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An Examination of Approximately Simultaneous Salt Lake Valley and Cache Valley Clearing (Ventilation) Indexes

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AN EXAMINATION OF APPROXIMATELY SIMULTANEOUS SALT LAKE VALLEY AND CACHE VALLEY CLEARING (VENTILATION) INDEXES

by

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George W. Reynolds
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SUMMARY

Objectives

In accordance with the agreement between the Utah State Division of Health and Utah State University, the objectives of this study were to:

"1. Provide information to support and verify clearing index (ventilation index) forecasts from Salt Lake City.

"2. Provide information on:

"a. The degree to which clearing (ventilation) indexes computed from Salt Lake City rawinsonde data represent the clearing (ventilation) indexes for the Cache Valley.

"b. The usefulness and values of correction factors which will improve the degree to which the clearing (ventilation) indexes based on Salt Lake City rawinsonde data represent conditions over the Cache Valley. The objective is to develop correction factors which are amenable to becoming a part of standard operating procedures.

"c. How well clearing (ventilation) indexes based upon early morning Cache Valley rawinsonde data and the maximum temperatures of the day estimate the actual contamination dispersion potential of the atmosphere throughout the day.

"d. The diurnal variation of clearing (ventilation) indexes within the Cache Valley.

"e. The capability of transient weather systems for changing the clearing (ventilation) indexes for the Cache Valley.

"f. The requirements for local measurement systems for determining clearing (ventilation) index values in the mountain West."

Procedures

Regular rawinsonde flights were scheduled to be taken twice daily, six days per week, every third week from July, 1969, through June, 1970, from a location in the Cache Valley.* These flights were scheduled to be released at 4:15 a.m. and 4:15 p.m. (M.S.T.), respectively, which are the scheduled release times for the official flights from Salt Lake City. Two hundred and four such flights were attempted, 192 of which were completed and provided usable information. The data from the regular morning flights were provided at about 7 a.m. (M.S.T.), on the morning of the flight to the Salt Lake City Weather Bureau Airport Station.

In order to provide an objective basis for estimating the air pollution level of the Cache Valley, pictures were scheduled to be taken at about 9 a.m. and 3 p.m. (local time) daily from the top of "Old Main" on the Utah State University campus. Beginning in December, 384 such pictures were taken.

The Clearing Index (CI) is the product of the calculated mixing depth (MD) in feet and the mean wind speed ($\overline{WS}$) in m.p.h.

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*On one occasion there were three weeks and on three occasions only one week between operational weeks.

within the mixed layer, divided by 100:

$$CI = \frac{MD \times \overline{WS}}{100}$$

Clearing Indexes from 14 different combinations of Cache Valley and Salt Lake Valley rawinsonde maximum temperature data were computed in accordance with the rules specified by the Salt Lake City Weather Bureau Airport Station. From these 14 different estimates of Clearing Index values, 18 sets of paired values were submitted to comparison analysis, using contingency tables, scattergrams, and correlation and regression techniques. Visibilities estimated from daily photographs were also related to Clearing Index values.

Vertical temperature profiles and winds aloft used were all observed data. In most cases, evening and morning rawinsonde flights were separated. Maximum temperature values were either forecast or observed. Thus, the use of the observed maximum temperature sometimes implied a perfect maximum temperature forecast.

The implication of the Clearing Index procedure is that there will be a time each day when the capability of the atmosphere for dispersing the contaminants dumped into it is at a maximum. In general, the most favorable period and the maximum temperature will occur in the afternoon. Consequently, the so-called Actual Clearing Index was estimated from the evening rawinsonde data and the observed maximum temperature of the same calendar day. This value is used as the basis for assessing the merit of the various Clearing Index calculations.

From the practical aspect, 500 is the critical Clearing Index value from the viewpoint of burning decisions. Less than 500 is considered unfavorable for burning. Therefore, two operational classes have been defined: Clearing Indexes <500; Clearing Indexes ≥ 500. For the most part, the data have been summarized from the operational viewpoint.

Results

Following are significant results from this study. It should be kept in mind that these are the results from a single year's data. This was a somewhat unusual year, weatherwise, but most years are in one way or another. The results and conclusions are certainly indicative, but more years of study would be required if one were to draw refined conclusions.

1. About 80% of the Salt Lake Valley forecasts were in the same operational category as the Salt Lake Valley Actual Clearing Indexes. However, observed 5 p.m. (M.S.T.) rather than forecast winds were employed. Further, modification in the method of forecasting mixing depths added by the Salt Lake City Weather Bureau Airport Station in February, 1970, were not incorporated into this investigation. Consequently, it seems likely that their forecast record may be somewhat better than the 80% herein indicated. The SLCWBAPS does not issue an evening forecast. However, an estimate of the accuracy of such a forecast through simulation was considered desirable. With the procedures used in this study, evening and morning forecasts appeared to be about equally accurate.

2. About 70% of the Actual Clearing Indexes for the Salt Lake Valley were in the same operational class as their companion Cache

Valley Actual Clearing Indexes. Twenty-two percent of the Salt Lake Valley Clearing Indexes were higher and 8% were lower than their respective Cache Valley Clearing Indexes. There was no obvious functional relationship between the two values.

3. During late fall and winter, there were extended periods, when a forecast of Clearing Index < 500 every day would verify as true on 80% or more of the days. This applied to both Cache Valley and the Salt Lake Valley.

4. Definite seasonal trends were indicated for Cache Valley Clearing Indexes, mixing depths, and mean wind speeds. The Salt Lake Valley Clearing Index also showed a seasonal trend.

5. About 60% of the forecasts based on Cache Valley rawinsonde data and forecast maximum temperatures were in the same operational classes as their companion Cache Valley Actual Clearing Indexes. There was little difference in the accuracies of the evening and morning forecasts. Sixty percent of the Actual Clearing Indexes were in the < 500 class so a forecast of < 500 every day would be about as accurate as the use of any of these procedures. However, the present maximum temperature forecasts in the Cache Valley are semi-qualitative, using "low," "mid," and "upper" terms. A more precise forecast might give better results.

6. Forecasting the maximum temperature $2^{o}F$ too high shifted more than one-fourth of the Cache Valley Actual Clearing Indexes from the lower to the higher operational class. An error of $5^{o}F$ too high

shifted almost one-half of the lower operational class Clearing Indexes to the higher category.

7. Using observed maximum temperatures made little change in the accuracy of the evening forecasts of Cache Valley Clearing Indexes (63% vs. 75%). For the morning forecasts it changed the accuracy from 59% to 63%.

8. Seventy-one percent of the Cache Valley and 78% of the Salt Lake Valley evening forecasts were in the same operational categories as their respective next morning forecasts.

9. Fifty-six percent of the evening and 62% of the morning Salt Lake Valley forecasts were in the same operational categories as the Actual Cache Valley Clearing Indexes. The respective figures for Cache Valley were 63% and 59%.

10. With perfect Salt Lake Valley maximum temperature predictions, 56% of the evening and 68% of the morning forecasts were in the same operational class as their companion Cache Valley Actual Clearing Indexes. Using the Salt Lake Valley rawinsonde data with Cache Valley's perfect maximum temperature forecasts improved these accuracies to 63% and 70% respectively. Using solely Cache Valley data with perfect maximum temperature forecasts the respective figures were 75% and 63%.

11. Visibilities were grouped into three classes: <3 miles; 3-7 miles; >7 miles. Restricted was defined as being ≤ 7 miles.

a. In Cache Valley morning forecasts, using the perfect maximum temperature forecast.

(1) The Clearing Index was <500 for 90% of the lowest, 50% of the medium, and 28% of the unrestricted visibilities.

(2) For those cases with Clearing Indexes <500, 43% had the lowest, 33% had medium, and 24% had unrestricted visibilities.

b. For Salt Lake Valley morning forecast, using the Salt Lake Valley perfect maximum temperature forecast:

(1) The Clearing Index was <500 for 82% of the lowest, 46% of the medium, and 28% of the unrestricted visibilities.

(2) For those cases with Clearing Indexes <500, 45% had lowest, 30% had medium and 25% had unrestricted visibilities.

c. For Cache Valley Actual Clearing Indexes:

(1) The Clearing Index was <500 for 91% of the lowest, 33% of the medium and 21% of the unrestricted visibilities.

(2) For those cases with Clearing Indexes <500, 44% had lowest, 22% had medium, and 35% had unrestricted visibilities.

12. For 10 cases under study for diurnal effects, the 5 a.m. and 9 a.m. (M.S.T.) forecasts were in the wrong operational category 4 and 3 times, respectively.

13. The Cache Valley Actual Clearing Index before the passage of the front increased for five and decreased for five of the 10 cases involving cold fronts. The operational class was increased three times, decreased two times, and remained the same five times.

Several tentative conclusions have developed from the results of this study. These conclusions are termed tentative, since conditions during only one year were investigated.

Conclusions

Actual Clearing Indexes for the Cache Valley often differed significantly from Actual Salt Lake Valley Clearing Indexes. Cache Valley Clearing Indexes are in a lower operational class than Salt Lake Valley Clearing Indexes more often than the reverse is true. There is no obvious functional relationship between the two that would provide a correction factor that would consistently make the two more compatible. There were periods when the use of a linear regression might have increased the similarity. However, there is no reason for believing that the same coefficient would apply to the same weeks each year.

There apparently are long periods during late fall and winter when one should forecast that the Clearing Index will be less than 500 every day, unless he has a special reason for doing otherwise. This applies to both Valleys.

Fluctuations in Clearing Indexes are related to changes in both the mixing depth and mean wind speed, with neither influence being obviously dominant. Further study could reveal that one is indeed more influential than the other, since this point was not pursued in this investigation.

An error of even $2^{o}F$ in the maximum temperature prediction can often change the operational category of the Clearing Index forecast.

Salt Lake Valley and Cache Valley Clearing Index forecasts for the same day are often not in the same operational class. Various modifications did not result in remarkable improvement in the compatibility of the two forecasts. However, only about 60% of the Cache Valley forecasts, based solely upon Cache Valley data, were in the correct operational category. The Cache Valley Actual Clearing Indexes appeared to be less than adequate for representing the contamination dispersal capability. Rawinsonde measurements are neither absolutely accurate nor completely representative. Consequently, Cache Valley Clearing Index forecasts based on Cache Valley rawinsonde and temperature data, do not appear to offer sufficient improvement to justify the additional effort and expense. Coupling Salt Lake Valley rawinsonde data with more precise forecasts of Cache Valley maximum temperatures may well be worthwhile.

Using visibility estimations from photographs to estimate the actual contamination containment capability of the air, the present Clearing Index system is inadequate for the Cache Valley.

If there is a diurnal dependence in the Clearing Index forecast, it is not sufficiently consistent so that it became obvious in the small sample examined.

There also were insufficient samples to allow definitive conclusions as to the effects of transient weather systems on Clearing Index values. It can be said that the passage of a cold front will not always result in a more favorable Clearing Index for the Cache Valley.

condensation below the level of the mixing depth; and the mean wind speed represents the wind conditions within the layer.

This method uses fewer parameters and forecasts for shorter periods than the Niemeyer "macroscale meteorological phenomena" approach (1960). In the latter procedure, the recognition of subsidence below the 600 mb level probably involves some subjectivity. Further, it is suspected that the air pollution potential of the Salt Lake Valley and environs is less bound to quasi-stationary anticyclones than the area of Niemeyer's investigation.

The Salt Lake Valley official Clearing Index is somewhat less sophisticated than "relative concentration" as computed by Miller and Holzworth (1967) and Holzworth (1967). However, mixing depth and wind speeds are basic to both procedures. In the Miller-Holzworth method, the mixing depth--wind speed--relative pollution concentration relationship is more complicated and requires the selection of a stability class and city size. It was intended for application to "metropolitan areas" whereas the Salt Lake Valley official Clearing Index is for rural as well as urban application. However, since the average Relative Concentration is inversely proportional to city size, it could be quite effective as an indicator of the air contamination containment potential for rural areas. It probably would be necessary to first establish some relationship between air pollution conditions and computed Relative Concentrations before these values could be used as a basis for decisions.

Intermountain geography

As indicated in Figure 1, the Salt Lake City Airport is near the eastern edge of a great valley which includes the Great Salt Lake. This valley is occasionally interrupted by somewhat scattered mountains. The eastern border of the Salt Lake Valley is the north-northwest--south-southeast-oriented Wasatch Front which rises abruptly to 3,000 to 5,000 feet above the Valley floor.

