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OFFICE NOTE 374

RADIATION ERROR CORRECTION PROCEDURE

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members

OFFICE NOTE #374- RADCOR91- The New Radiosonde Radiation Error Correction Procedure

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INTRODUCTION

The compatibility of geopotential and temperature measurements made by radiosonde instruments of different countries or manufacturers is a long-standing problem. Attempts to determine the differences in these measurements date back to the 1950's and the International Geophysical Year. The Commission for Instruments and Methods of Observations (CIMO) of the WMO has sponsored a number of intercomparison tests over the decades in an effort to quantify the differences.

The NMC has, since 1964, adjusted the reported geopotential heights and the temperatures by using tables of estimated adjustments incorporated in a program entitled RADCOR. These adjustments were determined by averaging day minus nighttime observed values and stratifying the results by sonde type, solar elevation angle, and pressure [McInturff et al, 1979]. The assumption was made that the primary radiative influence on the sondes was by short-wave flux, so that all observations would be adjusted to nighttime values. There were a number of problems with these assumptions which were readily recognized, but the large variation between sondes of various types made this procedure acceptable. These adjustments took care of the major problem due to solar radiative influence which varied with sonde type. However, there was no basis for which to correct the observations to a recognized standard to achieve compatibility between sonde types.

A number of recent events and changes in the knowledge base of sonde performance make it imperative to redo the NMC procedure for achieving sonde compatibility. These are, in approximately the order of importance:

-an increase in knowledge of sonde performance and an increased database of sonde comparison measurements.

-a changing global environment of sonde usage. Vaisala Oy now provides radiosondes to approximately 35% of the world's upper-air observing sites. Many nations formerly manufacturing their own instruments have found it economic to buy sounding equipment from Vaisala. In addition, the U.S. now uses two different makes of sondes, with some likelihood that additional types may be used in the future.

-an increasing sensitivity of numerical assimilation and prediction models to the accuracy and precision of upper-air measurements. Numerical weather prediction models now extend well into the middle stratosphere, are global, and have become sufficiently accurate that subtle observation bias can be detected.

-the impending transition to the BUFR code for transmission of sounding data, making it possible to provide specific information on the sonde used and corrections applied.

THE NEW THREE-THERMISTOR SONDE COMPARISON DATA FROM F. SCHMIDLIN, NASA/GODDARD/WALLOPS I.

The major impetus for this overhaul of the RADCOR program was the availability of data stemming from tests designed and carried out at Wallops Island, NASA, by Mr. Frank Schmidlin [Schmidlin, 1991]. These tests of sonde comparisons used specially-modified sondes carrying three thermistors; one a white-coated, another black-coated, and the third an aluminized coated element. By having three temperature measurements with thermistors with known and differing absorptivity and emissivity, three heat transfer equations could be solved, and a very accurate true ambient temperature calculated. These experiments were used to provide a set of temperature adjustments for the VIZ sondes now in use. The WMO Intercomparison results were then used to calibrate the Vaisala sonde, in addition to a number of sonde makes no longer in use. The tabular values provided to the NMC by Mr. Frank Schmidlin are given in Appendix A. These will be referred to, subsequently, as FS/NASA, and as the 'absolute standard'. It is important to recognize that the use of these corrections will provide temperature data closer to a true air temperature than previous RADCOR schemes, which corrected to nighttime sonde-observed conditions. Moreover, differences in sonde response from one intercomparison test to another, as well as some theoretical results of McMillan, et al [1991], strongly suggest that the long-wave influence on the sondes varies with the actual thermal stratification in which the sonde is immersed.

Schmidlin's results indicate that the day-night differences from the three-thermistor tests are of the same magnitude as the previous day-night adjustments used by the NMC. Thus, the adjustments provided over the years by RADCOR achieved the correct diurnal adjustment, but not the correct bias values relative to the long-wave radiation error.

AN EVALUATION OF RADIOSONDE COMPATIBILITY USING NUMERICAL PREDICTION MODELS.

Kitchen [1989] has provided some insightful material on the uncertainties of radiosonde geopotential measurements. The total observed geopotential variance, observed minus assimilating forecast, can be partitioned into 1), random forecast errors in the assimilating forecast; 2) errors of representativeness in the observed geopotential; 3) the reproducibility error in the observed geopotential (instrument error); and 4) systematic bias between the forecast and the measurement. It is the latter that concerns us here, but the remaining three are none-the-less important. Data on sonde reproducibility has come from the intercomparison tests, and for the Vaisala RS80 and VIZ sondes give an rms value at 100hPa of 9m. Random forecast and representative errors lumped together can be estimated by first estimating the bias (fourth term) from statistics of observed increments, and subtracting the variance thus contributed together with the reproducibility term variance. Kitchen provides the following analysis of the results for the VIZ sondes over the coterminous U.S. Here, it must be remarked, the radiosonde density is high; the sonde type uniform (at the time the study was made); and the radiative influences on the sonde relatively small owing to the relative occurrence of synoptic and solar times. The observed total variance of the observed increments was typically about 22**2 m**2, while the bias averaged about 10**2. Thus, the errors of representativeness and forecast together constituted about 17**2 m**2, and make up the largest portion of the 100hPa geopotential uncertainty. However, the importance of the bias term can easily be seen- a doubling of this error would make it comparable to the lumped errors. Reference to Appendix A, for the VIZ sonde at low to negative solar angles finds values less than or equal to the value of 10m for the ECMWF observed increments used by Kitchen.

The data on the ECMWF increments given by Kitchen can also be used to check on the error budget using day-night difference statistics. Using three high quality U.S. stations (using VIZ) in the tropical Pacific- the two Hawaiian stations plus Guam- the following statistics are found:

TABLE A

100hPa Variance Budget Hawaii plus Guam
ECMWF Statistics (Observed Increments)
Numbers in ( ) are square root values
Units: meters squared (meters)

	0000UTC[day]	1200UTC[night]
Total	840 (29.0)	1369 (37.0)
Ins err	81 (9.0)	81 (9.0)
Mean(bias)	324 (+18.0)	900 (-30.0)
Remainder	435 (20.8)	388 (19.7)

If there were no error in reproducing the 100hPa tidal oscillations in the EC model, then the day-night correction for the VIZ sonde at high solar elevation angles would be predicted to be about 48m. The three-thermistor data FS/NASA, however, specifies only about 30m.

With this information as background, two examples of intercomparisons of sonde agreement with the geopotential and temperature data from the NMC Global Data Assimilation Scheme are given.

The first example is a comparison of the geopotential height increments (observation minus forecast values) over Alaska and western North America. Figure 1 presents a time series of observed 200,150, and 100hPa increments for Fairbanks, Alaska. This station switched from the VIZ sonde to the Space Data Corporation(SDC) sonde in late May 1989. With high solar elevation angles occurring at the time of switchover, the effect of using an incorrect shortwave heating adjustment is plainly evident. Figure 2 is a comparison of the geopotential height increments (observation minus forecast values) averaged for December 1990 12UTC. The values, Figure 2, are in whole meters. The three Alaskan sites having mean increments of -23,-33, and -34 meters were using the SDC sonde, while all the other sites, including the Canadian sites, were using the VIZ-type sonde. All the soundings used in this comparison were made in total darkness; and, as such, only the SDC sounding data were corrected by RADCOR. At 100hPa, this correction amounted to a negative 17 meters. Thus, the uncorrected increments were, -6,-16, and -17 meters. Since the VIZ sonde data received no correction under the RADCOR program, these SDC uncorrected values may be compared in a relative sense to the surrounding station's increments- most of which are slightly positive. Under the [new] RADCOR91, the nighttime geopotential corrections for the VIZ sonde's 100hPa values will be -9m, and for the SDC values, -21m. Thus, under the new correction scheme, the relative change VIZ to SDC of 12m would indicate that the negative differences above are essentially accounted for.

This example illustrates that the assimilating model is capable of anticipating sonde compatibility corrections- in this instance, corrections that were verified by completely independent data.[Ahnert, 1991 and Appendix A].

A final example makes use of similar plot of 100hPa differences, observation minus forecast values, averaged for October 1990 at 00UTC. Figure 3 presents these statistics, but here the values are plotted in tenths of meters. This is one of a series of such monthly difference statistics used to estimate the relative difference between the Canadian version of the VIZ sonde (Sangamo) and the Vaisala RS80 sonde. As matters transpired, Coral Harbour,NWT (CH) at 64N and 82W had switched to the Vaisala DigiCora system sometime in early 1990, unbeknownst to the NMC. In retrospect, we examined the increments for surrounding stations and performed a subjective analysis on those increments omitting the CH value. This allowed an estimate to be made of what CH's value would have been had it been spatially consistent with its VIZ neighbors. The difference in the estimated and actual increment then gave a value that could be used to estimate the relative difference between the RS80 sonde and the VIZ Canadian instrument. Such a procedure was carried out for three months; June, August and September 1990 at both 00 and 12UTC, giving values over a spread of mean solar elevation angle. The value that can be estimated from Figure 2, for October, 00UTC, is about 36 meters. The results are shown in Figure 4. In spite of the crudeness of the procedure, the estimates do indicate a change of something on the order of 30-40 meters at night, to a value essentially zero at moderate solar angles. These values can be compared with the FS/NASA nighttime value of 22 meters.

The point here is that, if the intercomparison and functional precision test data are accepted and the observed increments statistics from sophisticated numerical weather prediction assimilation systems are assumed, the latter should be able to investigate biases in sondes with an uncertainty (at 100hPa) of something like 17m. These two examples indicate that such is indeed the case- and, perhaps, with an uncertainty somewhat less than the 17m quoted. This uncertainty is thus judged of value in making relative adjustments between different sondes; and, in fact, will be used to do so in constructing adjustments for the Chinese sonde in a subsequent Section. The adjustment to an absolute standard, however, must come from the FS/NASA data.

THE NEW PROCEDURE FOR CORRECTING THE VIZ,SDC, AND VAISALA SONDES

The FS/NASA data for the VIZ sonde were, as noted previously, used to calibrate the Vaisala sonde using the Intercomparison test results. For the new Space Data sonde, the corrections were obtained from a series of dual sonde ascents carried out by Mr. Peter Ahnert [formerly] of The Test and Evaluation Branch, OSO. These tests were made to evaluate the functional precision of the NWS sondes, and included data on the simultaneous temperature differences between the SDC and VIZ sondes stratified by solar angle and pressure. These data are also included in Appendix A.

To construct the correction Tables for RADCOR91, the material in Appendix A was transformed to the tabular solar angle format of the Tables. This procedure was necessary because of the relatively large range of solar angle in the Appendix A data. In some, cases some interpolation was carried out. The actual RADCOR91 Tables for VIZ, SDC, Vaisala, and Shanghai are given in Appendix B.

Tables provided to the NMC by Mr. Schmidlin contained temperature corrections for a number of sonde makes that had undergone the tests, but are no longer in use. These are the Mark 3 sonde formerly used in the United Kingdom; the Australian Phillips sonde, and two German Graw instruments. The new RADCOR, thus, incorporates the absolute standard corrections only for the Vaisala RS80 sonde and the standard VIZ sonde(including the Canadian version).

In addition, and most importantly, the FS/NASA data included geopotential height correction tables for the VIZ instrument. This circumstance is caused by the fact that NWS stations using the current MicrArt System have a programmed gravitation constant of 9.80000 m/s, whereas the WMO, internationally accepted, value is 9.80665. Therefore, until the MicroArt System can be changed, the RADCOR91 will also employ a geopotential height correction for NWS sites only. Other stations employing the VIZ or SDC sondes are assumed to be making height calculations with the proper constant. For reference purposes, the correction for geopotential height at 100hPa for the proper constant alone is 11meters, and at 10hPa, 21meters.

