# A TECHNIQUE FOR ANALYSIS

## AT 10 mb

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September 1965

433L SYSTEM PROGRAM OFFICE
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## FOREWORD

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# ABSTRACT

Two sets of vertical extrapolation equations were derived to specify initial-guess fields of 10-mb heights and temperatures using a five-year data sample.

Both past ($t_{-24}$) and present ($t_0$) data were considered as specifiers in the first set of equations. Only present ($t_0$) data were used as specifiers in the second set of equations. Both sets of equations showed stability when tested on independent data. Further, verification statistics showed that the results from the independent data were similar to those from the dependent data.

Both sets of equations were then compared by incorporating them into a modified successive approximation technique to produce initial-guess fields. These initial-guess fields were similar. An experiment comparing the two sets of equations with equations derived by the U.S. Weather Bureau showed that the TRC equations gave lower specification errors.

This technical report includes (or supersedes) information previously published under TM 11-7459-138.

# REVIEW AND APPROVAL

Publication of this technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Robert L. Houghten
Lt. Colonel, USAF
Acting System Program Director

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# SECTION I

## INTRODUCTION

An earlier report by Rahn and Spiegler [6] described a technique for objectively analyzing 10-mb heights and temperatures using vertical extrapolation equations for generating initial-guess fields.

These extrapolation equations had two shortcomings. First, a limited amount of data was available for their development, permitting only a gross geographic and seasonal stratification of the developmental sample. Second, as demonstrated by Snellman [7], repeated application of the equations to a series of height and temperature analyses in "no-data" regions led to a systematic increase in specification errors.

A larger (five-year) data sample has become available since the development of the earlier extrapolation equations, permitting the design of experiments to overcome these two shortcomings.

In this study, two sets of vertical extrapolation equations were derived using the five-year data sample. The first set used data at $t_0$ and $t_{-24}$ (as did the earlier study) as possible specifiers of 10-mb heights and temperatures. The second set used data at only $t_0$ as possible specifiers. Each set of extrapolation equations was then used to generate initial-guess fields of 10-mb heights and temperatures using a modified version of the 500–30 mb analysis build-up procedure [8].

It should be noted that there are two major experiments being described. The first is the development of the vertical regression equations, for which statistics are presented that describe the accuracy of these equations when applied to independent station data. The second is the use of these equations in a build-up procedure; the statistics presented describe the accuracy of the extrapolation equations when applied to grid-point data.

The method used to develop the vertical regression equations is presented in Section II. The application of the equations in the analysis procedure is presented in Section III. Section IV contains the results of the experiments, and Section V presents our conclusions.

# SECTION II

## DEVELOPMENT OF THE VERTICAL EXTRAPOLATION EQUATIONS

### 1. Data

The data used for the derivation of the 30—10 mb vertical extrapolation equations comprised sixty months (May 1958—April 1963) of Northern Hemisphere rawinsonde/ radiosonde observations. The data were edited, checked, and corrected for solar radiation errors.

### 2. Stratification of Data

An examination of the stratospheric map series, published by the U. S. Weather Bureau [11] , reveals that there are predominant circulations in the stratosphere that exist for certain periods of time (e.g., the anticyclone summer circulations over the North Pole, and the easterlies over the Northern Hemisphere which normally exist from June until about mid-August when the transition to the fall circulation begins).

Because the data sample is sufficiently large, it was decided that stratification of the data based on predominant circulation features was desirable because it would produce more useful extrapolation equations. The categories resulting from this stratification are termed "regimes." Table I defines these regimes. For each regime, all five years of the months included in that regime are used (e.g., Regime 2 comprises five months of March data — one month for each year of the five-year sample).

Because of the well-known gradients of temperatures and heights at stratospheric levels from equator to pole over the Northern Hemisphere, it was necessary to further stratify the data into "bands" (see Fig. 1 and Table II). The band stratification described here resulted from technical discussions with personnel of the U. S. Weather Bureau's Atmospheric Analysis Laboratory, Upper Atmospheric Branch. They have had extensive experience in analyzing and examining stratospheric charts, and although the band stratification may be considered arbitrary, it is based upon a realistic assessment of what will likely provide the optimum regression equations for extrapolation to 10-mb. To insure against discontinuities between bands, an overlap procedure was used (e.g., a few stations adjacent to the band boundaries were used as part of the data in generating the equations for a given band). The band stratification was limited to those areas for which data were available. There were eight bands generated for each regime.

TABLE I
REGIMES FOR WHICH EQUATIONS WERE DERIVED

| Regime | Months |
|--------|--------|
| 1 | December—January, February* |
| 1(a) | January 15—February 5, 1963$^{+}$ |
| 2 | March |
| 3 | April |
| 4 | May |
| 5 | June, July, August (1—15) |
| 6 | August (16—31), September |
| 7 | October, November |

*Except January 15—February 5, 1963 data

$^{+}$Explosive warming regime

The band stratification for Regime 1 (Dec—Feb) differs from that for the other regimes because, during the winter months, the Aleutian anticyclone is a semi-permanent circulation feature, requiring the breakdown over North America to consist of Bands 2A and 4A (see Fig. 2). One other exception is found in Regime 1a, in which Bands 1—4 were combined because there was insufficient data in the four individual bands to generate stable equations.

During the stratification processing, ten percent of the data for each band, except Band 5 (U.S.), were withheld as independent data; five percent of the data were withheld in Band 5.

3. Screening Regression Experiments

Covariance matrix generation and screening-regression programs written by Enger and Rodante [2] were used to derive the vertical extrapolation equations for specifying 10-mb height and temperature initial-guess fields used in the analysis program.

When multiple regression equations are being developed, a problem is encountered if the number of predictors used is too large. This may lead to unstable results when the equations are applied to new samples [4]. Thus, the first step in the procedure
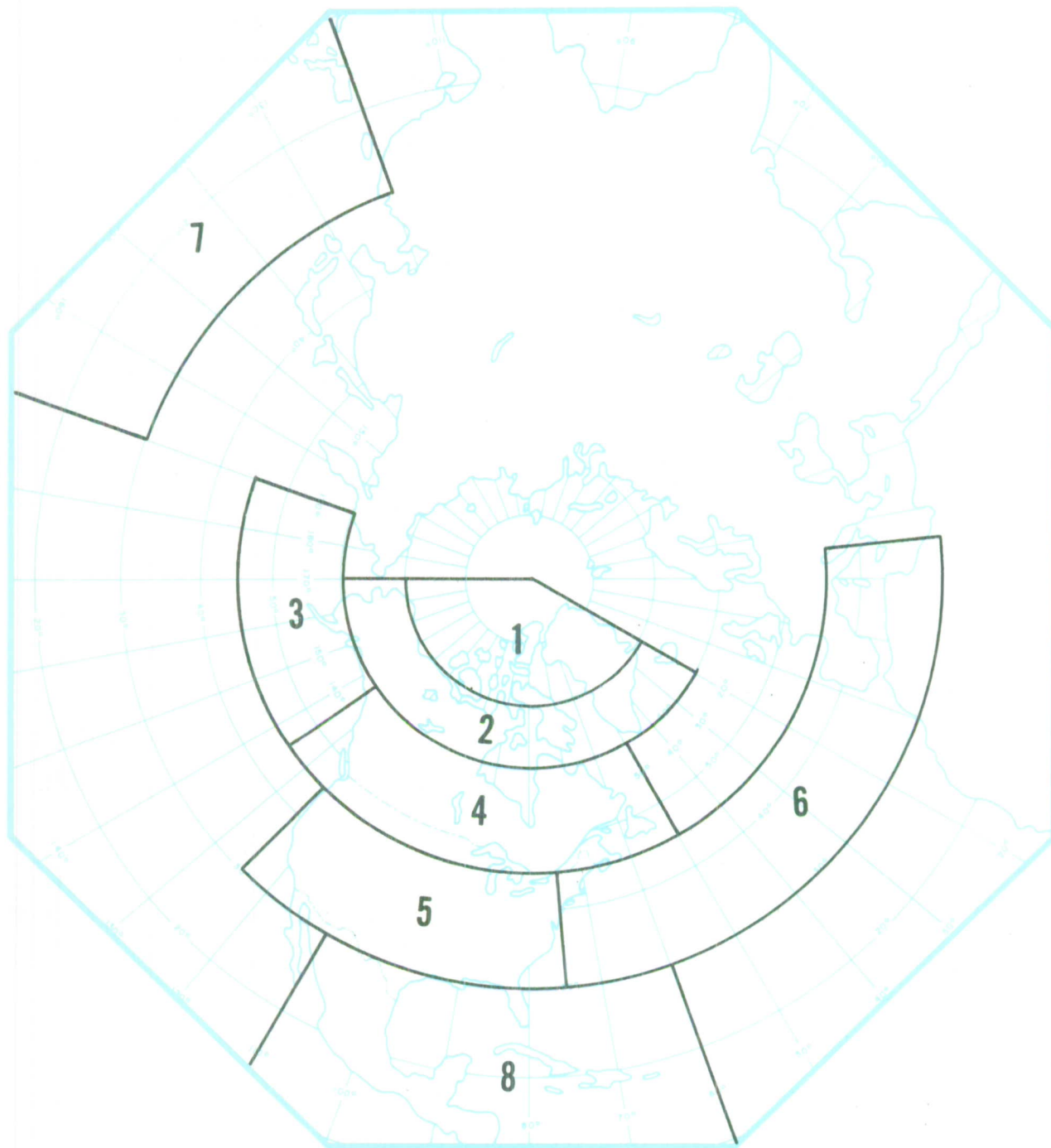
Fig. 1. Band stratification for Regimes 2-7.

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## TABLE II
## BAND BOUNDARIES

| Band | Boundaries |
|------|------------|
| 1 | $170°W - 20°W, \ 70°N - 90°N$ |
| 2 | $170°W - 20°W, \ 60°N - 70°N$ |
| 2A* | $170°E - 135°W, \ 45°N - 70°N$ |
| 3 | $170°E - 135°W, \ 45°N - 60°N$ |
| 4 | $135°W - 50°W, \ 45°N - 60°N$ |
| 4A* | $135°W - 20°W, \ 45°N - 70°N$ |
| 5 | $125°W - 75°W, \ 30°N - 45°N$ |
| 6 | $75°W - 15°E, \ 30°N - 45°N$ |
| 7 | $120°E - 155°W, \ 0° - 30°N$ |
| 8 | $110°W - 60°W, \ 0° - 30°N$ |

*Bands 2A and 4A, rather than Bands 2, 3, and 4, are used in the December–February regime.

is to consider specifiers having meteorological significance for specifying 10-mb heights and temperatures. The screening procedure further reduces the number of specifiers by accepting only those with the highest statistical significance according to a specified criterion. This method has been described by Miller [5] and is based on a paper by Bryan [1].

Using the screening procedure, two sets of extrapolation equations were derived for each band of each regime. The first set used data at $t_0$ and $t_{-24}$ as possible specifiers. The second set used data at $t_0$ only.

The specificands, and their possible specifiers used to develop the two sets of equations for each band of each regime, are presented in Table III. The possible specifiers for the set of equations using past data were those used by Rahn and Spiegler in the earlier report [6], with one addition. The mean temperature between 30 and 10 mb at $t_0$ was added as a possible specifier for 10-mb heights. The purpose of including this additional specifier in the screening regression experiments is explained in the following discussion.

Fig. 2. Band stratification for Regime 1.

TABLE III
## POSSIBLE SPECIFIERS FOR VERTICAL EXTRAPOLATION EXPERIMENTS

| Specificand | Specifiers* |
|---|---|
| $Z_0(10)$ | $Z_{-24}(10)$, $H_{-24}(50-30)$, $H_{-24}(30-10)$, $Z_0(30)$, $T_0(30)$, $H_0(50-30)$, $\overline{T}_0(30-10)$ |
| $T_0(10)$ | $T_{-24}(10)$, $\overline{T}_{-24}(50-30)$, $\overline{T}_{-24}(30-10)$, $Z_0(30)$, $T_0(30)$, $\overline{T}_0(50-30)$, $H_0(30-10)$ |

*$Z$ = height (decafeet), $T$ = temperature (°C), $H$ = thickness
of layer (decafeet), and $\overline{T}$ = mean temperature of layer (°C).
Subscript 0 denotes observation time. Subscript -24 denotes
24 hours prior to observation time.

In the earlier study [6] the thickness of the 30- to 10-mb layer at $t_0$ [$H_0(30-10)$] was found to be a significant specifier for 10-mb temperatures. It was available as a specifier because the 10-mb height analysis was generated first and, thus, permitted the computation of $H_0(30-10)$. However, if the temperature analysis is performed first, the $\overline{T}_0(30-10)$ becomes a possible specifier to 10-mb height. It is obvious that both cannot be used.

The $\overline{T}_0(30-10)$ was added as a possible specifier in an experiment to determine whether it is more advantageous to perform the height analysis prior to the temperature analysis or vice-versa. The question of preference is answered by determining whether $H_0(30-10)$ is a better specifier of 10-mb temperatures than is $\overline{T}_0(30-10)$ of 10-mb heights.

The vertical extrapolation equations developed by the series of screening regression experiments are used in the modified 500-30 mb analysis technique to generate 10-mb height and temperature initial-guess fields.

# SECTION III

## ANALYSIS TECHNIQUE

This section discusses the analysis technique used to generate 10-mb fields of height and temperature. The vertical extrapolation equations are used in the analysis procedure to provide the initial-guess fields necessary for the operation of this program. It should be noted that the data sample used to test the analysis technique is considerably smaller than the five-year data sample used to generate extrapolation equations.

### 4. Height and Temperature Analyses

The 10-mb height and temperature analyses are produced using a modified version of the 500- to 30-mb build-up procedure described in an early report [8]. The 500–30-mb technique uses vertical extrapolation equations to provide an initial-guess field for the level being analyzed. The initial-guess field is then corrected with observed data $(t_0)$ for that level using the successive approximation analysis technique (SAT) [8]. The same technique is used in the 10-mb analysis procedure.

Because of the small number of stations that report 10-mb data, the successive approximation analysis technique was modified so that past data (12- to 48-hr prior to analysis time) could be used to correct the initial guess. The weighting of past data relative to present data in the correction of the initial guess is a function of both the time of the observation and the density of reports in the area. The weighted value of a given past-data station is applied to the correction term in the SAT analysis.

The effect on the analysis of varying the weighting factors for past data was tested in an earlier report [6], but the results were inconclusive because of the small data sample (00Z February 3- 00Z February 5, 1962) used in the analysis program. Because the data sample used in this study (00Z February 3–12Z February 7, 1962) is merely two and one-half days larger than the earlier sample, only one set of weighting factors was used.

Table IV lists the weighting factors as functions of data density in the vicinity of each station, and the number of earlier observations at each station. (Earlier observations refer to the order of listing of station data on tape; $t_0$ reports are listed first; $t_{-12}$, $t_{-24}$, $t_{-36}$, and $t_{-48}$ are next in order, respectively. Therefore, when selecting

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TABLE IV
WEIGHTING FACTORS USED IN ANALYSIS TECHNIQUE
(based on station density and number of past-data reports)

| Time | Observational density | | | Conditions |
|------|------|--------|------|------------|
|      | Low | Medium | High |            |
| $t_0$ | 1.0 | 1.0 | 1.0 | — |
| $t_{-12}$ | 1.0 | 0.9 | 0.7 | 0* |
|           | 0.4 | 0.3 | 0.2 | 1* |
| $t_{-24}$ | 0.7 | 0.5 | 0.4 | 0≠ |
|           | 0.3 | 0.2 | 0.1 | 1≠ |
|           | 0.1 | 0.1 | 0.0 | 2≠ |
| $t_{-36}$ | 0.4 | 0.3 | 0.2 | 0≠ |
|           | 0.3 | 0.2 | 0.1 | 1≠ |
|           | 0.2 | 0.2 | 0.1 | 2≠ |
|           | 0.1 | 0.1 | 0.0 | 3≠ |
| $t_{-48}$ | 0.3 | 0.2 | 0.1 | 0≠ |
|           | 0.2 | 0.1 | 0.1 | 1≠ |
|           | 0.1 | 0.1 | 0.1 | 2≠ |
|           | 0.1 | 0.1 | 0.1 | 3≠ |
|           | 0.0 | 0.0 | 0.0 | 4≠ |

*Number of $t_0$ reports at station.

≠Number of earlier reports at station.

a weighting factor for a $t_{-24}$ report, the earlier observations are the $t_{-12}$ and $t_0$ reports.)

In the earlier 10-mb analysis study [6], a method was developed to determine the necessary observational density requirements for adequate analyses of particular areas. The Northern Hemisphere was divided into six areas as shown in Fig. 3. The number of radiosonde stations in each area was determined and observations at a specified percent of these were required as input to the analysis program (see Table V). If the observational density requirements were not met, "off-time" observations were
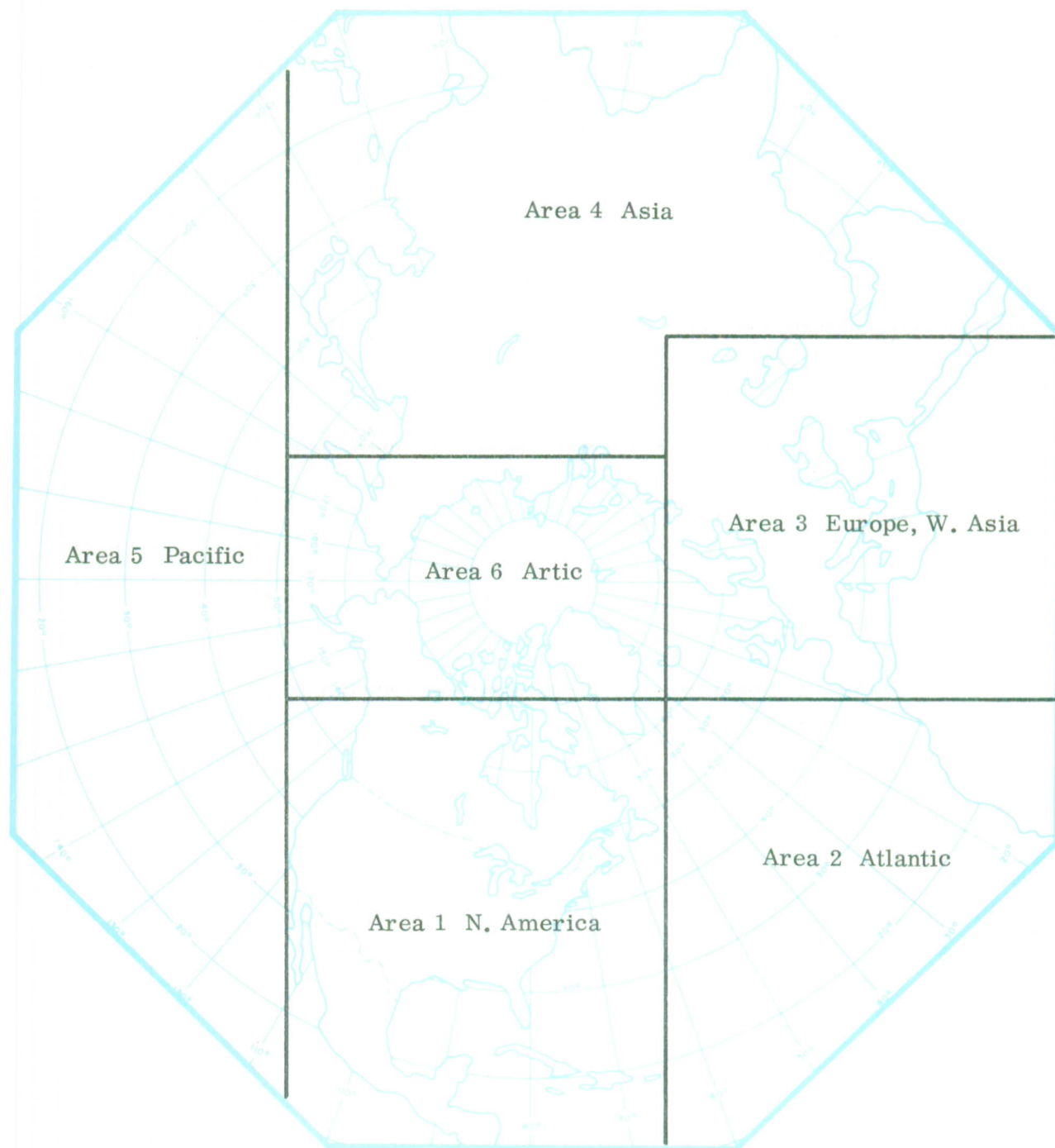
Fig. 3. Areas over northern hemisphere for which minimum number of observations are necessary in 10-mb analysis.