The concentration of human population and other air pollution sources lies in a narrow strip just to the west of the Wasatch Front, beginning to the south of Provo and extending northward to a little north of Brigham City. Salt Lake City and environs, and Ogden and environs all have enough industries, people, and traffic to justify concern over the possibility of local modifications of the vertical temperature profiles (Duckworth and Sandburg, 1954; DeMarrais, 1961). However, any such effect has not been quantified, or even identified for this region. It seems possible that the selective screening of the air pollution alone might cause dynamically significant changes in lapse rates during marginal conditions.

The Salt Lake City Airport is on the western edge of Salt Lake City. It seems possible that the rawinsonde sensor unit may pass through mildly thermally polluted air during its first few thousand feet of rise. On the other hand, from the viewpoint of air pollution dispersal, the Cache Valley, which is about 70 miles long and 10 miles wide is probably more representative of the many valleys within

THE APPROACH

General

Rawinsonde flights were taken at 4:15 a.m. and 4:15 p.m. (M.S.T.) daily, six days per week, every third week, in the Cache Valley. (Note: As indicated in the "Record of Regular Rawinsonde Flights" (Appendix A) there were a few deviations from "every third week," but the planned total of 17 weeks of observation was accomplished.) The official times at which flights are made daily by the Salt Lake City Weather Bureau Airport Station are 4:15 a.m. and 4:15 p.m. (M.S.T.). A few additional flights were taken in the Cache Valley to provide information concerning the effects of the time of day and changing meteorological conditions on Clearing Index values (Appendix A). Beginning with December, 1969, three pictures were taken twice daily on most flight days in an effort to document visibility conditions. As indicated in Appendix A, "Record of Scheduled Pictures Taken," these overlapping pictures cover all directions from south through west to north.

Clearing Index values were then computed from various combinations of Salt Lake City Airport and Cache Valley rawinsonde flight data, with Salt Lake City Airport and Cache Valley forecast and observed maximum temperatures. Clearing Index values were compared, as appropriate, using contingency tables, scattergrams, correlations,

Table 1. Continued

Abbreviation	Meaning
SLV	Salt Lake City Weather Bureau Airport Station data
CV	Cache Valley data Rawinsonde values were obtained by U. S. U., and maximum temperatures were obtained from the Logan U. S. U. station.
e	Evening rawinsonde flights
f	Forecast maximum temperatures In all cases, the forecast maximum temperatures were issued at about 5 a. m. (M. S. T.) on the morning of the calendar day for which the forecast was valid. Evening flights were combined with the temperature forecasts issued the next mornings; morning flights were combined with the temperature forecasts issued the same mornings.
m	Morning rawinsonde flights
n	Morning or evening, as appropriate, immediately following the morning or evening of the first member of the pair
sd	Same day This will only be applied to temperature values and only in combination with evening rawinsonde values.
t	Observed maximum temperature For evening flights the observed maximum temperature will be for the next calendar day; for morning flights it will be for the same calendar day.

diagram. The appropriate forecast maximum temperature is plotted on the same diagram, using the same surface pressure. The point at which the dry adiabat through the forecast maximum temperature intersects the sounding temperature profile defines the mixing depth. The product of the forecast arithmetic mean of the wind speed, within the mixed layer, and the mixing depth is divided by 100 to obtain the Clearing Index.*

The Clearing Index calculation

Since Clearing Indexes were to be computed for a variety of rawinsonde data--maximum temperature combinations, computerizing the calculations was especially desirable. From the practical viewpoint, this must be accomplished in a way which will give approximately the same results as the manual procedure. A computer program was written (Appendix B) and applied by which Clearing Index values (CI) were computed in the following manner. The input to this program was observed rawinsonde data with forecast or observed maximum temperatures. (Note: observed winds were applied directly; whereas, in practice, the SLCWBAPS uses forecast winds.)

1. The maximum temperature was assumed to occur at the surface pressure of its companion radiosonde data.

2. The maximum temperature was converted from Fahrenheit (T_{MF}) to Centigrade (T_M), using the relationship, $T_M = \frac{5}{9}(T_{MF} - 32)$.

3. The pressure at the top of the mixed layer was estimated as follows:

*See page 5 for changes in SLCWBAPS procedures during the experimental year.

a. Beginning with the maximum temperature and its accompanying surface pressure, the air was assumed to cool dry adiabatically.

(1) According to the Poisson equation for dry air,

$$T_1 = T_0\left(\frac{P_1}{P_0}\right)^{.286}$$

(a) T_0 and P_0 are the initial temperature and pressure.

(b) T_1 and P_1 are the temperature and pressure after lifting.

(c) Temperatures are in degrees Kelvin.

b. The cooling was accomplished in 10 mb increments until the calculated temperature (T_a) was equal to or less than the profile temperature (T_r) at the same pressure level. (That is, until $T_a - T_r = \Delta T \leq 0.$)

(1) If $\Delta T = 0$, that pressure level was considered to be at the top of the mixed layer.

(2) If $\Delta T < 0$, the air was rewarmed dry adiabatically by increasing the pressure by five mb.

(a) If the new $\Delta T > 0$, the previously calculated level, (before the five mb warming) was used as the top of the mixed layer.

(b) If the new $\Delta T \leq 0$, then this new level was considered to be the top of the mixed layer.

4. The mixing depth (MD) was computed as follows:

a. Assuming that the hydrostatic relationship for completely dry air, $dP = -\rho g dZ$, and the equation of state, $\rho = \frac{P}{R\overline{T}}$ were valid for this estimation, the height (M. S. L.) of the top of the mixed layer (Z_{ML}) was computed to be

$$Z_{ML} = \frac{R\overline{T}}{g} \log \frac{P_0}{P_1} + Z_0$$

(1) Z_{ML} is the height (M. S. L.) of the top of the mixed layer.

(2) dP is the change in air pressure.

(3) ρ refers to density.

(4) g is the acceleration due to gravity.

(5) dZ is the change in height.

(6) P_0 is the pressure at Z_0, and P_1 is the pressure at the top of the mixed layer.

(7) R is the appropriate gas constant.

(8) $\overline{T}$ is the mean temperature of the layer ($^\circ$ Kelvin).

(9) Z_0 is the height of the mandatory pressure level immediately below the top of the mixed layer.

b. The mixing depth (MD) was equal to the height of the top of the mixed layer minus the respective M. S. L. station height (4, 226 feet for Salt Lake City Airport flights and 4, 447 feet for Cache Valley flights).

5. Increments of 1, 000 feet were used for computing the mean wind speeds in the mixed layer. Linear interpolation was used for those values which were not reported. Mean wind speed values ($\overline{WS}$) were in miles per hour.

6. The computed Clearing Indexes were then l/100 of the product of the mixing depth (in feet) times the mean wind speed (m.p.h.) in the mixed layer, times a unit factor.

$$CI = \frac{MD \times \overline{WS}}{100}$$

To verify the validity of this procedure, Clearing Indexes were computed by both the standard manual method and by the outlined computer method. The results are plotted in Figure 2. (The letter symbols in all of the figures and tables indicate the respective weeks during which the relevant observations were made (Table 2)). Using 500 as the critical level, there were no cases in which the results from the two methods changed the Clearing Index classification.

Table 2. Letter Designations for the Weeks of Operation (M.S.T.)

July 21 to July 26	A
Aug. 18 to Aug. 23	B
Sept. 8 to Sept 3	C
Sept. 29 to Oct. 4	D
Oct. 20 to Oct. 25	E
Nov. 10 to Nov. 15	H
Dec. 1 to Dec. 6	J
Dec. 15 to Dec. 20	K
Jan. 5 to Jan. 10	M
Jan. 26 to Jan. 31	P
Feb. 16 to Feb. 21	Q
Mar. 9 to Mar. 14	R
Mar. 23 to Mar. 28	S
Apr. 6 to Apr. 11	T
Apr. 27 to May 2	V
May 18 to May 23	W
June 8 to June 13	X

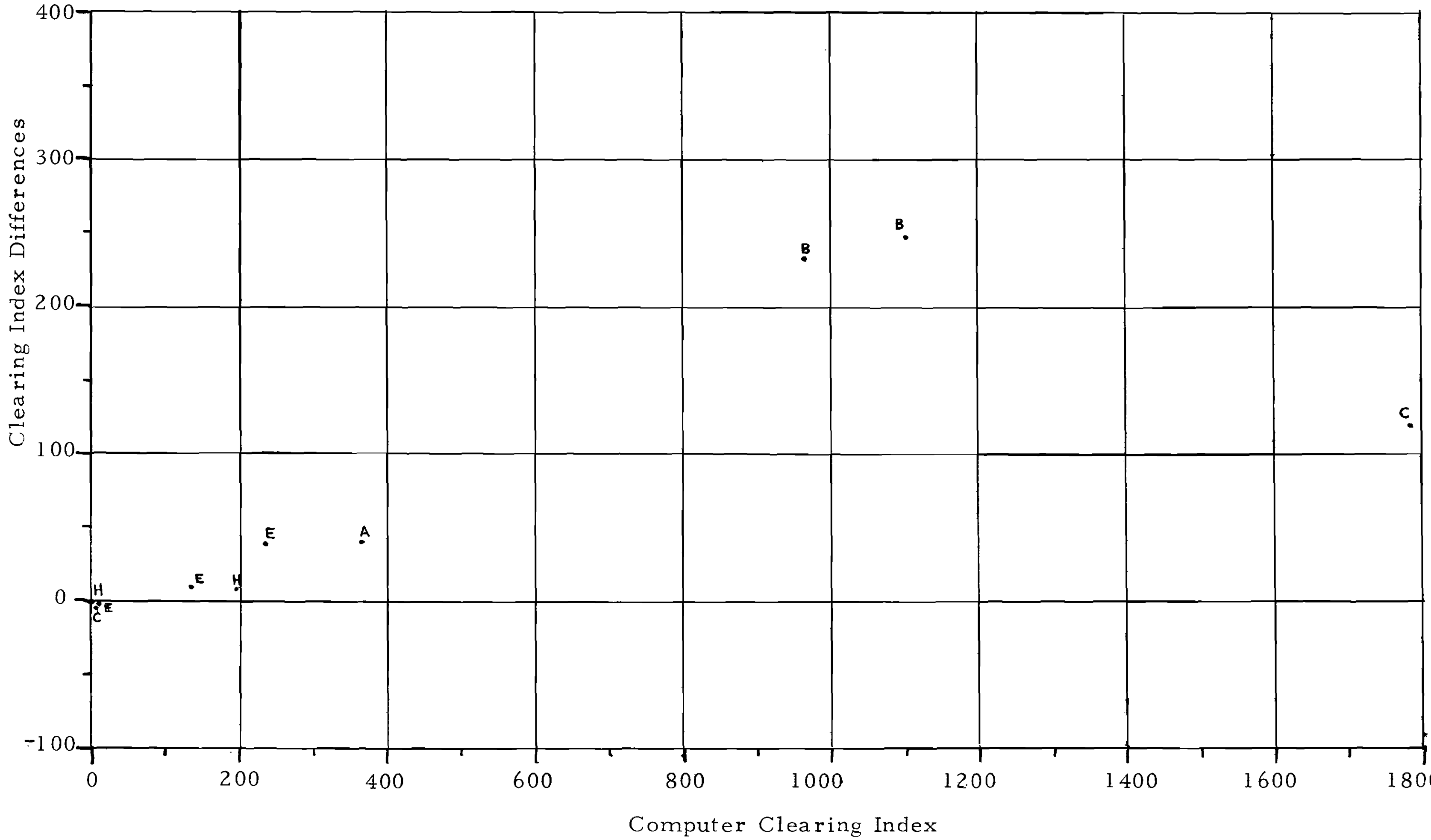

Figure 2. Computer Clearing Indexes vs. differences between Clearing Index values obtained by the manual method from those obtained by the computer method.

RESULTS

Paragraph one of the contract requires the provision of "information to support and verify clearing index (ventilation index) forecasts from Salt Lake City." The information in support of the Clearing Index forecasts, Cache Valley rawinsonde data, was furnished on a real time basis, by 7 a.m. (M.S.T.), immediately after morning flights.

