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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 344

THE HYDROSTATIC CHECKING OF RADIOSONDE HEIGHTS AND TEMPERATURES

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Background

The present NMC operations include a hydrostatic check of radiosonde data, but it can at best result in the rejection by analysis codes of questionable data. It does this by assigning flags to the heights, used later by the analysis preprocessor in determining data quality. In a number of cases, the operational code results in bad data being kept, good data being rejected, or good data being rejected in addition to bad data in a report. The approach reported in this paper is designed to identify hydrostatic errors that can be corrected, and to make the correction. It is recommended that it be incorporated into operations just prior to the operational 'hydrostatic check', HYDROCHEK. In this way, the corrected data will not get flagged, and will be used in the subsequent analysis. This procedure will not correct any of the present failings of HYDROCHK, which must await it replacement.

A total of about 70 reports are found to have hydrostatic errors for each data cycle. Of these, about 25 have errors that can be confidently corrected, being roughly evenly divided between height and temperature corrections. These data are particularly important as they can be located throughout the globe. Table 1 for a May 1988 test shows that a majority of the hydrostatic errors were from stations in the U.S.S.R., India, and China. Table 2 shows the distribution by station block for 15 cases in May, June, and July 1988. The same areas are seen to predominate.

Table 1. Hydrostatic Errors by Region

Region	Average No.	Percent
U.S.S.R.	8.0	20
India	8.3	16
China	7.9	15
Indonesia	2.8	5
Australia	2.0	4

In the complex quality control being designed at NMC (Gandin, 1988), the hydrostatic check forms one of several quality control steps to be performed in parallel, before decisions are made regarding data rejection or correction. The hydrostatic check is unique in being such a powerful check because of the redundancy of height and temperature data. It is because of its power that the hydrostatic check by itself can lead to corrections of the data. The next section of the paper will show the underlying theory used to determine hydrostatic errors and to make corrections. The next section will show some examples of errors and define the methods for their correction. The following sections will give statistical summaries of the errors encountered in tests, and outline inplementation plans.

Table 2. Number of Hydrostatic Errors by WMO Block Number for 15 Cases in May, June and July 1988.

tens \ units	0	1	2	3	4	5	6	7	8	9
00	-	2	3	0	1	-	0	3	4	0
10	2	0	1	1	-	15	7	13	-	-
20	0	2	3	5	9	9	7	9	9	12
30	9	13	3	2	3	6	7	13	25	-
40	5	19	48	37	21	0	4	19	17	-
50	4	14	13	7	14	6	21	15	6	12
60	15	5	4	5	0	0	0	3	3	-
70	1	7	3	0	0	-	11	-	4	-
80	2	1	5	5	1	2	0	3	0	3
90	-	19	-	4	24	-	13	7	0	-

Theory

The hydrostatic check is based on the redundancy of the reported heights and temperatures. The hydrostatic equation is used at station locations to determine the heights from the temperatures observed at known pressures. If the values received at NMC do not agree hydrostatically, then an error has occurred either during the computation at the observation location, during entry into the communications system, during the transfer of the data to NMC, or in our decoding of the data. No matter what the cause of the error, it is in many cases possible to determine that an error has occurred, and to find a correction. In many cases, it is also possible to suggest the nature of the error.

The hydrostatic error is determined by the left and right hand sides of the hydrostatic equation not agreeing. The disagreement is called the hydrostatic residual and is defined by

$$s_i^{i+1} = z_{i+1} - z_i - A_i^{i+1} - B_i^{i+1} (T_i + T_{i+1}).$$

with

$$A_i^{i+1} = (RTo/g) \ln(p_i / p_{i+1})$$

$$B_i^{i+1} = (R/2g)\ \ln(p_i/p_{i+1})$$

To = 273.16 K, R is the dry gas constant, and g is the acceleration of gravity. Temperatures are measured in degrees Celsius, and the difference between temperature and virtual temperature is accounted for by not requiring exact hydrostatic agreement.

The hydrostatic check described in this note only uses mandatory level data in the check, and assumes a linear in logarithm of pressure variation of temperature between mandatory levels. Furthermore, the temperatures are considered to be dry. Therefore, we do not expect the residuals to be zero, but rather they should be small, with maximum allowable values to be determined experimentally.

The possibility of error correction comes from comparing a consecutive pair of hydrostatic residuals. If the sum of the residual pair is small, but the residuals are large, then the intermediate height has an error. Conversely, if the difference of the residuals, divided by the layer B's, is small, then there is an error in the intermediate temperature. These ideas will be made more precise in the next section.

Application

Confident height or temperature corrections are made when residuals are large and the adjusted values would lead to hydrostatic residuals that are small. This statement is made precise by the following discussion. First, define the following quantities:

$$s_z = |s_i^{i+1} + s_j^{j+1}|$$

$$S_z = (B_i^{i+1} + B_j^{j+1})*DTALL$$

$$s_T = |s_i^{i+1}/B_i^{i+1} - s_j^{j+1}/B_j^{j+1}|$$

$$S_T = (1/B_i^{i+1} + 1/B_j^{j+1})*DZALL$$

where i to i+1 and j to j+1 are indices for the layers below and above the data level in question, the B's are summed over the whole layers i to i+1 and j to j+1 when there are intermediate missing data, and DTALL and DZALL are the allowable temperature and height errors: 5 Kelvin and 15 meters. We may call S_z the admissible difference between the height corrections for the layers above and below as suggested by the residuals, and S_T the admissible difference in temperature correction for the layers below and above.

Confident height correction

No corrections are made unless a hydrostatic residual exceeds SBIG, an experimentally determined value for the layer in question, which is presently about 7 times the standard deviation of residual. The values are shown in Table 3.