THE NEW PROCEDURE FOR CORRECTING THE CHINESE SONDE.

The quality monitoring program at the NMC has for a number of years calculated and examined both digital and graphical differences between the radiosonde measurements and the assimilating forecast as well as the resulting analysis. This type of monitoring is quite capable, as documented in Section 1, of detecting sonde biases. Early on, these monitoring efforts indicated a large and persistent area of positive increments (warm sonde bias) over China, with the maximum consistently over southeastern China. This phenomenon is also found by similar monitoring by the ECMWF and by JMA in Tokyo. That this anomaly is produced by some type of bias in the Chinese sonde measurements can hardly be doubted. Figure 5 shows the mean monthly 100hPa increments (to the forecast) of a station in Block 59 (Guangzhou) and also that of the Hong Kong station's data for the 12-month period from April 1990 to March 1991. These two stations are approximately 100km apart. Both 00UTC and 12UTC statistics are shown. It is evident that the Chinese sonde is producing a large seasonally-varying bias and a much smaller diurnal bias, while Hong Kong which uses the Vaisala RS80 sonde shows very little of these biases.

The Chinese participated in the most recent WMO Intercomparisons tests, at Dzhambul, USSR. Preliminary results of Mr. Schmidlin, however, show that the sonde exhibited no large bias in these tests. Subsequent inquiry did suggest that, in regular observing practice, the Chinese use a relatively short train between the balloon and the sonde; whereas in the comparison tests the train employed was much longer. In order to test whether the empirical behavior of the Chinese sonde was compatible with the hypothesis that their sonde is influenced by the balloon temperature, some detailed comparisons were made between the same stations as in Figure 5. (Hong Kong[45004] and Guangzhou[59287]). The mean monthly increments from the NMC Global Data Assimilation System and the full-field values taken from Monthly Climatic Data for the World were used. The latter were used both to remove any influence that the model might contribute to the bias, and to obtain data in the stratosphere above levels analyzed reliably by the Global Data Assimilation System.

Figure 6 and Table B present a summary of this investigation. The Figure shows 100hPa differences between the two stations from the Monthly Climatic Data for the World- that is, the full-field values. While only three years of data entered into these statistics (with some months having only two years), the seasonal variation in the comparison of the two sondes is quite clear. However, it is also quite clear that this seasonal variation is not symmetric with respect to the equinoxes, and that the bias cannot be entirely due to solar effects. An attempt to correct these differences for spatial gradient in the geopotential over the 100km by using the reported winds did not change the amplitude of the indicated curve by more than 10m at most, and also did not remove the asymmetry.

The differences shown in Table B reveal, moreover, a very interesting behavior with pressure. The inferred positive bias of the Chinese instrument increases up to 100hPa, the height of the tropical tropopause, and then decreases; so that at 20-30hPa the two sondes are indicating approximately the same values. This behavior is consistent with the hypothesis that the sonde is being influenced by the balloon temperature. With decreasing temperatures, as the balloon ascends in the troposphere, the balloon would be warmer than the air and influence the sonde temperature measurement through either radiative or convective means, or both. However, after passing through the cold tropical tropopause, the balloon would run colder than the ambient air and the influence on the sonde would reverse. There is even the possibility that the asymmetric behavior of the relative bias, Figure 5, is caused by the warmer tropopause temperatures in August to October interval over those in February to April.

To construct the correction Tables in RADCOR for the Chinese sonde, the following procedure was used: first, the solar angles appropriate to the data given in Table B were determined. Second, trial geopotential difference profiles were constructed for four solar angle categories (including night) by using the results of the Table and adding the geopotential profile appropriate to the Vaisala RS80 sonde. This is necessary, of course, to produce corrections to the Chinese sonde which are compatible with corrections made to the VIZ, SDC, and Vaisala sondes. Next, a program was written to fit these trial profiles with a polynomial approximation; the result differentiated; and the resulting temperature profile determined. Lastly, a check on the trial profile was made by re-integrating the temperature corrections and making minor adjustments to achieve a smooth profile. The results of this procedure is set out in Table B.

Two important points must be recognized. First, these corrections are provisional, and should be updated after either more sonde intercomparison tests, or after a year of monitoring the results of these corrections. Second, the asymmetric behavior of the empirical data has been neglected by forcing the corrections to be a function of solar angle. If the next change in RADCOR91, whenever it occurs, can accommodate adjustments based upon the actual radiative environment of the sonde [L. McMillin, et al 1991] then presumably this neglect can be remedied.

THE NEW PROCEDURE FOR CORRECTING THE REMAINING SONDE TYPES.

The sonde types other than VIZ, Vaisala, Space Data, and the Chinese Shanghai will receive the same corrections as in the old RADCOR. The USSR, Japan, and India are the principal countries involved. Hopefully, future intercomparison events will provide sufficient data to allow these sonde types to be corrected to the FS/NASA absolute standard.

SUMMARY OF ADJUSTMENTS MADE BY THE [OLD] RADCOR AND RADCOR91

1. New radiation correction tables for VIZ, SDC, and Vaisala sondes have been incorporated. These corrections apply to both short- and long-wave radiation; thus, establishing night-time corrections at all levels for the first time.

2. New corrections have also been incorporated for the Chinese Shanghai Radiosonde. These were established by utilizing differences to the NMC model and by means of Vaisala-Shanghai comparisons.

3. Sonde type designation in RADCOR91 is be BUFR Table designation. See Appendix B.

4. All reported temperatures for those sonde types having adjustments are first corrected according to solar elevation angle. Geopotential height values are then obtained by re-integrating the hydrostatic equation using standard level temperature <u>corrections</u>. Since the temperature corrections are interpolated linearly to the significant levels, these need not be used when the re-integration is performed.

5. For US stations using the MicroArt System, geopotential height corrections are applied directly to the re-integrated height values. This correction is due to the use of an incorrect gravitational constant in the MicroArts software and will be discontinued when the MicroArt software is updated.

6. The new program will retain the same name as the old (RADCOR) so that its introduction will be transparent to the user. The implementation date will be advertised.

FIGURE LEGENDS

Fig 1. Average monthly differences between the RADCOR adjusted geopotential heights and the 6-hour assimilating forecast for Fairbanks Alaska, Feb to Dec 1989. The station switched from the VIZ to the Space Data sonde in early June.

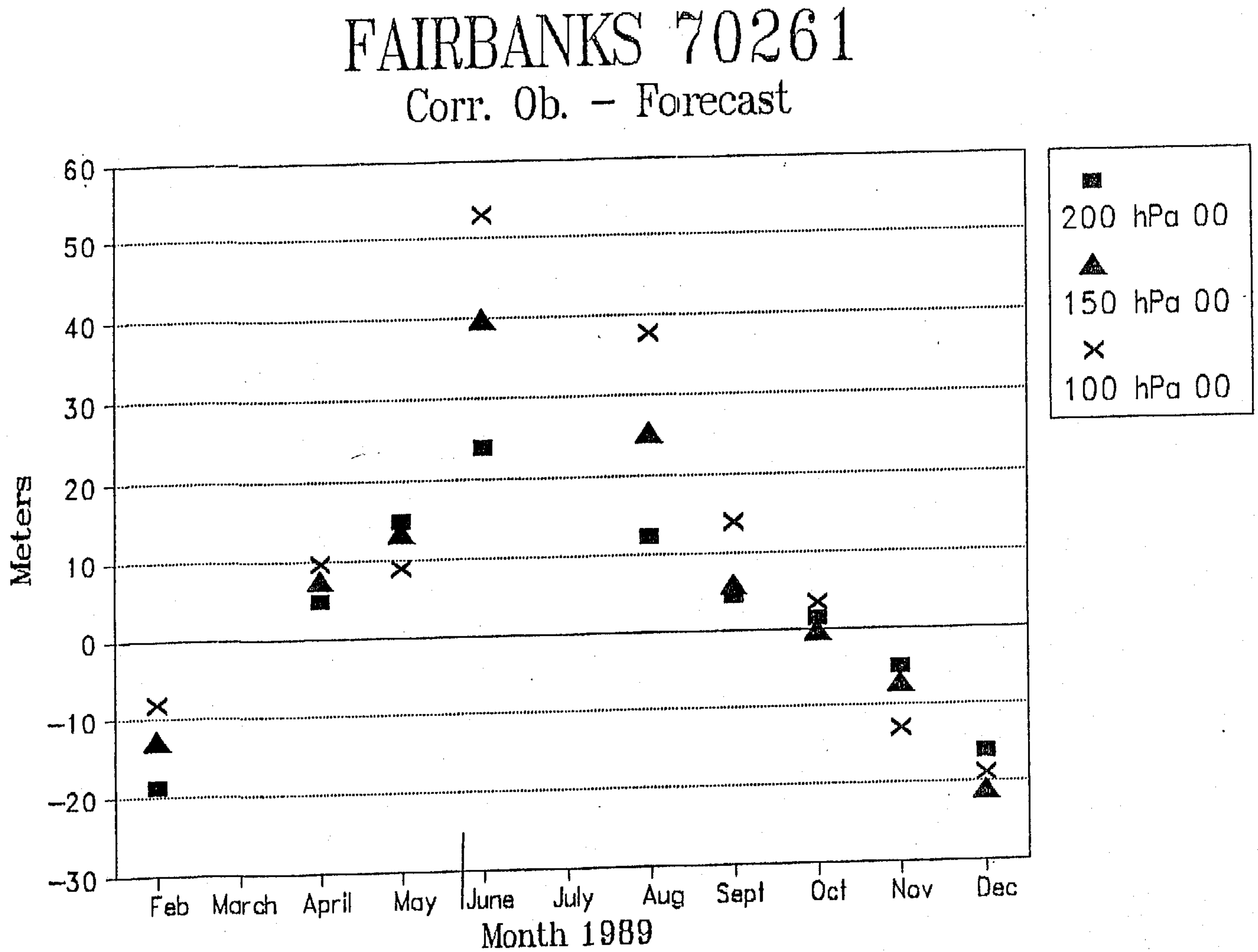
Fig 2. A map presenting the 100hPa monthly average differences, RADCOR-adjusted heights and the assimilating forecast for Dec 1990 at 12UTC. The values are in whole meters. The three Alaskan stations exhibiting large negative values all used the Space Data sonde. (See text)

Fig 3. A map, as in Figure 2, but for October 1990 at 00UTC. The monthly difference values here are in tenths of meters. Coral Harbour is represented by the shaded circle at 64N latitude. See text.

Fig 4. A plot of the actual monthly differences, observed minus forecast, for Coral Harbour minus the subjectively-derived values interpolated from surrounding stations. Data are for months, June, August and September, 1990, giving values over a range of solar elevation angle. Also shown are the Schmidlin, NASA, data for the Vaisala RS80 sonde. (Appendix A)

Fig 5. Time series for 12 months of the average monthly difference of the observed 100hPa geopotential height and the NMC assimilating forecast for Guangzhou, China and Hong Kong. The joined curve is the difference between the two observed increments. Both 00 and 12UTC are shown; the first value for the month being the 00UTC value.