## TABLE V
### SPECIFIED MINIMUM NUMBER OF STATIONS NECESSARY
### FOR 10-MB ANALYSIS OVER VARIOUS AREAS OF THE HEMISPHERE

| Area | No. of stations |
|------|-----------------|
| 1 | 60 |
| 2 | 8 |
| 3 | 20 |
| 4 | 11 |
| 5 | 8 |
| 6 | 18 |

included in the SAT analysis by the following procedure. If the $t_0$ observations are below a threshold limit, $t_{-12}$ observations are added; if this augmentation does not bring the observational density above the threshold limit, $t_{-24}$ observations are then included. The decision as to whether or not $t_{-36}$ and $t_{-48}$ observations will be included in the analysis is made in the same manner. In the sample used in this study, the above rules required the use of all four sets of off-time observations for adequate analyses.

# SECTION IV

## SCREENING REGRESSION AND ANALYSIS RESULTS

Two distinct groups of statistical results are discussed in this section. The first group relates to the derivation, and testing on independent data, of the vertical extrapolation equations. Also included in this group are the results of a comparison of the specification of 10-mb heights and temperatures produced by the TRC present-data equations with those produced with the USWB equations. The second group of statistical results relates to the testing of the TRC equations in the analysis procedure, and to the verification of the analyses using the areal-mean-error method [10].

### 5. Screening Regression Results

Vertical extrapolation equations were developed for all regimes and bands having sufficient data. Rms errors of the temperature equations with H(30—10) as a specifier were compared to those of the temperature equations without H(30—10) as a specifier. A similar comparison was made of the rms errors of the height equations with and without $\overline{T}$(30—10) as a specifier. Although $\overline{T}$(30—10) was significant for specifying 10-mb heights, the exclusion of H(30—10) as a specifier in the present-data equations resulted in large rms errors for the temperature equations; this was especially true for the winter-months data (see Table VI). It was decided that H(30—10) is more useful for specifying 10-mb temperature than is $\overline{T}$(30—10) for specifying 10-mb heights, and thus, height analyses should be made prior to temperature analyses.

The vertical extrapolation equations developed for each band of each regime were tested on the independent data sample. The dependent and independent statistical results are tabulated in Appendix II (where the specifiers are listed in the order of their selection). The tables have parts (a) and (b) for each regime; part (a) of each table gives the result of using both past ($t_{-24}$) and present ($t_0$) data as specifiers[1], and part (b) gives the results of using only present data as specifiers.

It is evident that the equations using both past and present data have the lower rms errors on both the dependent and independent data sample for 10-mb heights. When applying the equations in the analysis technique, one should use the past and present data

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[1] There are some bands in which no past-data specifiers were selected as significant predictors.

TABLE VI
COMPARISON OF rms ERRORS WITH (Exp. 1) AND WITHOUT (Exp. 2) $\overline{T(30-10)}$
AS A HEIGHT SPECIFIER AND WITH (Exp. 3) AND WITHOUT (Exp. 4) H(30-10) AS
A TEMPERATURE SPECIFIER (present data, dependent sample)

(a) December–February

| Band | Exp. 1 (ft) | Exp. 2 (ft) | Exp. 3 ($^\circ$C) | Exp. 4 ($^\circ$C) |
|------|-------------|-------------|-----------|-----------|
| 1  | 115 | 293 | 2.0 | 4.8 |
| 2A | 132 | 296 | 2.5 | 5.4 |
| 4  | 136 | 322 | 2.7 | 5.7 |
| 5  | 139 | 282 | 3.0 | 4.8 |
| 6  | 165 | 336 | 2.9 | 5.6 |
| 7  | 172 | 227 | 2.8 | 3.8 |
| 8  | 91  | 205 | 2.7 | 4.2 |

(b) June–1/2 August

| Band | Exp. 1 (ft) | Exp. 2 (ft) | Exp. 3 ($^\circ$C) | Exp. 4 ($^\circ$C) |
|------|-------------|-------------|-----------|-----------|
| 1 | 107 | 159 | 1.6 | 2.6 |
| 2 | 106 | 160 | 1.6 | 2.6 |
| 3 | 81  | 141 | 1.6 | 2.6 |
| 4 | 107 | 151 | 1.8 | 2.6 |
| 5 | 134 | 165 | 1.9 | 2.6 |
| 6 | 90  | 132 | 1.7 | 2.5 |
| 7 | 166 | 193 | 2.3 | 2.8 |
| 8 | 141 | 168 | 2.2 | 2.7 |

equations as specifiers for those areas where previous $(t_{-24})$ observations are available.
The temperature rms errors are about the same for both sets of TRC equations. The
reason for their similarity is that $H_0(30-10)$ was usually selected as the first predictor
in both sets of equations, and accounted for a significant part of the variance of the 10-
mb temperature.

In general, both sets of equations for specifying 10-mb heights and temperatures are relatively stable, with the independent-data errors close to those of the dependent data. The largest difference between dependent- and independent data errors is in the 1963 warming regime (see Table XXI in Appendix II). The warming first became apparent on January 15 and lasted through approximately February 5 [3]. Because the change-over is gradual, the data used to develop the equations reflect the conditions both before and after the warming; this is the probable cause of the high rms errors and standard deviations.

Vertical extrapolation equations developed by the U.S. Weather Bureau were also tested on the independent data sample (present-data only) for Regimes 1, 3, 4, 5, and 7. The Weather Bureau developed separate equations for January–February and for December, and each set was tested on the independent data for Regime 1.

The Weather Bureau equations use 30-mb heights and temperatures at $t_0$ for specifying 10-mb heights, and 30-mb temperatures at $t_0$ for specifying 10-mb temperatures. The results are presented in Table VII. A comparison of Table VII with Tables XIV(b), XVI(b), XVII(b), and XX(b) (in Appendix II) shows that the height and temperature rms errors obtained by using our (TRC) equations are generally lower than those from the Weather Bureau equations. To determine if the differences in the errors were significant, the height and temperature forecasts produced by the TRC and USWB equations were compared by means of the Student "t" test [12].

The results of comparing TRC and USWB specifications of 10-mb heights and temperatures are presented in Tables VIII through XI. It can be seen from the tables that the temperature specifications made with the TRC equations are significantly better than those made with USWB equations. The 10-mb height errors of the TRC equations are, in general, significantly lower, although there are some cases in which both TRC and USWB equations are equally good. One obvious reason why the TRC temperature equations give better results is that they use H(30–10) as a specifier.

The regression equations developed with past and present data, and present data only, are given in Appendix I. The format of the equations is such that only heights and temperatures are needed as input (e.g., thickness is converted to a difference of two heights).

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## TABLE VII
### RESULTS USING USWB EQUATIONS ON INDEPENDENT PRESENT DATA

#### (a) December, January, February

| Band | Specificand | Rms error | |
|------|-------------|-----------|---|
| | | December | January–February |
| 1 | $Z_0(10)$ | 321 ft | 337 ft |
| | $T_0(10)$ | 5.6°C | 5.9°C |
| 3* | $Z_0(10)$ | 376 ft | 477 ft |
| | $T_0(10)$ | 6.6°C | 9.0°C |
| 4 | $Z_0(10)$ | 324 ft | 359 ft |
| | $T_0(10)$ | 6.1°C | 6.5°C |
| 5 | $Z_0(10)$ | 328 ft | 299 ft |
| | $T_0(10)$ | 6.0°C | 5.4°C |
| 6 | $Z_0(10)$ | 396 ft | 355 ft |
| | $T_0(10)$ | 7.2°C | 6.5°C |
| 7 | $Z_0(10)$ | 243 ft | 243 ft |
| | $T_0(10)$ | 4.1°C | 4.0°C |
| 8 | $Z_0(10)$ | 275 ft | 270 ft |
| | $T_0(10)$ | 4.8°C | 4.7°C |

*Used on independent data from TRC Band 2A.

## TABLE VII

### (b) April, May, June–July, November

| Band | Specificand | Rms error | | | |
|------|-------------|-----------|------|-----------|----------|
|      |             | April | May | June–July | November |
| 1 | $Z_0(10)$ | 278 ft | 167 ft | 138 ft | 272 ft |
|   | $T_0(10)$ | $6.0°C$ | $3.0°C$ | $2.6°C$ | $5.5°C$ |
| 2 | $Z_0(10)$ | 254 ft | 204 ft | 159 ft | 221 ft |
|   | $T_0(10)$ | $4.8°C$ | $3.9°C$ | $3.1°C$ | $4.1°C$ |
| 3 | $Z_0(10)$ | 249 ft | 260 ft | 119 ft | 253 ft |
|   | $T_0(10)$ | $3.8°C$ | $3.8°C$ | $2.2°C$ | $4.6°C$ |
| 4 | $Z_0(10)$ | 185 ft | 249 ft | 201 ft | 251 ft |
|   | $T_0(10)$ | $3.1°C$ | $4.3°C$ | $3.7°C$ | $4.5°C$ |
| 5 | $Z_0(10)$ | 280 ft | 174 ft | 148 ft | 234 ft |
|   | $T_0(10)$ | $5.0°C$ | $3.6°C$ | $2.3°C$ | $3.9°C$ |
| 6 | $Z_0(10)$ | 312 ft | 220 ft | 147 ft | 297 ft |
|   | $T_0(10)$ | $5.7°C$ | $3.0°C$ | $2.7°C$ | $5.2°C$ |
| 7 | $Z_0(10)$ | 225 ft | 181 ft | 165 ft | 211 ft |
|   | $T_0(10)$ | $3.5°C$ | $3.5°C$ | $3.1°C$ | $3.6°C$ |
| 8 | $Z_0(10)$ | 241 ft | 195 ft | 187 ft | 226 ft |
|   | $T_0(10)$ | $3.7°C$ | $2.5°C$ | $2.8°C$ | $3.8°C$ |

## TABLE VIII
### STUDENT "t" COMPARISONS
#### December, January, February—Present Data

| Band | Specificand | No. of cases | TRC better | USWB better | Student "t" value | Significance level |
|---|---|---|---|---|---|---|
| 1 | $Z_0$ (10) | 11 | 8 | 3 | 1.228 | — |
|  | $T_0$ (10) | 11 | 10 | 1 | 3.801 | .01 |
| 3(2A) | $Z_0$ (10) | 92 | 62 | 30 | 4.978 | .001 |
|  | $T_0$ (10) | 92 | 81 | 11 | 10.946 | .001 |
| 4(4A) | $Z_0$ (10) | 96 | 67 | 29 | 3.665 | .001 |
|  | $T_0$ (10) | 96 | 82 | 14 | 8.643 | .001 |
| 5 | $Z_0$ (10) | 161 | 84 | 77 | 0.000 | — |
|  | $T_0$ (10) | 161 | 116 | 45 | 9.022 | .001 |
| 6 | $Z_0$ (10) | 72 | 38 | 34 | 0.685 | — |
|  | $T_0$ (10) | 72 | 64 | 8 | 8.477 | .001 |
| 7 | $Z_0$ (10) | 125 | 69 | 56 | 1.999 | .05 |
|  | $T_0$ (10) | 125 | 90 | 35 | 5.680 | .001 |
| 8 | $Z_0$ (10) | 183 | 101 | 82 | 2.904 | .01 |
|  | $T_0$ (10) | 183 | 127 | 56 | 8.772 | .001 |
| All bands | $Z_0$ (10) | 740 | 429 | 311 | 1.877 | .1 |
|  | $T_0$ (10) | 740 | 570 | 170 | 5.860 | .001 |

## TABLE IX
## STUDENT "t" COMPARISONS
### May—Present Data

| Band | Specificand | No. of cases | TRC better | USWB better | Student "t" value | Significance level |
|---|---|---|---|---|---|---|
| 1 | $Z_0$ (10) | 27 | 17 | 10 | 0.626 | — |
|   | $T_0$ (10) | 27 | 16 | 11 | 2.146 | .05 |
| 2 | $Z_0$ (10) | 22 | 10 | 12 | 0.096 | — |
|   | $T_0$ (10) | 22 | 16 | 6 | 3.176 | .01 |
| 3 | $Z_0$ (10) | 14 | 11 | 3 | 2.636 | .05 |
|   | $T_0$ (10) | 14 | 12 | 2 | 3.508 | .01 |
| 4 | $Z_0$ (10) | 40 | 26 | 14 | 2.391 | .05 |
|   | $T_0$ (10) | 40 | 29 | 11 | 4.232 | .001 |
| 5 | $Z_0$ (10) | 41 | 19 | 22 | 0.699 | — |
|   | $T_0$ (10) | 41 | 32 | 9 | 5.089 | .001 |
| 6 | $Z_0$ (10) | 41 | 26 | 15 | 1.926 | .1 |
|   | $T_0$ (10) | 41 | 31 | 10 | 3.359 | .01 |
| 7 | $Z_0$ (10) | 64 | 40 | 24 | 2.680 | .01 |
|   | $T_0$ (10) | 64 | 41 | 23 | 3.160 | .01 |
| 8 | $Z_0$ (10) | 57 | 32 | 25 | 0.967 | — |
|   | $T_0$ (10) | 57 | 37 | 20 | 2.840 | .01 |
| All bands | $Z_0$ (10) | 306 | 181 | 125 | 4.467 | .001 |
|   | $T_0$ (10) | 306 | 214 | 92 | 9.524 | .001 |

TABLE X
STUDENT "t" COMPARISONS
June, July, 1/2 August (1–15)–Present Data

| Band | Specificand | No. of cases | TRC better | USWB better | Student "t" value | Significance level |
|---|---|---|---|---|---|---|
| 1 | $Z_0$ (10)<br>$T_0$ (10) | 63<br>63 | 40<br>48 | 23<br>15 | 3.113<br>4.792 | .01<br>.001 |
| 2 | $Z_0$ (10)<br>$T_0$ (10) | 55<br>55 | 26<br>38 | 29<br>17 | 0.210<br>4.388 | —<br>.001 |
| 3 | $Z_0$ (10)<br>$T_0$ (10) | 33<br>33 | 18<br>23 | 15<br>10 | 0.893<br>3.513 | —<br>.01 |
| 4 | $Z_0$ (10)<br>$T_0$ (10) | 113<br>113 | 69<br>86 | 44<br>27 | 3.620<br>7.387 | .001<br>.001 |
| 5 | $Z_0$ (10)<br>$T_0$ (10) | 103<br>103 | 55<br>62 | 48<br>41 | 0.994<br>3.472 | —<br>.001 |
| 6 | $Z_0$ (10)<br>$T_0$ (10) | 97<br>97 | 47<br>66 | 50<br>31 | 0.910<br>4.720 | —<br>.001 |
| 7 | $Z_0$ (10)<br>$T_0$ (10) | 145<br>145 | 90<br>90 | 55<br>55 | 3.040<br>3.797 | .01<br>.001 |
| All bands | $Z_0$ (10)<br>$T_0$ (10) | 738<br>738 | 421<br>503 | 317<br>235 | 1.548<br>3.890 | —<br>.001 |

## TABLE XI
## STUDENT "t" COMPARISONS
### October, November—Present Data

| Band | Specificand | No. of cases | TRC better | USWB better | Student "t" value | Significance level |
|------|-------------|--------------|------------|-------------|-------------------|--------------------|
| 1 | $Z_0$ (10) | 10 | 7 | 3 | 1.230 | — |
|   | $T_0$ (10) | 10 | 9 | 1 | 4.110 | .01 |
| 2 | $Z_0$ (10) | 53 | 35 | 18 | 1.342 | — |
|   | $T_0$ (10) | 53 | 43 | 10 | 6.314 | .001 |
| 3 | $Z_0$ (10) | 38 | 23 | 15 | 1.814 | .1 |
|   | $T_0$ (10) | 38 | 32 | 6 | 5.474 | .001 |
| 4 | $Z_0$ (10) | 70 | 37 | 33 | 1.823 | .1 |
|   | $T_0$ (10) | 70 | 56 | 14 | 7.177 | .001 |
| 5 | $Z_0$ (10) | 88 | 57 | 31 | 2.723 | .01 |
|   | $T_0$ (10) | 88 | 68 | 20 | 7.597 | .001 |
| 6 | $Z_0$ (10) | 51 | 44 | 7 | 11.273 | .001 |
|   | $T_0$ (10) | 51 | 37 | 14 | 5.683 | .001 |
| 7 | $Z_0$ (10) | 92 | 61 | 31 | 2.851 | .01 |
|   | $T_0$ (10) | 92 | 60 | 32 | 4.458 | .001 |
| 8 | $Z_0$ (10) | 107 | 54 | 53 | 0.883 | — |
|   | $T_0$ (10) | 107 | 72 | 35 | 5.326 | .001 |
| All bands | $Z_0$ (10) | 509 | 318 | 191 | 3.897 | .001 |
|   | $T_0$ (10) | 509 | 377 | 132 | 7.507 | .001 |

## 6. Analysis Results

Over many areas of the Northern Hemisphere, the height and temperature analyses at stratospheric levels are usually represented by the initial-guess fields because of the scarcity of data at these levels to correct the initial guess. For this reason, it was decided to have the analysis verification on the initial-guess rather than on the final pass. This, in effect, treats all the available stations as withheld stations. Only the temperature analyses were verified, and this was done with the areal-mean-error method [10]. Heights were not verified because they are generally regarded as relatively unreliable at stratospheric levels [9].

Two sets of 10-mb height and temperature analyses were generated for the period 00Z February 3–12Z February 7. The first set of analyses were generated using the past- and present-data vertical extrapolation equations; the second set used only the present-data equations. These equations were developed for areas where data were available, and their application over the hemisphere in this study is given in Table XII.