A confident height correction is made when

$$s_z < S_z$$

and the value of the smaller of the s's is greater than $0.5*SBIG_j$. For the mandatory layers, SBIG varies from 30 meters (1000-850 mb) to 100 meters (20-10 mb). If a value is needed for the sum of more than one layer (as it is when height or temperature values are missing in a profile), the value is obtained as follows:

$$\text{SBIG(layers n to m)} = \text{SQRT}\left[\sum_{i=n}^{m} \text{SBIG}_i^{i+1\ 2}\right]$$

The height correction that is made is

$$ZCOR_J = -.5*(s_i^{i+1} - s_j^{j+1})$$

where i to i+1 are the indices for the higher pressure layer, j to j+1 are the indices for the lower pressure layer, and J is the index for the corrected height. The values of these and all suggested height corrections are rounded to the nearest meter at 1000, 850 and 700 mb, and rounded to the nearest 10 meters above, where no correction is made unless the magnitude is at least 100 meters.

Table 3. Admissible hydrostatic residuals for mandatory layers.

PRESSURE	ADMISSIBLE RESIDUAL
1000	
	65.
850	
	35.
700	
	50.
500	
	35.
400	
	40.
300	
	35.
250	
	40.
200	
	50.
150	
	85.
100	
	70.
70	
	70.
50	
	80.
30	
	70.
20	
	100.
10	

Table 4 shows an example of a confident height correction. The parameters are pressure, height, corrected height, temperature, corrected temperature, layer residual, height correction, temperature correction, and "correction type". In most of the similar tables, only a portion of the reported profile will be shown. The pair of residuals clearly indicate a height correction of 3000. meters. The error most likely results from a simple key typing mistake. The next example, shown in Table 5, is a confident height correction in which digits were transposed.

Table 4. Example of confident height correction in which a key typing mistake was made.

IDENT = 23472 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
50	21090.	21090.	-49.3	-49.3		0.0	0.0	
					-3007.4			
30	21420.	24420.	-50.9	-50.9		3000.	0.0	1
					2999.1			
20	27080.	27080.	-47.3	-47.3		0.0	0.0	

Table 5. Example of confident height correction in which digits were interchanged.

IDENT = 55299 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
300	9770.	9770.	-24.9	-24.9		0.0	0.0	
					-902.8			
250	10170.	11070.	-33.5	-33.5		900.	0.0	1
					900.9			
200	12600.	12600.	-44.9	-44.9		0.0	0.0	

<u>Confident temperature correction</u>

A confident temperature correction is made when

$$s_T < S_T$$

and the value of the smaller s exceeds 0.5*SBIG. The temperature correction that is made is

$$TCOR_J = .5*(s_i^{i+1}/BSUM_i^{i+1} + s_j^{j+1}/BSUM_j^{j+1})$$

where i to i+1 are the indices for the higher pressure layer, j to j+1 are the indices for the lower pressure layer, and J is the index for the corrected height. The values of all suggested temperature corrections are rounded to the nearest 0.1 degree. Table 6 shows an example of a confident temperature correction. The correct value is most likely 21.6, and the '2' was mistakenly entered as an '8'.

The examples have focused attention on the portion of profiles where errors appeared. Cases occur not infrequently where there is more than one confident height and/or temperature correction, and the procedures outlined in this note treat these situations just as well as isolated errors, so long as one level of good data intervenes. There will be more discussion later of complicated cases.

Table 6. Example of a confident temperature correction.

IDENT = 43371 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
1000	69.	69.	28.0	28.0		0.0	0.0	
					-144.1			
850	1486.	1486.	81.6	21.4		0.	-60.2	2
					-170.1			
700	3132.	3132.	10.8	10.8		0.0	0.0	

In some cases it is possible to make a sign correction in temperature. If $|2*T_J + TCOR_J| < DTALL$, then the sign is in error and must be corrected. Table 7 shows an example of a temperature sign correction. Many temperature corrections are sign corrections. A check is also made to make sure that a corrected temperature does not produce a statically unstable layer. This is accomplished by checking the lapse rates above and below a corrected level.

Table 7. Example of a confident temperature correction with sign error.

IDENT = 30230 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
700	3081.	3081.	1.2	1.2		0.0	0.0	
					-144.8			
500	5710.	5710.	15.4	-15.4		0.0	-29.8	2
					-98.4			
400	7360.	7360.	-26.7	-26.7		0.0	0.0	

<u>Other corrections</u>

In cases where a confident correction cannot be made, suggested corrections can sometimes be given. This information will be used along with the horizontal and vertical checks by the Decision Making Algorithm to determine further confident corrections.

If the error is in the bottom layer, it is most likely that the lowest temperature or height is in error, but usually not both. Accordingly, if the residual in the lowest layer is greater than SBIG, and is less than .5*SBIG in the second layer, the amount that the independent temperature or height must be changed to make the residual equal to 0. is given as the suggested change. The suggested corrections are

$$ZCOR_J = s_i^{i+1}$$

$$TCOR_J = s_i^{i+1} / BSUM_i^{i+1}$$

with the temperature and height rounded as described before. There is the additional strong possibility that a computational error giving incorrect thickness in the lowest layer is reflected in all heights above having the same error, rather than the lowest height being wrong. However, a choice between the possibilities can only be determined with the help of other Complex Quality Control components, particularly the horizontal check of height. Tables 8 and 9 give examples of errors in the bottom layer. Examination shows that the error is in the height (or possibly thickness) in the first, and in the sign of temperature in the second.

Table 8. Example of hydrostatic error in the bottom layer, due to height error.

IDENT = 20069 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
1000	112.	112.	-0.1	-0.1		-85.0	-355.6	4
					-84.8			
850	1318.	1318.	-3.9	-3.9		0.0	0.0	

Table 9. Example of hydrostatic error in the bottom layer, due to temperature error.