Salt Lake Valley verification

In order to meet the verification commitment, comparisons were made between forecast and "Actual" Clearing Indexes for the Salt Lake Valley. Hypothetical evening forecasts were included even though such are not issued by the Salt Lake City Weather Bureau Airport Station. This was an effort to estimate the accuracy potential of such forecasts if they were to be issued. The verifications of evening forecasts, reported in the following tables and figures, are based upon evening rawinsonde data and the morning forecast of the following day's maximum surface temperature.

"Actual" Clearing Indexes were estimated from the evening rawinsonde data, using the observed maximum temperatures of the same calendar days. Effectively, this assumes that the maximum temperature occurred in the afternoon, and that there were no advective or dynamic changes in the air column near the ground between the times of the temperature maxima and the times of the next rawinsonde flights. The results of these comparisons are presented in Tables 3 and 4.

The format of these contingency tables is employed throughout this report. In each block, the number on the left indicates how many observations fell into that particular category combination. It is simply the total number of letters in that block. The number on the right is the equivalent percent of all of the observations. Seventy-nine percent of the evening forecasts and 78% of the morning forecasts* were in the same operational class as the corresponding Actual Clearing Indexes.

It seems probable that using forecast winds and the modification in the procedures for computing the mixing depth would result in somewhat greater agreement between forecast and Actual Clearing Indexes.

Salt Lake Valley--Cache Valley Clearing Index relationships

A primary intention of the study was to obtain quantitative information on "The degree to which clearing (ventilation) indexes computed from Salt Lake City rawinsonde data represent the clearing (ventilation) indexes for the Cache Valley." A further objective was to provide information on "The usefulness and values of correction factors... "which would make the official Salt Lake Valley values more

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*If a forecast were issued in the evening, it would predict the Clearing Index for the next day. A morning forecast, issued in the morning, predicted the Clearing Index for the day of issue. This procedure implies that the Clearing Index is for mid-afternoon. Throughout this report the terms "morning" and "evening" in conjunction with forecasts will apply to the Actual or simulated time of issue.

Table 3. Salt Lake Valley Evening Clearing Index Forecasts Vs. the Salt Lake Valley Actual Clearing Indexes of the Next Calendar Day

$SLV_e\ SLV_f$ Vs. $SLV_{ne}\ SLV_{sd}$

$SLV_{ne}SLV_{sd}$ \ SLV_eSLV_f	< 500	$\geq$ 500	
	34-54%	29-46%	63-100%
$\geq$ 500	C D D J P S S W 8-13%	A B B B C C C D D J Q Q Q R R S S T T T V W W X 24-38%	32-51%
< 500	A E E E H H H J J K K K K M M M M P P Q R R R V X 26-41%	H M S V X 5-8%	31-49%

79% (50) of these forecasts were in the right Clearing Index class.

Table 4. Salt Lake Valley Morning Clearing Index Forecasts Vs. Salt Lake Valley Actual Clearing Indexes of the Same Calendar Day

SLV_mSLV_f Vs. $SLV_{ne}SLV_{sd}$

$SLV_{ne}SLV_{sd}$ \ SLV_mSLV_f	< 500	$\geq$ 500	
	33-39%	52-61%	85-100%
$\geq$ 500	D J P Q S T 6-7%	A A B B B B C C C C D D D E J Q Q Q R R S S S S T T T T T V V W W W W W X X X 39-46%	45-53%
< 500	E E E E H H H J J J 27-32%	A H P P P Q R R R S V V W 13-15%	40-47%

78% (66) of these forecasts were in the right Clearing Index class.

Table 5. A Comparison Between Salt Lake Valley and Cache Valley Actual Clearing Indexes

SLV_eSLV_{sd} Vs. CV_eCV_{sd}

CV_eCV_{sd} \ SLV_eSLV_{sd}	< 500	$\geq$ 500	
	42-[illegible]	50-55%	92-100%
$\geq$ 500	P R R R R X X [illegible]	A B B B C C D A D D E J J P Q Q Q S S S T T T T V W W W X X [illegible]	3[illegible]-40%
< 500	A E E E E H H H H J J J J K K K K K K M M M M M M P P P Q Q S V V V W [illegible]-58%	A A B C C C D D H Q R R S S T T V W W X 20-22%	55-60%

71[illegible] ([illegible]) of the pairs have both members in the same Clearing Index class.

representative of Cache Valley conditions.

The so-called Actual Clearing Indexes were computed from approximately simultaneous Salt Lake Valley and Cache Valley evening flights (92 pairs, 184 flights in all). The results are summarized in Table 5. For 71% of these pairs the Clearing Index classes were the same. For 8% of these comparisons Cache Valley Clearing Indexes were in a higher class than companion Salt Lake Valley Clearing Indexes. Salt Lake Valley had the higher Clearing Index classification for 22% of the comparisons. Thus, if the Salt Lake Valley Clearing Index were perfectly forecast, it would be representative for Cache Valley less than three-fourths of the time, with a definite tendency for over-estimation. Further, restricting atmospheres in the Cache Valley seem more likely to occur outside of the late fall to early spring season.

A scattergram of the same data (Figure 3) does not indicate a close functional relationship between the two Actual Clearing Indexes. However, as indicated in Table 6, a correlation coefficient of 0.90 was obtained for the six observational weeks during the 14 weeks between September 29 and January 10. A correlation coefficient of .80 was calculated for the 26 weeks (10 weeks of observation) between September 29 and March 28. By extending this period to May 23, the coefficient was reduced to .73. Thus, it appears that during the July 1969-June 1970 experimental year, for selected periods, using a linear relationship between Actual Clearing Indexes would have

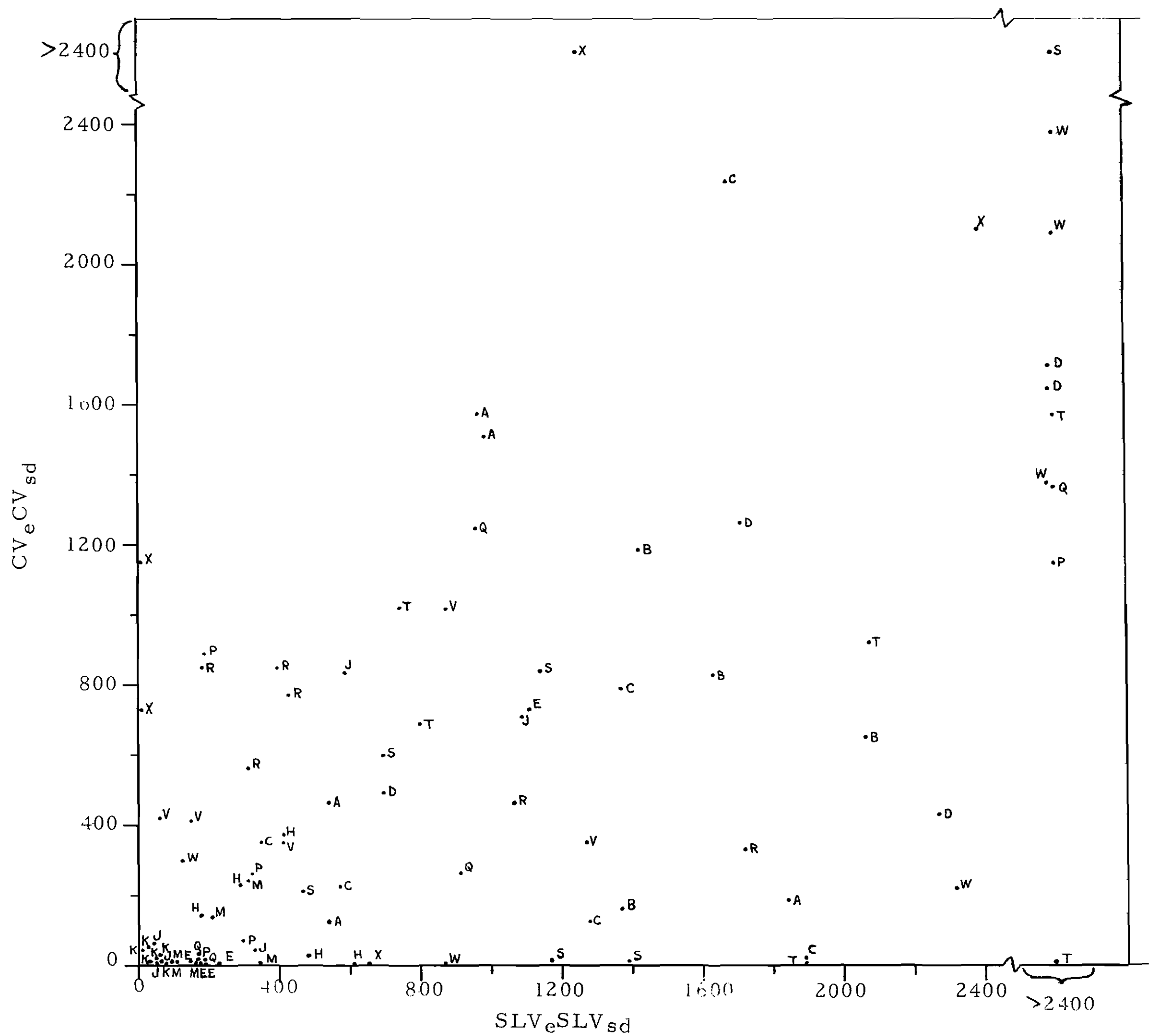

Figure 3. A comparison between Salt Lake Valley and Cache Valley Actual Clearing Indexes.

SLV_eSLV_{sd} Vs CV_eCV_{sd}

provided better estimates of Cache Valley Actual Clearing Indexes than the use of Salt Lake Valley Actual Clearing Indexes without adjustment.

A further examination of Table 5 reveals some interesting statistics. For Cache Valley the following percentages of Actual Clearing Indexes were less than the critical 500 for the indicated periods: the whole experimental year--60%; from October 20 through February 22--79%; from October 20 through February 1--85%. Thus, for the late fall-winter period, it is likely that the most reliable Clearing Index category forecast would be one which called for less than 500 every day. This procedure probably can be improved somewhat by also considering the effects of strong transient storm systems.

For the Salt Lake Valley, critical values were less dominant, for the year as a whole, but they were nearly the same for the late fall-winter period. Comparable percentages of Salt Lake Valley sub-500 Clearing Indexes were as follows: the whole experimental year--46%; October 20 through February 22--77%; October 20 through February 1 --85%. Thus, based upon this record, for selected periods for the Salt Lake Valley, climatology is an especially effective forecast tool.

One should be hesitant about assuming that the results of this year's experiment will hold precisely for all years. Without resorting to a specific climatological study, there was an impression that there were considerably fewer than normal transient storm systems during the 1969-70 cold season. Such storm systems may have an air cleansing effect, at least for the Salt Lake Valley, and with strong storm systems probably for the Cache Valley as well. Thus, the data for this year may over-estimate the frequency and duration of sub-critical Indexes. There is always the possibility that the statistics may be somewhat affected by accidents of sampling. However, the sampling procedure used would not introduce any statistical bias into the results.

The differences between Salt Lake Valley and Cache Valley mixing depths and mean wind speeds were each plotted against the appropriate differences in Clearing Indexes (Figures 4 and 5). These graphs provide no clearcut evidence that either of these factors is substantially more influential than the other, insofar as differences between concurrent Salt Lake Valley and Cache Valley Clearing Indexes are concerned.

Envelope curves of Actual Clearing Indexes (Figure 6), mixing depths (Figure 7), and mean wind speeds (Figure 8), all for the Cache Valley, against time (weeks) clearly indicate strong seasonal trends for each. These trends are only roughly compatible, emphasizing the dependency of Clearing Indexes on both mixing depths and mean wind speeds.

A similar time plot of Salt Lake Valley Actual Clearing Indexes (Figure 9) shows good but by no means perfect agreement with respect to Cache Valley Clearing Index trends. A comparison of Figures 6 and 9 clearly illustrate the tendency for Salt Lake Valley Clearing Indexes to be higher than Cache Valley Clearing Indexes.