TABLE XII
APPLICATION OF EQUATIONS OVER THE HEMISPHERE

| Band | Latitude interval | Longitude interval |
|------|-------------------|--------------------|
| 1    | $70°N - 90°N$     | $0 - 360°$         |
| 2A   | $45°N - 70°N$     | $170°E - 135°W$    |
| 4A   | $45°N - 70°N$     | $135°W - 170°E$    |
| 5    | $30°N - 45°N$     | $125°W - 75°W$     |
| 5    | $30°N - 45°N$     | $15°E - 140°E$     |
| 6    | $30°N - 45°N$     | $75°W - 15°E$      |
| 6    | $30°N - 45°N$     | $140°E - 125°W$    |
| 7    | $0 - 30°N$        | $120°E - 110°W$    |
| 7    | $0 - 30°N$        | $60°W - 15°W$      |
| 8    | $0 - 30°N$        | $110°W - 60°W$     |
| 8    | $0 - 30°N$        | $15°W - 120°E$     |

The verification statistics for the initial-guess fields of 10-mb temperatures, generated from both sets of equations, are given in Table XIII. From the results presented in Table XIII, one might conclude that the initial guess produced by the present-data extrapolation equations is just as good as the initial guess produced by the past- and present-data equations. From a purely statistical point of view, this may be a correct conclusion. However, the analyses generated from each set of equations do show certain differences. Figures 4 and 5 represent the 10-mb height and temperature initial-guess fields for 00Z Feb. 3 generated using the past- and present-data equations, and only the present-data equations, respectfully.

One difference between the figures is the stronger temperature gradient over Canada in Fig. 4 (past- and present-data equations). A second difference occurs over Russia in an area north of the Caspian Sea; the height and temperature fields generated with the past- and present-data equations are significantly lower and colder (respectively) than the height and temperature fields generated with the present-data equations. If the discrepancies were due to the differences in the equations, other areas also should have been affected. Because the differences occurred in only one area (north of the Caspian Sea), it was felt that other factors were involved. An investigation of the 30-mb

TABLE XIII
10-MB TEMPERATURE ANALYSIS RMS ERRORS (INITIAL-GUESS)

| Date | Time | Past and present data ($^{\circ}$C) | Present data ($^{\circ}$C) |
|---|---|---|---|
| Feb. 3 | 00Z | 3.4 | 3.7 |
| Feb. 3 | 12Z | 3.7 | 4.0 |
| Feb. 4 | 00Z | 3.7 | 4.1 |
| Feb. 4 | 12Z | 3.4 | 3.5 |
| Feb. 5 | 00Z | 3.0 | 3.2 |
| Feb. 5 | 12Z | 3.0 | 3.1 |
| Feb. 6 | 00Z | 4.0 | 4.4 |
| Feb. 6 | 12Z | 4.1 | 4.7 |
| Feb. 7 | 00Z | 4.5 | 4.5 |
| Feb. 7 | 12Z | 3.9 | 3.9 |
| Overall | | 3.7 | 4.0 |

Fig. 4. Ten-mb height and temperature analysis: 00Z, 3 February initial guess — past and present data equations.
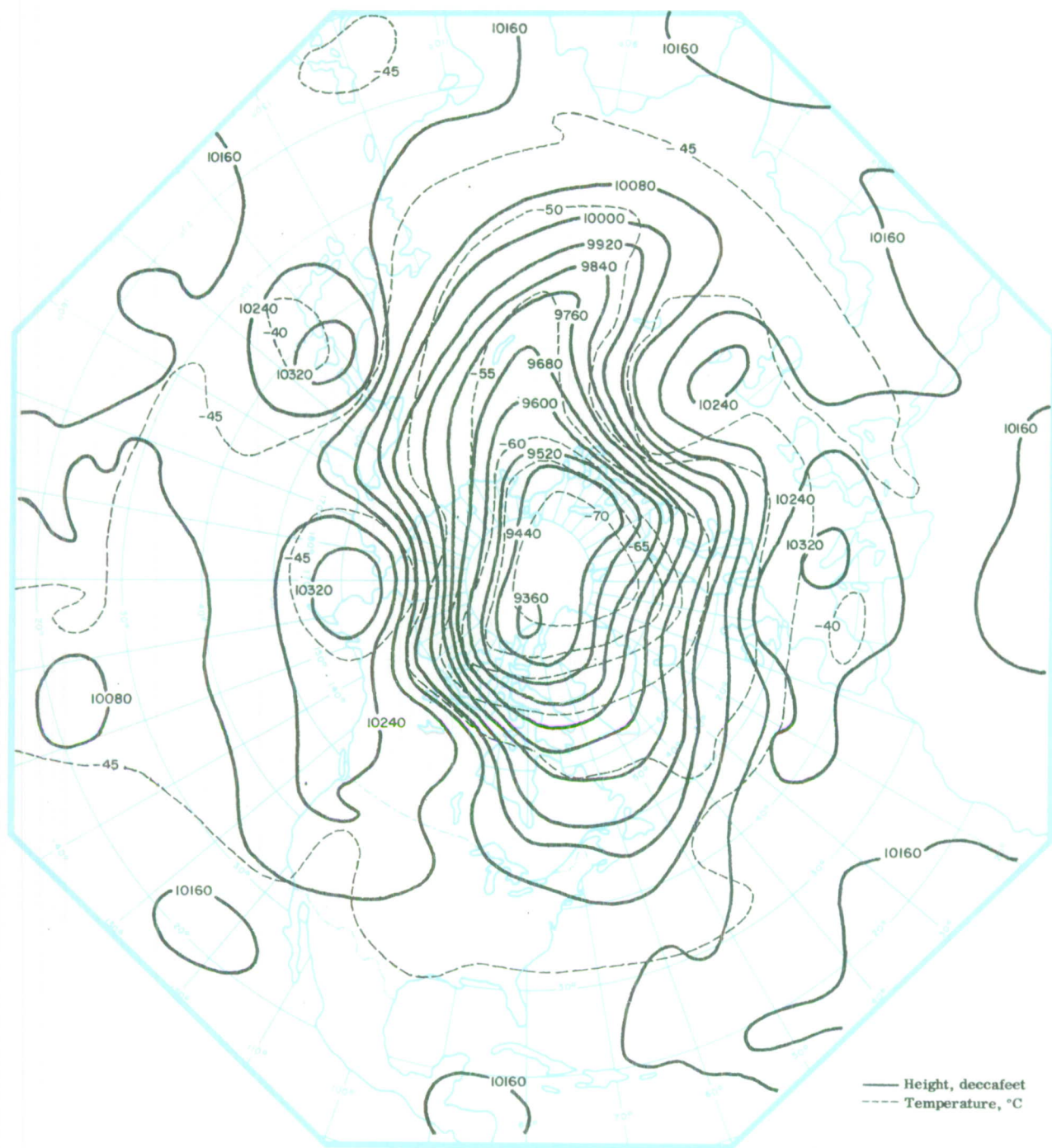
Fig. 5. Ten-mb height and temperature analysis: 00Z, 3 February initial
guess — present data equations.

data revealed the answer. We found that one station (28952) had a reported 30-mb temperature of -35°C and a 30-mb height of 77190 ft. The temperature was 15°C warmer than the 50-mb temperature for that station, and the reported height was about 1000 ft lower than the average. This observation is probably in error.

The initial-guess fields of height and temperature were regenerated with both sets of equations and excluding station 28952. The results are presented in Figs. 6 and 7. A comparison of these two figures shows that the analyses are more compatible, although there are still some differences in the temperature field.

The point being made is that, in the build-up procedure, the past- and present-data equations tend to dampen the effects of erroneous data at the lower levels, especially if it is the only station (data) in the area, while the present-data equations tend to magnify these effects.

The initial-guess fields of height and temperature generated with both sets of equations for 00Z Feb. 5 and 00Z Feb. 7 are shown in Figs. 8—11. The purpose is to show that both sets of equations generate similar initial-guess fields of height and temperature, especially over the back half of the hemisphere — essentially a no-data area in this study. Any differences that do occur are usually over "data" areas, and it is felt that the past- and present-data equations produce the more meaningful analysis.
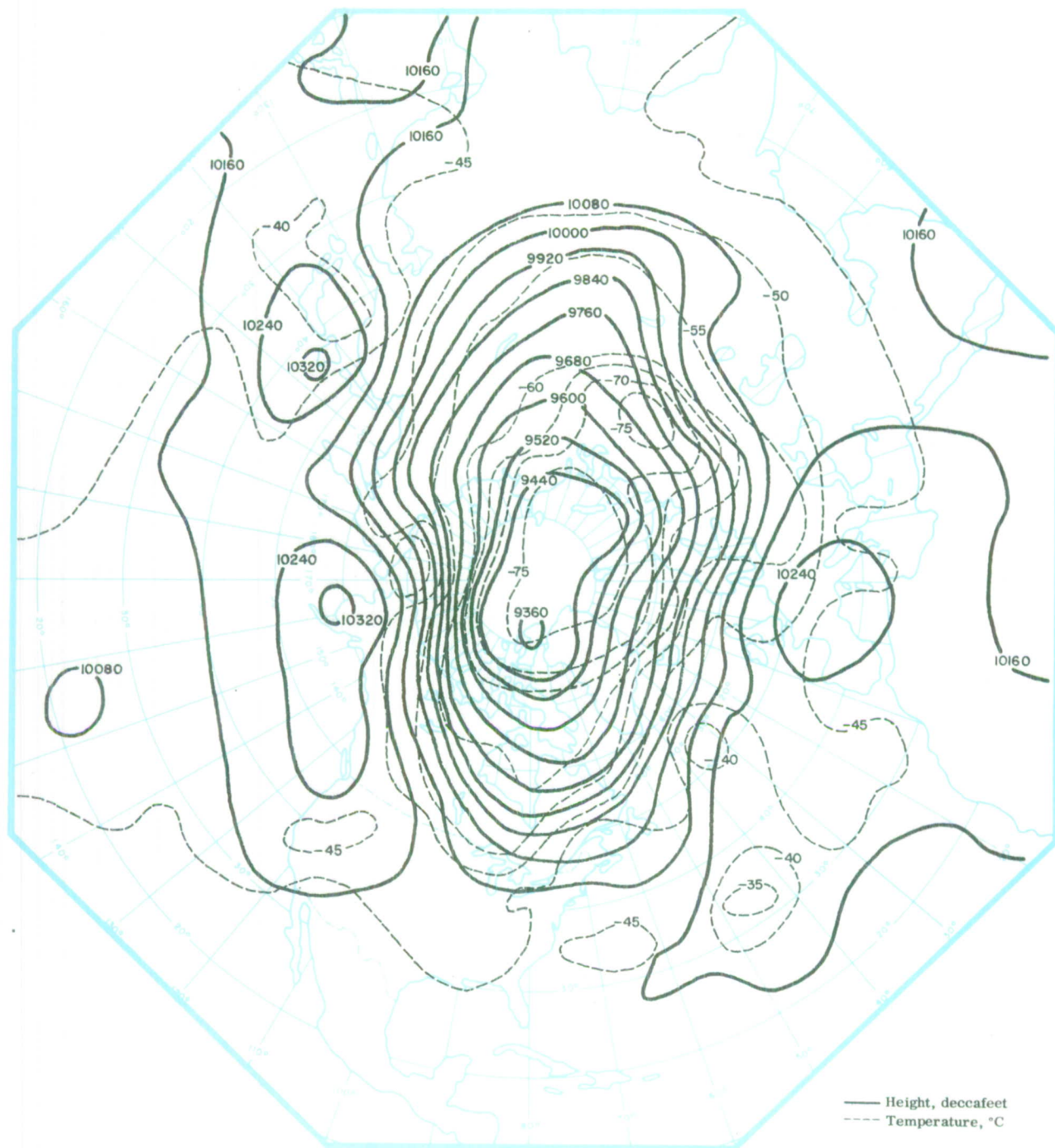
Fig. 6. Ten-mb height and temperature analysis: 00Z, 3 February initial guess — past and present data equations (Station 28952 excluded).
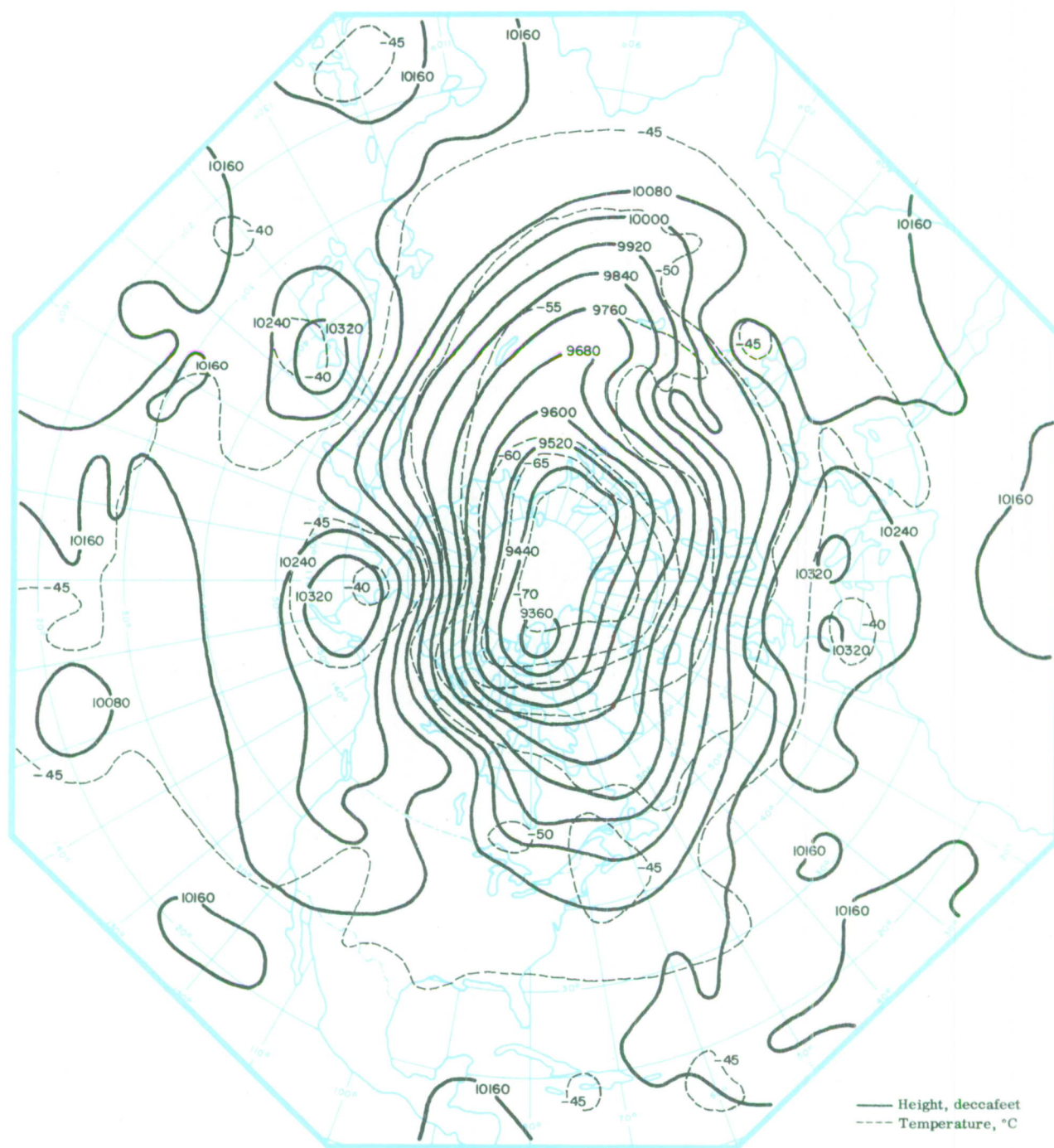
Fig. 7. Ten-mb height and temperature analysis: 00Z, 3 February initial guess — present data equations (Station 28952 excluded).
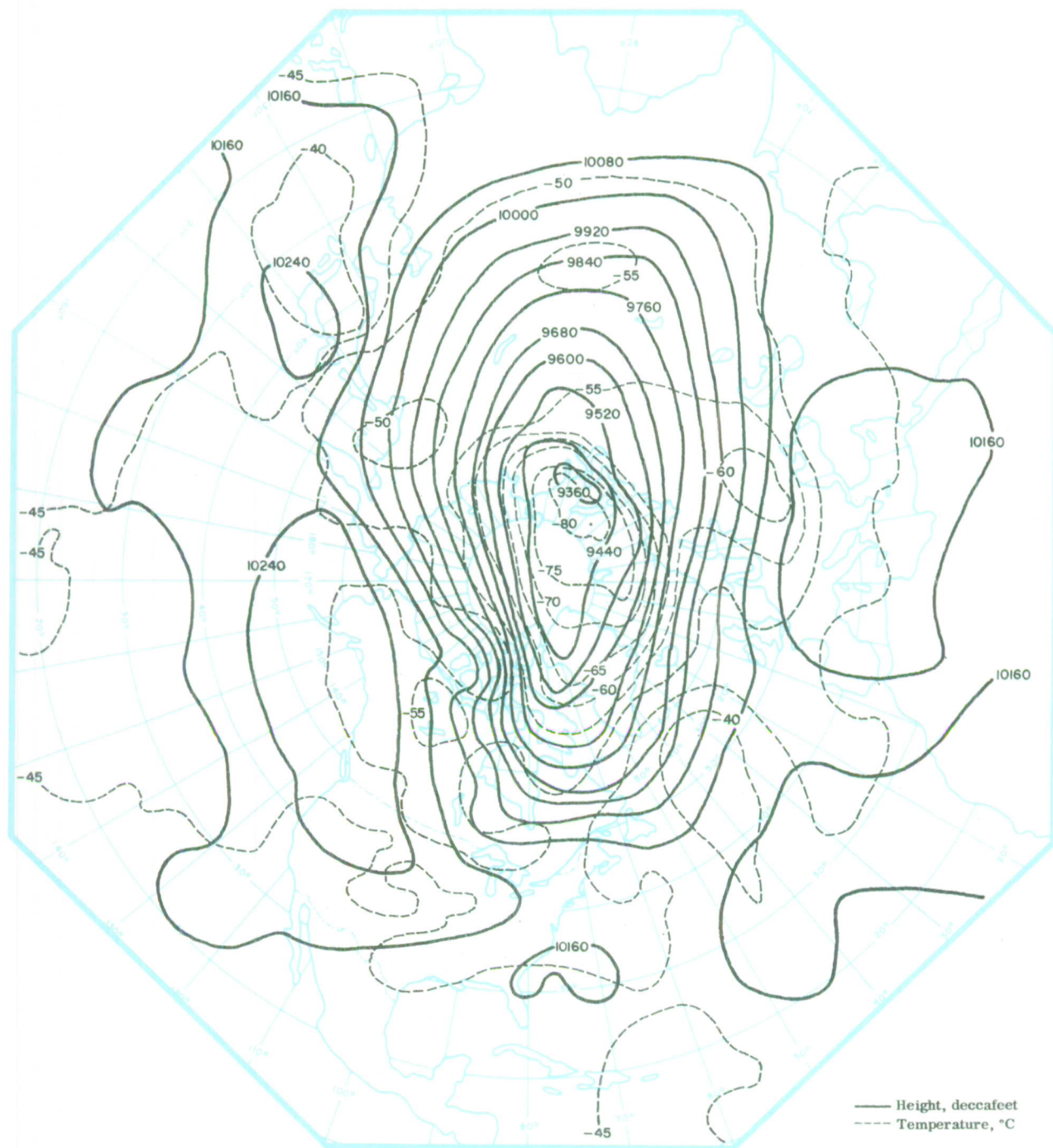
Fig. 8. Ten—mb height and temperature analysis: 00Z, 5 February initial guess — past and present data equations.