IDENT = 29231 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
1000	176.	176.	-22.9	-22.9		110.0	46.3	4
					110.2			
850	1570.	1570.	16.0	16.0		0.0	0.0	

Independent height and temperature corrections are also suggested for a large hydrostatic residual in the top layer when the next lower residual is less than .5*SBIG. The suggested corrections are

$$ZCOR_J = -s_i^{i+1}$$

$$TCOR_J = s_i^{i+1} / BSUM_i^{i+1} .$$

Examples of height and temperature errors at the top are given in Tables 10 and 11.

Table 10. Example of hydrostatic error in the top layer, due to height error.

IDENT = 71816 DATE = 12Z 31 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
20	26910.	26910.	-48.7	-48.7		0.0	0.0	
					310.1			
10	31840.	31840.	-42.5	-42.5		-310.0	30.5	5

Table 11. Example of hydrostatic error in the top layer, due to temperature error.

IDENT = 38879 DATE = 12Z 30 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
300	9470.	9470.	-42.5	-42.5		0.0	0.0	
					-127.0			
250	10700.	10700.	4.4	4.4		130.0	-47.6	5

A pair of corrections can be suggested for an intermediate layer in which the conditions for a confident correction are not met, i.e. where neither

$$s_z < S_z$$

nor

$$s_T < S_T .$$

The suggested corrections in this case are those which, when taken together, make the pair of residuals equal 0. It is rare to encounter a case where careful examination shows that simultaneous height and temperature errors have occurred at the same level, but the pair of suggested corrections can serve as a guide in further tests. These corrections are suggested only under the further restriction that the smaller of the residuals is greater than .5*SBIG. They are

$$ZCOR_J = \frac{(BSUM_i^{i+1} * s_j^{j+1} - BSUM_j^{j+1} * s_i^{i+1})}{BSUM_i^{i+1} + BSUM_j^{j+1}}$$

and

$$TCOR_J = \frac{s_i^{i+1} + s_j^{j+1}}{BSUM_i^{i+1} + BSUM_j^{j+1}}.$$

An example of a suggested correction pair is shown in Table 12. In this case, both corrections of the pair must be applied or the layer above will be statically unstable.

Table 12. Example of hydrostatic error which does not satisfy the criteria for being confidently a height or temperature error.

IDENT = 98646 DATE = 00Z 14 SEP 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
700	3156.	3156.	10.0	10.0		0.0	0.0	
					72.0			
500	5990.	5990.	4.2	4.2		-100.0	-5.7	3
					-119.0			
400	7620.	7620.	-15.3	-15.3		0.0	0.0	

In addition to these suggested corrections, the presence of isolated large residuals is detected, but in this case, it is rarely possible to suggest a correction without the help of other CQC elements. An example of an isolated large residual is shown in Table 13. In this case it is likely that the error is in the computation of the 100 to 70 mb thickness.

In some cases of more complicated error it is possible to automatically make corrections. The following case will serve as an example. Methods to handle such a case have been developed, but not yet included in the hydrostatic check code. The example, shown in Table 14, has two places in the profile where there are three consecutive large residuals. The suggested corrections are those found by the new procedure, not by the present code, which does not suggest confident corrections.

Table 13. Example of large isolated residual.

IDENT = 37789 DATE = 12Z 30 AUG 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
150	14000.	14000.	-51.7	-51.7		0.0	0.0	
					-9.8			
100	16600.	16600.	-55.1	-55.1		0.0	0.0	
					-429.7			
70	18440.	18440.	-56.7	-56.7		0.0	0.0	6
					-14.1			
50	20570.	20570.	-54.5	-54.5		0.0	0.0	

Table 14. Example of complicated corrections.

IDENT = 87623 DATE = 12Z 1 SEP 1988

PRESS	HEIGHT	NEW-HT	TEMP.	NEW-T	RESID	ZCOR	TCOR	TYP
1000	259.	259.	-0.3	-0.3		0.0	0.0	
					392.4			
850	1155.	1547.	-4.7	-4.7		392.0	0.0	
					640.3			
700	3306.	3079.	-10.3	-10.3		-227.0	0.0	
					-227.4			
500	5610.	5610.	-22.3	-22.3		0.0	0.0	
					3.1			
400	7220.	7220.	-32.3	-32.3		0.0	0.0	
					2.9			
300	9190.	9190.	-47.1	-47.1		0.0	0.0	
					2.3			
250	10400.	10400.	-46.9	-46.9		0.0	0.0	
					-7.7			
200	11860.	11860.	-50.3	-50.3		0.0	0.0	
					88.3			
150	13720.	13720.	-75.5	-54.5		0.0	21.0	
					-5157.6			
100	11000.	16260.	-60.3	-60.3		5260.0	0.0	
					5264.2			
70	18490.	18490.	-59.9	-59.9		0.0	0.0	
					3.1			
50	20580.	20580.	-62.9	-62.9		0.0	0.0	
					30.1			
30	23750.	23750.	-63.7	-63.7		0.0	0.0	
					18.9			
20	26260.	26260.	-63.1	-63.1		0.0	0.0	

Selection of Residual Pair

All of the hydrostatic error detection techniques use a residual pair for their detection. When there is more than one error in a profile, it is crucial that the proper order of residual pair consideration be chosen since the order can affect the conclusions of error type. In some cases it is necessary to consider three consecutive residuals for proper error determination, but the present method does not include that further complication. This section will discuss the priority system used to select pairs of residuals for error determination.

Some general principles are used in residual selection. The selection of a residual for consideration is based upon the size of the residual relative to the admissible residual, $s_i^{i+1}/SBIG_i^{i+1}$. The SBIG's themselves are related to the standard deviation of s_i^{i+1}. Therefore, we are interested in the magnitude of the residual, relative to its climatological variation at the level in question. We give priority to residuals having neighbors that have not already been tested (mid), since then the powerful methods outlined in the previous section may be used.