<u>The Cache Valley Clearing Index forecast</u>

The fundamental question is whether the Salt Lake Valley Clearing

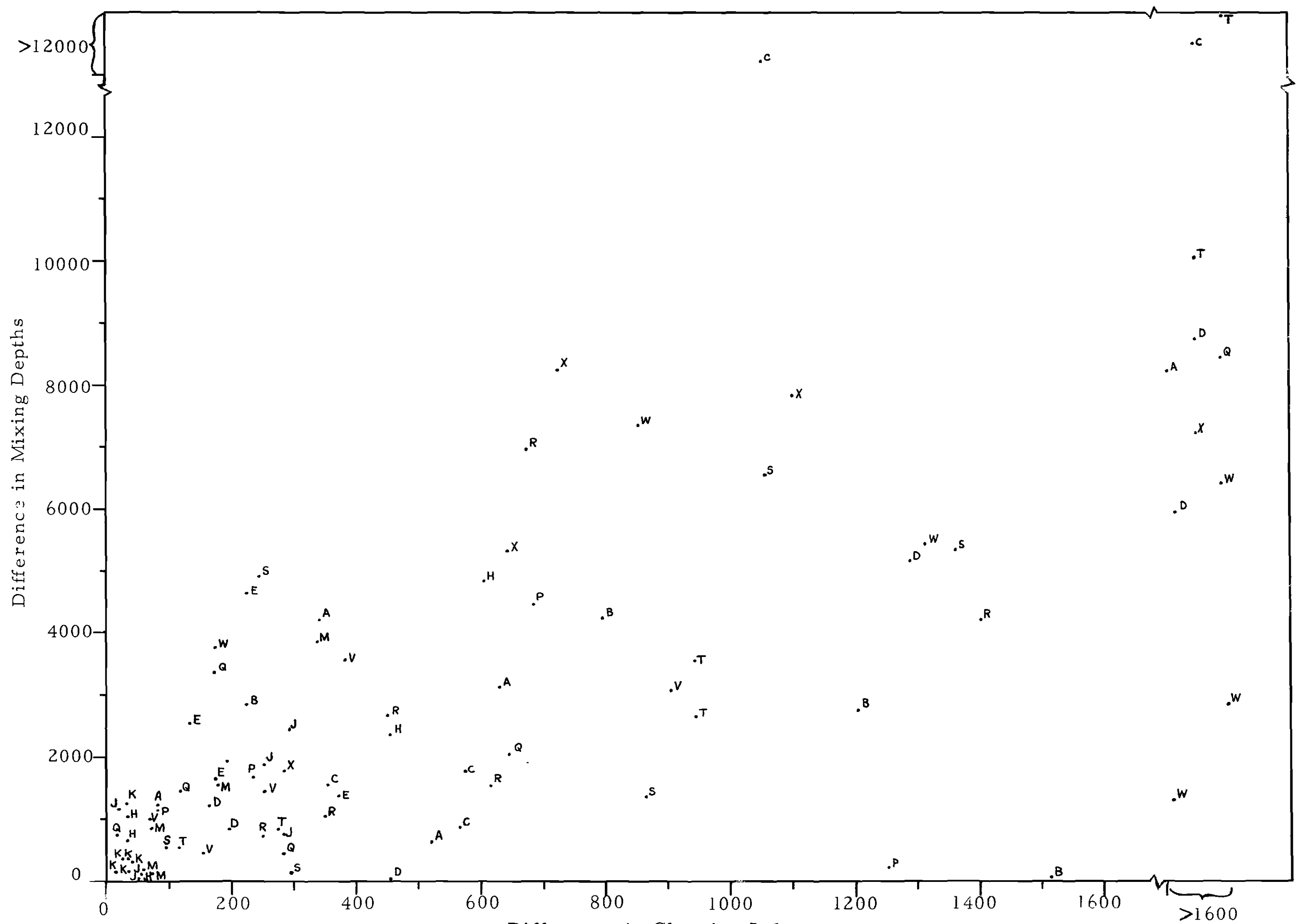

Figure 4. Differences in Actual Clearing Indexes (SLV_eSLV_{sd} - CV_eCV_{sd}) vs. differences in mixing depths (Salt Lake Valley - Cache Valley).

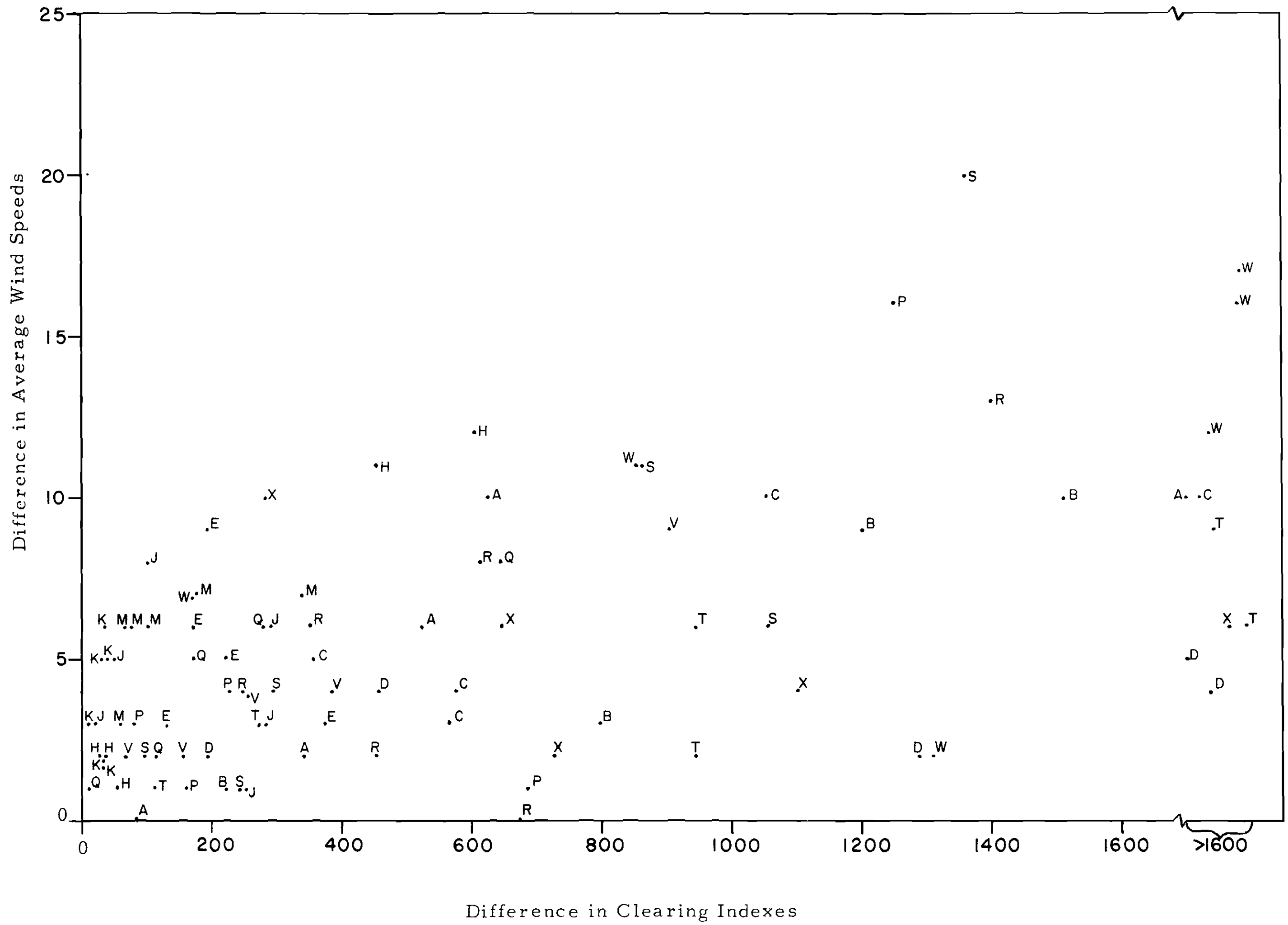

Figure 5. Differences in actual mean wind speeds within the mixed layers vs. differences in Actual Clearing Indexes (Salt Lake City--Cache Valley).

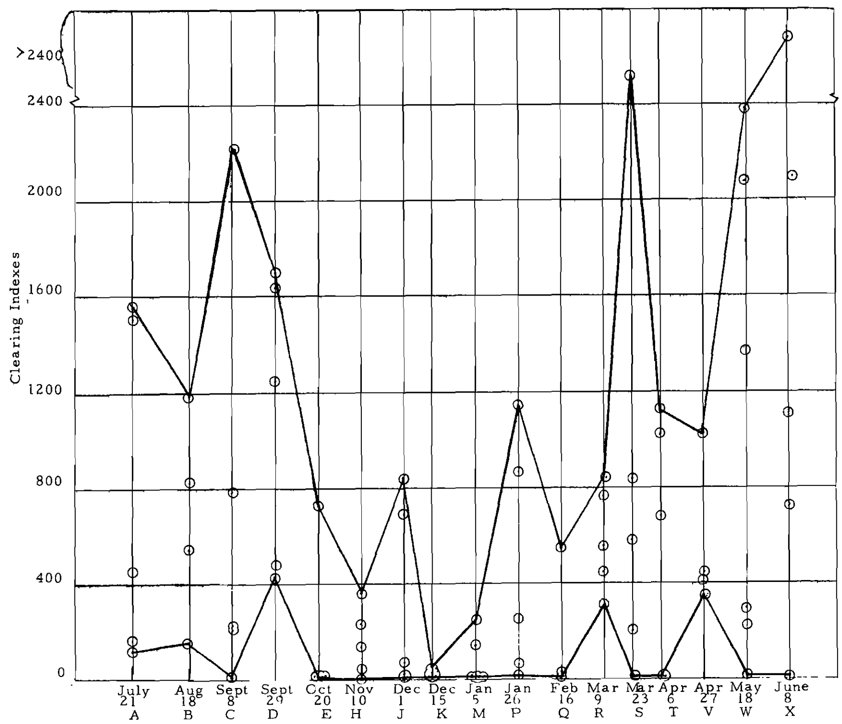

Figure 6. Cache Valley Actual Clearing Indexes by weeks (using CV_eCV_{sd}). The dates given are the first days of the respective weeks of observations.

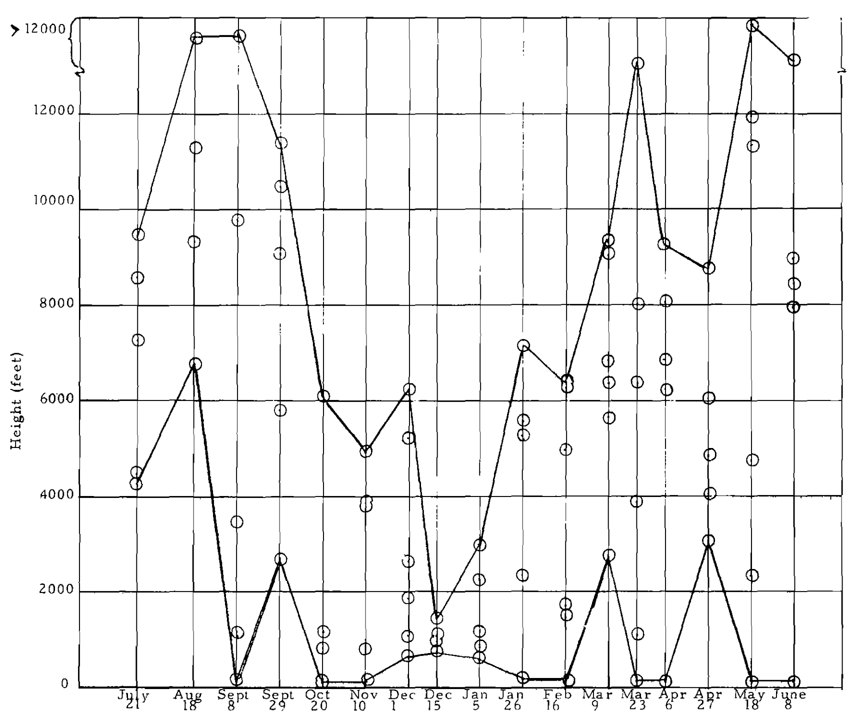

Figure 7. Cache Valley mixing depths by weeks (using CV_eCV_{sd}). The dates given are the first days of the respective weeks of observations.