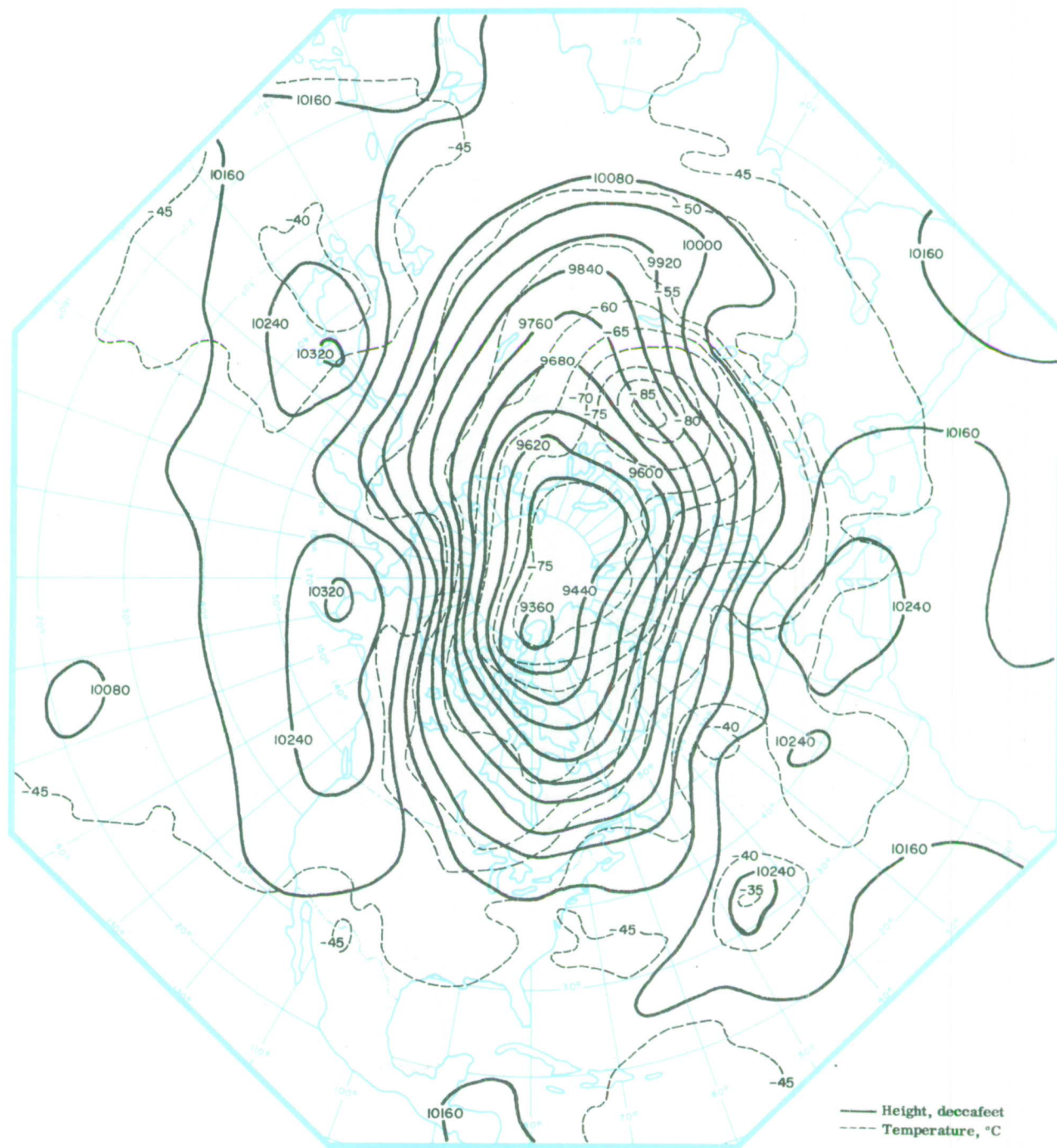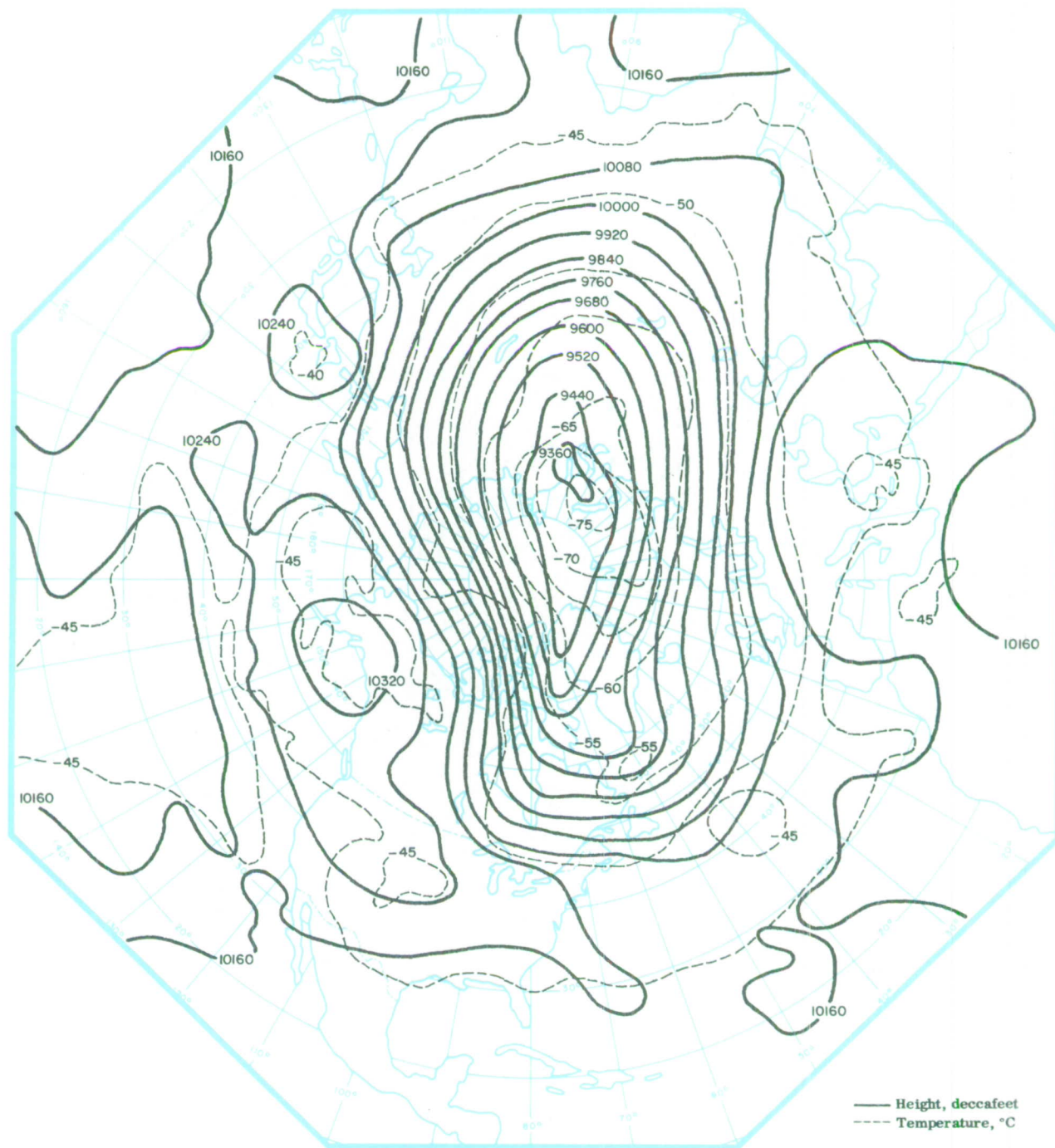Fig. 9. Ten—mb height and temperature analysis: 00Z, 5 February initial guess — present data equations.
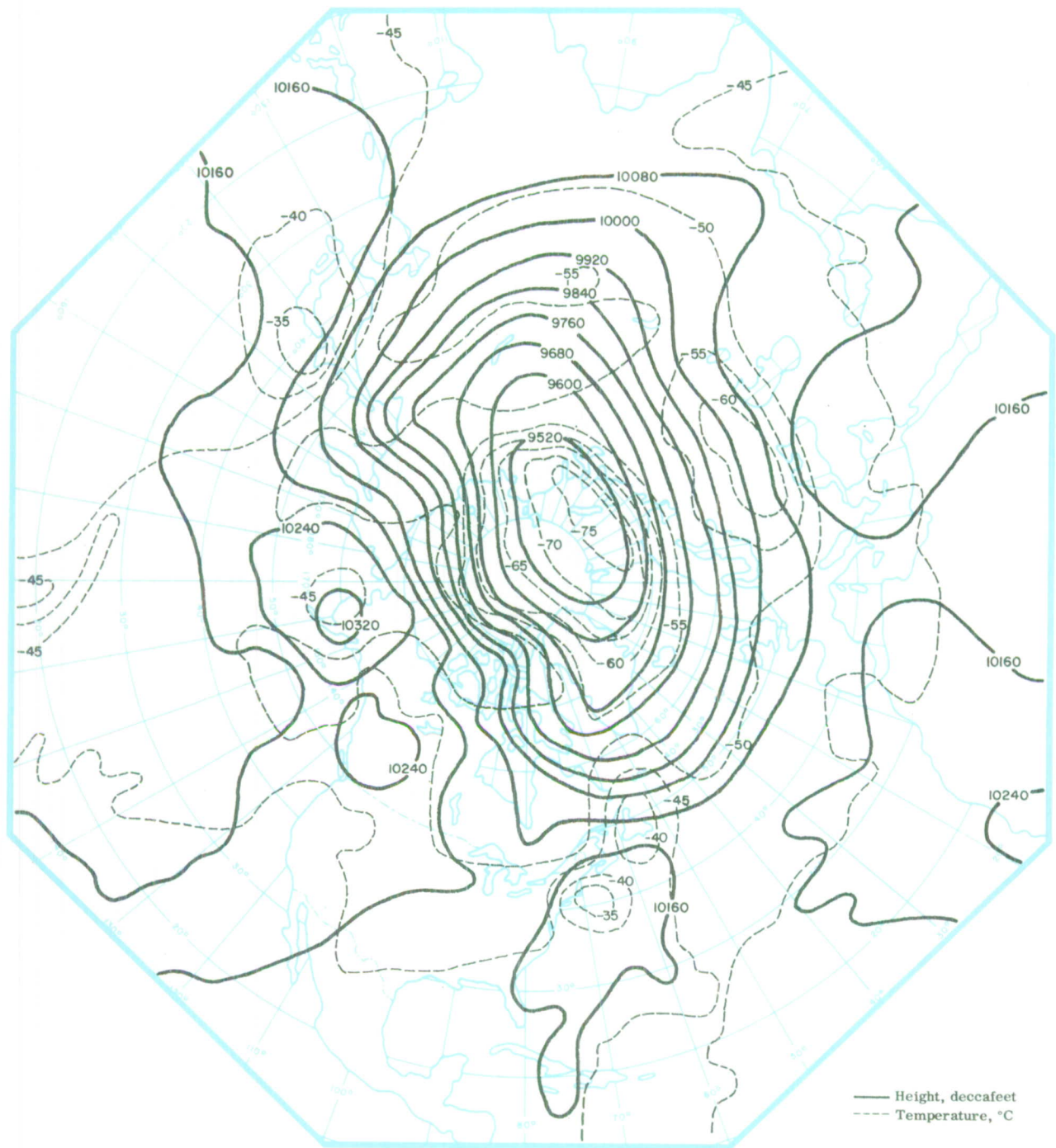
Fig. 10. Ten-mb height and temperature analysis: 00Z, 7 February initial guess — past and present data equations.
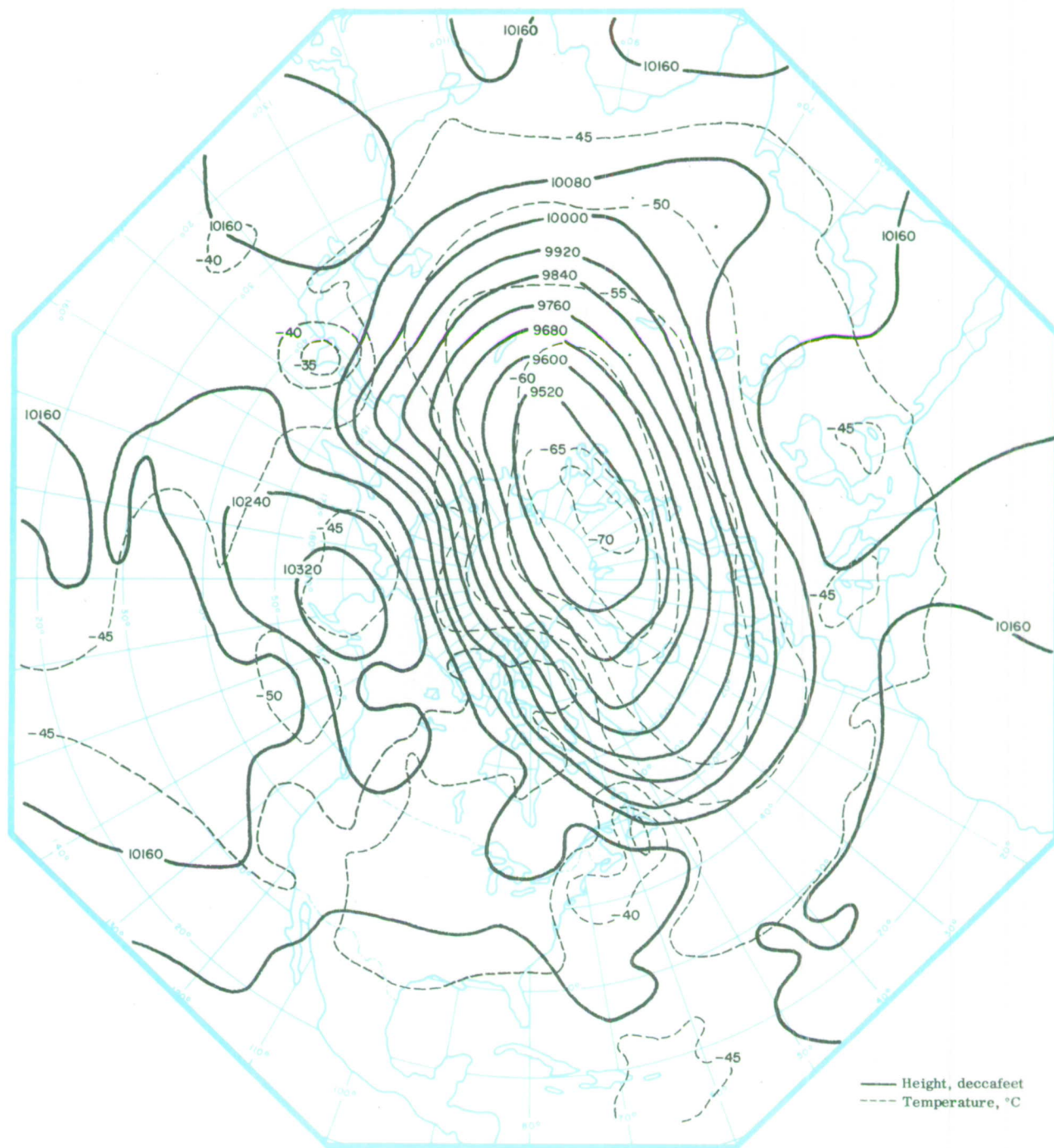
Fig. 11. Ten-mb height and temperature analysis: 00Z, 7 February initial guess — present data equations.

## SECTION V

## CONCLUSIONS AND RECOMMENDATIONS

The two sets of vertical extrapolation equations developed from a five-year data sample showed stability when tested on an independent data sample. The past- and present-data equations produced lower 10-mb height rms errors than did the present-data equations. The temperature equation rms errors were about the same. The past- and present-data equations should be used in the analysis technique over areas where previous $(t_{-24})$ data are available.

Results of experiments indicated that it is better to perform the height analysis first and to use $H_0(30\text{--}10)$ as a specifier of 10-mb temperatures.

The results of a Student "t" test comparing TRC equations with USWB equations for specifying 10-mb heights and temperatures clearly indicates that the inclusion of additional parameters in the TRC equations leads to significantly smaller specification errors.

The application of the TRC equations in the 10-mb analysis technique showed that both sets of equations (present-data only, and past- and present-data) produce similar initial-guess fields of 10-mb heights and temperatures. Any differences that do occur are usually over data areas, and it is felt that the past- and present-data equations produce the more meaningful analysis in these regions.

It is suggested that the 100--50 mb and 50--30 mb vertical extrapolation equations be rederived to make them compatible with the regime and band stratification used for the 10-mb equations.

APPENDIX I

TRC VERTICAL EXTRAPOLATION EQUATIONS FOR
SPECIFYING 10-mb HEIGHTS AND TEMPERATURES

# APPENDIX I

## TRC VERTICAL EXTRAPOLATION EQUATIONS FOR
## 10-mb HEIGHTS AND TEMPERATURES*

1.      Past and Present Data—December, January, February

Band    Predictand

2A

$$Z_0(10) = 2269.2 + 0.6812[Z_{-24}(10)] - 1.5402[Z_{-24}(30)] + 0.8009[Z_{-24}(50)]$$
$$+ 7.4966[T_0(30)] + 1.0239[Z_0(30)]$$

$$T_0(10) = -384.85 + 0.1325[Z_0(10)] - 0.1325[Z_0(30)] - 0.6374[T_0(30)]$$
$$+ 0.1907[T_{-24}(10)]$$

4A

$$Z_0(10) = 256.22 + 0.9686[Z_{-24}(10)] - 1.1189[Z_{-24}(30)] + 1.2565[Z_0(30)]$$

$$T_0(10) = -344.98 + 0.1186[Z_0(10)] - 0.1186[Z_0(30)] - 0.5611[T_0(30)]$$
$$+ 0.2480[T_{-24}(10)]$$

5

$$Z_0(10) = 991.17 + 0.7681[Z_{-24}(10)] - 1.4040[Z_{-24}(30)] + 0.5858[Z_{-24}(50)]$$
$$+ 1.0989[Z_0(30)] + 3.734[T_0(30)]$$

$$T_0(10) = -240.82 + 0.0817[Z_0(10)] - 0.0817[Z_0(30)] + 0.3917[T_{-24}(10)]$$
$$- 0.3721[T_{-24}(30)]$$

6

$$Z_0(10) = 986.02 + 0.7316[Z_{-24}(10)] - 0.9590[Z_{-24}(30)] + 1.1997[Z_0(30)]$$
$$+ 2.5889[T_0(30)]$$

$$T_0(10) = -394.66 + 0.1364[Z_0(10)] - 0.1364[Z_0(30)] - 0.6301[T_0(30)]$$
$$+ 0.1377[T_{-24}(10)]$$

7

$$Z_0(10) = 594.68 + 1.0711[Z_0(30)] + 0.5697[Z_{-24}(10)] - 0.5697[Z_{-24}(30)]$$
$$+ 2.4147[T_0(30)]$$

$$T_0(10) = -255.68 + 0.0875[Z_0(10)] - 0.0875[Z_0(30)] + 0.2519[T_{-24}(10)]$$
$$- 0.2865[T_{-24}(30)]$$

8

$$Z_0(10) = 888.25 + 0.7443[Z_{-24}(10)] - 0.9606[Z_{-24}(30)] + 1.1929[Z_0(30)]$$
$$+ 1.8779[T_0(30)]$$

$$T_0(10) = -276.36 + 0.0976[Z_0(10)] - 0.0976[Z_0(30)] + 0.3171[T_{-24}(10)]$$
$$- 0.2938[T_{-24}(30)]$$

---

*Heights are in decafeet; temperatures are in °C.

