# A MODEL FOR THE SIMULATION OF KANSAS TEMPERATURE DATA

by

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**THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.**

**THIS IS AS RECEIVED FROM CUSTOMER.**

ABSTRACT

Models for weather data were explored using records for Manhattan, Kansas, from 1900 through 1970. Precipitation was found to be independent of antecedent conditions, but a covariance model for minimum and maximum daily temperatures proved satisfactory. Daily extreme temperatures were regressed on the occurrence of precipitation during the preceding day and the day of interest and on the deviations from normal of the preceding two temperatures. Interaction terms were found to be insignificant.

Parameter estimates are listed for nine Kansas stations. Harmonic analysis has been used to smooth the estimates. The Fourier coefficients are tabulated and mapped.

Simulation of Manhattan weather was attempted using randomly generated precipitation. The distribution of wet and dry days was found to be correct, but precipitation amounts were too uniform. This did not degrade the temperature simulation.

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## INTRODUCTION

Weather is a momentary state of the atmosphere, measured primarily by atmospheric temperature, moisture content, wind speed, and air pressure. Meteorology is the study of weather and its prediction. Climate is the composite of day-to-day weather over a period of time for a particular region. It varies with location but not from moment to moment. Climate is ordinarily expressed by the distributions of precipitation and temperatures. Climatology is the study of climate and its effects.

Weather patterns affect everyone. Today's weather is of interest to the housewife hanging out her wash and to the pilot taking off for Kansas City. Next week's weather is important to the shopkeeper planning a sale and to the farmer planning to harvest his wheat. Next winter's weather is of vital concern to the university buying heating fuel and to the farm owner deciding what to plant. Man has been trying to control or predict the weather since before recorded history.

Prediction implies understanding, and understanding requires that weather data be recorded and analyzed. Early Man had to rely on visual observations and the lore which had been passed down by his ancestors. With the invention of the thermometer and barometer in the seventeenth century it became apparent that certain instrument readings, such as a rapidly falling barometer, were good predictors of coming weather. The development of accurate instruments, rapid communications, and high-speed computers have provided great improvements in forecasting, but there is much about weather that is not understood.

The Kansas Agricultural Experiment Station Weather Data Library is involved in a continuing effort to maintain and analyze Kansas weather data. The present data network consists of 240 cooperative stations, although records have been taken at 432 locations at one time or another [1]. Records from Leavenworth began in 1836, and Manhattan records are continuous back to 1858. The Weather Data Library maintains over one and a half million daily records on punched cards, representing 105 stations. Records for 24 stations with 70 years of punched data and 30 stations with 30 years of punched data are stored on magnetic tape. Information needed for the use of this data is listed in the User's Manual; an updated edition is being prepared. The Weather Data Library also makes available tabulations and summaries of data from all over Kansas.

The records on magnetic tape consist primarily of the three variables most important to agriculture: daily precipitation and minimum and maximum temperatures. For a few stations it is possible to obtain records of humidity, wind speed, barometric pressure, evaporation, insolation, and even hourly data, but they were not used in this study.

The nine stations (see Fig. 1) in this study all measure daily precipitation in the morning, at 7 or 8 a.m. (see Fig. 2). This means that the amount recorded on a daily weather record may have fallen at any time during the 24 hours or may have been spread throughout. Most precipitation occurs at night, however.

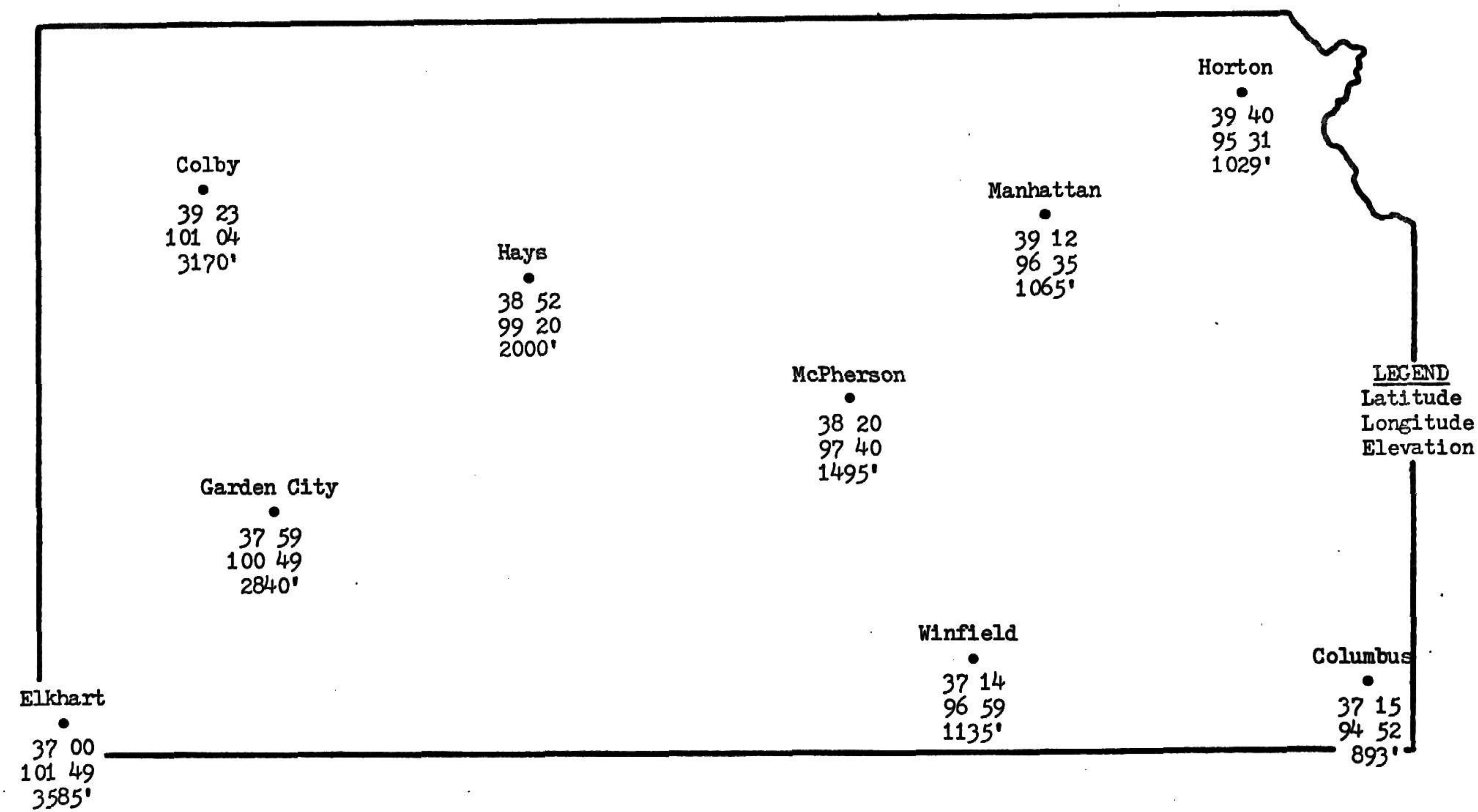
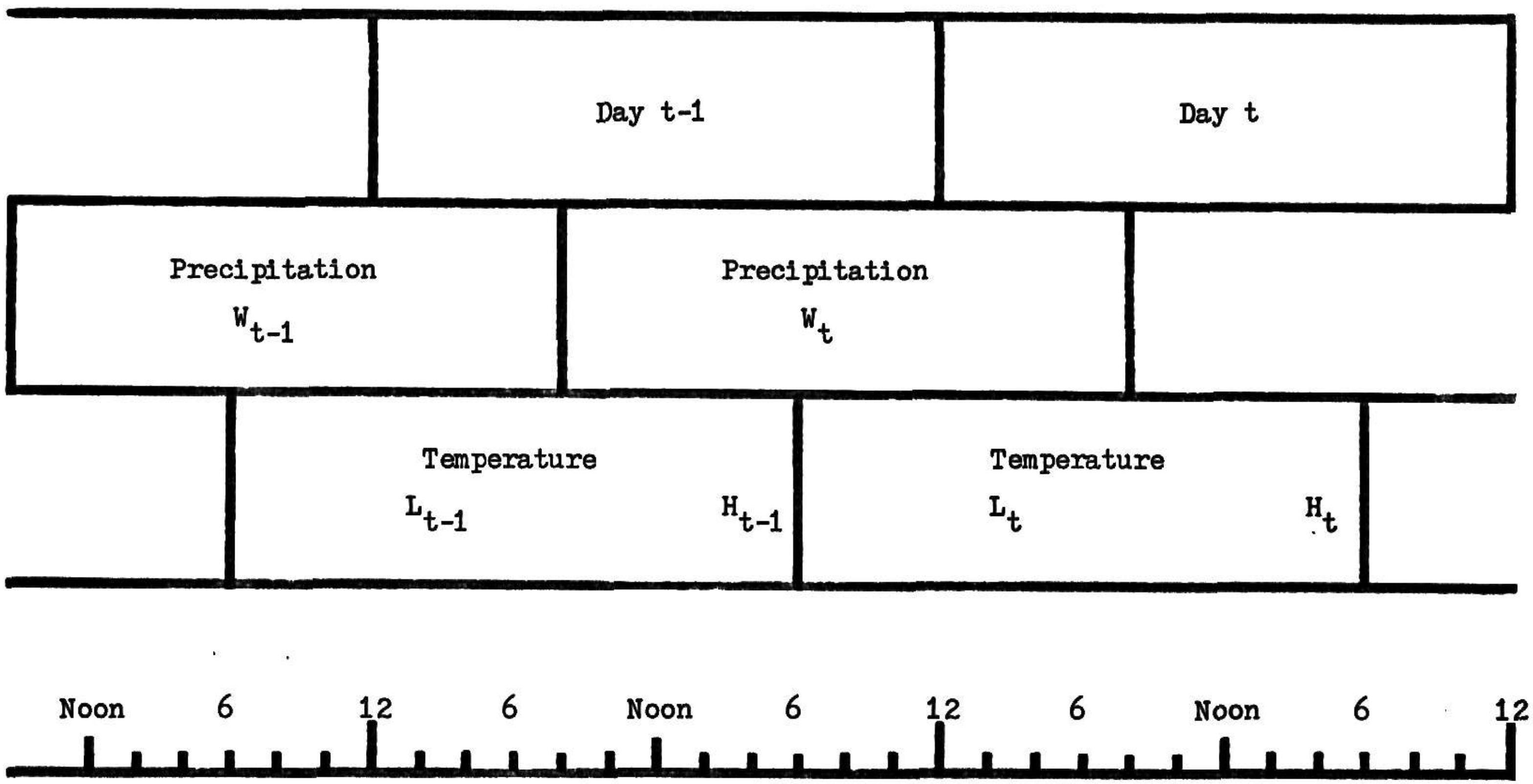



Figure 1. Locations of Kansas Stations




<u>Figure 2</u>. Observation Times of Daily Precipitation and Temperature Data

Three of the stations (Colby, Garden City, and Hays) record minimum and maximum temperatures in the morning; the remaining 6 record them in the evening (see Fig. 2). It is not known what effect this has on the results of the study; it has not even been verified that these same measurement times have been used throughout the 70-year period. If an effect is present it is partially confounded with both location and elevation.

Daily mean temperature is not recorded directly, but may be calculated easily as the mean of the minimum and maximum temperatures. Heating, cooling, and growing degree-days may be calculated from the mean temperature. Evapotranspiration and the Palmer Drought Index [2] may be estimated using all three of the weather variables.

Kansas is an excellent laboratory for the study of variation in precipitation and temperatures; the interactions of major weather systems over the state provide complex patterns of variation. The range of annual precipitation totals is from 16 inches in the southwest to 41 inches in the southeast. The coldest temperature ever recorded in Kansas was 40 degrees (Fahrenheit) below zero on February 13, 1905, at Lebanon. The hottest was 121 degrees at Fredonia, July 18, 1936, and at Alton, July 24, 1936. Monthly temperature averages range from 13.4 degrees at Oberlin in January to 95.4 degrees at Medicine Lodge in July. The annual progression of temperatures at Manhattan is shown in Figure 4.

While a single extreme temperature or heavy precipitation can be damaging, a long series of them can be disasterous. California's "Great

Freeze" of January 19, 1922, resulted in a total citrus loss of about $50,000,000. Kansas is subject to blizzards, such as the great blizzard of 1886, but is more famous for its droughts, periods of little precipitation (see Fig. 3) and high temperatures which destroy crops, kill livestock, and erode the soil. The Dust Bowl days of the 1930's is a well known example, although the drought of the 1860's may have been equally severe. Kansas is also troubled with floods, which destroy crops and take lives.

These extreme weather patterns occur so seldom that tabulations and summaries over a limited number of years may not reveal such events. Proper modeling and simulation, however, allow inferences about rare occurrences to be made. Simulation is the generation of pseudo-random weather records using a model and parameter estimates derived from climatological data. These records imitate the patterns of true weather although they in no sense predict it.

Experimentation with different models and parameter values provides insight into the mechanisms of the real weather. With luck a "fundamental" model can be developed: one with a minimum of parameters, each easily explained in terms of the real world. This report is one step toward that goal; it provides a workable model for simulation of Kansas weather data.

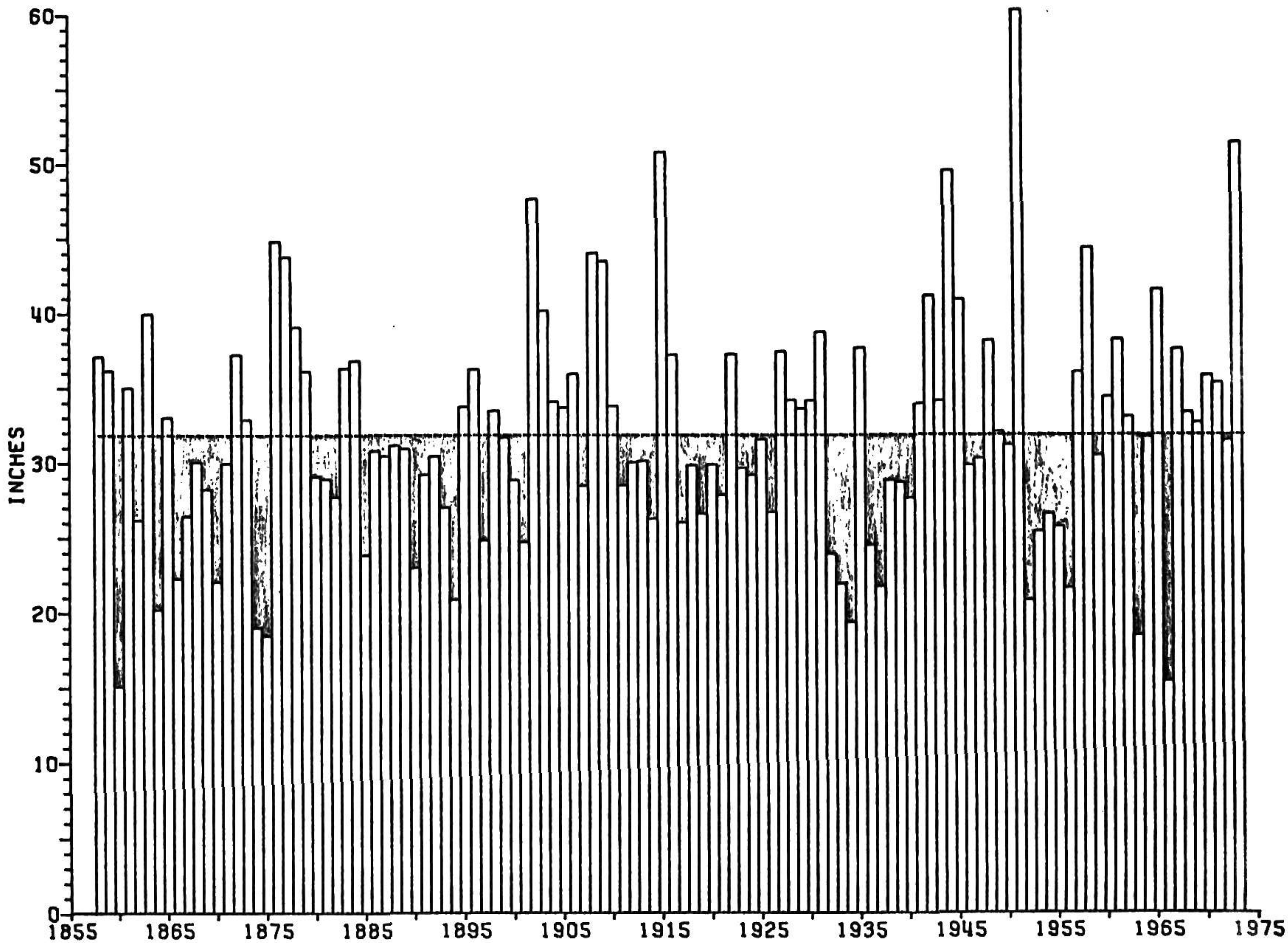



Figure 3. Manhattan Annual Precipitation Totals

## OBJECTIVES

The ultimate goal of modeling and simulation of weather data is the development of predictive equations for weather phenomena. This study is concerned with the more immediate goals listed below.

Statistical summaries and least square precedures provide estimates of the parameter values at stations throughout Kansas. Regression theory is used to explore and compare models. Hopefully these parameter estimates and the corresponding models can be used in place of vast stores of weather data to describe the climates at the evaluated stations.

Harmonic smoothing is used to clarify the patterns of variation in parameter values throughout the year. The Fourier coefficeints may be thought of as new parameters; together with the appropriate model they provide an even more concise description of a particular climate.

Mapping of Fourier coefficients across the state may allow patterns among stations to emerge, in which case it would seem reasonable that weather data may be simulated at locations not in the original analyses. Averaging of the coefficients across the state permits "Kansas weather" to be described and simulated, although the results might not represent the climate for any particular location.

Finally, computer simulation and subsequent statistical analysis can be used to test a model for accuracy and for weaknesses. Simulation permits the generation of thousands of years of data, providing counts of droughts and other rare occurrences which could not easily be predicted from available data over a shorter span of years.

## PREVIOUS RESEARCH

Researchers with the aid of the Weather Data Library have been investigating models for precipitation distributions for many years. An early example is provided by the work of Feyerherm and Bark [3]. Probabilities for transitions from dry days to wet ones, and from wet to dry, at ten Kansas stations were estimated for each week of the year. If a first-order Markov model [4] is assumed to hold, the probability of a dry spell of exactly n days is

$$P(\text{WET}) \cdot P(\text{DRY}|\text{WET}) \cdot P(\text{DRY}|\text{DRY})^{n-1} \cdot P(\text{WET}|\text{DRY})$$

Markov models for precipitation patterns have been investigated by many researchers; references are given by Feyerherm and Bark [5] and by Ison [6,7]. First and second-order Markov models were investigated by Feyerherm and Bark [5,8] for weather data from the North Central region of the United States. The first-order model was found to form an excellent approximation to the distribution of wet and dry days in Kansas.

Feyerherm and Bark used the method of Hartley [9] to determine the number of terms in a Fourier series which are needed to adequately represent the annual cycles of the probability estimates. It was found that terms beyond the fourth (i.e., the fourth harmonic) were generally not significant.

During wet periods the total amount of precipitation is an important variable. Ison [6,7] obtained good results by fitting parameters to a gamma distribution: a shape parameter which varies linearly with the length of wet spell and a scale parameter independent of the length. The iterative procedure of estimation is due to Choi and Wette [10].

Lundgren [11] investigated regression models for the minimum and maximum temperatures when the precipitation sequence is known. He concluded that data more than one day prior to the modeled day were of little value in predicting the new temperatures; thus his model may be described as being of first order.

For each week of the year and for each precipitation history (DRY,DRY; DRY,WET; WET,DRY; and WET,WET on days t-1 and t) Lundgren used the equations

$$H_{t-1} = \bar{H}_{t-1} + C_{HH}\cdot(H_{t-2} - \bar{H}_{t-2}) + C_{LH}\cdot(L_{t-1} - \bar{L}_{t-1}) + e_H$$

$$L_t = \bar{L}_t + C_{LL}\cdot(L_{t-1} - \bar{L}_{t-1}) + C_{HL}\cdot(H_{t-1} - \bar{H}_{t-1}) + e_L$$

where t-2, t-1, and t (t =1,2,...,364) are consecutive days with day t being within the week of analysis; L and H are the minimum and maximum temperatures on the subscript day; $\bar{L}$ and $\bar{H}$ are the mean temperatures for the subscript day and the given precipitaion history; $C_{HH}$, $C_{LH}$, $C_{LL}$, and $C_{HL}$ are partial regression coefficients considered constant for the analysis period; and $e_L$ and $e_H$ are the residual errors, assumed to be normally distributed with means zero and estimated variances $s_L^2$ and $s_H^2$, respectively.

Lundgren's model involves 52 periods and four precipitation histories, each having four coefficients, four average temperature extremes, and two error variances, a total of 2080 parameters per station. Fourier analysis of the parameter estimates enables each to be expressed as a partial Fourier sum involving nine coefficients (i.e., four harmonics) instead of 52; if $\bar{H}_{t-2}$ and $\bar{L}_t$ are omitted since they can be derived, the number of parameters is reduced to 288 per station.

## THE TEMPERATURE MODEL

### BACKGROUND

Lundgren's investigations were limited to data from Manhattan, Kansas. This work began with an attempt to apply the same model to data from other Kansas stations, notably Colby and Garden City. Two changes were made to Lundgren's model: the dependent maximum temperature was changed from day t-1 to day t, and two-week periods were used instead of one-week periods.

The change in the dependent variable simplifies notation, particularly with regard to precipitation history. The new equations for each period and precipitation history are

$$L_t = \bar{L}_t + C_{LL}\cdot(L_{t-1} - \bar{L}_{t-1}) + C_{HL}\cdot(H_{t-1} - \bar{H}_{t-1}) + e_L$$
$$H_t = \bar{H}_t + C_{HH}\cdot(H_{t-1} - \bar{H}_{t-1}) + C_{LH}\cdot(L_t - \bar{L}_t) + e_H$$

Lundgren has indicated that the variance of $e_H$ might be increased slightly by this modication (without regard to the change in period lengths).

The change to two-week periods was dictated by two considerations. First, the programs then in use would have generated an unmanageable amount of output for the 52 weeks at a cost of about $500 per station.

Second, analysis of western stations (e.g., Colby) during winter would involve some weeks for which there had been no WET,WET data; there were no two-week periods with this problem.

The programming system then in use involved sorting 70 years of data into 102 files, one for each two-week period and precipitation history. These files were used as input to STEPDEL, a sophisticated computer program for multiple linear regression which was made available by the Statistical Laboratory of Kansas State University. It was necessary to make 204 passes through the program since only one dependent variable for one data set could be analyzed in one pass.

This system was awkward and expensive, and it generated an enormous physical volume of output with only a few useful numbers per page; the numbers were not readily available as punched output. These factors spurred the development of a new program, LINMOD, which was specifically designed to evaluate regression models for weather records.

## THE REGRESSION PROGRAM

The FORTRAN IV program LINMOD (Appendix A) takes its name from the field of linear statistical models - the use of matrix algebra to estimate the parameters of statistical models. A good discussion of linear models may be found in Searle [12]. The program uses Moore-Penrose generalized inverses, which are discussed by Graybill [13].

LINMOD can perform multiple linear regressions, analyses of variance, and anlyses of covariance. Up to nine models may be specified in each run, with up to seven independent variables per model. Computations are carried out in single precision (i.e., seven significant digits). It would have been better to use double precision, although computational errors are probably small compared to the standard deviations of the parameter estimates.

The weather tapes used for input are in chronological order, one station per tape. The data is read from the tape using the COBOL subroutine RDREC (see Appendix C) and is stored on a disk pack as a direct access data set. This data set may be saved to avoid the cost of reconstructing it on subsequent runs ($30 for 70 years of data).

For each two-week period (or shorter period, if specified) data are gathered from each year to form a new file. The first period begins with March 1, the start of the climatological year; this avoids complications with February 29. The records in the new file are composed of six variables: the precipitation and minimum and maximum temperatures for day t-1 and the same information for day t. The symbols for these variables are $W_{t-1}$, $L_{t-1}$, $H_{t-1}$, $W_t$, $L_t$, and $H_t$. LINMOD prints a statistical summary of these variables including means, variances, standard deviations, standard errors of the means, coefficients of variation, cross-products, covariances, and correlations.

Each model may specify a regression of one of the variables on a subset of the others. Two types of transformation are also available: deviates and incidence variables. A deviate is simply an original variable from which has been subtracted the average observed value for the period (LINMOD is unable to form deviates around any value other than the average); an example of the notation for a deviate is $(L_t - \bar{L}_t)$. An incidence variable is one which is set to 0.0 if the original variable is less than or equal to 0.0 and is set to 1.0 if the original variable is positive. The incidence variables used in this study, $I_{t-1}$ and $I_t$, correspond to $W_{t-1}$ and $W_t$ and represent the occurrence of 0.01 inch or more of precipitation.

The product of any pair of independent variables (or transformed variables) in the model may also be formed, providing the models with interaction terms which measure the joint effect of a pair of variables beyond the sum of their main effects. Interaction terms may not be specified for variables omitted from the model.

LINMOD prints a statistical summary of the model variables which is identical in form to that for the original six variables. An analysis of variance table for the regression is printed, including $R^2$ (the coefficient of determination), the parameter estimates, their standard deviations, 95% confidence intervals, standardized values, sums of squares, t-test (for the tests of whether the parameters are significantly different from zero), the two-tailed probabilities of greater t-values, the $R^2$ values which would result from deleting each variable from the model, and the variances and covariances of the estimates. Unfortunately the correlations of the estimates are omitted, although they may be computed from the matrix of covariances.

Punched output includes the means and covariances of the original six variables, the means and covariances of the model variables, and the parameter estimates and their covariances; this amounts to just over 1000 cards. For the purposes of this study it would have been adequate to punch only the parameter estimates and the residual mean squares, $s_L^2$ and $s_H^2$.

If desired a LINMOD run may be restricted to a subset of the available records, such as those having precipitation on both day t-1 and day t. (Such selection may also be done for a single model within a run, but this is less efficient and does not provide the numbers around which deviates have been formed.) Selection may only be made by precipitation history, but may specify conditions on either or both days. This feature was used to check the program's functioning by recomputing values produced by the previous programming system.

## PRELIMINARY INVESTIGATION

The LINMOD program is flexible enough to permit many models to be tried. One measure of the success of a model is $R^2$, the coefficient of determination. It is the ratio of the sum of squares due to regression to the total sum of squares, and represents the proportion of the variance of the dependent variable explained by the model. The square root of $R^2$ is the simple correlation between the predicted and actual temperatures.

Evaluation of the model

$$H_t = \bar{H}_t + C_{HH}\cdot(H_{t-1} - \bar{H}_{t-1}) + C_{LH}\cdot(L_t - \bar{L}_t) + e_H$$

or the similar form

$$H_t = C_H + C_{HH} \cdot H_{t-1} + C_{LH} \cdot L_t + e_H$$

for the first two periods of March (and for 70 years of Manhattan data) gives an average $R^2$ value of 0.551. Thus 55% of the variance of $H_t$ can be "explained" without the use of precipitation history or interaction terms.

Lundgren's model involves separate parameter estimates for each of the four precipitation histories. Evaluation of the above equations for WET,WET records gives an average $R^2$ of 0.610 for the two periods. For many purposes the increased power of the model may not be worth the increased complexity.

The number of parameters may be reduced by combining Lundgren's four regression equations for $H_t$ into a single equation. In the terminology of covariance models (described in Snedecor and Cochran [14] and in Searle [12]) the precipitation history forms a two-way classification and the deviates of the previous two temperatures are covariates. The equation is

$$H_t = C_H + C_{H,t-1} \cdot I_{t-1} + C_{H,t} \cdot I_t + C_{HH} \cdot (H_{t-1} - \bar{H}_{t-1}) + C_{LH} \cdot (L_t - \bar{L}_t) + e_H$$

The terms of this model are described fully in the next section. Note that the constant term of Lundgren's model, $\bar{H}_t$, has been broken into three terms with the sum depending on the precipitation history. Essentially what has been done is to use a separate constant term for each precipitation history, but to keep the remaining parameters constant. The value of $R^2$ for unrestricted records is 0.606, negligibly less than the value for WET,WET records with Lundgren's model.

The same model was also tried with the actual amounts of precipitation, $W_{t-1}$ and $W_t$, used in place of the incidence variables. $R^2$ was 0.577, nearly the same as the model without any term for precipitation history. When both the incidence variables and the original precipitation variables were included, $R^2$ was 0.605, no better than with the incidence variables alone.

Interactions were than added to the model. The $I_{t-1}I_t$ term was added to each model containing incidence variables; the estimate of the coefficient was never significantly different from zero. A $W_{t-1}W_t$ term was added to models containing precipitation variables; it also had no effect. Interactions of an incidence variable with a precipitation variable (e.g., $I_tW_t$) have no meaning since they are identical to the precipitation variable alone.

The interaction between temperature deviates, $(H_{t-1} - \bar{H}_{t-1})\cdot(L_t - \bar{L}_t)$, was also investigated, with and without the precipitation interactions mentioned above. In no case was the interaction significant.

One type of interaction was found to be significant at the 0.05 level: the interaction between incidence of precipitation and the independent temperature variables in the regression equation for the dependent minimum temperature (no test was made of the interaction between precipitation amount and temperature deviates). The term $I_{t-1}\cdot(L_{t-1} - \bar{L}_{t-1})$ increased $R^2$ by 0.005, and the term $I_t\cdot(H_{t-1} - \bar{H}_{t-1})$ increased $R^2$ by 0.010 for the first four periods of the climatological year. It is doubtful that the gain in accuracy from using these terms is worth the trouble of including them; they are not used in this report.

There are many transformations which were not investigated, chiefly because LINMOD is not set up to handle them. Squares, cubes or logarithms of the original variables could have been tried either alone or as interactions. Interactions of more than two variables were ignored.

An attempt was made to predict daily precipitation, $W_t$, from the preceding day's observations ($W_{t-1}$ and $I_{t-1}$, $L_{t-1}$, and $H_{t-1}$). The $R^2$ value for these regressions was close to 0.03, indicating that only three per cent of the precipitation variance could be "explained" by main effects and interactions of the preceding day's observations. Prediction of the occurrence of precipitation, $I_t$, was not much more successful; $R^2$ was 0.06. Furthermore, estimation of the amount of precipitation, $W_t$, on days known to be wet gave an $R^2$ of 0.06. It was decided to omit the regression model for precipitation from further work.

## THE FINAL MODEL

The model for daily temperature extremes ultimately selected was

$$L_t = C_L + C_{L,t-1}I_{t-1} + C_{L,t}I_t + C_{LL}\cdot(L_{t-1} - \bar{L}_{t-1}) + C_{HL}\cdot(H_{t-1} - \bar{H}_{t-1}) + e_L$$

$$H_t = C_H + C_{H,t-1}I_{t-1} + C_{H,t}I_t + C_{HH}\cdot(H_{t-1} - \bar{H}_{t-1}) + C_{LH}\cdot(L_t - \bar{L}_t) + e_H$$

where

$L_t$ and $H_t$ are the minimum and maximum temperatures on day t,

$t = 1,2,\ldots,364$ in groups of 14 days beginning with March 1 of each year (with t-1 equal to 365 when t is equal to 1),

$I_{t-1}$ and $I_t$ are incidence variables set to 0.0 for no precipitation and to 1.0 for measurable precipitation on days t-1 and t,

$(L_{t-1} - \bar{L}_{t-1})$ and $(H_{t-1} - \bar{H}_{t-1})$ are the deviations of the minimum and maximum temperatures on day t-1 from their averages for the period (the averages are parameters which must be computed),

$(L_t - \bar{L}_t)$ is the deviation of the observed minumum on day t from its average for the period,

$C_L$ and $C_H$ are constants representing the average daily extreme (minimum and maximum) temperatures on day t for DRY,DRY records,

$C_{L,t-1}$ and $C_{H,t-1}$ are the effects on the constant terms of measurable precipitation on day t-1,

$C_{L,t}$ and $C_{H,t}$ are the effects of precipitation on day t,

$C_{LL}$ and $C_{HH}$ are the coefficients for carryover of deviations in the same extreme of temperature measured 24 hours earlier,

$C_{HL}$ and $C_{LH}$ are the coefficients for carryover of deviations in the opposite extreme of temperature, usually 12 hours earlier,

$e_L$ and $e_H$ are error (or lack-of-fit) terms assumed to have means of zero and variances estimated by $s_L^2$ and $s_H^2$, the error mean squares.

In simple language each temperature is assumed to be composed of three parts: a constant corrected for precipitation history, a carryover from the two previous temperatures (where the minimum is assumed to precede the maximum), and a random error term.

## ESTIMATION OF PARAMETERS

### LEAST SQUARES ESTIMATES

Nine stations (see Fig. 1) were analyzed in this study; 70 years of data were available on magnetic tape for each station, providing 980 observations during each two-week period. Program LINMOD was used to estimate the values of the parameters; the results for Manhattan are shown in Table 1. The average value of $R^2$ was 0.4796 for the regression of the minimum temperature, $L_t$, and 0.5859 for the maximum temperature, $H_t$; thus about 50% of the observed temperature variances can be accounted for by this model.

### HARMONIC ANALYSIS

The nature of harmonic smoothing may be understood most easily by examining Figures 4 - 10. These show the original parameter estimates for Manhattan (0 for the minimum and + for the maximum) and the smoothed parameter estimates (solid lines). Six harmonics were used to generate the lines, which would be much smoother if only two harmonics had been used.

A harmonic is one term in the partial Fourier sum

$$\sum_{i=0}^{n} \left[ A_i \cos(2\pi i p/26) + B_i \sin(2\pi i p/26) \right]$$

where p is the period number, p = 1,2,...,26; n is the maximum number of harmonics used, not to exceed 26; and $A_i$ and $B_i$ are the Fourier coefficients. Since the value of $B_0$ is arbitrary, it is customarily defined as 0.0.

A Fourier sum is able to fit the observed points as closely as

Table 1a. Manhattan Regression Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_{t-1}$ | $\bar{H}_{t-1}$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 27.18 | 50.88 | 27.59 | -2.03 | 1.99 | 0.23 | 0.39 | 7.66 |
| 2 | 32.92 | 58.35 | 33.02 | -0.43 | 1.10 | 0.21 | 0.44 | 7.73 |
| 3 | 37.93 | 63.54 | 37.72 | 0.43 | 2.49 | 0.15 | 0.47 | 7.53 |
| 4 | 43.33 | 69.29 | 43.13 | 0.18 | 2.08 | 0.21 | 0.49 | 7.54 |
| 5 | 47.94 | 72.10 | 47.74 | -0.84 | 1.93 | 0.25 | 0.47 | 6.79 |
| 6 | 52.15 | 76.57 | 52.21 | -0.45 | 1.66 | 0.32 | 0.45 | 6.52 |
| 7 | 57.72 | 80.98 | 57.83 | -0.30 | 0.98 | 0.34 | 0.40 | 5.89 |
| 8 | 61.96 | 85.58 | 62.26 | 0.06 | -0.23 | 0.41 | 0.29 | 5.42 |
| 9 | 65.25 | 89.71 | 65.77 | 0.02 | -1.17 | 0.34 | 0.38 | 5.29 |
| 10 | 66.97 | 92.25 | 67.01 | 0.00 | 0.13 | 0.37 | 0.33 | 5.01 |
| 11 | 67.74 | 92.98 | 67.57 | 0.11 | 0.31 | 0.38 | 0.33 | 4.78 |
| 12 | 66.87 | 92.38 | 66.79 | 0.25 | 0.04 | 0.41 | 0.34 | 4.97 |
| 13 | 64.96 | 90.31 | 64.80 | -0.35 | 0.16 | 0.39 | 0.35 | 5.24 |
| 14 | 61.96 | 87.44 | 61.09 | 0.53 | 1.03 | 0.37 | 0.41 | 6.22 |
| 15 | 56.27 | 81.73 | 55.49 | 0.16 | 0.95 | 0.42 | 0.39 | 7.24 |
| 16 | 50.07 | 76.77 | 48.72 | 0.59 | 3.67 | 0.35 | 0.39 | 7.73 |
| 17 | 45.11 | 71.86 | 44.19 | -0.71 | 3.40 | 0.41 | 0.40 | 7.20 |
| 18 | 37.99 | 63.97 | 37.06 | -0.15 | 3.19 | 0.33 | 0.37 | 7.47 |
| 19 | 32.47 | 56.76 | 31.76 | -1.06 | 3.14 | 0.27 | 0.37 | 7.56 |
| 20 | 27.77 | 50.61 | 26.82 | -0.35 | 4.56 | 0.29 | 0.34 | 7.11 |
| 21 | 21.73 | 42.64 | 21.36 | -1.95 | 2.44 | 0.39 | 0.37 | 7.56 |
| 22 | 20.06 | 41.14 | 20.49 | -4.22 | 0.21 | 0.39 | 0.31 | 7.77 |
| 23 | 18.03 | 39.52 | 17.89 | -1.91 | 2.23 | 0.27 | 0.44 | 8.19 |
| 24 | 17.94 | 39.59 | 18.35 | -3.24 | 0.37 | 0.37 | 0.36 | 8.16 |
| 25 | 19.80 | 42.85 | 20.39 | -2.00 | 0.19 | 0.34 | 0.36 | 8.43 |
| 26 | 22.68 | 45.66 | 22.66 | -1.63 | 2.45 | 0.29 | 0.36 | 7.89 |

Table 1b. Manhattan Regression Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $c_H$ | $c_{H,t-1}$ | $c_{H,t}$ | $c_{HH}$ | $c_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 27.58 | 51.34 | 53.37 | -2.44 | -7.44 | 0.40 | 0.49 | 8.92 |
| 2 | 33.16 | 58.86 | 60.92 | -2.48 | -7.74 | 0.33 | 0.55 | 8.82 |
| 3 | 38.49 | 63.85 | 66.42 | -2.28 | -7.63 | 0.36 | 0.46 | 8.35 |
| 4 | 43.76 | 69.57 | 71.71 | -1.68 | -6.00 | 0.31 | 0.42 | 7.60 |
| 5 | 48.11 | 72.48 | 74.56 | -0.39 | -5.87 | 0.42 | 0.38 | 6.91 |
| 6 | 52.60 | 76.87 | 79.12 | -1.87 | -5.21 | 0.37 | 0.35 | 6.26 |
| 7 | 58.06 | 81.32 | 83.27 | -1.32 | -4.30 | 0.40 | 0.38 | 5.48 |
| 8 | 62.21 | 85.87 | 87.42 | -0.79 | -3.91 | 0.48 | 0.35 | 5.20 |
| 9 | 65.47 | 89.99 | 90.80 | -0.33 | -2.67 | 0.52 | 0.31 | 4.81 |
| 10 | 67.05 | 92.33 | 93.47 | -0.49 | -3.61 | 0.56 | 0.26 | 4.77 |
| 11 | 67.68 | 93.03 | 94.07 | -0.45 | -3.92 | 0.52 | 0.31 | 4.90 |
| 12 | 66.87 | 92.29 | 93.21 | 0.46 | -3.86 | 0.53 | 0.29 | 5.34 |
| 13 | 64.75 | 90.11 | 91.39 | -0.95 | -4.08 | 0.52 | 0.28 | 5.49 |
| 14 | 61.51 | 87.03 | 88.57 | -0.89 | -5.00 | 0.44 | 0.34 | 5.73 |
| 15 | 55.76 | 81.27 | 82.81 | -0.42 | -6.03 | 0.38 | 0.34 | 6.61 |
| 16 | 49.74 | 76.57 | 78.49 | -1.33 | -6.76 | 0.37 | 0.36 | 6.99 |
| 17 | 44.69 | 71.43 | 73.05 | -1.80 | -7.13 | 0.47 | 0.29 | 7.14 |
| 18 | 37.66 | 63.37 | 64.98 | -0.99 | -7.28 | 0.54 | 0.27 | 7.85 |
| 19 | 32.10 | 56.29 | 57.77 | -2.04 | -7.15 | 0.42 | 0.46 | 7.91 |
| 20 | 27.46 | 50.21 | 51.28 | -1.49 | -5.80 | 0.44 | 0.36 | 7.66 |
| 21 | 21.42 | 42.19 | 43.61 | -3.15 | -6.47 | 0.36 | 0.50 | 7.44 |
| 22 | 19.89 | 40.98 | 42.47 | -3.00 | -6.81 | 0.39 | 0.48 | 7.56 |
| 23 | 17.93 | 39.54 | 40.90 | -1.94 | -7.49 | 0.29 | 0.62 | 7.57 |
| 24 | 17.93 | 39.51 | 40.72 | -1.52 | -6.77 | 0.23 | 0.64 | 8.60 |
| 25 | 20.10 | 43.23 | 45.04 | -3.39 | -7.48 | 0.31 | 0.58 | 8.33 |
| 26 | 22.81 | 45.91 | 47.85 | -3.00 | -7.16 | 0.42 | 0.47 | 8.48 |

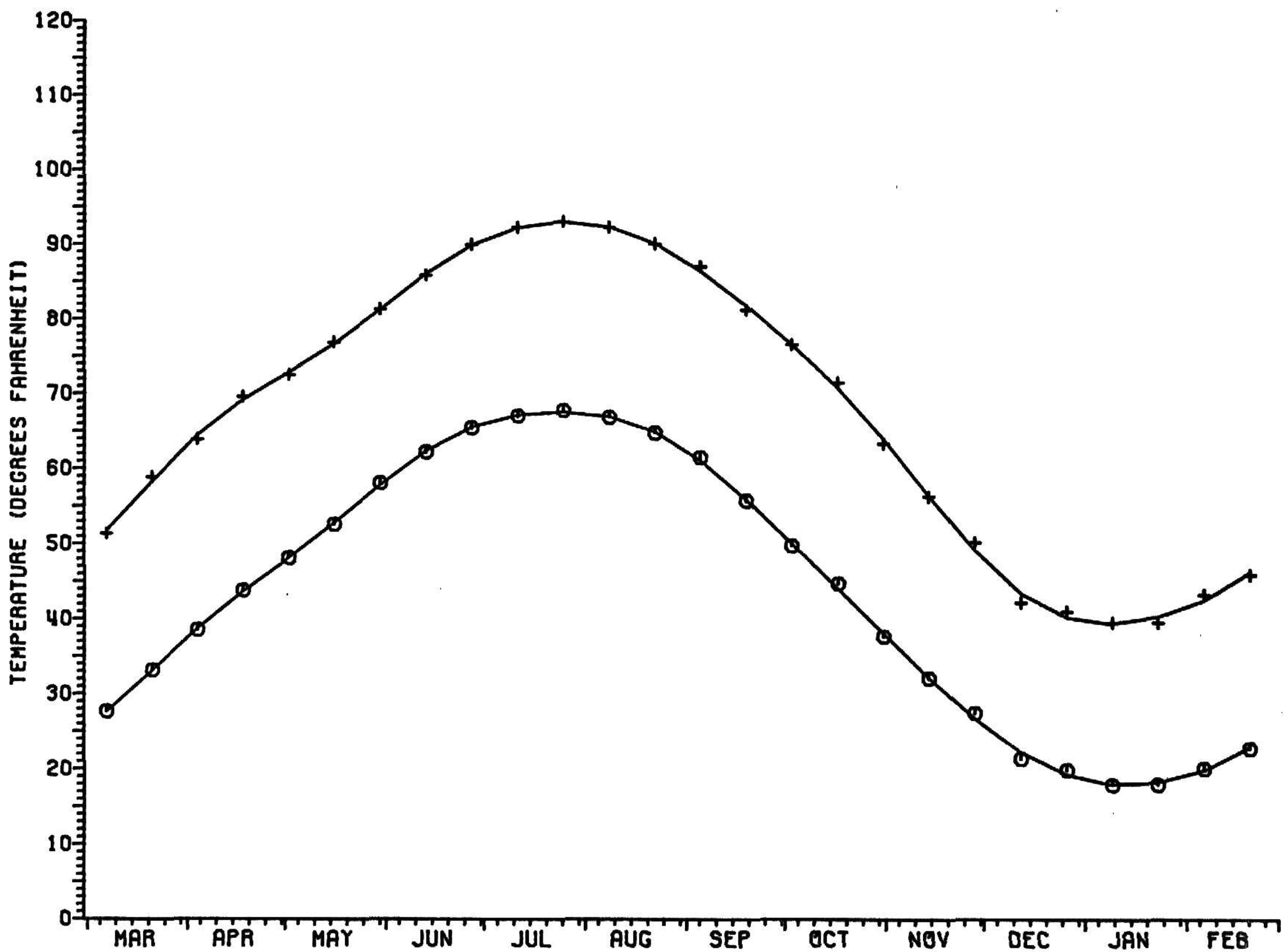



Figure 4. Manhattan Average Daily Temperature Extremes ($\overline{L}_t$ and $\overline{H}_t$)