During our examination of radiosonde data it was found that there are many reports that have not been successfully decoded at all levels, leading to missing data at upper levels. Since the reports arrive in parts (1000-100 mb and 70 mb up), it is often the case that an upper part can be decoded successfully, while levels of the lower part have been lost. This gives the appearance of a report with several layers missing, usually ending with 100 mb. When the hydrostatic check is applied to the levels bounding such a data gap, and particularly if the tropopause is within this layer, the check is not of much value. Therefore, priority is also given to layers without missing data (thin), since then the assumption of linearity of the temperature profile is more accurate and the conclusions of the analysis are more definite.

The specifics of the selection priority may be outlined as follows:

Selection of large residual--

It must not already have been tested.
Top priority--greatest s/SBIG, thin, mid.
2nd priority--greatest s/SBIG, top or bottom.
3rd priority--greatest s/SBIG.

Selection of neighbor--

It must not already have been tested.
If only one neighbor is untested, pick it.
If only one neighbor is thin, pick it.
Pick neighbor with largest s/SBIG.

If there are no untested neighbors or no untested residuals, the checking ends.

The FORTRAN codes for important subroutines for the hydrostatic corrections are given in the Appendix at the end of this Note.

Statistical results

This section will summarize some of the results of the new hydrostatic check. Out of an average of roughly 600 reports, about 70 were found to contain one or more hydrostatic errors. The following Tables 15 and 16 show the distribution of errors by error type and by pressure. It is noted that 37% of the errors can be confidently corrected.

In all the test cases, there were only a few decisions for a confident correction which close examination showed to be in error. They were a result of problems with the sounding that are probably beyond the capability of any procedure to rehabilitate. Therefore, there were no instances when a correction by the new hydrostatic check, and its data correction, introduced additional errors to the data. On the other hand, the overwhelming majority of its corrections to the data passed the subsequent checking by HYDROCHK (see DiMego et al, 1985), and therefore an increase of good data to the NMC operational codes would have resulted had they been run following these procedures.

Table 15. Distribution of Hydrostatic Errors by Type

No.	Error Type	Average No.	Percent
1	confident height correction	11.3	16
2	confident temperature correction	14.9	21
3	not confident, T, z pair of corrections given	6.0	8
4	error at bottom	8.0	11
5	error at top	13.6	19
6	large isolated residual	8.6	12
11	nearly confident height corr.	6.0	8
12	temperature correction diagnosed to give unstable lapse rate	3.0	5

Table 16. Distribution of Hydrostatic Errors by Pressure

Pressure	Average No.	Percent
1000	2.2	3
850	5.0	8
700	3.0	5
500	3.8	6
400	5.2	8
300	5.4	8
250	4.2	7
200	2.4	4
150	5.8	9
100	2.8	4
70	9.2	15
50	3.8	6
30	2.4	4
20	3.0	5
10	5.0	8

The present 'hydrostatic check' code, HYDROCHK, does more than a hydrostatic check. It also checks for layers with lapse rates outside specified ranges, it checks values against climatological ranges, and it checks wind shears. When it finds a problem, it flags the datum. In some cases, it used significant level data to try to reconstruct part of a profile of temperatures, and to modify and check mandatory level temperatures. Again, flags are used to indicate its decisions. Eight cases in May 1988 were used to investigate the validity of HYDROCHK's decisions. The following Table 17 summarizes those results.

Table 17. Reaction of the Present System to the Flags Set by HYDROCHK

Reaction of present system	Average No.	Percent
purged the datum (the proper response)	7.4	52
purged the level (z and T)	3.5	20
purged other data instead	1.3	7
purged other data in addition	2.0	11
purged many data	2.4	14
no reaction	.9	5
attempted to correct	.1	1

The fact that the HYDROCHK almost always has some reaction to hydrostatic errors is significant since it is proposed to include the new hydrostatic check just prior to HYDROCHK. As mentioned above, the tests show that the changes made by the new code are invariably seen to be acceptable to HYDROCHK.

There are many possible sources leading to errors in datum received at NMC, but the hydrostatic check can only detect those that lead to an inconsistency between the height and temperature fields. The possible reasons include the computation of the heights from the temperatures, transcription to the communication lines, and communication errors. Refer to Table 1, which shows the distribution of hydrostatic errors by geographical region for the 8 cases in May 1988. It is seen that the largest number of errors come from regions with the least automation. Generally, there are no errors from the U.S., so that the improvement to the analyses that will be effected by the introduction of the new hydrostatic check will be in other areas. Its impact on forecast quality will most likely usually be small, but not necessarily so.

Summary

This note has described a hydrostatic check which can be used to correct certain types of hydrostatic errors. Tests have shown the check to be reliable, and further testing in the operational framework are under way. It is proposed to perform the HSC just prior to the operational code HYDROCHK. In this way, the data that are corrected will not be flagged as erroneous by HYDROCHK, and they will likely be used in NMC's analyses and forecasts.

During a month-long test, the confident height and temperature corrections that the hydrostatic check would make to the data will be scrutinized by monitoring analysts of the Meteorological Operations Division. Following a positive result from that test, the HSC will be implemented. This procedure is seen as an interim measure for the following reasons. First of all, it is desirable that all the functions of HYDROCHK be taken over by the new code. But also, the HSC is designed to be one component of the Complex Quality Control. And in that framework, it may not be appropriate to make changes to the data without the results of the vertical and horizontal checks. The approach taken here, of modifying the data as a result of a single test, is only possible because of the power of the hydrostatic check. However, even it is not infallible, and in the future, when more components of the Complex Quality Control are available, and the Decision Making Algorithm has been written, we may reverse the present decision, and not allow the HSC alone to make data corrections.

Future work will concentrate first on the horizontal and then the vertical check of radiosonde data, followed by the Decision Making Algorithm for these data. The reader is referred to Gandin (1988) for further discussion. Each data type has its special types of errors and methods of cross-checking with other information, so that the development must be independent, but parallel.