2.     Present Data—December, January, February

| Band | Predictand |
|------|------------|

1       $Z_0(10) = 3324.5 + 0.9529[Z_0(30)] + 12.188[T_0(30)]$

$T_0(10) = -460.15 + 0.1602[Z_0(10)] - 0.1602[Z_0(30)] - 0.3353[T_0(50)]$
$- 0.3353[T_0(30)]$

2A      $Z_0(10) = 2575.2 + 1.0446[Z_0(30)] + 11.243[T_0(30)]$

$T_0(10) = -467.15 + 0.1603[Z_0(10)] - 0.1603[Z_0(30)] - 0.7900[T_0(30)]$

4A      $Z_0(10) = 2440.1 + 1.0449[Z_0(30)] + 8.4884[T_0(30)]$

$T_0(10) = -0452.96 + 0.1552[Z_0(10)] - 0.1552[Z_0(30)] - 0.7509[T_0(30)]$

5       $Z_0(10) = 1483.5 + 1.1567[Z_0(30)] + 6.5451[T_0(30)]$

$T_0(10) = -366.31 + 0.1232[Z_0(10)] - 0.1232[Z_0(30)] - 0.2642[T_0(50)]$
$- 0.2642[T_0(30)]$

6       $Z_0(10) = 2234.2 + 1.0729[Z_0(30)] + 8.4358[T_0(30)]$

$T_0(10) = -458.32 + 0.1578[Z_0(10)] - 0.1578[Z_0(30)] - 0.7641[T_0(30)]$

7       $Z_0(10) = 1232.8 + 1.1778[Z_0(30)] + 4.6769[T_0(30)]$

$T_0(10) = -335.19 + 0.1161[Z_0(10)] - 0.1161[Z_0(30)] - 0.3062[T_0(30)]$

8       $Z_0(10) = 381.02 + 1.2860[Z_0(30)] + 4.6352[T_0(30)]$

$T_0(10) = -381.39 + 0.1340[Z_0(10)] - 0.1340[Z_0(30)] - 0.3904[T_0(30)]$

3.     Past and Present Data—March

| Band | Predictand |
|------|------------|

1       $Z_0(10) = 2367.8 + 8.2878[T_0(30)] + 0.9727[Z_0(30)] + 0.6938[Z_{-24}(10)]$
$- 1.6155[Z_{-24}(30)] + 0.9217[Z_{-24}(50)]$

$T_0(10) = -415.83 + 0.1814[Z_0(10)] - 0.1951[Z_0(30)] - 0.6403[T_0(30)]$
$- 0.1296[T_{-24}(50)] - 0.1296[T_{-24}(30)]$

2       $Z_0(10) = 1767.9 + 1.9691[Z_0(30)] - 1.0042[Z_0(50)] + 0.6056[Z_{-24}(10)]$
$- 1.8447[Z_{-24}(30)] + 1.2391[Z_{-24}(50)] + 6.0913[T_0(30)]$

$T_0(10) = -528.01 + 0.1818[Z_0(10)] - 0.1818[Z_0(30)] - 0.8316[T_0(30)]$
$- 0.0827[T_{-24}(50)] - 0.0827[T_{-24}(30)]$

36

| Band | Predictand |
|------|------------|

3 $\quad Z_0(10) = 1700.4 + 0.4571[Z_{-24}(10)] - 0.6834[Z_{-24}(30)] + 1.2179[Z_0(30)]$
$\qquad\qquad\qquad + 69891[T_0(30)]$

$\quad T_0(10) = -426.10 + 0.1473[Z_0(10)] - 0.1473[Z_0(30)] - 0.4778[T_0(30)]$
$\qquad\qquad\qquad - 0.1001[T_{-24}(50)] - 0.1001[T_{-24}(30)] + 0.0875[T_{-24}(10)]$

4 $\quad Z_0(10) = 1473.2 + 0.6788[Z_{-24}(10)] - 0.8761[Z_{-24}(30)] + 1.1321[Z_0(30)]$
$\qquad\qquad\qquad + 3.9846[T_0(30)]$

$\quad T_0(10) = -209.32 + 0.4383[T_{-24}(10)] - 0.2854[T_{-24}(30)] + 0.0711[Z_0(10)]$
$\qquad\qquad\qquad - 0.0711[Z_0(30)]$

5 $\quad Z_0(10) = 1480.8 + 0.6684[Z_{-24}(10)] - 1.3374[Z_{-24}(30)] + 0.5690[Z_{-24}(50)]$
$\qquad\qquad\qquad + 1.1149[Z_0(30)] + 5.5190[T_0(30)]$

$\quad T_0(10) = -265.43 - 0.3621[T_{-24}(10)] - 0.1428T_{-24}(30)] + 0.0884[Z_0(10)]$
$\qquad\qquad\qquad - 0.0884[Z_0(30)] - 0.1820[T_0(50)] - 0.1820[T_0(30)]$

6 $\quad Z_0(10) = 2234.9 + 0.7197[Z_{-24}(10)] - 1.5388[Z_{-24}(30)] + 0.6898[Z_{-24}(50)]$
$\qquad\qquad\qquad + 1.0617[Z_0(30)] + 5.7838[T_0(30)]$

$\quad T_0(10) = -281.42 + 0.2311[T_{-24}(10)] - 0.2838[T_{-24}(30)] + 0.1291[Z_0(10)]$
$\qquad\qquad\qquad - 0.1423[Z_0(30)] - 0.5593[T_0(30)]$

7 $\quad Z_0(10) = 1202.9 = 1.0526[Z_0(30)] + 0.5306[Z_{-24}(10)] - 0.8566[Z_{-24}(30)]$
$\qquad\qquad\qquad + 0.3260[Z_{-24}(50)] + 2.8832[T_0(30)]$

$\quad T_0(10) = -305.58 + 0.1076[Z_0(10)] - 0.1076[Z_0(30)] - 0.1372[T_0(30)]$
$\qquad\qquad\qquad + 0.2059[T_0(50)] + 0.1661[T_{-24}(10)] - 0.3817[T_{-24}(30)]$

8 $\quad Z_0(10) = 1509.4 + 0.7187[Z_{-24}(10)] - 1.3290[Z_{-24}(30)] + 0.4392[Z_{-24}(50)]$
$\qquad\qquad\qquad + 4.8445[T_0(30)] + 1.1567[Z_0(30)]$

$\quad T_0(10) = -250.25 + 0.0894[Z_0(10)] - 0.0894[Z_0(30)] + 0.2876[T_{-24}(10)]$
$\qquad\qquad\qquad - 0.1643[T_{-24}(30)]$

## 4.     Present Data—March

**Band**     **Predictand**

1      $Z_0(10) = 4622.8 + 13.951[T_0(30)] + 0.7983[Z_0(30)]$

        $T_0(10) = -520.46 + 0.1801[Z_0(10)] - 0.1801[Z_0(30)] - 0.9319[T_0(30)]$

2      $Z_0(10) = 3321.1 + 0.9582[Z_0(30)] + 12.674[T_0(30)]$

        $T_0(10) = -482.91 + 0.1669[Z_0(10)] - 0.1669[Z_0(30)] - 0.2050[T_0(50)]$

                  $- 0.6015[T_0(30)]$

3      $Z_0(10) = 3212.3 + 0.7736[Z_0(30)] + 0.2348[Z_0(50)] + 13.091[T_0(30)]$

        $T_0(10) = -469.01 + 0.1637[Z_0(10)] - 0.1637[Z_0(30)] - 0.6835[T_0(30)]$

4      $Z_0(10) = 2879.3 + 0.9998[Z_0(30)] + 9.9652[T_0(30)]$

        $T_0(10) = -400.77 + 0.1378[Z_0(10)] - 0.1378[Z_0(30)] - 0.5517[T_0(30)]$

5      $Z_0(10) = 1323.9 + 1.1823[Z_0(30)] + 7.0132[T_0(30)]$

        $T_0(10) = -361.56 + 0.1239[Z_0(10)] - 0.1239[Z_0(30)] - 0.4513[T_0(30)]$

6      $Z_0(10) = 3920.2 - 0.0503[Z_0(30)] + 1.0851[Z_0(50)] + 12.611[T_0(30)]$

        $T_0(10) = -483.82 + 0.1640[Z_0(10)] - 0.1640[Z_0(30)] - 0.9767[T_0(30)]$

7      $Z_0(10) = 2320.2 + 1.0330[Z_0(30)] + 3.8186[T_0(30)]$

        $T_0(10) = -324.69 + 0.1121[Z_0(10)] - 0.1121[Z_0(30)] - 0.3092[T_0(30)]$

8      $Z_0(10) = 2576.1 + 8.5124[T_0(30)] + 1.0339[Z_0(30)]$

        $T_0(10) = -328.77 + 0.1163[Z_0(10)] - 0.1163[Z_0(30)] - 0.2059[T_0(30)]$

## 5.     Past and Present Data—April

**Band**     **Predictand**

1      $Z_0(10) = 2058.8 + 0.693[Z_{-24}(10)] - 0.7687[Z_{-24}(30)] + 4.7974[T_0(30)]$

                  $+ 0.9367[Z_0(30)]$

        $T_0(10) = -351.69 + 0.3330[T_{-24}(10)] + 0.1211[Z_0(10)] - 0.1211[Z_0(30)]$

                  $- 0.6848[T_0(30)]$

2      $Z_0(10) = 1831.4 + 0.7140[Z_{-24}(10)] - 1.4318[Z_{-24}(30)] + 0.6982[Z_{-24}(50)]$

                  $+ 1.0103[Z_0(30)] + 6.3295[T_0(30)]$

        $T_0(10) = -372.14 + 0.1283[Z_0(10)] - 0.1283[Z_0(30)] - 0.6777[T_0(30)] + 0.2595[T_{-24}(10)]$

| Band | Predictand |
|------|-----------|

3     $Z_0(10) = 541.00 + 1.1199[Z_0(30)] + 0.4694[Z_{-24}(10)] - 0.4694[Z_{-24}(30)]$
$$+ 4.5241[T_0(30)]$$
$T_0(10) = -357.76 + 0.1236[Z_0(10)] - 0.1236[Z_0(30)] - 0.3532[T_0(30)]$
$$- 0.2288[T_{-24}(10)] - 0.2338[T_{-24}(30)]$$

4     $Z_0(10) = 1144.6 + 1.4053[Z_0(30)] - 0.3435[Z_0(50)] + 0.5886[Z_{-24}(10)]$
$$- 1.3261[Z_{-24}(30)] + 0.7375[Z_{-24}(50)] + 4.491[T_0(30)]$$
$T_0(10) = -369.85 + 0.1280[Z_0(10)] - 0.1280[Z_0(30)] - 0.5628[T_0(30)]$
$$+ 0.1650[T_{-24}(10)]$$

5     $Z_0(10) = 1701.8 + 0.6983[Z_{-24}(10)] - 1.6272[Z_{-24}(30)] + 0.6958[Z_{-24}(50)]$
$$+ 1.2374[Z_0(30)] + 5.1802[T_0(30)]$$
$T_0(10) = -323.54 + 0.1105[Z_0(10)] - 0.1105[Z_0(30)] - 0.2379[T_0(30)]$
$$+ 0.2836[T_{-24}(10)] - 0.3264[T_{-24}(30)]$$

6     $Z_0(10) = 2025.1 + 0.6559[Z_{-24}(10)] - 1.5980[Z_{-24}(30)] + 0.9327[Z_{-24}(50)]$
$$+ 1.0255[Z_0(30)] + 6.3704[T_0(30)]$$
$T_0(10) = -354.28 + 0.1189[Z_0(10)] - 0.1189[Z_0(30)] - 0.4470[T_0(30)]$
$$+ 0.28391[T_{-24}(10)] - 0.33246[T_{-24}(30)]$$

7     $Z_0(10) = 688.13 + 1.2487[Z_0(30)] + 0.5694[Z_{-24}(10)] - 0.7564[Z_{-24}(30)]$
$$+ 2.60[T_0(30)]$$
$T_0(10) = -295.29 + 0.1008[Z_0(10)] - 0.1008[Z_0(30)] + 0.2144[T_{-24}(10)]$
$$- 0.2653[T_{-24}(30)] - 0.1554[T_0(30)]$$

8     $Z_0(10) = 1745.4 + 1.2610[Z_0(30)] + 0.5660[Z_{-24}(10)] - 0.8903[Z_{-24}(30)]$
$$+ 3.9533[T_0(30)]$$
$T_0(10) = -245.82 + 0.0827[Z_0(10)] - 0.0827[Z_0(30)] + 0.2257[T_{-24}(10)]$
$$- 0.3159[T_{-24}(30)]$$

## 6.    Present Data—April

| Band | Predictand |
|------|-----------|

1     $Z_0(10) = 3384.2 + 0.9401[Z_0(30)] + 10.932[T_0(30)]$
$T_0(10) = -492.31 + 0.1692[Z_0(10)] - 0.1692[Z_0(30)] - 0.8959[T_0(30)]$

| Band | Predictand |
|------|-----------|

2

$$Z_0(10) = 2601.5 + 1.0359[Z_0(30)] + 10.334[T_0(30)]$$

$$T_0(10) = -470.26 + 0.1622[Z_0(10)] - 0.1622[Z_0(30)] - 0.7889[T_0(30)]$$

3

$$Z_0(10) = 995.52 + 1.2304[Z_0(30)] + 8.6766[T_0(30)]$$

$$T_0(10) = -429.40 + 0.1488[Z_0(10)] - 0.1488[Z_0(30)] - 0.6119[T_0(30)]$$

4

$$Z_0(10) = 1997.7 + 1.0933[Z_0(30)] + 7.1946[T_0(30)]$$

$$T_0(10) = -435.78 + 0.1500[Z_0(10)] - 0.1500[Z_0(30)] - 0.6831[T_0(30)]$$

5

$$Z_0(10) = 2676.5 - 0.0280[Z_0(30)] + 1.2374[Z_0(50)] + 11.654[T_0(30)]$$

$$T_0(10) = -229.78 + 0.1452[Z_0(10)] - 0.1687[Z_0(30)] - 0.4859[T_0(30)]$$

6

$$Z_0(10) = 3449.6 - 0.0784[Z_0(30)] + 1.1833[Z_0(50)] + 12.060[T_0(30)]$$

$$T_0(10) = -445.52 + 0.1524[Z_0(10)] - 0.1524[Z_0(30)] - 0.7746[T_0(30)]$$

7

$$Z_0(10) = 1264.5 + 1.1806[Z_0(30)] + 5.2868[T_0(30)]$$

$$T_0(10) = -310.64 + 0.1075[Z_0(10)] - 0.1075[Z_0(30)] - 0.2541[T_0(30)]$$

8

$$Z_0(10) = 1702.3 + 1.1310[Z_0(30)] + 6.2547[T_0(30)]$$

$$T_0(10) = -286.06 + 0.0974[Z_0(10)] - 0.0974[Z_0(30)] - 0.2439[T_0(30)]$$

7.    Past and Present Data—May

| Band | Predictand |
|------|-----------|

1

$$Z_0(10) = 3235.3 + 0.69747[Z_0(30)] + 10.762[T_0(30)] + 0.48976[Z_{-24}(10)]$$
$$- 1.70346[Z_{-24}(30)] + 1.2137[Z_{-24}(50)] + 0.33033[Z_0(50)]$$

$$T_0(10) = -405.07 + 0.14057[Z_0(10)] - 0.14057[Z_0(30)] - 0.69257[T_0(30)]$$
$$+ 0.19037[T_{-24}(10)]$$

2

$$Z_0(10) = 99.335 + 1.3366[Z_0(30)] + 0.77099[Z_{-24}(10)] - 1.050[Z_{-24}(30)]$$

$$T_0(10) = -466.56 + 0.1601[Z_0(10)] - 0.1601[Z_0(30)] - 0.19512[T_0(50)]$$
$$- 0.64832[T_0(30)]$$

3

$$Z_0(10) = 1928.8 + 0.99613[Z_0(30)] + 7.8051[T_0(30)] + 0.36914[Z_{-24}(10)]$$
$$- 0.36914[Z_{-24}(30)]$$

$$T_0(10) = -569.30 + 0.20186[Z_0(10)] - 0.20186[Z_0(30)] - 1.26053[T_0(30)]$$
$$+ 0.35577[T_0(50)]$$

40

| Band | Predictand |
|------|-----------|

4     $Z_0(10) = 1500.3 + 1.7466[Z_0(30)] - 0.7354[Z_0(50)] + 0.66285[Z_{-24}(10)]$

$\qquad\qquad - 1.79795[Z_{-24}(30)] + 1.2351[Z_{-24}(50)] + 4.677[T_0(30)]$

$\qquad T_0(10) = -452.92 + 0.15664[Z_0(10)] - 0.15664[Z_0(30)] - 0.40592[T_0(30)]$

$\qquad\qquad + 0.05142[T_{-24}(50)] - 0.49028[T_{-24}(30)] + 0.13601[T_{-24}(10)]$

5     $Z_0(10) = 1423.8 + 1.0877[Z_0(30)] + 5.7789[T_0(30)] + 0.58129[Z_{-24}(10)]$

$\qquad\qquad - 1.33602[Z_{-24}(30)] + 0.75473[Z_{-24}(50)]$

$\qquad T_0(10) = -379.84 + 0.1301[Z_0(10)] - 0.1301[Z_0(30)] - 0.35576[T_0(30)]$

$\qquad\qquad - 0.30444[T_{-24}(30)] + 0.16735[T_{-24}(10)]$

6     $Z_0(10) = 1507.6 + 0.98025[Z_0(30)] + 3.8082[T_0(30)] + 0.51477[Z_{-24}(10)]$

$\qquad\qquad - 0.50956[Z_{-24}(30)] - 0.00521[Z_{-24}(50)]$

$\qquad T_0(10) = -402.38 + 0.14039[Z_0(10)] - 0.14039[Z_0(30)] + 0.28762[T_0(50)]$

$\qquad\qquad - 0.92248[T_0(30)] + 0.14498[T_{-24}(10)]$

7     $Z_0(10) = 623.31 + 1.1379[Z_0(30)] + 0.3604[Z_{-24}(10)] - 0.3604[Z_{-24}(30)]$

$\qquad\qquad + 3.2636[T_0(30)]$

$\qquad T_0(10) = -109.01 + 0.090998[Z_0(10)] - 0.109366[Z_0(30)] + 0.12688[T_{-24}(10)]$