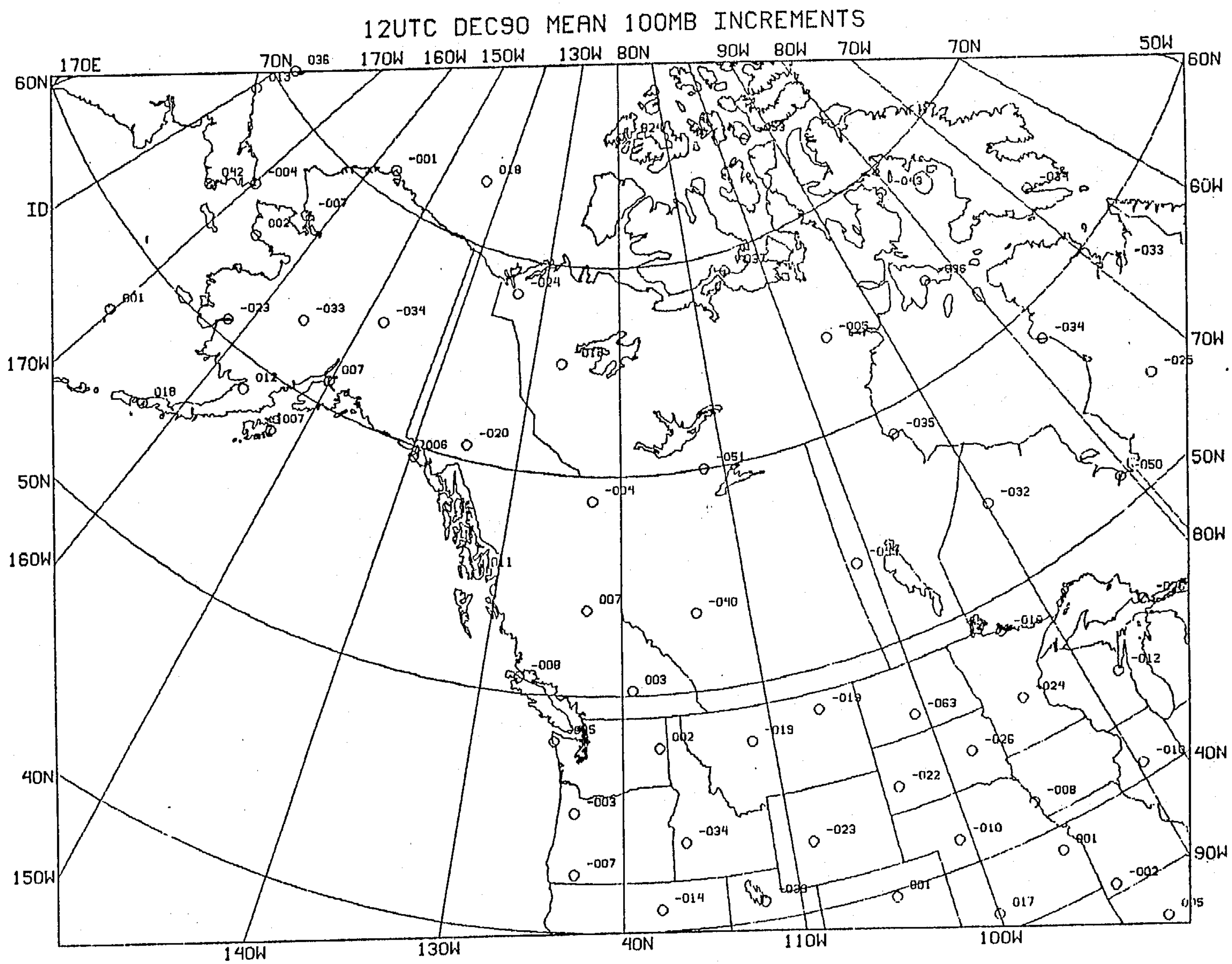
Fig 6. The observed differences in the monthly average 100hPa geopotential heights for the same stations as Fig 5. These values, however, are for the average of three years of 00UTC values reported in Monthly Climatic Data for the World, and therefore do not involve differences to the NMC model.



FAIRBANKS 70261
Corr. Ob. – Forecast
60
50
40
30
20
10
0
–10
–20
–30
Meters
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec
Month 1989
200 hPa 00
150 hPa 00
100 hPa 00

Fig. 1

Fig 2


12UTC DEC90 MEAN 100MB INCREMENTS
170E
70N
170W
160W
150W
130W
80N
90W
80W
70W
70N
50W
60N
60N
ID
60W
170W
70W
50N
50N
160W
80W
40N
40N
150W
90W
140W
130W
40N
110W
100W

00Z OCT MEAN 100MB INCREMENTS

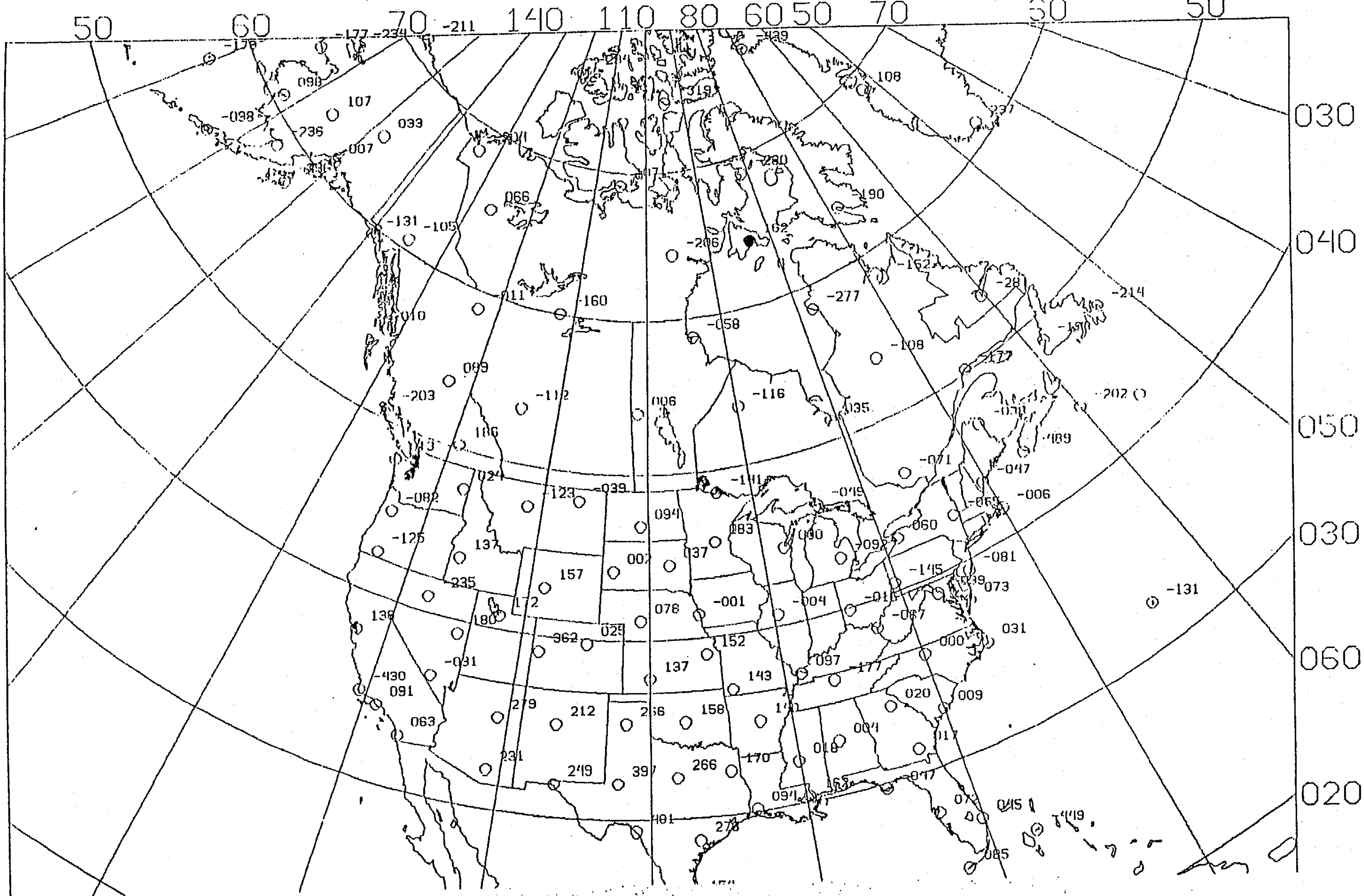
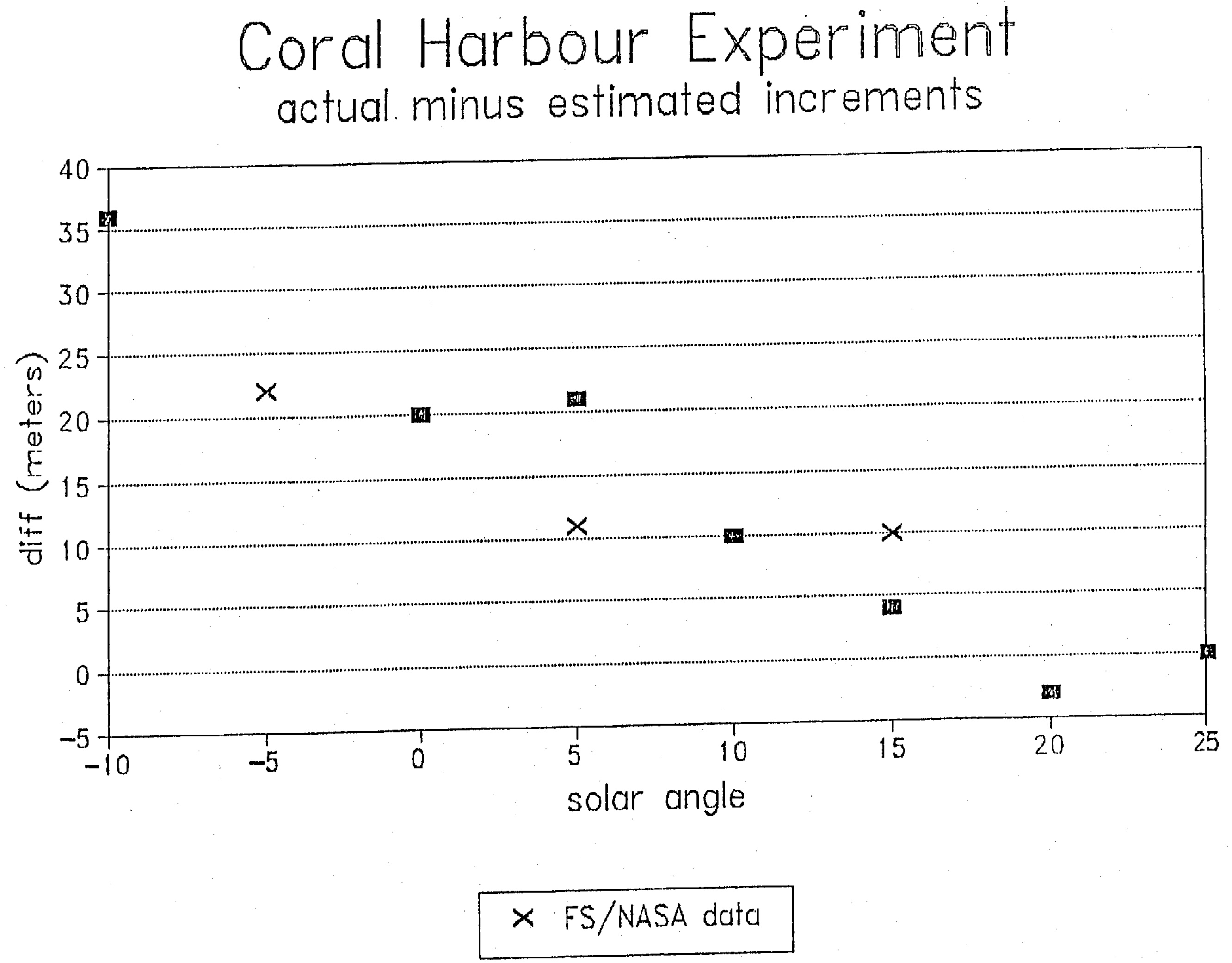