REFERENCES

Gandin, L.S., 1988: Complex quality control of meteorological observations. Mon. Wea.Rev., 116(5),1137-1156.

DiMego, G.J., P.A. Phoebus, and J.E. McDonell, Data processing, and quality control for optimum interpolation analyses at the National Meteorological Center, 1985: NOAA, National Weather Service, National Meteorological Center, Office Note 306.

APPENDIX

Code for subroutines CORECT, FNEXT, TEST, and RESID begins on the following page.

```
      SUBROUTINE CORECT(Z,T,ZCOR,TCOR,ZC,TC,S,SBIG,
     &  LEV,ICTYP,IETYP)
C$$$  SUBPROGRAM DOCUMENTATION BLOCK
C
C SUBPROGRAM:    CORECT      HYDROSTATIC CORRECTION TO DATA
C   PRGMMR: W.COLLINS        ORG: W/NMC22    DATE: 88-09-14
C
C ABSTRACT:  THIS SUBROUTINE MAKES CORRECTIONS TO HEIGHTS  AND
C   TEMPERATURES IN A RADIOSONDE REPORT BASED UPON
C   A HYDROSTATIC CHECK.
C
C PROGRAM HISTORY LOG:
C   88-09-14  ORIGINAL    W. COLLINS
C
C USAGE:    CALL CORECT(Z, T, ZCOR, TCOR, ZC, TC, S, SBIG,
C                       LEV, ICTYP, IETYP)
C   INPUT ARGUMENT LIST:
C           Z      - HEIGHT PROFILE
C           T      - TEMPERATURE PROFILE
C           SBIG   - ADMISSIBLE RESIDUAL FOR LAYER (M)
C           LEV    - NUMBER OF LEVELS TO CONSIDER
C
C   OUTPUT ARGUMENT LIST:
C           ZC     - CORRECTED HEIGHT PROFILE (METERS)
C           TC     - CORRECTED TEMPERATURE PROFILE (CELSIUS)
C           S      - NEW HYDROSTATIC RESIDUAL FOR LAYER (M)
C           ICTYP - CORRECTION TYPE CODE
C               0 = NO CORRECTION
C               1 = CONFIDENT HEIGHT CORRECTION
C               2 = CONFIDENT TEMPERATURE CORRECTION
C               3 = Z, T CORRECTIONS TO MAKE RESIDS = 0.
C               4 = BOTTOM LAYER CORRECTION CHOICE
C               5 = TOP LAYER CORRECTION CHOICE
C               6 = ISOLATED LARGE RESIDUAL
C              11 = HEIGHT CORRECTION .LT. 100 M
C              12 = TEMPERATURE CORRECTION, GIVING INSTABILITY
C           IETYP - ERROR TYPE CODE (NOT YET DEFINED)
C
C ATTRIBUTES:
C   LANGUAGE:  VS FORTRAN
C   MACHINE:  NAS
C
C$$$
      DIMENSION Z(1), T(1), ZC(1), TC(1), ICTYP(1), IETYP(1)
      DIMENSION ZCOR(1), TCOR(1), S(1), SBIG(1),
     &  BSUM(54), ISL(54), ISU(54), ITST(54)
      COMMON /CONSTS/ R, G, TO, A(54), B(54), SS(54)
      COMMON /LEVEL/ MBOGUS,NPLVL,IPLVL(55)
      DATA ZMSG /99999./, TMSG /9999.9/, ZMAX /90000./,
     &  TMAX /9000./, DZALL /15./, DTALL /5./,
     &  CP /1004.5/, PO /1000./, THLIM /-.05/
      LEVM = LEV - 1
      ROCP = R/CP
C
C     FIND THE HIGHEST NON-MISSING LEVEL. SET INDEX = KMAX.
C
      DO 10 K=1,NPLVL
        KK = NPLVL - K + 1
        KMAX = KK
        IF((Z(KK).LT.ZMAX).AND.(T(KK).LT.TMAX)) GO TO 20
```

```
   10 CONTINUE
C
C     COPY PROFILES INTO OUTPUT PROFILES.
C
   20 CONTINUE
      DO 30 K=1,LEV
        ZC(K) = Z(K)
        TC(K) = T(K)
   30 CONTINUE
C
C     ZERO SOME QUANTITIES.
C
      DO 40 K=1,LEVM
        ICTYP(K) = 0
        IETYP(K) = 0
   40 CONTINUE
C
C     ZERO CORRECTIONS, INDEX LIST, RESIDUALS.
C
      DO 50 K=1,NPLVL
        ZCOR(K) = 0.
        TCOR(K) = 0.
        ITST(K) = 0
        S(K) = 0.
   50 CONTINUE
C
C     COMPUTE RESIDUALS
C
  100 CONTINUE
      CALL RESID(ZC,TC,KMAX,S,SBIG,BSUM,ISL,ISU,KRES)
C
C     FIND THE (NEXT) LARGEST TEMPERATURE RESIDUAL, S(II)/SBIG(II)
C     AND LARGEST ADJACENT TEMPERATURE RESIDUAL, S(JJ)/SBIG(JJ)
C     AMONG LAYERS THAT HAVE NOT ALREADY BEEN TESTED.
C
  300 CONTINUE
      CALL FNEXT(S,SBIG,ITST,KRES,ISL,ISU,II,JJ,SI,SJ)
C
C     SEE IF LARGEST RESIDUAL IS LARGE.
C
      IF(ABS(SI).LE.SBIG(II)) RETURN
C
C     CHECK TO SEE IF ALL LEVELS HAVE BEEN CHECKED.
C
      CALL TEST(ITST,KRES,IT)
      IF((II.EQ.0).OR.(IT.EQ.KRES)) RETURN
C
C     TEST FOR ERROR TYPE. FIRST COMPUTE SOME QUANTITIES.