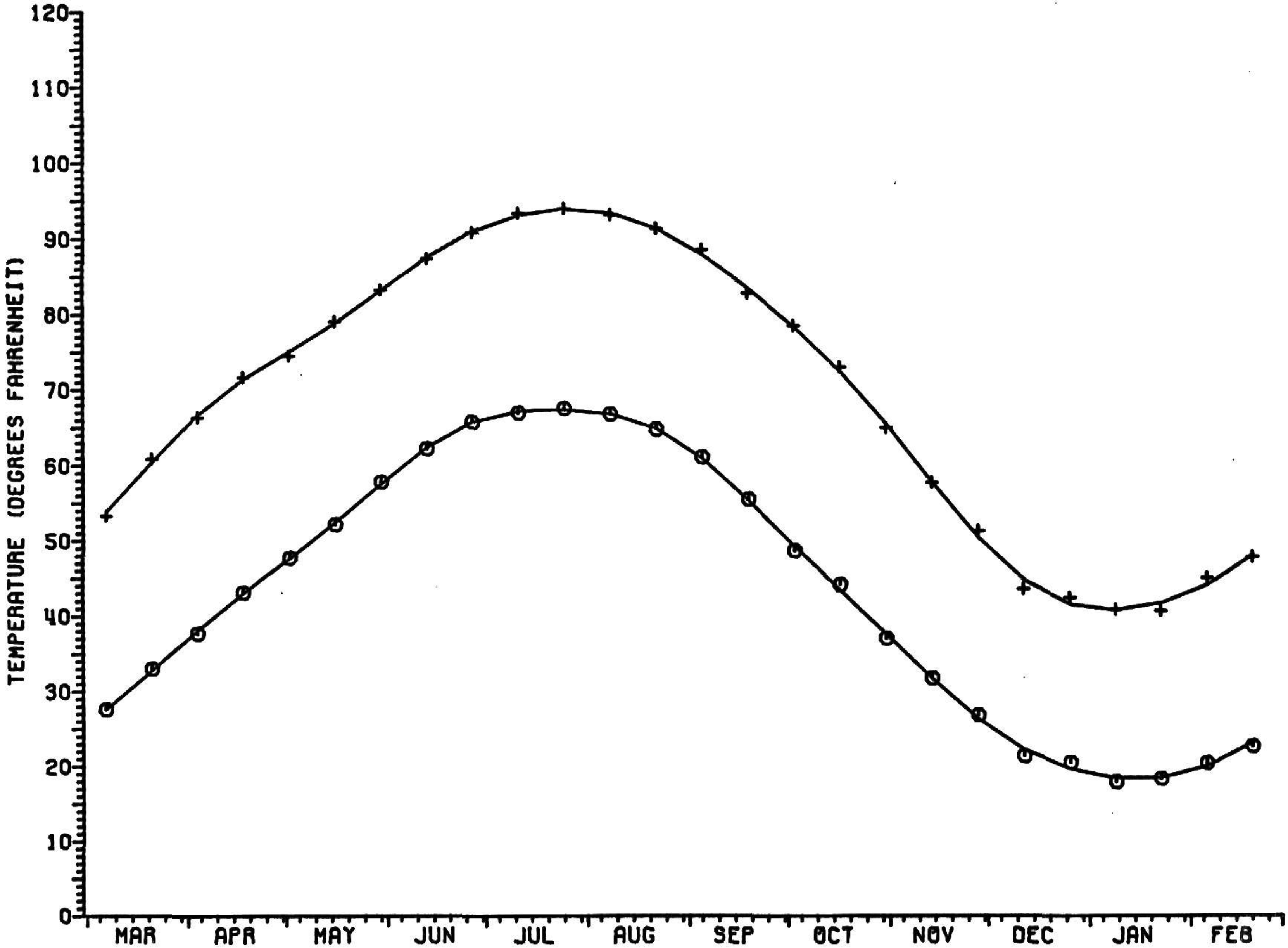
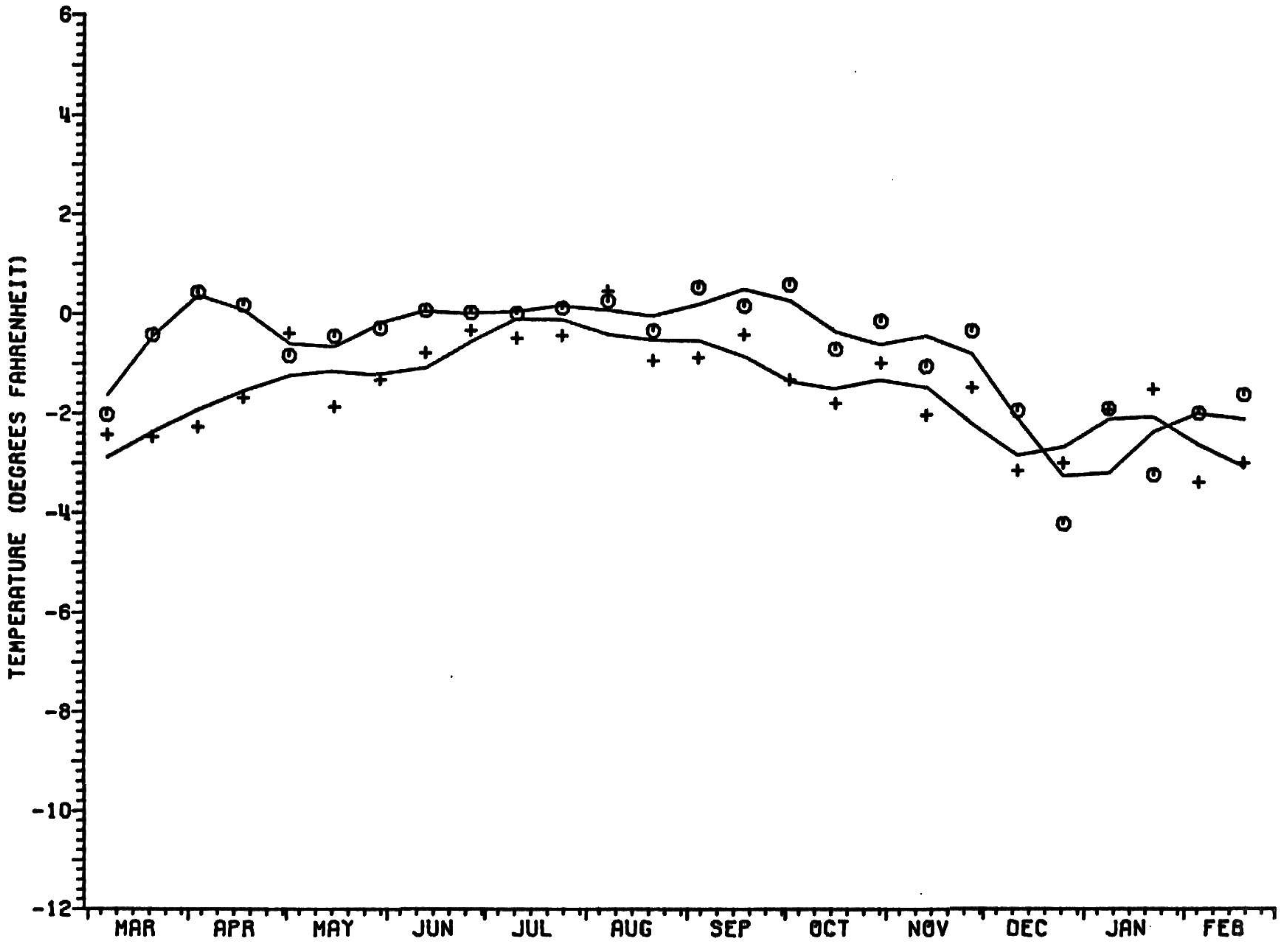
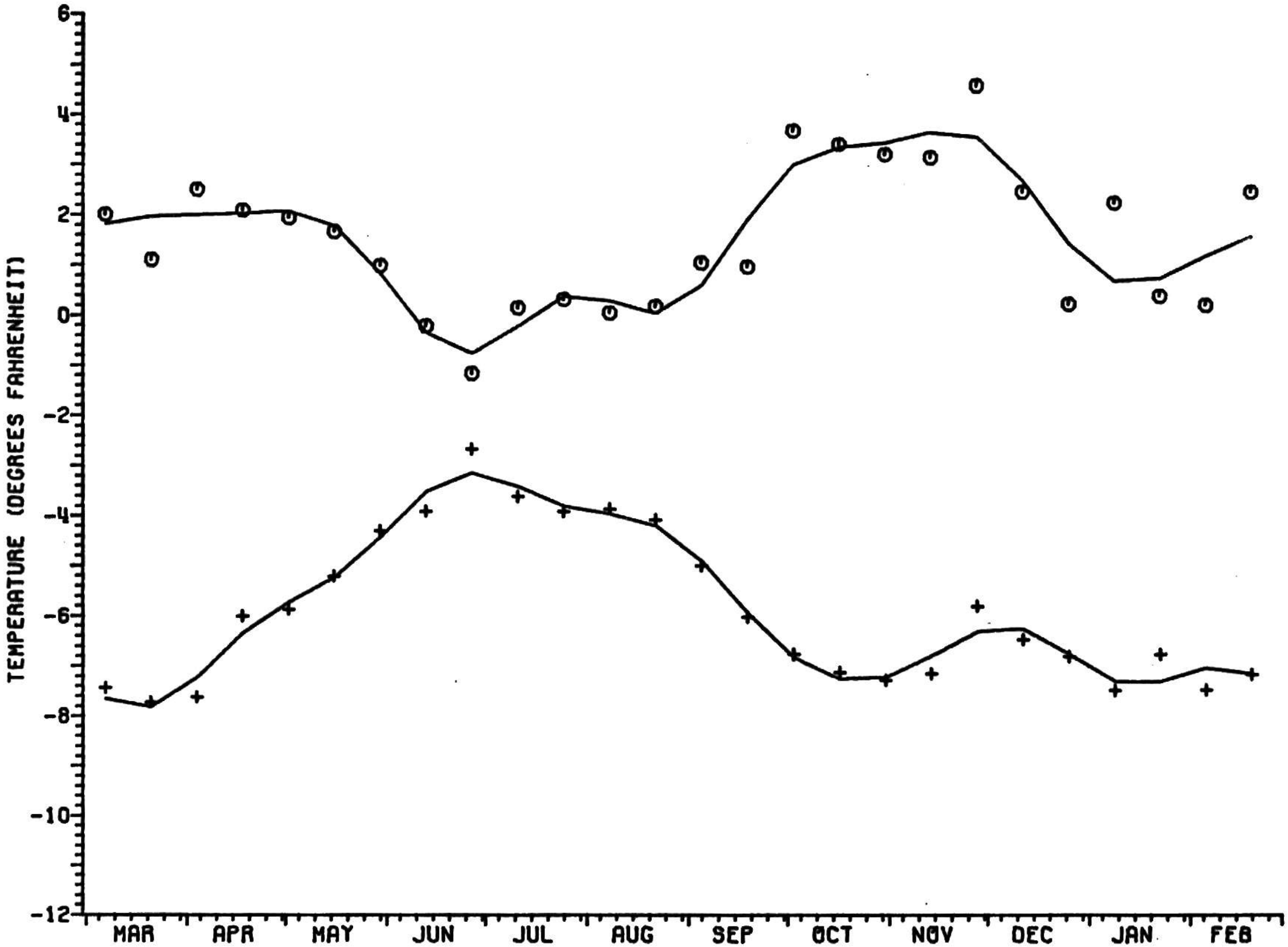



Figure 5. Manhattan Regression Constant Coefficients ($C_L$ and $C_H$)




<u>Figure 6</u>. Manhattan Day t-1 Precipitation Coefficients ($C_{L,t-1}$ and $C_{H,t-1}$)




<u>Figure 7</u>. Manhattan Day t Precipitation Coefficients ($C_{L,t}$ and $C_{H,t}$)

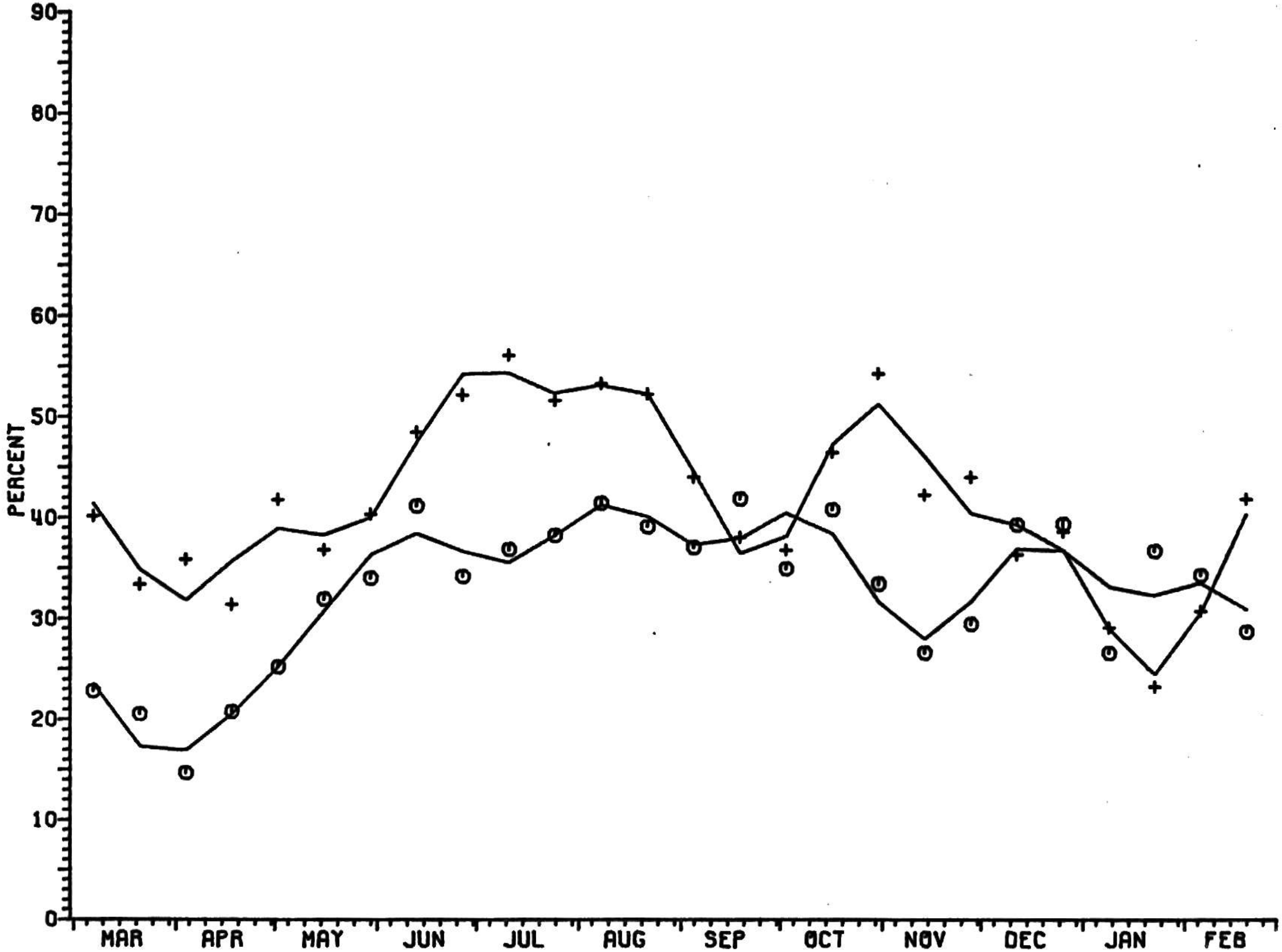



Figure 8. Manhattan Coefficients for 24-hour Carryover ($C_{LL}$ and $C_{HH}$)

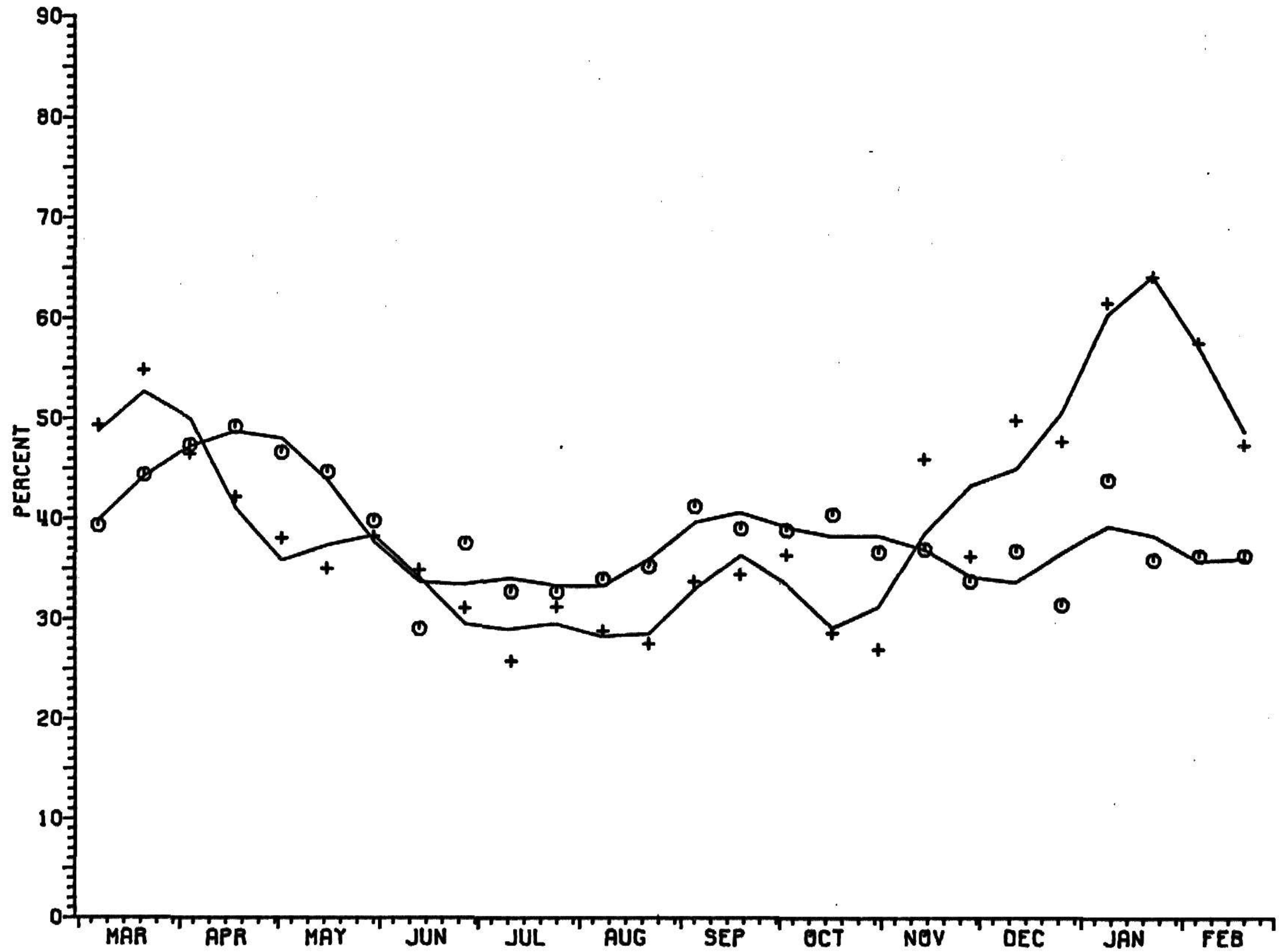



Figure 9. Manhattan Coefficients for 12-hour Carryover ($C_{HL}$ and $C_{LH}$)

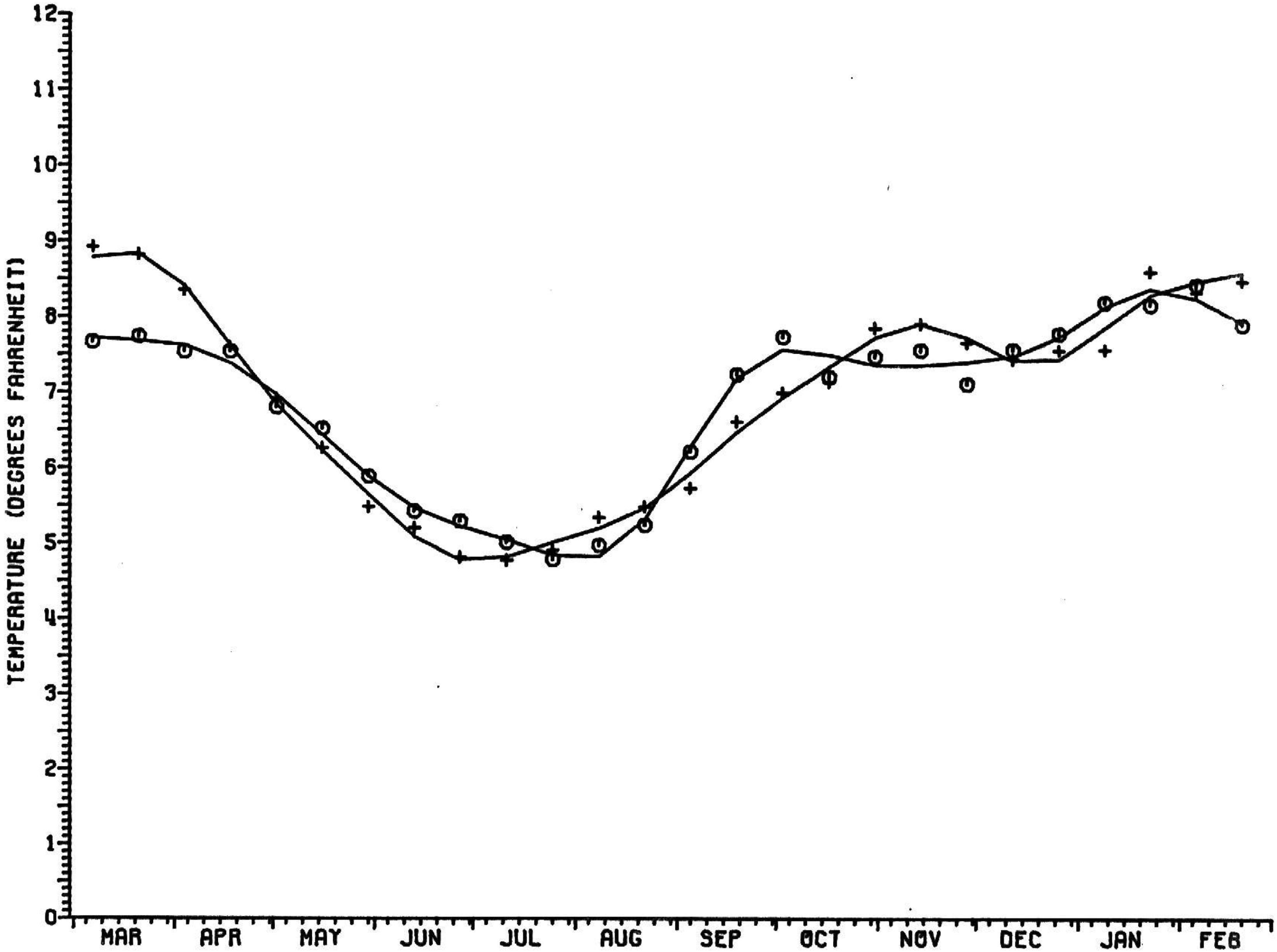



Figure 10. Manhattan Standard Deviations for Error ($s_L$ and $s_H$)

desired. The term of order 0, $A_0$, is the annual average. The first harmonic is the annual cycle, the second is a semi-annual cycle, etc. Some harmonics may have physical meaning (e.g., the 13th may represent the effect of lunar cycles), but in general the number of harmonics required for a good fit reflects nothing more than the deviation of the observed cycle from a simple sine wave (i.e., the first harmonic).

HARFIT, a program of the Kansas Agricultural Experiment Station Weather Data Library, was used to fit Fourier coefficients to the parameter estimates. It also plotted and listed the smoothed data points. HARFIT is built around the subroutine FORIT, from the IBM scientific Subroutine Package [15], which has been modified to accept an even number of periods in the annual cycle (the modification consists of replacing the expression 2*N+1 by N).

The smoothed parameters for the nine Kansas stations and for the average across Kansas are given in Tables 2 - 11. Six harmonics are used to generate each column, although comparisons between stations indicate that more smoothing is justified. Four harmonics should be adequate for most purposes, and two harmonics may even be sufficient; the remaining terms in the summation are ignored. The Fourier coefficients for each station and for the average are listed in Tables 12 - 21 and the coefficients for the constants and first harmonics are mapped in Figures 18 - 24.

Since $\bar{L}_{t-1}$ and $\bar{L}_t$ are identical except for a one-day shift, they are henceforth represented by $\bar{L}_t$ alone. Slight, but cumulative, errors will result if the one-day shift is not reconstructed before use in simulation models.

There are 10 regression coefficients, two average temperature extremes, and two standard deviations for error. If four harmonics are used, the number of parameters is 126, as opposed to 288 for Lundgren's model.

STATEWIDE PATTERNS

The average minimum and maximum temperatures, $\bar{L}_t$ and $\bar{H}_t$, and the regression coefficients $C_L$ and $C_H$ all follow the same annual pattern (see Figures 11 and 12); the annual cycle may be approximated very well by a first-order harmonic, although even two harmonics fail to fit the bulge in April and the peak in July. The values of $\bar{L}_t$ and $C_L$ tend to be higher in southeastern Kansas than in the northwest, particularly during winter. $\bar{H}_t$ and $C_H$ tend to be higher in the southwest than in the northeast. Detailed maps with isotherms for the monthly average minimum and maximum temperatures are available at the Weather Data Library; the patterns are not simple ones.

The effect of precipitation on day t-1 is to reduce the extreme temperatures by about two degrees, although the minimum is actually increased slightly at some stations during summer. The greatest cooling occurs in October and November for the minimum and in December and January for the maximum (see Fig. 13); this shift of two months causes minimum temperatures to be cooled more than maximum temperatures during winter. Values of $C_{L,t-1}$ are fairly constant across the state, but those for

$C_{H,t-1}$ are highest in the southeast except during winter.

The occurrence of precipitation on day t has a large effect on the temperatures for day t, as would be expected. During summer the minimum is reduced by one degree and the maximum is reduced by three degrees; these values are constant across the state. During the rest of the year $C_{L,t}$ and $C_{H,t}$ tend to be more negative than the state average (see Fig. 14) in the west and less negative in the east.

The estimates of $C_{LL}$ and $C_{HH}$, representing 24-hour carryover of temperature deviations, vary irregularly throughout the year (see Fig. 15). During summer both tend to be greatest in the southeast; in winter $C_{LL}$ is greatest in the northwest and $C_{HH}$ is greatest in the west.

The estimates of $C_{HL}$ and $C_{LH}$, representing 12-hour carryover of temperature deviations, also vary irregularly, although they tend to be more parallel (see Fig. 16), with $C_{HL}$ greatest in the east, while $C_{LH}$ is greatest in the northwest except during winter.

The standard deviations, $s_L$ and $s_H$, of the residual errors indicate lack of fit of the model. They are needed as parameters in the simulation model. The average curves (see Fig. 17) are at a minimum in summer: this reflects the low variance of summer temperatures. The estimates of $s_L$ are greatest in the north during summer and in the east during winter; $s_H$ is always greatest in the northwest.

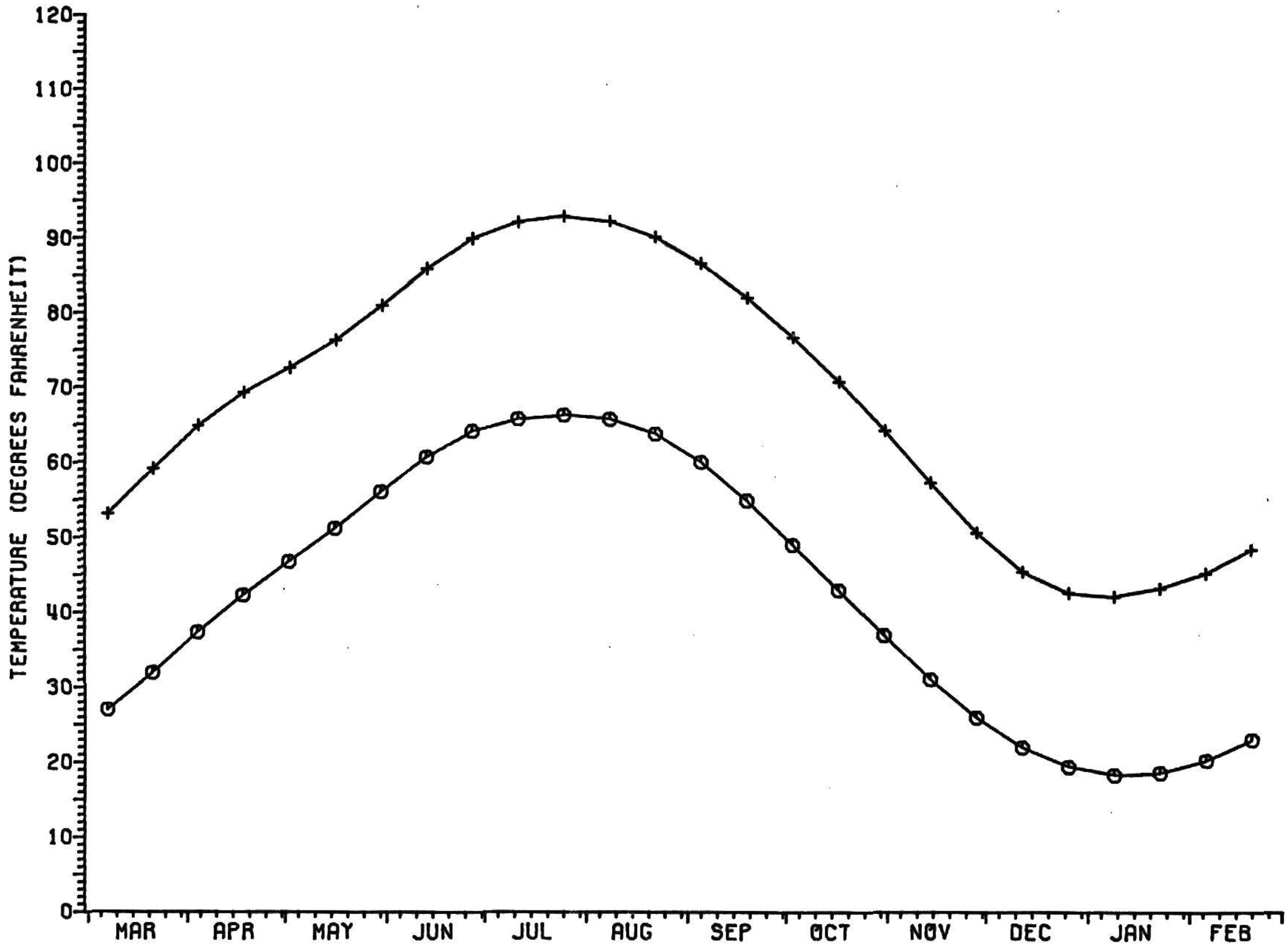



Figure 11. Kansas Average Daily Extreme Temperatures ($\bar{L}_t$ and $\bar{H}_t$)

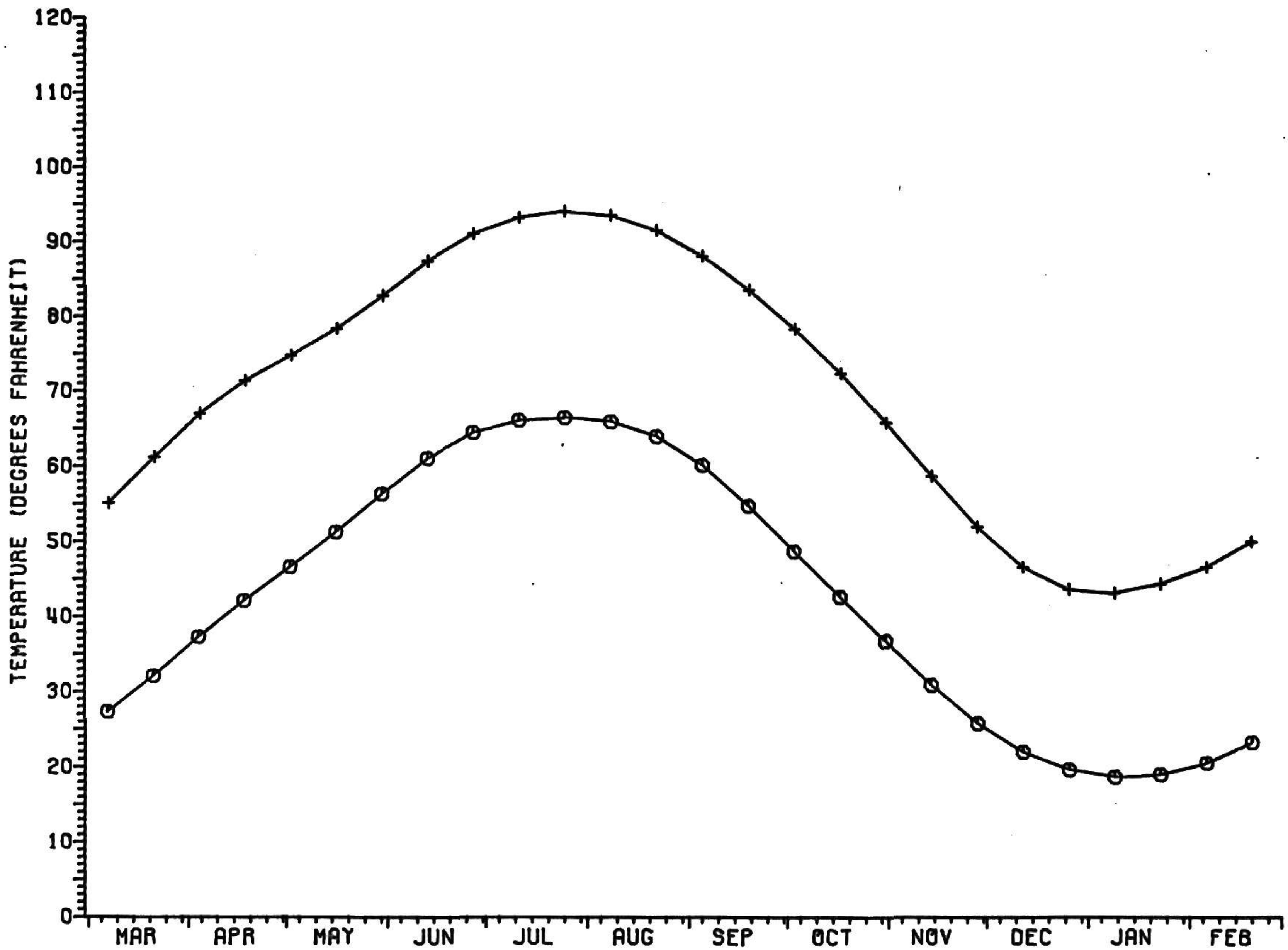
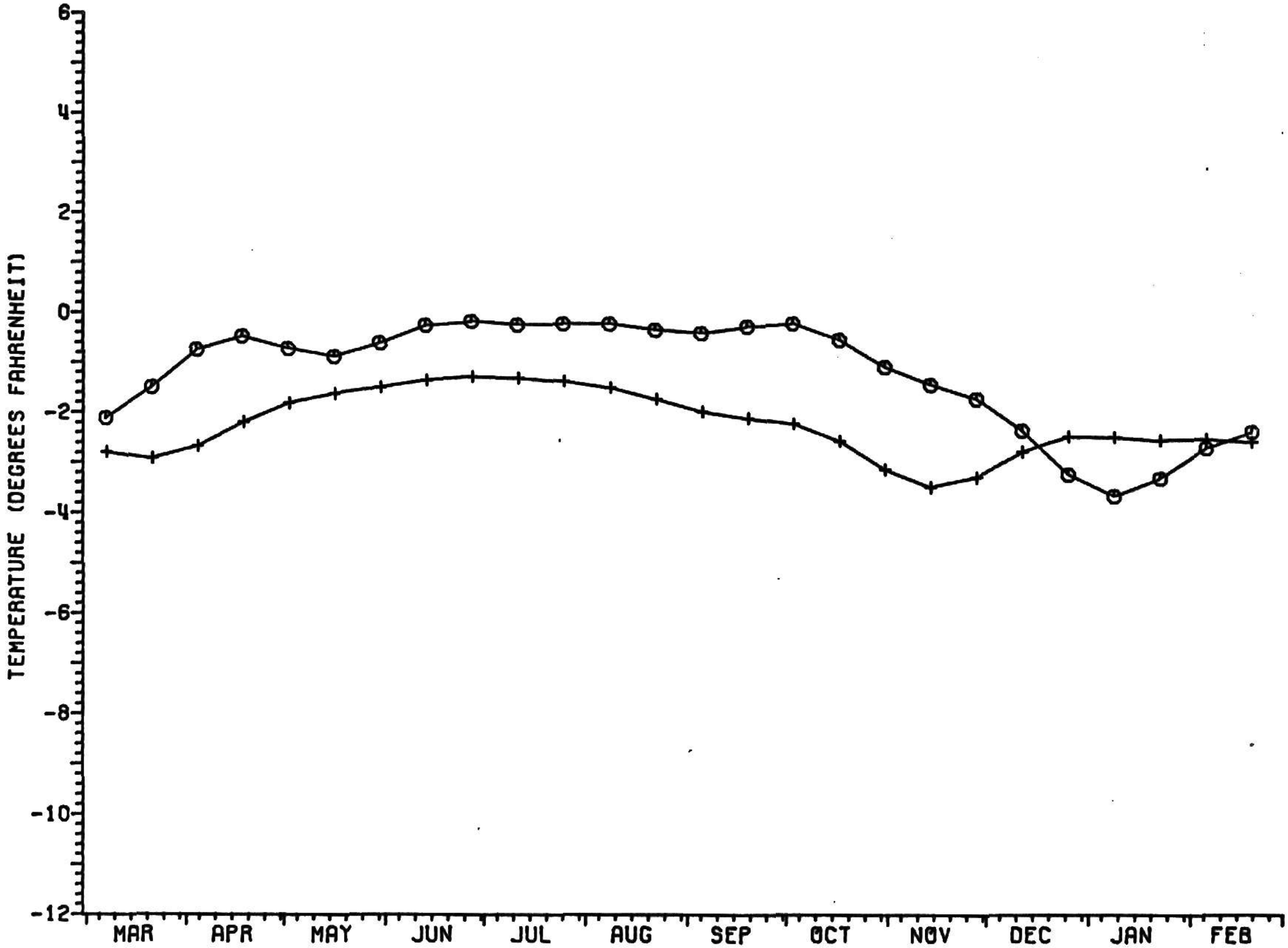
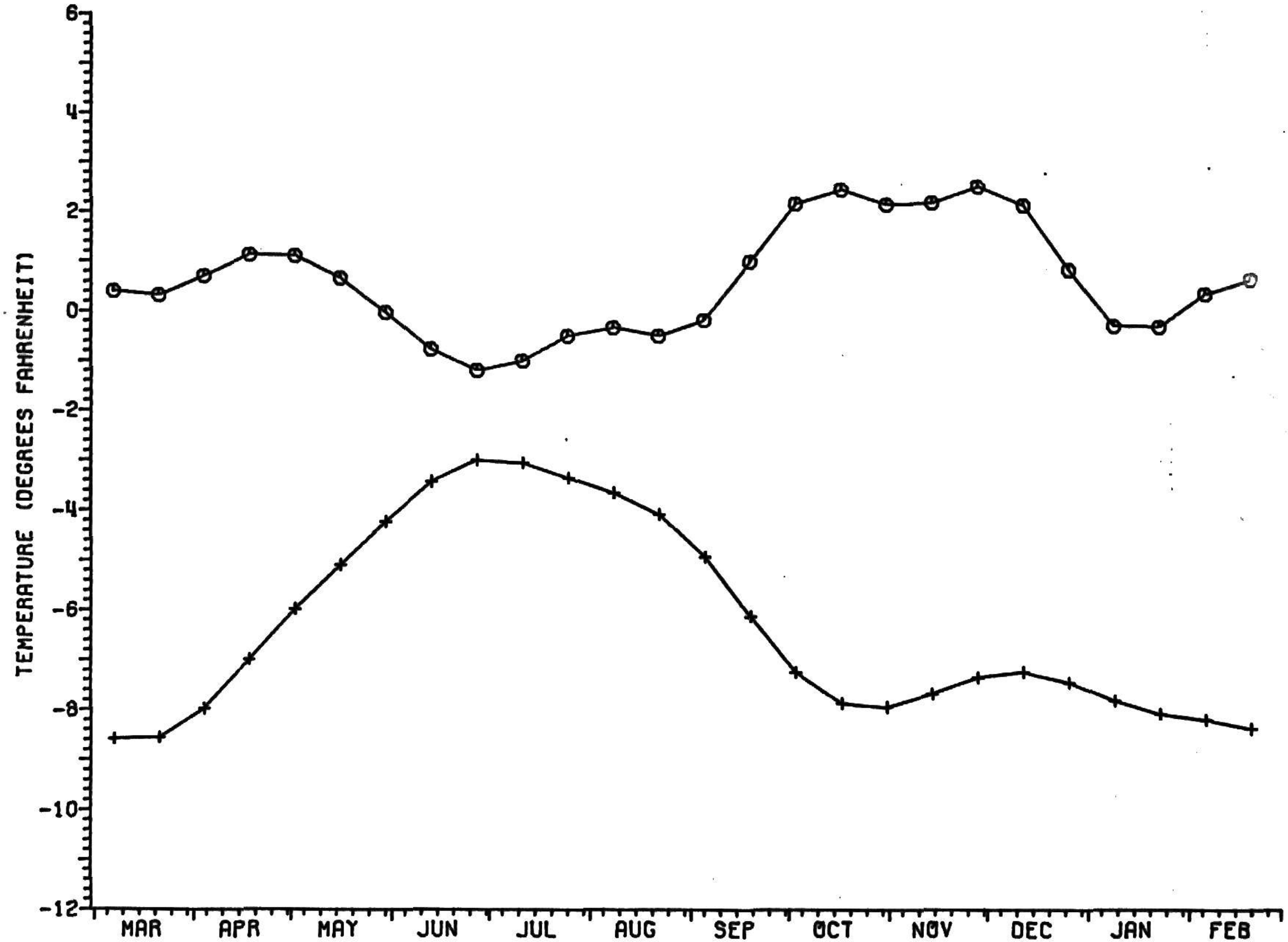



Figure 12. Kansas Regression Constant Coefficients ($C_L$ and $C_H$)




<u>Figure 13</u>. Kansas Day t-1 Precipitation Coefficients ($C_{L,t-1}$ and $C_{H,t-1}$)




<u>Figure 14</u>. Kansas Day t Precipitation Coefficients ($C_{L,t}$ and $C_{H,t}$)

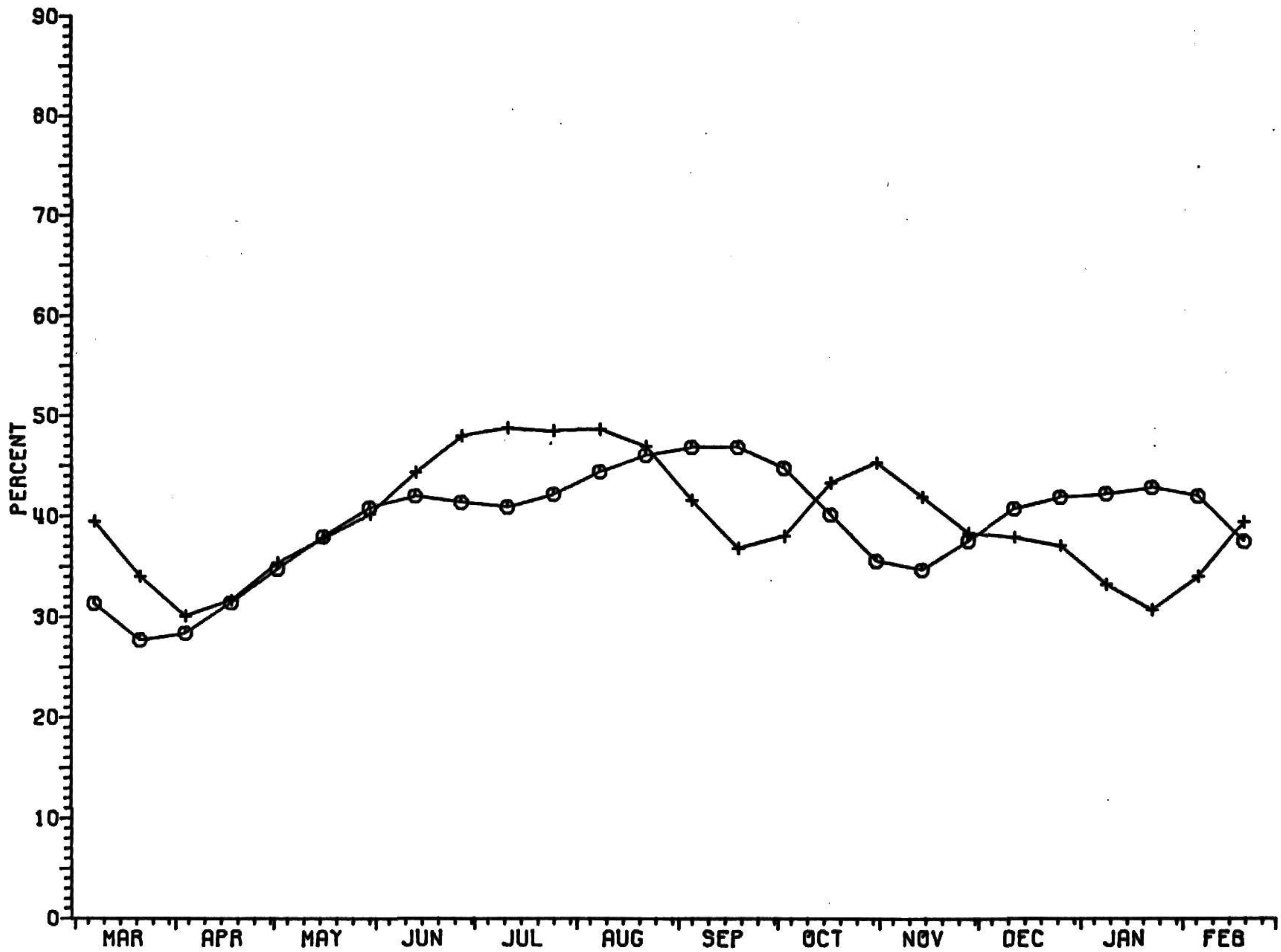



Figure 15. Kansas Coefficients for 24-hour Carryover ($C_{LL}$ and $C_{HH}$)