Fig 3



Coral Harbour Experiment
actual minus estimated increments
diff (meters)
solar angle
FS/NASA data

Fig. 4

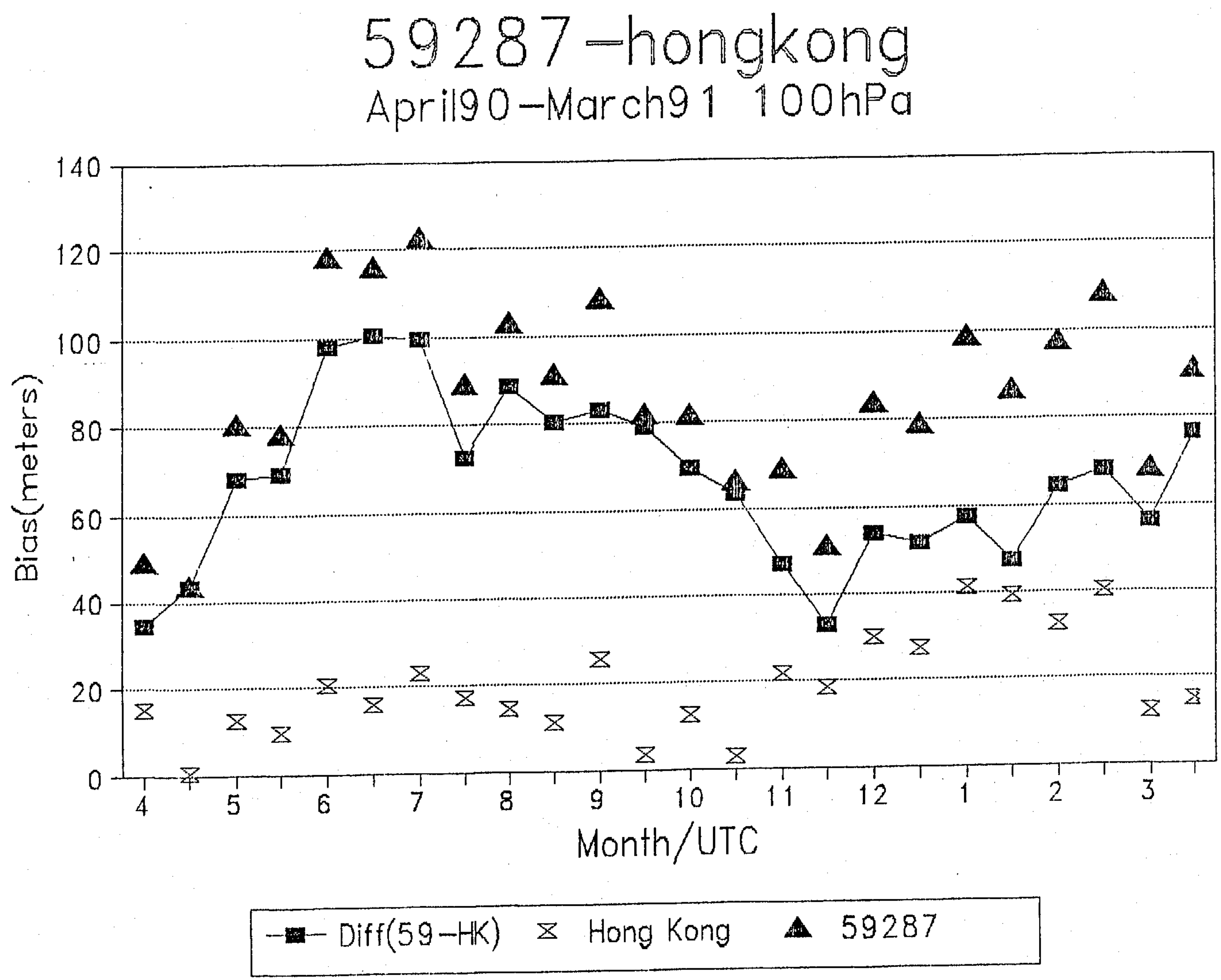

59287-hongkong
April90-March91 100hPa
Bias(meters)
140
120
100
80
60
40
20
0
4
5
6
7
8
9
10
11
12
1
2
3
Month/UTC
Diff(59-HK)
Hong Kong
59287

Fig. 5

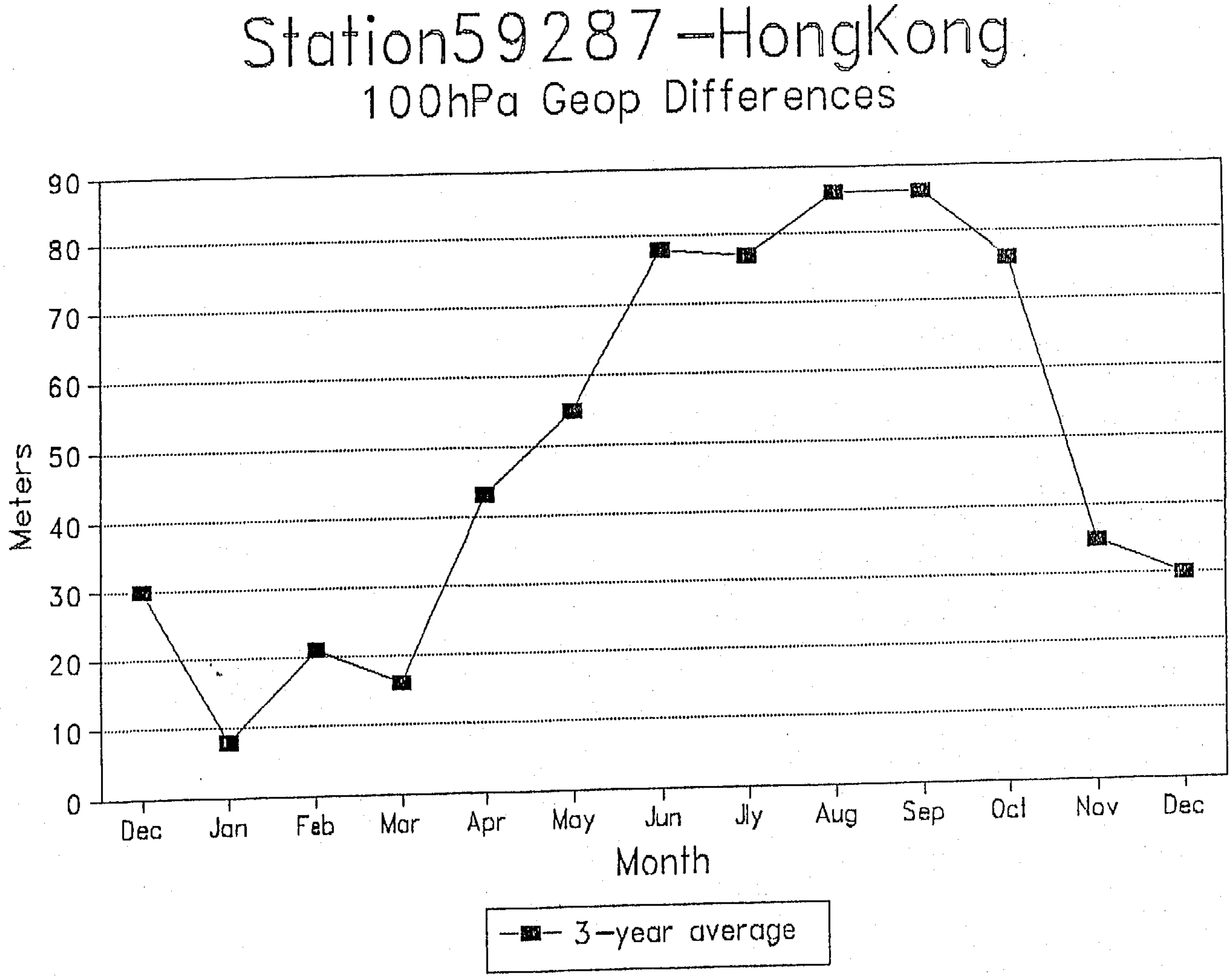

Station59287–HongKong
100hPa Geop Differences
90
80
70
60
50
40
30
20
10
0
Meters
Dec
Jan
Feb
Mar
Apr
May
Jun
Jly
Aug
Sep
Oct
Nov
Dec
Month
3–year average

Fig. 6

APPENDIX A: Radiosonde Radiation-error Correction Tables

Enclosures 1-3: F. Schmidlin, NASA/GSFC
Enclosure 4 : P. Ahnert, NWS

TABLE OF TEMPERATURE CORRECTIONS APPLICABLE ONLY TO THE US STANDARD RADIOSONDE USING THE OUTRIGGER TYPE WHITE THERMISTOR

PRESSURE		SOLAR ELEVATION ANGLES				
log	hPa	<15	15-30	30-60	60-90	NIGHT
3.00	1000	-0.02	-0.08	-0.09	-0.15	-0.02
2.95	900	-0.03	-0.12	-0.14	-0.18	0.01
2.93	850	-0.03	-0.13	-0.17	-0.23	0.03
2.85	700	-0.06	-0.19	-0.20	-0.30	0.05
2.78	600	-0.09	-0.23	-0.23	-0.35	0.06
2.70	500	-0.13	-0.29	-0.25	-0.41	0.06
2.60	400	-0.17	-0.37	-0.28	-0.47	0.05
2.48	300	-0.24	-0.43	-0.33	-0.54	0.02
2.40	250	-0.31	-0.48	-0.43	-0.62	-0.01
2.30	200	-0.37	-0.52	-0.56	-0.69	-0.01
2.18	150	-0.44	-0.60	-0.71	-0.78	0.02
2.00	100	-0.55	-0.72	-0.81	-0.87	0.07
1.85	70	-0.63	-0.84	-0.89	-0.95	0.15
1.70	50	-0.61	-0.92	-0.95	-0.99	0.23
1.48	30	-0.58	-1.01	-0.99	-0.99	0.33
1.30	20	-0.54	-1.07	-0.98	-0.92	0.48
1.18	15	-0.48	-1.12	-0.95	-0.77	0.72
1.00	10	-0.38	-1.18	-0.93	-0.43	1.06
.90	8	-0.32	-1.20	-0.91	-0.15	1.43
.85	7	-0.24	-1.21	-0.88	0.08	1.67
.70	5	-0.03	-1.23	-0.86	0.56	2.35

Table 1. Temperature corrections applicable to the U.S. standard radiosonde (VIZ).

GEOPOTENTIAL CORRECTIONS (METERS) TO US STANDARD RADIOSONDE

PRESSURE HPA	SOLAR ANGLE <15	15-30	30-60	60-90	NIGHT
1000	0	0	0	0	0
900	0	-0	-0	-1	0
850	0	-1	-1	-1	0
700	0	-1	-2	-2	0
600	-1	-2	-3	-4	0
500	-1	-4	-4	-6	1
400	-2	-6	-6	-9	1
300	-4	-9	-8	-13	1
250	-5	-12	-10	-16	1
200	-8	-15	-14	-20	1
150	-11	-20	-19	-27	1
100	-17	-28	-28	-36	2
70	-23	-36	-37	-46	3
50	-29	-44	-46	-55	5
30	-38	-59	-60	-70	9
20	-45	-71	-72	-82	14
15	-49	-80	-80	-89	19
10	-54	-94	-91	-96	30
8	-56	-102	-97	-98	38
7	-58	-107	-101	-98	44
5	-59	-119	-109	-98	64

Table 2. Geopotential corrections to the U.S. standard radiosonde (VIZ) derived from the temperature corrections given in Table 1.

