed the same trend. The fact that the means from this sample (given in column 4 of Table V) could have been derived from populations with mean zero at each individual pressure level was regarded as fortuitous in the light of the results in column 2. A certain bias in this sample could have been expected. Consideration of the 90% fiducial limits of the means in column 2 showed that the means in column 4 did not lie within these limits at pressure levels from 618 mb to 207 mb. Outside this pressure range the sonde pressure results were treated as unbiased. It also followed that outside this range, the differences (in columns 6 and 8) between the sonde pressure readings and derived pressure derived from radar readings were representative estimates of the sonde pressure sensor errors. However, at pressures less than 100 mb the results in columns 6 and 8 were based on relatively few cases. When all the results for pressures in the interval 100 to 45 mb inclusive were meaned the following results were obtained:-

	Jan, June & July	Selected Cases		
Approximate Pressure Level (mb)	Direct Comparison Kew-Vaisala (mb)	Direct Comparison Kew-Vaisala (mb)	Kew-Radar (mb)	Vaisala -Radar (mb)
65	-4.7	-5.1	-6.0	-1.5

and these were consistent within small limits. These **means** were therefore taken as representative of the differences at about 65 mb.

Between 618 mb and 100 mb the means from the small sample (column 4) were generally greater (algebraically) than the corresponding figure for the larger sample (column 2). Such a bias was more likely to be associated with a batch of one sonde than to be due to bias in both. If it was assumed that this was so, then either the differences Kew-Radar should have been amended and the difference Vaisala-Radar left alone the correction at each level being the difference in the means in column 2 and 4, or the Vaisala-Radar figure should have been amended and the Kew-Radar figures left alone. In this way the limits of the differences in column 6 and 8 of Table V were assessed. These newly assessed differences were consolidated into Table X and constitute an estimate of the errors of the sonde pressure sensors. It was considered that the first alternative above was more likely in view of the large corrections applied to the Kew sonde pressure readings and the fit of the estimated errors at 65 mb. The arrangement of Table X reflected this view. In reaching this conclusion it was noted that the residual differences for the Kew sonde were only some 20% of the total correction applied to the pressure sensor readings during calculation. The corrections were of the order of 20 to 40 mb at pressures less than 200 mbs. It was also noted that the corrections to the pressure sensor readings on the Vaisala sonde were small at low pressures and were obtained by interpolation between two pressure calibration curves, one obtained with the temperature at +20°C and the other with the temperature at -60°C. On a considerable part of the ascents used in this study temperatures were less than -60°C. Pressures for these parts of the Vaisala results were obtained from the calibration curves for -60°C. However at the low pressure end of the two pressure calibration curves the differences between them was only of the order of 1 mb and the error introduced in the Vaisala pressure was considered to be negligible.

10. <u>Summary</u>

The differences in temperature, geopotential and relative humidity, assigned to given pressure levels by Kew Mk IIB and Vaisala RS 13 radiosondes flown on the same balloon under routine operational conditions in daylight have been investigated. Trials were carried out in January, June and July, 1969 with solar angles between 15 and 35 degrees. It has been shown that differences in mean temperature of the following order can be expected, the temperature given by the Vaisala sonde being usually higher than that given by the Kew sonde:-

$<\frac{1}{2}$°C at pressures greater than 500 mb
$\frac{1}{2}$°C at pressures 500 - 250 mb
1°C at pressures 249 - 175 mb
$1\frac{1}{2}$°C at pressure 174 - 100 mb
2° - 4°C at pressures 99 - 50 mb

The major part of these differences can be attributed to temperature sensor differences below the tropopause level (about 90 mb) but at pressures less than this the pressure sensor differences make an appreciable contribution to the difference in the temperatures assigned to the (indicated) pressure levels. These results apply to the normal operational case when lag and radiation corrections are applied to the Kew sonde and radiation corrections alone are applied to the Vaisala sondes.

Application of "t" tests to the differences in relative humidity obtained on the trials showed that they were not members of the same population at the 700, 350 and 300 mb levels. Scrutiny of the individual results showed that the January figures were heavily biased by the results of soundings on three days where large differences of the order of 25% were obtained. No mistakes were found in the computation so that it was accepted that occasional differences of this magnitude could occur. When these results were rejected the figures from the two trials were compatible and that the differences to the expected in the means of routine soundings were found to be

2% or less from surface to 600 mb
3½% or less up to 250 mb,
the Kew sonde value being the lower.

The differences in the means of the geopotential (reflecting the differences in mean virtual temperature) were

10 m or less from surface to 500 mb
50 m or less up to 200 mb
100 m or less up to 90 mb, and
150 m or less up to 40 mb
with the value from the Kew sonde usually lower than that of the Vaisala value.