C
      IF(JJ.NE.0) THEN
        IF(II.LT.JJ) THEN
          JMM = ISL(II)
          JM = ISU(II)
          JP = ISU(JJ)
          SIGN = 1.0
        ELSE
          JMM = ISL(JJ)
          JM = ISU(JJ)
          JP = ISU(II)
          SIGN = -1.0
```

```
          ENDIF
          SHGT = ABS(SI + SJ)
          SSHGT = (BSUM(II)+BSUM(JJ)) * DTALL
          STMP = ABS(SI/BSUM(II) - SJ/BSUM(JJ))
          SSTMP = (1./BSUM(II)+1./BSUM(JJ)) * DZALL
        ENDIF
        JT = ISU(II)
        JB = ISL(II)
        ICT = 0
C
C         CONFIDENT HEIGHT CORRECTION (ICTYP = 1).
C
        IF((ABS(SJ).GT.0.5*SBIG(JJ)).AND.JJ.NE.0.
     &   AND.(SHGT.LT.SSHGT)) THEN
          ZCOR(JM) = -0.5 * SIGN * (SI - SJ)
C         ROUND TO NEAREST 10 METERS ABOVE 700 MB
C         ROUND TO NEAREST METER BELOW 500 MB
          IF(JM.LE.3) THEN
            ZCOR(JM) = ANINT(ZCOR(JM))
            ICTYP(JM) = 1
            ICT = 1
          ELSE
            ZCOR(JM) = 10. * ANINT(ZCOR(JM)/10.)
            IF(ABS(ZCOR(JM)).GE.100.) THEN
              ICTYP(JM) = 1
              ICT = 1
            ELSE
              ZCOR(JM) = 0.
              ICTYP(JM) = 11
              ICT = 11
            ENDIF
          ENDIF
          ZC(JM) = ZC(JM) + ZCOR(JM)
          ITST(II) = 1
          ITST(JJ) = 1
C
C         CONFIDENT TEMPERATURE CORRECTION (ICTYP = 2).
C
        ELSE IF((ABS(SJ).GT.0.5*SBIG(JJ)).AND.JJ.NE.0.
     &   AND.(STMP.LT.SSTMP)) THEN
          TCOR(JM) = 0.5 * (SI/BSUM(II)+SJ/BSUM(JJ))
          TCOLD = TC(JM)
          IF(ABS(2.*TC(JM)+TCOR(JM)).LT.DTALL) THEN
            TC(JM) = -TC(JM)
          ELSE
C           ROUND TO NEAREST 1/10 DEGREE
            TCOR(JM) = 0.1 * ANINT(10.*TCOR(JM))
            TC(JM) = TC(JM) + TCOR(JM)
          ENDIF
C
C       MAKE SURE THAT THE LAPSE RATES ABOVE AND BELOW
C       ARE ADIABATICALLY STABLE.  IF NOT, RESTORE
C       THE ORIGINAL TEMPERATURE, TCOLD.
C
C       ALSO, CHECK FOR TEMPERATURE LAPSES ABOVE AND
C       BELOW OF SAME SIGN.
C
C       ALSO, DO NOT GIVE CORRECTIONS FOR LAYERS WITH
C       MISSINGS.
C
```

```
        IF(JP.NE.0.AND.JMM.NE.0) THEN
          PJP = IPLVL(JP)
          THJP = (T0+TC(JP)) * (P0/PJP)**ROCP
          PJM = IPLVL(JM)
          THJM = (T0+TC(JM)) * (P0/PJM)**ROCP
          THOLD = (T0+TCOLD) * (P0/PJM)**ROCP
          PJMM = IPLVL(JMM)
          THJMM = (T0+TC(JMM)) * (P0/PJMM)**ROCP
          IF(THJP-THJM.GT.THLIM
     &       .AND.THJM-THJMM.GT.THLIM
     &       .AND.JP-JMM.EQ.2
     &       .AND.((TC(JP)-TC(JM))*(TC(JM)-TC(JMM))).GT.0.)
     &       THEN
            ICTYP(JM) = 2
            ICT = 2
            ITST(II) = 1
            ITST(JJ) = 1
          ELSE
            TC(JM) = TCOLD
            ICTYP(JM) = 12
            ICT = 12
            ITST(II) = 1
            ITST(JJ) = 1
          ENDIF
        ENDIF
C
C     A CONFIDENT CORRECTION CANNOT BE MADE, THEREFORE:
C     COMPUTE CORRECTION PAIR MAKING S-PAIR = 0. (ICTYP = 3)
C
      ELSE IF(ABS(SJ).GT.0.5*SBIG(JJ)
     &  .AND.JJ.NE.0) THEN
        ZCOR(JM) = SIGN * (BSUM(II)*SJ-BSUM(JJ)*SI)
     &    /(BSUM(II) + BSUM(JJ))
C       ROUND TO NEAREST 10 METERS ABOVE 700 MB
C       ROUND TO NEAREST METER BELOW 500 MB
        IF(JM.LE.3) ZCOR(JM) = ANINT(ZCOR(JM))
        IF(JM.GT.3) ZCOR(JM) = 10. * ANINT(ZCOR(JM)/10.)
        TCOR(JM) = (SI + SJ) / (BSUM(II) + BSUM(JJ))
C       ROUND TO NEAREST 1/10 DEGREE
        TCOR(JM) = 0.1 * ANINT(10.*TCOR(JM))
        ICTYP(JM) = 3
        ICT = 3
        ITST(II) = 1
        ITST(JJ) = 1
C
C     CORRECTION AT BOTTOM. (ICTYP = 4)
C
      ELSE IF((II.EQ.1).
     &  AND.((JJ.EQ.0).OR.((JJ.NE.0).AND.(ABS(SJ).
     &  LT.0.5*SBIG(JJ))))) THEN
        ZCOR(JB) = SI