TEMPERATURE CORRECTIONS (°C)

NIGHT

press level	INSTRUMENT usa	fin	aus	ind	uk	G78	M60
1000	-0.02	-0.2	0.4	0.3	-0.3	-0.1	0.5
900	0.01	0.0	0.1	0.0	0.2	0.1	-0.1
850	0.03	0.0	-0.1	-0.1	0.2	0.1	-0.3
700	0.05	-0.1	0.1	0.2	0.1	-0.1	-0.4
600	0.06	-0.2	0.2	0.2	0.1	-0.2	-0.2
500	0.06	-0.1	0.4	0.3	0.0	-0.3	-0.2
400	0.05	-0.2	0.4	0.0	0.1	-0.5	-0.2
300	0.02	-0.4	0.0	-0.5	0.1	-0.8	-0.6
250	-0.01	-0.6	-0.1	-0.3	0.0	-1.0	-0.8
200	-0.01	-0.5	-0.1	-0.4	0.0	-0.5	-0.8
150	0.02	-0.5	-0.1	-0.3	0.0	-0.4	-0.5
100	0.07	-0.5	0.0	-0.3	0.0	-0.4	-0.3
70	0.15	-0.4	0.0	-0.2	0.0	-0.1	-0.1
50	0.23	-0.6	0.1	-0.2	0.0	0.1	-0.2
30	0.33	-0.7	0.3	0.1	-0.1	0.4	0.6
20	0.48	-1.1	0.2	-0.4	-0.3	0.5	0.3
15	0.72	-1.4	0.2	-0.1	-0.5	0.7	1.3
10	1.06	-2.0	-0.5	0.2	-0.6	2.2	3.0

Table 3. a) Nighttime corrections to be algebraically added to radiosonde temperatures reported over the GTS. These corrections are only valid for darkness (i.e., an assumed sunrise or sunset terminator can not be used; actual sunrise or sunset must be determined for the sensor). It is necessary to determine whether the sensor is in darkness or daylight at very low solar angles. Solar angles are with reference to the sensor's horizon. If the sensor is in daylight Table 3b (angles below 15 degrees) should be used.

for reference:
usa = VIZ radiosonde
fin = Vaisala RS-80
aus = Australian Philips
ind = Indian
uk = UK Mark 3
G78 = German Graw 78
M60 = German Graw 60

TEMPERATURE CORRECTIONS (°C)

DAYLIGHT - SOLAR ANGLES BELOW 15 DEGREES

press level	usa	fin	aus	ind	uk	G78	M60
			INSTRUMENT				
1000	-0.02	0.0	0.4	0.7	0.4	0.2	0.2
900	-0.03	-0.1	-0.1	0.5	0.3	0.0	0.0
850	-0.03	-0.1	0.2	0.4	0.4	0.0	0.1
700	-0.06	-0.2	0.3	0.7	-0.1	-0.1	0.0
600	-0.09	-0.3	0.0	0.2	0.1	-0.3	-0.1
500	-0.13	-0.2	0.0	0.0	0.2	-0.3	-0.3
400	-0.17	-0.4	-0.2	0.1	0.0	-0.6	-0.6
300	-0.24	-0.5	-0.6	-0.9	0.0	-0.8	-0.8
250	-0.31	-0.7	-0.6	-0.7	-0.2	-0.9	-0.8
200	-0.37	-0.5	-0.7	-0.6	-0.1	-0.5	-0.8
150	-0.44	-0.6	-0.7	-0.5	-0.2	-0.7	-0.7
100	-0.55	-0.6	-0.3	-0.3	-0.2	-0.7	-0.8
70	-0.63	-0.7	-0.7	-0.8	-0.2	-0.8	-0.9
50	-0.61	-0.4	-0.4	-0.9	-0.3	-0.4	-0.1
30	-0.58	-0.3	-0.4	-1.3	-0.2	-0.1	2.1
20	-0.54	-0.3	-0.2	-1.6	-0.3	0.9	1.5
15	-0.48	-0.4	0.3	-1.6	-0.6	1.7	5.5
10	-0.38	-1.5	0.0	-3.0	-1.1	2.1	10.5

Table 3. b) Temperature corrections to be algebraically added to radiosonde temperatures reported over the GTS. These corrections are only valid for daylight. Solar angles must be lower than 15 degrees above the instrument's horizon. (These angles correspond to zenith angles of >75 degrees.) Actual determination of whether the sensor is in daylight at very low angles is necessary. If the sensor is in darkness use Table 3a.

TEMPERATURE CORRECTIONS (°C)

DAYLIGHT - SOLAR ANGLES BETWEEN 15 AND 30

press level	INSTRUMENT usa	fin	aus	ind	uk	G78	M60
1000	-0.08	-0.2	-0.1	-0.4	0.3	0.1	0.0
900	-0.12	-0.3	-0.2	-0.5	0.2	0.0	0.1
850	-0.13	-0.2	0.0	-0.2	0.1	0.0	-0.1
700	-0.19	-0.3	0.0	-0.2	0.0	-0.1	0.2
600	-0.23	-0.1	0.0	-0.3	0.2	-0.1	-0.3
500	-0.29	-0.1	0.0	-0.3	0.0	-0.5	-0.4
400	-0.37	-0.1	-0.1	-0.5	0.0	-0.7	-0.3
300	-0.43	-0.3	-0.3	-0.6	-0.1	-1.0	-0.8
250	-0.48	-0.4	-0.5	-0.6	-0.3	-1.2	-0.9
200	-0.52	-0.5	-0.7	-0.7	-0.2	-0.3	-0.5
150	-0.60	-0.3	-0.5	-0.7	-0.2	-0.8	-0.1
100	-0.72	-0.3	-0.7	-0.9	-0.1	-0.3	-0.9
70	-0.84	-0.3	-0.9	-1.2	-0.2	-0.1	-0.5
50	-0.92	0.1	-0.8	-1.2	-0.5	0.7	
30	-1.02	0.2	-1.0	-1.5	-0.4	1.5	
20	-1.07	0.2	-1.1	-1.1	-0.5	2.8	
15	-1.12	0.0	-1.3	-1.3	-0.5	4.3	
10	-1.18	-1.1	-2.5	-1.8	-1.1	7.8	

Table 3. c) Temperature corrections that must be added algebraically to radiosonde temperatures reported over the GTS. Solar angles must lie between 15 degrees and 30 degrees above the instrument's horizon. (These angles correspond to zenith angles of 75 degrees to 60 degrees.)

TEMPERATURE CORRECTIONS (°C)

DAYLIGHT - SOLAR ANGLES BETWEEN 30 AND 60

press			INSTRUMENT				
level	usa	fin	aus	ind	uk	G78	M60
1000	-0.09	-0.1	-0.4	-0.4	0.6	0.1	-0.3
900	-0.14	-0.2	-0.1	-0.2	0.2	0.0	-0.1
850	-0.17	-0.1	-0.3	-0.3	0.3	0.0	-0.2
700	-0.20	0.0	-0.1	-0.1	0.2	0.0	0.1
600	-0.23	0.0	-0.3	-0.2	0.2	-0.2	-0.1
500	-0.25	0.0	-0.2	-0.1	0.3	-0.3	-0.1
400	-0.28	0.1	-0.2	-0.2	0.3	-0.5	-0.1
300	-0.33	-0.1	-0.4	-0.4	0.2	-0.9	-0.3
250	-0.43	-0.3	-0.6	-0.7	0.1	-1.0	-0.3
200	-0.56	-0.4	-0.9	-0.8	-0.1	-0.3	-0.4
150	-0.71	-0.4	-0.9	-0.8	0.0	-0.6	-0.6
100	-0.81	-0.3	-0.8	-1.1	-0.2	-0.4	-0.6
70	-0.89	-0.2	-0.9	-1.0	-0.2	0.2	-1.0
50	-0.95	-0.3	-1.1	-1.3	-0.2	0.4	-0.9
30	-0.99	-0.0	-1.1	-1.5	-0.2	1.2	-0.4
20	-0.98	0.1	-1.0	-1.9	-0.1	2.1	0.0
15	-0.95	-0.2	-1.2	-2.5	-0.2	3.1	0.8
10	-0.93	-0.7	-1.6	-2.1	-1.0	3.5	2.7

Table 3. d) Same as Table 3c, except for solar angles above instruments horizon of 30 degrees to 60 degrees (i.e., zenith angles of 60 degrees to 30 degrees).

GEOPOTENTIAL CORRECTIONS (METERS)

NIGHT

press level	INSTRUMENT usa	fin	aus	ind	uk	G78	M60
1000	0	-2.	0.	0.	-1.	0.	1.
900	-1	-3.	0.	-1.	-1.	-1.	3.
850	-1	-3.	0.	-2.	-1.	0.	3.
700	-2	-4.	0.	-3.	-1.	-1.	2.
600	-2	-3.	2.	-3.	0.	-1.	2.
500	-3	-5.	3.	-3.	1.	-2.	0.
400	-4	-5.	7.	-7.	2.	-4.	0.
300	-5	-9.	8.	-4.	4.	-9.	-5.
250	-6	-13.	7.	-7.	5.	-15.	-9.
200	-7	-18.	6.	-11.	5.	-19.	-15.
150	-8	-23.	5.	-16.	6.	-23.	-19.
100	-9	-29.	7.	-21.	7.	-27.	-26.
70	-9	-33.	11.	-23.	8.	-29.	-26.
50	-9	-39.	13.	-30.	7.	-29.	-27.
30	-7	-46.	15.	-35.	6.	-28.	-23.
20	-4	-50.	17.	-44.	3.	-22.	-21.
15	0	-67.	14.	-47.	1.	-20.	-15.
10	9	-71.	18.	-40.	-6.	-6.	11.

a) Same as Table 3a, except table for geopotential correction.

GEOPOTENTIAL CORRECTIONS (°C)

DAYLIGHT - SOLAR ANGLES BETWEEN 15 AND 30

press level	INSTRUMENT usa	fin	aus	ind	uk	G78	M60
1000	0	-1.	0.	0.	0.	1.	1.
900	-1	-3.	0.	-2.	0.	1.	0.
850	-2	-3.	-1.	-4.	1.	1.	0.
700	-4	-5.	-1.	-6.	0.	0.	-1.
600	-5	-4.	1.	-8.	2.	0.	0.
500	-8	-5.	0.	-11.	1.	-3.	-1.
400	-11	-6.	0.	-14.	1.	-7.	-3.
300	-16	-8.	-1.	-22.	1.	-14.	-9.
250	-19	-11.	-3.	-26.	-1.	-21.	-13.
200	-23	-16.	-7.	-31.	-4.	-29.	-17.
150	-29	-19.	-12.	-39.	-5.	-35.	-22.
100	-39	-23.	-19.	-53.	-3.	-47.	-32.
70	-48	-24.	-26.	-64.	-2.	-47.	-40.
50	-58	-21.	-33.	-81.	0.	-45.	
30	-75	-22.	-48.	-101.	-5.	-31.	
20	-89	-22.	-62.	-98.	-11.	-5.	
15	-99	-21.	-77.	-119.	-17.	24.	
10	-115	-16.	-98.	-136.	-30.	92.	

c) Same as Table 3c, except for geopotential corrections.