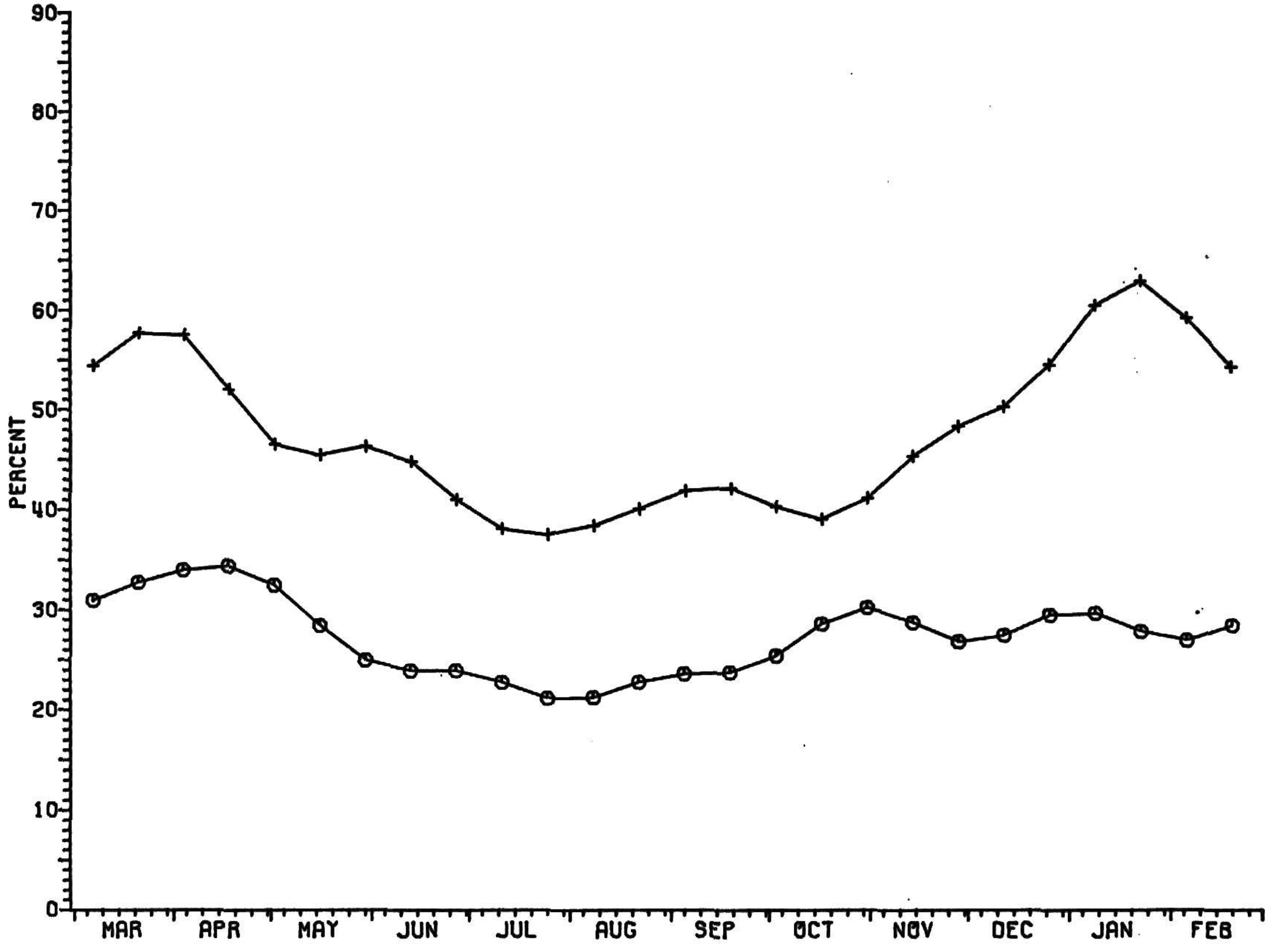



Figure 16. Kansas Coefficients for 12-hour Carryover ($C_{HL}$ and $C_{LH}$)

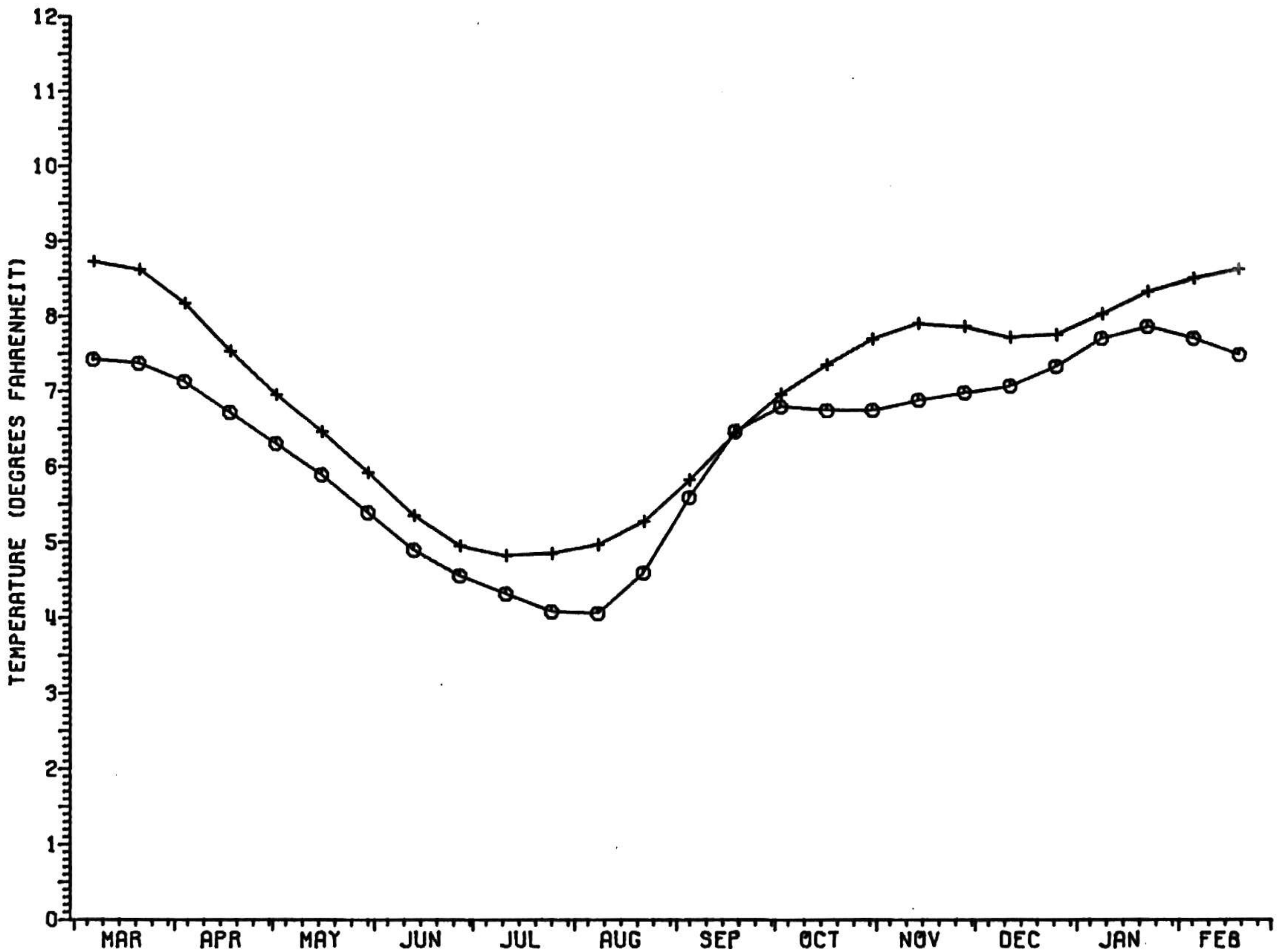



Figure 17. Kansas Standard Deviations for Error ($s_L$ and $s_H$)

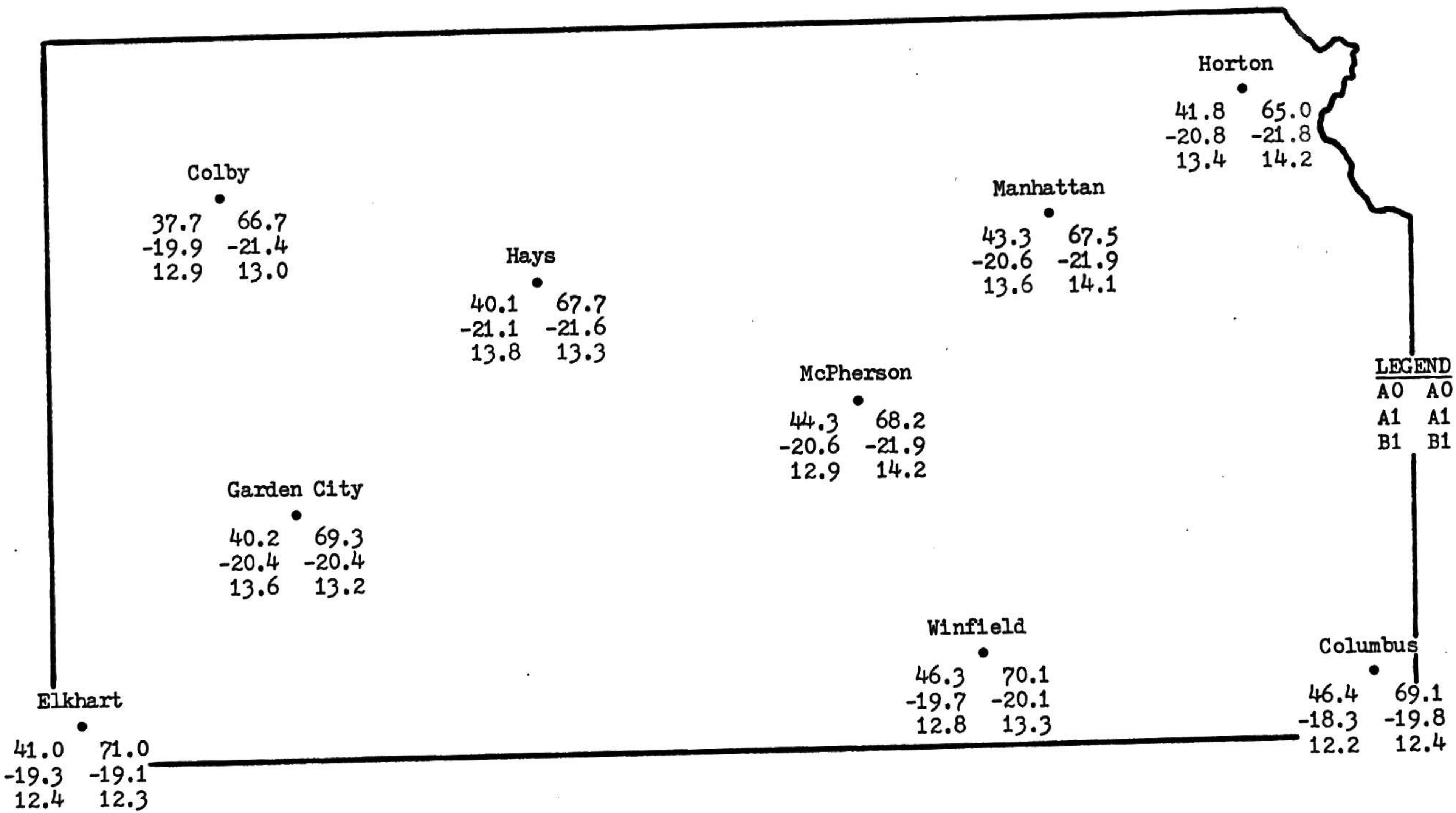



Figure 18. Fourier Coefficients for the Average Temperatures ($\overline{L}_t$ and $\overline{H}_t$)

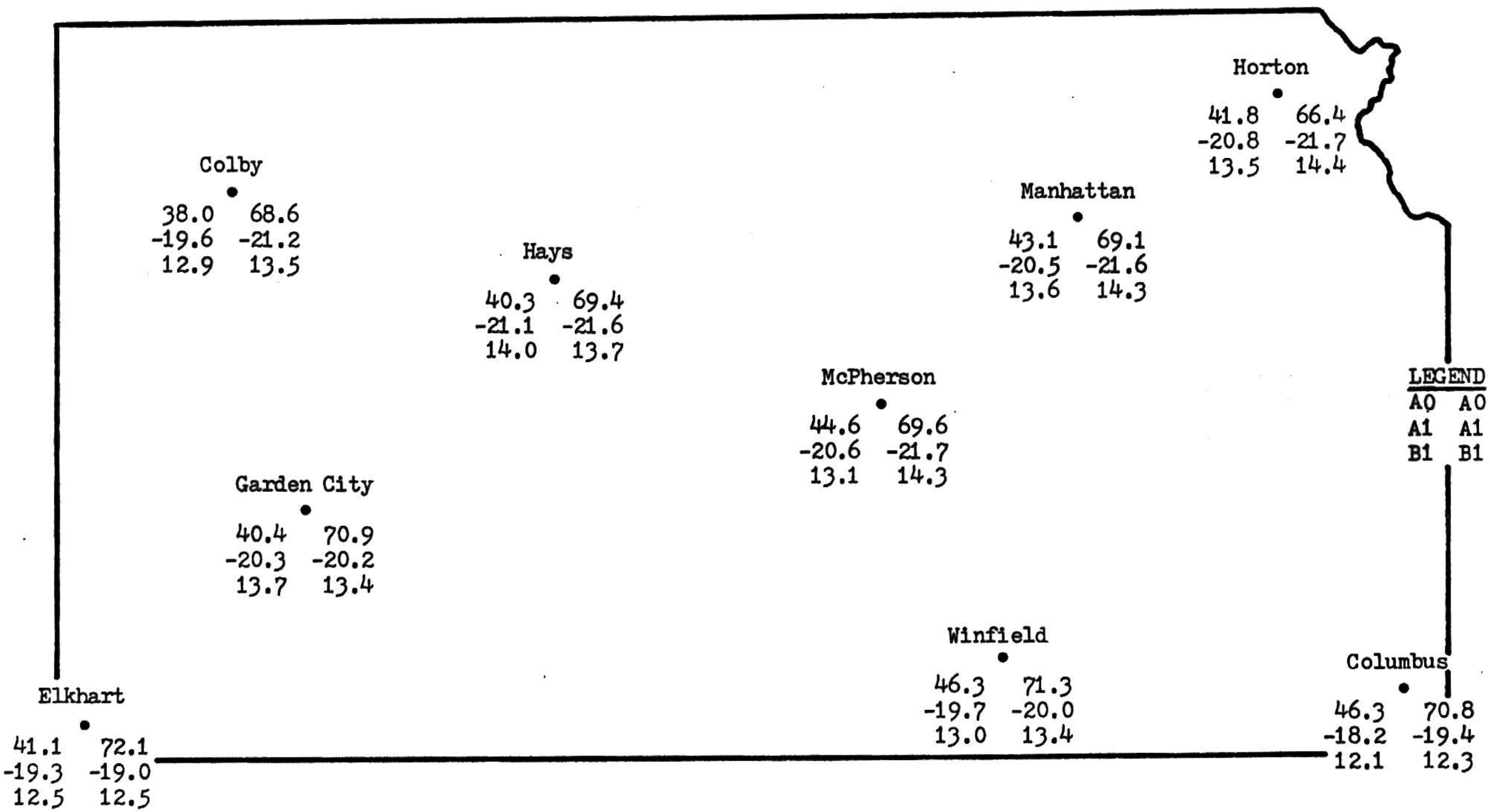
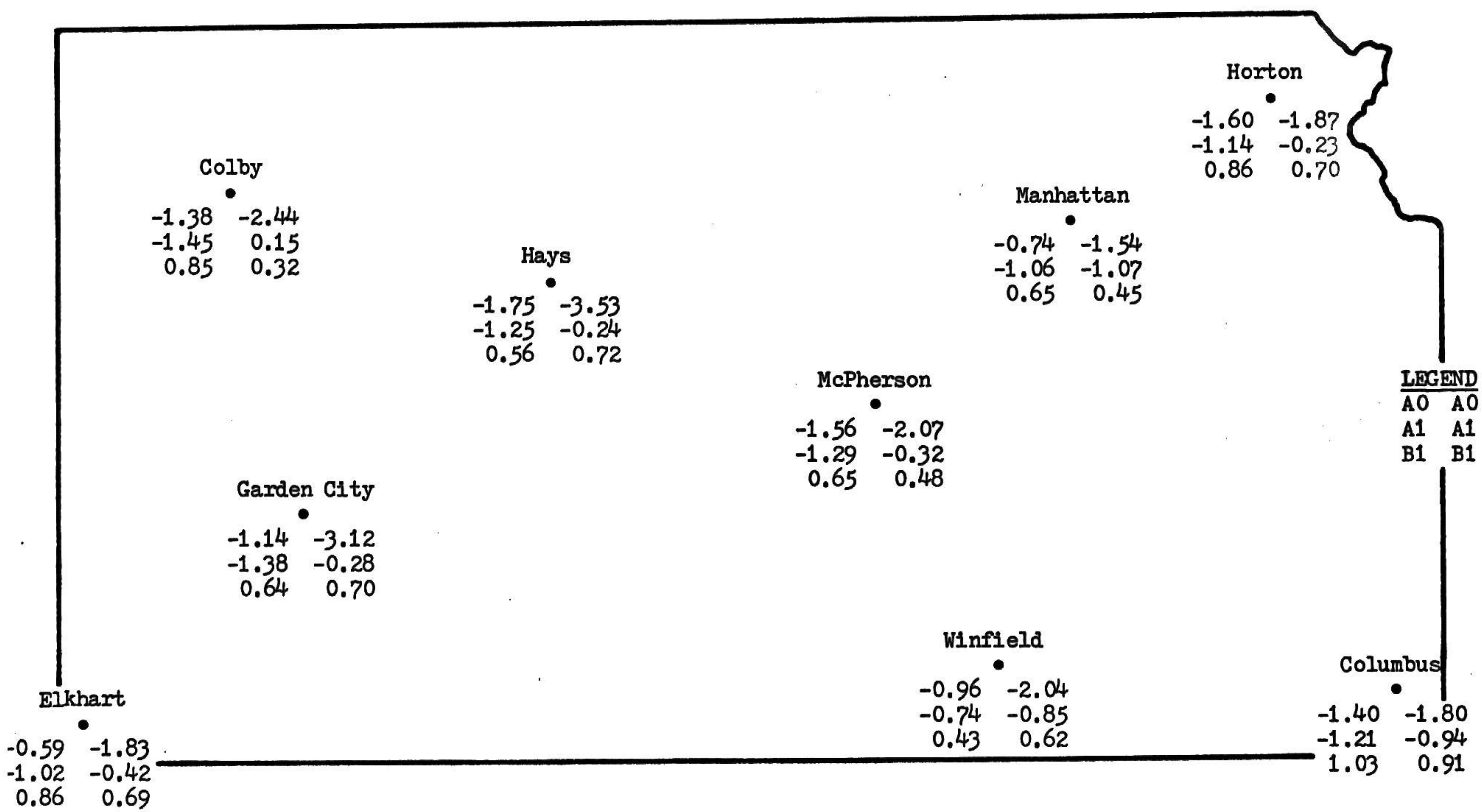



Figure 19. Fourier Coefficients for the Constant Coefficient ($C_L$ and $C_H$)




<u>Figure 20</u>. Fourier Coefficients for Day t-1 Precipitation ($C_{L,t-1}$ and $C_{H,t-1}$)

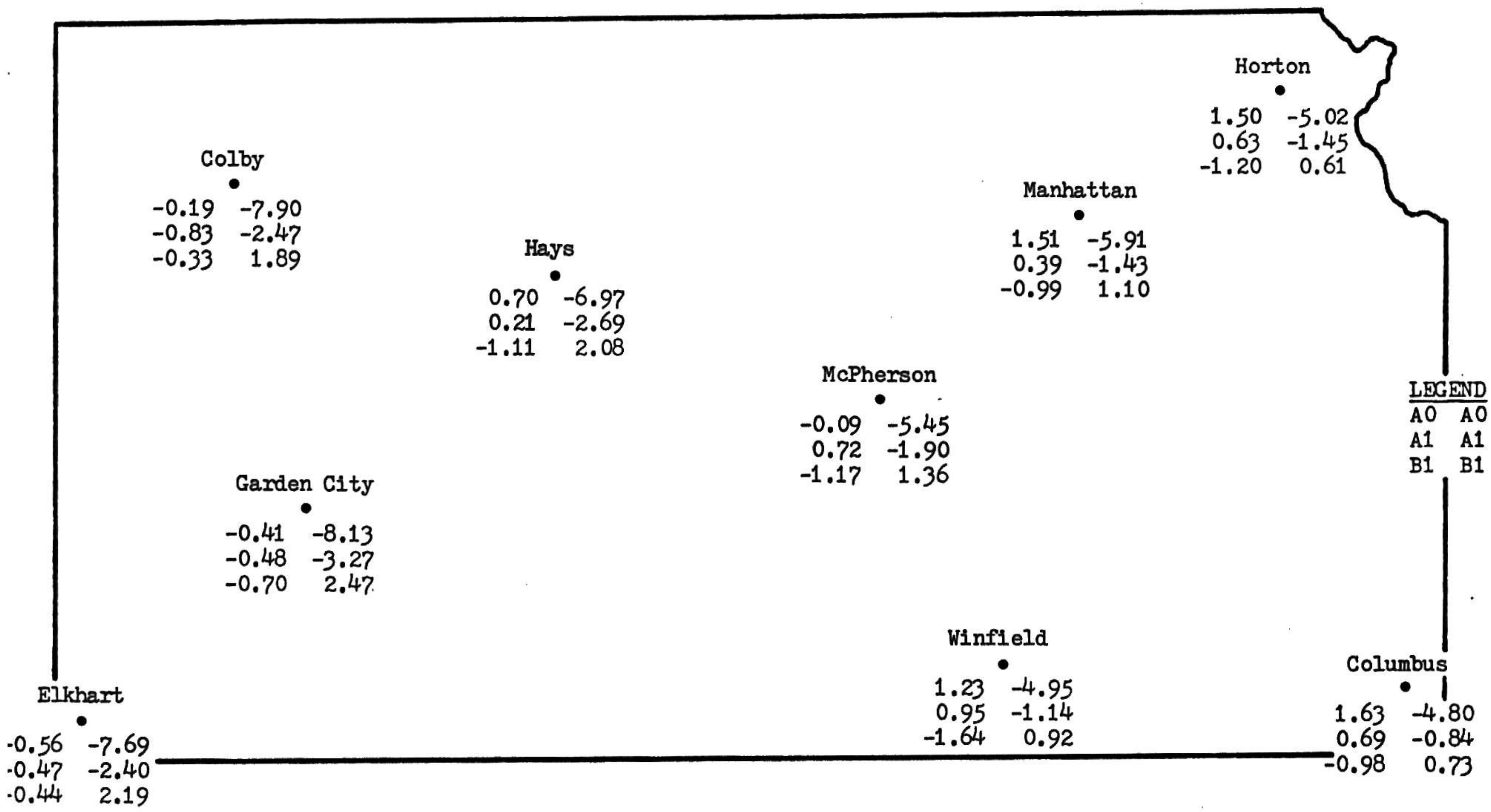



Figure 21. Fourier Coefficients for Day t Precipitation ($C_{L,t}$ and $C_{H,t}$)

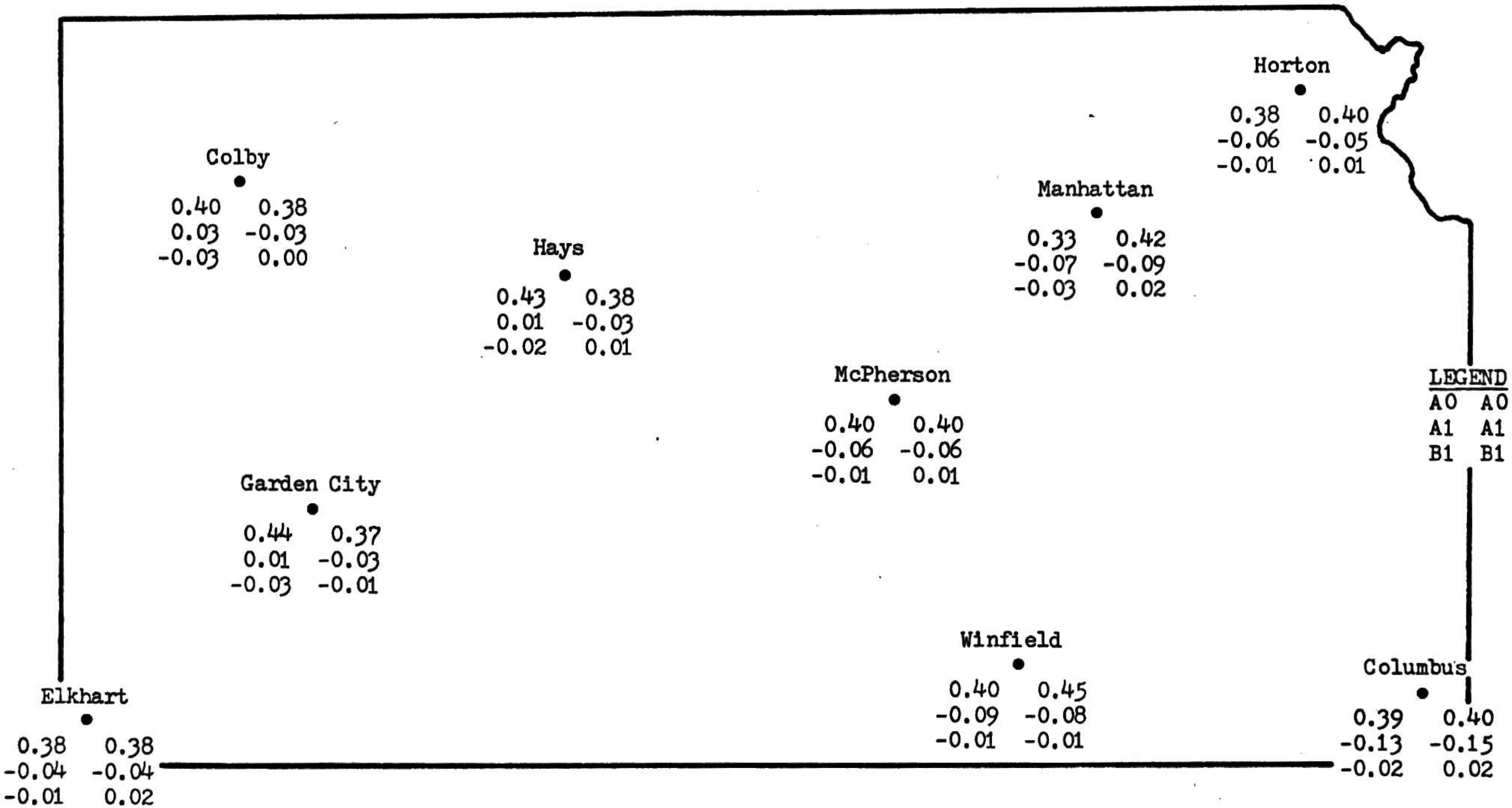



Figure 22. Fourier Coefficients for 24-hour Carryover ($C_{LL}$ and $C_{HH}$)

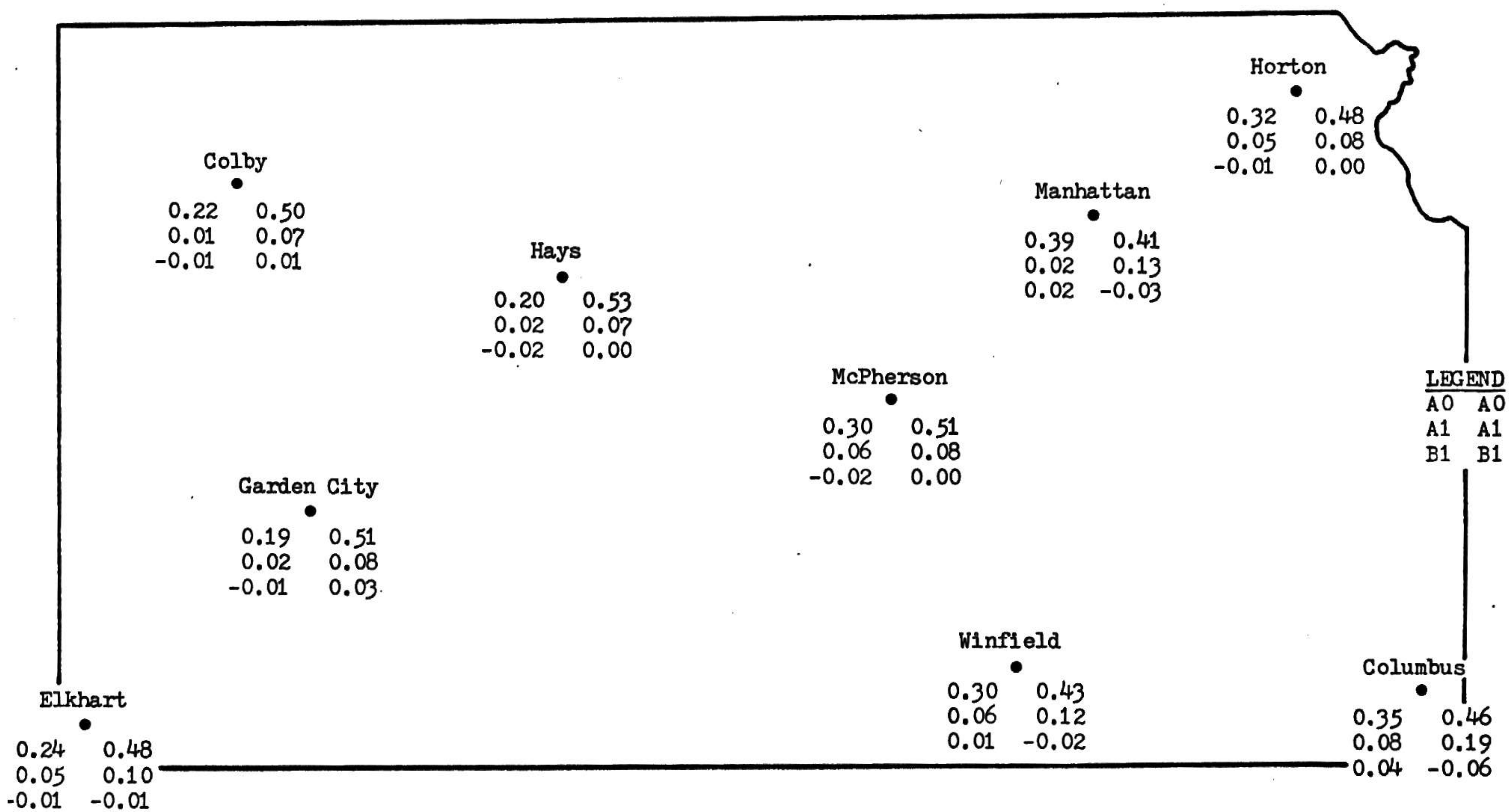



Figure 23. Fourier Coefficients for 12-hour Carryover ($C_{HL}$ and $C_{LH}$)

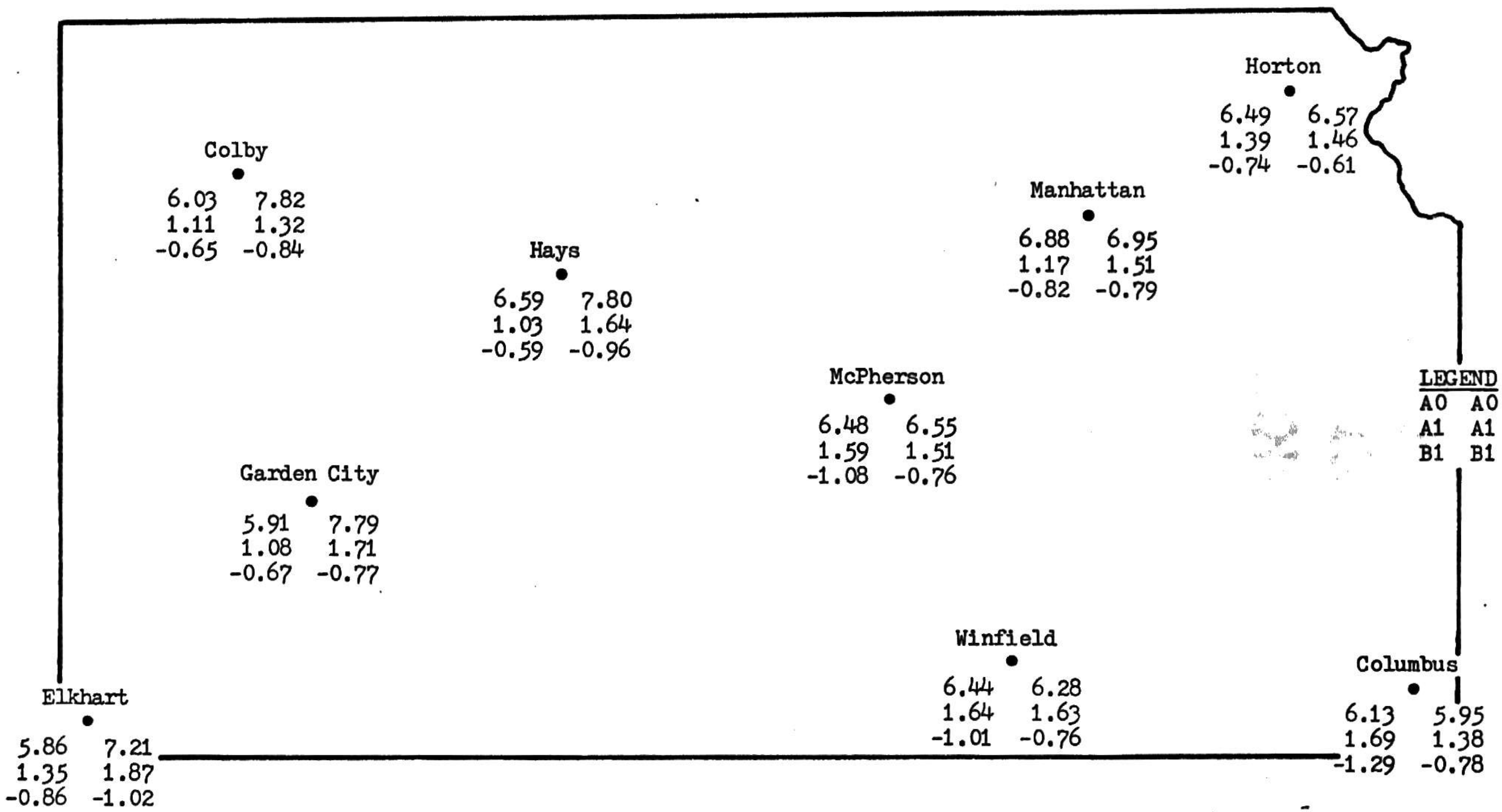



Figure 24. Fourier Coefficients for Standard Deviations ($s_L$ and $s_H$)

## SIMULATION

### THE SIMULATION MODEL

Although this study is concerned primarily with a model for daily extreme temperatures, simulation of daily weather records requires that some model be used for precipitation. Preliminary investigation established that no suitable regression or covariance model could predict either the occurrence or the amount of precipitation, much less its distribution. It was therefore decided to use the Markov model of Feyerherm and Bark [3,5,8] for determination of wet sequences and to use Ison's model [6,7] for the amount of precipitation in a wet spell. No model was available for the distribution of precipitation within a wet spell.

The equations used for simulating temperatures,

$$L_t = C_L + C_{L,t-1}I_{t-1} + C_{L,t}I_t + C_{LL}\cdot(L_{t-1} - \bar{L}_{t-1}) + C_{HL}\cdot(H_{t-1} - \bar{H}_{t-1}) + s_L D_1$$

$$H_t = C_H + C_{H,t-1}I_{t-1} + C_{H,t}I_t + C_{HH}\cdot(H_{t-1} - \bar{H}_{t-1}) + C_{LH}\cdot(L_t - \bar{L}_t) + s_H D_2$$

differ from the regression equations only by the final terms. $D_1$ and $D_2$ are pseudo-random normal deviates generated by the method of Box and Mueller [16]; they are multiplied by the estimated standard deviations of the error terms. It is this feature that makes the simulation of temperature realistic; without a random term year after year of "average" weather would be generated.

THE SIMULATION PROGRAM

The FORTRAN IV program used to generate simulated weather records is named SIMREC (Appendix B). It is neither as general nor as complicated as the regression program; most changes must be made in the coding rather than the parameter cards.

More than half of the main program, SIMREC, is devoted to reading the parameter estimates, expanding them, and printing the results. The printouts could be eliminated, if they are not desired, and the expanded parameter tables could be saved on disk for repeated use.

The Markov transition probabilities are expanded by linear interpolation from 52 points per parameter to 365 points; this eliminated repeated interpolation during the simulation phase of the program. It may be, however, that the 52 values were sufficiently accurate without interpolation, or that the increased accuracy of harmonic interpolation is needed. The transition probabilities might also be entered in the form of Fourier coefficients. During the simulation phase pseudo-random numbers distributed uniformly between 0.0 and 0.9999999 are compared to the transition probabilities to determine whether a day is to be wet or dry.

Ison's gamma parameters [6,7] are expanded into 13 sets of six cumulative distribution functions each. During the simulation phase pseudo-random numbers generated by the congruence method of the IBM subroutine RANDU [15] are searched for in the appropriate cumulative distribution function. A linear search is used although binary search would probably be faster. When the proper interval is found, the corresponding amount of precipitaion is divided equally among the days of the wet spell. When the wet spell exceeds one day, there is no guarantee that the simulated amount of precipitation per day will be greater than 0.01 inch (the cutoff between dry and wet).

SIMREC calls for these precipitations one at a time; it is "unaware" that succeeding precipitations may already have been determined by the subroutines. The precipitation values (or rather their incidences) are introduced into the equations for temperature extremes, along with the temperature deviates from the previous simulated day and the pseudo-random normal deviates. The regression coefficients have also been linearly expanded to 365 points to save time during the simulation phase.

## TESTING THE MODEL

Program SIMREC was used to simulate 70 years of Manhattan data. Since the results were to be compared to the past 70 years of actual data, the original parameter estimates (see Table 1) were used rather than the smoothed ones. The cost of simulation was $5.00 plus about 20 cents per year of data.

The simulated data was summarized using a program of the Weather Data Library. A similar summary for the actual Manhattan data was available. The summary tabulates the means and standard deviations of the temperature extremes by annual, monthly, weekly, and daily periods. Even more extensive statistics are available for the distributions of dry spells, wet spells, and precipitation amounts. Covariances could be investigated with the LINMOD program, but it has not been done.

The average monthly and annual simulated temperatures were very close to averages of the actual temperatures: the annual average was only 0.07 degree too high for the minimum temperature and 0.09 degree too high for the maximum temperature. These values are well within the range of normal stochastic variation.

The standard deviations of the daily temperatures were slightly low, 0.49 degree for the annual average minimum temperature and 0.64 for the annual average maximum. This could be due to any of the following factors. The temperature model assumes normality of the error terms and assuming normality of parameter estimates from a skew distribution may be reducing the variances. The problem might also be related to the use of only one error coefficient for four precipitation histories. Perhaps the most likely explanation may be that the variances of the original temperature observations were underestimated by program LINMOD, which used only single precision in calculations. This effect was estimated using WET,WET Manhattan records in March (the effect would be greater if all the records were used): the mean squares for error were too low by only 0.035, or 0.057%. Means and variances of the model variables were accurate to at least the fifth significant digit. The summary program also uses single precision, but the effect should be the same for both simulated and observed data.

The simulated precipitations were too low both in amount and in variation. The shortage amounted to 1.57 inches per year, although simulation of an additional 30 years lowered this to 1.08 inches per year; neither of these values is significant at the 0.05 or even the 0.20 level. The standard deviation of the annual simulated precipitation total is 5.90 versus 7.97 for the actual data. A breakdown of the precipitation distribution shows that two few small (0.01 to 0.10 inch) and very large (over 1.00 inch) precipitations are being generated. This was to be expected since the Ison model for wet spell precipitations divides the total amount equally among the days of the wet spell.

Amount of precipitation does not enter into the temperature model. Periods of wet and dry days, which do affect temperatures, seem to be adequately simulated. The average number of wet days per year, for instance, is only 0.27 too low. Lundgren found in his work that long wet and dry periods were inadequately simulated. This was established using Palmer Drought Index [2], which has not been applied in the present case. A summary of wet and dry spells showed close conformity to actual distributions.

The Smirnov test could be applied to the distributions of weather variables over the 70 years of observations within one period. This was done for precipitation amounts by Ison [6,7]; no significant differences were found. There seems to be no reason to believe that temperatures do not conform to the normal distribution which is the basis of the simulation model (aside from the underestimation of the error variance).

It is difficult to test annual patterns statistically. There is no reason to doubt that monthly temperature averages have been well simulated, but the pattern of average monthly precipitation totals looks suspiciously high in August and low in September. The Smirnov test may not be used because discrete categories (i.e., months) are involved. The Chi-square test is inappropriate because the values are not count data and are correlated. The proper test is a multivariate profile analysis, which has not been used.

## SUGGESTED RESEARCH

The most needed change in the temperature models is elimination of $C_L$ and $C_H$. These constants could be set equal to $\bar{L}_t$ and $\bar{H}_t$, respectively, with very little distortion of the model. The model could be further simplified by removing the $\bar{L}_t$ and $\bar{H}_t$ terms entirely: using original variables instead of deviates and omitting the constant terms. This would reduce the number of parameters of 90 instead of 126, but would make the model less "fundamental".

There are high negative correlations (close to -0.7) between the parameters $C_{LL}$ and $C_{LH}$ and also between $C_{HH}$ and $C_{LH}$. Perhaps two of these could be eliminated.

It is evident that further work is needed with the precipitation model. The pattern of rainfall within a wet spell affects runoff and erosion, and may affect crop growth. Hourly precipitation patterns may also be important.

Some mechanism is needed whereby temperatures are introduced into the precipitation model. If the simulation were for several stations simultaneously, frontal systems could be modeled; interstation parameters would allow proper movement of precipitation. A language such as GPSS might facilitate such an investigation.

More variables, such as humidity, should be added. Even if hypothetical parameters must be used, this could lead to a more "fundamental" model. Once the basic model is developed, a method should be found to estimate the parameters from available summaries instead of from original data. Finally, multiple regression on latitude, longitude, and altitude should be used to reduce all parameter estimates to these three values. Equivalently, isoline maps may be drawn: these are more graphic but are difficult to insert into computer programs.