8     $Z_0(10) = 1212.0 + 1.0661[Z_0(30)] + 4.3270[T_0(30)] + 0.64354[Z_{-24}(10)]$

$\qquad\qquad - 1.25061[Z_{-24}(30)] + 0.60707[Z_{-24}(50)]$

$\qquad T_0(10) = -216.54 + 0.075573[Z_0(10)] - 0.075573[Z_0(30)] - 0.36384[T_{-24}(30)]$

$\qquad\qquad + 0.17973[T_{-24}(10)] + 0.3145[T_0(30)]$

## 8.    Present Data—May

| Band | Predictand |
|------|-----------|

1     $Z_0(10) = 4872.3 - 1.0760[Z_0(30)] + 2.1750[Z_0(50)] + 17.480[T_0(30)]$

$\qquad T_0(10) = -465.34 + 0.16091[Z_0(10)] - 0.16091[Z_0(30)] - 0.76577[T_0(30)]$

2     $Z_0(10) = 2654.4 + 0.74404[Z_0(30)] + 0.31756[Z_0(50)] + 7.8293[T_0(30)]$

$\qquad T_0(10) = -459.59 + 0.15738[Z_0(10)] - 0.15738[Z_0(30)] - 0.82979[T_0(30)]$

3     $Z_0(10) = 2980.5 + 0.32621[Z_0(30)] + 0.77929[Z_0(50)] + 11.342[T_0(30)]$

$\qquad T_0(10) = -512.95 + 0.17874[Z_0(10)] - 0.17874[Z_0(30)] - 0.8764[T_0(30)]$

| Band | Predictand |
|------|-----------|

4     $Z_0(10) = 2290.6 + 0.5352[Z_0(30)] + 0.6197[Z_0(50)] + 8.8075[T_0(30)]$

$T_0(10) = -473.21 + 0.16338[Z_0(10)] - 0.16338[Z_0(30)] - 0.81368[T_0(30)]$

5     $Z_0(10) = 2241.5 + 0.1900[Z_0(30)] + 1.0436[Z_0(50)] + 10.873[T_0(30)]$

$T_0(10) = -403.06 + 0.13924[Z_0(10)] - 0.13924[Z_0(30)] - 0.5544[T_0(30)]$

6     $Z_0(10) = 3025.5 + 0.2274[Z_0(30)] + 0.8807[Z_0(50)] + 10.415[T_0(30)]$

$T_0(10) = -421.83 + 0.14629[Z_0(10)] - 0.14629[Z_0(30)] - 0.864035[T_0(30)]$
$\qquad\qquad + 0.243465[T_0(50)]$

7     $Z_0(10) = 1137.5 + 1.72436[Z_0(30)] - 0.62196[Z_0(50)] + 3.8658[T_0(30)]$

$T_0(10) = -119.92 + 0.10134[Z_0(10)] - 0.12213[Z_0(30)]$

8     $Z_0(10) = 1814.3 + 1.115[Z_0(30)] + 5.9867[T_0(30)]$

$T_0(10) = -217.53 + 0.097643[Z_0(10)] - 0.104845[Z_0(30)]$

9.     **Past and Present Data—June, July, 1/2 August (1—15)**

| Band | Predictand |
|------|-----------|

1     $Z_0(10) = 1988.9 + 1.0036[Z_0(30)] + 0.6009[Z_{-24}(10)] - 1.24385[Z_{-24}(30)]$
$\qquad\qquad + 0.64295[Z_{-24}(50)] + 7.125[T_0(30)]$

$T_0(10) = -401.68 + 0.14051[Z_0(10)] - 0.14051[Z_0(30)] - 0.39504[T_0(30)]$
$\qquad\qquad + 0.149715[T_{-24}(10)] - 0.196605[T_{-24}(30)]$

2     $Z_0(10) = 1850.6 + 0.99791[Z_0(30)] + 0.59124[Z_{-24}(10)] - 1.10224[Z_{-24}(30)]$
$\qquad\qquad + 0.511[Z_{-24}(50)] + 5.7607[T_0(30)]$

$T_0(10) = -414.47 + 0.14353[Z_0(10)] - 0.14353[Z_0(30)] - 0.69459[T_0(30)]$
$\qquad\qquad + 0.12523[T_{-24}(10)]$

3     $Z_0(10) = 1421.8 + 1.95869[Z_0(30)] - 0.91059[Z_0(50)] + 3.7031[T_0(30)]$
$\qquad\qquad + 0.37711[Z_{-24}(10)] - 1.31552[Z_{-24}(30)] + 0.93841[Z_{-24}(50)]$

$T_0(10) = -437.09 + 0.15001[Z_0(10)] - 0.15001[Z_0(30)] - 0.177795[T_0(50)]$
$\qquad\qquad - 0.554115[T_0(30)]$

| Band | Predictand |
|---|---|

4

$$Z_0(10) = 1682.9 + 1.2435[Z_0(30)] + 4.6478[T_0(30)] + 0.31750[Z_{-24}(10)]$$
$$- 0.53576[Z_{-24}(30)]$$

$$T_0(10) = -264.31 + 0.13604[Z_0(10)] - 1.54064[Z_0(30)] - 0.37164[T_0(30)]$$
$$+ 0.17881[T_0(50)]$$

5

$$Z_0(10) = 1064.0 + 1.3019[Z_0(30)] + 3.3702[T_0(30)] + 0.43259[Z_{-24}(10)]$$
$$- 0.67436[Z_{-24}(30)]$$

$$T_0(10) = 201.81 + 0.10631[Z_0(10)] - 0.117716[Z_0(30)] + 0.079653[T_{-24}(10)]$$

6

$$Z_0(10) = 1482.4 + 1.2567[Z_0(30)] + 5.609[T_0(30)] + 0.2611[Z_{-24}(10)]$$
$$- 0.44447[Z_{-24}(30)]$$

$$T_0(10) = -300.69 + 0.12683[Z_0(10)] - 0.133596[Z_0(30)] - 0.19561[T_0(30)]$$

7

$$Z_0(10) = 953.79 + 1.0743[Z_0(30)] + 0.42748[Z_{-24}(10)] - 0.42748[Z_{-24}(30)]$$
$$+ 3.2084[T_0(30)]$$

$$T_0(10) = -168.86 + 0.087103[Z_0(10)] - 0.0969068[Z_0(30)] + 0.089489[T_{-24}(10)]$$

8

$$Z_0(10) = 881.28 + 1.60249[Z_0(30)] - 0.54379[Z_0(50)] + 3.1667[T_0(30)]$$
$$+ 0.2664[Z_{-24}(10)] - 0.2664[Z_{-24}(30)]$$

$$T_0(10) = -287.11 + 0.10242[Z_0(10)] - 0.10242[Z_0(30)] + 0.062582[T_{-24}(10)]$$
$$- 0.068159[T_0(30)]$$

10. Present Data—June, July, 1/2 August (1—15)

| Band | Predictand |
|---|---|

1

$$Z_0(10) = 3392.9 + 0.34927[Z_0(30)] + 0.69323[Z_0(50)] + 11.241[T_0(30)]$$

$$T_0(10) = -395.30 + 0.1388[Z_0(10)] - 0.1388[Z_0(30)] - 0.42019[T_0(30)]$$

2

$$Z_0(10) = 2472.8 + 1.036[Z_0(30)] + 6.781[T_0(30)]$$

$$T_0(10) = -415.58 + 0.14424[Z_0(10)] - 0.14424[Z_0(30)] - 0.28672[T_0(50)]$$
$$- 0.28672[T_0(30)]$$

3

$$Z_0(10) = 2444.9 + 1.0397[Z_0(30)] + 6.892[T_0(30)]$$

$$T_0(10) = -418.48 + 0.14456[Z_0(10)] - 0.14456[Z_0(30)] - 0.306075[T_0(50)]$$
$$- 0.306075[T_0(30)]$$

| Band | Predictand |
|------|-----------|

**4**

$$Z_0(10) = 1628.7 + 1.1373[Z_0(30)] + 6.0409[T_0(30)]$$

$$T_0(10) = -230.62 + 0.13492[Z_0(10)] - 0.153176[Z_0(30)] - 0.23118[T_0(30)]$$

**5**

$$Z_0(10) = 1054.3 + 0.64155[Z_0(30)] - 0.51885[Z_0(50)] + 3.4235[T_0(30)]$$

$$T_0(10) = -131.79 + 0.10627[Z_0(10)] - 0.125715[Z_0(30)] + 0.08661[T_0(50)]$$
$$+ 0.08661[T_0(30)]$$

**6**

$$Z_0(10) = 1773.2 + 1.1207[Z_0(30)] + 6.3807[T_0(30)]$$

$$T_0(10) = -297.73 + 0.13325[Z_0(10)] - 0.142416[Z_0(30)] - 0.20885[T_0(30)]$$

**7**

$$Z_0(10) = 1705.9 + 1.1197[Z_0(30)] + 4.8823[T_0(30)]$$

$$T_0(10) = -220.82 + 0.091553[Z_0(10)] - 0.096875[Z_0(30)] - 0.043861[T_0(30)]$$

**8**

$$Z_0(10) = 1163.3 + 1.75279[Z_0(30)] - 0.66229[Z_0(50)] + 3.6123[T_0(30)]$$

$$T_0(10) = -248.26 + 0.089354[Z_0(10)] - 0.089354[Z_0(30)] + 0.057875[T_0(50)]$$
$$+ 0.057875[T_0(30)]$$

## 11.    Past and Present Data—1/2 August (16—31), September

| Band | Predictand |
|------|-----------|

**1**

$$Z_0(10) = 1226.8 + 1.0868[Z_0(30)] + 0.6898[Z_{-24}(10)] - 1.4961[Z_{-24}(30)]$$
$$+ 0.8063[Z_{-24}(50)] + 5.8009[T_0(30)]$$

$$T_0(10) = -329.19 + 0.11479[Z_0(10)] - 0.11479[Z_0(30)] - 0.24559[T_0(30)]$$
$$+ 0.25259[T_{-24}(10)] - 0.103175[T_{-24}(50)] - 0.103175[T_{-24}(30)]$$

**2**

$$Z_0(10) = 944.98 + 0.720854[Z_{-24}(10)] - 0.8053[Z_{-24}(30)] + 4.6491[T_0(30)]$$

$$T_0(10) = -339.09 + 0.11937[Z_0(10)] - 0.11937[Z_0(30)] - 0.445[T_0(30)]$$
$$+ 0.26909[T_{-24}(10)]$$

**3**

$$Z_0(10) = 621.8 + 1.0348[Z_0(30)] + 0.6739[Z_{-24}(10)] - 0.6739[Z_{-24}(30)]$$
$$+ 2.3992[T_0(30)]$$

$$T_0(10) = -496.76 + 0.17324[Z_0(10)] - 0.17324[Z_0(30)] - 0.85131[T_0(30)]$$
$$+ 0.067205[T_{-24}(10)]$$

| Band | Predictand |
|---|---|

4
$$Z_0(10) = 1284.4 + 1.1141[Z_0(30)] + 0.52705[Z_{-24}(10)] - 1.20957[Z_{-24}(30)]$$
$$+ 0.68252[Z_{-24}(50)] + 6.2393[T_0(30)]$$

$$T_0(10) = -340.10 + 0.11832[Z_0(10)] - 0.11832[Z_0(30)] - 0.27826[T_0(30)]$$
$$+ 0.24551[T_{-24}(10)] - 0.21413[T_{-24}(30)]$$

5
$$Z_0(10) = 400.34 + 1.71471[Z_0(30)] - 0.55351[Z_0(50)] + 0.53437[Z_{-24}(10)]$$
$$- 1.4347[Z_{-24}(30)] + 0.90033[Z_{-24}(50)] + 3.674[T_0(30)]$$

$$T_0(10) = -312.50 + 0.10865[Z_0(10)] - 0.10865[Z_0(30)] - 0.149875[T_{-24}(50)]$$
$$- 0.149875[T_{-24}(30)] + 0.12986[T_{-24}(10)]$$

6
$$Z_0(10) = 332.82 + 1.50185[Z_0(30)] - 0.27375[Z_0(50)] + 5.0755[T_0(30)]$$
$$+ 0.40565[Z_{-24}(10)] - 1.10682[Z_{-24}(30)] + 0.70117[Z_{-24}(50)]$$

$$T_0(10) = -368.72 + 0.13047[Z_0(10)] - 0.13047[Z_0(30)] - 0.40427[T_0(30)]$$
$$+ 0.13479[T_{-24}(10)]$$

7
$$Z_0(10) = 1209.2 + 1.0189[Z_0(30)] + 0.49349[Z_{-24}(10)] - 0.49349[Z_{-24}(30)]$$
$$+ 2.8387[T_0(30)]$$

$$T_0(10) = -167.10 + 0.099233[Z_0(10)] - 0.113495[Z_0(30)] + 0.171745[T_{-24}(10)]$$
$$- 0.145835[T_{-24}(30)]$$

8
$$Z_0(10) = 692.38 + 1.318[Z_0(30)] + 0.52368[Z_{-24}(10)] - 0.77132[Z_{-24}(30)]$$
$$+ 2.1127[T_0(30)]$$

$$T_0(10) = -243.24 + 0.12364[Z_0(10)] - 0.135411[Z_0(30)] + 0.018701[T_{-24}(10)]$$

12.    Present Data—1/2 August (16—31), September

| Band | Predictand |
|---|---|

1
$$Z_0(10) = 1600.1 + 0.49716[Z_0(30)] + 0.76594[Z_0(50)] + 9.0294[T_0(30)]$$
$$T_0(10) = -404.3 + 0.15571[Z_0(10)] - 0.1603824[Z_0(30)] - 0.51378[T_0(30)]$$

2
$$Z_0(10) = 1898.6 + 1.1216[Z_0(30)] + 9.4179[T_0(30)]$$
$$T_0(10) = -400.67 + 0.14076[Z_0(10)] - 0.14076[Z_0(30)] - 0.113085[T_0(50)]$$
$$- 0.310415[T_0(30)]$$

| Band | Predictand |
|------|-----------|

3

$$Z_0(10) = 2243.1 + 0.60613[Z_0(30)] + 0.54927[Z_0(50)] + 9.6266[T_0(30)]$$

$$T_0(10) = -476.32 + 0.16689[Z_0(10)] - 0.16689[Z_0(30)] - 0.6826[T_0(30)]$$

4

$$Z_0(10) = 1406.9 + 0.56964[Z_0(30)] + 0.71396[Z_0(50)] + 9.6371[T_0(30)]$$

$$T_0(10) = -381.92 + 0.13402[Z_0(10)] - 0.13402[Z_0(30)] - 3.7419[T_0(30)]$$

5

$$Z_0(10) = 448.24 + 1.275[Z_0(30)] + 4.5126[T_0(30)]$$

$$T_0(10) = -319.98 + 0.11068[Z_0(10)] - 0.11068[Z_0(30)] - 0.12261[T_0(50)]$$
$$- 0.12261[T_0(30)]$$

6

$$Z_0(10) = -476.61 + 1.3822[Z_0(30)] + 3.2255[T_0(30)]$$

$$T_0(10) = -360.67 + 0.12777[Z_0(10)] - 0.12777[Z_0(30)] - 0.26067[T_0(30)]$$

7

$$Z_0(10) = 1776.7 + 1.1067[Z_0(30)] + 4.3956[T_0(30)]$$

$$T_0(10) = -139.61 + 0.10479[Z_0(10)] - 0.124134[Z_0(30)]$$

8

$$Z_0(10) = 489.71 + 1.2587[Z_0(30)] + 2.7603[T_0(30)]$$

$$T_0(10) = -194.51 + 0.11697[Z_0(10)] - 0.132994[Z_0(30)]$$

13.     Past and Present Data—October-November

| Band | Predictand |
|------|-----------|

1

$$Z_0(10) = 82.542 + 0.97006[Z_{-24}(10)] - 1.2149[Z_{-24}(30)] + 1.2553[Z_0(30)]$$
$$+ 1.6675[T_0(30)]$$

$$T_0(10) = -362.25 + 0.32749[T_{-24}(10)] + 0.12627[Z_0(10)] - 0.12627[Z_0(30)]$$
$$- 0.90762[T_0(30)] + 0.134645[T_{-24}(50)] + 0.134645[T_{-24}(50)]$$

2

$$Z_0(10) = 1674.8 + 0.63275[Z_{-24}(10)] - 1.23019[Z_{-24}(30)] + 0.50501[Z_{-24}(50)]$$

$$T_0(10) = -355.12 + 0.11963[Z_0(10)] - 0.11963[Z_0(30)] - 0.32729[T_0(50)]$$
$$- 0.32729[T_0(30)] + 0.19539[T_{-24}(10)]$$

3

$$Z_0(10) = 972.6 + 0.442812[Z_{-24}(10)] - 0.42673[Z_{-24}(30)] + 1.0625[Z_0(30)]$$
$$+ 5.4235[T_0(30)]$$

$$T_0(10) = -415.4 + 0.14216[Z_0(10)] - 0.14216[Z_0(30)] - 0.76711[T_0(30)]$$
$$+ 0.16145[T_{-24})]$$

| Band | Predictand |
|------|-----------|

**4**

$$Z_0(10) = 1610.1 + 0.68338[Z_0(30)] + 0.55262[Z_0(50)] + 10.797[T_0(30)]$$
$$+ 0.0053834[Z_{-24}(10)]$$

$$T_0(10) = -266.72 + 0.091752[Z_0(10)] - 0.091752[Z_0(30)] + 0.39929[T_{-24}(10)]$$
$$- 0.41496[T_{-24}(30)]$$

**5**

$$Z_0(10) = 886.81 + 1.0927[Z_0(30)] + 0.71701[Z_{-24}(10)] - 1.38211[Z_{-24}(30)]$$
$$+ 0.6651[Z_{-24}(50)] + 4.4486[T_0(30)]$$

$$T_0(10) = -246.59 + 0.085166[Z_0(10)] - 0.085166[Z_0(30)] + 0.40911[T_{-24}(10)]$$
$$- 0.34129[T_{-24}(30)]$$

**6**

$$Z_0(10) = 885.69 + 1.1247[Z_0(30)] + 0.63856[Z_{-24}(10)] - 1.29971[Z_{-24}(30)]$$
$$+ 0.66115[Z_{-24}(50)] + 5.669[T_0(30)]$$

$$T_0(10) = -353.9 + 0.12455[Z_0(10)] - 0.12455[Z_0(30)] - 0.38547[T_0(30)]$$
$$+ 0.12583[T_{-24}(10)]$$

**7**

$$Z_0(10) = 1026.5 + 1.1026[Z_0(30)] + 0.61638[Z_{-24}(10)] - 1.32284[Z_{-24}(30)]$$
$$+ 0.70646[Z_{-24}(50)] + 3.17\ 69[T_0(30)]$$

$$T_0(10) = -313.1 + 0.11098[Z_0(10)] - 0.11098[Z_0(30)] + 0.25109[T_{-24}(10)]$$
$$- 0.146025[T_{-24}(50)] - 0.146025[T_{-24}(30)]$$