GEOPOTENTIAL CORRECTIONS (°C)

DAYLIGHT - SOLAR ANGLES BETWEEN 30 AND 60

press level	INSTRUMENT usa	fin	aus	ind	uk	G78	M60
1000	0	-1.	1.	0.	1.	0.	1.
900	-1	-2.	0.	-1.	1.	1.	0.
850	-2	-2.	-1.	-3.	2.	0.	-1.
700	-4	-3.	-2.	-5.	4.	0.	-1.
600	-6	-2.	-3.	-7.	5.	0.	-1.
500	-8	-2.	-4.	-9.	6.	0.	-1.
400	-11	-3.	-5.	-11.	8.	-3.	-1.
300	-15	-4.	-7.	-16.	10.	-8.	-5.
250	-17	-4.	-9.	-19.	11.	-12.	-6.
200	-21	-8.	-14.	-25.	11.	-15.	-9.
150	-28	-12.	-21.	-34.	10.	-20.	-14.
100	-39	-18.	-29.	-48.	8.	-25.	-25.
70	-49	-22.	-35.	-61.	5.	-26.	-33.
50	-60	-26.	-45.	-72.	2.	-27.	-43.
30	-76	-28.	-58.	-94.	0.	-20.	-52.
20	-90	-27.	-67.	-126.	1.	-1.	-49.
15	-99	-25.	-70.	-138.	-4.	19.	-43.
10	-112	-25.	-88.	-158.	-10.	50.	-13.

d) Same as Table 3d, except for geopotential corrections.

hPa	Solar Elevation Angle (-90,-5) DEG.	(0,30) DEG.	(30,90) DEG.
11-16	M	M	-1.9
16-24	-0.65	-1.4	-1.7
24-41	-0.64	-1.3	-1.6
41-58	-0.62	-1.2	-1.5
58-84	-0.58	-1.1	-1.3
84-119	-0.54	-1.0	-1.1
119-164	-0.51	-1.0	-1.0
164-245	-0.48	-0.85	-0.92
245-415	-0.30	-0.48	-0.66
415-589	0.07	-0.06	-0.20
589-840	0.23	0.17	0.04
840-975	0.25	0.27	0.15
975-1070	0.26	0.29	0.21

Mean differences (VIZA minus SDC) of Temperature (measured at the same time) in degrees C for various pressure layers and solar elevation angle intervals for the (VIZA,SDC) series. M denotes missing values due to insufficient samples.

hPa	Solar Elevation Angle (-90,-5) DEG.	(0,30) DEG.	(30,90) DEG.
11-16	M	M	M
16-24	0.31	0.59	0.66
24-41	0.28	0.48	0.65
41-58	0.28	0.39	0.59
58-84	0.25	0.40	0.56
84-119	0.27	0.40	0.49
119-164	0.27	0.35	0.39
164-245	0.24	0.31	0.40
245-415	0.28	0.31	0.40
415-589	0.33	0.28	0.31
589-840	0.27	0.32	0.30
840-975	0.21	0.33	0.20
975-1070	M	M	M

Standard deviations of Temperature (measured at the same time) in degrees C for various pressure layers and solar elevation angle intervals for the (VIZA,SDC) series. M denotes missing values due to insufficient samples.