Table 2a. Manhattan Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 27.55 | 51.68 | 27.53 | -1.66 | 1.80 | 0.24 | 0.40 | 7.72 |
| 2 | 33.09 | 58.24 | 32.74 | -0.46 | 1.95 | 0.17 | 0.44 | 7.68 |
| 3 | 38.65 | 64.40 | 38.05 | 0.37 | 1.98 | 0.17 | 0.47 | 7.62 |
| 4 | 43.60 | 69.15 | 43.00 | 0.08 | 2.01 | 0.21 | 0.49 | 7.38 |
| 5 | 48.11 | 72.83 | 47.63 | -0.60 | 2.07 | 0.25 | 0.48 | 6.96 |
| 6 | 52.81 | 76.66 | 52.44 | -0.66 | 1.78 | 0.31 | 0.44 | 6.43 |
| 7 | 57.80 | 81.27 | 57.61 | -0.21 | 0.82 | 0.36 | 0.38 | 5.88 |
| 8 | 62.33 | 86.06 | 62.39 | 0.05 | -0.35 | 0.38 | 0.34 | 5.46 |
| 9 | 65.48 | 89.92 | 65.68 | -0.00 | -0.77 | 0.37 | 0.33 | 5.22 |
| 10 | 67.09 | 92.23 | 67.14 | 0.03 | -0.23 | 0.36 | 0.34 | 5.05 |
| 11 | 67.53 | 93.04 | 67.41 | 0.15 | 0.37 | 0.38 | 0.33 | 4.84 |
| 12 | 66.95 | 92.40 | 66.85 | 0.07 | 0.28 | 0.41 | 0.33 | 4.82 |
| 13 | 64.94 | 90.20 | 64.91 | -0.05 | 0.03 | 0.40 | 0.36 | 5.32 |
| 14 | 61.15 | 86.52 | 60.95 | 0.18 | 0.58 | 0.37 | 0.40 | 6.28 |
| 15 | 55.92 | 81.83 | 55.35 | 0.50 | 1.89 | 0.38 | 0.41 | 7.19 |
| 16 | 50.04 | 76.59 | 49.28 | 0.27 | 2.99 | 0.41 | 0.39 | 7.57 |
| 17 | 44.07 | 70.75 | 43.43 | -0.36 | 3.34 | 0.38 | 0.38 | 7.49 |
| 18 | 38.12 | 64.00 | 37.62 | -0.63 | 3.42 | 0.32 | 0.38 | 7.36 |
| 19 | 32.22 | 56.47 | 31.72 | -0.45 | 3.63 | 0.28 | 0.37 | 7.35 |
| 20 | 26.75 | 49.16 | 26.32 | -0.81 | 3.55 | 0.32 | 0.34 | 7.39 |
| 21 | 22.29 | 43.46 | 22.21 | -2.10 | 2.68 | 0.37 | 0.34 | 7.47 |
| 22 | 19.33 | 40.25 | 19.63 | -3.27 | 1.42 | 0.37 | 0.37 | 7.73 |
| 23 | 17.99 | 39.41 | 18.38 | -3.21 | 0.66 | 0.33 | 0.39 | 8.13 |
| 24 | 18.18 | 40.27 | 18.41 | -2.39 | 0.71 | 0.32 | 0.38 | 8.37 |
| 25 | 19.82 | 42.45 | 19.94 | -2.01 | 1.15 | 0.34 | 0.36 | 8.24 |
| 26 | 22.96 | 46.18 | 23.08 | -2.11 | 1.55 | 0.31 | 0.36 | 7.92 |

Table 2b. Manhattan Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 27.55 | 51.68 | 53.79 | -2.89 | -7.65 | 0.41 | 0.49 | 8.78 |
| 2 | 33.09 | 58.24 | 60.47 | -2.39 | -7.82 | 0.35 | 0.53 | 8.83 |
| 3 | 38.65 | 64.40 | 66.66 | -1.93 | -7.24 | 0.32 | 0.50 | 8.41 |
| 4 | 43.60 | 69.15 | 71.38 | -1.56 | -6.35 | 0.36 | 0.41 | 7.62 |
| 5 | 48.11 | 72.83 | 75.05 | -1.25 | -5.73 | 0.39 | 0.36 | 6.84 |
| 6 | 52.81 | 76.66 | 78.81 | -1.15 | -5.23 | 0.38 | 0.37 | 6.23 |
| 7 | 57.80 | 81.27 | 83.17 | -1.23 | -4.43 | 0.40 | 0.38 | 5.65 |
| 8 | 62.33 | 86.06 | 87.54 | -1.09 | -3.52 | 0.47 | 0.34 | 5.09 |
| 9 | 65.48 | 89.92 | 91.00 | -0.57 | -3.14 | 0.54 | 0.30 | 4.77 |
| 10 | 67.09 | 92.23 | 93.15 | -0.10 | -3.42 | 0.54 | 0.29 | 4.81 |
| 11 | 67.53 | 93.04 | 94.02 | -0.12 | -3.80 | 0.52 | 0.30 | 5.01 |
| 12 | 66.95 | 92.40 | 93.51 | -0.41 | -3.95 | 0.53 | 0.28 | 5.19 |
| 13 | 64.94 | 90.20 | 91.44 | -0.52 | -4.19 | 0.52 | 0.29 | 5.46 |
| 14 | 61.15 | 86.52 | 87.93 | -0.54 | -4.91 | 0.45 | 0.33 | 5.93 |
| 15 | 55.92 | 81.83 | 83.49 | -0.85 | -5.94 | 0.36 | 0.36 | 6.47 |
| 16 | 50.04 | 76.59 | 78.41 | -1.36 | -6.82 | 0.38 | 0.34 | 6.92 |
| 17 | 44.07 | 70.75 | 72.51 | -1.51 | -7.26 | 0.47 | 0.29 | 7.33 |
| 18 | 38.12 | 64.00 | 65.53 | -1.32 | -7.23 | 0.51 | 0.31 | 7.72 |
| 19 | 32.22 | 56.47 | 57.81 | -1.48 | -6.81 | 0.46 | 0.39 | 7.91 |
| 20 | 26.75 | 49.16 | 50.47 | -2.22 | -6.31 | 0.40 | 0.43 | 7.72 |
| 21 | 22.29 | 43.46 | 44.81 | -2.85 | -6.25 | 0.39 | 0.45 | 7.41 |
| 22 | 19.33 | 40.25 | 41.62 | -2.68 | -6.77 | 0.37 | 0.51 | 7.44 |
| 23 | 17.99 | 39.41 | 40.78 | -2.13 | -7.30 | 0.29 | 0.60 | 7.85 |
| 24 | 18.18 | 40.27 | 41.70 | -2.07 | -7.31 | 0.24 | 0.64 | 8.28 |
| 25 | 19.82 | 42.45 | 44.07 | -2.63 | -7.04 | 0.31 | 0.57 | 8.47 |
| 26 | 22.96 | 46.18 | 48.07 | -3.06 | -7.14 | 0.40 | 0.49 | 8.58 |

Table 3a. Colby Smoothed Parameter Estimates
for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 22.27 | 50.41 | 23.06 | -2.41 | -1.76 | 0.40 | 0.22 | 6.97 |
| 2 | 26.70 | 56.00 | 27.39 | -2.19 | -1.47 | 0.34 | 0.24 | 6.97 |
| 3 | 31.96 | 61.98 | 32.29 | -1.35 | -0.44 | 0.32 | 0.24 | 6.65 |
| 4 | 37.06 | 66.68 | 36.98 | -0.55 | 0.80 | 0.34 | 0.25 | 6.17 |
| 5 | 41.58 | 70.09 | 41.36 | -0.44 | 1.36 | 0.35 | 0.25 | 5.91 |
| 6 | 46.07 | 73.74 | 46.03 | -0.75 | 0.90 | 0.36 | 0.23 | 5.83 |
| 7 | 51.05 | 78.71 | 51.32 | -0.80 | -0.12 | 0.37 | 0.19 | 5.59 |
| 8 | 55.99 | 84.37 | 56.43 | -0.52 | -0.94 | 0.38 | 0.19 | 5.10 |
| 9 | 59.76 | 89.12 | 60.16 | -0.36 | -1.09 | 0.37 | 0.21 | 4.62 |
| 10 | 61.82 | 91.91 | 62.08 | -0.45 | -0.72 | 0.36 | 0.20 | 4.29 |
| 11 | 62.39 | 92.63 | 62.57 | -0.43 | -0.38 | 0.38 | 0.18 | 4.04 |
| 12 | 61.69 | 91.64 | 61.84 | -0.15 | -0.43 | 0.41 | 0.17 | 4.02 |
| 13 | 59.44 | 89.20 | 59.53 | 0.15 | -0.50 | 0.41 | 0.20 | 4.57 |
| 14 | 55.42 | 85.55 | 55.34 | 0.28 | 0.11 | 0.39 | 0.24 | 5.61 |
| 15 | 49.98 | 80.86 | 49.69 | 0.29 | 1.30 | 0.40 | 0.24 | 6.45 |
| 16 | 43.79 | 75.29 | 43.44 | 0.10 | 2.09 | 0.41 | 0.21 | 6.54 |
| 17 | 37.45 | 68.98 | 37.27 | -0.56 | 1.78 | 0.39 | 0.20 | 6.18 |
| 18 | 31.39 | 62.21 | 31.46 | -1.56 | 0.91 | 0.35 | 0.22 | 6.01 |
| 19 | 25.99 | 55.38 | 26.20 | -2.33 | 0.56 | 0.34 | 0.24 | 6.22 |
| 20 | 21.48 | 49.08 | 21.69 | -2.63 | 0.79 | 0.40 | 0.23 | 6.49 |
| 21 | 17.94 | 44.18 | 18.19 | -2.91 | 0.61 | 0.46 | 0.24 | 6.67 |
| 22 | 15.53 | 41.58 | 15.94 | -3.52 | -0.52 | 0.48 | 0.25 | 6.94 |
| 23 | 14.58 | 41.41 | 15.16 | -3.97 | -1.81 | 0.47 | 0.25 | 7.29 |
| 24 | 15.14 | 42.70 | 15.77 | -3.66 | -2.28 | 0.49 | 0.22 | 7.41 |
| 25 | 16.76 | 44.40 | 17.39 | -2.85 | -1.99 | 0.51 | 0.20 | 7.18 |
| 26 | 19.07 | 46.62 | 19.76 | -2.39 | -1.74 | 0.48 | 0.20 | 6.95 |

Table 3b. Colby Smoothed Parameter Estimates
for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 22.27 | 50.41 | 52.70 | -1.83 | -10.53 | 0.38 | 0.55 | 9.07 |
| 2 | 26.70 | 56.00 | 58.51 | -2.72 | -10.40 | 0.37 | 0.55 | 8.86 |
| 3 | 31.96 | 61.98 | 64.58 | -3.13 | -9.76 | 0.33 | 0.56 | 8.68 |
| 4 | 37.06 | 66.68 | 69.34 | -2.82 | -8.81 | 0.32 | 0.55 | 8.42 |
| 5 | 41.58 | 70.09 | 72.89 | -2.29 | -7.99 | 0.34 | 0.53 | 7.97 |
| 6 | 46.07 | 73.74 | 76.62 | -1.99 | -7.08 | 0.37 | 0.51 | 7.40 |
| 7 | 51.05 | 78.71 | 81.33 | -1.91 | -5.70 | 0.39 | 0.52 | 6.81 |
| 8 | 55.99 | 84.37 | 86.41 | -1.94 | -4.24 | 0.40 | 0.54 | 6.29 |
| 9 | 59.76 | 89.12 | 90.64 | -2.06 | -3.57 | 0.41 | 0.52 | 5.89 |
| 10 | 61.82 | 91.91 | 93.27 | -2.19 | -3.66 | 0.43 | 0.44 | 5.68 |
| 11 | 62.39 | 92.63 | 94.13 | -2.30 | -3.75 | 0.43 | 0.38 | 5.70 |
| 12 | 61.69 | 91.64 | 93.27 | -2.46 | -3.71 | 0.42 | 0.39 | 5.93 |
| 13 | 59.44 | 89.20 | 90.87 | -2.64 | -4.45 | 0.39 | 0.44 | 6.33 |
| 14 | 55.42 | 85.55 | 87.24 | -2.61 | -6.33 | 0.36 | 0.47 | 6.87 |
| 15 | 49.98 | 80.86 | 82.62 | -2.30 | -8.30 | 0.35 | 0.45 | 7.50 |
| 16 | 43.79 | 75.29 | 77.11 | -2.25 | -9.28 | 0.36 | 0.43 | 8.10 |
| 17 | 37.45 | 68.98 | 70.84 | -2.97 | -9.58 | 0.40 | 0.43 | 8.51 |
| 18 | 31.39 | 62.21 | 64.06 | -3.98 | -10.05 | 0.43 | 0.46 | 8.68 |
| 19 | 25.99 | 55.38 | 57.14 | -4.11 | -10.51 | 0.40 | 0.48 | 8.69 |
| 20 | 21.48 | 49.08 | 50.56 | -3.02 | -10.09 | 0.36 | 0.49 | 8.64 |
| 21 | 17.94 | 44.18 | 45.32 | -1.85 | -8.95 | 0.35 | 0.51 | 8.58 |
| 22 | 15.53 | 41.58 | 42.56 | -1.76 | -8.40 | 0.37 | 0.54 | 8.57 |
| 23 | 14.58 | 41.41 | 42.52 | -2.43 | -9.07 | 0.37 | 0.55 | 8.70 |
| 24 | 15.14 | 42.70 | 44.13 | -2.60 | -10.13 | 0.35 | 0.56 | 8.97 |
| 25 | 16.76 | 44.40 | 46.13 | -1.94 | -10.59 | 0.34 | 0.56 | 9.20 |
| 26 | 19.07 | 46.62 | 48.63 | -1.42 | -10.56 | 0.36 | 0.56 | 9.23 |

Table 4a. Columbus Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 32.36 | 54.96 | 32.20 | -1.69 | 2.27 | 0.15 | 0.46 | 7.32 |
| 2 | 37.31 | 60.71 | 37.13 | -1.43 | 2.02 | 0.18 | 0.47 | 7.28 |
| 3 | 42.29 | 65.93 | 42.10 | -1.35 | 1.97 | 0.25 | 0.48 | 6.99 |
| 4 | 46.74 | 69.99 | 46.45 | -1.07 | 1.98 | 0.26 | 0.51 | 6.38 |
| 5 | 50.80 | 73.46 | 50.40 | -0.72 | 1.84 | 0.26 | 0.53 | 5.70 |
| 6 | 55.00 | 77.19 | 54.62 | -0.49 | 1.46 | 0.32 | 0.47 | 5.13 |
| 7 | 59.48 | 81.36 | 59.25 | -0.26 | 0.83 | 0.42 | 0.37 | 4.61 |
| 8 | 63.56 | 85.37 | 63.53 | 0.03 | 0.05 | 0.49 | 0.29 | 4.17 |
| 9 | 66.35 | 88.59 | 66.44 | 0.17 | -0.47 | 0.49 | 0.26 | 3.90 |
| 10 | 67.64 | 90.79 | 67.72 | 0.06 | -0.37 | 0.50 | 0.23 | 3.78 |
| 11 | 67.88 | 91.94 | 67.85 | -0.08 | 0.13 | 0.53 | 0.20 | 3.68 |
| 12 | 67.37 | 91.83 | 67.27 | -0.11 | 0.43 | 0.55 | 0.21 | 3.73 |
| 13 | 65.73 | 90.15 | 65.68 | -0.29 | 0.45 | 0.53 | 0.24 | 4.21 |
| 14 | 62.47 | 86.91 | 62.47 | -0.80 | 0.73 | 0.52 | 0.26 | 5.05 |
| 15 | 57.78 | 82.56 | 57.70 | -1.33 | 1.61 | 0.53 | 0.27 | 5.79 |
| 16 | 52.43 | 77.59 | 52.14 | -1.41 | 2.60 | 0.51 | 0.30 | 6.20 |
| 17 | 47.04 | 72.15 | 46.59 | -1.22 | 3.08 | 0.42 | 0.37 | 6.52 |
| 18 | 41.66 | 66.02 | 41.22 | -1.25 | 3.11 | 0.33 | 0.40 | 7.01 |
| 19 | 36.28 | 59.23 | 35.93 | -1.62 | 3.16 | 0.31 | 0.38 | 7.41 |
| 20 | 31.31 | 52.59 | 31.06 | -1.99 | 3.23 | 0.35 | 0.33 | 7.43 |
| 21 | 27.45 | 47.43 | 27.35 | -2.30 | 2.82 | 0.39 | 0.31 | 7.32 |
| 22 | 25.09 | 44.65 | 25.29 | -2.91 | 1.94 | 0.40 | 0.31 | 7.59 |
| 23 | 24.12 | 44.04 | 24.64 | -3.82 | 1.33 | 0.42 | 0.30 | 8.17 |
| 24 | 24.29 | 44.84 | 24.89 | -4.29 | 1.53 | 0.43 | 0.28 | 8.45 |
| 25 | 25.61 | 46.71 | 25.97 | -3.73 | 2.16 | 0.37 | 0.32 | 8.10 |
| 26 | 28.29 | 50.03 | 28.31 | -2.55 | 2.45 | 0.24 | 0.41 | 7.56 |

Table 4b. Columbus Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 32.36 | 54.96 | 57.27 | -2.90 | -6.12 | 0.32 | 0.63 | 7.54 |
| 2 | 37.31 | 60.71 | 63.08 | -2.60 | -6.15 | 0.26 | 0.64 | 7.60 |
| 3 | 42.29 | 65.93 | 68.26 | -1.93 | -6.05 | 0.24 | 0.59 | 7.16 |
| 4 | 46.74 | 69.99 | 72.28 | -1.54 | -5.60 | 0.27 | 0.51 | 6.36 |
| 5 | 50.80 | 73.46 | 75.65 | -1.58 | -4.73 | 0.30 | 0.44 | 5.63 |
| 6 | 55.00 | 77.19 | 79.15 | -1.55 | -3.76 | 0.32 | 0.43 | 5.14 |
| 7 | 59.48 | 81.36 | 82.92 | -1.09 | -3.12 | 0.38 | 0.41 | 4.76 |
| 8 | 63.56 | 85.37 | 86.52 | -0.50 | -2.91 | 0.49 | 0.34 | 4.37 |
| 9 | 66.35 | 88.59 | 89.51 | -0.20 | -2.97 | 0.59 | 0.26 | 4.12 |
| 10 | 67.64 | 90.79 | 91.67 | -0.18 | -3.23 | 0.61 | 0.23 | 4.09 |
| 11 | 67.88 | 91.94 | 92.88 | -0.18 | -3.60 | 0.59 | 0.25 | 4.21 |
| 12 | 67.37 | 91.83 | 92.85 | -0.21 | -3.91 | 0.59 | 0.27 | 4.41 |
| 13 | 65.73 | 90.15 | 91.35 | -0.55 | -4.07 | 0.58 | 0.27 | 4.67 |
| 14 | 62.47 | 86.91 | 88.41 | -1.17 | -4.34 | 0.52 | 0.30 | 4.98 |
| 15 | 57.78 | 82.56 | 84.35 | -1.72 | -4.94 | 0.44 | 0.34 | 5.29 |
| 16 | 52.43 | 77.59 | 79.52 | -2.02 | -5.60 | 0.42 | 0.38 | 5.64 |
| 17 | 47.04 | 72.15 | 74.04 | -2.22 | -5.80 | 0.45 | 0.38 | 6.16 |
| 18 | 41.66 | 66.02 | 67.81 | -2.50 | -5.50 | 0.45 | 0.41 | 6.72 |
| 19 | 36.28 | 59.23 | 60.98 | -2.79 | -5.20 | 0.39 | 0.48 | 6.98 |
| 20 | 31.31 | 52.59 | 54.37 | -3.01 | -5.25 | 0.33 | 0.56 | 6.80 |
| 21 | 27.45 | 47.43 | 49.22 | -3.13 | -5.37 | 0.32 | 0.60 | 6.52 |
| 22 | 25.09 | 44.65 | 46.37 | -3.08 | -5.22 | 0.33 | 0.61 | 6.61 |
| 23 | 24.12 | 44.04 | 45.67 | -2.77 | -4.95 | 0.31 | 0.63 | 6.99 |
| 24 | 24.29 | 44.84 | 46.47 | -2.36 | -5.02 | 0.29 | 0.64 | 7.26 |
| 25 | 25.61 | 46.71 | 48.51 | -2.27 | -5.48 | 0.31 | 0.63 | 7.28 |
| 26 | 28.29 | 50.03 | 52.11 | -2.62 | -5.93 | 0.34 | 0.62 | 7.32 |

Table 5a. Elkhart Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 26.00 | 56.62 | 26.25 | -1.12 | -1.04 | 0.33 | 0.27 | 7.20 |
| 2 | 29.98 | 61.55 | 30.16 | -1.09 | -0.79 | 0.29 | 0.29 | 7.02 |
| 3 | 35.08 | 67.04 | 35.07 | -0.04 | -0.14 | 0.28 | 0.31 | 6.56 |
| 4 | 40.34 | 71.55 | 40.24 | 0.72 | 0.07 | 0.31 | 0.29 | 6.06 |
| 5 | 44.94 | 74.81 | 44.92 | 0.43 | -0.30 | 0.35 | 0.25 | 5.72 |
| 6 | 49.15 | 78.16 | 49.27 | -0.12 | -0.63 | 0.39 | 0.21 | 5.42 |
| 7 | 53.69 | 82.68 | 53.90 | -0.09 | -0.78 | 0.39 | 0.20 | 4.99 |
| 8 | 58.35 | 87.73 | 58.60 | 0.16 | -1.10 | 0.39 | 0.21 | 4.54 |
| 9 | 62.01 | 91.60 | 62.28 | 0.11 | -1.53 | 0.40 | 0.21 | 4.24 |
| 10 | 63.97 | 93.37 | 64.20 | 0.05 | -1.50 | 0.41 | 0.20 | 4.01 |
| 11 | 64.43 | 93.52 | 64.62 | 0.31 | -1.12 | 0.41 | 0.18 | 3.69 |
| 12 | 63.79 | 92.74 | 63.98 | 0.43 | -1.06 | 0.42 | 0.18 | 3.54 |
| 13 | 61.87 | 91.04 | 62.06 | 0.08 | -1.21 | 0.43 | 0.19 | 3.99 |
| 14 | 58.33 | 88.05 | 58.39 | -0.10 | -0.55 | 0.44 | 0.21 | 5.00 |
| 15 | 53.36 | 83.71 | 53.16 | 0.45 | 1.06 | 0.43 | 0.22 | 5.96 |
| 16 | 47.48 | 78.40 | 47.12 | 1.00 | 2.17 | 0.40 | 0.22 | 6.33 |
| 17 | 41.14 | 72.54 | 40.90 | 0.47 | 1.63 | 0.38 | 0.23 | 6.27 |
| 18 | 34.80 | 66.39 | 34.80 | -0.70 | 0.37 | 0.36 | 0.24 | 6.26 |
| 19 | 29.14 | 60.23 | 29.24 | -1.23 | 0.00 | 0.34 | 0.25 | 6.45 |
| 20 | 24.70 | 54.57 | 24.76 | -1.18 | 0.34 | 0.35 | 0.25 | 6.67 |
| 21 | 21.48 | 50.14 | 21.62 | -1.85 | -0.13 | 0.37 | 0.26 | 6.83 |
| 22 | 19.34 | 47.72 | 19.68 | -3.41 | -1.65 | 0.40 | 0.28 | 6.99 |
| 23 | 18.45 | 47.55 | 18.88 | -4.12 | -2.66 | 0.41 | 0.29 | 7.16 |
| 24 | 19.04 | 48.95 | 19.34 | -2.88 | -2.16 | 0.40 | 0.30 | 7.22 |
| 25 | 20.80 | 50.92 | 20.95 | -1.05 | -1.13 | 0.37 | 0.28 | 7.18 |
| 26 | 23.13 | 53.23 | 23.29 | -0.54 | -0.84 | 0.35 | 0.27 | 7.18 |

Table 5b. Elkhart Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 26.00 | 56.62 | 57.94 | -2.43 | -9.35 | 0.41 | 0.50 | 9.07 |
| 2 | 29.98 | 61.55 | 63.11 | -3.38 | -9.96 | 0.33 | 0.56 | 8.74 |
| 3 | 35.08 | 67.04 | 68.73 | -3.09 | -9.94 | 0.28 | 0.59 | 8.10 |
| 4 | 40.34 | 71.55 | 73.26 | -1.83 | -8.80 | 0.30 | 0.56 | 7.53 |
| 5 | 44.94 | 74.81 | 76.55 | -0.91 | -7.35 | 0.35 | 0.50 | 7.20 |
| 6 | 49.15 | 78.16 | 79.88 | -0.81 | -6.27 | 0.40 | 0.46 | 6.84 |
| 7 | 53.69 | 82.68 | 84.15 | -0.84 | -5.22 | 0.43 | 0.46 | 6.27 |
| 8 | 58.35 | 87.73 | 88.77 | -0.62 | -3.94 | 0.45 | 0.46 | 5.66 |
| 9 | 62.01 | 91.60 | 92.40 | -0.69 | -3.12 | 0.44 | 0.43 | 5.22 |
| 10 | 63.97 | 93.37 | 94.32 | -1.29 | -3.31 | 0.41 | 0.39 | 4.89 |
| 11 | 64.43 | 93.52 | 94.69 | -1.65 | -3.92 | 0.43 | 0.36 | 4.56 |
| 12 | 63.79 | 92.74 | 93.87 | -1.27 | -4.20 | 0.48 | 0.35 | 4.45 |
| 13 | 61.87 | 91.04 | 92.00 | -0.86 | -4.47 | 0.48 | 0.36 | 4.83 |
| 14 | 58.33 | 88.05 | 89.04 | -1.22 | -5.55 | 0.40 | 0.40 | 5.58 |
| 15 | 53.36 | 83.71 | 84.95 | -1.90 | -7.27 | 0.32 | 0.44 | 6.31 |
| 16 | 47.48 | 78.40 | 79.77 | -2.04 | -8.72 | 0.33 | 0.45 | 6.89 |
| 17 | 41.14 | 72.54 | 73.79 | -1.87 | -9.63 | 0.40 | 0.43 | 7.47 |
| 18 | 34.80 | 66.39 | 67.49 | -2.34 | -10.43 | 0.42 | 0.43 | 8.11 |
| 19 | 29.14 | 60.23 | 61.35 | -3.34 | -10.98 | 0.38 | 0.45 | 8.56 |
| 20 | 24.70 | 54.57 | 55.70 | -3.73 | -10.55 | 0.34 | 0.49 | 8.66 |
| 21 | 21.48 | 50.14 | 51.09 | -3.05 | -9.32 | 0.35 | 0.52 | 8.61 |
| 22 | 19.34 | 47.72 | 48.43 | -2.17 | -8.68 | 0.36 | 0.57 | 8.65 |
| 23 | 18.45 | 47.55 | 48.21 | -1.81 | -9.33 | 0.33 | 0.62 | 8.74 |
| 24 | 19.04 | 48.95 | 49.75 | -1.63 | -10.20 | 0.32 | 0.62 | 8.78 |
| 25 | 20.80 | 50.92 | 51.88 | -1.31 | -10.07 | 0.38 | 0.56 | 8.84 |
| 26 | 23.13 | 53.23 | 54.33 | -1.44 | -9.37 | 0.43 | 0.50 | 9.01 |

Table 6a. Garden City Smoothed Parameter Estimates
*for the Minimum Temperature*

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 24.66 | 54.15 | 25.12 | -2.02 | -1.18 | 0.44 | 0.20 | 6.99 |
| 2 | 29.33 | 59.73 | 29.74 | -1.64 | -1.32 | 0.37 | 0.22 | 6.92 |
| 3 | 34.73 | 65.43 | 34.93 | -0.83 | -0.65 | 0.33 | 0.24 | 6.62 |
| 4 | 39.95 | 69.82 | 39.97 | -0.22 | 0.11 | 0.37 | 0.23 | 6.27 |
| 5 | 44.59 | 73.18 | 44.65 | -0.33 | 0.20 | 0.44 | 0.20 | 6.01 |
| 6 | 49.20 | 76.97 | 49.42 | -0.70 | -0.25 | 0.46 | 0.16 | 5.70 |
| 7 | 54.24 | 81.93 | 54.59 | -0.66 | -0.78 | 0.43 | 0.17 | 5.25 |
| 8 | 59.12 | 87.17 | 59.53 | -0.31 | -1.28 | 0.39 | 0.20 | 4.79 |
| 9 | 62.70 | 91.21 | 63.14 | -0.21 | -1.65 | 0.38 | 0.20 | 4.49 |
| 10 | 64.54 | 93.39 | 64.97 | -0.42 | -1.61 | 0.39 | 0.17 | 4.22 |
| 11 | 65.02 | 93.88 | 65.37 | -0.49 | -1.14 | 0.41 | 0.13 | 3.88 |
| 12 | 64.42 | 92.97 | 64.66 | -0.28 | -0.76 | 0.42 | 0.14 | 3.78 |
| 13 | 62.41 | 90.72 | 62.57 | -0.09 | -0.70 | 0.45 | 0.17 | 4.34 |
| 14 | 58.61 | 87.23 | 58.67 | 0.00 | -0.36 | 0.47 | 0.19 | 5.42 |
| 15 | 53.20 | 82.68 | 53.08 | 0.26 | 0.71 | 0.48 | 0.19 | 6.33 |
| 16 | 46.78 | 77.26 | 46.50 | 0.54 | 1.84 | 0.46 | 0.19 | 6.60 |
| 17 | 39.95 | 71.14 | 39.68 | 0.31 | 2.00 | 0.43 | 0.20 | 6.43 |
| 18 | 33.29 | 64.60 | 33.19 | -0.53 | 1.30 | 0.42 | 0.20 | 6.27 |
| 19 | 27.42 | 58.01 | 27.47 | -1.35 | 0.78 | 0.42 | 0.19 | 6.29 |
| 20 | 22.74 | 51.89 | 22.84 | -1.81 | 0.69 | 0.43 | 0.19 | 6.36 |
| 21 | 19.26 | 47.06 | 19.44 | -2.32 | 0.20 | 0.45 | 0.21 | 6.46 |
| 22 | 16.97 | 44.43 | 17.32 | -3.26 | -1.06 | 0.48 | 0.22 | 6.66 |
| 23 | 16.07 | 44.22 | 16.55 | -4.06 | -2.07 | 0.49 | 0.22 | 6.87 |
| 24 | 16.68 | 45.59 | 17.13 | -3.91 | -1.85 | 0.50 | 0.20 | 6.93 |
| 25 | 18.49 | 47.54 | 18.84 | -3.00 | -0.97 | 0.51 | 0.19 | 6.88 |
| 26 | 21.12 | 50.10 | 21.50 | -2.27 | -0.72 | 0.50 | 0.19 | 6.90 |

Table 6b. Garden City Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 24.66 | 54.15 | 56.22 | -2.83 | -11.99 | 0.38 | 0.54 | 9.56 |
| 2 | 29.33 | 59.73 | 62.00 | -3.36 | -11.88 | 0.34 | 0.60 | 9.29 |
| 3 | 34.73 | 65.43 | 67.78 | -3.81 | -10.66 | 0.29 | 0.62 | 8.90 |
| 4 | 39.95 | 69.82 | 72.16 | -3.44 | -9.01 | 0.28 | 0.58 | 8.50 |
| 5 | 44.59 | 73.18 | 75.40 | -2.49 | -7.57 | 0.32 | 0.53 | 8.12 |
| 6 | 49.20 | 76.97 | 78.97 | -1.88 | -6.20 | 0.36 | 0.51 | 7.64 |
| 7 | 54.24 | 81.93 | 83.68 | -2.02 | -4.66 | 0.38 | 0.53 | 6.96 |
| 8 | 59.12 | 87.17 | 88.65 | -2.41 | -3.36 | 0.38 | 0.56 | 6.21 |
| 9 | 62.70 | 91.21 | 92.47 | -2.46 | -2.85 | 0.37 | 0.54 | 5.65 |
| 10 | 64.54 | 93.39 | 94.54 | -2.27 | -3.00 | 0.38 | 0.46 | 5.39 |
| 11 | 65.02 | 93.88 | 95.12 | -2.34 | -3.26 | 0.42 | 0.39 | 5.35 |
| 12 | 64.42 | 92.97 | 94.41 | -2.81 | -3.58 | 0.43 | 0.40 | 5.45 |
| 13 | 62.41 | 90.72 | 92.30 | -3.23 | -4.42 | 0.40 | 0.47 | 5.77 |
| 14 | 58.61 | 87.23 | 88.74 | -3.14 | -5.93 | 0.35 | 0.50 | 6.41 |
| 15 | 53.20 | 82.68 | 84.05 | -2.74 | -7.68 | 0.32 | 0.45 | 7.19 |
| 16 | 46.78 | 77.26 | 78.66 | -2.69 | -9.19 | 0.35 | 0.39 | 7.84 |
| 17 | 39.95 | 71.14 | 72.76 | -3.40 | -10.27 | 0.39 | 0.40 | 8.23 |
| 18 | 33.29 | 64.60 | 66.39 | -4.44 | -10.75 | 0.42 | 0.46 | 8.44 |
| 19 | 27.42 | 58.01 | 59.69 | -4.91 | -10.52 | 0.42 | 0.48 | 8.57 |
| 20 | 22.74 | 51.89 | 53.27 | -4.37 | -9.97 | 0.40 | 0.46 | 8.61 |
| 21 | 19.26 | 47.06 | 48.18 | -3.38 | -9.85 | 0.39 | 0.46 | 8.59 |
| 22 | 16.97 | 44.43 | 45.48 | -2.95 | -10.40 | 0.36 | 0.54 | 8.65 |
| 23 | 16.07 | 44.22 | 45.35 | -3.34 | -10.98 | 0.32 | 0.63 | 8.88 |
| 24 | 16.68 | 45.59 | 46.87 | -3.81 | -11.04 | 0.32 | 0.65 | 9.21 |
| 25 | 18.49 | 47.54 | 49.03 | -3.62 | -10.95 | 0.35 | 0.58 | 9.51 |
| 26 | 21.12 | 50.10 | 51.89 | -3.00 | -11.36 | 0.39 | 0.52 | 9.64 |

Table 7a. Hays Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 24.01 | 51.89 | 24.43 | -3.13 | 0.44 | 0.41 | 0.20 | 7.51 |
| 2 | 28.93 | 58.05 | 29.17 | -2.08 | 0.43 | 0.35 | 0.22 | 7.59 |
| 3 | 34.45 | 63.83 | 34.48 | -1.07 | 0.78 | 0.36 | 0.23 | 7.42 |
| 4 | 39.87 | 68.06 | 39.81 | -0.94 | 1.24 | 0.40 | 0.22 | 7.14 |
| 5 | 44.72 | 71.30 | 44.75 | -1.45 | 1.35 | 0.41 | 0.20 | 6.89 |
| 6 | 49.40 | 75.05 | 49.60 | -1.66 | 0.93 | 0.41 | 0.18 | 6.51 |
| 7 | 54.43 | 80.03 | 54.82 | -1.26 | 0.08 | 0.42 | 0.16 | 5.96 |
| 8 | 59.41 | 85.47 | 59.96 | -0.78 | -0.91 | 0.44 | 0.16 | 5.47 |
| 9 | 63.18 | 89.97 | 63.75 | -0.63 | -1.48 | 0.42 | 0.18 | 5.22 |
| 10 | 65.11 | 92.67 | 65.53 | -0.65 | -1.21 | 0.38 | 0.19 | 4.96 |
| 11 | 65.56 | 93.47 | 65.84 | -0.72 | -0.48 | 0.37 | 0.18 | 4.55 |
| 12 | 64.95 | 92.63 | 65.27 | -1.00 | -0.14 | 0.41 | 0.16 | 4.41 |
| 13 | 62.92 | 90.35 | 63.34 | -1.37 | -0.39 | 0.48 | 0.16 | 5.08 |
| 14 | 58.93 | 86.80 | 59.24 | -1.30 | -0.33 | 0.51 | 0.16 | 6.32 |
| 15 | 53.24 | 82.13 | 53.20 | -0.64 | 0.73 | 0.47 | 0.17 | 7.22 |
| 16 | 46.81 | 76.57 | 46.48 | -0.09 | 2.19 | 0.42 | 0.20 | 7.30 |
| 17 | 40.36 | 70.32 | 40.01 | -0.35 | 2.91 | 0.38 | 0.23 | 6.97 |
| 18 | 34.02 | 63.55 | 33.81 | -1.16 | 2.79 | 0.38 | 0.23 | 6.82 |
| 19 | 27.98 | 56.49 | 27.87 | -1.87 | 2.67 | 0.40 | 0.20 | 6.89 |
| 20 | 22.77 | 49.81 | 22.71 | -2.36 | 2.83 | 0.44 | 0.18 | 6.94 |
| 21 | 18.85 | 44.59 | 18.90 | -2.98 | 2.52 | 0.46 | 0.20 | 7.00 |
| 22 | 16.29 | 41.74 | 16.51 | -3.63 | 1.30 | 0.46 | 0.24 | 7.26 |
| 23 | 15.08 | 41.23 | 15.40 | -3.83 | -0.05 | 0.46 | 0.25 | 7.57 |
| 24 | 15.33 | 42.17 | 15.65 | -3.58 | -0.46 | 0.49 | 0.21 | 7.62 |
| 25 | 17.06 | 43.97 | 17.41 | -3.41 | -0.00 | 0.52 | 0.17 | 7.43 |
| 26 | 20.03 | 47.02 | 20.46 | -3.47 | 0.44 | 0.49 | 0.17 | 7.36 |

Table 7b. Hays Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 24.01 | 51.89 | 53.93 | -3.96 | -9.83 | 0.40 | 0.58 | 9.68 |
| 2 | 28.93 | 58.05 | 60.25 | -3.72 | -9.90 | 0.35 | 0.61 | 9.55 |
| 3 | 34.45 | 63.83 | 66.22 | -3.93 | -8.91 | 0.30 | 0.61 | 9.00 |
| 4 | 39.87 | 68.06 | 70.50 | -3.91 | -7.17 | 0.31 | 0.56 | 8.19 |
| 5 | 44.72 | 71.30 | 73.62 | -3.15 | -5.66 | 0.36 | 0.51 | 7.47 |
| 6 | 49.40 | 75.05 | 77.30 | -2.19 | -4.97 | 0.40 | 0.50 | 6.98 |
| 7 | 54.43 | 80.03 | 82.26 | -1.89 | -4.67 | 0.40 | 0.52 | 6.54 |
| 8 | 59.41 | 85.47 | 87.49 | -2.33 | -4.08 | 0.41 | 0.52 | 6.08 |
| 9 | 63.18 | 89.97 | 91.55 | -2.79 | -3.15 | 0.43 | 0.49 | 5.71 |
| 10 | 65.11 | 92.67 | 93.95 | -2.88 | -2.54 | 0.45 | 0.47 | 5.53 |
| 11 | 65.56 | 93.47 | 94.87 | -2.90 | -2.67 | 0.46 | 0.46 | 5.50 |
| 12 | 64.95 | 92.63 | 94.34 | -3.23 | -3.31 | 0.46 | 0.48 | 5.56 |
| 13 | 62.92 | 90.35 | 92.17 | -3.58 | -4.07 | 0.42 | 0.50 | 5.89 |
| 14 | 58.93 | 86.80 | 88.49 | -3.49 | -4.97 | 0.36 | 0.51 | 6.61 |
| 15 | 53.24 | 82.13 | 83.79 | -3.14 | -6.28 | 0.32 | 0.50 | 7.47 |
| 16 | 46.81 | 76.57 | 78.38 | -3.28 | -7.83 | 0.33 | 0.48 | 8.10 |
| 17 | 40.36 | 70.32 | 72.20 | -4.21 | -8.92 | 0.38 | 0.47 | 8.38 |
| 18 | 34.02 | 63.55 | 65.29 | -5.36 | -9.01 | 0.41 | 0.49 | 8.49 |
| 19 | 27.98 | 56.49 | 58.05 | -5.75 | -8.43 | 0.40 | 0.50 | 8.57 |
| 20 | 22.77 | 49.81 | 51.26 | -4.97 | -8.10 | 0.38 | 0.50 | 8.62 |
| 21 | 18.85 | 44.59 | 45.88 | -3.53 | -8.56 | 0.38 | 0.51 | 8.67 |
| 22 | 16.29 | 41.74 | 42.78 | -2.50 | -9.49 | 0.38 | 0.56 | 8.82 |
| 23 | 15.08 | 41.23 | 42.15 | -2.60 | -10.04 | 0.34 | 0.64 | 9.09 |
| 24 | 15.33 | 42.17 | 43.33 | -3.59 | -9.84 | 0.32 | 0.68 | 9.34 |
| 25 | 17.06 | 43.97 | 45.56 | -4.45 | -9.39 | 0.34 | 0.65 | 9.48 |
| 26 | 20.03 | 47.02 | 48.91 | -4.47 | -9.39 | 0.40 | 0.59 | 9.59 |

Table 8a. Horton Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 26.04 | 49.05 | 26.33 | -2.88 | 1.45 | 0.31 | 0.34 | 7.62 |
| 2 | 31.60 | 55.88 | 31.63 | -1.47 | 1.17 | 0.25 | 0.36 | 7.63 |
| 3 | 37.06 | 62.13 | 36.78 | -0.51 | 1.57 | 0.23 | 0.39 | 7.50 |
| 4 | 42.04 | 66.98 | 41.76 | -0.89 | 2.00 | 0.27 | 0.40 | 7.20 |
| 5 | 46.72 | 70.88 | 46.70 | -1.67 | 1.74 | 0.33 | 0.37 | 6.79 |
| 6 | 51.52 | 74.78 | 51.67 | -1.55 | 0.97 | 0.37 | 0.33 | 6.26 |
| 7 | 56.46 | 79.13 | 56.59 | -0.69 | 0.29 | 0.40 | 0.30 | 5.62 |
| 8 | 60.92 | 83.55 | 61.03 | -0.18 | -0.11 | 0.42 | 0.29 | 5.02 |
| 9 | 64.08 | 87.18 | 64.26 | -0.33 | -0.31 | 0.43 | 0.28 | 4.62 |
| 10 | 65.69 | 89.44 | 65.90 | -0.51 | -0.26 | 0.44 | 0.26 | 4.38 |
| 11 | 66.10 | 90.18 | 66.18 | -0.40 | 0.06 | 0.43 | 0.26 | 4.19 |
| 12 | 65.44 | 89.44 | 65.45 | -0.39 | 0.31 | 0.43 | 0.29 | 4.23 |
| 13 | 63.36 | 87.23 | 63.44 | -0.64 | 0.25 | 0.44 | 0.30 | 4.80 |
| 14 | 59.56 | 83.63 | 59.67 | -0.83 | 0.37 | 0.47 | 0.28 | 5.78 |
| 15 | 54.46 | 79.05 | 54.40 | -0.84 | 1.23 | 0.49 | 0.26 | 6.62 |
| 16 | 48.92 | 73.96 | 48.62 | -1.05 | 2.50 | 0.46 | 0.28 | 6.94 |
| 17 | 43.32 | 68.36 | 42.97 | -1.49 | 3.20 | 0.39 | 0.34 | 6.90 |
| 18 | 37.46 | 61.82 | 37.22 | -1.73 | 3.13 | 0.34 | 0.35 | 6.87 |
| 19 | 31.31 | 54.28 | 31.12 | -1.71 | 3.02 | 0.33 | 0.33 | 6.94 |
| 20 | 25.51 | 46.82 | 25.31 | -2.08 | 3.27 | 0.36 | 0.31 | 6.98 |
| 21 | 20.88 | 41.06 | 20.83 | -3.07 | 3.30 | 0.39 | 0.33 | 7.07 |
| 22 | 17.81 | 37.91 | 18.00 | -3.84 | 2.57 | 0.38 | 0.37 | 7.37 |
| 23 | 16.23 | 37.00 | 16.52 | -3.61 | 1.68 | 0.38 | 0.38 | 7.80 |
| 24 | 16.13 | 37.51 | 16.32 | -2.98 | 1.54 | 0.38 | 0.36 | 8.02 |
| 25 | 17.74 | 39.38 | 17.88 | -2.98 | 1.95 | 0.40 | 0.34 | 7.90 |
| 26 | 21.16 | 43.19 | 21.42 | -3.35 | 1.98 | 0.37 | 0.33 | 7.69 |