**8**

$$Z_0(10) = 1098.2 + 1.1661[Z_0(30)] + 0.94071[Z_{-24}(10)] - 0.94071[Z_{-24}(30)]$$
$$+ 2.2762[T_0(30)] - 0.20941[T_{-24}(10)]$$

$$T_0(10) = -274.55 + 0.094757[Z_0(10)] - 0.094757[Z_0(30)] + 0.34467[T_{-24}(10)]$$
$$- 0.18674[T_{-24}(50)] - 0.18674[T_{-24}(30)]$$

## 14. Present Data—October, November

| Band | Predictand |
|------|-----------|

**1**

$$Z_0(10) = 5207.3 - 0.46681[Z_0(30)] + 1.3974(Z_0(50)) + 15.844[T_0(30)]$$

$$T_0(10) = -483.98 + 0.16642[Z_0(10)] - 0.16642[Z_0(30)] - 0.83989[T_0(30)]$$

**2**

$$Z_0(10) = 2554.1 + 1.0316[Z_0(30)] + 8.9399[T_0(30)]$$

$$T_0(10) = -460.49 + 0.15823[Z_0(10)] - 0.15823[Z_0(30)] - 0.75149[T_0(30)]$$

| Band | Predictand |
|---|---|

**3**

$$Z_0(10) = 1989.0 + 1.0991(Z_0(30)] + 8.0509[T_0(30)]$$

$$T_0(10) = -477.94 + 0.16425[Z_0(10)] - 0.16425[Z_0(30)] - 0.81825[T_0(30)]$$

**4**

$$Z_0(10) = 983.76 + 1.2311[Z_0(30)] + 8.454[T_0(30)]$$

$$T_0(10) = -376.87 + 0.12936[Z_0(10)] - 0.12936[Z_0(30)] - 0.22831[T_0(50)]$$
$$- 0.22831[T_0(30)]$$

**5**

$$Z_0(10) = 960.36 + 0.50637[Z_0(30)] + 0.85363[Z_0(50)] + 9.6107[T_0(30)]$$

$$T_0(10) = -362.10 + 0.1261[Z_0(10)] - 0.1261[Z_0(30)] - 0.34441[T_0(30)]$$

**6**

$$Z_0(10) = 1235.6 + 1.2104[Z_0(30)] + 9.7816[T_0(30)]$$

$$T_0(10) = -416.02 + 0.14546[Z_0(10)] - 0.14546[Z_0(30)] - 0.51329[T_0(30)]$$

**7**

$$Z_0(10) = 2245.9 + 1.0473[Z_0(30)] + 4.3796[T_0(30)]$$

$$T_0(10) = -388.93 + 0.13769[Z_0(10)] - 0.13769[Z_0(30)] - 0.33907[T_0(30)]$$

**8**

$$Z_0(10) = 1627.9 + 1.1327[Z_0(30)] + 5.5417[T_0(30)]$$

$$T_0(10) = -290.6 + 0.13959[Z_0(10)] - 0.153136[Z_0(30)] - 0.193975[T_0(50)]$$
$$- 0.193975[T_0(30)]$$

### 15. Past and Present Data—Warming: January, February '63

| Band | Predictand |
|---|---|

**W**

$$Z_0(10) = 2302.4 + 0.6955[Z_{-25}(10)] - 1.8019[Z_{-24}(30)] + 1.8019[Z_{-24}(50)]$$
$$+ 7.6937[T_0(30)] + 0.4040[Z_0(30)]$$

$$T_0(10) = -414.10 + 0.1219[T_{-24}(10)] + 0.1397[Z_0(10)] - 0.1397[Z_0(30)]$$
$$- 0.8183[T_0(30)]$$

### 16. Present Data—Warming: January, February '63

| Band | Predictand |
|---|---|

**W**

$$Z_0(10) = 6437.3 + 8.7449[T_0(30)] + 0.5339[Z_0(30)]$$

$$T_0(10) = -473.6 + 0.1590[Z_0(10)] - 0.1590[Z_0(30)] - 0.9808[T_0(30)]$$

APPENDIX II

RESULTS USING
TRC VERTICAL EXTRAPOLATION EQUATIONS
FOR SPECIFYING 10-mb HEIGHTS AND TEMPERATURES
(Independent and Dependent Data)

## TABLE XIV
## DECEMBER, JANUARY, FEBRUARY
### (a) Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases | | Rms error | | Std. dev. | |
|---|---|---|---|---|---|---|---|---|
| | | | Dep. | Ind. | Dep. | Ind. | Dep. | Ind. |
| 1 | – | – | – | – | – | – | – | – |
| 2A | $Z_0(10)$ | $Z_{-24}(10)$, $T_0(30)$, $Z_0(30)$, $H_{-24}(30-10)$, $H_{-24}(50-30)$ | 362 | 39 | 201 ft | 163 ft | 1255 ft | 1148 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$ | 362 | 39 | 2.4°C | 2.0°C | 8.5°C | 9.2°C |
| 4A | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$ | 320 | 34 | 214 ft | 189 ft | 863 ft | 1031 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$ | 320 | 34 | 2.3°C | 2.6°C | 6.0°C | 7.1°C |
| 5 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $H_{-24}(50-30)$ | 1325 | 68 | 165 ft | 177 ft | 666 ft | 704 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 1325 | 68 | 2.4°C | 2.6°C | 4.9°C | 6.0°C |
| 6 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$ | 238 | 25 | 192 ft | 176 ft | 756 ft | 750 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$ | 238 | 25 | 2.4°C | 2.3°C | 6.1°C | 5.3°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$ | 693 | 75 | 167 ft | 168 ft | 421 ft | 388 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 693 | 75 | 2.6°C | 2.2°C | 3.7°C | 4.0°C |
| 8 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$ | 640 | 69 | 154 ft | 145 ft | 451 ft | 424 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 640 | 69 | 2.3°C | 2.5°C | 4.2°C | 4.5°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\bar{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript –24 indicates 24 hrs before observation time.

TABLE XIV

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|------|-------------|----------------------|------|------|------|------|------|------|
| 1 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 122 | 11 | 292 ft | 322 ft | 1159 ft | 1036 ft |
| 1 | $T_0(10)$ | $H_0(30-10)$, $T_0(50-30)$ | 122 | 11 | 2.0°C | 1.9°C | 8.3°C | 8.8°C |
| 2 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 853 | 92 | 296 ft | 333 ft | 1279 ft | 1322 ft |
| 2 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 853 | 92 | 2.5°C | 2.5°C | 8.4°C | 9.7°C |
| 4A | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 889 | 96 | 322 ft | 294 ft | 894 ft | 983 ft |
| 4A | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 889 | 96 | 2.7°C | 2.9°C | 6.4°C | 6.5°C |
| 5 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 3111 | 161 | 282 ft | 296 ft | 691 ft | 687 ft |
| 5 | $T_0(10)$ | $H_0(30-10)$, $\overline{T}_0(50-30)$ | 3111 | 161 | 2.9°C | 2.6°C | 5.3°C | 5.4°C |
| 6 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 664 | 72 | 335 ft | 319 ft | 736 ft | 658 ft |
| 6 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 664 | 72 | 2.8°C | 3.0°C | 6.5°C | 6.5°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 1153 | 125 | 227 ft | 233 ft | 461 ft | 413 ft |
| 7 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 1153 | 125 | 2.8°C | 2.5°C | 3.9°C | 4.0°C |
| 8 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 1686 | 183 | 205 ft | 246 ft | 478 ft | 431 ft |
| 8 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 1686 | 183 | 2.7°C | 2.7°C | 4.3°C | 4.5°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

TABLE XV
MARCH

(a) Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $T_0(30)$, $Z_0(30)$, $H_{-24}(30\text{-}10)$, $H_{-24}(50\text{-}30)$ | 40 | – | 158 ft | – | 1773 ft | – |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $Z_0(30)$, $\bar{T}_{-24}(50\text{-}30)$ | 40 | – | 2.1°C | – | 13.8°C | – |
| 2 | $Z_0(10)$ | $H_0(50\text{-}30)$, $Z_0(30)$, $H_{-24}(30\text{-}10)$, $H_{-24}(50\text{-}30)$, $T_0(30)$ | 170 | 18 | 154 ft | 179 ft | 1459 ft | 1600 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $\bar{T}_{-24}(50\text{-}30)$ | 170 | 18 | 1.7°C | 1.6°C | 8.0°C | 10.3°C |
| 3 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $T_0(30)$, $H_{-24}(30\text{-}10)$ | 116 | 12 | 166 ft | 148 ft | 1070 ft | 1291 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $\bar{T}_{-24}(50\text{-}30)$, $T_{-24}(10)$ | 116 | 12 | 1.9°C | 1.5°C | 7.1°C | 6.6°C |
| 4 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$ | 246 | 27 | 159 ft | 143 ft | 800 ft | 786 ft |
| | $T_0(10)$ | $T_{-24}(10)$, $H_0(30\text{-}10)$, $\bar{T}_{-24}(30\text{-}10)$ | 246 | 27 | 2.1°C | 1.7°C | 5.1°C | 3.9°C |
| 5 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$, $H_{-24}(50\text{-}30)$ | 685 | 36 | 141 ft | 110 ft | 659 ft | 610 ft |
| | $T_0(10)$ | $T_{-24}(10)$, $H_0(30\text{-}10)$, $\bar{T}_0(50\text{-}30)$, $\bar{T}_{-24}(30\text{-}10)$ | 685 | 36 | 2.2°C | 2.4°C | 4.7°C | 4.3°C |
| 6 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$, $H_{-24}(50\text{-}30)$ | 162 | 18 | 161 ft | 118 ft | 566 ft | 601 ft |
| | $T_0(10)$ | $T_{-24}(10)$, $H_0(30\text{-}10)$, $\bar{T}_{-24}(30\text{-}10)$, $Z_0(30)$ | 162 | 18 | 2.4°C | 2.2°C | 5.3°C | 5.9°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$, $H_{-24}(50\text{-}30)$ | 288 | 31 | 159 ft | 120 ft | 306 ft | 320 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $T_{-24}(10)$, $\bar{T}_{-24}(30\text{-}10)$, $\bar{T}_0(50\text{-}30)$ | 288 | 31 | 2.3°C | 2.9°C | 3.3°C | 3.4°C |
| 8 | $Z_0(10)$ | $Z_{-24}(10)$, $T_0(30)$, $Z_0(30)$, $H_{-24}(30\text{-}10)$, $H_{-24}(50\text{-}30)$ | 316 | 35 | 141 ft | 149 ft | 421 ft | 376 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_{-24}(10)$, $\bar{T}_{-24}(30\text{-}10)$ | 316 | 35 | 2.1°C | 1.9°C | 4.4°C | 4.2°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\bar{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

TABLE XV

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases | | Rms error | | Std. dev. | |
|---|---|---|---|---|---|---|---|---|
| | | | Dep. | Ind. | Dep. | Ind. | Dep. | Ind. |
| 1 | $Z_0(10)$ | $T_0(30), Z_0(30)$ | 99 | 9 | 283 ft | 344 ft | 1680 ft | 1375 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 99 | 9 | 2.1°C | 1.4°C | 12.1°C | 11.9°C |
| 2 | $Z_0(10)$ | $Z_0(30), T_0(30)$ | 419 | 45 | 235 ft | 223 ft | 1443 ft | 1435 ft |
| | $T_0(10)$ | $H_0(30-10), \overline{T}_0(50-30), T_0(30)$ | 419 | 45 | 1.8°C | 2.1°C | 8.5°C | 9.0°C |
| 3 | $Z_0(10)$ | $H_0(50-30), Z_0(30), T_0(30)$ | 273 | 29 | 229 ft | 239 ft | 1159 ft | 1293 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 273 | 29 | 1.9°C | 1.7°C | 7.8°C | 7.6°C |
| 4 | $Z_0(10)$ | $Z_0(30), T_0(30)$ | 616 | 68 | 257 ft | 239 ft | 848 ft | 806 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 616 | 68 | 2.3°C | 1.7°C | 5.1°C | 4.4°C |
| 5 | $Z_0(10)$ | $Z_0(30), T_0(30)$ | 1464 | 77 | 251 ft | 235 ft | 662 ft | 631 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 1464 | 77 | 2.7°C | 2.6°C | 4.6°C | 4.2°C |
| 6 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 338 | 37 | 274 ft | 257 ft | 563 ft | 637 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 338 | 37 | 2.5°C | 2.5°C | 5.4°C | 5.6°C |
| 7 | $Z_0(10)$ | $Z_0(30), T_0(30)$ | 484 | 52 | 188 ft | 202 ft | 324 ft | 358 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 484 | 52 | 2.4°C | 2.7°C | 3.3°C | 3.6°C |
| 8 | $Z_0(10)$ | $T_0(30), Z_0(30)$ | 723 | 80 | 220 ft | 214 ft | 418 ft | 383 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 723 | 80 | 2.4°C | 2.4°C | 4.3°C | 3.9°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

## TABLE XVI
## APRIL

### (a) Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_{-24}(10)$, $T_0(30)$, $Z_0(30)$, $H_{-24}(30-10)$ | 94 | 10 | 148 ft | 138 ft | 1305 ft | 1554 ft |
| 1 | $T_0(10)$ | $T_{-24}(10)$, $H_0(30-10)$, $T_0(30)$ | 94 | 10 | 2.0°C | 1.6°C | 7.2°C | 7.1°C |
| 2 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $H_{-24}(50-30)$ | 170 | 18 | 128 ft | 105 ft | 1280 ft | 1490 ft |
| 2 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$ | 170 | 18 | 1.6°C | 2.4°C | 6.5°C | 7.5°C |
| 3 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$ | 108 | 11 | 125 ft | 118 ft | 981 ft | 1155 ft |
| 3 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 108 | 11 | 1.7°C | 1.7°C | 5.4°C | 6.0°C |
| 4 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $H_{-24}(50-30)$, $H_0(50-30)$ | 265 | 29 | 134 ft | 132 ft | 676 ft | 687 ft |
| 4 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$ | 265 | 29 | 1.9°C | 1.8°C | 3.7°C | 3.9°C |
| 5 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $H_{-24}(50-30)$ | 767 | 40 | 124 ft | 134 ft | 548 ft | 489 ft |
| 5 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 767 | 40 | 1.8°C | 1.7°C | 4.5°C | 4.1°C |
| 6 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $H_{-24}(50-30)$ | 177 | 19 | 129 ft | 146 ft | 467 ft | 478 ft |
| 6 | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 177 | 19 | 1.9°C | 2.1°C | 4.2°C | 4.1°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $Z_{-24}(10)$ | 335 | 37 | 153 ft | 140 ft | 353 ft | 287 ft |
| 7 | $T_0(10)$ | $H_0(30-10)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$, $T_0(30)$ | 335 | 37 | 2.2°C | 2.1°C | 3.0°C | 2.3°C |
| 8 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30-10)$, $T_0(30)$, $Z_{-24}(10)$ | 356 | 39 | 142 ft | 99 ft | 453 ft | 429 ft |
| 8 | $T_0(10)$ | $H_0(30-10)$, $T_{-24}(10)$, $\bar{T}_{-24}(30-10)$ | 356 | 39 | 2.1°C | 2.0°C | 3.1°C | 2.8°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\bar{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript −24 indicates 24 hrs before observation time.

TABLE XVI

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases | | Rms error | | Std. dev. | |
|---|---|---|---|---|---|---|---|---|
| | | | Dep. | Ind. | Dep. | Ind. | Dep. | Ind. |
| 1 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 220 | 24 | 240 ft | 237 ft | 1357 ft | 1520 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 220 | 24 | 2.0°C | 1.6°C | 7.1°C | 7.2°C |
| 2 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 394 | 42 | 197 ft | 247 ft | 1263 ft | 1298 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 394 | 42 | 1.9°C | 2.2°C | 6.4°C | 7.1°C |
| 3 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 247 | 26 | 168 ft | 180 ft | 972 ft | 989 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 247 | 26 | 1.7°C | 1.7°C | 5.5°C | 5.3°C |
| 4 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 607 | 66 | 183 ft | 165 ft | 694 ft | 711 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 607 | 66 | 2.1°C | 1.8°C | 3.8°C | 3.9°C |
| 5 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50\text{-}30)$ | 1489 | 78 | 221 ft | 217 ft | 560 ft | 474 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $Z_0(30)$ | 1489 | 78 | 2.1°C | 2.0°C | 4.5°C | 4.2°C |
| 6 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50\text{-}30)$ | 365 | 39 | 203 ft | 239 ft | 493 ft | 475 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 365 | 39 | 2.2°C | 2.2°C | 4.3°C | 4.9°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 526 | 58 | 182 ft | 142 ft | 369 ft | 296 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 526 | 58 | 2.1°C | 2.1°C | 3.0°C | 2.7°C |
| 8 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 732 | 80 | 189 ft | 171 ft | 451 ft | 447 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$ | 732 | 80 | 2.3°C | 2.2°C | 3.2°C | 3.0°C |

*Listed in order of selection. $H$ is thickness, $Z$ is height, $T$ is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

## TABLE XVII
## MAY

### (a)  Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), H_{-24}(50-30), H_0(50-30)$ | 120 | 13 | 122 ft | 101 ft | 696 ft | 733 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30), T_{-24}(10)$ | 120 | 13 | 1.4°C | 1.4°C | 3.7°C | 3.5°C |
| 2 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), Z_{-24}(10)$ | 86 | 9 | 135 ft | 152 ft | 658 ft | 582 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30), \overline{T}_0(50-30)$ | 86 | 9 | 1.4°C | 1.7°C | 3.4°C | 3.1°C |
| 3 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10)$ | 50 | - | 131 ft | - | 401 ft | - |
| | $T_0(10)$ | $H_0(30-10), T_0(30), \overline{T}_0(50-30)$ | 50 | - | 1.3°C | - | 3.6°C | - |
| 4 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30), H_{-24}(50-30), H_0(50-30)$ | 161 | 16 | 149 ft | 125 ft | 453 ft | 329 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30), \overline{T}_{-24}(50-30), T_{-24}(10), \overline{T}_{-24}(30-10)$ | 161 | 16 | 1.8°C | 2.0°C | 4.1°C | 3.4°C |
| 5 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30), H_{-24}(50-30)$ | 377 | 19 | 123 ft | 118 ft | 424 ft | 430 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30), T_{-24}(10), \overline{T}_{-24}(30-10)$ | 377 | 19 | 1.9°C | 1.7°C | 3.7°C | 4.1°C |
| 6 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), H_{-24}(50-30)$ | 176 | 19 | 143 ft | 125 ft | 425 ft | 414 ft |
| | $T_0(10)$ | $H_0(30-10), T_0(30), \overline{T}_0(50-30), T_{-24}(10)$ | 176 | 19 | 1.8°C | 1.5°C | 3.3°C | 3.2°C |
| 7 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30)$ | 380 | 42 | 147 ft | 147 ft | 398 ft | 290 ft |
| | $T_0(10)$ | $H_0(30-10), Z_0(30), T_{-24}(10)$ | 380 | 42 | 2.1°C | 2.6°C | 2.9°C | 3.3°C |
| 8 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30), H_{-24}(50-30)$ | 232 | 25 | 127 ft | 134 ft | 378 ft | 340 ft |
| | $T_0(10)$ | $H_0(30-10), T_{-24}(10), \overline{T}_{-24}(30-10), T_0(30)$ | 232 | 25 | 2.0°C | 1.5°C | 3.0°C | 2.3°C |

*Listed in order of selection.  H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces.  Subscript 0 indicates observation time and subscript −24 indicates 24 hrs before observation time.