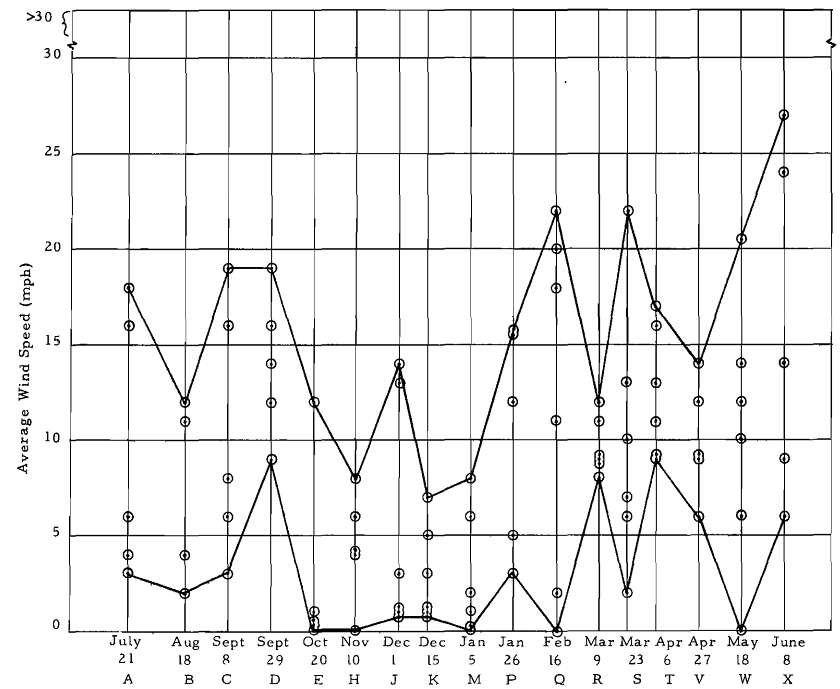

Figure 8. Cache Valley mean wind speeds within the mixed layers by weeks (using CV_eCV_{sd}). The dates given are the first days of the respective weeks of observations.

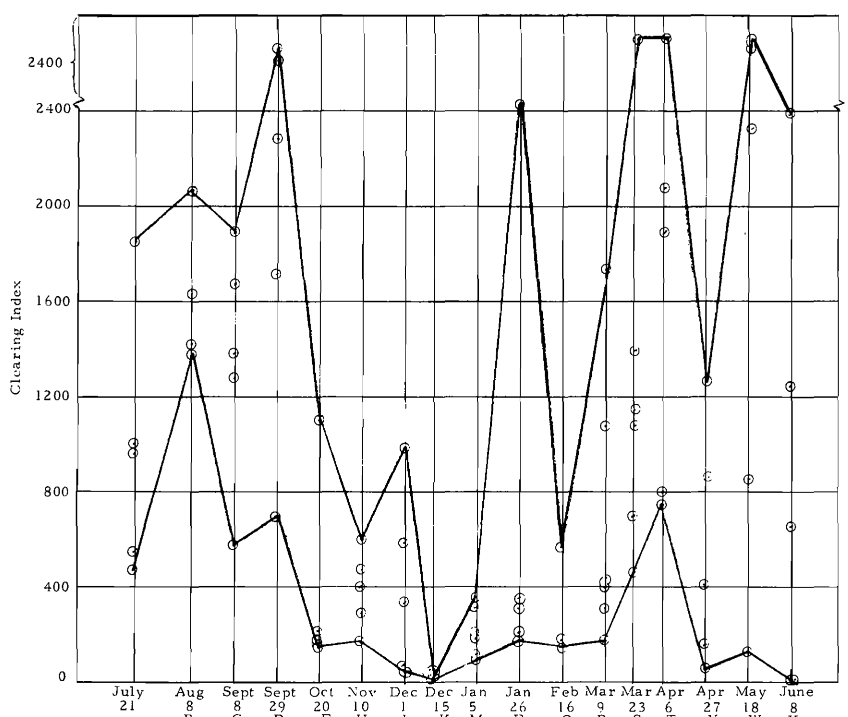

Figure 9. Salt Lake Valley Clearing Indexes by weeks (using SLV_eSLV_{sd}). The dates given are the first days of the respective weeks of observations.

Index, with or without correction factors, is adequate for use in the Cache Valley. Conversely, should separate forecasts be issued for the Cache Valley and similar valleys, with perhaps a requirement for special rawinsonde flights at these locations? In the previous section, it was reported that Salt Lake Valley and Cache Valley Actual Clearing Indexes were in the same category for only 71% of the 92 cases, and that there was an apparent tendency for the Salt Lake Valley classification to be the higher (22% of the 92 cases). These data were not submitted to statistical significance tests. Further, the differences between Actual Clearing Indexes were not sufficiently consistent to allow a straightforward subtraction or ratio procedure. Thus, perfect Cache Valley Clearing Indexes forecasts would provide better information than perfect Salt Lake Valley Clearing Indexes forecasts for decisions concerning burning in the Cache Valley.

Only 71% agreement between Salt Lake Valley and Cache Valley Actual Clearing Indexes, by itself, suggests the need for a special measurement-forecasting service for Cache Valley. However, several conceivably compensating factors suggested the possibility that such a special Cache Valley forecast service might not offer a practical advantage over the use of Salt Lake Valley forecasts.

Tables 7 and 8 provide verifications of Cache Valley forecasts based upon rawinsonde flights from the Cache Valley and the official Logan maximum temperature forecast. This temperature forecast required interpretation since the wording was somewhat qualitative. For example, "the low 70's" was called 73, "mid 70's--75, and "high 70's

Table 7 The Cache Valley Evening Clearing Index Forecasts Vs. the Cache Valley Actual Clearing Indexes of the Next Calendar Day

CV_eCV_f Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$	26-39%	41-61%	67-100%
≥500	D E Q 3-4%	B B C D J P Q R R R S S T T V W X X X 19-28%	22-33%
<500	D D E E E E H H J J K K K K K M M M M M P Q W 23-34%	A B C C H H J J P P Q Q R R S S S T V V V W 22-33%	45-67%
	<500	≥500	
	CV_eCV_f		

63% (42) of the forecasts were in the right Clearing Index class.

Table 8. Cache Valley Morning Clearing Index Forecasts Vs. Cache Valley Actual Clearing Indexes of the Same Calendar Day

CV_mCV_f Vs. CV_eCV_{sd}

CV_eCV_{sd}	33-39%	52-61%	85-100%
≥ 500	B J Q R R T T V X 9-11%	A B B C D D E J P P Q Q R R S S S T T V W W W X X X 26-31%	35-41%
< 500	E E E H H J J J J K K K K K M M M M M P Q S V W 24-28%	A A B C C C D D E H H K P P Q Q R R S S T T V V W W 26-31%	50-59%
	< 500	≥500	
	CV_mCV_f		

59% (50) of these forecasts were in the right Clearing Index class.

Table 9. Actual Cache Valley Clearing Indexes

CV_eCV_{sd}

55-60%	37-40%	92-100%
A A A B C C C D D E E E E H H H H H J J J J K K K K K K M M M M M M P P P Q Q Q R R S S S T T V V V V W W W X	A A B B B C C D D D E J J P P Q Q Q R R R R S S S T T T T V W W W X X X X	
< 500	≥500	
CV_eCV_{sd}		

--78. From these two tables, it appears that using the Cache Valley rawinsonde data and the official Logan maximum temperature forecast* predicts the right Clearing Index classification on about 60% of the days. There is more of a tendency to forecast a too high than a too low category. This percentage verification is about the same that one would get by forecasting less than 500 for all days (Table 9). However, during the period from October 20 through February 1, 85% (28) of the 33 calculated Actual Clearing Indexes were less than 500. The percentage of correct forecasts issued in the evening and in the morning for the same period were 75% and 77% respectively. Thus, insofar as the experimental year was representative, during the late fall and early winter, the best climatological forecast is for a Clearing Index of less than 500.

Cache Valley maximum temperature forecasts were somewhat qualitative and were for Logan U.S.U. rather than the rawinsonde site.**

Therefore, an effort was made to investigate the effects of errors in the temperature forecast on the resulting Clearing Index values. Separate calculations were made, using the evening rawinsonde data with: the observed same calendar day Logan maximum temperature (Actual Clearing Index); the observed same calendar day Logan maximum temperature plus $2^{o}F$; the observed same calendar day Logan maximum temperature plus $5^{o}F$. The results are summarized in

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*Issued by the Salt Lake City Weather Bureau Airport Station

**The rawinsonde site is at 4,447 feet M.S.L.--Logan U.S.U. is at 4,785 feet M.S.L.

Tables 10 and 11.

Even the 2°F change resulted in a shift of more than one-fourth of the <500 class Clearing Indexes to a higher category. The addition of 5°F raised the category of nearly half of the <500 class. The effects of subtracting 2°F and 5°F, respectively, on the number in the ≥ 500 class would be less pronounced but still of practical significance. The results of these two small experiments are sufficient to indicate the sensitivity of Clearing Index values to the accuracy of maximum temperature forecasts.

Using the quasi-qualitative Logan maximum temperature forecast undoubtedly resulted in a loss of forecast accuracy. It therefore seemed desirable to estimate the accuracy of the Clearing Index forecast system for Cache Valley by assuming perfect maximum temperature forecasts. It was also assumed that the Logan maximum temperature was the same as the maximum temperature at the rawinsonde site. With these assumptions, 75% of the evening and 63% of the morning Clearing Index predictions were in the right classes (Table 12 and 13). The morning issue shows little advantage over the use of the official temperature forecast, and often over-estimates Clearing Indexes in the <500 class. The evening predictions advance from 63% to 75% in the correct category with a considerable lessening of the tendency to over-estimate smaller values.

There were cases when the observed maximum temperatures were less than their companion rawinsonde surface temperatures. For these cases, Clearing Indexes could not be computed using this

Table 10. Changes in Clearing Indexes Caused by Adding 2^oF to the Maximum Temperatures

$CV_eCV_{sd+2^oF}$ Vs. CV_eCV_{sd}

CV_eCV_{sd} \ $CV_eCV_{sd+2^oF}$	<500	≥500	
	38-41%	54-59%	92-100%
≥500	0-0%	A A B B B D D D E J J P P Q Q Q R R R R S S S T T T W W W X X X X 37-40%	37-40%
<500	A B C E E E E H H H H J J J J K K K K K K M M M M M M P P Q Q R S S V V W W W X 38-41%	A A C C D D H P Q R S T T V V 17-18%	55-60%

82% (75) of these pairs had both members in the same Clearing Index class.

Table 11. Changes in Clearing Indexes Caused by Adding 5^oF to the Maximum Temperatures

$CV_eCV_{sd+5^oF}$ Vs. CV_eCV_{sd}

CV_eCV_{sd} \ $CV_eCV_{sd+5^oF}$	<500	≥500	
	30-33%	62-67%	92-100%
≥500	0-0%	A A B B B C C D D D E J J P P Q Q Q R R R R S S S T T T T V W W W X X 37-40%	37-40%
<500	A B E E E E H H H H J J J J K K K K K K M M M M M M P P Q Q 30-33%	A A C C C D D H M Q R R S S S T T V V V V W W W X 25-27%	55-60%

73% (67) of these pairs had both members in the same Clearing Index class.

Table 12 Cache Valley Evening Clearing Indexes with Perfect Maximum Temperature Forecasts Vs. the Cache Valley Actual Clearing Indexes of the Next Calendar Day

CV_eCV_t Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$ \ CV_eCV_t	< 500	≥ 500	
	39-65%	21-35%	60-100%
≥ 500	D D E J P Q R S S W 10-17%	B B C J R R R R S S T T V W X X 16-27%	26-43%
< 500	A A B C D E E E H H H H J J J J K K K K M M M M M P P Q S 29-48%	C Q V V W 5-8%	34-57%

75% (45) of these forecasts were in the right Clearing Index class.

Table 13 Cache Valley Morning Clearing Indexes with Perfect Maximum Temperature Forecasts Vs. the Cache Valley Actual Clearing Indexes of the Same Calendar Day

CV_mCV_t Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$ \ CV_mCV_t	<500	≥500	
	41-48%	15-52%	86-100%
≥500	B D J P Q R R T T X 10-12%	A B B C D E J P Q Q R R S S S T T W W W X X V 23-27%	33-38%
<500	C E E E H H H J J J J K K K K K M M M M M P Q R S T V W W W S 31-36%	A A B C C D D E H H P P Q Q R S T V V V X K 22-26%	53-62%

63% (54) of these forecasts were in the right Clearing Index class.

procedure. In general,but not always, this is the result of a passing cold front. These cases were not included in the calculations. The Salt Lake City Weather Bureau Airport Station has a special procedure for handling such circumstances.