Enclosure 4

APPENDIX B: RADCOR91 Radiosonde Radiation-error Correction Tables.

```
C*****************************************************************************
C                         RADIATION CORRECTION TABLES
C*****************************************************************************
C
C
C                              KEY FOR INSTRUMENT TYPES
C  THIS IS BUFR-FM94 TABLE 02 011
C     BTYPE           CODE NAME                          TABLE NUMBER
C      0 TO 1                    NOT USED
C      2              NO SONDE- PASSIVE TARGET FOR WIND FINDING
C      3              NO SONDE- ACTIVE TARGET FOR WIND FINDING
C      4              NO SONDE- PASSIVE TEMP/HUMIDITY PROFILER
C      5              NO SONDE- ACTIVE TEMP/HUMIDITY PROFILER
C      6              NO SONDE- RADIO-ACOUSTIC SOUNDER
C      7 TO 8                    RESERVED
C      9              UNKNOWN  SONDE TYPE
C     10              VIZ TYPE A
C     11              VIZ TYPE B
C     12              SPACE DATA CORP
C     13              ASTOR                 (AUSTRALIA-OBSOLETE)
C     14              BEUKERS MICROSONDE (USA)
C     15              EEC TYPE 23 (USA)
C     16              ELIN                  (AUSTRIA)
C     17              GRAW G                (GERMANY)
C     18              RESEREVD
C     19              GRAW M60
C     20              INDIAN MET SER TYPE MK3
C     21              JINYANG (S. KOREA)
C     22              MEISEI RS-2-80 (JAPAN)
C     23              MENSURAL FMO 1950A   (FRANCE)
C     24              MENSURAL FMO 1945A
C     25              MENSURAL MH73A
C     26              METEOLABOR BASORA     (SWISS)
C     27              METEORITE A22IV       (USSR)
C     28              METEORITE MARZ22-1    (USSR)
C     29              METEORITE MARZ22-2    (USSR)
C     30              OKI RS2-80            (JAPAN)
C     31              SANGAMO               (CANADA)
C     32              SHANGHAI RADIO        (CHINA)
C     33              UK MET OFFICE  MK3
C     34              VINORADY              (CZECH)
C     35              VAISALA  RS18
C     36              VAISALA  RS21
C     37              VAISALA  RS80
C     38              BUEKERS LOCATE        (USA)
C     39              SPRENGER E076         (GERMANY)
C     40              SPRENGER E084         (GERMANY)
C     41              SPRENGER E085         (GERMANY)
C     42              SPRENGER E086         (GERMANY)
C     43              AIR IS-4A/1680        (UK)
C     43              AIR IS-4AX/1680       (UK)
C     45              RS MSS SPACE DATA     (US)
C     39 TO 59                  RESERVED FOR ADDITIONAL SONDES
C     45              MSS      SPACE DATA
C     60              VAISALA  RS80/MICROCORA
C     61              VAISALA  RS80/DIGICORA  OR MARWIN
C     62              VAISALA  RS80/PCCORA
C     63              VAISALA  RS80/STAR
C*****************************************************************************
C                LEVEL INDICATOR IN DATA TABLES BELOW:
C*****************************************************************************
C
C        1 - 1000 MB
C        2 --  850 MB        T --   20 MB
C        3 --  700 MB        L --   10 MB
C        4 --  500 MB        A --  400 MB (INTERP. BETWEEN 500 & 300 MB)
C        5 --  300 MB        B --  250 MB (INTERP. BETWEEN 300 & 200 MB)
C        6 --  200 MB        C --  150 MB (INTERP. BETWEEN 200 & 100 MB)
C        7 --  100 MB        D --   70 MB (INTERP. BETWEEN 100 &  50 MB)
C        8 --   50 MB        E --   30 MB (INTERP. BETWEEN  50 &  10 MB)
C        9 --   30 MB        F --   20 MB (INTERP. BETWEEN  50 &  10 MB)
C-----------------------------------------------------------------------------
C
```

```
C                                   CHINESE
C                   =====>  JTYPE = 32   --     ITAB =         <=====
C           TEMPERATURE CORRECTIONS *10 TO BE SUBTRACTED
C------------------------------------------------------------------------
         DATA  SHANGHEI/ SONDE TYPE 32
C          NITE     -5      5       15      25      35      45      55      65      75
1000 1    0.5,    0.3,    0.0,    0.4,    0.5,    0.9,    0.9,    0.9,    0.9,    0.9,
850  2    0.5,    0.9,    1.9,    2.0,    1.5,    0.9,    0.9,    0.9,    0.9,    0.9,
700  3   -0.1,    1.9,    2.6,    2.7,    1.8,    1.8,    1.8,    1.9,    1.9,    1.9,
500  4    1.2,    5.5,    6.3,    6.0,    4.9,    4.1,    4.1,    4.1,    4.2,    4.2,
     A    4.7,    8.8,    9.8,    9.7,    9.1,    9.0,    9.0,    9.0,    9.0,    9.0,
300  5   10.3,   13.7,   14.2,   14.7,   15.2,   16.0,   16.0,   15.0,   16.0,   16.0,
     B   13.7,   15.3,   16.4,   17.2,   18.5,   19.9,   19.9,   19.9,   19.9,   19.9,
200  6   16.7,   17.4,   18.0,   18.9,   21.1,   22.8,   22.8,   22.8,   22.8,   22.8,
     C   17.4,   17.2,   17.1,   17.6,   20.3,   22.0,   22.0,   22.0,   22.0,   22.0,
100  7    8.7,    8.3,    8.1,    6.0,    7.6,    7.4,    7.4,    7.4,    7.4,    7.4,
 70  D -11.5,-10.1,- 9.1,-13.9,-13.4,-13.2,-13.2,-13.2,-13.2,-13.2,
 50  8 - 9.0,-12.6,-13.3,-20.3,-18.9,-18.9,-18.9,-18.9,-18.9,-18.9,
 30  9    1.8,- 6.7,- 7.4,-15.3,-15.0,-17.0,-17.1,-17.1,-17.1,-17.1,
 20  T   11.4,    5.0,    2.0,- 5.0,- 6.4,-10.0,-10.0,-10.0,-10.0,-10.0,
 10  L   16.6,   13.5,   12.1,    8.5,    5.7,    4.0,    4.0,    4.0     4.0     4.0/
C
C************************************************************************
C     TEMPERATURE CORRECTION TABLES (* 10 K) FOR ALL RADIATION EFFECTS
C************************************************************************
C------------------------------------------------------------------------
C        NOAA / VIZ - A 1990   SMIDLIN
C        TEMPORARILY  MSS  ALSO
C        TEMP CORRECTION*10 TO BE SUBTRACTED
C                   =====>  JTYPE = 10   --     ITAB = 1     <=====
C                   =====>  JTYPE = 38   --     ITAB = 1     <=====
C------------------------------------------------------------------------
         DATA  VIZA   /
C          NITE     -5      5       15      25      35      45      55      65      75
1000 1    0.2,    0.2,    0.2,    0.8,    0.8,    0.9,    0.9,    0.9,    0.9,    0.9,
850  2   -0.3,   -0.3,    0.3,    1.3,    1.3,    1.5,    1.7,    1.7,    1.7,    1.7,
700  3   -0.5,   -0.5     0.6,    1.9,    1.9,    2.0,    2.0,    2.0,    2.0,    2.0,
500  4   -0.6,   -0.6,    1.3,    2.9,    2.9,    2.7,    2.5,    2.5,    2.5,    2.5,
     A   -0.5,   -0.5,    1.7,    3.7,    3.7,    3.3,    2.8,    2.8,    2.8,    2.8,
300  5   -0.2,   -0.2,    2.4     4.3,    4.3,    3.8,    3.3,    3.3,    3.3,    3.3,
     B    0.1,    0.1,    3.1,    4.8,    4.8,    4.5,    4.3,    4.3,    4.3,    4.3,
200  6    0.1,    0.1,    3.7,    5.2,    5.2,    5.4,    5.6,    5.6,    5.6,    5.6,
     C   -0.2,   -0.2     4.4,    6.0,    6.0,    6.5,    7.1,    7.1,    7.1,    7.1,
100  7   -0.7,   -0.7,    5.5,    7.2,    7.2,    7.6,    8.1,    8.1,    8.1,    8.1,
 70  D   -1.5,   -1.5,    6.3,    8.4,    8.4,    8.6,    8.9,    8.9,    8.9,    8.9,
 50  8   -2.3,   -2.3,    6.1,    9.2,    9.2,    9.3,    9.5,    9.5,    9.5,    9.5,
 30  9   -3.3,   -3.3,    5.8,   10.2,   10.2,   10.0,    9.9,    9.9,    9.9,    9.9,
 20  T   -4.8,   -4.8,    5.4,   10.7,   10.7,   10.2,    9.8,    9.8,    9.8,    9.8,
 10  L -10.6,-10.6,       3.8    11.8,   11.8,   10.5,    9.3,    9.3,    9.3,    9.3/
C
C************************************************************************
C     GEOPOTENTIAL CORRECTION TABLES (WHOLE M) FOR ALL RADIATION EFFECTS
C     AND INCORRECT GRAVITY CONSTANT IN MICROARTS
C************************************************************************
C          NITE     -5      5       15      25      35      45      55      65      75
1000 1     0.,     0.,     0.,     0.,     0.,     0.,     0.,     0.,     0.,     0.,
850  2     1.,     1.,     1.,     2.,     2.,     2.,     2.,     2.,     2.,     2.,
700  3     2.,     2.      3.,     4.,     4.,     4.,     4.,     4.,     4.,     4.,
500  4     3.,     3.,     5.,     8.,     8.,     8.,     8.,     8.,     8.,     8.,
     A     4.,     4.,     7.,    11.,    11.,    11.,    11.,    11.,    11.,    11.,
300  5     5.,     5.,    10.,    16.,    16.,    16.,    15.,    15.,    15.,    15.,
     B     6.,     6.,    13.,    19.,    19.,    18.,    17.,    17.,    17.,    17.,
200  6     7.,     7.,    16.,    23.,    23.,    22.,    21.,    21.,    21.,    21.,
     C     8.,     8.     20.,    29.,    29.,    29.,    28.,    28.,    28.,    28.,
100  7     9.,     9.,    28.,    39.,    39.,    39.,    39.,    39.,    39.,    39.,
 70  D     9.,     9.,    36.,    48.,    48.,    48.,    49.,    49.,    49.,    49.,
 50  8     9.,     9.,    43.,    58.,    59.,    59.,    60.,    60.,    60.,    60.,
 30  9     7.,     7.,    54.,    75.,    75.,    75.,    76.,    76.,    76.,    76.,
 20  T     4.,     4.,    63.,    89.,    89.,    89.,    90.,    90.,    90.,    90.,
 10  L    -9.,    -9.,    75.,   115.,   115.,   113.,   112.,   112.,   112.,   110./
C------------------------------------------------------------------------
```

```
C
C     =====>  JTYPE = 12,45 SPACEDATA   TEMPERATURE--    ITAB = 21   <=====
C      TEMP CORRECTION*10 TO BE SUBTRACTED
C              =====>  JTYPE = 12,45  --    ITAB = 2    <=====
C
C-----------------------------------------------------------------------
C        DATA  SDC  /
C          NITE    -5      5      15      25      35      45      55      65      75
C
1000 1  -2.4,  -2.4,  -2.3,  -2.1,  -1.8,  -1.5,  -1.2,  -1.2,  -1.2,  -1.2,
850  2  -2.8,  -2.8,  -2.1,  -1.4,  -1.0,  -0.4,   0.2,   0.2,   0.2,   0.2,
700  3  -2.8,  -2.8,  -1.7,   0.2,   0.8,   1.3,   1.6,   1.6,   1.6,   1.6,
500  4  -1.3,  -1.3,   1.1,   3.5,   3.8,   4.1,   4.5,   4.5,   4.5,   4.5,
     A   0.7,   0.7,   3.0,   6.0,   6.2,   6.4,   6.7,   6.7,   6.7,   6.7,
300  5   2.8,   2.8,   6.5,   9.1,   9.4,   9.7,   9.9,   9.9,   9.9,   9.9,
     B   3.8,   3.8,   7.9,  11.4,  11.8,  12.1,  12.4,  12.4,  12.4,  12.4,
200  6   4.9,   4.9,   9.1,  13.7,  14.2,  14.6,  14.8,  14.8,  14.8,  14.8,
     C   4.9,   4.9,  10.9,  16.0,  16.6,  16.8,  17.1,  17.1,  17.1,  17.1,
100  7   4.7,   4.7,  11.0,  17.2,  18.4,  18.8,  19.1,  19.1,  19.1,  19.1,
 70  D   4.3,   4.3,  12.2,  19.4,  20.5,  20.7,  21.9,  21.9,  21.9,  21.9,
 50  8   3.9,   3.9,  14.0,  21.2,  22.2,  23.4,  24.5,  24.5,  24.5,  25.5,
 30  9   3.1,   3.1,  17.4,  23.2,  23.5,  24.4,  25.9,  25.9,  25.9,  25.9,
 20  T   1.7,   1.7,  14.7,  24.7,  25.5,  26.2,  26.8,  26.8,  26.8,  26.8,
 10  L  -4.0,  -4.0,  12.0,  25.8,  26.6,  27.7,  28.3,  28.3,  28.3,  28.3/
C
C***********************************************************************
C     GEOPOTENTIAL CORRECTION TABLES (WHOLE M) FOR ALL RADIATION EFFECTS
C     AND INCORRECT GRAVITY CONSTANT IN MICROARTS
C***********************************************************************
C                                5     15     25     35     45     55     65     75
C          NITE     -5          0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,
1000 1      0.,     0.,     0.,    1.,    1.,    1.,    1.,    1.,    1.,    1.,
850  2      0.,     0.,     0.,    1.,    2.,    3.,    3.,    3.,    3.,    3.,
700  3      0.,     0.      1.,    5.,    6.,    7.,    7.,    7.,    7.,    7.,
500  4     -1.,    -1.,     3.,    9.,   11.,   11.,   12.,   12.,   12.,   12.,
     A      0.,     0.,     4.,   17.,   18.,   19.,   21.,   21.,   21.,   21.,
300  5      3.,     3.,    10.,   23.,   25.,   26.,   27.,   27.,   27.,   27.,
     B      5.,     5.,    13.,   32.,   33.,   35.,   37.,   37.,   37.,   37.,
200  6      9.,     9.,    16.,   46.,   48.,   50.,   52.,   52.,   52.,   52.,
     C     14.,    14.     25.,   67.,   69.,   72.,   75.,   75.,   75.,   75.,
100  7     21.,    21.,    38.,   87.,   90.,   94.,   98.,   98.,   98.,   98.,
 70  D     27.,    27.,    56.,  108.,  113.,  117.,  122.,  122.,  122.,  122.,
 50  8     33.,    33.,    85.,  144.,  152.,  157.,  162.,  162.,  162.,  162.,
 30  9     41.,    41.,    94.,  175.,  182.,  189.,  195.,  162.,  162.,  162.,
 20  T     45.,    45.,   123.,  230.,  236.,  247.,  256.,  256.,  256.,  256./
 10  L     46.,    45.,   155.,
C
C
C***********************************************************************
C      TEMPERATURE CORRECTION TABLES (* 10 K) FOR ALL RADIATION EFFECTS
C***********************************************************************
C-----------------------------------------------------------------------
C
C      VAISALA/VRS80   1990   SMIDLIN
C      TEMP CORRECTION*10 TO BE SUBTRACTED
C       =====>  JTYPES= 37,60,61,62,63     ITAB = 3   <=====
C
C-----------------------------------------------------------------------
C        DATA   VRS80  /
C          NITE    -5      5      15      25      35      45      55      65      75
C
1000 1    2.0,   2.0,   0.0,   2.0,   2.0,   1.5,   1.0,   1.0,   1.0,   1.0,
850  2    0.0,   0.0,   1.0,   2.0,   2.0,   1.5,   1.0,   1.0,   1.0,   1.0,
700  3    1.0    1.0    2.0,   3.0,   3.0,   1.5,   0.0,   0.0,   0.0,   0.0,
500  4    1.0,   1.0,   2.0,   1.0,   1.0,   0.5,   0.0,   0.0,   0.0,   0.0,
     A    2.0,   2.0,   4.0,   1.0,   1.0,   0.0,  -1.0,  -1.0,  -1.0,  -1.0,
300  5    4.0,   4.0,   5.0    3.0,   3.0,   2.0,   1.0,   1.0,   1.0,   1.0,
     B    6.0,   6.0,   7.0,   4.0,   4.0,   3.5,   3.0,   3.0,   3.0,   3.0,
200  6    5.0,   5.0,   5.0,   5.0,   5.0,   4.5,   4.0,   4.0,   4.0,   4.0,
     C    5.0,   5.0    6.0,   3.0,   3.0,   3.5,   4.0,   4.0,   4.0,   4.0,
100  7    5.0,   5.0,   6.0,   3.0,   3.0,   3.0,   3.0,   3.0,   3.0,   3.0,
 70  D    4.0,   4.0,   7.0,   3.0,   3.0,   2.5,   2.0,   2.0,   2.0,   2.0,
 50  8    6.0,   6.0,   4.0,  -1.0,  -1.0,   1.0,   3.0,   3.0,   3.0,   3.0,
 30  9    7.0,   7.0,   3.0,  -2.0,  -2.0,  -1.0,   0.0,   0.0,   0.0,   0.0,
 20  T   11.0,  11.0,   3.0,  -2.0,  -2.0,  -1.5,  -1.0,  -1.0,  -1.0,  -1.0,
 10  L   20.0,  20.0,  15.0   11.0,  11.0,   9.0,   7.0,   7.0,   7.0,   7.0/
C
```