C       ROUND TO NEAREST 10 METERS ABOVE 700 MB
C       ROUND TO NEAREST METER BELOW 500 MB
        IF(JB.LE.3) ZCOR(JB) = ANINT(ZCOR(JB))
        IF(JB.GT.3) ZCOR(JB) = 10. * ANINT(ZCOR(JB)/10.)
        TCOR(JB) = SI/BSUM(II)
C       ROUND TO NEAREST 1/10 DEGREE
        TCOR(JB) = 0.1 * ANINT(10.*TCOR(JB))
        ICTYP(JB) = 4
        ICT = 4
```

```
          ITST(II) = 1
C
C       CORRECTION AT TOP. (ICTYP = 5)
C
        ELSE IF((II.EQ.KRES).
     &   AND.((JJ.EQ.0).OR.((JJ.NE.0).AND.(ABS(SJ).
     &   LT.0.5*SBIG(JJ))))) THEN
          ZCOR(JT) = -SI
C         ROUND TO NEAREST 10 METERS ABOVE 700 MB
C         ROUND TO NEAREST METER BELOW 500 MB
          IF(JT.LE.3) ZCOR(JT) = ANINT(ZCOR(JT))
          IF(JT.GT.3) ZCOR(JT) = 10. * ANINT(ZCOR(JT)/10.)
          TCOR(JT) = SI/BSUM(II)
C         ROUND TO NEAREST 1/10 DEGREE
          TCOR(JT) = 0.1 * ANINT(10.*TCOR(JT))
          ICTYP(JT) = 5
          ICT = 5
          ITST(II) = 1
C
C       ISOLATED LARGE RESIDUAL. (ICTYP = 6)
C
        ELSE IF (ABS(SI).GT.1.5*SBIG(II)
     &   .AND.(ABS(SJ).LT.SBIG(JJ).AND.JJ.NE.0)) THEN
          ICTYP(JT) = 6
          ICT = 6
          ITST(II) = 1
          ITST(JJ) = 1
        ELSE
          ITST(II) = 1
          ICT = 0
        ENDIF
        IF((ICT.EQ.1).OR.(ICT.EQ.2)) THEN
          GO TO 100
        ELSE
          GO TO 300
        ENDIF
        END
C***********************************************************************
        SUBROUTINE FNEXT(S,SBIG,ITST,KRES,ISL,ISU,II,JJ,SI,SJ)
C
C       FIND THE (NEXT) LARGEST TEMPERATURE RESIDUAL, S(II)/SBIG(II)
C       AND LARGEST ADJACENT TEMPERATURE RESIDUAL, S(JJ)/SBIG(JJ)
C       AMONG LAYERS THAT HAVE NOT ALREADY BEEN TESTED.
C       A PRIORITY SYSTEM IS USED FOR THE CORRECTIONS OR
C       SUGGESTED CORRECTIONS.  THE LAYER WITH THE LARGEST
C       RESIDUAL IS CHOSEN, BUT MID, THIN LAYERS ARE GIVEN TOP
C       PRIORITY, THEN TOP OR BOTTOM LAYERS, AND OTHER CASES
C       ARE GIVEN LAST PRIORITY.  THE NEIGHBORS ARE ALSO SEARCHED
C       WITH PRIORITY.  LARGEST THIN NEIGHBOR FIRST, THEN OTHERS.
C       (NEW VERSION 6/20/88)
C
        DIMENSION S(1), SBIG(1), ITST(1), ISL(1), ISU(1)
        II = 0
        JJ = 0
        IIMID = 0
        IIBT = 0
        IITHK = 0
        SMID = 0.
        SBT = 0.
        STHK = 0.
```

```
      SI = 0.
      SJ = 0.
      RATO = 0.
      DO 200 I=1,KRES
        IF(ITST(I).EQ.0) THEN
          RAT = ABS(S(I)/SBIG(I))
          IDIF = ISU(I) - ISL(I)
          IF(RAT.GT.RATO.AND.IDIF.LE.2.AND.
     &       I.NE.1.AND.I.NE.KRES) THEN
            IIMID = I
            SMID = S(I)
            RATO = RAT
          ENDIF
        ENDIF
  200 CONTINUE
      RATO = 0.
      DO 210 I=1,KRES
        IF(ITST(I).EQ.0) THEN
          RAT = ABS(S(I)/SBIG(I))
          IF(RAT.GT.RATO.AND.
     &       (I.EQ.1.OR.I.EQ.KRES)) THEN
            IIBT = I
            SBT = S(I)
            RATO = RAT
          ENDIF
        ENDIF
  210 CONTINUE
      RATO = 0.
      DO 220 I=1,KRES
        IF(ITST(I).EQ.0) THEN
          RAT = ABS(S(I)/SBIG(I))
          IF(RAT.GT.RATO) THEN
            IITHK = I
            STHK = S(I)
            RATO = RAT
          ENDIF
        ENDIF
  220 CONTINUE
C
C     CHOOSE II AMONG POSSIBLE VALUES IN THE PRIORITY:
C       1. IIMID,   2.  IIBT,   3.  IITHK
C
      IF(IIMID.NE.0.AND.ABS(SMID).GT.SBIG(IIMID)) THEN
        II = IIMID
      ELSE IF(IIBT.NE.0.AND.ABS(SBT).GT.SBIG(IIBT)) THEN
        II = IIBT
      ELSE
        II = IITHK
      ENDIF
      SI = S(II)
      IF(II.EQ.0) GO TO 390
      IF(KRES.EQ.1) GO TO 390
C
C     NOW, FIND LARGEST NEIGHBOR.
C
C     IF JJ REMAINS SET = 0, THEN NO UNCHECKED NEIGHBORS
C     EXIST.
C
C     CHECK FOR BOTTOM.