It is notable that, using so-called perfect maximum temperature forecasts, the evening Clearing Index forecast for the next afternoon is more accurate than the forecast issued the following morning (the day for which the Clearing Index is issued). This suggests considerable continuity in air mass conditions from day to day, when the diurnal influence is excluded. It also suggests a nocturnal distortion that results in a departure from the theory on which this procedure is based. Still another possibility is greater agreement between the wind speeds of the same time of day.

The October 20--February 1 period offers some especially interesting statistics:

1. Twenty-six evening cases (Table 12).

   a. Percent of forecasts in the right operational class--88%.

   b. Percent of the 26 with Actual Clearing Indexes in $<$500 class--96%.

2. Thirty-one morning cases (Table 13).

   a. Percent of forecasts in the right operational class--77%.

   b. Percent of the 31 with Actual Clearing Indexes in $<$500 class--84%.

Thus, for this period, the forecast which appears to have the greatest operational accuracy is $<$500 for every day, unless there is strong reason to do otherwise.

There are apparent discrepancies in some of the statistics of this report, and particularly in the percentage statistics. In combining parameters, some samples are excluded from some combinations but included in others. Thus, the total number on which the percentages are based varies. For example, there were 67 samples of the regular Cache Valley evening forecast but only 60 samples of the Cache Valley evening forecast which used the observed maximum temperature of the next day. Therefore, it sometimes has been necessary to confine comparisons to the data within a table.

As a matter of curiosity, contingency tables were prepared (Tables 14 and 15) which compare evening and the following morning Clearing Index predictions separately for the Cache Valley and Salt Lake Valley. The official Logan maximum temperature forecasts were used for Cache Valley. From the operational viewpoint, only 71% of the Cache Valley and 78% of the Salt Lake Valley pairs were compatible.

Since the same maximum temperature prediction is used with morning and evening Clearing Index forecasts, this lack of complete compatibility must be the result of diurnal variations in the mean wind speeds and/or the temperature profiles.

It is indeed interesting that the operational accuracy of the Salt Lake Valley evening and morning predictions of the Clearing Index are 79% and 78% respectively (Tables 2 and 3), but the accuracies of the evening and morning Cache Valley predictions, using the observed Logan maximum temperatures are not so alike being

Table 14. Cache Valley Evening Clearing Index Forecasts Vs. Cache Valley Next Morning Clearing Index Forecasts

CV_eCV_f Vs. $CV_{nm}CV_f$

		14-24%	44-76%	58-100%
$CV_{nm}CV_f$	≥500	D D D E E K 6-10%	A A B B B C C C C E H J P P P Q Q Q R R R S S S S T T V V W W X X 33-57%	39-67%
	< 500	E E H J J J K K K K M M M M M P Q Q 8-14%	B D H J R R S T V W X 11-19%	19-33%
		<500	≥ 500	
		CV_eCV_f		

71% (41) of the evening forecasts are in the same Clearing Index class as the forecasts issued the following mornings.

Table 15. Salt Lake Valley Evening Clearing Index Forecasts Vs. Salt Lake Valley Next Morning Clearing Index Forecasts

SLV_eSLV_f Vs. $SLV_{nm}SLV_f$

		37-54%	32-46%	69-100%
$SLV_{nm}SLV_f$	≥500	A C D E P P Q R R S 12-17%	A B B B B C C C D D J H Q Q R R S S S T T T V V W W W X X 29-42%	41-59%
	< 500	D E E E E H H J J J K K K K K M M M M P P Q R S X 25-38%	J M Q 3-4%	28-41%
		< 500	≥ 500	
		SLV_eSLV_f		

78% (54) of the evening forecasts were in the same Clearing Index class as the forecasts issued the following mornings.

Table 16. Salt Lake Valley Morning Clearing Index Forecasts Vs. Cache Valley Morning Clearing Index Forecasts

SLV_mSLV_f Vs. CV_mCV_f

		34-37%	58-63%	92-100%
CV_mCV_f	≥500	D E E H K P Q R 8-9%	A A A B B B B B C C C C C D D D E H J P P P Q Q Q R R R S S S S S T T T T V V V V W W W W W X X X X 50-54%	58-63%
	<500	E E E H H J J J J J K K K K K M M M M M P Q S T V X 26-28%	B D Q R R T V W 8-9%	34-37%
		< 500	≥500	
		SLV_mSLV_f		

83% (76) of these Salt Lake Valley morning forecasts were in the same Clearing Index categories as their companion Cache Valley morning forecasts.

75% and 63% respectively. This suggests the possibility of a significant difference between Cache Valley and Salt Lake Valley low level wind and temperature profile modifications by diurnal factors.

For obvious reasons, it is desirable to base Clearing Index forecasts for the immediate neighboring Intermountain area on data already regularly available at the official station*, unless available evidence shows this procedure to result in an unacceptable loss in operational accuracy.

From Table 16 it is evident that a substantial portion of morning Clearing Index forecasts using only Salt Lake Valley data are in a different operational class than those morning forecasts based solely on Cache Valley data. The comparison scattergram (Figure 10) gives no obvious indication of a functional relationship between the two forecasts.

Since the forecasts using only Cache Valley data (Tables 7 and 8) were operationally correct only about three-fifths of the time it is possible that Salt Lake Valley forecasts might do as well, even though the two forecasts differ. Salt Lake Valley evening and morning forecasts were each compared to appropriate Actual Cache Valley Clearing Indexes. For the Salt Lake Valley evening forecasts (Table 17) only 56% were in the right operational category as opposed to 63% for the Cache Valley regular forecasts (Table 7), and 75% for the forecasts using the observed maximum temperatures (Table 12). Sixty-two of the morning

*Salt Lake City Weather Bureau Airport Station

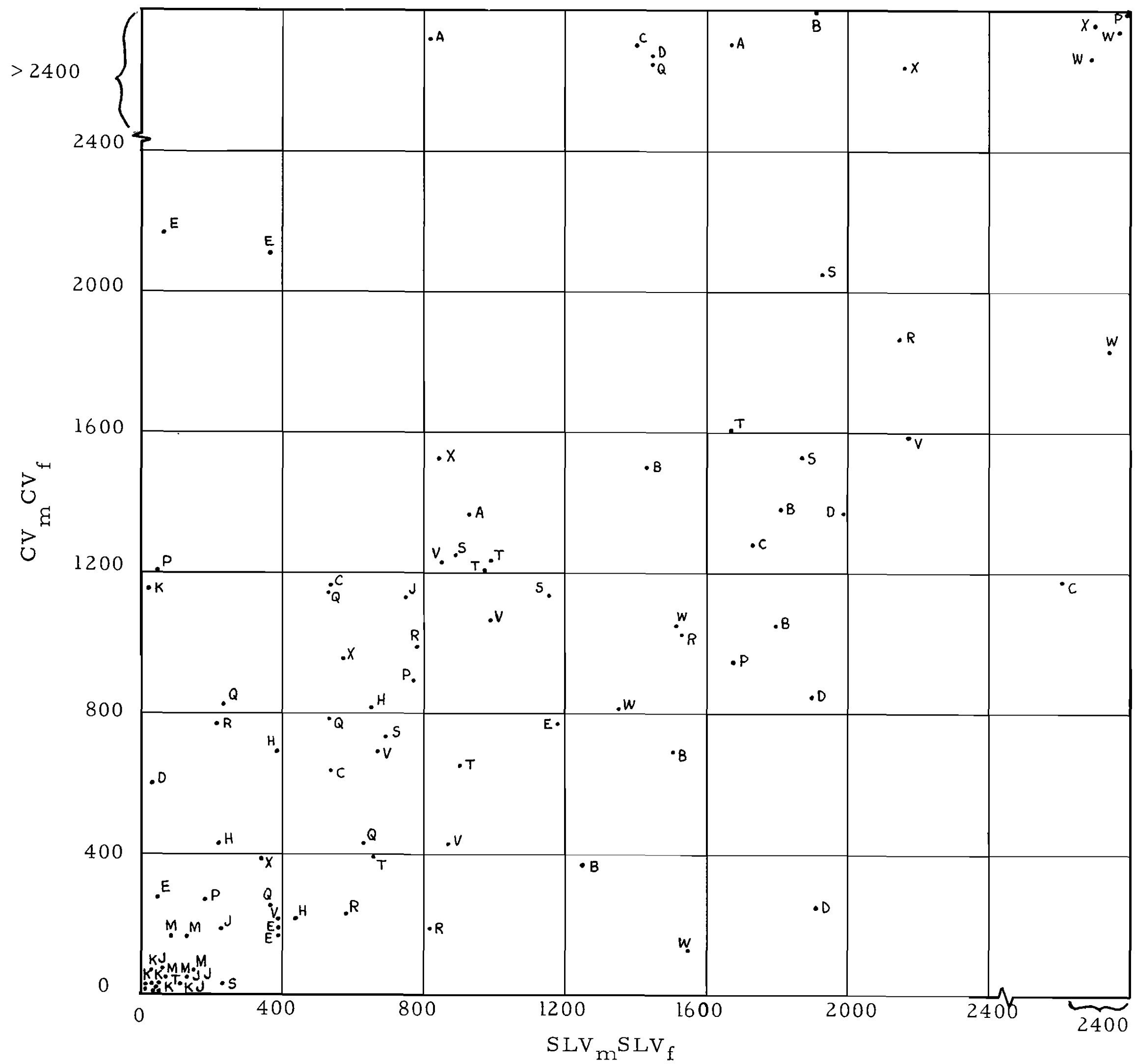

Figure 10. Salt Lake Valley morning forecast Clearing Indexes vs.
Cache Valley morning forecast Clearing Indexes.

$SLV_m SLV_f$ Vs. $CV_m CV_f$

Table 17. Salt Lake Valley Evening Clearing Index Forecasts Vs. the Cache Valley Actual Clearing Indexes of the Next Calendar Day

SLV_cSLV_f Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$ \ SLV_cSLV_f	<500	≥500	
	37-57%	28-43%	65-100%
≥500	D E J P Q R R R S W X 11-17%	B B C D J Q S T T V 10-15%	21-32%
<500	A C D E E E H H H J J K K K K K M M M M P P P Q S V 26-40%	A A B C D H J M Q Q R R S S T V W W 18-28%	44-68%

56%(36) of the Salt Lake Valley forecasts were in right Clearing Index class.

Table 18. Salt Lake Valley Morning Clearing Index Forecasts Vs. Cache Valley Actual Clearing Indexes of the Same Calendar Day

SLV_mSLV_f Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$ \ SLV_mSLV_f	<500	≥500	
	33-39%	51-61%	84-100%
≥500	D J P Q R T X 7-8%	A B B B C D E J P Q Q R R R S S S T T T V W W W X X 26-31%	33-39%
<500	E E E E H H J J J J K K K K K K M M M M M P Q S V H 26-31%	A A B C C C D D P P Q Q R R S S T T V V V W W W X 25-30%	51-61%

62% (52) of the Salt Lake Valley forecasts were in the right Clearing Index class.

Table 19. Salt Lake Valley Evening Clearing Indexes with Perfect Maximum Temperature Forecasts Vs. the Cache Valley Actual Clearing Indexes of the Next Calendar Day

SLV_cSLV_t Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$ \ SLV_cSLV_t	<500	≥500	
	37-60%	25-40%	62-100%
≥500	D E J J Q Q R R R S X 11-18%	B B C D S T T V W 9-15%	20-32%
<500	A B D E E E H H H J J J K K K K K M M M M M P P Q S 26-42%	A A C C D H P Q R R S S T V V W 16-26%	42-68%

56% (35) of these forecasts are in the right Clearing Index class.

Table 20. Salt Lake Valley Morning Clearing Indexes with Perfect Maximum Temperature Forecasts Vs. the Cache Valley Actual Clearing Indexes of the Same Calendar Day

SLV_mSLV_t Vs. $CV_{ne}CV_{sd}$

$CV_{ne}CV_{sd}$ \ SLV_mSLV_t	<500	≥500	
	37-44%	48-56%	85-100%
≥500	D J P Q R T 6-7%	A B B B C D E J P Q Q R R R S S S T T T V W W W X X X 27-32%	33-39%
<500	C E E E E H H H H J J J J K K K K K K M M M M M P Q Q S V W X 31-36%	A A B C C D D P P Q R R S S T T V V V W W 21-25%	52-61%

68% (58) of these forecasts are in the right Clearing Index class.