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C-----------------------------------------------------------------------
C      WEST GERMAN GRAW M60 SMIDLIN
C      TEMP CORRECTION*10 TO BE SUBTRACTED
C       =====>   JTYPE= 19              ITAB = 4             <=====
C-----------------------------------------------------------------------
        DATA   M60      /
C           NITE    -5       5       15      25      35      45      55      65      75
1000 1    -5.0,  -5.0,  -2.0,    0.0,    0.0,   1.5,    3.0,    3.0,    3.0,    3.0,
850  2     3.0,   3.0,  -1.0,    1.0,    1.0,   1.5,    2.0,    2.0,    2.0,    2.0,
700  3     4.0    4.0    0.0,   -2.0,   -2.0,  -1.5,   -1.0,   -1.0,   -1.0,   -1.0,
500  4     2.0,   2.0,   3.0,    4.0,    4.0,   2.5,    1.0,    1.0,    1.0,    1.0,
     A     2.0,   2.0,   6.0,    3.0,    3.0,   2.0,    1.0,    1.0,    1.0,    1.0,
300  5     6.0,   6.0,   8.0     8.0,    8.0,   5.0,    3.0,    3.0,    3.0,    3.0,
     B     8.0,   8.0,   8.0,    9.0,    9.0,   6.0,    3.0,    3.0,    3.0,    3.0,
200  6     8.0,   8.0,   8.0,    5.0,    5.0,   4.5,    4.0,    4.0,    4.0,    4.0,
     C     5.0,   5.0    7.0,    1.0,    1.0,   3.5,    6.0,    6.0,    6.0,    6.0,
100  7     3.0,   3.0,   8.0,    9.0,    9.0,   7.5,    6.0,    6.0,    6.0,    6.0,
 70  D     1.0,   1.0,   9.0,    5.0,    5.0,   7.5,   10.0,   10.0,   10.0,   10.0,
 50  8     2.0,   2.0,   1.0,    2.0,    3.0,   5.0,    9.0,    9.0,    9.0,    9.0,
 30  9    -6.0,  -6.0, -11.0,   -8.0,   -5.0,   0.0,    4.0,    4.0,    4.0,    4.0,
 20  T    -3.0,  -3.0, -15.0,  -10.0,   -7.5,  -5.0,    0.0,    0.0,    0.0,    0.0,
 10  L    -3.0,  -3.0, -99.0   -75.0,  -50.0, -35.0,  -27.0,  -27.0,  -27.0,  -27.0/
C
C-----------------------------------------------------------------------
C      USSR A22    1990   FROM PREVIOUS TABLES AVERAGED
C      TEMP CORRECTION*10 TO BE SUBTRACTED
C                  =====>  JTYPE = 27  --    ITAB =        <=====
C-----------------------------------------------------------------------
        DATA            /
C           NITE    -5       5       15      25      35      45      55      65      75
C
1000 1     0.0,   0.0,   0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
250  2     0.0,   0.0,   0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
700  3     0.0,   0.0    0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
500  4     0.0,   0.0,   1.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
     A     0.0,   0.0,   1.0,    1.0,    1.0,   1.0,    0.0,    0.0,    0.0,    0.0,
300  5     0.0,   0.0,   2.0     1.0,    1.0,   1.0,    0.0,    0.0,    0.0,    0.0,
     B     0.0,   0.0,   2.0,    2.0,    2.0,   2.0,    0.0,    0.0,    0.0,    0.0,
200  6     0.0,   0.0,   2.0,    2.0,    2.0,   2.0,    1.0,    0.0,    0.0,    0.0,
     C     0.0,   0.0    2.0,    3.0,    3.0,   3.0,    2.0,    0.0,    0.0,    0.0,
100  7     0.0,   0.0,   3.0,    4.0,    4.0,   5.0,    3.0,    1.0,    0.0,    0.0,
 70  D     0.0,   0.0,   3.0,    4.0,    5.0,   7.0,    5.0,    3.0,    0.0,    0.0,
 50  8     0.0,   0.0,   4.0,    6.0,    6.0,   8.0,    6.0,    4.0,    0.0,    0.0,
 30  9     0.0,   0.0,   4.0,    7.0,    7.0,   8.0,    6.0,    6.0,    0.0,    0.0,
 20  T     0.0,   0.0,   5.0,   10.0,    5.0,  11.0,   11.0,    6.0,    0.0,    0.0,
 10  L     0.0,   0.0,   6.0    22.0,   16.0,  11.5,   11.3,   11.0,    0.0,    0.0/
C
C-----------------------------------------------------------------------
C      USSR MARZ2 1990   FROM PREVIDU TABLES AVERAGED
C      TEMP CORRECTION*10 TO BE SUBTRACTED
C                  =====>  JTYPES= 28,29    ITAB =        <=====
C-----------------------------------------------------------------------
        DATA            /
C           NITE    -5       5       15      25      35      45      55      65      75
1000 1     0.0,   0.0,   0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
250  2     0.0,   0.0,   0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
700  3     0.0,   0.0    0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
500  4     0.0,   0.0,   0.0,    0.0,    0.0,   0.0,    0.0,    0.0,    0.0,    0.0,
     A     0.0,   0.0,   1.0,    1.0,    1.0,   1.0,    0.0,    0.0,    0.0,    0.0,
300  5     0.0,   0.0,   1.0     1.0,    1.0,   1.0,    0.0,    0.0,    0.0,    0.0,
     B     0.0,   0.0,   2.0,    2.0,    2.0,   1.0,    0.0,    0.0,    0.0,    0.0,
200  6     0.0,   0.0,   2.0,    2.0,    2.0,   1.0,    0.0,    0.0,    0.0,    0.0,
     C     0.0,   0.0    3.5,    3.0,    2.5,   1.0,    0.5,    0.0,    0.0,    0.0,
100  7     0.0,   1.0,   4.0,    4.0,    2.5,   1.0,    0.5,    0.0,    0.0,    0.0,
 70  D     0.0,   2.0,   4.5,    4.5,    2.5,   1.0,    0.5,    0.0,    0.0,    0.0,
 50  8     0.0,   3.0,   6.0,    6.0,    3.5,   1.5,    1.0,    0.0,    0.0,    0.0,
 30  9     0.0,   4.0,   8.5,    7.5,    5.0,   2.5,    1.0,    0.0,    0.0,    0.0,
 20  T     0.0,   5.0,  10.0,   10.0,    6.0,   4.5,    1.0,    0.0,    0.0,    0.0,
 10  L     0.0,  11.0,  22.0    17.0,   11.5,  10.5,    2.0,    1.0,    0.0,    0.0/
C-----------------------------------------------------------------------
C
C
```

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C
C------------------------------------------------------------------------------------
C                                    SANGAMO CANADIAN
C                      =====>  JTYPE = 31   --     ITAB = 15    <=====
C        SAME CORRECTIONS AS VIZ-A
C------------------------------------------------------------------------------------
          DATA   TCSG /
C            NITE    -5        5      15        25       35       45       55       65       75
C LEVEL
1000 1      0.2,    0.2,    0.2,    0.8,    0.8,    0.9,    0.9,    3.9,    0.9,    0.9,
850  2     -0.3,   -0.3,    0.3,    1.3,    1.3,    1.5,    1.7,    1.7,    1.7,    1.7,
700  3     -0.5,   -0.5     0.6,    1.9,    1.9,    2.0,    2.0,    2.0,    2.0,    2.0,
500  4     -0.6,   -0.6,    1.3,    2.9,    2.9,    2.7,    2.5,    2.5,    2.5,    2.5,
     A     -0.5,   -0.5,    1.7,    3.7,    3.7,    3.3,    2.8,    2.8,    2.8,    2.8,
300  5     -0.2,   -0.2,    2.4     4.3,    4.3,    3.8,    3.3,    3.3,    3.3,    3.3,
     B      0.1,    0.1,    3.1,    4.8,    4.8,    4.5,    4.3,    4.3,    4.3,    4.3,
200  6      0.1,    0.1,    3.7,    5.2,    5.2,    5.4,    5.6,    5.6,    5.6,    5.6,
     C     -0.2,   -0.2     4.4,    6.0,    6.0,    6.5,    7.1,    7.1,    7.1,    7.1,
100  7     -0.7,   -0.7,    5.5,    7.2,    7.2,    7.6,    8.1,    8.1,    8.1,    8.1,
 70  D     -1.5,   -1.5,    6.3,    8.4,    8.4,    8.6,    8.9,    8.9,    8.9,    8.9,
 50  8     -2.3,   -2.3,    6.1,    9.2,    9.2,    9.3,    9.5,    9.5,    9.5,    9.5,
 30  9     -3.3,   -3.3,    5.8,   10.2,   10.2,   10.0,    9.9,    9.9,    9.9,    9.9,
 20  T     -4.8,   -4.8,    5.4,   10.7,   10.7,   10.2,    9.8,    9.8,    9.8,    9.8,
 10  L    -10.6,  -10.6,    3.8    11.8,   11.8,   10.5,    9.3,    9.3,    9.3,    9.3/
C
C------------------------------------------------------------------------------------
C                                         JAPANESE
C                       =====>  JTYPE = 22   --     ITAB =        <=====
C------------------------------------------------------------------------------------
           DATA   T9R /
C              N     -5      5     15     25     35     45     55     65     75     85   --> SOLAR
C             ---    ---    ---    ---    ---    ---    ---    ---    ---    ---    ---      ANGLE
C LEVEL
           1  0.,    0.,    0.,    0.,    0.,    0.,    3.,    0.,    0.,    0.,    0.,
           2  0.,    0.,    0.,    0.,    0.,    0.,    3.,    0.,    0.,    0.,    0.,
           3  0.,    0.,    3.,    0.,    1.,    2.,    2.,    2.,    3.,    0.,    0.,
           4  0.,    0.,    0.,    2.,    3.,    3.,    4.,    5.,    7.,    0.,    0.,
           A  0.,    0.,    0.,    3.,    3.,    3.,    4.,    5.,    6.,    0.,    0.,
           5  0.,    0.,    0.,    6.,    4.,    3.,    4.,    5.,    6.,    0.,    0.,
           B  0.,    0.,    0.,    5.,    4.,    4.,    4.,    4.,    5.,    0.,    0.,
           6  0.,    0.,    0.,    4.,    6.,    6.,    4.,    4.,    5.,    0.,    0.,
           C  0.,    0.,    0.,    5.,    6.,    6.,    5.,    5.,    4.,    0.,    0.,
           7  0.,    0.,    0.,    7.,    8.,    7.,    8.,    8.,    4.,    0.,    0.,
           D  0.,    0.,    0.,   10.,   10.,    8.,    8.,    8.,    2.,    0.,    0.,
           8  0.,    0.,    0.,   13.,   12.,   10.,    8.,    9.,    2.,    1.,    0.,
           9  0.,    0.,    0.,   26.,   19.,   16.,   12.,   11.,   10.,   -5.,    0.,
           T  0.,    0.,    0.,   33.,   30.,   28.,   19.,   13.,   14.,  -10.,    0.,
           L  0.,    0.,    0.,   43.,   41.,   35.,   15.,   18.,   14.,    0.,    0./

C
C------------------------------------------------------------------------------------
C         UK   MARK3                    SMIDLIN
C         TEMP CORRECTION*10 TO BE SUBTRACTED
C                       =====>  JTYPE = 33   --     ITAB = 1    <=====
C------------------------------------------------------------------------------------
          DATA   UKMK3   /
C            NITE     -5       5      15       25       35       45       55       65       75
1000 1      3.0,    3.0,   -4.0,   -3.0    -3.0,   -4.0,   -6.0,   -5.0,   -6.0,   -6.0,
850  2     -2.0,   -2.0,   -4.0,   -1.0,   -1.0,   -2.0,   -3.0,   -3.0,   -3.0,   -3.0,
700  3     -1.0,   -1.0     1.0,    0.0,    0.0,   -1.0,   -2.0,   -2.0,   -2.0,   -2.0,
500  4      0.0,    0.0,   -2.0,    0.0,    0.0,   -1.0,   -3.0,   -3.0,   -3.0,   -3.0,
     A     -1.0,   -1.0,    0.0,    0.0,    0.0,   -1.0,   -3.0,   -3.0    -3.0,   -3.0,
300  5     -1.0,   -1.0,    0.0     1.0,    1.0,    0.0,   -2.0,   -2.0,   -2.0,   -2.0,
     B      0.0,    0.0,    2.0,    3.0,    3.0,    1.0,   -1.0,   -1.0,   -1.0,   -1.0,
200  6      0.0,    0.0,    1.0,    2.0,    2.0,    1.0,    1.0,    1.0,    1.0,    1.0,
     C      0.0,    0.0     2.0,    2.0,    2.0,    1.0,    1.0,    1.0,    1.0,    1.0,
100  7      0.0,    0.0,    2.0,    1.0,    1.0,    1.0,    2.0,    2.0,    2.0,    2.0,
 70  D      0.0,    0.0,    2.0,    2.0,    2.0,    2.0,    2.0,    2.0,    2.0,    2.0,
 50  8      0.0,    0.0,    3.0,    5.0,    5.0,    3.0,    2.0,    2.0,    2.0,    2.0,
 30  9      1.0,    1.0,    2.0,    4.0,    4.0,    3.0,    2.0,    2.0,    2.0,    2.0,
 20  T      3.0,    3.0,    3.0,    5.0,    5.0,    3.0,    1.0,    1.0,    1.0,    1.0,
 10  L      6.0,    6.0,   11.0    11.0,   11.0,   10.0,   10.0,   10.0,   10.0,   10.0/
C
```