In the course of the investigation it was established that:-

(i) differences in temperature at given pressure levels obtained with Vaisala sondes in daylight to which standard temperature corrections had been applied, and corresponding values obtained in darkness were small.

(ii) from comparison with simultaneous radar readings both the Kew sonde and the Vaisala sonde appeared to indicate pressures which were too low at pressures less than 400 mb. The Kew sonde readings were 6 mb low in the lower stratosphere and the Vaisala reading 1½ mb low in the same region. For ascents in the tropics the Vaisala low temperature pressure calibration should ideally be carried out at -85°C rather than -60°C to enable proper corrections to be applied to pressure readings at and near the tropopause levels. However errors due to using the calibration curve taken at -60°C at the temperatures lower than this which are likely to occur in the upper troposphere and lower stratosphere are only of the order of 1 mb.

(iii) the differences in temperature obtained from the two sondes when at the same height (determined independently of the pressures indication) was different when the temperature in the environment was increasing with pressure from those when the temperature was decreasing with pressure. This suggested that the lag corrections needed modification. No lag corrections were applied to the Vaisala results. That modifications to the lag corrections for the Kew sonde are necessary has already been suggested (Apps, 1,2). Successive applications to the results of column 14 and 16 of Table IV of (a) Vaisala lag corrections and (b) modified Kew lag corrections to the results of (a) are given in columns 2 and 3 of Table VIII respectively.

Similar manipulation of column 10 of Table VI gives the results in Table IX. The extrapolation of the Vaisala temperature calibration curves to temperatures less than -65°C should not be necessary and is believed to be a significant cause of the temperature differences observed in temperatures ranging down to -85°C. It was clear that this shortcoming would not have been noted in previous radiosonde comparison trials since the latter were held under conditions where these low temperatures were not reached.

11. Acknowledgements

I have to thank the staff of the Upper Air Section of the Royal Observatory for carrying out the observations which form the basis of this paper and Mr. Lo Yu Ying for supervising the programme and carrying out much of the basic calculation. Statistical work on the results was done by Messrs. S. Cheng and Leong Hao Chung and members of the Climatology Section.

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TABLE I. 1 Temperatures (°C) at indicated Pressure Levels

JANUARY

Pressure (mb)	5-year(1964-1968) Mean °C	5-year(1964-1968) Standard Deviation °C	Kew Mean °C	Kew Standard Deviation °C	Vaisala Mean °C	Vaisala Standard Deviation °C	Kew-Vaisala Mean °C/ Cases	Kew-Vaisala Standard Deviation °C
1000			15.9	4.0	15.9	3.9	0.0(16)	0.2
950			14.4	4.3	14.2	4.3	+0.1(16)	0.8
900			13.4	3.4	13.3	3.6	+0.1(16)	0.6
850	9.5	1.0	12.5	3.5	12.4	3.6	+0.1(16)	0.7
800			10.3	2.8	10.1	3.2	+0.1(16)	0.8
700	4.1	1.0	5.9	2.0	5.7	1.9	+0.2(16)	1.1
600			-0.3	2.3	0.0	2.2	-0.3(16)	0.6
500	-8.4	1.1	-9.4	2.6	-8.9	2.4	-0.5(16)	0.9
400			-20.9	2.6	-20.5	2.5	-0.3(16)	0.8
350			-27.7	2.5	-26.8	2.5	-0.9(16)	0.9
300	-32.7	1.0	-35.0	2.6	-34.3	2.6	-0.7(16)	0.7
250			-44.2	2.0	-43.1	2.1	-1.1(15)	0.8
200	-53.8	0.9	-55.0	1.6	-53.3	1.7	-1.6(15)	0.7
175			-60.6	1.8	-59.3	2.0	-1.1(14)	1.2
150	-66.9	0.9	-66.3	1.9	-64.7	2.2	-1.6(14)	1.2
125			-71.8	2.9	-70.7	2.8	-1.1(13)	0.7
100	-79.1	2.2	-77.3	2.7	-76.8	2.5	-0.5(12)	1.2
90			-79.4	2.4	-77.9	2.1	-1.5(12)	1.6
80	-79.4	1.9	-80.5	2.7	-77.6	2.0	-2.9(12)	2.4
70			-78.9	3.6	-74.7	3.3	-4.2(12)	4.0
60			-75.1	4.1	-70.6	3.1	-4.1(8)	5.1
50	-64.1		-68.6	4.7	-63.4	1.0	-4.1(4)	3.8
40			-64.4	3.9	-61.2	0.8	-3.2(3)	3.7
30			-62.5	2.1	-58.8	1.8	-3.7(2)	0.4
20			(-63.0)		(-59.6)		(-3.4)	