Appendix A: Record of Non-regular Rawinsonde Flights (Continued)

DATE	DAY	HOUR (MST)	
9 April 1970	Thursday	11 pm	*
30 April 1970	Thursday	9 am	*
30 April 1970	Thursday	1 pm	*
30 April 1970	Thursday	10 pm	*

* Completed Flights that are usable

- Completed Flights that are not usable

```
      C      ******************************************************************
      C
      C      THIS PROGRAM IS DESIGNED TO COMPUTE CLEARING INDICES SIMULTANEOUSLY FOR
      C      TWO STATIONS FOR AS MANY AS 250 SOUNDINGS EACH.  INPUT IS STANDARD CODED
      C      RAOBS WITH MINOR MODIFICATIONS AS SPECIFIED BELOW ALONG WITH FORECAST
      C      MAXIMUM TEMPERATURES FOR EACH DAY ON WHICH A RAOB IS ENTERED.
      C
      C      ******************************************************************
      C
      C                          PROGRAM WRITTEN BY
      C               GEORGE W. REYNOLDS AND RONALD H. CAMPBELL
      C                      UTAH WATER RESEARCH LABORATORY
      C                         UTAH STATE UNIVERSITY
      C                              LOGAN, UTAH
      C                 UNDER THE AIR POLLUTION STUDY CONTRACT
      C             FOR EVALUATING METEROLOGICAL CLEARING INDICES
      C                    GRANT NO. 2632        PROJECT WG81
      C               STATE OF UTAH - DEPARTMENT OF HEALTH AND WELFARE
      C
      C
      C      ******************************************************************
      C
      C                      DEFINITION OF INPUT VARIABLES
      C     IDX IS STATION IDENTIFICATION (4 LETTERS) FOUND ON CODED RAOB CARDS
      C     SITE IS AN 8 SPACE IDENTIFICATION FOR EACH STATION (APPEARS ON PRINT OUT)
      C     HITE IS ELEVATION OF EACH STATION IN FEET (4 DIGIT NUMBER)
      C        THESE THREE VARIABLES ARE READ IN ON THE FIRST DATA CARD AS SHOWN BELOW
      C     LOGAN    4447DFLGSLC      4226APSL
      C     FORMAT IS (2A4,F4.0,A4,2A4,F4.0,A4)
      C     KDAT IS STATION-YEAR-MONTH-DAY GROUP ON MAXIMUM TEMPERATURE CARD.  STATION
      C        IS EITHER A 1 OR 2 AS DESIGNATED BY POSITION ON THE FIRST INPUT CARD.
      C     TTMAX IS FORECAST MAXIMUM TEMPERATURE
      C     TEMPID IS ANY IDENTIFICATION DESIRED ON THE TEMPERATURE CARDS
      C     ID IS IDENTIFICATION FOR STATIONS
      C     CODE IS RAWINSONDE DESIGNATION TT, VV, OR QQ
      C     DAT IS THE DATA ARRAY OF 5 DIGIT GROUPS FOR EACH SOUNDING (STANDARD CODE)
      C
      C                       LIST OF OUTPUT VARIABLES
      C     KHR IS HOUR OF RAOB
      C     MO IS MONTH OF RAOB
      C     KDA IS DAY OF RAOB
      C     KYR IS YEAR OF RAOB
      C     STP IS MANDITORY PRESSURE LEVEL
      C     STT IS TEMPERATURE AT MANDITORY LEVEL
      C     STH IS HEIGHT OF MANDITORY LEVEL
      C     STWS IS WIND SPEED AT MANDITORY LEVEL
      C     SIGP IS SIGNIFICANT LEVEL PRESSURE
      C     SIGT IS SIGNIFICANT LEVEL TEMPERATURE
      C     WHH AND WSS ARE WIND HEIGHTS AND SPEEDS
      C     PI IS PRESSURE MISING DEPTH PLUS STATION ELEVATION IN METERS
      C     CI IS CLEARING INDEX
      C     HT IS MIXING DEPTH
      C     AVW IS AVERAGE WIND SPEED
      C
      C      ******************************************************************
      C
      C      *************       INPUT CARD FORMATS       **********
      C             RAWINSONDE CARDS ARE PUNCHED IN THE FOLLOWING MANNER
      C      COLUMNS 1-5 STATION IDENTIFICATION CODE, 5-7 LAST 2 DIGITS OF THE YEAR
      C     8-9 MONTH OF THE YEAR, 10-11 DAY OF THE MONTH, 12 IS A 5, 13-17 FROM
      C    RAWINSONDE CODE FOR DAY, HOUR OF SOUNDING GMT, LAST ISOBARIC SURFACE,
      C     18-19 TT,VV,QQ, FOR THE PART OF THE RAWINSONDE CODE WANTED, 20-79 IS THE
      C     CODED NUMBERS AND THEY ARE IN ORDER, BLANKS ARE LEFT AS SPACES.
      C     IF 2 OR MORE CARDS ARE NEEDED THEN REPUNCH COLUMNS 1-12 THEN SKIP TO 20
      C      AND CONTINUE WITH THE CODE
      C     EACH SECTION OF THE CODE IS DONE, FIRST TT, SECOND VV, THIRD QQ
      C     FOR THE QQ SECTION IF WIND DATA IS MISSING FOR A LEVEL FIND THE PLACE THAT
      C     IT WOULD NORMALLY GO AND PUNCH IN PLACE OF IT 99999.
      C     ********** MAXIMUM TEMPERATURE CARDS AS FOLLOWS **************
      C     COLUMN 1 STATION IDENTIFICATION, 2-3 YEAR ONLY THE LAST 2 DIGITS,
      C      4-5 MONTH OF THE YEAR, 5-7 DAY OF THE MONTH, 9-11 SPACES
      C     11-12 TEMPERATURE IN DEGREES F.
            DIMENSION SITE (2,2),TEMP(500),WSS(30),WHH(30),CI(500),HT(500)
            DIMENSION AVW(500),IDCI(500),KHOUR(500),CODE(10),TEMPID(15,500)
            DIMENSION KDAT(500),TTMAX(500),IDX(2),ID(10,3),DAT(10,12),HITE(2)
            DIMENSION STP(10),STH(10),STT(10),STWS(10),SIGP(20),SIGT(20)
            DIMENSION WH(30),WS(30),KAP(30)
      C     READ IN CODE IDENTIFICATION FOR COMPARISON WITH CODE IS ON THE DATA CARDS
            READ (5,24) ((SITE(I,J),J=1,2),HITE(I),IDX(I),I=1,2)
         24 FORMAT (2(2A4,F4.0,A4))
            DATA TT,VV,QQ/'TT','VV','QQ'/
            KAPX=0
            IPAGE=0
      C     READ IN MAXIMUM TEMPERATURES
            DO 301 I=1,500
      C     A 4 IN THE FIRST COLUMN INDICATES THE END OF MAX TEMP DATA
            READ (5,300) KDAT(I),TTMAX(I),(TEMPID(J,I),J=1,15)
            WRITE (6,733) KDAT(I),TTMAX(I),(TEMPID(J,I),J=1,15)
        733 FORMAT (1X,I7,4X,F4.0,5X,15A4)
        300 FORMAT (I7,2X,F4.0,5X,15A4)
            IF (KDAT(I).LT.3000000) GO TO 301
      C     NTMAX IS THE NUMBER OF MAXIMUM TEMPERATURES READ IN
            NTMAX=I-1
            GO TO 302
        301 CONTINUE
        302 CONTINUE
      C     INITIALIZE PROGRAM  BY READING FIRST DATA CARD
      C     THE LAST DATA CARD SHOULD BE A CARD WITH A TT PUNCH IN COLUMNS 18 AND 19
            I=1
            READ(5,1,ERR=55,END=120)(ID(I,J),J=1,3),CODE(I),(DAT(I,J),J=1,12)
          1 FORMAT (A4,1X,I6,3X,I2,1X,A2,12F5.0)
        173 I=1
      C     READ THE REST OF THE SOUNDING
         11 CONTINUE
        407 FORMAT (1X,A4,1X,I6,2X,I2,2X,A2,12F7.0)
            I=I+1
         55 CONTINUE
            READ(5,1,ERR=55,END=120)(ID(I,J),J=1,3),CODE(I),(DAT(I,J),J=1,12)
DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
            IF (CODE(I).EQ.TT) GO TO 20
            GO TO 11
         20 CONTINUE
            KAST=I
      C     FIND WHICH CARDS CONTAIN MANDITORY LEVELS,SIGNIFICANT LEVELS, AND WINDS
            K=1
         12 K=K+1
DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
            IF (CODE(K).EQ.VV) GO TO 21
            GO TO 12
         21 NA=K-1
         13 K=K+1
DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
            IF (CODE(K).EQ.QQ) GO TO 22
            GO TO 13
         22 NB=K-1
         14 K=K+1
DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
            IF (CODE(K).EQ.TT) GO TO 23
            GO TO 14
         23 NC=K-1
      C     DECODE PRESSURE,HIGHT,WIND SPEED, ETC. FROM DATA
            STP(1)=DAT(1,1)-99000.
            STH(1)=1288.
            IF (IDX(1).EQ.ID(1,1)) STH(1)=1354.
            STT(1)=POSNEG(DAT(1,2))
            STWS(1)=WSCOMP(DAT(1,3))
            H=-1.
            DO 50 I=1,4
            K=4+3*I
            KT=K
            KR=(KT+11)/12
            KS=KT+12-KR*12
            H=DAT(KR,KS)*.001
            STP(I+1)=H*10
            A=I
            STH(I+1)=(H+2.*A)*1000.+DAT(KR,KS)-(STP(I+1)*100.)
            IF (I.GE.3) GO TO 49
            GO TO 48
         49 BB=STH(I+1)
            KW=BB
            KV=BB*.001
            KV=KV*1000
            STH(I+1)=(KW-KV)*10
         48 CONTINUE
            KT=K+1
            KR=(KT+11)/12
            KS=KT+12-KR*12
            STT(I+1)=POSNEG(DAT(KR,KS))
            KT=K+2
            KR=(KT+11)/12
            KS=KT+12-KR*12
         50 STWS(I+1)=WSCOMP(DAT(KR,KS))
            IF (STH(3).GT.3600.) STH(3)=STH(3)-1000.
      C     DECODE SIGNIFICANT LEVELS
            NCARDS=NB-NA
            NSIGL=5*NCARDS
            M=12*NA
            DO 60 I=1,NSIGL
            MM=M-1+2*I
            KT=MM
            KR=(KT+11)/12
            KS=KT+12-KR*12
            K=DAT(KR,KS)*.001
            A=K*1000
            SIGP(I)=DAT(KR,KS)-A
            KT=MM+1
            KR=(KT+11)/12
            KS=KT+12-KR*12
         60 SIGT(I)=POSNEG(DAT(KR,KS))
      C     ZERO WIND SPEEDS AND WIND SPEED HEIGHTS
            DO 900 I=1,20
            WS(I)=0.
            WH(I)=0.
            WSS(I)=0.
        900 WHH(I)=0.
      C     FIND WIND SPEED HEIGHTS FOR WHICH THERE IS DATA OR SPACES FOR DATA
            M=12*NB
            KO=-2
            DO 901 I=1,21,4
            KT=M+I
            KR=(KT+11)/12
            KS=KT+12-KR*12
            R=DAT(KR,KS)+.5
            IF (R.LT.90000.) GO TO 902
            KO=KO+3
            KDEC=R*.001-90.
            LAP=R*.001
            LAP=LAP*10