C
```

```
      IF(II.EQ.1) THEN
        IF(ITST(2).EQ.0) THEN
          JJ = 2
        ELSE
          JJ = 0
        ENDIF
C
C     CHECK FOR TOP.
C
      ELSE IF(II.EQ.KRES) THEN
        IF(ITST(KRES-1).EQ.0) THEN
          JJ = KRES - 1
        ELSE
          JJ = 0
        ENDIF
C
C     LAYERS ARE IN MIDDLE. SEE IF ALREADY TESTED.
C
      ELSE
        IIM = II - 1
        IIP = II + 1
        IF(ITST(IIM).EQ.1.AND.ITST(IIP).EQ.0) THEN
          JJ = IIP
        ELSE IF(ITST(IIM).EQ.0.AND.ITST(IIP).EQ.1) THEN
          JJ = IIM
C       GIVE PRIORITY TO THIN NEIGHBOR.
        ELSE IF(ITST(IIM).EQ.0.AND.ITST(IIP).EQ.0) THEN
          SM = S(IIM)/SBIG(IIM)
          SP = S(IIP)/SBIG(IIP)
          IDIFM = ISU(IIM) - ISL(IIM)
          IDIFP = ISU(IIP) - ISL(IIP)
          IF(IDIFM.LE.2.AND.IDIFP.GT.2) THEN
            JJ = IIM
          ELSEIF(IDIFP.LE.2.AND.IDIFM.GE.2) THEN
            JJ = IIP
          ELSE
          IF(ABS(SM).GT.ABS(SP)) JJ = IIM
          IF(ABS(SP).GT.ABS(SM)) JJ = IIP
          ENDIF
        ENDIF
      ENDIF
      SJ = S(JJ)
  390 CONTINUE
      RETURN
      END
C***********************************************************************
      SUBROUTINE TEST(ITST,KRES,IT)
      DIMENSION ITST(1)
      IT = 0
      DO 10 I=1,KRES
        IT = IT + ITST(I)
   10 CONTINUE
      RETURN
      END
C***********************************************************************
```

```
      SUBROUTINE RESID(Z,T,MAN,S,SBIG,BSUM,ISL,ISU,KMAX)
C$$$ SUBPROGRAM DOCUMENTATION BLOCK
C
C SUBPROGRAM:    RESID   CALCULATE HYDROSTATIC RESIDUALS
C   PRGMMR: W. COLLINS    ORG: W/NMC22    DATE: 88-09-14
C
C ABSTRACT:  CALCULATE HYDROSTATIC RESIDUALS FOR MANDATORY
C            LAYERS.  ACCOUNT FOR MISSINGS.
C
C PROGRAM HISTORY LOG:
C   88009-14  ORIGINAL    W. COLLINS
C
C USAGE:     CALL RESID(Z, T, MAN, S, SBIG, BSUM, ISL,
C              ISU, KMAX)
C
C       INPUT ARGUMENT LIST:
C         Z    - HEIGHT PROFILE
C         T    - TEMPERATURE PROFILE
C         MAN  - NUMBER OF MANDATORY LEVELS
C         SBIG - ADMISSIBLE RESIDUALS
C       OUTPUT ARGUMENT LIST:
C         S    - HYDROSTATIC RESIDUALS
C         BSUM - B FOR OUTPUT LAYERS
C         ISL  - INDICES FOR LOWER LAYER LIMITS
C         ISU  - INDICES FOR UPPER LAYER LIMITS
C         KMAX - NUMBER OF OUTPUT LAYERS
C
C ATTRIBUTES:
C   LANGUAGE:  VS FORTRAN
C   MACHINE:  NAS
C
C$$$
      COMMON /CONSTS/ R, G, T0, A(54), B(54), SS(54)
      DIMENSION Z(1), T(1), S(1), SBIG(1), ISL(1), ISU(1),
     &  BSUM(1)
      DATA ZMSG/99999./, TMSG/9999.9/, ZMAX/90000./, TMAX/9000./
      RES(Z1,Z2,T1,T2,A0,B0) = Z2 - Z1 - A0 - B0 * (T1+T2)
      MANM = MAN - 1
C
C     COMPUTE RESIDUALS.
C
      DO 10 K=1,54
        S(K) = 0.
        SBIG(K) = 0.
        BSUM(K) = 1.E-6
        ISL(K) = 0
        ISU(K) = 0
   10 CONTINUE
      IK = 1
      KMAX = IK - 1
      DO 50 K=1,MANM
        IF(Z(K).GT.ZMAX.OR.T(K).GT.TMAX) GO TO 50
C
C     KLOW IS LOWER LEVEL WITHOUT MISSING DATA.
C
        KLOW = K
        KP = K + 1
        DO 20 KK=KP,MAN
          KHIGH = KK
          IF(Z(KK).LT.ZMAX.AND.T(KK).LT.TMAX) GO TO 25
```

```
   20   CONTINUE
        GO TO 50
C
C     KHIGH IS UPPER LEVEL WITHOUT MISSING DATA.
C
   25   ASUM = 0.
        SSUM = 0.
        KHIGHM = KHIGH - 1
        ISL(IK) = KLOW
        ISU(IK) = KHIGH
        DO 30 KK=KLOW,KHIGHM
          ASUM = ASUM + A(KK)
          BSUM(IK) = BSUM(IK) + B(KK)
          SSUM = SSUM + SS(KK)**2
   30   CONTINUE
        SBIG(IK) = SQRT(SSUM)
        S(IK)=RES(Z(KLOW),Z(KHIGH),T(KLOW),T(KHIGH),
     &    ASUM,BSUM(IK))
      IK = IK + 1
C
C     KMAX IS NUMBER OF LEVELS OF RESIDUALS.
C
      KMAX = IK - 1
   50 CONTINUE
      RETURN
      END
```