TABLE I.2 Geopotential (m.) at indicated Pressure Levels

JANUARY

Pressure (mb)	5-year(1964-1968) Mean (m.)	5-year(1964-1968) Standard Deviation (m.)	Kew Mean (m.)	Kew Standard Deviation (m.)	Vaisala Mean (m.)	Vaisala Standard Deviation (m.)	Kew-Vaisala Mean (m.)/ Cases	Kew-Vaisala Standard Deviation (m.)
1000			144.3	35.4	144.3	35.2	0.0(16)	0.7
950			581.0	30.7	586.9	27.3	-5.9(16)	10.2
900			1037.6	23.4	1052.8	23.2	-15.2(16)	9.9
850	1536	9.8	1519.9	19.2	1518.3	18.4	+ 1.7(16)	6.8
800			2028.4	16.0	2040.9	15.5	-12.5(16)	9.0
700	3133	16.5	3128.9	14.8	3125.0	14.4	+ 3.9(16)	6.0
600			4376.7	18.9	4373.9	17.4	+ 2.8(16)	8.0
500	5812	29.0	5813.6	32.3	5810.3	25.8	+ 3.3(16)	16.1
400			7504.2	44.0	7500.3	35.9	+ 3.9(16)	26.3
350			8467.8	49.6	8485.6	45.0	-17.8(16)	25.8
300	9599	38.3	9566.8	56.9	9573.2	48.0	- 6.4(16)	23.5
250			10827.7	37.5	10838.6	36.7	-10.9(16)	23.1
200	12332	37.6	12287.8	44.0	12306.9	44.1	-19.1(15)	29.5
175			13126.0	42.7	13158.0	48.1	-32.0(15)	34.5
150			14077.5	47.8	14113.0	48.3	-30.9(14)	28.5
125			15172.9	35.2	15222.9	47.8	-50.0(14)	38.4
100	16496	34.8	16473.7	31.8	16515.6	44.5	-42.2(12)	31.2
90			17074.5	29.7	17140.7	50.5	-65.8(12)	36.8
80	17762	39.6	17740.2	31.4	17814.6	50.7	-74.3(12)	40.3
70			18494.5	36.3	18562.4	48.7	-67.9(12)	41.0
60			19378.7	43.2	19502.9	59.6	-115.7(7)	67.9
50	20516	55.9	20464.8	75.7	20551.5	29.3	-79.0(4)	92.3
40			21853.0	116.5	21986.7	23.1	-133.7(3)	100.2
30			23544.5	60.1	23700.0	15.6	-155.5(2)	44.6
20			(25992.0)		(26221.0)		(-229.0)	

TABLE I.3 Relative Humidity (%) at indicated Pressure Levels

JANUARY

Pressure (mb)	5-year(1964-1968) Mean %	5-year(1964-1968) Standard Deviation %	Kew Mean %	Kew Standard Deviation %	Vaisala Mean %	Vaisala Standard Deviation %	Kew-Vaisala Mean % / Cases	Kew-Vaisala Standard Deviation %
1000			89.3	10.4	89.2	10.2	+0.1(16)	1.7
950			87.8	8.7	88.9	6.5	-1.1(16)	6.8
900			83.9	7.1	84.1	7.2	-0.2(16)	10.5
850	69	8.7	69.1	19.8	69.6	21.6	-0.5(16)	8.6
800			65.4	18.4	65.6	17.6	-0.3(16)	6.3
700	49	10.6	43.3	29.8	48.9	26.1	-5.7(16)	13.1
600			20.2	22.0	23.2	28.9	-2.9(16)	6.8
500	21	9.1	18.4	20.6	23.7	20.5	-5.2(16)	5.9
400	17	7.1	21.9	22.1	27.6	22.0	-5.8(16)	8.8
350			25.9	23.6	31.6	23.8	-5.6(14)	7.4
300			27.1	19.9	32.4	21.8	-5.3(12)	9.6
250			29.0	15.6	34.6	14.5	-5.6(9)	11.8