Table 8b. Horton Smoothed Parameter Estimates
for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 26.04 | 49.05 | 50.87 | -2.11 | -7.51 | 0.43 | 0.52 | 8.39 |
| 2 | 31.60 | 55.88 | 57.79 | -2.01 | -7.23 | 0.38 | 0.59 | 8.26 |
| 3 | 37.06 | 62.13 | 64.10 | -1.83 | -6.61 | 0.32 | 0.62 | 7.79 |
| 4 | 42.04 | 66.98 | 69.06 | -1.81 | -5.93 | 0.33 | 0.54 | 7.13 |
| 5 | 46.72 | 70.88 | 73.00 | -1.87 | -5.18 | 0.38 | 0.45 | 6.58 |
| 6 | 51.52 | 74.78 | 76.80 | -1.78 | -4.37 | 0.41 | 0.44 | 6.16 |
| 7 | 56.46 | 79.13 | 80.91 | -1.48 | -3.70 | 0.40 | 0.47 | 5.67 |
| 8 | 60.92 | 83.55 | 85.00 | -1.12 | -3.22 | 0.43 | 0.45 | 5.07 |
| 9 | 64.08 | 87.18 | 88.31 | -0.84 | -2.90 | 0.49 | 0.40 | 4.65 |
| 10 | 65.69 | 89.44 | 90.35 | -0.67 | -2.79 | 0.51 | 0.38 | 4.59 |
| 11 | 66.10 | 90.18 | 91.07 | -0.70 | -2.97 | 0.48 | 0.43 | 4.72 |
| 12 | 65.44 | 89.44 | 90.51 | -1.00 | -3.25 | 0.44 | 0.47 | 4.85 |
| 13 | 63.36 | 87.23 | 88.55 | -1.45 | -3.47 | 0.43 | 0.46 | 5.06 |
| 14 | 59.56 | 83.63 | 85.16 | -1.79 | -3.85 | 0.40 | 0.44 | 5.52 |
| 15 | 54.46 | 79.05 | 80.71 | -1.98 | -4.77 | 0.37 | 0.42 | 6.08 |
| 16 | 48.92 | 73.96 | 75.67 | -2.24 | -5.89 | 0.38 | 0.41 | 6.47 |
| 17 | 43.32 | 68.36 | 70.01 | -2.71 | -6.32 | 0.44 | 0.39 | 6.68 |
| 18 | 37.46 | 61.82 | 63.29 | -3.19 | -5.70 | 0.48 | 0.40 | 6.93 |
| 19 | 31.31 | 54.28 | 55.58 | -3.35 | -4.88 | 0.45 | 0.44 | 7.21 |
| 20 | 25.51 | 46.82 | 48.03 | -3.12 | -4.86 | 0.40 | 0.49 | 7.31 |
| 21 | 20.88 | 41.06 | 42.22 | -2.68 | -5.46 | 0.39 | 0.50 | 7.16 |
| 22 | 17.81 | 37.91 | 38.96 | -2.20 | -5.75 | 0.38 | 0.51 | 7.08 |
| 23 | 16.23 | 37.00 | 37.90 | -1.75 | -5.47 | 0.34 | 0.56 | 7.30 |
| 24 | 16.13 | 37.51 | 38.43 | -1.49 | -5.38 | 0.29 | 0.61 | 7.71 |
| 25 | 17.74 | 39.38 | 40.58 | -1.59 | -6.07 | 0.31 | 0.58 | 8.06 |
| 26 | 21.16 | 43.19 | 44.77 | -1.91 | -7.06 | 0.39 | 0.52 | 8.28 |

Table 9a. McPherson Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 28.48 | 52.96 | 28.95 | -2.68 | 0.19 | 0.29 | 0.32 | 7.58 |
| 2 | 33.66 | 59.32 | 34.02 | -1.90 | -0.01 | 0.28 | 0.33 | 7.43 |
| 3 | 39.17 | 65.10 | 39.31 | -1.19 | 0.39 | 0.31 | 0.32 | 7.19 |
| 4 | 44.08 | 69.23 | 44.17 | -1.01 | 0.66 | 0.35 | 0.31 | 6.78 |
| 5 | 48.33 | 72.44 | 48.60 | -1.21 | 0.28 | 0.38 | 0.27 | 6.31 |
| 6 | 52.71 | 76.32 | 53.24 | -1.34 | -0.36 | 0.41 | 0.22 | 5.83 |
| 7 | 57.71 | 81.42 | 58.40 | -1.17 | -0.92 | 0.43 | 0.21 | 5.31 |
| 8 | 62.55 | 86.69 | 63.31 | -0.80 | -1.57 | 0.44 | 0.21 | 4.84 |
| 9 | 66.04 | 90.78 | 66.76 | -0.44 | -2.20 | 0.43 | 0.22 | 4.52 |
| 10 | 67.83 | 93.25 | 68.40 | -0.28 | -2.18 | 0.42 | 0.21 | 4.30 |
| 11 | 68.43 | 94.31 | 68.87 | -0.41 | -1.53 | 0.43 | 0.20 | 4.09 |
| 12 | 68.05 | 93.85 | 68.51 | -0.59 | -1.32 | 0.47 | 0.19 | 4.04 |
| 13 | 66.15 | 91.59 | 66.70 | -0.51 | -1.89 | 0.51 | 0.18 | 4.51 |
| 14 | 62.35 | 87.60 | 62.86 | -0.25 | -2.02 | 0.53 | 0.16 | 5.47 |
| 15 | 57.19 | 82.53 | 57.42 | -0.31 | -0.63 | 0.51 | 0.18 | 6.41 |
| 16 | 51.57 | 76.88 | 51.51 | -0.82 | 1.27 | 0.46 | 0.24 | 6.84 |
| 17 | 45.80 | 70.68 | 45.67 | -1.26 | 1.92 | 0.39 | 0.32 | 6.85 |
| 18 | 39.74 | 63.80 | 39.66 | -1.23 | 1.48 | 0.34 | 0.34 | 6.85 |
| 19 | 33.55 | 56.46 | 33.48 | -1.15 | 1.59 | 0.34 | 0.31 | 7.07 |
| 20 | 27.96 | 49.45 | 27.86 | -1.81 | 2.54 | 0.37 | 0.28 | 7.36 |
| 21 | 23.63 | 43.90 | 23.70 | -3.10 | 2.65 | 0.41 | 0.28 | 7.66 |
| 22 | 20.85 | 40.72 | 21.26 | -3.99 | 1.00 | 0.42 | 0.29 | 8.05 |
| 23 | 19.62 | 40.08 | 20.26 | -3.87 | -0.88 | 0.43 | 0.29 | 8.45 |
| 24 | 19.89 | 41.33 | 20.47 | -3.25 | -1.12 | 0.42 | 0.27 | 8.58 |
| 25 | 21.50 | 43.82 | 21.95 | -2.96 | -0.09 | 0.39 | 0.28 | 8.30 |
| 26 | 24.36 | 47.59 | 24.80 | -2.98 | 0.50 | 0.34 | 0.30 | 7.87 |

Table 9b. McPherson Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 28.48 | 52.96 | 54.97 | -2.90 | -8.08 | 0.41 | 0.54 | 8.27 |
| 2 | 33.66 | 59.32 | 61.37 | -2.74 | -7.81 | 0.33 | 0.60 | 8.41 |
| 3 | 39.17 | 65.10 | 67.07 | -2.11 | -7.01 | 0.28 | 0.61 | 8.04 |
| 4 | 44.08 | 69.23 | 71.17 | -1.63 | -5.92 | 0.31 | 0.54 | 7.31 |
| 5 | 48.33 | 72.44 | 74.38 | -1.63 | -4.90 | 0.37 | 0.47 | 6.61 |
| 6 | 52.71 | 76.32 | 78.17 | -1.76 | -4.04 | 0.39 | 0.47 | 6.03 |
| 7 | 57.71 | 81.42 | 83.02 | -1.65 | -3.20 | 0.41 | 0.49 | 5.41 |
| 8 | 62.55 | 86.69 | 87.95 | -1.44 | -2.43 | 0.46 | 0.47 | 4.79 |
| 9 | 66.04 | 90.78 | 91.77 | -1.45 | -2.06 | 0.51 | 0.43 | 4.45 |
| 10 | 67.83 | 93.25 | 94.13 | -1.53 | -2.26 | 0.50 | 0.43 | 4.40 |
| 11 | 68.43 | 94.31 | 95.22 | -1.38 | -2.84 | 0.48 | 0.47 | 4.41 |
| 12 | 68.05 | 93.85 | 94.93 | -1.22 | -3.42 | 0.48 | 0.48 | 4.45 |
| 13 | 66.15 | 91.59 | 92.89 | -1.47 | -3.89 | 0.47 | 0.47 | 4.80 |
| 14 | 62.35 | 87.60 | 89.14 | -2.05 | -4.43 | 0.41 | 0.47 | 5.51 |
| 15 | 57.19 | 82.53 | 84.20 | -2.36 | -5.22 | 0.36 | 0.47 | 6.23 |
| 16 | 51.57 | 76.88 | 78.56 | -2.21 | -6.14 | 0.38 | 0.43 | 6.67 |
| 17 | 45.80 | 70.68 | 72.29 | -2.11 | -6.82 | 0.46 | 0.39 | 6.99 |
| 18 | 39.74 | 63.80 | 65.27 | -2.49 | -6.92 | 0.47 | 0.40 | 7.36 |
| 19 | 33.55 | 56.46 | 57.77 | -3.00 | -6.44 | 0.42 | 0.47 | 7.57 |
| 20 | 27.96 | 49.45 | 50.62 | -3.09 | -5.83 | 0.38 | 0.51 | 7.35 |
| 21 | 23.63 | 43.90 | 45.00 | -2.73 | -5.68 | 0.40 | 0.52 | 6.98 |
| 22 | 20.85 | 40.72 | 41.83 | -2.29 | -6.17 | 0.40 | 0.54 | 6.99 |
| 23 | 19.62 | 40.08 | 41.25 | -2.03 | -6.94 | 0.33 | 0.62 | 7.43 |
| 24 | 19.89 | 41.33 | 42.63 | -1.93 | -7.51 | 0.28 | 0.68 | 7.82 |
| 25 | 21.50 | 43.82 | 45.35 | -2.07 | -7.80 | 0.32 | 0.63 | 7.91 |
| 26 | 24.36 | 47.59 | 49.40 | -2.52 | -7.98 | 0.41 | 0.55 | 7.99 |

Table 10a. Winfield Smoothed Parameter Estimates for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 31.19 | 56.24 | 31.22 | -1.57 | 1.33 | 0.25 | 0.37 | 7.88 |
| 2 | 36.55 | 62.26 | 36.65 | -1.38 | 0.75 | 0.27 | 0.38 | 7.83 |
| 3 | 42.09 | 67.78 | 42.11 | -0.92 | 0.81 | 0.31 | 0.38 | 7.56 |
| 4 | 46.79 | 71.67 | 46.66 | -0.57 | 1.17 | 0.32 | 0.39 | 7.05 |
| 5 | 50.79 | 74.57 | 50.61 | -0.67 | 1.34 | 0.34 | 0.37 | 6.47 |
| 6 | 55.07 | 78.01 | 54.98 | -0.80 | 1.06 | 0.39 | 0.32 | 5.90 |
| 7 | 59.91 | 82.55 | 60.00 | -0.53 | 0.24 | 0.44 | 0.27 | 5.30 |
| 8 | 64.33 | 87.19 | 64.59 | -0.09 | -0.79 | 0.45 | 0.26 | 4.68 |
| 9 | 67.27 | 90.72 | 67.60 | 0.02 | -1.35 | 0.43 | 0.26 | 4.17 |
| 10 | 68.73 | 92.87 | 68.97 | -0.10 | -1.07 | 0.43 | 0.25 | 3.86 |
| 11 | 69.29 | 93.88 | 69.41 | -0.11 | -0.52 | 0.45 | 0.24 | 3.75 |
| 12 | 68.98 | 93.64 | 69.10 | -0.14 | -0.45 | 0.48 | 0.24 | 3.93 |
| 13 | 67.20 | 91.74 | 67.43 | -0.52 | -0.63 | 0.49 | 0.24 | 4.53 |
| 14 | 63.67 | 88.13 | 63.90 | -0.99 | -0.21 | 0.51 | 0.23 | 5.43 |
| 15 | 58.84 | 83.37 | 58.87 | -0.94 | 0.86 | 0.53 | 0.21 | 6.28 |
| 16 | 53.34 | 78.04 | 53.14 | -0.53 | 1.72 | 0.51 | 0.24 | 6.81 |
| 17 | 47.48 | 72.28 | 47.21 | -0.53 | 2.07 | 0.44 | 0.30 | 7.09 |
| 18 | 41.41 | 65.98 | 41.16 | -1.06 | 2.74 | 0.38 | 0.34 | 7.27 |
| 19 | 35.50 | 59.26 | 35.16 | -1.33 | 4.18 | 0.35 | 0.32 | 7.34 |
| 20 | 30.24 | 52.69 | 29.75 | -0.92 | 5.22 | 0.36 | 0.30 | 7.25 |
| 21 | 26.08 | 47.36 | 25.63 | -0.62 | 4.49 | 0.37 | 0.31 | 7.19 |
| 22 | 23.40 | 44.32 | 23.26 | -1.28 | 2.46 | 0.38 | 0.32 | 7.44 |
| 23 | 22.37 | 43.87 | 22.52 | -2.41 | 1.07 | 0.42 | 0.31 | 7.92 |
| 24 | 22.81 | 45.29 | 22.99 | -2.84 | 1.27 | 0.43 | 0.28 | 8.23 |
| 25 | 24.38 | 47.75 | 24.40 | -2.35 | 2.06 | 0.38 | 0.29 | 8.17 |
| 26 | 27.07 | 51.25 | 27.02 | -1.76 | 2.08 | 0.29 | 0.33 | 7.97 |

Table 10b. Winfield Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 31.19 | 56.24 | 57.74 | -3.37 | -6.20 | 0.41 | 0.54 | 8.19 |
| 2 | 36.55 | 62.26 | 63.85 | -3.45 | -5.87 | 0.36 | 0.52 | 8.06 |
| 3 | 42.09 | 67.78 | 69.29 | -2.46 | -5.65 | 0.35 | 0.48 | 7.50 |
| 4 | 46.79 | 71.67 | 73.15 | -1.40 | -5.38 | 0.36 | 0.43 | 6.75 |
| 5 | 50.79 | 74.57 | 76.10 | -1.27 | -4.78 | 0.37 | 0.41 | 6.18 |
| 6 | 55.07 | 78.01 | 79.57 | -1.63 | -3.96 | 0.38 | 0.40 | 5.78 |
| 7 | 59.91 | 82.55 | 83.97 | -1.51 | -3.37 | 0.42 | 0.39 | 5.27 |
| 8 | 64.33 | 87.19 | 88.38 | -0.92 | -3.21 | 0.49 | 0.36 | 4.63 |
| 9 | 67.27 | 90.72 | 91.7C | -0.61 | -3.24 | 0.54 | 0.34 | 4.14 |
| 10 | 68.73 | 92.87 | 93.72 | -0.76 | -3.28 | 0.55 | 0.34 | 4.05 |
| 11 | 69.29 | 93.88 | 94.69 | -0.92 | -3.35 | 0.54 | 0.34 | 4.23 |
| 12 | 68.98 | 93.64 | 94.52 | -1.01 | -3.50 | 0.54 | 0.34 | 4.45 |
| 13 | 67.20 | 91.74 | 92.78 | -1.36 | -3.69 | 0.53 | 0.35 | 4.70 |
| 14 | 63.67 | 88.13 | 89.34 | -1.89 | -4.01 | 0.50 | 0.36 | 5.07 |
| 15 | 58.84 | 83.37 | 84.70 | -2.08 | -4.71 | 0.47 | 0.34 | 5.53 |
| 16 | 53.34 | 78.04 | 79.41 | -1.96 | -5.63 | 0.48 | 0.32 | 5.98 |
| 17 | 47.48 | 72.28 | 73.63 | -2.11 | -6.13 | 0.50 | 0.33 | 6.43 |
| 18 | 41.41 | 65.98 | 67.22 | -2.58 | -5.84 | 0.49 | 0.36 | 6.86 |
| 19 | 35.50 | 59.26 | 60.26 | -2.64 | -5.26 | 0.46 | 0.40 | 7.14 |
| 20 | 30.24 | 52.69 | 53.50 | -2.09 | -5.15 | 0.45 | 0.42 | 7.14 |
| 21 | 26.08 | 47.36 | 48.21 | -1.86 | -5.59 | 0.44 | 0.47 | 7.02 |
| 22 | 23.40 | 44.32 | 45.37 | -2.60 | -6.03 | 0.40 | 0.53 | 7.06 |
| 23 | 22.37 | 43.87 | 45.03 | -3.52 | -6.12 | 0.35 | 0.59 | 7.36 |
| 24 | 22.81 | 45.29 | 46.40 | -3.49 | -6.13 | 0.35 | 0.59 | 7.68 |
| 25 | 24.38 | 47.75 | 48.84 | -2.84 | -6.29 | 0.40 | 0.56 | 7.89 |
| 26 | 27.07 | 51.25 | 52.51 | -2.77 | -6.39 | 0.43 | 0.54 | 8.06 |

Table 11a. Kansas Smoothed Parameter Estimates
for the Minimum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 26.78 | 52.90 | 27.07 | -2.14 | 0.40 | 0.32 | 0.31 | 7.42 |
| 2 | 31.51 | 58.63 | 31.69 | -1.57 | 0.29 | 0.28 | 0.33 | 7.38 |
| 3 | 36.69 | 64.26 | 36.67 | -0.83 | 0.64 | 0.28 | 0.34 | 7.16 |
| 4 | 41.57 | 68.68 | 41.42 | -0.49 | 1.07 | 0.31 | 0.34 | 6.78 |
| 5 | 45.92 | 72.01 | 45.80 | -0.68 | 1.14 | 0.34 | 0.33 | 6.38 |
| 6 | 50.18 | 75.41 | 50.19 | -0.90 | 0.78 | 0.37 | 0.29 | 5.99 |
| 7 | 54.80 | 79.72 | 54.96 | -0.73 | 0.15 | 0.40 | 0.26 | 5.53 |
| 8 | 59.44 | 84.54 | 59.72 | -0.36 | -0.57 | 0.42 | 0.24 | 5.03 |
| 9 | 63.16 | 88.75 | 63.51 | -0.18 | -1.13 | 0.42 | 0.24 | 4.65 |
| 10 | 65.36 | 91.55 | 65.68 | -0.23 | -1.15 | 0.41 | 0.23 | 4.40 |
| 11 | 66.22 | 92.84 | 66.43 | -0.26 | -0.71 | 0.41 | 0.22 | 4.17 |
| 12 | 66.12 | 92.80 | 66.26 | -0.23 | -0.36 | 0.43 | 0.21 | 4.01 |
| 13 | 64.93 | 91.45 | 65.10 | -0.29 | -0.43 | 0.45 | 0.22 | 4.26 |
| 14 | 62.20 | 88.71 | 62.38 | -0.41 | -0.46 | 0.47 | 0.23 | 5.05 |
| 15 | 57.89 | 84.76 | 57.91 | -0.38 | 0.25 | 0.47 | 0.24 | 6.04 |
| 16 | 52.54 | 79.97 | 52.32 | -0.22 | 1.52 | 0.46 | 0.24 | 6.67 |
| 17 | 46.78 | 74.60 | 46.43 | -0.30 | 2.38 | 0.43 | 0.27 | 6.79 |
| 18 | 40.92 | 68.69 | 40.64 | -0.73 | 2.35 | 0.38 | 0.29 | 6.73 |
| 19 | 35.10 | 62.22 | 34.94 | -1.23 | 2.09 | 0.35 | 0.30 | 6.78 |
| 20 | 29.63 | 55.52 | 29.50 | -1.51 | 2.27 | 0.35 | 0.28 | 6.92 |
| 21 | 24.95 | 49.35 | 24.84 | -1.83 | 2.50 | 0.38 | 0.27 | 7.00 |
| 22 | 21.40 | 44.74 | 21.44 | -2.52 | 1.94 | 0.41 | 0.28 | 7.11 |
| 23 | 19.14 | 42.38 | 19.43 | -3.34 | 0.62 | 0.42 | 0.30 | 7.39 |
| 24 | 18.25 | 42.15 | 18.67 | -3.65 | -0.36 | 0.42 | 0.30 | 7.74 |
| 25 | 18.69 | 43.31 | 19.07 | -3.26 | -0.27 | 0.43 | 0.28 | 7.87 |
| 26 | 20.32 | 45.31 | 20.61 | -2.69 | 0.37 | 0.42 | 0.27 | 7.70 |

Table 11b. Kansas Smoothed Parameter Estimates for the Maximum Temperature

| PERIOD | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 26.78 | 52.90 | 54.84 | -2.79 | -8.58 | 0.40 | 0.54 | 8.73 |
| 2 | 31.51 | 58.63 | 60.70 | -2.93 | -8.58 | 0.34 | 0.58 | 8.64 |
| 3 | 36.69 | 64.26 | 66.38 | -2.74 | -8.07 | 0.30 | 0.58 | 8.24 |
| 4 | 41.57 | 68.68 | 70.80 | -2.29 | -7.15 | 0.31 | 0.53 | 7.63 |
| 5 | 45.92 | 72.01 | 74.13 | -1.88 | -6.16 | 0.35 | 0.47 | 7.05 |
| 6 | 50.18 | 75.41 | 77.48 | -1.67 | -5.29 | 0.37 | 0.45 | 6.57 |
| 7 | 54.80 | 79.72 | 81.61 | -1.55 | -4.46 | 0.39 | 0.46 | 6.07 |
| 8 | 59.44 | 84.54 | 86.11 | -1.41 | -3.65 | 0.43 | 0.46 | 5.51 |
| 9 | 63.16 | 88.75 | 89.98 | -1.31 | -3.09 | 0.47 | 0.42 | 5.06 |
| 10 | 65.36 | 91.55 | 92.59 | -1.30 | -2.99 | 0.49 | 0.39 | 4.85 |
| 11 | 66.22 | 92.84 | 93.89 | -1.36 | -3.22 | 0.49 | 0.38 | 4.83 |
| 12 | 66.12 | 92.80 | 93.98 | -1.45 | -3.52 | 0.49 | 0.38 | 4.90 |
| 13 | 64.93 | 91.45 | 92.74 | -1.62 | -3.84 | 0.48 | 0.39 | 5.10 |
| 14 | 62.20 | 88.71 | 90.11 | -1.87 | -4.43 | 0.45 | 0.41 | 5.52 |
| 15 | 57.89 | 84.76 | 86.27 | -2.06 | -5.44 | 0.39 | 0.42 | 6.11 |
| 16 | 52.54 | 79.97 | 81.59 | -2.15 | -6.62 | 0.36 | 0.42 | 6.68 |
| 17 | 46.78 | 74.60 | 76.27 | -2.32 | -7.53 | 0.40 | 0.40 | 7.11 |
| 18 | 40.92 | 68.69 | 70.32 | -2.75 | -7.94 | 0.45 | 0.39 | 7.48 |
| 19 | 35.10 | 62.22 | 63.74 | -3.28 | -7.88 | 0.45 | 0.42 | 7.79 |
| 20 | 29.63 | 55.52 | 56.91 | -3.49 | -7.58 | 0.41 | 0.46 | 7.92 |
| 21 | 24.95 | 49.35 | 50.63 | -3.19 | -7.29 | 0.38 | 0.49 | 7.84 |
| 22 | 21.40 | 44.74 | 45.92 | -2.70 | -7.24 | 0.38 | 0.51 | 7.71 |
| 23 | 19.14 | 42.38 | 43.49 | -2.46 | -7.48 | 0.37 | 0.55 | 7.79 |
| 24 | 18.25 | 42.15 | 43.27 | -2.50 | -7.84 | 0.33 | 0.61 | 8.07 |
| 25 | 18.69 | 43.31 | 44.55 | -2.55 | -8.08 | 0.31 | 0.63 | 8.36 |
| 26 | 20.32 | 45.31 | 46.76 | -2.52 | -8.19 | 0.34 | 0.59 | 8.52 |

Table 12a. Manhattan Fourier Coefficients for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 43.260 | 67.515 | 43.065 | -0.742 | 1.511 | 0.327 | 0.385 | 6.880 |
| A1 | -20.611 | -21.936 | -20.501 | -1.061 | 0.386 | -0.066 | 0.024 | 1.171 |
| B1 | 13.554 | 14.129 | 13.576 | 0.653 | -0.990 | -0.027 | 0.020 | -0.824 |
| A2 | 0.752 | 1.175 | 0.890 | -0.073 | -0.698 | 0.007 | -0.006 | 0.003 |
| B2 | 0.850 | 2.385 | 0.460 | 0.706 | 1.075 | -0.045 | 0.046 | 0.509 |
| A3 | -0.089 | 0.320 | -0.071 | 0.098 | 0.044 | 0.009 | -0.021 | 0.076 |
| B3 | 0.440 | 0.857 | 0.383 | 0.307 | 0.297 | -0.035 | -0.010 | -0.312 |
| A4 | -0.111 | -0.526 | -0.091 | -0.037 | 0.144 | 0.008 | -0.014 | -0.190 |
| B4 | 0.140 | -0.281 | 0.190 | 0.050 | -0.178 | 0.003 | -0.008 | -0.007 |
| A5 | -0.289 | -0.392 | -0.346 | -0.072 | 0.329 | 0.012 | -0.003 | 0.056 |
| B5 | -0.163 | -0.185 | -0.140 | -0.318 | 0.138 | 0.015 | -0.004 | -0.098 |
| A6 | 0.048 | 0.027 | 0.131 | -0.228 | -0.171 | 0.014 | -0.005 | -0.072 |
| B6 | -0.028 | -0.040 | 0.054 | -0.257 | -0.119 | -0.017 | 0.011 | 0.002 |

Table 12b. Manhattan Fourier Coefficients for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 43.260 | 67.515 | 69.123 | -1.537 | -5.906 | 0.415 | 0.405 | 6.950 |
| A1 | -20.611 | -21.936 | -21.625 | -1.072 | -1.432 | -0.085 | 0.130 | 1.513 |
| B1 | 13.554 | 14.129 | 14.314 | 0.448 | 1.097 | 0.017 | -0.032 | -0.788 |
| A2 | 0.752 | 1.175 | 1.120 | -0.004 | -0.140 | -0.007 | 0.026 | 0.169 |
| B2 | 0.850 | 2.385 | 2.806 | -0.063 | -0.931 | -0.016 | -0.023 | 0.684 |
| A3 | -0.089 | 0.320 | 0.309 | -0.083 | -0.129 | 0.025 | -0.011 | 0.116 |
| B3 | 0.440 | 0.857 | 0.747 | -0.006 | 0.046 | 0.050 | -0.025 | 0.151 |
| A4 | -0.111 | -0.526 | -0.513 | -0.109 | 0.221 | 0.019 | -0.012 | 0.009 |
| B4 | 0.140 | -0.281 | -0.251 | -0.262 | 0.128 | -0.005 | 0.009 | -0.064 |
| A5 | -0.289 | -0.392 | -0.371 | -0.117 | 0.087 | 0.001 | -0.018 | -0.074 |
| B5 | -0.163 | -0.185 | -0.103 | -0.148 | -0.222 | 0.012 | -0.009 | -0.019 |
| A6 | 0.048 | 0.027 | 0.020 | -0.144 | 0.161 | 0.036 | -0.033 | -0.108 |
| B6 | -0.028 | -0.040 | -0.064 | 0.149 | -0.064 | 0.017 | -0.007 | -0.004 |

Table 13a. Colby Fourier Coefficients
for the Minimum Temperature

| | $\overline{L}_t$ | $\overline{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 37.780 | 66.719 | 38.014 | -1.383 | -0.192 | 0.399 | 0.220 | 6.025 |
| A1 | -19.940 | -21.360 | -19.649 | -1.449 | -0.830 | 0.025 | 0.014 | 1.112 |
| B1 | 12.916 | 13.003 | 12.945 | 0.846 | -0.332 | -0.034 | -0.009 | -0.649 |
| A2 | 1.480 | 1.904 | 1.607 | 0.099 | -0.878 | 0.028 | -0.009 | 0.003 |
| B2 | -0.244 | 0.967 | -0.463 | 0.691 | 0.953 | -0.037 | 0.009 | 0.361 |
| A3 | -0.184 | 0.308 | -0.057 | -0.013 | -0.317 | 0.001 | -0.015 | 0.057 |
| B3 | 0.185 | 0.548 | 0.287 | -0.123 | -0.120 | -0.031 | -0.002 | -0.384 |
| A4 | -0.123 | -0.721 | -0.075 | -0.016 | -0.100 | 0.006 | -0.007 | -0.117 |
| B4 | 0.009 | -0.409 | 0.089 | 0.007 | -0.135 | 0.000 | 0.007 | 0.206 |
| A5 | -0.061 | -0.240 | -0.176 | 0.190 | 0.528 | 0.014 | 0.000 | 0.025 |
| B5 | -0.290 | -0.482 | -0.264 | -0.126 | 0.088 | 0.005 | -0.007 | -0.043 |
| A6 | 0.116 | 0.008 | 0.100 | 0.180 | 0.053 | 0.012 | -0.001 | -0.152 |
| B6 | -0.084 | -0.135 | -0.065 | -0.112 | -0.140 | -0.014 | 0.014 | 0.005 |

Table 13b. Colby Fourier Coefficients
for the Maximum Temperature

| | $\overline{L}_t$ | $\overline{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 37.780 | 66.719 | 68.593 | -2.443 | -7.903 | 0.377 | 0.499 | 7.818 |
| A1 | -19.940 | -21.360 | -21.193 | 0.154 | -2.473 | -0.026 | 0.067 | 1.316 |
| B1 | 12.916 | 13.003 | 13.484 | 0.321 | 1.892 | 0.001 | 0.013 | -0.841 |
| A2 | 1.480 | 1.904 | 1.770 | 0.224 | 0.124 | -0.003 | -0.006 | -0.067 |
| B2 | -0.244 | 0.967 | 1.454 | -0.356 | -1.621 | -0.016 | -0.003 | 0.600 |
| A3 | -0.184 | 0.308 | 0.333 | 0.028 | -0.421 | 0.017 | 0.002 | 0.108 |
| B3 | 0.185 | 0.548 | 0.498 | -0.330 | 0.075 | 0.015 | -0.015 | -0.075 |
| A4 | -0.123 | -0.721 | -0.563 | 0.027 | -0.069 | 0.003 | 0.000 | 0.013 |
| B4 | 0.009 | -0.409 | -0.473 | 0.307 | 0.138 | -0.006 | 0.018 | -0.069 |
| A5 | -0.061 | -0.240 | -0.262 | 0.427 | -0.160 | -0.009 | -0.011 | 0.024 |
| B5 | -0.290 | -0.482 | -0.434 | 0.221 | 0.178 | 0.015 | -0.017 | -0.018 |
| A6 | 0.116 | 0.008 | -0.049 | 0.160 | 0.345 | 0.000 | 0.009 | 0.018 |
| B6 | -0.084 | -0.135 | -0.155 | -0.098 | 0.001 | 0.008 | 0.004 | -0.023 |

Table 14a. Columbus Fourier Coefficients
for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 46.398 | 69.116 | 46.317 | -1.403 | 1.629 | 0.390 | 0.345 | 6.133 |
| A1 | -18.339 | -19.848 | -18.235 | -1.208 | 0.686 | -0.131 | 0.082 | 1.688 |
| B1 | 12.172 | 12.412 | 12.127 | 1.027 | -0.983 | -0.018 | 0.035 | -1.292 |
| A2 | 0.720 | 1.319 | 0.899 | -0.314 | -0.390 | 0.025 | -0.042 | -0.006 |
| B2 | 0.728 | 2.220 | 0.463 | 0.278 | 0.789 | -0.068 | 0.084 | 0.346 |
| A3 | -0.068 | 0.204 | -0.080 | 0.052 | 0.093 | -0.011 | -0.004 | 0.067 |
| B3 | 0.237 | 0.607 | 0.126 | 0.455 | 0.141 | -0.049 | 0.007 | -0.130 |
| A4 | -0.159 | -0.309 | -0.239 | 0.139 | 0.199 | -0.024 | 0.010 | -0.108 |
| B4 | 0.134 | -0.214 | 0.143 | 0.168 | -0.129 | 0.001 | -0.011 | -0.057 |
| A5 | -0.310 | -0.417 | -0.366 | 0.023 | 0.221 | -0.005 | 0.003 | -0.080 |
| B5 | -0.170 | -0.086 | -0.243 | 0.147 | 0.101 | -0.012 | 0.008 | -0.137 |
| A6 | 0.051 | -0.040 | 0.020 | 0.157 | 0.016 | -0.007 | 0.011 | -0.135 |
| B6 | 0.015 | -0.021 | 0.026 | 0.071 | -0.159 | -0.030 | 0.019 | 0.022 |

Table 14b. Columbus Fourier Coefficients
for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 46.398 | 69.116 | 70.817 | -1.795 | -4.801 | 0.401 | 0.456 | 5.947 |
| A1 | -18.339 | -19.848 | -19.425 | -0.944 | -0.838 | -0.145 | 0.190 | 1.376 |
| B1 | 12.172 | 12.412 | 12.347 | 0.912 | 0.728 | 0.017 | -0.059 | -0.778 |
| A2 | 0.720 | 1.319 | 1.268 | 0.213 | -0.272 | 0.033 | -0.000 | 0.117 |
| B2 | 0.728 | 2.220 | 2.661 | -0.308 | -0.800 | -0.051 | 0.012 | 0.465 |
| A3 | -0.068 | 0.204 | 0.154 | 0.003 | 0.022 | 0.027 | -0.012 | 0.095 |
| B3 | 0.237 | 0.607 | 0.580 | -0.002 | -0.241 | 0.023 | -0.003 | 0.193 |
| A4 | -0.159 | -0.309 | -0.303 | -0.067 | 0.158 | 0.003 | 0.004 | 0.023 |
| B4 | 0.134 | -0.214 | -0.177 | -0.179 | 0.024 | -0.007 | 0.018 | -0.036 |
| A5 | -0.310 | -0.417 | -0.351 | -0.093 | -0.110 | -0.004 | -0.005 | -0.146 |
| B5 | -0.170 | -0.086 | -0.043 | -0.144 | -0.070 | -0.000 | 0.009 | -0.022 |
| A6 | 0.051 | -0.040 | -0.051 | 0.066 | -0.085 | 0.024 | -0.014 | -0.089 |
| B6 | 0.015 | -0.021 | -0.012 | -0.106 | 0.084 | 0.012 | -0.015 | 0.023 |

Table 15a. Elkhart Fourier Coefficients
for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 40.954 | 70.954 | 41.065 | -0.589 | -0.564 | 0.377 | 0.243 | 5.864 |
| A1 | -19.338 | -19.068 | -19.256 | -1.022 | -0.471 | -0.038 | 0.049 | 1.353 |
| B1 | 12.446 | 12.291 | 12.491 | 0.860 | -0.438 | -0.009 | -0.013 | -0.861 |
| A2 | 1.531 | 1.579 | 1.559 | 0.036 | -0.378 | 0.012 | 0.000 | -0.058 |
| B2 | -0.004 | 1.093 | -0.206 | 0.878 | 1.131 | -0.028 | 0.010 | 0.429 |
| A3 | -0.111 | 0.370 | -0.128 | 0.296 | 0.214 | -0.005 | -0.004 | 0.150 |
| B3 | -0.113 | 0.255 | -0.086 | 0.147 | 0.002 | -0.030 | 0.003 | -0.205 |
| A4 | -0.175 | -0.495 | -0.136 | 0.127 | -0.080 | 0.002 | -0.014 | -0.126 |
| B4 | -0.019 | -0.190 | 0.004 | -0.141 | 0.065 | -0.000 | 0.000 | 0.166 |
| A5 | 0.079 | -0.210 | 0.001 | 0.416 | 0.445 | 0.004 | -0.007 | 0.093 |
| B5 | -0.255 | -0.551 | -0.228 | -0.202 | -0.002 | 0.006 | -0.009 | -0.018 |
| A6 | 0.188 | 0.097 | 0.185 | 0.192 | -0.001 | 0.001 | 0.000 | -0.098 |
| B6 | -0.047 | -0.098 | 0.020 | -0.447 | -0.436 | 0.006 | -0.000 | 0.037 |

Table 15b. Elkhart Fourier Coefficients
for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 40.954 | 70.954 | 72.134 | -1.828 | -7.692 | 0.384 | 0.479 | 7.214 |
| A1 | -19.338 | -19.068 | -19.011 | -0.420 | -2.401 | -0.039 | 0.098 | 1.869 |
| B1 | 12.446 | 12.291 | 12.513 | 0.685 | 2.191 | 0.017 | -0.012 | -1.019 |
| A2 | 1.531 | 1.579 | 1.483 | 0.178 | 0.364 | 0.011 | -0.007 | -0.281 |
| B2 | -0.004 | 1.093 | 1.415 | -0.351 | -1.414 | -0.027 | -0.001 | 0.403 |
| A3 | -0.111 | 0.370 | 0.315 | 0.124 | -0.175 | 0.023 | -0.014 | 0.199 |
| B3 | -0.113 | 0.255 | 0.289 | -0.709 | -0.222 | 0.007 | -0.020 | 0.023 |
| A4 | -0.175 | -0.495 | -0.465 | 0.117 | 0.057 | 0.037 | -0.030 | 0.050 |
| B4 | -0.019 | -0.190 | -0.238 | -0.255 | 0.362 | -0.006 | 0.007 | 0.079 |
| A5 | 0.079 | -0.210 | -0.138 | 0.009 | 0.126 | -0.010 | -0.014 | 0.022 |
| B5 | -0.255 | -0.551 | -0.496 | 0.014 | 0.153 | 0.022 | -0.012 | 0.007 |
| A6 | 0.188 | 0.097 | 0.016 | 0.382 | 0.345 | 0.026 | -0.011 | -0.064 |
| B6 | -0.047 | -0.098 | -0.155 | 0.106 | 0.203 | 0.005 | -0.008 | 0.087 |

Table 16a. Garden City Fourier Coefficients for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 40.212 | 69.318 | 40.419 | -1.138 | -0.405 | 0.435 | 0.193 | 5.910 |
| A1 | -20.412 | -20.418 | -20.278 | -1.383 | -0.476 | 0.009 | 0.020 | 1.079 |
| B1 | 13.595 | 13.158 | 13.724 | 0.640 | -0.695 | -0.031 | -0.006 | -0.667 |
| A2 | 1.601 | 1.665 | 1.674 | -0.208 | -0.552 | 0.017 | -0.007 | -0.054 |
| B2 | 0.118 | 1.191 | -0.104 | 0.910 | 1.019 | -0.014 | 0.011 | 0.551 |
| A3 | -0.175 | 0.403 | -0.153 | 0.134 | 0.102 | -0.001 | -0.003 | 0.124 |
| B3 | -0.034 | 0.501 | 0.005 | 0.134 | -0.034 | -0.039 | 0.000 | -0.285 |
| A4 | -0.178 | -0.569 | -0.157 | -0.043 | 0.101 | 0.021 | -0.015 | -0.146 |
| B4 | 0.137 | -0.226 | 0.187 | 0.042 | -0.193 | -0.007 | 0.012 | 0.154 |
| A5 | -0.057 | -0.295 | -0.106 | 0.160 | 0.364 | 0.018 | -0.009 | 0.079 |
| B5 | -0.252 | -0.420 | -0.233 | -0.073 | 0.041 | 0.006 | -0.007 | -0.035 |
| A6 | 0.132 | -0.004 | 0.098 | 0.209 | 0.150 | 0.000 | 0.009 | -0.088 |
| B6 | -0.081 | -0.152 | -0.035 | -0.143 | -0.268 | 0.009 | 0.001 | 0.054 |

Table 16b. Garden City Fourier Coefficients for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 40.212 | 69.318 | 70.925 | -3.121 | -8.128 | 0.365 | 0.509 | 7.790 |
| A1 | -20.412 | -20.418 | -20.216 | -0.277 | -3.270 | -0.026 | 0.077 | 1.710 |
| B1 | 13.595 | 13.158 | 13.418 | 0.697 | 2.474 | -0.013 | 0.028 | -0.769 |
| A2 | 1.601 | 1.665 | 1.634 | 0.080 | -0.173 | -0.005 | 0.005 | -0.088 |
| B2 | 0.118 | 1.191 | 1.597 | -0.216 | -1.635 | -0.017 | -0.011 | 0.624 |
| A3 | -0.175 | 0.403 | 0.379 | 0.018 | -0.283 | 0.017 | -0.006 | 0.166 |
| B3 | -0.034 | 0.501 | 0.594 | -0.363 | -0.123 | 0.021 | -0.023 | -0.103 |
| A4 | -0.178 | -0.569 | -0.480 | -0.094 | 0.263 | 0.029 | -0.014 | 0.043 |
| B4 | 0.137 | -0.226 | -0.287 | 0.191 | 0.069 | -0.005 | 0.011 | -0.034 |
| A5 | -0.057 | -0.295 | -0.372 | 0.373 | 0.085 | 0.002 | -0.043 | 0.057 |
| B5 | -0.252 | -0.420 | -0.416 | 0.379 | -0.197 | 0.019 | -0.028 | 0.027 |
| A6 | 0.132 | -0.004 | 0.016 | 0.020 | 0.149 | 0.004 | -0.005 | -0.038 |
| B6 | -0.081 | -0.152 | -0.127 | 0.060 | -0.148 | -0.000 | 0.012 | -0.007 |

Table 17a. Hays Fourier Coefficients for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 40.142 | 67.660 | 40.323 | -1.747 | 0.699 | 0.429 | 0.195 | 6.593 |
| A1 | -21.132 | -21.623 | -21.096 | -1.245 | 0.210 | 0.007 | 0.017 | 1.027 |
| B1 | 13.765 | 13.333 | 13.950 | 0.564 | -1.106 | -0.020 | -0.015 | -0.585 |
| A2 | 1.298 | 1.772 | 1.430 | -0.280 | -0.898 | 0.022 | -0.009 | -0.060 |
| B2 | 0.278 | 1.615 | 0.047 | 0.627 | 0.919 | -0.021 | 0.008 | 0.596 |
| A3 | -0.180 | 0.306 | -0.155 | 0.198 | -0.121 | -0.007 | -0.003 | 0.040 |
| B3 | 0.229 | 0.827 | 0.213 | 0.159 | 0.261 | -0.040 | 0.005 | -0.343 |
| A4 | -0.130 | -0.706 | -0.046 | -0.373 | 0.137 | 0.024 | -0.023 | -0.189 |
| B4 | 0.089 | -0.187 | 0.174 | -0.069 | -0.194 | 0.010 | -0.006 | 0.160 |
| A5 | -0.132 | -0.353 | -0.191 | -0.005 | 0.325 | 0.006 | -0.006 | 0.071 |
| B5 | -0.218 | -0.323 | -0.231 | -0.101 | 0.266 | -0.021 | 0.007 | -0.095 |
| A6 | 0.166 | -0.040 | 0.192 | -0.021 | 0.085 | 0.013 | 0.004 | -0.123 |
| B6 | 0.030 | -0.073 | 0.083 | -0.240 | -0.206 | -0.003 | 0.008 | 0.088 |

Table 17b. Hays Fourier Coefficients for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 40.142 | 67.660 | 69.404 | -3.531 | -6.968 | 0.381 | 0.534 | 7.804 |
| A1 | -21.132 | -21.623 | -21.572 | -0.244 | -2.687 | -0.029 | 0.072 | 1.643 |
| B1 | 13.765 | 13.333 | 13.693 | 0.723 | 2.079 | 0.013 | -0.004 | -0.963 |
| A2 | 1.298 | 1.772 | 1.703 | -0.052 | -0.122 | -0.004 | 0.031 | 0.101 |
| B2 | 0.278 | 1.615 | 2.028 | -0.506 | -0.989 | -0.030 | -0.008 | 0.588 |
| A3 | -0.180 | 0.306 | 0.329 | -0.286 | -0.346 | 0.015 | -0.001 | 0.207 |
| B3 | 0.229 | 0.827 | 0.841 | -0.612 | 0.113 | 0.026 | -0.018 | -0.013 |
| A4 | -0.130 | -0.706 | -0.587 | -0.337 | 0.353 | 0.020 | -0.011 | -0.093 |
| B4 | 0.089 | -0.187 | -0.180 | 0.341 | -0.119 | -0.007 | -0.000 | 0.071 |
| A5 | -0.132 | -0.353 | -0.390 | 0.086 | 0.373 | 0.004 | -0.025 | -0.004 |
| B5 | -0.218 | -0.323 | -0.298 | 0.449 | -0.286 | 0.021 | -0.011 | 0.030 |
| A6 | 0.166 | -0.040 | 0.019 | -0.105 | 0.009 | 0.009 | -0.011 | -0.071 |
| B6 | 0.030 | -0.073 | -0.166 | 0.014 | 0.035 | 0.010 | -0.004 | -0.020 |