TABLE XVII

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 252 | 27 | 167 ft | 157 ft | 711 ft | 627 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 252 | 27 | 1.5 °C | 1.9 °C | 4.1 °C | 3.6 °C |
| 2 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 212 | 22 | 194 ft | 210 ft | 653 ft | 556 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 212 | 22 | 1.6 °C | 1.5 °C | 3.6 °C | 3.8 °C |
| 3 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 132 | 14 | 164 ft | 156 ft | 527 ft | 615 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 132 | 14 | 1.7 °C | 1.4 °C | 3.7 °C | 3.8 °C |
| 4 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 375 | 40 | 199 ft | 194 ft | 478 ft | 395 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 375 | 40 | 1.9 °C | 1.9 °C | 4.0 °C | 3.7 °C |
| 5 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 798 | 41 | 165 ft | 159 ft | 446 ft | 397 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30)$ | 798 | 41 | 2.0 °C | 1.9 °C | 3.6 °C | 3.7 °C |
| 6 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 376 | 41 | 159 ft | 191 ft | 435 ft | 438 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30), \bar{T}_0(50-30)$ | 376 | 41 | 2.0 °C | 1.8 °C | 3.3 °C | 3.0 °C |
| 7 | $Z_0(10)$ | $Z_0(30), T_0(30), H_0(50-30)$ | 585 | 64 | 170 ft | 163 ft | 409 ft | 331 ft |
|   | $T_0(10)$ | $H_0(30-10), Z_0(30)$ | 585 | 64 | 2.1 °C | 2.5 °C | 3.0 °C | 3.6 °C |
| 8 | $Z_0(10)$ | $Z_0(30), T_0(30)$ | 528 | 57 | 199 ft | 183 ft | 424 ft | 353 ft |
|   | $T_0(10)$ | $H_0(30-10), Z_0(30)$ | 528 | 57 | 2.1 °C | 1.8 °C | 3.1 °C | 2.4 °C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\bar{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

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## TABLE XVIII
## JUNE, JULY, 1/2 AUGUST (1-15)
### (a) Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|------|-------------|----------------------|------|------|------|------|------|------|
| 1 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30), H_{-24}(50-30)$ | 250 | 26 | 115 ft | 94 ft | 470 ft | 399 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30), T_{-24}(10), \overline{T}_{-24}(30-10)$ | 250 | 26 | 1.4°C | 1.7°C | 3.1°C | 2.9°C |
| 2 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30), H_{-24}(50-30)$ | 190 | 20 | 114 ft | 131 ft | 528 ft | 452 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30), T_{-24}(10)$ | 190 | 20 | 1.5°C | 2.0°C | 2.8°C | 3.4°C |
| 3 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), H_{-24}(50-30), H_0(50-30)$ | 137 | 13 | 121 ft | 102 ft | 544 ft | 511 ft |
|   | $T_0(10)$ | $H_0(30-10), \overline{T}_0(50-30), T_0(30)$ | 137 | 13 | 1.5°C | 1.6°C | 2.6°C | 2.3°C |
| 4 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), Z_{-24}(10)$ | 410 | 44 | 107 ft | 120 ft | 445 ft | 465 ft |
|   | $T_0(10)$ | $H_0(30-10), Z_0(30), T_0(30), \overline{T}_0(50-30)$ | 410 | 44 | 1.6°C | 1.4°C | 2.7°C | 2.9°C |
| 5 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), Z_{-24}(10)$ | 869 | 44 | 119 ft | 116 ft | 450 ft | 490 ft |
|   | $T_0(10)$ | $H_0(30-10), Z_0(30), T_{-24}(10)$ | 869 | 44 | 1.8°C | 1.6°C | 2.7°C | 2.6°C |
| 6 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), Z_{-24}(10)$ | 415 | 46 | 112 ft | 142 ft | 484 ft | 482 ft |
|   | $T_0(10)$ | $H_0(30-10), T_0(30), Z_0(30)$ | 415 | 46 | 1.6°C | 1.8°C | 2.8°C | 3.0°C |
| 7 | $Z_0(10)$ | $Z_0(30), H_{-24}(30-10), T_0(30)$ | 697 | 76 | 138 ft | 142 ft | 507 ft | 464 ft |
|   | $T_0(10)$ | $H_0(30-10), Z_0(30), T_{-24}(10)$ | 697 | 76 | 2.1°C | 2.0°C | 2.8°C | 2.7°C |
| 8 | $Z_0(10)$ | $Z_0(30), T_0(30), H_{-24}(30-10), H_0(50-30)$ | 581 | 64 | 155 ft | 156 ft | 466 ft | 438 ft |
|   | $T_0(10)$ | $H_0(30-10), T_{-24}(10), T_0(30)$ | 581 | 64 | 2.1°C | 2.0°C | 3.0°C | 2.8°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

TABLE XVIII

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 596 | 63 | 159 ft | 116 ft | 480 ft | 404 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 596 | 63 | 1.6 °C | 1.6 °C | 3.1 °C | 2.7 °C |
| 2 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 515 | 55 | 160 ft | 161 ft | 534 ft | 542 ft |
| | $T_0(10)$ | $H_0(30-10)$, $\overline{T}_0(50-30)$ | 515 | 55 | 1.6 °C | 1.7 °C | 2.9 °C | 3.4 °C |
| 3 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 322 | 33 | 140 ft | 111 ft | 539 ft | 484 ft |
| | $T_0(10)$ | $H_0(30-10)$, $\overline{T}_0(50-30)$ | 322 | 33 | 1.6 °C | 1.3 °C | 2.9 °C | 2.2 °C |
| 4 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 1043 | 113 | 151 ft | 171 ft | 505 ft | 462 ft |
| | $T_0(10)$ | $H_0(30-10)$, $Z_0(30)$, $T_0(30)$ | 1043 | 113 | 1.8 °C | 1.8 °C | 2.9 °C | 3.2 °C |
| 5 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 2014 | 103 | 165 ft | 135 ft | 525 ft | 519 ft |
| | $T_0(10)$ | $H_0(30-10)$, $Z_0(30)$, $\overline{T}_0(50-30)$ | 2014 | 103 | 1.9 °C | 1.8 °C | 2.9 °C | 2.6 °C |
| 6 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 900 | 97 | 132 ft | 142 ft | 501 ft | 443 ft |
| | $T_0(10)$ | $H_0(30-10)$, $Z_0(30)$, $T_0(30)$ | 900 | 97 | 1.7 °C | 1.8 °C | 2.9 °C | 3.0 °C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 1189 | 129 | 193 ft | 149 ft | 523 ft | 491 ft |
| | $T_0(10)$ | $H_0(30-10)$, $Z_0(30)$, $T_0(30)$ | 1189 | 129 | 2.3 °C | 1.9 °C | 3.0 °C | 2.6 °C |
| 8 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 1324 | 145 | 167 ft | 164 ft | 503 ft | 466 ft |
| | $T_0(10)$ | $H_0(30-10)$, $\overline{T}_0(50-30)$ | 1324 | 145 | 2.2 °C | 2.1 °C | 3.0 °C | 3.0 °C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

TABLE XIX

1/2 AUGUST (16-31), SEPTEMBER

(a)  Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases | | Rms error | | Std. dev. | |
|---|---|---|---|---|---|---|---|---|
| | | | Dep. | Ind. | Dep. | Ind. | Dep. | Ind. |
| 1 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$, $H_{-24}(50\text{-}30)$ | 112 | 12 | 96 ft | 79 ft | 990 ft | 898 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $T_{-24}(10)$, $\overline{T}_{-24}(50\text{-}30)$ | 112 | 12 | 1.1°C | 1.2°C | 4.3°C | 4.2°C |
| 2 | $Z_0(10)$ | $Z_{-24}(10)$, $T_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$ | 96 | 9 | 95 ft | 116 ft | 872 ft | 672 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $T_{-24}(10)$ | 96 | 9 | 1.4°C | 1.1°C | 4.5°C | 3.4°C |
| 3 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$ | 67 | – | 105 ft | – | 585 ft | – |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $T_{-24}(10)$ | 67 | – | 1.5°C | – | 3.4°C | – |
| 4 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$, $H_{-24}(50\text{-}30)$ | 228 | 24 | 132 ft | 122 ft | 644 ft | 602 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $T_{-24}(10)$, $\overline{T}_{-24}(30\text{-}10)$ | 228 | 24 | 1.7°C | 1.4°C | 3.9°C | 4.1°C |
| 5 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$, $H_{-24}(50\text{-}30)$, $H_0(50\text{-}30)$ | 546 | 28 | 117 ft | 134 ft | 452 ft | 419 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $\overline{T}_{-24}(50\text{-}30)$, $T_{-24}(10)$ | 546 | 28 | 1.9°C | 1.9°C | 3.0°C | 2.8°C |
| 6 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_{-24}(30\text{-}10)$, $H_{-24}(50\text{-}30)$, $H_0(50\text{-}30)$ | 215 | 23 | 101 ft | 156 ft | 442 ft | 515 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $T_0(30)$, $T_{-24}(10)$ | 215 | 23 | 1.7°C | 2.7°C | 3.0°C | 4.3°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $T_0(30)$ | 342 | 37 | 142 ft | 158 ft | 490 ft | 543 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $Z_0(30)$, $T_{-24}(10)$, $\overline{T}_{-24}(30\text{-}10)$ | 342 | 37 | 2.1°C | 2.1°C | 3.0°C | 2.7°C |
| 8 | $Z_0(10)$ | $Z_0(30)$, $H_{-24}(30\text{-}10)$, $Z_{-24}(10)$, $T_0(30)$ | 363 | 40 | 128 ft | 138 ft | 433 ft | 418 ft |
| | $T_0(10)$ | $H_0(30\text{-}10)$, $Z_0(30)$, $T_{-24}(10)$ | 363 | 40 | 2.4°C | 2.3°C | 3.2°C | 3.8°C |

*Listed in order of selection.  H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces.  Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

TABLE XIX

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 300 | 32 | 159 ft | 148 ft | 1046 ft | 1102 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$, $Z_0(30)$ | 300 | 32 | 1.6°C | 1.5°C | 4.6°C | 5.4°C |
| 2 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 328 | 33 | 168 ft | 174 ft | 902 ft | 788 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $\overline{T}_0(50-30)$, $T_0(30)$ | 328 | 33 | 1.7°C | 1.0°C | 4.5°C | 3.7°C |
| 3 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 189 | 19 | 157 ft | 147 ft | 621 ft | 560 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 189 | 19 | 1.5 C | 1.7°C | 3.7°C | 3.2°C |
| 4 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 594 | 64 | 166 ft | 131 ft | 652 ft | 626 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 594 | 64 | 1.7°C | 1.5°C | 3.8°C | 3.7°C |
| 5 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 1267 | 65 | 149 ft | 159 ft | 495 ft | 417 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $\overline{T}_0(50-30)$ | 1267 | 65 | 1.9°C | 1.9°C | 2.9°C | 2.7°C |
| 6 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 491 | 52 | 127 ft | 194 ft | 488 ft | 442 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 491 | 52 | 1.7°C | 2.3°C | 3.0°C | 3.5°C |
| 7 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 586 | 63 | 178 ft | 169 ft | 517 ft | 501 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $Z_0(30)$ | 586 | 63 | 2.5°C | 2.4°C | 3.2°C | 2.8°C |
| 8 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 859 | 95 | 138 ft | 169 ft | 453 ft | 419 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $Z_0(30)$ | 859 | 95 | 2.2°C | 2.3°C | 3.0°C | 3.3°C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript –24 indicates 24 hrs before observation time.

TABLE XX
OCTOBER, NOVEMBER

(a) Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $H_{-24}(30{-}10)$, $T_0(30)$ | 28 | – | 107 ft | – | 779 ft | – |
|   | $T_0(10)$ | $T_{-24}(10)$, $H_0(30{-}10)$, $T_0(30)$, $\overline{T}_{-24}(50{-}30)$ | 28 | – | 1.2 °C | – | 4.7 °C | – |
| 2 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $T_0(30)$, $H_{-24}(30{-}10)$, $H_{-24}(50{-}30)$ | 153 | 17 | 130 ft | 103 ft | 812 ft | 788 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $\overline{T}_0(50{-}30)$, $T_{-24}(10)$ | 153 | 17 | 1.8 °C | 2.0 °C | 4.5 °C | 5.0 °C |
| 3 | $Z_0(10)$ | $Z_{-24}(10)$, $Z_0(30)$, $T_0(30)$, $H_{-24}(30{-}10)$ | 126 | 13 | 126 ft | 124 ft | 743 ft | 942 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $T_0(30)$, $T_{-24}(10)$ | 126 | 13 | 2.0 °C | 1.5 °C | 4.4 °C | 3.6 °C |
| 4 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50{-}30)$, $Z_{-24}(10)$ | 211 | 22 | 139 ft | 176 ft | 732 ft | 722 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $T_{-24}(10)$, $\overline{T}_{-24}(30{-}10)$ | 211 | 22 | 1.7 °C | 1.6 °C | 4.7 °C | 4.9 °C |
| 5 | $Z_0(10)$ | $H_{-24}(30{-}10)$, $T_0(30)$, $H_{-24}(50{-}30)$ | 661 | 33 | 133 ft | 121 ft | 666 ft | 747 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $T_{-24}(10)$, $\overline{T}_{-24}(30{-}10)$ | 661 | 33 | 1.8 °C | 1.6 °C | 4.3 °C | 4.7 °C |
| 6 | $Z_0(10)$ | $H_{-24}(30{-}10)$, $T_0(30)$, $H_{-24}(50{-}30)$ | 187 | 20 | 120 ft | 151 ft | 656 ft | 721 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $T_0(30)$, $T_{-24}(10)$ | 187 | 20 | 1.9 °C | 1.8 °C | 4.6 °C | 5.6 °C |
| 7 | $Z_0(10)$ | $H_{-24}(30{-}10)$, $T_0(30)$, $H_{-24}(50{-}30)$ | 486 | 53 | 146 ft | 129 ft | 395 ft | 404 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $T_{-24}(10)$, $\overline{T}_{-24}(50{-}30)$ | 486 | 53 | 2.4 °C | 2.2 °C | 3.8 °C | 3.2 °C |
| 8 | $Z_0(10)$ | $H_{-24}(30{-}10)$, $T_0(30)$, $T_{-24}(10)$ | 337 | 37 | 129 ft | 134 ft | 472 ft | 438 ft |
|   | $T_0(10)$ | $H_0(30{-}10)$, $T_{-24}(10)$, $\overline{T}_{-24}(50{-}30)$ | 337 | 37 | 2.1 °C | 1.9 °C | 3.8 °C | 3.1 °C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript $-24$ indicates 24 hrs before observation time.

TABLE XX

(b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 105 | 10 | 189 ft | 187 ft | 902 ft | 786 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 105 | 10 | $1.3°C$ | $2.1°C$ | $5.1°C$ | $4.4°C$ |
| 2 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 497 | 53 | 218 ft | 216 ft | 876 ft | 977 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 497 | 53 | $2.0°C$ | $1.6°C$ | $5.0°C$ | $5.6°C$ |
| 3 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 363 | 38 | 217 ft | 238 ft | 750 ft | 683 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 363 | 38 | $2.2°C$ | $1.5°C$ | $4.9°C$ | $4.5°C$ |
| 4 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 650 | 70 | 230 ft | 224 ft | 786 ft | 729 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $\bar{T}_0(50-30)$ | 650 | 70 | $1.9°C$ | $1.9°C$ | $4.8°C$ | $5.3°C$ |
| 5 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$, $H_0(50-30)$ | 1011 | 88 | 167 ft | 204 ft | 694 ft | 688 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 1011 | 88 | $2.1°C$ | $1.8°C$ | $4.3°C$ | $4.2°C$ |
| 6 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 481 | 51 | 217 ft | 257 ft | 771 ft | 794 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 481 | 51 | $2.1°C$ | $1.8°C$ | $5.3°C$ | $6.2°C$ |
| 7 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 843 | 92 | 182 ft | 194 ft | 417 ft | 429 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 843 | 92 | $2.6°C$ | $2.4°C$ | $3.6°C$ | $3.7°C$ |
| 8 | $Z_0(10)$ | $Z_0(30)$, $T_0(30)$ | 972 | 107 | 208 ft | 219 ft | 486 ft | 501 ft |
|   | $T_0(10)$ | $H_0(30-10)$, $\bar{T}_0(50-30)$, $Z_0(30)$ | 972 | 107 | $2.4°C$ | $2.2°C$ | $3.9°C$ | $3.9°C$ |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\bar{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript -24 indicates 24 hrs before observation time.

## TABLE XXI

### WARMING – JANUARY, FEBRUARY, 1963

#### (a) Past and Present Data

| Band | Specificand | Selected specifiers* | No. of cases Dep. | No. of cases Ind. | Rms error Dep. | Rms error Ind. | Std. dev. Dep. | Std. dev. Ind. |
|---|---|---|---|---|---|---|---|---|
| 1-4 | $Z_0(10)$ | $Z_{-24}(10)$, $H_{-24}(50-30)$, $T_0(30)$, $Z_0(30)$ | 36 | – | 384 ft | – | 1138 ft | – |
| | $T_0(10)$ | $T_{-24}(10)$, $H_0(30-10)$, $T_0(30)$ | 36 | – | 3.8°C | – | 12.9°C | – |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript –24 indicates 24 hrs before observation time.

# TABLE XXI

## (b) Present Data

| Band | Specificand | Selected specifiers* | No. of cases | | Rms error | | Std. dev. | |
|---|---|---|---|---|---|---|---|---|
| | | | Dep. | Ind. | Dep. | Ind. | Dep. | Ind. |
| 1–4 | $Z_0(10)$ | $T_0(30)$, $Z_0(30)$ | 120 | 13 | 639 ft | 395 ft | 1227 ft | 1002 ft |
| | $T_0(10)$ | $H_0(30-10)$, $T_0(30)$ | 120 | 13 | $4.7\,^\circ$C | $2.8\,^\circ$C | $12.0\,^\circ$C | $9.1\,^\circ$C |

*Listed in order of selection. H is thickness, Z is height, T is temperature and $\overline{T}$ is the average temperature between two constant pressure surfaces. Subscript 0 indicates observation time and subscript –24 indicates 24 hrs before observation time.

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**13. ABSTRACT**

Two sets of vertical extrapolation equations were derived to specify initial-guess fields of 10-mb heights and temperatures using a five-year data sample.

Both past ($t_{-24}$) and present ($t_0$) data were considered as specifiers in the first set of equations. Only present ($t_0$) data were used as specifiers in the second set of equations. Both sets of equations showed stability when tested on independent data. Further, verification statistics showed that the results from the independent data were similar to those from the dependent data.

Both sets of equations were then compared by incorporating them into a modified successive approximation technique to produce initial-guess fields. These initial-guess fields were similar. An experiment comparing the two sets of equations with equations derived by the U.S. Weather Bureau showed that the TRC equations gave lower specification errors.

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