TABLE I.4 Temperature (°C) at indicated Pressure Levels

	JUNE		JUNE/JULY					
			Kew		Vaisala		Kew-Vaisala	
	5-year(1964-1968)							
Pressure (mb)	Mean °C	Standard Deviation °C	Mean °C	Standard Deviation °C	Mean °C	Standard Deviation °C	Mean °C/ Cases	Standard Deviation °C
1000			26.1	2.4	26.2	2.3	-0.1(14)	0.2
950			23.0	1.7	23.2	1.7	-0.1(27)	0.7
900			20.9	1.1	21.1	1.2	-0.1(27)	0.7
850	17.7	0.2	18.5	1.0	18.8	1.2	-0.2(27)	0.9
800			16.0	1.0	16.4	1.1	-0.3(27)	0.8
700	9.8	1.3	11.2	1.0	11.5	1.1	-0.4(27)	0.7
600			4.2	1.1	4.8	0.8	-0.6(27)	1.0
500	-4.4	0.6	-3.8	0.8	-3.3	0.7	-0.5(27)	0.9
400			-14.0	1.2	-13.3	1.0	-0.7(27)	1.0
350			-20.7	1.3	-19.7	1.0	-1.0(27)	1.2
300	-28.6	0.7	-28.3	1.3	-27.2	1.2	-1.0(27)	1.4
250			-38.3	1.2	-37.3	1.2	-1.1(27)	1.5
200	-50.6	1.4	-51.1	1.1	-49.1	1.8	-2.0(27)	1.9
175			-58.2	1.4	-55.8	1.7	-2.4(27)	2.0
150	-65.2	0.9	-66.3	1.7	-63.1	1.7	-3.2(23)	2.4
125			-74.6	2.0	-71.3	1.6	-3.2(20)	2.4
100	-78.5	1.4	-80.7	2.1	-76.9	1.3	-3.8(19)	1.6
90			-81.8	2.2	-78.1	1.3	-3.7(15)	1.5
80	-78.7	1.9	-82.0	2.3	-77.7	2.1	-4.3(10)	2.5
70			-78.3	4.3	-73.8	3.7	-4.5(5)	4.1
60			-71.3	4.2	-71.0	6.9	-0.3(2)	2.7
50	-64.2		(-66.4)		(-71.9)		(-5.5)	

TABLE I.5 - Geopotential (m.) at indicated Pressure Levels

	JUNE		JUNE/JULY					
			Kew		Vaisala		Kew Vaisala	
	5-year(1964-1968)							
Pressure (mb)	Mean (m.)	Standard Deviation (m.)	Mean (m.)	Standard Deviation (m.)	Mean (m.)	Standard Deviation (m.)	Mean (m.)/ Cases	Standard Deviation (m.)
1000			64.6	14.4	64.6	14.3	0.0(27)	0.2
950			516.8	14.2	522.3	15.6	-5.5(27)	7.7
900			987.8	13.6	997.4	13.7	-9.6(27)	9.2
850	1476	9.1	1481.8	13.7	1482.6	13.5	-0.9(27)	3.9
800			2000.4	13.9	2014.1	18.2	-13.6(27)	12.0
700	3119	10.0	3130.4	20.3	3132.2	14.2	- 1.8(27)	16.3
600			4403.6	22.3	4408.3	15.4	- 4.7(27)	18.4
500	5848	6.7	5866.2	24.7	5874.3	17.5	- 8.1(27)	20.9
400			7595.4	25.9	7608.6	19.6	-13.2(27)	23.2
350			8584.3	28.3	9623.7	21.3	-39.4(27)	25.4
300	9702	13.1	9719.6	28.8	9742.4	23.6	-22.7(27)	29.3
250			11000.8	31.5	11027.6	26.3	-26.7(27)	32.8
200	12477	22.5	12494.1	36.5	12531.1	33.1	-37.1(27)	42.5
175			13341.1	44.7	13396.1	36.1	-55.0(26)	55.4
150			14301.1	46.4	14360.1	43.2	-59.0(24)	59.6
125			15378.2	53.6	15458.2	47.5	-80.0(22)	67.5
100	16667	28.3	16658.8	61.9	16748.4	56.3	-89.5(19)	80.3
90			17257.0	64.4	17367.1	69.9	-110.1(17)	104.7
80	17938	27.7	17921.9	80.4	18062.2	39.7	-140.3(10)	97.5
70			18679.6	24.3	18816.2	36.4	-136.6(5)	48.7
60			19596.0	29.7	19730.0	99.0	-134.0(2)	69.3
50	20726	51.3	20685.5	34.7	20790.0	127.3	-104.5(2)	92.6

TABLE I.6 - Relative Humidity at indicated Pressure Levels

JUNE/JULY

Pressure (mb)	5-year(1964-1968) Mean %	5-year(1964-1968) Standard Deviation %	Kew Mean %	Kew Standard Deviation %	Vaisala Mean %	Vaisala Standard Deviation %	Kew-Vaisala Mean % / Cases	Kew-Vaisala Standard Deviation %
1000			88.4	5.7	87.9	5.5	+0.5(13)	1.3
950			86.8	9.4	88.1	8.7	-1.3(26)	7.3
900			80.4	17.2	81.0	16.6	-0.6(26)	7.6
850	82	3.9	80.3	14.4	80.0	18.1	+0.3(26)	8.6
800			78.8	9.8	79.3	11.5	-0.5(26)	7.1
700	69	5.8	69.5	12.1	68.2	14.6	+1.3(26)	7.6
600			59.9	17.3	60.2	19.9	-0.2(26)	7.1
500	59	8.0	47.3	17.6	48.8	20.7	-1.5(26)	9.0
400	50	7.1	43.8	14.9	44.4	15.6	-0.6(26)	8.3
350			42.3	16.0	42.4	15.9	-0.1(25)	8.3
300			37.3	13.2	36.0	13.3	+1.3(25)	8.6
250			34.5	13.3	35.4	15.2	-0.9(23)	8.9