            LID=R*.01
            LID=LID-LAP
            KAP(KO)=KDEC*10+LID
            LAP=R*.01
            LAP=LAP*10
            LID=R*.1
            LID=LID-LAP
            KAP(KO+1)=KDEC*10+LID
            LAP=R*.1
            LAP=LAP*10
            LID=R
            LID=LID-LAP
            KAP(KO+2)=KDEC*10+LID
        901 CONTINUE
        902 JIM=KO+2
            DO 70 I=1,JIM
            A=I-1
            J=.34*A
            K=M+1+J+I
            KT=K
            KR=(KT+11)/12
            KS=KT+12-KR*12
            WS(I)=WSCOMP(DAT(KR,KS))
         70 WH(I)=KAP(I)*1000
            WHH(1)=4000
            WSS(1)=WS(1)
            IF(WSS(1).GT.98.)WS(1)=0
            KAP(1)=4
            DO 903 I=2,30
            M=I+3
        903 WHH(I)=M*1000
            IX=0
            JAM=JIM-1
            DO 908 I=2,JAM
        915 IF (WS(I).LT.98.) GO TO 908
            JIFF=JAM-IX
            IF (I.GT.JIFF) GO TO 915
            DO 909 J=I,JIFF
            WS(J)=WS(J+1)
            WH(J)=WH(J+1)
        909 KAP(J)=KAP(J+1)
            IX=IX+1
            GO TO 915
        908 CONTINUE
        916 IF (WS(JIM).LT..1.OR.WS(JIM).GT.98.) IX=IX+1
            IX=JIM-IX
            DO 907 I=2,30
            M=I+3
            DO 906 J=2,IX
            IF (KAP(J)-M) 906,452,451
        451 JAX=J
            GO TO 912
        452 WSS(I)=WS(J)
            GO TO 907
        906 CONTINUE
            WSS(I)=WS(IX)
            GO TO 907
        912 A=KAP(JAX)-KAP(JAX-1)
            B=M-KAP(JAX-1)
            WSS(I)=WS(JAX-1)+B/A*(WS(JAX)-WS(JAX-1))
        907 CONTINUE
        910 CONTINUE
      C  WRITE OUT THE RAWINSONDE RUN AND FIND IDTMAX (USED FOR FINDING MAX TEMP)
      C  WRITE OUT MANDITORY LEVEL PRESSURES, TEMPERATURES, HEIGHTS, AND WIND SPEEDS.
      C  FIND OUT ID NUMBER OF RAWINSONDE SITE
            NRND=2
            DO 315 I=1,NRND
            IF (ID(1,1).NE.IDX(I)) GO TO 316
            NRAD=I
            GO TO 317
        316 CONTINUE
        317 IDTMAX=NRAD*1000000+ID(1,2)
            KYR=IDTMAX/10000-NRAD*100
```

```
      MO=IDTMAX/100-(NRAD*10000+KYR*100)
      KDA=IDTMAX-(IDTMAX/100)*100
      KHR=ID(1,3)
      WRITE (6,4559)
 4559 FORMAT (1X,3('**********************************************'))
      WRITE (6,318) (SITE(NRAD,JJ),JJ=1,2),KHR,MO,KDA,KYR
  318 FORMAT ('0RAWINSONDE AT '2A4,4X,I2,' HOURS ZULU TIME, '3I2)
      WRITE(6,315) (STP(I),STT(I),STH(I),STWS(I),I=1,5)
  315 FORMAT (' MANDITORY LEVELS FOLLOW'/' PRESSURE     TEMPERATURE
     1HEIGHT       WIND SPEED'/'    (MB)          (DEG. C.)      (METERS)
     2(MILES/HOUR)'/' '10(F6.0,7X,F8.1,6X,F8.0,6X,F7.0/1X))
      WRITE (6,320) (SIGP(I),SIGT(I),I=1,NSIGL)
  320 FORMAT (' SIGNIFICANT LEVELS FOLLOW'/' '6('PRESS     TEMP      ')/
     11X,6(' (MB)     (C.)       ')/1X,5(6(F5.0,F8.1,5X)/1X))
      WRITE (6,321) (WHH(I),WSS(I),I=1,30)
  321 FORMAT (' WIND HEIGHTS AND SPEEDS FOLLOW'/1X,4('WIND HEIGHT  WIND
     2SPEED'6X)/1X,4('   (FEET)'4X,'(MILES/HOUR)'5X)/1X,8(4(F8.0,4X,F11.0
     3,6X)/1X))
C  FIND MAXIMUM TEMPERATURE
      DO 310 I=1,NTMAX
      IF (IDTMAX.NE.KDAT(I)) GO TO 310
      IAB=I
      GO TO 311
  310 CONTINUE
      WRITE (6,312)
  312 FORMAT (' THERE IS NO MAXIMUM TEMPERATURE LISTED FOR THE ABOVE RAO
     1B.')
      WRITE (6,731)IDTMAX
  731 FORMAT ('WE ARE LOOKING FOR TEMPERATURE WITH ID'I8)
      GO TO 465
  311 TMAX=TTMAX(IAB)
C     CHANGE TMAX TO DEGREES ABSOLUTE ON THE KELVIN SCALE
      TMAX=(TMAX-32.)*.5555+273.16
      KARX=KARX+1
      IDCI(KARX)=IDTMAX
      KHOUR(KARX)=ID(1,3)
      TEMP(KARX)=TMAX-273.16
      WRITE (6,551) TEMP(KARX),(TEMPID(JX,IAB),JX=1,15)
  551 FORMAT (' MAX TEMP USED ON THIS RAOB IS 'F5.1,' WHICH IS '15A4)
C     FIND WHERE MAXIMUM TEMPERATURE DESCENDED DRY ADIABATICALLY AND THE
C     SOUNDING CROSS
      J=2
      P1=SIGP(1)
C     P1 WILL BE INCREMENTED BY -10 MB EACH ITERATION
C     SIGP(1) IS THE SURFACE PRESSURE
      DO 520 I=1,60
      P1=P1-10.
      T1=TMAX*((P1/SIGP(1))**.286)
      T1=T1-273.16
C     FIND PRESSURES AND TEMPERATURES WHICH BRACKET THE PA BEING TESTED
      DO 252 L=J,NSIGL
      LL=L
      IF (P1.GT.SIGP(L)) GO TO 530
  252 CONTINUE
      WRITE (6,19)
   19 FORMAT (' ERROR')
C     A IS THE SLOPE OF THE TEMPERATURE PRESSURE CURVE
  530 A=(SIGT(LL)-SIGT(LL-1))/(SIGP(LL)-SIGP(LL-1))
C     TR IS THE ACTUAL TEMPERATURE AT HEIGHT P1
      J=LL
      TR=SIGT(LL-1)+(P1-SIGP(LL-1))*A
C     DT IS THE DIFFERENCE IN DEGREES CENTIGRADE BETWEEN T1, AND TR
  552 FORMAT (' AT PRESSURE 'F5.0,' MB, ACTUAL TEMP IS 'F6.1,' MAX TEMP
     1EXPANDED ADIABATICALLY IS 'F6.1)
      DT=T1-TR
      DT=T1-TR
      IF (DT) 540,541,520
  520 CONTINUE
  540 P1=P1+5.
      TR=SIGT(LL-1)+(P1-SIGP(LL-1))*A
      T1=TMAX*((P1/SIGP(1))**.286)
      T1=T1-273.16
      WRITE (6,552) P1,TR,T1
      IF (DT.LE.0.) GO TO 541
      P1=P1-5.
C     DETERMINE VENTILLATION HEIGHT VH
  541 DO 605 I=2,5
      K=I
      IF (P1.GT.STP(I)) GO TO 610
  605 CONTINUE
  610 PLOG=P1/STP(K-1)
      B=(P1-STP(K-1))/(STP(K)-STP(K-1))
      TBAR=STT(K-1)+273.16+B*(STT(K)-STT(K-1))*.5
      VH=STH(K-1)-29.2898*TBAR*ALOG(PLOG)
      WRITE (6,553) P1,VH,STH(K-1),STH(K)
  553 FORMAT (' P1=',F9.1,'VH= 'F9.1,'STD HTS ='2F10.2)
C     FIND THE MEAN WIND SPEED
      HEIGHT=VH*3.28
      DO 700 I=1,12
      K=I
      IF(WHH(I).GT.HEIGHT) GO TO 701
  700 CONTINUE
  701 K=K-1
      AVWS=0.0
      DO 702 I=1,K
  702 AVWS=AVWS+WSS(I)
      A=K
      AVWS=AVWS/A
      AVWS=AVWS*1.1515
C     COMPUTE CLEARING INDEX
      HEIGHT=HEIGHT-HITE(NRAD)
      CI(KARX)=HEIGHT*AVWS*.01
      HT(KARX)=HEIGHT
      AVW(KARX)=AVWS
      WRITE (6,554) CI(KARX),HT(KARX),AVW(KARX)
  554 FORMAT (' CI,HT,AND AVW ARE '3F10.2)
  465 CONTINUE
      NC=NC+1
      DO 1040 I=1,3
 1040 ID(1,I)=ID(NC,I)
      DO 1041 I=1,12
 1041 DAT(1,I)=DAT(NC,I)
      CODE(1)=CODE(NC)
      I=1
      GO TO 173
C  EVAL CIS
  120 CONTINUE
      DO 350 I=1,KARX
      NAA=IDCI(I)/1000000
      KDYR=IDCI(I)-NAA*1000000
      WRITE (6,352) (SITE(NAA,K),K=1,2),KDYR,KHOUR(I),CI(I),HT(I),AVW(I)
  352 FORMAT (1X,2A4,' DATE'I7,I3,'00 HOURS ZULU   CI = 'F8.0,5X,'VENTIL
     *LATION HEIGHT = 'F8.0,5X,' AVERAGE WIND SPEED = 'F8.0)
  350 CONTINUE
C  DO COMPARISONS
      WRITE (6,2)
    2 FORMAT ('1 MO DAY YEAR HR            TMAX      TMAX     HEIGHT    HEIGHT
     *        WIND      WIND        CI         CI      RATIO      DIFF     RATIO
     *  DIFF'/'                                      LOGAN     SLC      LOGAN     SLC
     *        LOGAN     SLC      LOGAN       SLC     OF CI     OF CI     OF HTS
     *  OF HTS'/1X)
C  FIND PAIRS
      DO 360 I=1,KARX
      IF (IDCI(I).GT.1990000) GO TO 360
      IDENT=IDCI(I)+1000000
      DO 361 J=1,KARX
      IF (IDENT.NE.IDCI(J)) GO TO 361
      IF (KHOUR(J).NE.KHOUR(I)) GO TO 361
      K=J
      GO TO 362
  361 CONTINUE
      KDYR=IDCI(I)/1000000
      KDYR=IDCI(I)-1000000*KDYR
      WRITE (6,363) KDYR,KHOUR(I)
  363 FORMAT (' THERE IS NO RAWINSONDE WITH WHICH TO COMPARE THAT OF LOG
     *AN AT DATE 'I7,I3,'00 HOURS')
      GO TO 360
C  DO COMPARISONS
  362 MON=IDCI(I)/1000000
      KDATE=IDCI(I)-MON*1000000
      MON=KDATE/10000
      KDATE=KDATE-MON*10000
      KDY=KDATE/100
      KYR=KDATE-KDY*100
      CIX=CI(I)/CI(J)
      CIDIF=CI(I)-CI(J)
      HTRAT=HT(I)/HT(J)
      HTDIF=HT(I)-HT(J)
      IPAGE=IPAGE+1
      IF (IPAGE.LT.40) GO TO 365
      WRITE (6,2)
      IPAGE=0
  365 WRITE (6,755) MON,KDY,KYR,KHOUR(I),TEMP(I),TEMP(J),HT(I),HT(J),
     *AVW(I),AVW(J),CI(I),CI(J),CIX,CIDIF,HTRAT,HTDIF
  755 FORMAT (1X,4(I2,2X),4X,8F9.0,F9.2,F9.0,F9.2,F9.0)
  360 CONTINUE
  658 CONTINUE
      STOP
      END
      FUNCTION POSNEG(A)
      K=(A+1.)*.01
      A=K
      KA=(A+.1)*.5
      KB=(A+1.1)*.5
      IF (KB-KA) 5,6,5
    5 A=-A
    6 POSNEG=A*.1
      RETURN
      END
      FUNCTION WSCOMP(X)
      K=X*.01
      A=K*100
      WSCOMP=X-A
      RETURN
      END
```

Key Words: Clearing Index, Ventilation Index, Air pollution potential, Air pollution dispersion, Mixing depths.

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1. Actual Salt Lake Valley and Cache Valley Clearing Indexes were in the same operational classes 71% of the time.

2. As presently computed, the Clearing Index is significantly less than a perfect indicator of the air pollution potential of the Cache Valley.

3. The improvement (if any) in the air pollution potential prediction for the Cache Valley, which should result from having an additional rawinsonde station in the Cache Valley, would be too little to justify the effort and expenses. The same is probably true for other Intermountain valleys. This conclusion could change if the procedures for estimating this potential were sufficiently improved.

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