Table 18a. Horton Fourier Coefficients for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 41.828 | 64.992 | 41.847 | -1.603 | 1.495 | 0.380 | 0.323 | 6.491 |
| A1 | -20.822 | -21.810 | -20.760 | -1.137 | 0.628 | -0.064 | 0.045 | 1.386 |
| B1 | 13.449 | 14.183 | 13.528 | 0.855 | -1.199 | -0.014 | -0.005 | -0.744 |
| A2 | 0.481 | 0.789 | 0.582 | -0.079 | -0.556 | 0.020 | -0.009 | -0.018 |
| B2 | 1.025 | 2.541 | 0.847 | 0.363 | 0.542 | -0.036 | 0.014 | 0.591 |
| A3 | 0.023 | 0.226 | 0.041 | 0.050 | -0.029 | 0.010 | -0.016 | 0.029 |
| B3 | 0.559 | 0.854 | 0.496 | 0.266 | 0.130 | -0.039 | 0.001 | -0.314 |
| A4 | -0.119 | -0.551 | -0.064 | -0.132 | -0.009 | 0.006 | -0.011 | -0.140 |
| B4 | 0.114 | -0.308 | 0.164 | 0.041 | -0.214 | 0.010 | -0.016 | 0.018 |
| A5 | -0.301 | -0.435 | -0.290 | -0.268 | 0.263 | 0.021 | -0.015 | 0.028 |
| B5 | -0.047 | -0.097 | -0.008 | -0.262 | 0.065 | -0.002 | 0.003 | -0.077 |
| A6 | 0.074 | -0.020 | 0.069 | -0.182 | 0.186 | 0.001 | 0.012 | -0.088 |
| B6 | 0.034 | 0.038 | 0.142 | -0.289 | -0.185 | -0.001 | 0.003 | 0.027 |

Table 18b. Horton Fourier Coefficients for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_H$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 41.828 | 64.992 | 66.448 | -1.873 | -5.022 | 0.402 | 0.481 | 6.566 |
| A1 | -20.822 | -21.810 | -21.698 | -0.225 | -1.449 | -0.050 | 0.078 | 1.463 |
| B1 | 13.449 | 14.183 | 14.406 | 0.702 | 0.614 | 0.008 | 0.001 | -0.612 |
| A2 | 0.481 | 0.789 | 0.691 | 0.412 | -0.274 | -0.014 | 0.030 | 0.118 |
| B2 | 1.025 | 2.541 | 3.001 | -0.468 | -1.012 | -0.013 | -0.004 | 0.561 |
| A3 | 0.023 | 0.226 | 0.208 | -0.013 | -0.227 | 0.027 | -0.024 | 0.119 |
| B3 | 0.559 | 0.854 | 0.779 | -0.128 | -0.081 | 0.035 | 0.001 | 0.077 |
| A4 | -0.119 | -0.551 | -0.492 | -0.199 | 0.201 | 0.011 | -0.005 | 0.077 |
| B4 | 0.114 | -0.308 | -0.246 | -0.051 | -0.093 | -0.001 | 0.002 | 0.027 |
| A5 | -0.301 | -0.435 | -0.399 | 0.008 | -0.121 | 0.007 | -0.026 | 0.024 |
| B5 | -0.047 | -0.097 | -0.058 | -0.018 | -0.326 | 0.016 | -0.009 | 0.009 |
| A6 | 0.074 | -0.020 | 0.013 | -0.023 | -0.168 | 0.012 | -0.014 | -0.090 |
| B6 | 0.034 | 0.038 | 0.043 | -0.068 | 0.035 | 0.025 | -0.025 | -0.031 |

Table 19a. McPherson Fourier Coefficients
for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 44.277 | 68.158 | 44.622 | -1.559 | -0.086 | 0.403 | 0.259 | 6.480 |
| A1 | -20.595 | -21.932 | -20.588 | -1.292 | 0.717 | -0.064 | 0.055 | 1.590 |
| B1 | 12.858 | 14.194 | 13.078 | 0.650 | -1.171 | -0.007 | -0.023 | -1.078 |
| A2 | 1.033 | 1.877 | 1.153 | -0.066 | -0.898 | 0.016 | -0.015 | -0.013 |
| B2 | 0.779 | 2.087 | 0.550 | 0.517 | 0.774 | -0.026 | 0.023 | 0.310 |
| A3 | -0.006 | 0.375 | 0.007 | 0.090 | -0.018 | -0.027 | 0.016 | 0.044 |
| B3 | 0.408 | 1.006 | 0.286 | 0.251 | 0.429 | -0.047 | 0.024 | -0.325 |
| A4 | -0.203 | -0.463 | -0.167 | 0.023 | 0.087 | 0.002 | -0.014 | -0.191 |
| B4 | 0.006 | -0.140 | 0.071 | -0.056 | -0.026 | 0.009 | -0.012 | 0.039 |
| A5 | -0.292 | -0.440 | -0.371 | -0.033 | 0.500 | 0.002 | -0.008 | 0.046 |
| B5 | -0.190 | -0.231 | -0.170 | -0.360 | 0.257 | -0.010 | 0.008 | -0.067 |
| A6 | 0.148 | 0.016 | 0.144 | -0.140 | 0.201 | 0.003 | 0.011 | -0.089 |
| B6 | -0.050 | -0.133 | 0.023 | -0.040 | -0.446 | -0.005 | 0.003 | -0.001 |

Table 19b. McPherson Fourier Coefficients
for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 44.277 | 68.158 | 69.630 | -2.068 | -5.453 | 0.400 | 0.507 | 6.545 |
| A1 | -20.595 | -21.932 | -21.709 | -0.324 | -1.904 | -0.063 | 0.082 | 1.511 |
| B1 | 12.858 | 14.194 | 14.325 | C.480 | 1.362 | 0.007 | -0.003 | -0.760 |
| A2 | 1.033 | 1.877 | 1.919 | 0.082 | -0.582 | -0.007 | 0.036 | 0.032 |
| B2 | 0.779 | 2.087 | 2.501 | -0.229 | -1.058 | -0.028 | -0.020 | 0.757 |
| A3 | -0.006 | 0.375 | 0.391 | -0.109 | -0.272 | 0.029 | -0.023 | 0.141 |
| B3 | 0.408 | 1.006 | 0.918 | -0.195 | -0.020 | 0.026 | -0.011 | 0.080 |
| A4 | -0.203 | -0.463 | -0.410 | -0.144 | 0.052 | 0.015 | -0.006 | -0.035 |
| B4 | 0.006 | -0.140 | -0.109 | -0.252 | 0.218 | 0.001 | 0.001 | -0.029 |
| A5 | -0.292 | -0.440 | -0.428 | -0.090 | 0.131 | 0.006 | -0.019 | -0.054 |
| B5 | -0.190 | -0.231 | -0.197 | 0.017 | -0.138 | 0.022 | -0.014 | -0.051 |
| A6 | 0.148 | 0.016 | 0.009 | 0.135 | 0.046 | 0.031 | -0.025 | -0.146 |
| B6 | -0.050 | -0.133 | -0.113 | -0.103 | -0.011 | 0.018 | -0.017 | 0.025 |

Table 20a. Winfield Fourier Coefficients for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 46.338 | 70.104 | 46.320 | -0.959 | 1.228 | 0.400 | 0.298 | 6.435 |
| A1 | -19.674 | -20.093 | -19.735 | -0.736 | 0.947 | -0.085 | 0.056 | 1.644 |
| B1 | 12.798 | 13.309 | 12.970 | 0.427 | -1.638 | -0.013 | 0.010 | -1.013 |
| A2 | 0.938 | 1.725 | 1.103 | -0.315 | -0.941 | 0.012 | -0.020 | -0.027 |
| B2 | 0.950 | 2.193 | 0.845 | 0.065 | 0.399 | -0.021 | 0.028 | 0.669 |
| A3 | -0.076 | 0.291 | -0.040 | -0.062 | -0.130 | -0.008 | -0.007 | 0.125 |
| B3 | 0.239 | 0.880 | 0.180 | 0.305 | 0.347 | -0.049 | 0.023 | -0.223 |
| A4 | -0.216 | -0.338 | -0.262 | -0.086 | 0.527 | -0.012 | -0.004 | -0.082 |
| B4 | 0.076 | -0.165 | 0.110 | 0.156 | -0.052 | -0.001 | -0.009 | -0.019 |
| A5 | -0.318 | -0.441 | -0.427 | 0.178 | 0.537 | -0.007 | -0.005 | -0.048 |
| B5 | -0.206 | -0.287 | -0.230 | 0.110 | -0.088 | -0.005 | 0.005 | -0.060 |
| A6 | 0.076 | 0.004 | 0.063 | 0.219 | -0.087 | -0.010 | 0.013 | -0.077 |
| B6 | -0.129 | -0.142 | -0.078 | -0.175 | -0.267 | -0.015 | 0.011 | 0.009 |

Table 20b. Winfield Fourier Coefficients for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 46.338 | 70.104 | 71.302 | -2.041 | -4.952 | 0.445 | 0.425 | 6.275 |
| A1 | -19.674 | -20.093 | -19.968 | -0.854 | -1.140 | -0.083 | 0.116 | 1.627 |
| B1 | 12.798 | 13.309 | 13.439 | 0.621 | 0.920 | -0.006 | -0.020 | -0.762 |
| A2 | 0.938 | 1.725 | 1.709 | -0.301 | -0.195 | 0.011 | 0.028 | 0.092 |
| B2 | 0.950 | 2.193 | 2.451 | -0.221 | -0.495 | -0.021 | -0.025 | 0.520 |
| A3 | -0.076 | 0.291 | 0.315 | -0.135 | -0.152 | 0.024 | -0.010 | 0.108 |
| B3 | 0.239 | 0.880 | 0.767 | 0.108 | 0.054 | 0.024 | -0.011 | 0.095 |
| A4 | -0.216 | -0.338 | -0.363 | -0.005 | 0.250 | 0.006 | -0.001 | 0.096 |
| B4 | 0.076 | -0.165 | -0.138 | -0.053 | 0.138 | 0.002 | 0.004 | -0.008 |
| A5 | -0.318 | -0.441 | -0.478 | 0.283 | -0.060 | 0.008 | -0.011 | -0.055 |
| B5 | -0.206 | -0.287 | -0.220 | -0.143 | -0.115 | -0.001 | 0.003 | 0.045 |
| A6 | 0.076 | 0.004 | -0.005 | 0.283 | -0.141 | 0.018 | -0.008 | -0.083 |
| B6 | -0.129 | -0.142 | -0.094 | -0.209 | 0.013 | -0.001 | 0.008 | -0.005 |

Table 21a. Kansas Fourier Coefficients
for the Minimum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_L$ | $C_{L,t-1}$ | $C_{L,t}$ | $C_{LL}$ | $C_{HL}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 42.354 | 68.282 | 42.443 | -1.236 | 0.591 | 0.393 | 0.273 | 6.312 |
| A1 | -20.096 | -20.899 | -20.011 | -1.170 | 0.200 | -0.045 | 0.040 | 1.339 |
| B1 | 13.061 | 13.335 | 13.154 | 0.725 | -0.950 | -0.019 | -0.001 | -0.857 |
| A2 | 1.093 | 1.534 | 1.211 | -0.133 | -0.688 | 0.018 | -0.013 | -0.025 |
| B2 | 0.498 | 1.810 | 0.271 | 0.560 | 0.845 | -0.033 | 0.026 | 0.485 |
| A3 | -0.096 | 0.312 | -0.071 | 0.094 | -0.018 | -0.005 | -0.006 | 0.079 |
| B3 | 0.239 | 0.704 | 0.210 | 0.211 | 0.161 | -0.040 | 0.006 | -0.280 |
| A4 | -0.157 | -0.520 | -0.137 | -0.044 | 0.112 | 0.004 | -0.010 | -0.143 |
| B4 | 0.076 | -0.236 | 0.126 | 0.022 | -0.117 | 0.003 | -0.005 | 0.073 |
| A5 | -0.187 | -0.358 | -0.252 | 0.065 | 0.390 | 0.007 | -0.006 | 0.030 |
| B5 | -0.199 | -0.296 | -0.194 | -0.132 | 0.096 | -0.002 | 0.001 | -0.070 |
| A6 | 0.111 | 0.005 | 0.111 | 0.043 | 0.048 | 0.003 | 0.006 | -0.102 |
| B6 | -0.038 | -0.084 | 0.019 | -0.181 | -0.247 | -0.008 | 0.008 | 0.027 |

Table 21b. Kansas Fourier Coefficients
for the Maximum Temperature

| | $\bar{L}_t$ | $\bar{H}_t$ | $C_H$ | $C_{H,t-1}$ | $C_{H,t}$ | $C_{HH}$ | $C_{LH}$ | $s_L$ |
|---|---|---|---|---|---|---|---|---|
| A0 | 42.354 | 68.282 | 69.819 | -2.249 | -6.314 | 0.397 | 0.477 | 6.990 |
| A1 | -20.096 | -20.899 | -20.713 | -0.467 | -1.955 | -0.061 | 0.101 | 1.559 |
| B1 | 13.061 | 13.335 | 13.549 | 0.621 | 1.484 | 0.007 | -0.010 | -0.810 |
| A2 | 1.093 | 1.534 | 1.478 | 0.093 | -0.141 | 0.002 | 0.016 | 0.021 |
| B2 | 0.498 | 1.810 | 2.213 | -0.302 | -1.106 | -0.024 | -0.009 | 0.578 |
| A3 | -0.096 | 0.312 | 0.304 | -0.050 | -0.220 | 0.023 | -0.011 | 0.140 |
| B3 | 0.239 | 0.704 | 0.668 | -0.248 | -0.044 | 0.025 | -0.014 | 0.048 |
| A4 | -0.157 | -0.520 | -0.464 | -0.090 | 0.165 | 0.016 | -0.008 | 0.020 |
| B4 | 0.076 | -0.236 | -0.233 | -0.024 | 0.096 | -0.004 | 0.008 | -0.007 |
| A5 | -0.187 | -0.358 | -0.354 | 0.098 | 0.039 | 0.001 | -0.019 | -0.023 |
| B5 | -0.199 | -0.296 | -0.252 | 0.070 | -0.114 | 0.014 | -0.010 | 0.001 |
| A6 | 0.111 | 0.005 | -0.001 | 0.086 | 0.074 | 0.018 | -0.012 | -0.075 |
| B6 | -0.038 | -0.084 | -0.094 | -0.028 | 0.016 | 0.010 | -0.006 | 0.005 |