TABLE II

Temperature Differences (Kew-Vaisala) at indicated Pressure Levels - Results of "t" test on the results of the two trials

Pressure (mb)	1000	950	900	850	800	700	600	500		
$\lvert t \rvert$	1.38	0.98	0.99	1.11	1.71	1.93	1.81	1.71		
Degrees of freedom	28	41	41	41	41	41	41	41		
Pressure (mb)	**400**	**350**	**300**	**250**	**200**	**175**	**150**	**125**	**100**	**90**
$\lvert t \rvert$	1.40	0.43	0.78	0.00	0.79	<u>2.25</u>	<u>2.35</u>	<u>3.11</u>	<u>6.33</u>	<u>3.75</u>
Degrees of freedom	41	41	41	41	40	39	35	31	29	25
Pressure (mb)	**80**	**70**	**60**	**50**						
$\lvert t \rvert$	1.37	0.13	0.97	2.24						
Degrees of freedom	20	15	8	3						

Values of $\lvert t \rvert$ underlined exceeded those which would be obtained with probability 5% in random sampling from a normal population and were therefore significant.

TABLE III

Estimate of the maximum error in temperature difference between the sondes at the same level due to oscillation of one sonde suspended below the other

	Pressure (mb)	850	700	500	300	200	150	100	80
$\frac{\Delta T}{\Delta P}$ (°C/mb)	Jan.	.03	.05	.10	.17	.22	.23	.22	-.02
	June	.05	.06	.09	.19	.26	.30	.12	-.02
	1 mb equivalent (m)	10	12	16	24	33	41	60	70
Modulus of max. error in difference in temperature	Jan.	.07	.11	.15	.18	.17	.14	.09	.01
	June	.12	.13	.14	.20	.20	.18	.05	.01

This error arose from the assumption that the Vaisala sonde remained 25 m vertically below the Kew sonde at all times.

TABLE IV   Temperature differences /Kew-Vaisala/ at the same temperature

	JANUARY						JUNE/JULY						JANUARY, JUNE & JULY				"t" TESTS					
	All Cases		Temp. Incr. with pressure		Temp. Decr. with pressure		All Cases		Temp. Incr. with pressure		Temp. Decr. with pressure		Temp. Incr. with pressure		Temp. Decr. with pressure		All Cases		Temp. Inc. with pressure		Temp. Decr. with pressure	
	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Mean °C	Cases/ Stand. Dev. °C	Deg. of free -dom	|t|	Deg. of free -dom	|t|	Deg. of free -dom	|t|
27½							+2.1	1 / -					+2.1	1 / -								
22½							+0.1	23 / 0.7					+0.1	23 / 0.7								
17½	-0.2	12 / 0.7	-0.2	10 / 0.5	-0.3	2 / 0.1	-0.1	45 / 0.6					-0.1	55 / 0.6	-0.3	2 / 0.1	55	0.7	53	0.6	-	-
12½	-0.5	20 / 0.5	-0.4	15 / 0.2	-0.6	5 / 0.3	-0.1	34 / 0.7					-0.2	49 / 0.5	-0.6	5 / 0.3	52	<u>2.2</u>	47	1.9	-	-
7½	-0.2	30 / 0.7	-0.3	19 / 0.2	-0.1	11 / 0.7	-0.3	30 / 0.7					-0.3	49 / 0.4	-0.1	11 / 0.7	58	0.8	47	0.3	-	-
2½	-0.3	24 / 0.7	-0.4	18 / 0.6	+0.1	6 / 0.3	-0.4	25 / 0.7					-0.4	43 / 0.7	+0.1	6 / 0.3	47	0.4	41	0.3		
-2½	-0.2	16 / 0.7					-0.2	30 / 0.7					-0.2	46 / 0.7			44	0.1				
-7½	-0.5	15 / 0.6					-0.7	24 / 0.7					-0.6	39 / 0.7			37	1.0				
-12½	-0.4	16 / 0.8					-0.6	27 / 0.8					-0.5	43 / 0.8			41	0.7				
-17½	-0.4	14 / 0.5					-0.8	22 / 0.7					-0.6	36 / 0.7			34	1.8				
-22½	-0.7	16 / 0.6					-0.6	19 / 0.7					-0.6	35 / 0.6			33	0.3				
-27½	-0.8	14 / 0.8					-1.0	13 / 0.7					-0.9	27 / 0.7			25	0.9				
-32½	-0.9	13 / 0.5					-1.2	20 / 0.7					-1.1	33 / 0.6			31	1.4				
-37½	-1.2	13 / 0.8					-0.9	16 / 0.6					-1.0	29 / 0.7			27	1.4				
-42½	-0.6	8 / 0.9					-1.2	14 / 0.8					-1.0	22 / 0.9			20	1.5				
-47½	-1.6	11 / 0.9					-1.5	17 / 0.9					-1.5	28 / 0.9			16	0.5				
-52½	-1.5	10 / 0.8					-1.4	12 / 0.6					-1.4	22 / 0.7			20	0.5				
-57½	-1.1	16 / 1.8	-2.0	12 / 1.0	+1.6	4 / 1.0	-1.5	18 / 1.0	-1.6	17 / 1.0	+0.2	1	-1.8	29 / 1.0	+1.3	5 / 1.1	32	0.8	27	1.1	3	1.3
-62½	-2.2	17 / 1.4	-2.4	11 / 1.0	-1.8	6 / 2.1	-1.4	12 / 1.2	-1.9	9 / 0.7	+0.1	3 / 1.4	-2.2	20 / 0.9	-1.2	9 / 2.0	27	1.8	18	1.2	7	1.4
-67½	-2.1	20 / 2.1	-2.8	15 / 1.3	0.0	5 / 2.7	-2.6	15 / 1.7	-2.7	14 / 1.7	-1.2	1	-2.8	29 / 1.5	-0.2	6 / 2.5	33	0.8	27	0.3	4	0.4
-72½	-2.0	22 / 2.1	-3.2	11 / 1.2	-0.3	11 / 2.0	-1.7	21 / 2.0	-2.4	16 / 1.8	+0.5	5 / 1.0	-2.7	27 / 1.6	-0.4	16 / 1.8	41	0.5	25	1.4	14	1.4
-77½	-2.6	29 / 1.8	-3.0	20 / 1.9	-1.7	9 / 1.6	-1.4	38 / 1.7	-2.5	16 / 1.4	-0.6	22 / 1.4	-2.8	36 / 1.7	-0.9	31 / 1.6	65	<u>2.9</u>	34	0.9	29	1.9
-82½	-3.5	16 / 1.4	-3.8	11 / 1.5	-2.8	5 / 1.0	-2.6	5 / 1.1	-3.5	2 / 1.1	-2.0	3 / 0.8	-3.7	19 / 1.4	-2.5	8 / 1.0	19	1.3	11	0.3	6	1.2

Values of |t| underlined exceeded those which would be obtained with probability 5% in random sampling and were therefore significant.

TABLE V

PRESSURE DIFFERENCES

(JANUARY, JUNE & JULY)