# APPENDIX A

# THE LINMOD PROGRAM

```
C
C     ..........................................................
C
C        PROGRAM
C           LINMOD, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO PERFORM MULTIPLE REGRESSIONS OR ANALYSES OF COVARIANCE
C           ON DAILY WEATHER DATA.
C
C        USAGE
C           THE INPUT STREAM REQUIRES THE FOLLOWING:
C              A STANDARD WDL TITLE CARD (USED AS A COMMENT).
C              A STANDARD WDL STATION CARD (USED AS A COMMENT).
C              A STANDARD WDL DATES CARD.
C              A STANDARD PERFORM CARD WITH THE INDICATOR INDCPY.
C              A SELECT CARD.
C              A LGRP CARD.
C              A MINGRP CARD.
C              A NMDLS CARD.
C              ALTERNATING MODEL AND NAMES CARDS.
C           WEATHER RECORDS MUST BE AVAILABLE TO SUBROUTINE RDREC.
C
C        DESCRIPTION OF PARAMETERS
C           INDCPY - SET TO .TRUE. IF DATA MUST BE COPIED TO DISK.
C           SELECT - A SELECTION CRITERION OF THE FORM 'DW', WHERE
C                    N IS NO SELECTION, D IS DRY, AND W IS WET.
C           LGRP   - THE NUMBER OF DAYS IN EACH PERIOD (EXCEPT LAST).
C           MINGRP - THE NUMBER OF THE FIRST GROUP TO BE USED.
C           NMDLS  - THE NUMBER OF MODELS TO BE USED WITH EACH GROUP.
C           MODEL  - SEE THE SUBROUTINE 'DESIGN' FOR DETAILS.
C           NAMES  - 8-CHAR. NAMES FOR THE MODEL VARIABLES.
C           FOR INFORMATION ABOUT THE STANDARD INPUT CARDS
C           SEE THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY.
C
C        REMARKS
C           THIS PROGRAM WILL SOLVE A FULL RANK LINEAR MODEL OF UP
C           TO 7 PARAMETERS WITHOUT STORAGE AND FORMAT MODIFICATION.
C           THE ANALYSIS OF VARIANCE TABLE ASSUMES THAT THE FIRST
C           PARAMETER OF THE MODEL IS A CONSTANT (OR MEAN).
C
C           UP TO 1000 OBSERVATIONS MAY BE IN EACH GROUP.
C           UP TO 9 MODELS MAY BE APPLIED TO EACH DATA GROUP.
```

```
C           DISK SPACE IS RESERVED FOR 71 YEARS OF DATA.
C
C           SELECTION OF A PRECIPITATION PATTERN MAY BE DONE FOR THE
C           ENTIRE RUN OR FOR INDIVIDUAL MODELS.  IN THE LATTER CASE
C           THE MEANS SUBTRACTED TO FORM DEVIATE VARIABLES ARE NOT
C           AVAILABLE.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           ERRSET (ALTERS SYSTEM ERROR HANDLING)
C           RDTITL (READS A STANDARD WEATHER DATA LIBRARY TITLE CARD)
C           RDSTAT (READS A STANDARD WDL STATION CARD)
C           RDDATE (READS A STANDARD WDL DATES CARD)
C           RDPERF (READS A STANDARD PERFORM CARD)
C           ABEND  (PRINTS A MESSAGE AND TERMINATES)
C           DSKCPY (TRANSFERS WEATHER DATA FROM TAPE TO DISK)
C           GRPLIM (CALCULATES INITIAL AND FINAL DAYS OF ANY GROUP)
C           CPYGRP (BUILDS A GROUP MATRIX FROM DISK RECORDS)
C           PTSTAT (PRINTS A VARIETY OF STATISTICS)
C           DESIGN (BUILDS THE DESIGN MATRIX FOR A LINEAR MODEL)
C           CTIE   (CATENATES TWO MATRICES BY COLUMNS)
C           PTREG  (COMPUTES AND PRINTS REGRESSION DATA)
C
C        METHOD
C           RECORDS FROM TAPE ARE TRANSFERRED TO DISK.  THEN THE
C           RECORDS FOR A SINGLE PERIOD ARE READ INTO CORE.  THESE
C           ARE SELECTED TO FORM THE DESIGN MATRIX OF A GENERAL
C           LINEAR MODEL, WHICH IS SOLVED FOR THE PARAMETER
C           ESTIMATES.
C
C     ..................................................................
C
      LOGICAL INDEND/.FALSE./,INDYR,INDCPY
      INTEGER MODEL(68,9),IBLANK(68)/68*' '/
      REAL GRP(6000),X(7000),Y(1000),ASEL(9)/'NN','ND','NW','DN',
     1   'DD','DW','WN','WD','WW'/
      REAL*8 GRPLBL(8)/'PREWET  ','PREMIN  ','PREMAX  ','PSTWET  ',
     1   'PSTMIN  ','PSTMAX  '/,XLBL(8,10)
      COMMON /DSKREC/ NUL1(3),NXTREC
      COMMON /EQUIV/ GRPT(7000),XY(8000)
      COMMON /STATUS/ SELECT,NOWGRP,MNDAY,MXDAY,NOWMDL
C
C     SUPRESS UNDERFLOW AND DIVIDE CHECK MESSAGES.
C
      CALL ERRSET (208,0,-1,0,0,0)
      CALL ERRSET (209,256,-1,0,0,0)
C
C     READ THE RUN PARAMETERS.
C
C        READ THE RUN TITLE, STATION NAME, AND DATES TO BE USED.
C
      CALL RDTITL (INDEND)
      CALL RDSTAT (INDEND)
      CALL RDDATE (INDEND)
C
```

```
C         DETERMINE WHETHER THE DISK DATA SET MUST BE CREATED.
C
      CALL RDPERF (INDEND,INDCPY)
C
C         READ AND INTERPRET THE CRITERION FOR SELECTION OF RECORDS.
C
      READ (5,2) SELECT
      DO 10 KSEL=1,9
      IF (SELECT.EQ.ASEL(KSEL)) GO TO 20
   10 CONTINUE
      KSEL=1
C
C         READ THE NUMBER OF DAYS PER GROUP AND FIRST GROUP NUMBER.
C
   20 READ (5,1) LGRP,MINGRP
C
C         READ THE MODEL CARDS AND CORRESPONDING VARIABLE NAMES.
C
      READ (5,1) NMDLS
      IF (NMDLS.GT.9) CALL ABEND ('LINMOD  ',
     1   'THE NUMBER OF MODELS EXCEEDS 9.                            ')
      IF (NMDLS.GT.0) READ (5,3) ((MODEL(I,J),I=1,68),
     1   (XLBL(I,J),I=1,8),J=1,NMDLS)
C
C      DEFINE THE DIRECT ACCESS FILE.
C
      DEFINE FILE 4(25915,3,U,NXTREC)
C
C      TRANSFER TAPE RECORDS TO DISK IF THE DISK FILE DOES NOT EXIST.
C
      IF (INDCPY) CALL DSKCPY
C
C      PROCESS THE RECORDS FOR ONE PERIOD.
C
      NOWGRP=MINGRP-1
C
C         CALCULATE THE BEGINNING AND ENDING DAYS.
C
   30 NOWGRP=NOWGRP+1
      NOWMDL=0
      CALL GRPLIM (NOWGRP,LGRP,MNDAY,MXDAY,INDYR)
      IF (INDYR) GO TO 50
C
C         RETRIEVE THE RECORDS FOR THIS PERIOD.
C
      CALL CPYGRP (GRP,MNDAY,MXDAY,NRECS,KSEL,GRPT)
      IF (NRECS.LT.2) GO TO 30
C
C      COMPUTE AND WRITE STATISTICS FOR THE ENTIRE GROUP.
C
      CALL PTSTAT (GRP,NRECS,6,10,IBLANK,GRPLBL)
C
C      PROCESS EACH MODEL.
C
```

```
      IF (NMDLS.LT.1) GO TO 30
      DO 40 NOWMDL=1,NMDLS
C
C        SET THE OUTPUT DATA SET NUMBER FOR THIS MODEL.
C
      IUNT=NOWMDL+10
C
C        CONSTRUCT X, THE DESIGN MATRIX.
C
      CALL DESIGN (GRP,NRECS,MODEL(1,NOWMDL),Y,X,NOBS,NCOLS,GRPT)
      IF (NOBS.LT.2) GO TO 40
C
C        WRITE STATISTICS FOR THIS DESIGN MATRIX AND Y VECTOR.
C
      CALL CTIE (X,Y,XY,NOBS,NCOLS,0,0,1)
      CALL PTSTAT (XY,NOBS,NCOLS+1,IUNT,MODEL(1,NOWMDL),
     1   XLBL(1,NOWMDL))
C
C        COMPUTE AND PRINT THE REGRESSION PARAMETERS AND THE
C        ANALYSIS OF VARIANCE.
C
      CALL PTREG (X,Y,NOBS,NCOLS,IUNT,MODEL(1,NOWMDL),XLBL(1,NOWMDL))
   40 CONTINUE
      GO TO 30
   50 WRITE (6,4)
      STOP
C
C     ..............................................................
C
    1 FORMAT (12X,I3)
    2 FORMAT (13X,A2)
    3 FORMAT (12X,68A1/12X,8A8)
    4 FORMAT (/4X,'(NORMAL TERMINATION)')
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           DSKCPY, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO COPY A PERIOD OF WEATHER DATA FROM TAPE TO A
C           DIRECT ACCESS DATA SET.
C
C        USAGE
C           CALL DSKCPY
C           COMMON /DATES/ MINDTE,MAXDTE,NUL1(4),MINYR,MINDAY,MAXYR,
C              NUL2
C           COMMON /DSKREC/ NUL1(3),NXTREC
C
C        DESCRIPTION OF PARAMETERS
C           MINDTE - THE FIRST RECORD DATE (YYMMDD) TO BE USED.
C           MAXDTE - THE LAST RECORD DATE (YYMMDD) TO BE USED.
C           MINYR  - THE CLIMATIC YEAR (YYYY) OF THE FIRST RECORD.
C           MINDAY - THE CLIMATIC DAY (DDD) OF THE FIRST RECORD.
C           MAXYR  - THE CLIMATIC YEAR (YYYY) OF THE LAST RECORD.
C           NXTREC - THE ASSOCIATED VARIABLE FOR THE DISK DATA SET.
C
C        REMARKS
C           THE DIRECT ACCESS FILE MUST BE DEFINED ELSEWHERE.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           RDREC  (READS AND INTERPRETS A STANDARD WEATHER RECORD)
C           ABEND  (WRITES AN ERROR MESSAGE AND ENDS EXECUTION)
C
C        METHOD
C           THE DATA ARE READ FROM TAPE WITH SUBROUTINE RDREC.
C           EACH RECORD IS STORED IN LOCATION 365*(YEAR-MINYR)+DAY.
C
C     ..................................................................
C
      SUBROUTINE DSKCPY
      LOGICAL INDEND/.FALSE./
      REAL REC(3)
      COMMON /DATES/ MINDTE,MAXDTE,NUL1(4),MINYR,MINDAY,MAXYR,NUL2
      COMMON /DSKREC/ MAX,MIN,WET,NXTREC
      EQUIVALENCE (REC(1),MAX)
C
```

```
C     SET THE INITIAL DATE AND RECORD NUMBER.
C
      NOWDTE=MINDTE
      NXTREC=MINDAY
C
C     READ THE NEXT RECORD.
C
   10 CALL RDREC (INDEND,NOWDTE,MAX,MIN,WET)
      IF (INDEND.OR.NOWDTE.GT.MAXDTE) GO TO 20
      WRITE (4'NXTREC) REC
      GO TO 10
C
C     TERMINATE IF INSUFFICIENT DATA IS PRESENT.
C
   20 IF (NOWDTE.GE.MAXDTE) RETURN
      CALL ABEND ('DSKCPY  ',
     1   'END OF FILE BEFORE MAXDTE WAS REACHED.                         ')
      END
```

```
C
C     .........................................................................
C
C         SUBROUTINE
C            GRPLIM, MODEL 1, VERSION 1.
C
C         PROGRAMMER
C            KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C            AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C            SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C            NORTH CENTRAL REGION.
C
C         INSTALLATION
C            KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C            USING FORTRAN IV COMPILER G, LEVEL 21.
C
C         PURPOSE
C            TO FIND THE BEGINNING AND ENDING DAYS OF A SPECIFIED
C            GROUP.
C
C         USAGE
C            CALL GRPLIM (NOWGRP,LGRP,MINDAY,MAXDAY,INDYR)
C
C         DESCRIPTION OF PARAMETERS
C            NOWGRP - THE NUMBER OF THE GROUP.
C            LGRP   - THE LENGTH OF EACH GROUP.
C            MINDAY - THE RESULTANT INITIAL DAY.
C            MINDAY - THE RESULTANT FINAL DAY.
C            INDYR  - A LOGICAL INDICATOR SET TO .TRUE. IF THE GROUP
C                     DOES NOT BEGIN WITHIN THE BASE YEAR.
C
C         REMARKS
C            NOWGRP AND LGRP ARE ASSUMED TO BE POSITIVE INTEGERS.
C
C         SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C            NONE
C
C         METHOD
C            THE FIRST GROUP BEGINS WITH MINDAY EQUAL TO 1.
C            MINDAY IS COMPUTED MODULO 365; AN INDICATOR IS SET IF
C            IT EXCEEDS 365 DAYS.  MAXDAY IS COMPUTED FROM MINDAY AND
C            IS SET TO 365 IF IT WOULD OTHERWISE EXCEED THIS VALUE.
C
C     .........................................................................
C
      SUBROUTINE GRPLIM (NOWGRP,LGRP,MINDAY,MAXDAY,INDYR)
      LOGICAL INDYR
C
C     RESET THE LOGICAL INDICATOR.
C
      INDYR=.FALSE.
C
C     COMPUTE THE INITIAL DAY OF THE GROUP.
C
```

```
      MINDAY=1+LGRP*(NOWGRP-1)
C
C        VERIFY THAT THE INITIAL DAY IS WITHIN THE BASE YEAR.
C
   10 IF (MINDAY.LT.366) GO TO 20
      MINDAY=MINDAY-365
      INDYR=.TRUE.
      GO TO 10
C
C     COMPUTE THE FINAL DAY OF THE GROUP.
C
   20 MAXDAY=MINDAY+LGRP-1
      IF (MAXDAY.GT.365) MAXDAY=365
      RETURN
      END
```

```
C
C     ..............................................................
C
C        SUBROUTINE
C           CPYGRP, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO CONSTRUCT A MATRIX OF 2-DAY WEATHER RECORDS FOR A
C           GIVEN PERIOD AND SELECTION CRITERION FROM 1-DAY RECORDS
C           PREVIOUSLY STORED ON DISK.
C
C        USAGE
C           CALL CPYGRP (GRP,MNDAY,MXDAY,NRECS,KSEL,GRPT)
C           COMMON /DATES/ NUL1(6),MINYR,MINDAY,MAXYR,MAXDAY
C           COMMON /DSKREC/ NUL3(3),NXTREC
C
C        DESCRIPTION OF PARAMETERS
C           GRP     - THE MATRIX TO BE FILLED WITH REAL*4 VALUES.
C           MNDAY   - THE FIRST CLIMATIC DAY (DDD) OF THIS GROUP.
C           MXDAY   - THE LAST CLIMATIC DAY (DDD) OF THIS GROUP.
C           NRECS   - THE NUMBER OF RECORDS COPIED INTO GRP.  THIS
C                     VALUE IS RESET TO 0 INITIALLY.
C           KSEL    - THE SELECTION CRITERION.
C           GRPT    - THE TRANSPOSE OF GRP.
C           MINYR   - THE CLI. YEAR (YYYY) OF THE FIRST DISK RECORD.
C           MINDAY  - THE CLIMATIC DAY (DDD) OF THE FIRST DISK RECORD.
C           MAXYR   - THE CLI. YEAR (YYYY) OF THE LAST DISK RECORD.
C           MAXDAY  - THE CLIMATIC DAY (DDD) OF THE LAST DISK RECORD.
C           NXTREC  - THE ASSOCIATED VARIABLE FOR THE DISK DATA SET.
C
C        REMARKS
C           THE MATRIX IS STORED IN COLUMN VECTOR FORM (MODE 0).
C           AFTER TRANSPOSITION THE COLUMNS REPRESENT WET1,MIN1,MAX1,
C           WET2,MIN2,MAX2.  ALL VALUES ARE REAL*4.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           GMTRA  (TRANSPOSES A MODE 0 MATRIX)
C
C        METHOD
C           THE RECORDS IN GRP CONTAIN DATA FOR THE PREVIOUS DAY
C           AS WELL AS FOR THE SPECIFIED DAY.  BOTH DAYS' RECORDS
C           MUST BE READ FROM THE DIRECT ACCESS DATA SET.  ANY 2-DAY
C           RECORD CONTAINING A MISSING VALUE IS ELIMINATED, AS IS
C           ANY RECORD NOT MEETING THE SELECTION CRITERIA.  ALL
```

```
C           NEGATIVE PRECIPITATIONS ARE SET TO 0.
C
C     ..............................................................
C
      SUBROUTINE CPYGRP (GRP,MNDAY,MXDAY,NRECS,KSEL,GRPT)
      LOGICAL INDSKP,INDBAD
      REAL GRP(1),REC(3),GRPT(1)
      COMMON /DATES/ NUL1(6),MINYR,MINDAY,MAXYR,MAXDAY
      COMMON /DSKREC/ MAX,MIN,WET,NXTREC
      EQUIVALENCE (REC(1),MAX)
C
C     ESTABLISH THE SELECTION CRITERIA (0, 1, OR 2 FOR N, D, OR W).
C
      KSEL1=(KSEL-1)/3
      KSEL2=(KSEL-1)-3*KSEL1
C
C     CALCULATE THE NUMBER OF THE LAST DISK RECORD.
C
      MAXREC=MAXDAY+365*(MAXYR-MINYR)
C
C     READ THE RECORDS FOR THE PERIOD FROM ONE YEAR AT A TIME.
C
      NRECS=0
      NOWYR=0
   10 NOWYR=NOWYR+1
      LSTDAY=MNDAY-1
      IF (NOWYR.GT.1) GO TO 30
C
C        CHOOSE THE FIRST YEAR AND DAY.
C
      IF (MXDAY.LE.MINDAY) NOWYR=2
      IF (MNDAY.GT.MINDAY.OR.NOWYR.EQ.2) GO TO 30
      LSTDAY=MINDAY
C
C        READ THE 1-DAY RECORD WHICH JUST PRECEDES THIS PERIOD.
C
   30 NOWDAY=LSTDAY-1
      NXTREC=LSTDAY+365*(NOWYR-1)
      MINSUB=1+6*NRECS
      INDSKP=.TRUE.
      GO TO 50
C
C        READ THE REMAINING RECORDS OF THIS PERIOD AND YEAR.
C        USE NXTREC, THE ASSOCIATED VARIABLE.
C
   40 INDSKP=.FALSE.
   50 NOWDAY=NOWDAY+1
      IF (NOWDAY.GT.MXDAY) GO TO 10
      IF (NXTREC.GT.MAXREC) GO TO 100
      READ (4'NXTREC) REC
      IF (NXTREC.LT.MAXREC) FIND (4'NXTREC)
      IF (WET.LT.0.) WET=0.
C
C        TEST THE RECORD FOR MISSING VALUES.
```

```
C
      INDBAD=.FALSE.
      IF (WET.GE.0..AND.MIN.LT.200.AND.MAX.LT.200) GO TO 60
      INDBAD=.TRUE.
      INDSKP=.TRUE.
   60 IF (INDBAD) GO TO 50
      IF (INDSKP) GO TO 80
C
C        SKIP THIS RECORD UNLESS THE SECOND CRITERION IS MET.
C
      IF (KSEL2.LT.1) GO TO 70
      IF (KSEL2.LT.2.AND.WET.LT..01) GO TO 70
      IF (KSEL2.GT.1.AND.WET.GT.0.) GO TO 70
      INDSKP=.TRUE.
      GO TO 50
C
C        COMPLETE THE LAST 2-DAY RECORD.
C
   70 GRPT(MINSUB+3)=WET
      GRPT(MINSUB+4)=MIN
      GRPT(MINSUB+5)=MAX
      NRECS=NRECS+1
      MINSUB=MINSUB+6
C
C        SKIP THIS RECORD UNLESS THE FIRST CRITERION IS MET.
C
   80 IF (KSEL1.LT.1) GO TO 90
      IF (KSEL1.LT.2.AND.WET.LT..01) GO TO 90
      IF (KSEL1.GT.1.AND.WET.GT.0.) GO TO 90
      INDSKP=.TRUE.
      GO TO 50
C
C        BEGIN A NEW 2-DAY RECORD.
C
   90 GRPT(MINSUB)=WET
      GRPT(MINSUB+1)=MIN
      GRPT(MINSUB+2)=MAX
      IF (NXTREC.LT.30) WRITE (6,1) MAXREC,NXTREC,MAX,MIN,WET,REC
      IF (NXTREC.LT.30) WRITE (6,2) GRPT(MINSUB+2),GRPT(MINSUB+1),
     1   GRPT(MINSUB)
      GO TO 40
C
C     TRANSPOSE THE MATRIX TO FORM GRP.
C
  100 CALL GMTRA (GRPT,GRP,6,NRECS)
      RETURN
      END
```

```
C
C     ................................................................
C
C        SUBROUTINE
C           PTSTAT, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO CALCULATE AND PRINT STATISTICS CORRESPONDING TO THE
C           COLUMNS OF A MATRIX OF REAL NUMBERS.
C
C        USAGE
C           CALL PTSTAT (ARRAY,NOBS,NCOLS,IUNT,MODEL,DLBL)
C           COMMON /XSTATS/ AVE(8),SCP(64),COV(64)
C
C        DESCRIPTION OF PARAMETERS
C           ARRAY  - THE MATRIX OF REAL NUMBERS.
C           NOBS   - THE NUMBER OF ROWS IN THE MATRIX.
C           NCOLS  - THE NUMBER OF COLUMNS IN THE MATRIX.
C           IUNT   - THE OUTPUT DATA SET NUMBER.
C           MODEL  - THE STATEMENT OF THE MODEL.
C           DLBL   - AN ARRAY OF LABELS TO BE PRINTED AS HEADINGS.
C           XSTATS - OUTPUT STATISTICS FOR THE DESIGN MATRIX.
C
C        REMARKS
C           THE CORRELATION OF A CONSTANT VECTOR WITH ITSELF WILL BE
C           COMPUTED AS ZERO.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           CORRE  (CALCULATES STATISTICS FOR A MATRIX OF DATA)
C           DSCRBE (PROVIDES ADDITIONAL STATISTICS)
C           SDIV   (DIVIDES EACH ELEMENT OF A MATRIX BY A SCALAR)
C           GMPRD  (MULTIPLIES TWO MODE 0 MATRICES)
C           SMPY   (MULTIPLIES EACH ELEMENT OF A MATRIX BY A SCALAR)
C           GMADD  (ADDS TWO MODE 0 MATRICES)
C           MCPY   (COPIES A MATRIX)
C           MSTR   (CHANGES THE STORAGE FORM OF A MATRIX)
C           LCTN   (CONVERTS DOUBLE SUBSCRIPTS TO SINGLE)
C           PTHDR  (PRINTS A PAGE HEADER)
C           PTDECK (PUNCHES A DECK OF PARAMETERS)
C
C        METHOD
C           SUBROUTINES FROM THE IBM SSP PACKAGE ARE USED TO PERFORM
C           VECTOR ARITHMETIC.
C
```

```
C     ..............................................................
C
      SUBROUTINE PTSTAT (ARRAY,NOBS,NCOLS,IUNT,MODEL,DLBL)
      INTEGER MODEL(68)
      REAL ARRAY(NOBS,NCOLS),WRKO(64),WRK1(8),WRK2(8),WRK3(48),
     1   DSC(8,5),STD(8),COR(64)
      REAL*8 DLBL(8)
      COMMON /XSTATS/ AVE(8),SCP(64),COV(64)
      EQUIVALENCE (WRKO(1),WRK1(1)),(WRKO(9),WRK2(1)),
     1   (WRKO(17),WRK3(1))
C
C     FIND AVERAGES, STANDARD DEVIATIONS, CROSS-PRODUCTS (CORRECTED
C     FOR THE MEANS), AND CORRELATIONS OF THE COLUMNS.
C
      CALL CORRE (NOBS,NCOLS,1,ARRAY,AVE,STD,SCP,COR,WRK1,WRK2,WRK3)
C
C     FIND VARIANCES, STANDARD ERRORS OF THE MEANS, AND COEFFICIENTS
C     OF VARIATION.
C
      CALL DSCRBE (NOBS,NCOLS,AVE,STD,DSC)
C
C     FIND THE VARIANCE-COVARIANCE MATRIX.
C
      CALL SDIV (SCP,FLOAT(NOBS-1),COV,NCOLS,NCOLS,0)
C
C     BUILD THE UNCORRECTED CROSS-PRODUCTS MATRIX.
C
      CALL GMPRD (AVE,AVE,WRKO,NCOLS,1,NCOLS)
      CALL SMPY (WRKO,FLOAT(NOBS),WRKO,NCOLS,NCOLS,0)
      CALL GMADD (WRKO,SCP,SCP,NCOLS,NCOLS)
C
C     CONVERT COR FROM SYMMETRIC (MODE 1) TO GENERAL (MODE 0).
C
      CALL MCPY (COR,WRKO,NCOLS,NCOLS,1)
      CALL MSTR (WRKO,COR,NCOLS,1,0)
C
C     WRITE THE PAGE HEADINGS.
C
      CALL PTHDR (IUNT,NOBS,MODEL)
C
C     WRITE THE DESCRIPTIVE TABLE.
C
      WRITE (IUNT,1) (DLBL(I),(DSC(I,J),J=1,5),I=1,NCOLS)
C
C     WRITE THE UNCORRECTED CROSS-PRODUCTS MATRIX.
C
      WRITE (IUNT,2) (DLBL(I),I=1,NCOLS)
      DO 10 I=1,NCOLS
   10 WRITE (IUNT,3) DLBL(I),(SCP(LCTN(I,J,NCOLS)),J=1,NCOLS)
C
C     WRITE THE VARIANCE-COVARIANCE MATRIX.
C
      WRITE (IUNT,4) (DLBL(I),I=1,NCOLS)
      DO 20 I=1,NCOLS
```

```
   20 WRITE (IUNT,5) DLBL(I),(COV(LCTN(I,J,NCOLS)),J=1,NCOLS)
C
C     WRITE THE CCRRELATIONS MATRIX.
C
      WRITE (IUNT,6) (DLBL(I),I=1,NCOLS)
      DO 30 I=1,NCOLS
   30 WRITE (IUNT,5) DLBL(I),(COR(LCTN(I,J,NCOLS)),J=1,NCOLS)
C
C     PUNCH THE COLUMN MEANS AND THEIR COVARIANCES.
C
      CALL PTDECK (AVE,COV,NOBS,NCOLS,MODEL)
      RETURN
C
C     ...........................................................
C
    1 FORMAT (//4X,'DESCRIPTIVE STATISTICS'/65X,'STANDARD',4X,
     1   'COEFFICIENT'/9X,'VARIABLE',34X,'STANDARD',6X,'ERROR OF',8X,
     2   'OF'/11X,'NAME',10X,'MEAN',8X,'VARIANCE',6X,'DEVIATION',5X,
     3   'THE MEAN      VARIATION'/(10X,A8,F13.5,3F14.5,3X,F9.2,'%'))
    2 FORMAT (//4X,'CROSS-PRODUCTS MATRIX'//17X,8(6X,A8))
    3 FORMAT (10X,A8,8E14.5)
    4 FORMAT (//4X,'VARIANCE-COVARIANCE MATRIX'//17X,8(6X,A8))
    5 FORMAT (10X,A8,F12.4,7F14.4)
    6 FORMAT (//4X,'CORRELATIONS MATRIX'//17X,8(6X,A8))
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           DSCRBE, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO CALCULATE DESCRIPTIVE STATISTICS FOR A GROUP OF
C           VARIABLES, BASED ON THE MEANS AND STANDARD DEVIATIONS.
C
C        USAGE
C           CALL DSCRBE (NRECS,NCOLS,AVE,STD,DSC)
C
C        DESCRIPTION OF PARAMETERS
C           NRECS  - THE NUMBER OF RECORDS IN THE GROUP.
C           NCOLS  - THE NUMBER OF VARIABLES.
C           AVE    - A VECTOR OF THE SIX AVERAGES.
C           STD    - A VECTOR OF THE SIX STANDARD DEVIATIONS.
C           DSC    - AN ARRAY WHICH IS TO CONTAIN THE STATISTICS.
C
C        REMARKS
C           DIVIDE CHECKS ARE HANDLED BY THE SYSTEM.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE OUTPUT MATRIX IS IN DOUBLE SUBSCRIPT FORM.  EACH
C           ROW REPRESENTS A VARIABLE.
C
C     ..................................................................
C
      SUBROUTINE DSCRBE (NRECS,NCOLS,AVE,STD,DSC)
      REAL AVE(1),STD(1),DSC(8,8)
      DO 10 NOWVAR=1,NCOLS
C
C     STORE THE ESTIMATE OF THE MEAN.
C
      VARAVE=AVE(NOWVAR)
      DSC(NOWVAR,1)=VARAVE
C
C     STORE THE ESTIMATE OF THE VARIANCE.
C
      STDDEV=STD(NOWVAR)
```

```
      DSC(NOWVAR,2)=STDDEV*STDDEV
C
C     STORE THE ESTIMATE OF THE STANDARD DEVIATION.
C
      DSC(NOWVAR,3)=STDDEV
C
C     STORE THE STANDARD ERROR OF THE MEAN.
C
      DSC(NOWVAR,4)=STDDEV/SQRT(FLOAT(NRECS))
C
C     STORE THE COEFFICIENT OF VARIATION.
C
   10 DSC(NOWVAR,5)=100.*STDDEV/VARAVE
      RETURN
      END
```

```
C
C     ..............................................................
C
C        FUNCTION
C           LCTN, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO LOCATE A DOUBLE-SUBSCRIPTED CELL IN A MODE 0 MATRIX.
C
C        USAGE
C           LCTN (NOWROW,NOWCOL,NROWS)
C
C        DESCRIPTION OF PARAMETERS
C           LCTN   - THE ONE-DIMENSIONAL CELL LOCATION.
C           NOWROW - THE FIRST OF THE DOUBLE SUBSCRIPTS.
C           NOWCOL - THE SECOND OF THE DOUBLE SUBSCRIPTS.
C           NROWS  - THE NUMBER OF ROWS IN THE MODE 0 MATRIX.
C
C        REMARKS
C           THE SSP SUBROUTINE LOC CAN ALSO HANDLE MATRICES OF
C           MODES 1 AND 2.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           MODE 0 MATRICES ARE STORED AS COLUMN VECTORS; CONVERSION
C           FROM DOUBLE TO SINGLE SUBSCRIPTING REQUIRES ONLY A SIMPLE
C           FORMULA.
C
C     ..............................................................
C
      FUNCTION LCTN (NOWROW,NOWCOL,NROWS)
C
C     VERIFY THAT THE ROW AND COLUMN NUMBERS ARE VALID.
C
      IF (NOWROW.LT.1.OR.NOWROW.GT.NROWS) CALL ABEND ('LCTN    ',
     1   'THE SPECIFIED ROW IS NOT BETWEEN 1 AND NROWS.              ')
      IF (NOWCOL.LT.1) CALL ABEND ('LCTN    ',
     1   'THE SPECIFIED COLUMN IS LESS THAN 1.                       ')
C
C     FIND THE LOCATION OF THE CELL.
C
      LCTN=NOWROW+(NOWCOL-1)*NROWS
      RETURN
      END
```

```
C
C     ..............................................................
C
C        SUBROUTINE
C        PTHDR, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO PRINT PAGE HEADINGS FOR PROGRAM LINMOD.
C
C        USAGE
C           CALL PTHDR (IUNT,NOBS,MODEL)
C           COMMON /TITL/ TITLE(17)
C           COMMON /STATUS/ SELECT,NOWGRP,MNDAY,MXDAY,NOWMDL
C
C        DESCRIPTION OF PARAMETERS
C           IUNT   - THE OUTPUT DATA SET NUMBER.
C           NOBS   - THE NUMBER OF ROWS IN THE OBSERVATION VECTOR.
C           MODEL  - THE STATEMENT OF THE MODEL.
C           TITLE  - THE RUN TITLE.
C           SELECT - A TWO-LETTER RUN SELECTION INDICATOR.
C           NOWGRP - THE NUMBER OF THIS GROUP OR PERIOD.
C           MNDAY  - THE DAY NUMBER (DDD) OF THE GROUP'S FIRST DAY.
C           MXDAY  - THE DAY NUMBER (DDD) OF THE GROUP'S LAST DAY.
C           NOWMDL - THE NUMBER OF THE MODEL BEING PROCESSED.
C
C        REMARKS
C           SELECTION WITHIN THE MODEL IS NOT SHOWN BY SELECT.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C
C     ..............................................................
C
      SUBROUTINE PTHDR (IUNT,NOBS,MODEL)
      INTEGER MODEL(68)
      COMMON /TITL/ TITLE(17)
      COMMON /STATUS/ SELECT,NOWGRP,MNDAY,MXDAY,NOWMDL
C
C     WRITE THE PAGE HEADINGS.
C
      WRITE (IUNT,1) TITLE,NOWGRP,MNDAY,MXDAY,NOBS,SELECT
      IF (NOWMDL.GT.0) WRITE (IUNT,2) NOWMDL,MODEL
```

```
      RETURN
C
C     ..................................................................
C
    1 FORMAT ('1',3X,17A4/4X,'PRODUCED FROM RECORDS OF THE KANSAS ',
     1   'AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY.'/
     2   4X,'PERIOD ',I3,', CLIMATIC DAYS ',I3,' THRU ',I3,',',I5,
     3   ' OBSERVATIONS SELECTED FOR (',A2,').')
    2 FORMAT (/4X,'MODEL',I2,': ',68A1)
      END
```

```
C
C     ..............................................................
C
C        SUBROUTINE
C           PTDECK, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO OUTPUT STATION PARAMETERS AND THEIR COVARIANCES.
C
C        USAGE
C           CALL PTDECK (AVE,COV,NOBS,NCOLS,MODEL)
C           COMMON /STAT/ ASTATE,ADIVSN,ASITE,ISITE,SITE(4)
C           COMMON /DATES/ MINDTE,MAXDTE,NUL(8)
C           COMMON /STATUS/ SELECT,NOWGRP,MNDAY,MXDAY,NOWMDL
C
C        DESCRIPTION OF PARAMETERS
C           AVE    - THE PARAMETER VALUES.
C           COV    - THE VARIANCE-COVARIANCE MATRIX.
C           NOBS   - THE NUMBER OF OBSERVATIONS UPON WHICH THE
C                    PARAMETER ESTIMATES ARE BASED.
C           NCOLS  - THE NUMBER OF PARAMETERS.
C           MODEL  - THE MODEL STATEMENT TO BE OUTPUT.
C           STAT   - STATION PARAMETERS TO BE OUTPUT.
C           DATES  - THE PERIOD FOR WHICH THE PARAMETERS APPLY.
C           STATUS - THE SELECTION MODE AND PERIOD OF THE YEAR .
C
C        REMARKS
C           OUTPUT UNITS 20 TO 29 SHOULD BE AVAILABLE.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           TWO HEADER CARDS ARE PRODUCED BEFORE THE DATA CARDS.
C           THE NUMBER OF DATA CARDS DEPENDS UPON NOWCOL; SEVEN
C           VALUES ARE PLACED UPON EACH CARD WITH FORMAT 3X,7F11.6.
C
C     ..............................................................
C
      SUBROUTINE PTDECK (AVE,COV,NOBS,NCOLS,MODEL)
      INTEGER MODEL(68)
      REAL AVE(NCOLS),COV(1)
      COMMON /STAT/ ASTATE,ADIVSN,ASITE,ISITE,SITE(4)
      COMMON /DATES/ MINDTE,MAXDTE,NUL(8)
```

```
      COMMON /STATUS/ SELECT,NOWGRP,MNDAY,MXDAY,NOWMDL
C
C     SET THE OUTPUT UNIT NUMBER.
C
      IUNT=NOWMDL+20
C
C     WRITE THE HEADER CARDS.
C
      WRITE (IUNT,1) ASTATE,ADIVSN,ASITE,SITE,SELECT,MINDTE,MAXDTE,
     1   MNDAY,MXDAY,NOBS,NCOLS,NOWMDL,MODEL
C
C     OUTPUT THE PARAMETERS IN STANDARD FORM.
C
C        WRITE THE VECTOR OF AVERAGES.
C
      DO 10 MIN=1,NCOLS,7
      MAX=MIN+6
      IF (MAX.GT.NCOLS) MAX=NCOLS
   10 WRITE (IUNT,2) MIN,(AVE(I),I=MIN,MAX)
C
C        WRITE THE MATRIX OF COVARIANCES.
C
      NPOS=NCOLS*NCOLS
      DO 20 MIN=1,NPOS,7
      MAX=MIN+6
      IF (MAX.GT.NPOS) MAX=NPOS
   20 WRITE (IUNT,2) MIN,(COV(I),I=MIN,MAX)
      RETURN
C
C     ...........................................................
C
    1 FORMAT (A2,A1,A4,1X,4A4,2X,A2,6I8/'MODEL',I2,':',68A1)
    2 FORMAT (I3,7F11.6)
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           DESIGN, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO BUILD A DESIGN MATRIX FOR A LINEAR MODEL.
C
C        USAGE
C           CALL DESIGN (GRP,NRECS,MODEL,Y,X,NOBS,NCOLS,SGRP)
C
C        DESCRIPTION OF PARAMETERS
C           GRP    - A MATRIX CONTAINING THE DATA FOR THE REGRESSION.
C           NRECS  - THE NUMBER OF RECORDS (ROWS) IN GRP.
C           MODEL  - THE STATEMENT OF THE DESIGN MODEL.
C           Y      - THE DEPENDENT VARIABLES CORRESPONDING TO X.
C           X      - THE DESIGN MATRIX.
C           NOBS   - A SCALAR WHICH WILL BE  SET TO THE NUMBER OF
C                    ROWS IN X AND Y.
C           NCOLS  - A SCALAR SET TO THE NUMBER OF COLUMNS OF X.
C           SGRP   - A WORK AREA THE SAME SIZE AS GRP.
C
C        REMARKS
C           ALL MATRICES ARE IN COLUMN VECTOR FORM (MODE 0) AND
C           CONTAIN REAL*4 VALUES.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           IDIGIT (CONVERTS A DIGIT FROM A-FORMAT TO I-FORMAT)
C           SUBST  (FILLS AN INCIDENCE VECTOR FOR SELECTION CRITERIA)
C           SCALAR (REDUCES A VECTOR TO A SCALAR)
C           SUBMX  (COPIES A SPECIFIED SUBSET OF MATRIX ROWS)
C           CCPY   (COPIES A MATRIX COLUMN)
C           MCPY   (COPIES AN ENTIRE MATRIX)
C           SCLA   (SETS A MATRIX COLUMN EQUAL TO A SCALAR)
C           CSUM   (SUMS THE COLUMNS OF A MATRIX)
C           SSUB   (SUBTRACTS A SCALAR FROM A MATRIX COLUMN)
C           GTPRD  (MULTIPLIES A TRANSPOSED MATRIX BY A MATRIX)
C
C        METHOD
C           EACH RECORD IN GRP IS OF THE FORM WET1,MIN1,MAX1,WET2,
C           MIN2,MAX2.  THE PROPER ROWS ARE CHOSEN BY MEANS OF
C           THE SELECTION CRITERIA, THEN THE PROBER COLUMNS ARE
C           CHOSEN AND MODIFIED ACCORDING TO THE MODEL.
```

```
C
C           THE INPUT MODEL SHOULD BE OF THE FORM :
C              S(DW);V5=C,D1,D4,P(2,3),D2,D3,P(5,6)  WHERE
C              S IS FOR SELECT (THIS TERM IS OPTIONAL),
C                 N FOR NOT CHECKED, D FOR DRY, AND W FOR WET,
C              V IS FOR AN UNTRANSFORMED VARIABLE (USED HERE FOR Y),
C              C IS FOR A CONSTANT VECTOR OF ONES,
C              D IS FOR A DEVIATE FROM ITS COLUMN AVERAGE,
C              I IS FOR AN INCIDENCE VECTOR FOR ABOVE-ZERO ENTRIES,
C              P IS FOR THE PRODUCT OF TWO OTHER COLUMNS OF X.
C
C           THE INPUT MODEL IS IN A-FORMAT FORM.  THE PUNCTUATION IS
C           TO BE DELETED AND THE NUMBERS CONVERTED TO I-FORMAT.
C           THE NUMBERS ARE LATER DELETED AFTER THEY ARE USED.
C
C     ..................................................................
C
      SUBROUTINE CESIGN (GRP,NRECS,MODEL,Y,X,NOBS,NCOLS,SGRP)
      INTEGER MODEL(68),MDL(68),S/'S'/,V/'V'/,D/'D'/,C/'C'/,
     1   P/'P'/,N/'N'/,A0/'0'/,A9/'9'/
      REAL GRP(1),SGRP(1),X(1),Y(1),WRK(2),CND(3,2),COLTOT(8)
      COMMON /SCLR/ NCND
      EXTERNAL SCALAR
C
C     COMPRESS THE STATEMENT OF THE MODEL.
C
      NOWMOD=0
      NOWMDL=0
      NCOLS=-1
C
C        STORE THE SELECTION CRITERIA, IF ANY.
C
      KSEL1=-1
      KSEL2=-1
      IF (MODEL(1).NE.S) GO TO 20
      NOWMOD=6
      IF (MODEL(3).EQ.N) GO TO 10
      KSEL1=0
      IF (MODEL(3).EQ.D) GO TO 10
      KSEL1=1
   10 IF (MODEL(4).EQ.N) GO TO 20
      KSEL2=0
      IF (MODEL(4).EQ.D) GO TO 20
      KSEL2=1
C
C        REMOVE PUNCTUATION MARKS FROM THE MODEL.
C
   20 NOWMOD=NOWMCD+1
      IF (NOWMOD.GT.68) GO TO 50
      KEEP=MODEL(NOWMOD)
      IF (KEEP.LT.C.OR.KEEP.GT.A9) GO TO 20
      NOWMDL=NOWMDL+1
      IF (KEEP.GT.A0.AND.KEEP.LE.A9) GO TO 30
      NCOLS=NCOLS+1
```

```
      GO TO 40
   30 CALL IDIGIT (KEEP,KEEP)
   40 MDL(NOWMDL)=KEEP
      GO TO 20
C
C     SELECT AND COPY THE ROWS TO BE INCLUDED IN THE MODEL.
C
   50 NCND=0
C
C        SET THE FIRST SELECTION CRITERION, IF ANY.
C
      IF (KSEL1.LT.0) GO TO 60
      NCND=1
      CND(1,1)=1.
      CND(2,1)=2.
      CND(3,1)=0.
      IF (KSEL1.EQ.0) GO TO 60
      CND(2,1)=6.
C
C        SET THE SECOND SELECTION CRITERION, IF ANY.
C
   60 IF (KSEL2.LT.0) GO TO 70
      NCND=NCND+1
      CND(1,NCND)=4.
      CND(2,NCND)=2.
      CND(3,NCND)=0.
      IF (KSEL2.EQ.0) GO TO 70
      CND(2,NCND)=6.
C
C        COPY THE SELECTED ROWS OF THE INPUT MATRIX.
C
   70 IF (NCND.LT.1) GO TO 80
      CALL SUBST (GRP,CND,WRK,SCALAR,Y,NRECS,6,NCND)
      CALL SUBMX (GRP,SGRP,Y,NRECS,6,NOBS)
      GO TO 90
   80 CALL MCPY (GRP,SGRP,NRECS,6,0)
      NOBS=NRECS
C
C     COPY THE PROPER COLUMN INTO THE Y VECTOR.
C
   90 CALL CCPY (SGRP,MDL(2),Y,NOBS,6,0)
C
C     FILL THE DESIGN MATRIX, X.
C
C        FIRST PASS: VARIABLES, CONSTANTS, AND INCIDENCE VARIABLES.
C        FURTHER CONDENSE THE STATEMENT OF THE MODEL.
C
      NOWCOL=0
      NOWMDL=1
      NEWMDL=0
  100 NOWCOL=NOWCOL+1
      IF (NOWCOL.GT.NCOLS) GO TO 130
      NOWMDL=NOWMDL+2
      NEWMDL=NEWMDL+1
```

```
      KND=MDL(NOWMDL)
      MDL(NEWMDL)=KND
C
C           COPY THE VARIABLES (V AND D SPECIFICATIONS).
C
      IF (KND.NE.V.AND.KND.NE.D) GO TO 110
      CALL CCPY (SGRP,MDL(NOWMDL+1),X(NOBS*(NOWCOL-1)+1),NOBS,6,0)
      GO TO 100
C
C           STORE A COLUMN OF ONES (C AND P SPECIFICATIONS).
C
  110 IF (KND.NE.C.AND.KND.NE.P) GO TO 120
      CALL SCLA (X(NOBS*(NOWCOL-1)+1),1.,NOBS,1,0)
      NOWMDL=NOWMDL-1
      IF (KND.NE.P) GO TO 100
      NOWMDL=NOWMDL+2
      MDL(NEWMDL+1)=MDL(NOWMDL)
      MDL(NEWMDL+2)=MDL(NOWMDL+1)
      NEWMDL=NEWMDL+2
      GO TO 100
C
C           STORE AN INCIDENCE VARIABLE (I SPECIFICATION).
  120 CND(1,1)=MDL(NOWMDL+1)
      CND(2,1)=6.
      CND(3,1)=0.
      CALL SUBST (SGRP,CND,WRK,SCALAR,X(NOBS*(NOWCOL-1)+1),NOBS,6,1)
      GO TO 100
C
C        SECOND PASS: CONVERSION OF VARIATES TO DEVIATES.
C
  130 CALL CSUM (X,COLTOT,NOBS,NCOLS,0)
      NOWCOL=0
      NOWMDL=0
  140 NOWCOL=NOWCOL+1
      NOWMDL=NOWMDL+1
      IF (NOWCOL.GT.NCOLS) GO TO 160
      KEEP=MDL(NOWMDL)
      IF (KEEP.NE.D) GO TO 150
      AVE=COLTOT(NOWCOL)/NOBS
      CALL SSUB (X(NOBS*(NOWCOL-1)+1),AVE,X(NOBS*(NOWCOL-1)+1),
     1   NOBS,1,0)
      GO TO 140
  150 IF (KEEP.EQ.P) NOWMDL=NOWMDL+2
      GO TO 140
C
C        THIRD PASS: INTERACTIONS (PRODUCTS OF OTHER COLUMNS).
C
  160 NOWCOL=0
      NOWMDL=0
  170 NOWCOL=NOWCOL+1
      NOWMDL=NOWMDL+1
      IF (NOWCOL.GT.NCOLS) RETURN
      IF (MDL(NOWMDL).NE.P) GO TO 170
      ISUB=NOBS*(NOWCOL-1)
```

```
      ISUB1=NOBS*(MDL(NOWMDL+1)-1)
      ISUB2=NOBS*(MDL(NOWMDL+2)-1)
      DO 180 NOWROW=1,NOBS
  180 X(ISUB+NOWROW)=X(ISUB1+NOWROW)*X(ISUB2+NOWROW)
      NOWMDL=NOWMDL+2
      GO TO 170
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           IDIGIT, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO CONVERT A SINGLE DIGIT FROM A-FORMAT TO I-FORMAT.
C
C        USAGE
C           CALL IDIGIT (AFORM,IFORM)
C
C        DESCRIPTION OF PARAMETERS
C           AFORM  - A VARIABLE CONTAINING THE CHARACTER.
C           IFORM  - AN INTEGER SET TO THE VALUE OF AFORM.
C
C        REMARKS
C           AFORM MAY BE EITHER REAL OR INTEGER.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           TABLE LOOK-UP IS USED.
C
C     ..................................................................
C
      SUBROUTINE IDIGIT (AFORM,IFORM)
      INTEGER INTEGR(9)/'1','2','3','4','5','6','7','8','9'/,AFORM
      DO 10 IFORM=1,9
      IF (AFORM.EQ.INTEGR(IFORM)) GO TO 20
   10 CONTINUE
      IFORM=0
   20 RETURN
      END
```

```
C
C     ................................................................
C
C        SUBROUTINE
C           SCALAR, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO REDUCE A SELECTION VECTOR TO A SINGLE ELEMENT.
C
C        USAGE
C           CALL SCALAR (VECTOR,RESULT)
C           COMMON /SCLR/ NCND
C
C        DESCRIPTION OF PARAMETERS
C           VECTOR - A VECTOR OF ONES AND ZEROS.
C           RESULT - A SINGLE ELEMENT TO BE SET TO 1 OR 0.
C           NCND   - THE LENGTH OF THE VECTOR.
C
C        REMARKS
C           THE INPUT VECTOR OR SCALAR IS PROVIDED BY SUBROUTINE
C           SUBST OF THE IBM SCIENTIFIC SUBROUTINE PACKAGE.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           RESULT IS THE PRODUCT OF THE VECTOR ELEMENTS.
C           MULTIPLICATION REPRESENTS LOGICAL INTERSECTION, THE 'AND'
C           OPERATOR.
C
C     ................................................................
C
      SUBROUTINE SCALAR (VECTOR,RESULT)
      COMMON /SCLR/ NCND
      REAL VECTOR(NCND)
      RESULT=1.
      DO 10 I=1,NCND
   10 RESULT=RESULT*VECTOR(I)
      RETURN
      END
```

```
C
C     ..............................................................
C
C        SUBROUTINE
C           PTREG, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO COMPUTE AND PRINT THE PARAMETERS AND ANALYSIS OF
C           A MULTIPLE REGRESSION.
C
C        USAGE
C           CALL PTREG (X,Y,NOBS,NCOLS,IUNT,MODEL,DLBL)
C           COMMON /XSTATS/ AVE(8),SCP(64),COV(64)
C
C        DESCRIPTION OF PARAMETERS
C           X      - THE DESIGN MATRIX.
C           Y      - THE VECTOR OF OBSERVATIONS.
C           NOBS   - THE NUMBER OF OBSERVATIONS.
C           NCOLS  - THE NUMBER OF COLUMNS IN THE DESIGN MATRIX.
C           IUNT   - THE OUTPUT DATA SET NUMBER.
C           MODEL  - THE MODEL TO BE PRINTED.
C           DLBL   - A VECTOR OF VARIABLE NAMES.
C           STAT   - STATISTICS RELATING TO THIS DESIGN MATRIX.
C
C        REMARKS
C           IT IS ASSUMED THAT THE FIRST COLUMN REPRESENTS A
C           CONSTANT (OR MEAN) TERM.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           GTPRD  (PREMULTIPLIES A MATRIX BY ITS TRANSPOSE)
C           MCPY   (COPIES A MATRIX)
C           MINV   (FINDS THE INVERSE OF A MATRIX)
C           ABEND  (WRITES A MESSAGE AND TERMINATES)
C           GMTRA  (TRANSPOSES A MODE 0 MATRIX)
C           GMPRD  (MULTIPLIES TWO MODE 0 MATRICES)
C           PTAOV  (WRITES AN ANALYSIS OF VARIANCE TABLE)
C           SMPY   (MULTIPLIES A MATRIX BY A SCALAR)
C           LCTN   (CONVERTS DOUBLE SUBSCRIPTS TO SINGLE)
C           PTDECK (PUNCHES THE PARAMETERS AND THEIR COVARIANCES)
C
C        METHOD
C           A SUBROUTINE IS CALLED TO DO THE ANALYSIS OF VARIANCE.
C           SSP SUBROUTINES ARE CALLED TO DO VECTOR ARITHMETIC.
C
```

```
C     ..............................................................
C
      SUBROUTINE PTREG (X,Y,NOBS,NCOLS,IUNT,MODEL,DLBL)
      INTEGER MODEL(68)
      REAL XTX(64),XTXINV(64),BTA(7),COVBTA(64),WRK1(8),WRK2(8),
     1   F(7)/2.71,2.30,2.08,1.94,1.85,1.77,1.72/,X(NOBS,NCOLS),
     2   Y(NOBS)
      REAL*8 DLBL(8)
      COMMON /XSTATS/ AVE(8),SCP(64),COV(64)
      COMMON /EQUIV/ XT(7000),XGNV(7000),YHAT(1000)
C
C     FORM X'X, THE MATRIX OF CROSS-PRODUCTS.
C
      CALL GTPRD (X,X,XTX,NOBS,NCOLS,NCOLS)
C
C     INVERT X'X, THE CROSS-PRODUCTS MATRIX.
C
      CALL MCPY (XTX,XTXINV,NCOLS,NCOLS,0)
      CALL MINV (XTXINV,NCOLS,DETXTX,WRK1,WRK2)
      IF (DETXTX.EQ.0.) CALL ABEND ('PTREG   ',
     1   'THE MATRIX X''X IS SINGULAR.                                  ')
C
C     COMPUTE THE MOORE-PENROSE GENERALIZED INVERSE OF X.
C
      CALL GMTRA (X,XT,NOBS,NCOLS)
      CALL GMPRD (XTXINV,XT,XGNV,NCOLS,NCOLS,NOBS)
C
C     FIND THE VECTOR OF PARAMETER ESTIMATES.
C
      CALL GMPRD (XGNV,Y,BTA,NCOLS,NOBS,1)
C
C     PERFORM THE ANALYSIS OF VARIANCE.
C
C
C        WRITE THE PAGE HEADING AND THE MODEL.
C
      CALL PTHDR (IUNT,NOBS,MODEL)
C
C        FIND THE TOTAL SUM OF SQUARES AND THOSE FOR THE MEAN
C        AND THE REGRESSION.
C
      NVARS=NCOLS+1
      SSTOT=SCP(NVARS*NVARS)
      SSAVE=NOBS*(AVE(NVARS))**2
      CALL GMPRD (X,BTA,YHAT,NOBS,NCOLS,1)
      CALL GTPRD (Y,YHAT,SSREG,NOBS,1,1)
      SSREG=SSREG-SSAVE
C
C        COMPUTE AND PRINT THE REMAINING VALUES.
C
      CALL PTAOV (SSTOT,SSAVE,SSREG,NOBS,NCOLS,MSRES,IUNT)
C
C     COMPUTE THE COVARIANCE MATRIX.
C
```

```
      CALL SMPY (XTXINV,MSRES,COVBTA,NCOLS,NCOLS,0)
C
C     FIND AND WRITE RELATED STATISTICS FOR EACH PARAMETER ESTIMATE.
C
C
C        WRITE THE TABLE HEADINGS AND SET THE CONSTANTS.
C
      WRITE (IUNT,1)
      FACTOR=SQRT(NCOLS*F(NCOLS))
      VARY=COV(NVARS*NVARS)
      NDFRES=NOBS-NCOLS
      SSCFM=SSTOT-SSAVE
      DO 10 NOWCOL=1,NCOLS
C
C        FIND THE STANDARD DEVIATION OF EACH PARAMETER ESTIMATE.
C
      BTANOW=BTA(NOWCOL)
      SDVBTA=SQRT(COVBTA(LCTN(NOWCOL,NOWCOL,NCOLS)))
C
C        FIND 95% SIMULTANEOUS CONFIDENCE INTERVALS FOR THE PARAMETER
C        ESTIMATES (BASED ON INFINITE D.F. FOR MSRES).
C
      SUBBTA=BTANOW-(FACTOR*SDVBTA)
      SUPBTA=BTANOW+(FACTOR*SDVBTA)
C
C        FIND THE STANDARDIZED PARAMETER ESTIMATE.
C
      VARCOL=COV(LCTN(NOWCOL,NOWCOL,NVARS))
      STDBTA=BTANOW*SQRT(VARCOL/VARY)
C
C        FIND THE SUM OF SQUARES COMPONENT DUE TO THIS PARAMETER.
C
      SSBTA=BTANOW*BTANOW/XTXINV(LCTN(NOWCOL,NOWCOL,NCOLS))
C
C        FIND THE T-RATIO AND ITS TWO-TAILED PROBABILITY.
C
      T=BTANOW/SDVBTA
      TPRB=TPROB(T,NDFRES)
C
C        COMPUTE THE VALUE OF R-SQUARED WITHOUT THIS PARAMETER.
C        (THIS HAS NO MEANING FOR A CONSTANT TERM).
C
      R2DEL=(SSREG-SSBTA)/SSCFM
      IF (NOWCOL.EQ.1) R2DEL=1111.
C
C        WRITE THE PARAMETER ESTIMATES AND THEIR RELIABILITIES.
C
   10 WRITE (IUNT,2) DLBL(NOWCOL),BTA(NOWCOL),SDVBTA,SUBBTA,SUPBTA,
     1   STDBTA,SSBTA,T,TPRB,R2DEL
C
C     WRITE THE MATRIX OF COVARIANCES OF THE PARAMETER ESTIMATES.
C
      WRITE (IUNT,3) (DLBL(NOWCOL),NOWCOL=1,NCOLS)
      DO 20 NOWCOL=1,NCOLS
```

```
   20 WRITE (IUNT,4) DLBL(NOWCOL),(COVBTA(NOWCOL+(I-1)*NCOLS),
     1    I=1,NCOLS)
C
C     PUNCH THE PARAMETER ESTIMATES AND THEIR COVARIANCES.
C
      CALL PTDECK (BTA,COVBTA,NOBS,NCOLS,MODEL)
      RETURN
C
C     ..............................................................
C
    1 FORMAT (//4X,'PARAMETER ESTIMATES'//22X,'PARAMETER',6X,
     1    'STANDARD',8X,'95% SIMULTANEOUS',7X,'STANDARD',5X,'SUMS OF',
     2    7X,'T',9X,'T',8X,'R**2'/22X,'ESTIMATES',5X,'DEVIATIONS',5X,
     3    'CONFIDENCE INTERVALS',7X,'BETAS',6X,'SQUARES',5X,'RATIO',
     4    5X,'PROB.',5X,'DELETE')
    2 FORMAT (10X,A8,F12.4,F14.4,F15.4,' --',F8.4,F13.3,F13.0,F10.2,
     1    F10.3,5X,F6.4)
    3 FORMAT (//4X,'COVARIANCES OF THE PARAMETER ESTIMATES'//23X,
     1    8(A8,6X))
    4 FORMAT (10X,A8,F12.4,7F14.4)
      END
```

```
C
C     .................................................................
C
C        FUNCTION
C           TPROB, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATICN
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO FIND THE PROBABILITY OF A VALUE FROM THE CENTRAL
C           T DISTRIBUTION BEING FURTHER FROM ZERO THAN A
C           SPECIFIED VALUE.
C
C        USAGE
C           TPROB (T,NDF)
C
C        DESCRIPTION OF PARAMETERS
C           TPROB  - THE TWO-TAILED PROBABILITY OF EXCEEDING T.
C           T      - THE SPECIFIED VALUE.
C           NDF    - THE NUMBER OF DEGREES OF FREEDOM.
C
C        REMARKS
C           THIS IS AN APPROXIMATION BASED ON LARGE NDF.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           T IS CONVERTED TO AN APPROXIMATELY NORMAL DEVIATE (SEE
C           AMS-55, 26.7.8).  THE NORMAL QUANTILE IS THEN FOUND WITH
C           ABSOLUTE ERROR LESS THAN 1.5E-7 (SEE AMS-55, 26.2.19,
C           FROM HASTING'S APPROXIMATIONS FOR DIGITAL COMPUTERS).
C
C     .................................................................
C
      FUNCTION TPROB (T,NDF)
      REAL*8 X
      DF=NDF
C
C     TRANSFORM TO A NORMAL DEVIATE.
C
      X=ABS(T)*(1.-.25/DF)/SQRT(1.+T*T/(2.*DF))
C
C     FIND THE QUANTILE OF THE NORMAL DISTRIBUTION.
C
      TPROB=1.0D0-5.0D-1/(1.0D0+X*(4.9867347D-2+X*(2.11410061D-2
```

```
     1    +X*(3.27762630-3+X*(3.800360-5+X*(4.889060-5+5.3830-6*X)))))
     2    **16
C
C     CONVERT THE QUANTILE TO A TWO-TAILED PROBABILITY.
C
      TPROB=2.*(1.-TPROB)
      RETURN
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           PTAOV, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO PRINT AN ANALYSIS OF VARIANCE TABLE FCR A REGRESSION.
C
C        USAGE
C           CALL PTAOV (SSTOT,SSAVE,SSREG,NOBS,NCOLS,FMSRES,IUNT)
C
C        DESCRIPTION OF PARAMETERS
C           SSTOT  - THE TOTAL SUM OF SQUARES.
C           SSAVE  - THE CORRECTION FOR THE MEAN.
C           SSREG  - THE SUM OF SQUARES DUE TO THE REGRESSION,
C                    AFTER CORRECTION FOR THE MEAN.
C           NOBS   - THE NUMBER OF OBSERVATIONS.
C           NCOLS  - THE NUMBER OF COLUMNS IN THE DESIGN MATRIX.
C           FMSRES - THE RESIDUAL MEAN SQUARE TO BE RETURNED.
C           IUNT   - THE OUTPUT DATA SET NUMBER.
C
C        REMARKS
C           IT IS ASSUMED THAT THE MEAN IS INCLUDED IN THE DESIGN.
C           ONE DEGREE OF FREEDOM IS ALLOWED FOR IT.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           FPROB (FINDS THE PROBABILITY OF AN F RATIO)
C
C        METHOD
C           THE TOTAL SUM OF SQUARES IS BROKEN INTO SUMS OF SQUARES
C           DUE TO THE MEAN AND THE CORRECTED TOTAL.  THE LATTER IS
C           BROKEN INTO THE SUMS OF SQUARES FOR REGRESSION AND FOR
C           RESIDUAL ERROR.
C
C     ..................................................................
C
      SUBROUTINE PTAOV (SSTOT,SSAVE,SSREG,NOBS,NCOLS,FMSRES,IUNT)
C
C     CALCULATE THE DEGREES OF FREEDOM.
C
      NDFTOT=NOBS
      NDFAVE=1
      NDFCFM=NDFTOT-NDFAVE
```

```
      NDFREG=NCOLS-NDFAVE
      NDFRES=NDFCFM-NDFREG
C
C     CALCULATE THE REMAINING SUMS OF SQUARES.
C
      SSCFM=SSTOT-SSAVE
      SSRES=SSCFM-SSREG
C
C     CALCULATE THE MEAN SQUARES.
C
      FMSAVE=SSAVE
      FMSREG=SSREG/NDFREG
      FMSRES=SSRES/NDFRES
C
C     CALCULATE THE F RATIOS FOR THE MEAN AND REGRESSION.
C
      FAVE=FMSAVE/FMSRES
      FREG=FMSREG/FMSRES
C
C     FIND THE PROBABILITIES OF THE F RATIOS (ASSUMING CENTRALITY).
C
      PAVE=FPROB(FAVE,NDFAVE,NDFRES)
      PREG=FPROB (FREG,NDFREG,NDFRES)
C
C     CALCULATE THE SQUARED MULTIPLE CORRELATION COEFFICIENT.
C
      R2=SSREG/SSCFM
C
C     WRITE THE ANALYSIS OF VARIANCE TABLE.
C
      WRITE (IUNT,1) NDFTOT,SSTOT,NDFAVE,SSAVE,FMSAVE,FAVE,PAVE,
     1   NDFCFM,SSCFM,NDFREG,SSREG,FMSREG,FREG,PREG,NDFRES,SSRES,
     2   FMSRES,R2
      RETURN
C
C     ..................................................................
C
    1 FORMAT (//4X,'ANALYSIS OF VARIANCE'//44X,'SUM OF',9X,'MEAN',
     1   13X,'F',14X,'F'/10X,'SOURCE',14X,'D.F.',10X,'SQUARES',7X,
     2   'SQUARE',10X,'RATIO',10X,'PROB.'//10X,'TOTAL',I17,F19.0//13X,
     3   'MEAN',I16,4X,F14.0,2F14.2,F15.3//13X,'CORRECTED TOTAL',I5,
     4   F18.0//16X,'REGRESSION',I8,3X,F14.0,2F14.2,F15.3//16X,
     5   'RESIDUAL',I10,3X,F14.0,F14.2//10X,'R**2 = ',F7.5)
      END
```

```
C
C     ..............................................................
C
C        FUNCTION
C           FPROB, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO FIND THE PROBABILITY OF A VALUE FROM THE CENTRAL
C           F DISTRIBUTION EXCEEDING THE SPECIFIED VALUE.
C
C        USAGE
C           FPROB (F,NDFNMR,NDFDNM)
C
C        DESCRIPTION OF PARAMETERS
C           FPROB  - ONE MINUS THE QUANTILE CORRESPONDING TO F.
C           F      - THE SPECIFIED VALUE.
C           NDFNMR - DEGREES OF FREEDOM IN THE NUMERATOR.
C           NDFDNM - DEGREES OF FREEDOM IN THE DENOMINATOR.
C
C        REMARKS
C           THE SOURCE OF THIS CODING IS UNKNOWN.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE CONVERGENT SERIES EXPANSION OF POSITIVE TERMS: SEE
C           AMS-55, PAGE 944.
C
C     ..............................................................
C
      FUNCTION FPROB (F,NDFNMR,NDFDNM)
C
C     F-PROBABILITY VIA CONVERGENT SERIES OF POSITIVE TERMS.
C
      A=.5*NDFNMR
      B=.5*NDFDNM
      TEMP=B+A*F
      X=A*F/TEMP
      FPROB=1.0
      IF(F.LE.0.0.OR.X.LE.0.0)RETURN
      XC=B/TEMP
      AB=A+B
      CON=0.
```

```
      SGN=+1.
      IF(F.GE.1.0)GO TO 10
      TEMP=A
      A=B
      B=TEMP
      TEMP=XC
      XC=X
      X=TEMP
      CON=1.
      SGN=-1.
C
C     CONVERGENT SERIES EXPANSION.
C
   10 TOP=AB
      BOT=B+1.
      SUM=1.
      TERM=1.
   20 TEMP=SUM
      TERM=TERM*(TOP/BOT)*XC
      SUM=SUM+TERM
      TOP=TOP+1.
      BOT=BOT+1.
      IF(SUM.GT.TEMP)GO TO 20
      FPROB=CON+SGN*EXP(A*ALOG(X)+B*ALOG(XC)+ALGAMA(AB)-ALGAMA(A)
     1 -ALGAMA(B))*SUM/B
      RETURN
      END
```

# APPENDIX B

# THE SIMREC PROGRAM

```
C
C     ..............................................................
C
C        PROGRAM
C           SIMREC, MODEL 1, VERSION 2.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 370/158
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO SIMULATED DAILY PRECIPITATION AND TEMPERATURE READINGS
C           FROM INPUT PARAMETERS
C
C        USAGE
C           THE INPUT STREAM MUST CONTAIN THE FOLLOWING:
C              A STANDARD TITLE CARD
C              A STANDARD WDL TITLE CARD (USED AS A COMMENT).
C              A STANDARD STATION CARD.
C              A STANDARD DATES CARD.
C              AN ISEED CARD.
C              A STANDARD DECK OF TRANSITION PROBABILITIES
C                 (.01 LEVEL).
C              A DECK OF PRECIPITATION SIMULATION PARAMETERS.
C              A NGRPS CARD.
C              A DECK OF GROUP MEANS.
C           STANDARD DECKS OF THE FOLLOWING:
C              AVEMIN, SDVMIN, AVEMAX, SDVMAX.
C              CNSMIN, PREOC1, PSTOC1, MNMIN, MXMIN.
C              CNSMAX, PREOC2, PSTOC2, MXMAX, MNMAX.
C
C        DESCRIPTION OF PARAMETERS
C           ISEED  - ANY EIGHT-DIGIT INTEGER.  TWO RUNS FOR ONE
C                    STATION WILL GENERATE THE SAME OUTPUT UNLESS
C                    THE STARTING DATE OR THE SEED IS CHANGED.
C           NGRPS  - THE NUMBER OF PRECIPITATION INTERVALS.
C           AVEMIN - AVERAGE DAILY MINIMUM TEMPERATURES.
C           SDVMIN - STANDARD DEVIATIONS OF THE MINIMUM TEMPERATURES.
C           AVEMAX - AVERAGE DAILY MAXIMUM TEMPERATURES.
C           SDVMAX - STANDARD DEVIATIONS OF THE MAXIMUM TEMPERATURES.
C           CNSMIN - CONSTANT TERM IN THE REGRESSION FOR THE MINIMUM.
C           PREOC1 - ADDITIVE TERM FOR PREWET PRECIPITATION (MIN).
C           PSTOC1 - ADDITIVE TERM FOR PSTWET PRECIPITATION (MIN).
C           MNMIN  - THE PARAMETERS FOR THE EFFECT OF THE LAST DAY'S
C                    MINIMUM TEMPERATURE ON THE NEW MINIMUM.
C           MXMIN  - THE PARAMETERS FOR THE EFFECT OF THE LAST DAY'S
C                    MAXIMUM TEMPERATURE ON THE NEW MINIMUM.
C           CNSMIN - CONSTANT TERM IN THE REGRESSION FOR THE MAXIMUM.
```

```
C           PREOC2 - ADDITIVE TERM FOR PREWET PRECIPITATION (MAX).
C           PSTOC2 - ADDITIVE TERM FOR PSTWET PRECIPITATION (MAX).
C           MXMAX  - THE PARAMETERS FOR THE EFFECT OF THE LAST DAY'S
C                    MAXIMUM TEMPERATURE ON THE NEW MAXIMUM.
C           MNMAX  - THE PARAMETERS FOR THE EFFECT OF THE SAME DAY'S
C                    MINIMUM TEMPERATURE ON THE NEW MAXIMUM.
C           SEE THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY FOR FURTHER
C           INFORMATION ABOUT THE STANDARD INPUT CARDS OR THE INPUT
C           DECKS.
C
C        REMARKS
C           SIMULATED DAILY RECORDS ARE WRITTEN ON UNIT 9.  FORTRAN
C           FORMATS ARE USED, SO INITIAL ZEROES ARE SUPPRESSED.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           RDTITL (READS A STANDARD WDL TITLE CARD)
C           RDSTAT (READS A STANDARD WDL STATION CARD)
C           RDDATE (READS A STANDARD WDL DATES CARD)
C           CDFGMM (BUILDS GAMMA CUMULATIVE DISTRIBUTION FUNCTIONS)
C           INTERP (LINEARLY INTERPOLATES MISSING VECTOR ELEMENTS)
C           DAYWET (GENERATES A RANDOM PRECIPITATION)
C           INCDTE (INCREMENTS A CALENDAR DATE)
C           INCDAY (INCREMENTS A DAY NUMBER)
C           NRMDEV (GENERATES TWO RANDOM NORMAL DEVIATES)
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           CUMULATIVE DISTRIBUTION FUNCTIONS ARE CALCULATED BY
C           SUBROUTINE CDFGMM.  THESE VALUES ARE USED BY
C           SUBROUTINE DAYWET TO CALCULATE THE PRECIPITATION ON
C           ANY GIVEN DAY.  MAX AND MIN TEMPERATURES ARE THEN
C           SIMULATED BY ADDING A NORMAL DEVIATE (WITH THE PROPER
C           VARIANCE) TO THE AVERAGE MAX AND MIN TEMPERATURES FOR
C           THE PROPER DAY AND PRECIPITATION HISTORY. A PORTION OF
C           THE PREVIOUS TEMPERATURES IS ALSO CARRIED INTO THE NEW
C           ONES.
C
C     ................................................................
C
      LOGICAL INDEND/.FALSE./,INDYR,INDMO
      REAL TOTWET/0./,PRECIP/0./,AVEMIN(365),SDVMIN(365),AVEMAX(365),
     1   SDVMAX(365),CNSMIN(365),PREOC1(365),PSTOC1(365),MNMIN(365),
     2   MXMIN(365),CNSMAX(365),PREOC2(365),PSTOC2(365),MXMAX(365),
     3   MNMAX(365)
      COMMON /DATES/ NOWDTE,MAXDTE,NULKAL(4),KLIYR,KLIDAY,MAXYR,
     1   MAXDAY
      COMMON /STAT/ ASTATE,ADIVSN,ASITE,ISITE,SITE(5)
      COMMON /RAND/ ISEED
      COMMON /MEANS/ NGRPS,GRPAVE(120)
      COMMON /PRBDRY/ AFTDRY(365),AFTWET(365)
      COMMON /PRMTRS/ BETA1(13),ALPHA1(13),BETA2(13),GAMMA2(13),
     1   DELTA2(13)
      COMMON /GMMA/ CDF(6,120,13)
```

```
C
C     READ AND ECHO THE RUN PARAMETERS.
C
      CALL RDTITL (INDEND)
      CALL RDSTAT (INDEND)
      CALL RDDATE (INDEND)
      READ (5,1) ISEED
      WRITE (6,2) ISEED
C
C     READ AND ECHO THE TABLE OF TRANSITION PROBABILITIES.  FILL IN
C     THE MISSING VALUES BY LINEAR INTERPOLATION.
C
      READ (5,3) (AFTDRY(I),I=4,365,7)
      CALL INTERP (AFTDRY,4,7)
      READ (5,3) (AFTWET(I),I=4,365,7)
      CALL INTERP (AFTWET,4,7)
      WRITE (6,4) AFTDRY,AFTWET
C
C     READ, ECHO THE TABLE OF SIMULATION PARAMETERS FOR THIS STATION.
C
      READ (5,5) (BETA1(I),ALPHA1(I),BETA2(I),GAMMA2(I),DELTA2(I),
     1   I=1,13)
      WRITE (6,6) (BETA1(I),ALPHA1(I),BETA2(I),GAMMA2(I),DELTA2(I),
     1   I=1,13)
C
C     READ AND CHECK THE VECTOR OF PRECIPITATION VALUES USED AS CLASS
C     MEANS IN THE FORMATION OF CUMULATIVE DISTRIBUTION FUNCTIONS.
C
      READ (5,7) NGRPS,(GRPAVE(I),I=1,NGRPS)
      IF (NGRPS.LT.2.OR.NGRPS.GT.120) CALL ABEND ('SIMREC  ',
     1   'THE NUMBER OF GROUPS IS LESS THAN 2 OR GREATER THAN 120.')
      DO 30 I=2,NGRPS
      IF (GRPAVE(I).LT.GRPAVE(I-1)) CALL ABEND ('SIMREC  ',
     1   'THE GROUP AVERAGES DO NOT FORM AN ASCENDING SEQUENCE.   ')
   30 CONTINUE
C
C     FILL THE CUMULATIVE DISTRIBUTION FUNCTION FOR EACH PERIOD.
C     ECHO THEM ALONG WITH THE GROUP MEANS.
C
      CALL CDFGMM
      DO 40 NOWPRD=1,13
   40 WRITE (6,8) (GRPAVE(J),(CDF(I,J,NOWPRD),I=1,6),J=1,NGRPS)
C
C     READ, INTERPOLATE, AND ECHO THE AVERAGE MINIMUM AND MAXIMUM
C     TEMPERATURES AND STANDARD DEVIATIONS.
C
      READ (5,9) (AVEMIN(I),I=7,365,14)
      CALL INTERP (AVEMIN,7,14)
      WRITE (6,10) AVEMIN
      READ (5,9) (SDVMIN(I),I=7,365,14)
      CALL INTERP (SDVMIN,7,14)
      WRITE (6,11) SDVMIN
      READ (5,9) (AVEMAX(I),I=7,365,14)
      CALL INTERP (AVEMAX,7,14)
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```
      WRITE (6,12) AVEMAX
      READ (5,9) (SDVMAX(I),I=7,365,14)
      CALL INTERP (SDVMAX,7,14)
      WRITE (6,13) SDVMAX
C
C     READ, INTERPOLATE, AND ECHO THE PARAMETERS FOR THE MIN TEMP.
C
      READ (5,9) (CNSMIN(I),I=7,365,14)
      CALL INTERP (CNSMIN,7,14)
      WRITE (6,14) CNSMIN
      READ (5,9) (PREOC1(I),I=7,365,14)
      CALL INTERP (PREOC1,7,14)
      WRITE (6,15) PREOC1
      READ (5,9) (PSTOC1(I),I=7,365,14)
      CALL INTERP (PSTOC1,7,14)
      WRITE (6,16) PSTOC1
      READ (5,9) (MNMIN(I),I=7,365,14)
      CALL INTERP (MNMIN,7,14)
      WRITE (6,17) MNMIN
      READ (5,9) (MXMIN(I),I=7,365,14)
      CALL INTERP (MXMIN,7,14)
      WRITE (6,18) MXMIN
C
C     READ, INTERPOLATE, AND ECHO THE PARAMETERS FOR THE MAX TEMP.
C
      READ (5,9) (CNSMAX(I),I=7,365,14)
      CALL INTERP (CNSMAX,7,14)
      WRITE (6,19) CNSMAX
      READ (5,9) (PREOC2(I),I=7,365,14)
      CALL INTERP (PREOC2,7,14)
      WRITE (6,20) PREOC2
      READ (5,9) (PSTOC2(I),I=7,365,14)
      CALL INTERP (PSTOC2,7,14)
      WRITE (6,21) PSTOC2
      READ (5,9) (MXMAX(I),I=7,365,14)
      CALL INTERP (MXMAX,7,14)
      WRITE (6,22) MXMAX
      READ (5,9) (MNMAX(I),I=7,365,14)
      CALL INTERP (MNMAX,7,14)
      WRITE (6,23) MNMAX
C
C     SET THE WEATHER CONDITIONS FOR THE INITIAL 'PREVIOUS' DAY TO
C     REASONABLE VALUES.
C
      LSTDAY=KLIDAY-1
      IF (LSTDAY.LT.1) LSTDAY=365
      NEWWET=0
      PSTMIN=AVEMIN(LSTDAY)
      PSTMAX=AVEMAX(LSTDAY)
      GO TO 60
C
C     SIMULATE EACH DAY'S PRECIPITATION AND TEMPERATURE.
C
C        INCREMENT THE DATE COUNTERS.
```

```
C
   50 IF (KLIDAY.EQ.MAXDAY.AND.KLIYR.EQ.MAXYR) GO TO 70
      LSTDAY=KLIDAY
      CALL INCDTE (NOWDTE,INDYR,INDMO)
      CALL INCDAY (KLIYR,KLIDAY,INDYR)
C
C        SELECT A NEW PRECIPITATION.
C
   60 LSTWET=NEWWET
      CALL DAYWET (KLIDAY,PRECIP)
      TOTWET=TOTWET+PRECIP
      NEWWET=0
      IF (PRECIP.GT.0.) NEWWET=1
C
C        CALCULATE THE NEW MINIMUM TEMPERATURE.
C
      PREMIN=PSTMIN
      PREMAX=PSTMAX
      CALL NRMDEV (DEV1,DEV2)
      DEVMIN=PREMIN-AVEMIN(LSTDAY)
      DEVMAX=PREMAX-AVEMAX(LSTDAY)
      PSTMIN=CNSMIN(KLIDAY)+LSTWET*PREOC1(KLIDAY)+NEWWET
     1   *PSTOC1(KLIDAY)+MNMIN(KLIDAY)*DEVMIN+MXMIN(KLIDAY)*DEVMAX
     2   +SDVMIN(KLIDAY)*DEV1
C
C        CALCULATE THE NEW MAXIMUM TEMPERATURE.
C
      DEVMIN=PSTMIN-AVEMIN(KLIDAY)
      PSTMAX=CNSMAX(KLIDAY)+LSTWET*PREOC2(KLIDAY)+NEWWET
     1   *PSTOC2(KLIDAY)+MXMAX(KLIDAY)*DEVMAX+MNMAX(KLIDAY)*DEVMIN
     2   +SDVMAX(KLIDAY)*DEV2
C
C        WRITE THE SIMULATED RECORD (AFTER ROUNDING OFF).
C
      IWET=100*(PRECIP+.005)
      NEWMAX=PSTMAX+.5
      NEWMIN=PSTMIN+.5
      WRITE (9,24) ASTATE,ASITE,NOWDTE,ADIVSN,NEWMAX,NEWMIN,IWET
C
C        DETERMINE WHETHER THE END OF THE YEAR HAS BEEN REACHED.
C
      IF (KLIDAY.LT.365) GO TO 50
C
C     WRITE THE TOTAL PRECIPITATION FOR THE YEAR.
C
      WRITE (6,25) KLIYR, TOTWET
      TOTWET=0.
      GO TO 50
C
C     WRITE A TERMINATION MESSAGE.
C
   70 WRITE (6,26) TOTWET,KLIDAY, KLIYR
      STOP
C
```