1969

	DIRECT COMPARISON		DIRECT COMPARISON (SELECTED CASES)		COMPARISON WITH RADAR (SELECTED CASES)			
	Kew-Vaisala		Kew-Vaisala		Kew-Radar		Vaisala-Radar	
Pressure (mb)	Mean and 90% Fiducial Range (mb)/Cases	Standard Deviation mb.	Mean mb/ Cases	Standard Deviation mb.	Mean mb/ Cases	Standard Deviation mb.	Mean mb/ Cases	Standard Deviation mb.
914	-1.2 ±1.8(37)	6.6	-0.7(14)	4.8	-1.3(14)	6.9	-0.7(14)	7.5
836	-2.9 ±1.9(38)	7.0	-1.6(16)	4.9	-1.1(16)	5.1	+0.4(16)	6.8
762	-2.8 ±1.8(39)	6.9	-2.8(17)	5.8	-1.9(17)	4.9	+1.7(17)	7.1
691	-1.6 ±1.6(36)	6.2	-1.3(15)	6.5	-1.1(15)	4.9	+0.2(15)	5.3
618	-3.4 ±2.0(35)	7.0	-1.1(15)	4.4	-0.4(15)	4.0	+0.7(15)	5.1
565	-3.5 ±2.0(34)	6.9	-0.8(13)	5.0	-1.5(15)	5.7	+0.7(13)	5.2
507	-3.8 ±1.6(33)	5.5	-1.4(13)	6.2	-1.0(14)	5.0	+0.8(13)	4.4
454	-2.8 ±1.5(34)	5.3	-1.2(12)	4.6	-0.4(13)	4.1	0.0(12)	4.3
407	-3.3 ±1.7(34)	5.9	+0.6(12)	7.1	-0.8(12)	5.1	-1.4(12)	5.4
360	-2.1 ±1.7(34)	5.9	+1.3(13)	6.5	-0.5(13)	4.0	-1.2(13)	5.9
317	-3.1 ±2.0(29)	6.4	+0.3(11)	6.1	-1.1(11)	5.0	-1.4(11)	3.3
277	-1.0 ±1.4(44)	5.5	-0.1(12)	4.1	-3.8(12)	4.4	-3.7(12)	3.0
240	-1.5 ±1.8(33)	6.2	+2.4(8)	6.1	-2.7(8)	3.3	-5.1(8)	4.3
207	-1.5 ±1.5(31)	4.9	+0.7(9)	4.1	-3.2(9)	2.1	-3.7(9)	2.5
178	-1.4 ±1.5(31)	5.0	+0.1(6)	5.3	-4.6(6)	2.5	-5.0(7)	3.3
149	-2.1 ±1.7(35)	6.3	-0.6(9)	6.8	-6.8(9)	3.6	-5.5(11)	4.8
122	-2.2 ±2.0(35)	6.9	-3.5(4)	8.1	-6.5(4)	4.8	-4.0(7)	3.1
100	-3.9 ±1.9(33)	6.6	-1.5(6)	6.9	-4.7(6)	3.7	-4.0(8)	4.4
85	-5.0 ±2.2(25)	6.5	-6.6(2)	14.1	-7.6(2)	9.9	-1.7(3)	3.2
75	-4.9 ±2.7(17)	6.4	-7.1(3)	8.7	-7.4(3)	7.6	-3.8(5)	5.3
65	-5.1 ±2.3(19)	5.7	-7.1(5)	4.9	-6.3(5)	5.6	-0.3(7)	3.3
55	-3.1 ±2.9(10)	5.0	-1.3(3)	5.2	-3.3(3)	3.5	-1.0(5)	1.9
45	-5.4 ±7.2(5)	8.0	-6.2(2)	9.9	-6.7(2)	6.4	-1.0(3)	2.7
35	-1.7 ±2.6(4)	2.4						
25	-0.5 ±1.8(4)	1.7						
15	-1.0 (1)	-						

When a "t" test was applied to the means in the above table to ascertain whether they could have been obtained from a normal population of mean zero the entries underlined gave values of |t| which exceeded those which would have been obtained with probability 5% in random sampling.

TABLE VI Estimated temperature differences at indicated pressure levels.

	JANUARY				JUNE/JULY				
Pressure (mb)	Temp. Diff. °C	Temp.Diff. (Press term) °C	Sum °C	Observed Diff. °C	Temp. Diff. °C	Temp. Diff. (Press term) °C	Sum °C	Observed Diff °C	Mean of Cols 4 and 8 °C
1000	-0.1			0.0	+2.1			-0.1	-
950	-0.4	0.0	-0.4	+0.1	+0.1	+0.1	+0.2	-0.1	-0.1
900	-0.4	0.0	-0.4	+0.1	+0.1	+0.1	+0.2	-0.1	-0.1
850	-0.5	0.0	-0.5	+0.1	-0.1	+0.2	+0.1	-0.2	-0.2
800	-0.3	+0.1	-0.2	+0.1	-0.1	+0.2	+0.2	-0.3	0.0
700	-0.2	+0.2	0.0	+0.2	-0.1	+0.2	+0.1	-0.4	+0.1
600	-0.2	+0.2	0.0	-0.3	-0.3	+0.3	0.0	-0.6	0.0
500	-0.5	+0.3	-0.2	-0.5	-0.3	+0.4	+0.1	-0.5	-0.1
400	-0.6	+0.2	-0.4	-0.3	-0.6	+0.5	-0.1	-0.7	-0.3
350	-0.8	0.0	-0.8	-0.9	-0.6	+0.5	-0.1	-1.0	-0.5
300	-1.0	+0.1	-0.9	-0.7	-1.0	+0.7	-0.3	-1.0	-0.6
250	-0.9	+0.1	-0.8	-1.1	-1.0	+0.5	-0.5	-1.1	-0.7
200	-1.3	+0.3	-1.0	-1.6	-1.4	+0.5	-0.9	-2.0	-0.9
175	-1.6	+0.5	-1.1	-1.1	-1.5	+0.3	-1.2	-2.4	-1.1
150	2.1	+0.6	-1.5	-1.6	-2.4	+0.6	-1.8	-3.2	-1.7
125	-2.0	+0.7	-1.3	-1.1	-1.5	+0.5	-1.0	-3.2	-1.1
100	-2.6	+1.2	-1.4	-0.5	-2.0	+0.3	-1.7	-3.8	-1.5
90	-3.0	+0.9	-2.1	-1.5	-2.5	+0.2	-2.3	-3.7	-2.2
80	-3.1	-0.3	-3.4	-2.9	-2.6	-0.1	-2.7	-4.3	-3.1
70	-2.8	-1.8	-4.6	-4.2	-1.7	-1.3	-3.0	-4.5	-3.8
60	-2.3	-2.8	-5.1	-4.1	-1.9	+0.6	-1.3	-0.3	-3.2
50	-2.1	-1.7	-3.8	-4.1	-2.4	-2.0	-4.4		-4.1
40	-2.2	-1.1	-3.3	-3.2					(-3.3)
30	-2.2	-0.4	-2.6	-3.7					(-2.6)

TABLE VII

Comparison between nighttime & daytime ascents - Vaisala sonde

JANUARY, JUNE AND JULY 1969

Pressure (mb)	Mean Temp. Diff. (Day - Night) °C/Cases	Standard Deviation °C
700	-0.5(68)	1.0
600	-0.4(73)	1.1
500	-0.3(68)	1.3
400	-0.2(54)	1.3
300	-0.3(41)	0.9
250	-0.5(48)	1.6
200	0.0(41)	1.7
150	-0.1(45)	1.5
100	+0.2(24)	1.5
90	-0.8(19)	1.3
80	-0.4(12)	1.5
70	-0.2(6)	3.0
60	-2.1(1)	-

TABLE VIII

Temperature differences /Kew-Vaisala/ at the same temperature corrected for (a) Vaisala lag and (b) then adjusted for modified Kew lag correction.

JANUARY, JUNE AND JULY

Indicated Temperature °C	Temperature /Increasing with Pressure/ Corrected for Vaisala lag °C	With adjusted Kew lag correction °C
27½	(+2.4)	(+2.5)
22½	+0.4	+0.5
17½	+0.2	+0.3
12½	+0.1	+0.2
7½	0.0	+0.1
2½	-0.1	0.0
-2½	+0.2	+0.3
-7½	-0.2	0.0
-12½	-0.1	+0.1
-17½	-0.2	0.0
-22½	-0.2	0.0
-27½	-0.5	-0.3
-32½	-0.7	-0.5
-37½	-0.6	-0.3
-42½	-0.6	-0.3
-47½	-1.1	-0.8
-52½	-1.0	-0.7
-57½	-1.4	-1.1
-62½	-1.7	-1.3
-67½	-2.3	-1.9
-72½	-2.2	-1.7
-77½	-2.3	-1.7
-82½	-3.2	-2.6

TABLE IX

Temperature differences /Kew-Vaisala/ at the same indicated pressure level, corrected (a) for Vaisala lag and (b) then adjusted for modified Kew lag correction.

JANUARY, JUNE AND JULY

Pressure (mb)	Corrected for Vaisala lag (°C)	With adjusted Kew lag correction (°C)
1000	-	-
950	+0.2	(+0.3)
900	+0.2	+0.3
850	+0.1	+0.2
800	+0.3	+0.4
700	+0.4	+0.5
600	+0.3	+0.4
500	+0.3	+0.5
400	+0.1	+0.3
350	-0.1	+0.1
300	-0.2	0.0
250	-0.3	0.0
200	-0.5	-0.2
175	-0.7	-0.3
150	-1.2	-0.8
125	-0.6	0.0
100	-1.0	-0.4
90	-1.7	-1.1

TABLE X

Estimates of the difference between radiosonde pressure indications and pressures derived from radar observations

Pressure (mb)	Kew-Radar (mb)	Vaisala-Radar (mb)
914	-1.3	-0.7
836	-1.1	+0.4
762	-1.9	+1.7
691	-1.1	+0.2
618	-0.4 to -2.7	+3.0 to +0.7
565	-1.5 to -4.2	+3.4 to +0.7
507	-1.0 to -3.4	+3.2 to +0.8
454	-0.4 to -2.0	+1.6 to 0.0
407	-0.8 to -4.7	-1.4 to -2.5
360	-0.5 to -3.9	-1.2 to -2.2
317	-1.1 to -4.5	-1.4 to -3.0
277	-3.8 to -4.7	-2.8 to -3.7
240	-2.7 to -6.6	-1.2 to -5.1
207	-3.2 to -5.4	-0.5 to -3.7
178	-4.6 to -6.1	-3.5 to -5.0
149	-6.3 to -8.3	-4.0 to -5.5
122	-5.2 to -6.5	-4.0 to -5.3
200	-4.7 to -7.1	-1.6 to -4.0
85	(	(
75	(	(
65	(-6.0	(-1.5
55	(	(
45	(	(

Columns 2 and 3 constitute an estimate of sonde pressure sensor errors after routine correction procedures have been applied.