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C     ..........................................................
C
    1 FORMAT (12X,I8)
    2 FORMAT ('0   THE SEED VALUE IS',I9,'.')
    3 FORMAT (3X,7F11.6)
    4 FORMAT ('1   DRY-TO-DRY TRANSITION PROBABILITIES:'/52(4X,
     1   7F11.6/),4X,F11.6/'1   WET-TO-DRY TRANSITION PROBABILITIES:'
     2   /(4X,7F11.6))
    5 FORMAT (5F10.4)
    6 FORMAT ('1    SIMULATION PARAMETERS:'/9X,'BETA1    ALPHA1   ',
     1   '  BETA2    GAMMA2    DELTA2'/(4X,5F10.4))
    7 FORMAT (12X,I3/(10F8.2))
    8 FORMAT ('1      GROUP       1 DAY     2 DAY     3 DAY     ',
     1   '4 DAY     5 DAY    6+ DAY'/(4X,F8.2,2X,6F10.4))
    9 FORMAT (3X,7F11.6)
   10 FORMAT ('1   AVERAGE MINIMUM TEMPERATURES:'/(4X,7F11.6))
   11 FORMAT ('1   STANDARD DEVIATIONS OF THE MINIMUM TEMPERATURES:'/
     1   (4X,7F11.6))
   12 FORMAT ('1   AVERAGE MAXIMUM TEMPERATURES:'/(4X,7F11.6))
   13 FORMAT ('1   STANDARD DEVIATIONS OF THE MAXIMUM TEMPERATURES:'/
     1   (4X,7F11.6))
   14 FORMAT ('1   MINIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' CONSTANT TERM:'/(4X,7F11.6))
   15 FORMAT ('1   MINIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' OCCURRENCE OF PREWET PRECIPITATION:'/(4X,7F11.6))
   16 FORMAT ('1   MINIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' OCCURRENCE OF PSTWET PRECIPITATION:'/(4X,7F11.6))
   17 FORMAT ('1   MINIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' DEVIATION OF THE PREVIOUS MINIMUM:'/(4X,7F11.6))
   18 FORMAT ('1   MAXIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' DEVIATION OF THE PREVIOUS MAXIMUM:'/(4X,7F11.6))
   19 FORMAT ('1   MAXIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' CONSTANT TERM:'/(4X,7F11.6))
   20 FORMAT ('1   MAXIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' OCCURRENCE OF PREWET PRECIPITATION:'/(4X,7F11.6))
   21 FORMAT ('1   MAXIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' OCCURRENCE OF PSTWET PRECIPITATION:'/(4X,7F11.6))
   22 FORMAT ('1   MAXIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' DEVIATION OF THE PREVIOUS MINIMUM:'/(4X,7F11.6))
   23 FORMAT ('1   MAXIMUM TEMPERATURE COEFICIENTS FOR THE',
     1   ' DEVIATION OF THE PREVIOUS MAXIMUM:'/52(4X,7F11.6/),
     2   4X,F11.6/'1')
   24 FORMAT (A2,A4,I6,A1,2I3,3X,I4)
   25 FORMAT ('0   TOTAL PRECIPITATION FOR THE SIMULATED CLIMATIC',
     1   ' YEAR ',I4,' IS',F6.2,' INCHES.')
   26 FORMAT ('0   (END OF PROCESSING WITH ',F5.2,' INCHES ',
     1   'ACCUMULATED BY DAY ',I3,' OF YEAR ',I4,'.)')
      END
```

```
C
C     ..............................................................
C
C        SUBROUTINE
C           INTERP, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO COMPLETE (BY INTERPOLATION) A CYCLIC VECTOR FOR WHICH
C           ONLY EVERY NTH VALUE HAS BEEN ENTERED.
C
C        USAGE
C           CALL INTERP (VECTOR,IFIRST,NTH)
C
C        DESCRIPTION OF PARAMETERS
C           VECTOR - A VECTOR OF 365 CONTIGUOUS POINTS. ROW OF A
C                    MATRIX.
C           IFIRST - THE FIRST POINT TO CONTAIN A LEGITIMATE VALUE.
C           NTH    - THE INCREMENT BETWEEN POINTS WITH LEGITIMATE
C                    VALUES.
C
C        REMARKS
C           ONE ROW OF A MATRIX MAY BE FILLED BY CALLING INTERP
C           (MATRIX(1,IROW),IFIRST,NTH).
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE POINTS BETWEEN TWO LEGITIMATE VALUES ARE FILLED BY
C           LINEAR INTERPOLATION BETWEEN THOSE VALUES. POINTS 365
C           AND 1 ARE CONSIDERED ADJACENT.
C
C     ..............................................................
C
      SUBROUTINE INTERP (VECTOR,IFIRST,NTH)
      REAL VECTOR(365)
      FACTOR=1.0/NTH
C
C     INITIALIZE THE POSITION MARKERS
C
      LSTPOS=IFIRST-NTH
      NXTPOS=IFIRST
C
C     INCREMENT THE POSITION MARKERS
```

```
C
   10 IF (NXTPOS+NTH.GT.365) GO TO 30
      LSTPOS=NXTPOS
      NXTPOS=NXTPOS+NTH
      MINPOS=LSTPOS+1
      MAXPOS=NXTPOS-1
C
C     FILL THE POINTS BETWEEN TWO LEGITIMATE VALUES.
C
      VALUE=VECTOR(LSTPOS)
      CHANGE=FACTOR*(VECTOR(NXTPOS)-VALUE)
      DO 20 NOWPOS=MINPOS,MAXPOS
      VALUE=VALUE+CHANGE
   20 VECTOR(NOWPOS)=VALUE
      GO TO 10
C     PERFORM AROUND-THE-CLOCK INTERPOLATION.
C
   30 LSTPOS=NXTPOS
      NXTPOS=IFIRST+365
      JUMP=NXTPOS-LSTPOS
      IF (JUMP.LT.2) RETURN
      MINPOS=LSTPOS+1
      MAXPOS=NXTPOS-1
C
C        FILL THE POINTS AROUND-THE-CLOCK.
C
      VALUE=VECTOR(LSTPOS)
      CHANGE=(1.0/JUMP)*(VECTOR(IFIRST)-VALUE)
      DO 40 I=MINPOS,MAXPOS
      NOWPOS=I
      IF (NOWPOS.GT.365) NOWPOS=NOWPOS-365
      VALUE=VALUE+CHANGE
   40 VECTOR(NOWPOS)=VALUE
      RETURN
      END
```

```
C
C     ..............................................................
C
C        SUBROUTINE
C           CDFGMM, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C           THE COMPUTATION SECTION WAS PROGRAMMED BY NORBERTO T.
C           ISON WHEN HE HELD THE SAME POST.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50,
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO FILL IN A TABLE OF CUMULATIVE DISTRIBUTION FUNCTIONS
C           FOR EACH 28-DAY PERIOD OF THE CLIMATIC YEAR.
C
C        USAGE
C           CALL CDFGMM
C           COMMON /MEANS/ NGRPS,GRPAVE(120)
C           COMMON /PRMTRS/ BETA1(13),ALPHA1(13),BETA2(13),
C              GAMMA2(13),DELTA2(13)
C           COMMON /GMMA/ CDF(6,120,13)
C
C        DESCRIPTION OF PARAMETERS
C           NGRPS  - THE NUMBER OF PRECIPITATION INTERVALS (OR
C                    GROUPS) TO BE USED IN THE PRECIPITATION MODEL.
C           GRPAVE - A VECTOR CONTAINING THE PRECIPITATION VALUES
C                    WHICH ARE TO FORM THE (APPROXIMATE) CENTERS OF
C                    THEIR RESPECTIVE PRECIPITATION GROUPS.
C           PRMTRS - THESE VECTORS CONTAIN THE GAMMA DISTRIBUTION
C                    PARAMETERS WHICH WERE FOUND BY PROGRAM RNFALL1.
C           CDF    - THIS ARRAY HOLDS 13 TABLES, ONE FOR EACH PERIOD,
C                    EACH CONTAINING CUMULATIVE DISTRIBUTION
C                    FUNCTIONS FOR WET SEQUENCES OF FROM ONE THROUGH
C                    SIX+ DAYS.
C
C        REMARKS
C           THE LAST VALUE IN EACH CDF VECTOR IS ALWAYS 1.0.
C
C           SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           THE CUMULATIVE RELATIVE FREQUENCIES OF THE INCOMPLETE
C           GAMMA DISTRIBUTION ARE COMPUTED BY USING AN EXPANSION
C           GIVEN BY K. PEARSON IN HIS 'TABLES OF THE INCOMPLETE
C           GAMMA FUNCTION, CAMBRIDGE UNIVERSITY PRESS, REISSUE,
```

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C           1951'.
C
C     ..............................................................
C
      SUBROUTINE CDFGMM
      REAL TOPBND(119),BETA(6),ALPHA(6)
      REAL*8 R,P
      COMMON /MEANS/ NGRPS,GRPAVE(120)
      COMMON /PRMTRS/ BETA1(13),ALPHA1(13),BETA2(13),GAMMA2(13),
     1   DELTA2(13)
      COMMON /GMMA/ CDF(6,120,13)
C
C     CALCULATE UPPER BOUNDS OF CLASS INTERVALS FOR THE CUMULATIVE
C     DISTRIBUTION FUNCTIONS.
C
      NBNDS=NGRPS-1
      DO 10 NOWGRP=1,NBNDS
   10 TOPBND(NOWGRP)=.5*(GRPAVE(NOWGRP)+GRPAVE(NOWGRP+1))
C
C     FILL IN THE CDF TABLE FOR EACH PERIOD.
C
      DO 50 NOWPRD=1,13
C
C        FIND THE BETA AND ALPHA VALUE FOR EACH LENGTH OF SEQUENCE.
C
      BETA(1)=BETA1(NOWPRD)
      ALPHA(1)=ALPHA1(NOWPRD)
      DO 20 LSEQ=2,6
      BETA(LSEQ)=BETA2(NOWPRD)
   20 ALPHA(LSEQ)=GAMMA2(NOWPRD)+(LSEQ-2)*DELTA2(NOWPRD)
C
C        CALCULATE THE CDF VALUES FOR EACH LENGTH OF SEQUENCE.
C
      DO 50 LSEQ=1,6
      IF (BETA(LSEQ).EQ.0.) GO TO 60
      NCODE=0
      TMP=GAMMA(ALPHA(LSEQ)+1.)
      DO 40 NOWGRP=1,NBNDS
      IF (NCODE.GT.0) GO TO 40
      T=TOPBND(NOWGRP)*BETA(LSEQ)
      P=1.0
      R=1.0
      I=0
   30 I=I+1
      R=R*(T/(ALPHA(LSEQ)+I))
      P=P+R
      IF (DABS(R).GE..000001) GO TO 30
      F=((T**ALPHA(LSEQ))/EXP(T))*(P/TMP)
      IF (F.GT.1.) F=1.
      IF (F.EQ.1.) NCODE=1
   40 CDF(LSEQ,NOWGRP,NOWPRD)=F
   50 CDF(LSEQ,NGRPS,NOWPRD)=1.
      RETURN
C
```

```
C     WRITE AN ERROR MESSAGE AND TERMINATE EXECUTION.
C
   60 WRITE (6,1) NOWPRD,LSEQ
      CALL ABEND ('CDFGMM  ',
     1   'AN ILLEGAL VALUE HAS OCCURRED AS LISTED ABOVE.              ')
C
C     ..............................................................
C
    1 FORMAT ('0   (SUBROUTINE CDFGMM HAS CALCULATED A ZERO BETA ',
     1   'FOR PERIOD',I3,', SEQUENCE',I2,'.)')
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           DAYWET, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO PROVIDE A SIMULATED PRECIPITATION FOR ANY DAY OF THE
C           YEAR, BASED UPON THE TRANSITION PROBABILITY TABLE AND
C           THE CUMULATIVE DISTRIBUTION FUNCTION TABLES.
C
C        USAGE
C           CALL DAYWET (KLIDAY,PRECIP)
C           COMMON /RAND/ ISEED
C           COMMON /PRBDRY/ AFTDRY(53),AFTWET(53)
C           COMMON /GMMA/ CDF(6,120,13)
C
C        DESCRIPTION OF PARAMETERS
C           KLIDAY - THE CLIMATIC DAY NUMBER.
C           PRECIP - THE SIMULATED PRECIPITATION.
C           ISEED   - THE SEED VALUE USED TO PICK A RANDOM NUMBER.
C           AFTDRY - A VECTOR CONTAINING THE PROBABILITIES OF
C                    TRANSITION FROM DRY TO DRY.
C           AFTWET - A VECTOR CONTAINING THE PROBABILITIES OF
C                    TRANSITION FROM WET TO DRY.
C           CDF    - THIRTEEN TABLES CONTAINING THE CUMULATIVE
C                    DISTRIBUTION FUNCTION FOR EACH PERIOD AND EACH
C                    LENGTH OF SEQUENCE.
C
C        REMARKS
C           WET DAYS ARE THOSE HAVING AT LEAST .01 INCHES OF
C           PRECIPITATION.  THE SIMULATED PRECIPITATION FOR SUCH A
C           DAY, HOWEVER, MAY FALL BELOW .01.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           DAYKND (DETERMINES WHETER A DAY IS TO BE DRY OR WET)
C           SEQWET (DETERMINES TOTAL PRECIPITATICN FOR A SEQUENCE)
C
C        METHOD
C           THIS SUBROUTINE RUNS A LITTLE AHEAD OF THE CALLING
C           PROGRAM.  WHENEVER A WET DAY IS SIMULATED, THE LENGTH OF
C           THE ENTIRE WET SEQUENCE IS DETERMINED AND A PRECIPITATION
C           VALUE IS ASSIGNED TO EACH DAY.
C
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C     ..........................................................
C
      SUBROUTINE DAYWET (KLIDAY,PRECIP)
      LOGICAL INDWET/.FALSE./
      INTEGER LSEQ/-1/
C
C     TEST WHETHER THE NEXT DAY IS: UNDEFINED, THE DRY DAY AT THE END
C     OF A WET SPELL, OR A CONTINUATION OF THE WET SPELL.
C
      IF (LSEQ) 10,20,30
C
C     GENERATE A DRY DAY OR A WET SPELL.
C
   10 LSEQ=LSEQ+1
      CALL DAYKND (KLIDAY,INDWET)
      IF (INDWET) GO TO 10
      IF (LSEQ.LT.1) GO TO 30
      CALL SEQWET (KLIDAY,LSEQ,PRECIP)
      GO TO 30
C
C     REMOVE ONE DAY FROM THE PRESENT WET SEQUENCE (ZERO THE
C     PRECIPITATION IF IT IS THE LAST DAY).
C
   20 PRECIP=0.
   30 LSEQ=LSEQ-1
      RETURN
      END
```

```
C
C     ...........................................................
C
C        SUBROUTINE
C           DAYKND, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO RANDOMLY DETERMINE WHETHER A GIVEN DAY SHOULD BE
C           INCLUDED IN THE SIMULATION AS WET OR DRY.
C
C        USAGE
C           CALL DAYKND (KLIDAY,INDWET)
C           COMMON /RAND/ ISEED
C           COMMON /PRBDRY/ AFTDRY(53),AFTWET(53)
C
C        DESCRIPTION OF PARAMETERS
C           KLIDAY - THE CLIMATIC DAY NUMBER.
C           INDWET - A LOGICAL INDICATOR SET TO .TRUE. FOR A WET DAY.
C           ISEED   - THE SEED VALUE USED TO PICK A RANDOM NUMBER.
C           AFTDRY - A VECTOR CONTAINING THE PROBABILITIES OF
C                    TRANSITION FROM DRY TO DRY.
C           AFTWET - A VECTOR CONTAINING THE PROBABILITIES OF
C                    TRANSITION FROM WET TO DRY.
C
C        REMARKS
C           SUBROUTINE RANDU IS IN THE IBM SSP PACKAGE.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           RANDU  (RETURNS A UNIFORM RANDOM NUMBER FROM 0 TO 1)
C
C        METHOD
C           A RANDOM NUMBER FROM 0. TO .9999999 IS CHOSEN.  IF IT
C           EXCEEDS THE TABLE VALUE FOR THIS PERIOD THE DAY IS
C           CONSIDERED WET.
C
C     ...........................................................
C
      SUBROUTINE DAYKND (KLIDAY,INDWET)
      LOGICAL INDLST,INDWET
      COMMON /RAND/ ISEED
      COMMON /PRBDRY/ AFTDRY(365),AFTWET(365)
C
C     SAVE THE LAST DRY/WET CONDITION, AND RESET INDWET.
C
```

```
      INDLST=INDWET
      INDWET=.FALSE.
C
C     DRAW A RANDOM NUMBER FROM 0.0 THROUGH 0.9999999.
C
      CALL RANDU (ISEED,IRNDM,RNDM)
      ISEED=IRNDM
C
C     DETERMINE WHETHER THIS NUMBER CORRESPONDS TO A WET OR DRY DAY.
C
      IF (INDLST) GO TO 10
      IF (RNDM.GT.AFTDRY(KLIDAY)) INDWET=.TRUE.
      GO TO 20
   10 IF (RNDM.GT.AFTWET(KLIDAY)) INDWET=.TRUE.
   20 RETURN
      END
```

```
C
C     ..........................................................
C
C        SUBROUTINE
C           SEQWET, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO RANDOMLY SELECT A PRECIPITATION VALUE WHICH IS TO
C           BE APPLIED EQUALLY AMONG THE DAYS OF A WET SPELL.
C
C        USAGE
C           CALL SEQWET (KLIDAY,LSEQ,PRECIP)
C           COMMON /RAND/ ISEED
C           COMMON /GMMA/ CDF(6,120,13)
C           COMMON /MEANS/ NGRPS,GRPAVE(120)
C
C        DESCRIPTION OF PARAMETERS
C           KLIDAY - THE CLIMATIC DAY NUMBER.
C           LSEQ   - THE LENGTH OF THE WET SEQUENCE.
C           PRECIP - THE SIMULATED PRECIPITATION.
C           ISEED  - THE SEED VALUE USED TO PICK A RANDOM NUMBER.
C           CDF    - THIRTEEN TABLES CONTAINING THE CUMULATIVE
C                    DISTRIBUTION FUNCTION FOR EACH PERIOD AND EACH
C                    LENGTH OF SEQUENCE.
C           NGRPS  - THE NUMBER OF PRECIPITATION GROUPS TO BE USED.
C           GRPAVE - A VECTOR CONTAINING THE VALUE OF PRECIPITATION
C                    TO BE ASSIGNED TO EACH SEQUENCE ASSIGNED TO
C                    THE GROUP.
C
C        REMARKS
C           SUBROUTINE RANDU IS IN THE IBM SSP PACKAGE.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           RANDU  (RETURNS A UNIFORM RANDOM NUMBER FROM 0 TO 1)
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           THE CUMULATIVE DISTRIBUTION FUNCTION FOR THIS PERIOD
C           AND LENGTH OF SEQUENCE CONTAINS THE BOUNDARIES OF EACH
C           PRECIPITATION GROUP.  THE PRECIPITATION CORRESPONDING TO
C           A RANDOM NUMBER IS DIVIDED EQUALLY AMONG THE DAYS OF
C           THE WET SEQUENCE.
C
C     ..........................................................
```

```
C
      SUBROUTINE SEQWET (KLIDAY,LSEQ,PRECIP)
      COMMON /RAND/ ISEED
      COMMON /GMMA/ CDF(6,120,13)
      COMMON /MEANS/ NGRPS,GRPAVE(120)
C
C     CALCULATE THE PERIOD INVOLVED.
C
      IPRD=(KLIDAY+27)/28
      IF (IPRD.GT.13) IPRD=13
C
C     SET NDAYS TO THE LENGTH OF SEQUENCE (LIMITED TO 6).
C
      NDAYS=LSEQ
      IF (LSEQ.GT.6) NDAYS=6
C
C     DRAW A RANDOM NUMBER FROM 0.0 THROUGH 0.9999999.
C
      CALL RANDU (ISEED,IRNDM,RNDM)
      ISEED=IRNDM
C
C     FIND THE INTERVAL OF THE CUMULATIVE DISTRIBUTION FUNCTION
C     WHICH CONTAINS THIS RANDOM NUMBER.
C
      DO 10 NOWGRP=1,NGRPS
      IF (RNDM.LT.CDF(NDAYS,NOWGRP,IPRD)) GO TO 20
   10 CONTINUE
      CALL ABEND ('SEQWET  ',
     1   'THE RANDOM NUMBER EXCEEDED ALL ENTRIES IN THE CDF.        ')
C
C     SET THE PRECIPITATION TO THE AVERAGE VALUE FOR THIS WET PERIOD.
C
   20 PRECIP=GRPAVE(NOWGRP)/NDAYS
      RETURN
      END
```

```
C
C     ..........................................................
C
C        SUBROUTINE
C           NRMDEV, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO GENERATE PSEUDO-RANDOM NUMBERS WITH THE STANDARD
C           NORMAL DISTRIBUTION.
C
C        USAGE
C           CALL NRMDEV (DEV1,DEV2)
C           COMMON /RAND/ ISEED
C
C        DESCRIPTION OF PARAMETERS
C           DEV1   - A NORMAL DEVIATE WHICH IS RETURNED BY NRMDEV.
C           DEV2   - A SECOND NORMAL DEVIATE.
C           ISEED  - THE SEED VALUE FOR THE RANDOM NUMBER GENERATOR.
C
C        REMARKS
C           THE TWO DEVIATES ARE INDEPENDENT.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           RANDU  (RETURNS A UNIFORM RANDOM NUMBER FROM 0 TO 1)
C
C        METHOD
C           THE METHOD IS DUE TO BOX AND MULLER.
C
C     ..........................................................
C
      SUBROUTINE NRMDEV (DEV1,DEV2)
      COMMON /RAND/ ISEED
C
C     GENERATE A RANDOM NUMBER FROM 0.0 THROUGH .9999999.
C
      CALL RANDU (ISEED,IRAND,RAND)
      ISEED=IRAND
C
C     DRAW A SECOND RANDOM NUMBER AND COMBINE THEM TO FORM THE TWO
C     NORMAL DEVIATES.
C
      TLOG=SQRT(-2.0*ALOG(RAND))
      CALL RANDU (ISEED,IRAND,RAND)
      ISEED=IRAND
```

```
DEV1=TLOG*COS(6.2831853*RAND)
DEV2=TLOG*SIN(6.2831853*RAND)
RETURN
END
```

# APPENDIX C

# WEATHER DATA LIBRARY SUBROUTINES

```
C
C     ..............................................................
C
C        SUBROUTINE
C           RDTITL, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO READ A STANDARD TITLE CARD AND CHECK ITS VALIDITY.
C
C        USAGE
C           CALL RDTITL (INDEND)
C           COMMON /TITL/ TITLE(17)
C           A STANDARD TITLE CARD IN THE INPUT STREAM.
C
C        DESCRIPTION OF PARAMETERS
C           INDEND - A LOGICAL INDICATOR WHICH WILL BE RETURNED WITH
C                    A VALUE OF .TRUE. ONLY IF ITS ENTRY VALUE WAS
C                    .TRUE. AND AN END OF FILE CONDITION OCCURED.
C           TITLE  - A VECTOR HOLDING THE ALPHAMERIC TITLE.
C           SEE THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY FOR FURTHER
C           INFORMATION ABOUT THE STANDARD TITLE CARD.
C
C        REMARKS
C           THE COMMON STATEMENT MAY BE OMITTED IN THE CALLING
C           PROGRAM IF THE INFORMATION IS TO BE TREATED AS A COMMENT.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           COLUMNS 4-7 ARE CHECKED FOR THE LETTERS 'TITL'. COLUMNS
C           13-80 ARE TREATED AS A COMMENT STATEMENT.
C
C     ..............................................................
C
      SUBROUTINE RDTITL (INDEND)
      LOGICAL INDEND
      INTEGER IDTITL/'TITL'/
      REAL REMARK(10)
      COMMON /TITL/ TITLE(17)
C
C     READ A CARD AND TEST IT FOR THE PROPER TYPE.
C
```

```
      READ (5,1,END=10) ICARD,ID,TITLE
      IF (ID.NE.IDTITL) CALL ABEND ('RDTITL  ',
     1   'CARD COLUMNS 4-7 DID NOT CONTAIN THE IDENTIFIER "TITL". ')
C
C     RESET THE END-OF-FILE INDICATOR.
C
      INDEND=.FALSE.
C
C     ECHO THE CONTENTS OF THE CARD AND RETURN.
C
      WRITE (6,2) ICARD,TITLE
      GO TO 20
C
C     SIMPLY RETURN IF INDEND=.TRUE., OTHERWISE TERMINATE THE RUN.
C
   10 IF (.NOT.INDEND) CALL ABEND ('RDTITL  ',
     1   'END OF FILE ON UNIT 5: MISSING TITLE CARD.               ')
   20 RETURN
C
C     ..........................................................
C
    1 FORMAT (I2,1X,A4,5X,17A4)
    2 FORMAT ('0',I2,' THE TITLE IS: ',17A4)
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C           RDSTAT, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO READ A STANDARD STATION CARD AND CHECK ITS VALIDITY.
C
C        USAGE
C           CALL RDSTAT (INDEND)
C           COMMON /STAT/ ASTATE,ADIVSN,ASITE,ISITE,SITE(4)
C           A STANDARD STATION CARD IN THE INPUT STREAM.
C
C        DESCRIPTION OF PARAMETERS
C           INDEND - A LOGICAL INDICATOR WHICH WILL BE RETURNED WITH
C                    A VALUE OF .TRUE. ONLY IF ITS ENTRY VALUE WAS
C                    .TRUE. AND AN END OF FILE CONDITION OCCURED.
C           ASTATE - THE 2-DIGIT STATE NUMBER IN ALPHAMERIC FORM.
C           ADIVSN - THE 1-DIGIT STATE NUMBER IN ALPHAMERIC FORM.
C           ASITE  - THE 4-DIGIT STATION NUMBER IN ALPHAMERIC FORMAT.
C           ISITE  - THE 4-DIGIT STATION NUMBER IN INTEGER FORMAT.
C           SITE   - A VECTOR CONTAINING THE STATION NAME.
C           SEE THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY FOR FURTHER
C           INFORMATICN ABOUT THE STANDARD DATES CARD AND THE
C           VALUES PASSED IN COMMON.
C
C        REMARKS
C           THE COMMON STATEMENT MAY BE OMITTED IN THE CALLING
C           PROGRAM IF THE INFORMATION IS TO BE TREATED AS A COMMENT.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           INTEGR (CONVERTS A NUMBER FROM A-FORM TO I-FORM)
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           COLUMNS 4-7 ARE CHECKED FOR THE LETTERS 'STAT'.  OTHER
C           FIELDS ARE NOT CHECKED FOR VALIDITY.
C
C     ..................................................................
C
      SUBROUTINE RDSTAT (INDEND)
      LOGICAL INDEND
```

```
      INTEGER IDSTAT/'STAT'/
      REAL REMARK(10)
      COMMON /STAT/ ASTATE,ADIVSN,ASITE,ISITE,SITE(4)
C
C     READ A CARD AND TEST IT FOR THE PROPER TYPE.
C
      READ (5,1,END=10) ICARD,ID,ASTATE,ADIVSN,ASITE,SITE,REMARK
      IF (ID.NE.IDSTAT) CALL ABEND ('RDSTAT  ',
     1   'CARD COLUMNS 4-7 DID NOT CONTAIN THE IDENTIFIER "STAT". ')
C
C     RESET THE END-OF-FILE INDICATOR.
C
      INDEND=.FALSE.
C
C
C     SET ISITE EQUAL TO THE INTEGER VALUE OF ASITE.
C
      CALL INTEGR (ASITE,ISITE)
C     ECHO THE CONTENTS OF THE CARD AND RETURN.
C
      WRITE (6,2) ICARD,ASTATE,ADIVSN,ISITE,SITE,REMARK
      GO TO 20
C
C     SIMPLY RETURN IF INDEND=.TRUE., OTHERWISE TERMINATE THE RUN.
C
   10 IF (.NOT.INDEND) CALL ABEND ('RDSTAT  ',
     1   'END OF FILE ON UNIT 5: MISSING STATION CARD.             ')
   20 RETURN
C
C     ..........................................................
C
    1 FORMAT (I2,1X,A4,5X,A2,1X,A1,1X,A4,1X,4A4,2X,10A4)
    2 FORMAT ('0',I2,' THE STATION REQUESTED IS NUMBER ',A2,'-',A1,
     1   '-',I4,', ',4A4,'. ',10A4)
      END
```

```
C
C     ................................................................
C
C        SUBROUTINE
C           RDDATE, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO READ AND INTERPRET A STANDARD DATES CARD.
C
C        USAGE
C           CALL RDDATE (INDEND)
C           COMMON /DATES/ MINDTE,MAXDTE,KALMIN(2),KALMAX(2),
C              KLIMIN(2),KLIMAX(2)
C           A STANDARD DATES CARD IN THE INPUT STREAM
C
C        DESCRIPTION OF PARAMETERS
C           INDEND - A LOGICAL INDICATOR WHICH WILL BE RETURNED WITH
C                    A VALUE OF .TRUE. ONLY IF ITS ENTRY VALUE WAS
C                    .TRUE. AND AN END OF FILE CONDITION OCCURED.
C           MINDTE - THE DATE OF THE FIRST RECORD TO BE PROCESSED,
C                    IN THE FORM YR/MO/DAY (E.G., 711231).
C           MAXDTE - THE DATE OF THE LAST RECORD TO BE PROCESSED.
C           KALMIN - A VECTOR CONTAINING THE CALENDAR YEAR AND DAY
C                    OF THE FIRST DAY TO BE PROCESSED.
C           KALMAX - A VECTOR CONTAINING THE CALENDAR YEAR AND DAY
C                    OF THE LAST DAY TO BE PROCESSED.
C           KLIMIN - A VECTOR CONTAINING THE CLIMATIC YEAR AND DAY
C                    OF THE FIRST DAY TO BE PROCESSED.
C           KLIMAX - A VECTOR CONTAINING THE CLIMATIC YEAR AND DAY
C                    OF THE LAST DAY TO BE PROCESSED.
C           SEE THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY FOR FURTHER
C           INFORMATION ABOUT THE STANDARD DATES CARD AND THE
C           VALUES PASSED IN CCMMON.
C
C        REMARKS
C           THIS SUBROUTINE ASSUMES A 365-DAY YEAR. IF FEB 29 IS TO
C           BE PROCESSED, THIS MUST BE DETERMINED AND ARRANGED BY
C           THE USER'S PROGRAM.
C
C           THE MAX DAYS MAY BE LESS THAN THE CORRESPONDING MIN
C           DAYS IF PROCESSING EXTENDS THROUGH THE CHANGE OF YEAR.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
```

```
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           YEAR, MONTH, AND DAY VALUES ARE READ AND CHECKED.
C           MINDTE AND MAXDTE ARE CALCULATED FROM THESE, AND THE
C           MONTH DAYS ARE CHANGED TO CALENDAR DAYS.  THEN CLIMATIC
C           DATES ARE DERIVED FROM THE CALENDAR ONES.
C
C
      SUBROUTINE RDDATE (INDEND)
      LOGICAL INDEND
      INTEGER IDDATE/'DATE'/,
     1   MOFST(13)/1,32,60,91,121,152,182,213,244,274,305,335,366/
      REAL REMARK(10)
      COMMON /DATES/ MINDTE,MAXDTE,KALMIN(2),KALMAX(2),KLIMIN(2),
     1   KLIMAX(2)
      EQUIVALENCE (KALMIN(1),MINYR),(KALMAX(1),MAXYR)
C
C     READ THE DATES CARD AND CHECK ITS VALIDITY.
C
      READ (5,1,END=30) ICARD,ID,MINYR,MINMO,MINDAY,MAXYR,MAXMO,
     1   MAXDAY,REMARK
      IF (ID.NE.IDDATE) CALL ABEND ('RDDATE  ',
     1   'CARD COLUMNS 4-7 DID NOT CONTAIN THE IDENTIFIER "DATE". ')
C
C     RESET THE END-OF-FILE INDICATOR.
C
      INDEND=.FALSE.
C
C        CHECK THE YEARS FOR PROPER RANGE.
C
      IF (MINYR.LT.1800.OR.MINYR.GT.2200) CALL ABEND ('RDDATE  ',
     1   'THE FIRST YEAR IS LESS THAN 1800 OR GREATER THAN 2200.  ')
      IF (MAXYR.LT.1800.OR.MAXYR.GT.2200) CALL ABEND ('RDDATE  ',
     1   'THE FINAL YEAR IS LESS THAN 1800 OR GREATER THAN 2200.  ')
C
C        CHECK THE MONTHS FOR PROPER RANGE.
C
      IF (MINMO.LT.1.OR.MINMO.GT.12) CALL ABEND ('RDDATE  ',
     1   'THE FIRST MONTH IS LESS THAN 1 OR GREATER THAN 12.      ')
      IF (MAXMO.LT.1.OR.MAXMO.GT.12) CALL ABEND ('RDDATE  ',
     1   'THE FINAL MONTH IS LESS THAN 1 OR GREATER THAN 12.      ')
C
C        BUILD THE DATES AND CHECK FOR PROPER SEQUENCE.
C
      MINDTE=10000*MOD(MINYR,100)+100*MINMO+MINDAY
      MAXDTE=10000*MOD(MAXYR,100)+100*MAXMO+MAXDAY
      IF (MAXDTE.LT.MINDTE) CALL ABEND ('RDDATE  ',
     1   'THE FINAL DATE IS LESS THAN THE FIRST DATE.             ')
C
C        CONVERT MONTH DAYS TO CALENDAR DAYS AND CHECK THEM.
C
      IF (MINDAY.LT.1.OR.MAXDAY.LT.1) CALL ABEND ('RDDATE  ',
     1   'EITHER THE FIRST OR THE LAST DAY NUMBER IS LESS THAN 1. ')
```

```
      KALMIN(2)=MOFST(MINMO)+MINDAY-1
      IF (KALMIN(2).GE.MOFST(MINMO+1)) CALL ABEND ('RDDATE  ',
     1   'THE FIRST DAY NUMBER EXCEEDS THE LENGTH OF ITS MONTH.   ')
      KALMAX(2)=MOFST(MAXMO)+MAXDAY-1
      IF (KALMAX(2).GE.MOFST(MAXMO+1)) CALL ABEND ('RDDATE  ',
     1   'THE FINAL DAY NUMBER EXCEEDS THE LENGTH OF ITS MONTH.   ')
C
C     CONVERT CALENDAR DAYS TO CLIMATIC DAYS.
C
      KLIMIN(1)=KALMIN(1)
      KLIMIN(2)=KALMIN(2)-59
      IF (KLIMIN(2).GT.0) GO TO 10
      KLIMIN(1)=KLIMIN(1)-1
      KLIMIN(2)=KLIMIN(2)+365
   10 KLIMAX(1)=KALMAX(1)
      KLIMAX(2)=KALMAX(2)-59
      IF (KLIMAX(2).GT.0) GO TO 20
      KLIMAX(1)=KLIMAX(1)-1
      KLIMAX(2)=KLIMAX(2)+365
C     ECHO THE CONTENTS OF THE DATES CARD.
C
   20 WRITE (6,2) ICARD,MINDTE,MAXDTE,KALMIN,KALMAX,KLIMIN,KLIMAX,
     1   REMARK
      GO TO 40
C     SIMPLY RETURN IF INDEND=.TRUE., OTHERWISE TERMINATE THE RUN.
   30 IF (.NOT.INDEND) CALL ABEND ('RDDATE  ',
     1   'END OF FILE ON UNIT 5: MISSING DATES CARD.              ')
   40 RETURN
C
C     .............................................................
C
    1 FORMAT (I2,1X,A4,5X,2(I4,1X,I2,1X,I2,1X),T41,10A4)
    2 FORMAT ('0',I2,' PROCESSING IS TO BEGIN WITH RECORD',I7,
     1   ' AND TO END WITH RECORD',I7,'.'/4X,'THIS IS FROM CALENDAR ',
     2   'YEAR',I5,', DAY',I4,' THROUGH YEAR',I5,', DAY',I4,
     3   ', AND'/4X,'IS ALSO FROM CLIMATIC YEAR',I5,', DAY',I4,
     4   ' THROUGH YEAR',I5,', DAY',I4,'.'/4X,10A4)
      END
```

```
C
C     ..................................................................
C
C        SUBROUTINE
C        RDPERF, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO READ AND INTERPRET A STANDARD PERFORM CARD.
C
C        USAGE
C           CALL RDPERF (INDEND,INDDO)
C           A STANDARD PERFORM CARD IN THE INPUT STREAM
C
C        DESCRIPTION OF PARAMETERS
C           INDEND - A LOGICAL INDICATOR WHICH WILL BE RETURNED WITH
C                    A VALUE OF .TRUE. ONLY IF ITS ENTRY VALUE WAS
C                    .TRUE. AND AN END OF FILE CONDITION OCCURED.
C           INDDO  - A LOGICAL INDICATOR READ FROM THE PERFORM CARD.
C           SEE THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY FOR FURTHER
C           INFORMATION ABOUT THE STANDARD PERFORM CARD.
C
C        REMARKS
C           THE IDENTIFIER ON THE PERFORM CARD MAY BE 'INPUT',
C           'PERFORM', OR 'OUTPUT'.  THE USER PROGRAM MUST INTERPRET
C           INDDO WITHOUT KNOWING WHICH IDENTIFIER WAS USED.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           ABEND  (WRITES A MESSAGE AND TERMINATES EXECUTION)
C
C        METHOD
C           THE CARD IS CHECKED FOR A VALID IDENTIFIER AND IS THEN
C           ECHOED.
C
C     ..................................................................
C     ..................................................................
C
      SUBROUTINE RDPERF (INDEND,INDDO)
      LOGICAL INDEND,INDDO
      INTEGER IDINPU/'INPU'/,IDPERF/'PERF'/,IDOUTP/'OUTP'/
      REAL REMARK(10),STEP*8
C
C     READ THE CARD, CHECK IT FOR VALIDITY, AND WRITE THE APPROPRIATE
C     ECHO MESSAGE.
```

```
C
      READ (5,1,END=30) ICARD,ID,STEP,INDDO,REMARK
C
C        RESET THE END-OF-FILE INDICATOR.
C
      INDEND=.FALSE.
C
C        CHECK FOR AN 'INPUT' CARD.
C
      IF (ID.NE.IDINPU) GO TO 10
      IF (INDDO) WRITE (6,2) ICARD,STEP,REMARK
      IF (.NOT.INDDO) WRITE (6,3) ICARD,STEP,REMARK
      GO TO 40
C
C        CHECK FOR A 'PERFORM' CARD.
C
   10 IF (ID.NE.IDPERF) GO TO 20
      IF (INDDO) WRITE (6,4) ICARD,STEP,REMARK
      IF (.NOT.INDDO) WRITE (6,5) ICARD,STEP,REMARK
      GO TO 40
C
C        CHECK FOR AN 'OUTPUT' CARD.
C
   20 IF (ID.NE.IDOUTP) CALL ABEND ('RDPERF  ',
     1   'CARD COLUMNS 4-7 DID NOT CONTAIN INPU, PERF, OR OUTP.   ')
      IF (INDDO) WRITE (6,6) ICARD,STEP,REMARK
      IF (.NOT.INDDO) WRITE (6,7) ICARD,STEP,REMARK
      GO TO 40
C
C     SIMPLY RETURN IF INDEND=.TRUE., OTHERWISE TERMINATE THE RUN.
C
   30 IF (.NOT.INDEND) CALL ABEND ('RDPERF  ',
     1   'END OF FILE ON UNIT 5: MISSING PERFORM CARD.            ')
   40 RETURN
C
C     ..............................................................
C
    1 FORMAT (I2,1X,A4,5X,A8,1X,L1,T41,10A4)
    2 FORMAT (/I3,' INPUT CARDS ARE PROVIDED FOR THE ',A8,' STEP. ',
     1   10A4)
    3 FORMAT (/I3,' NO INPUT CARDS ARE PROVIDED FOR THE ',A8,
     1   ' STEP.  ',10A4)
    4 FORMAT (/I3,' THE ',A8,' STEP IS TO BE PERFORMED. ',10A4)
    5 FORMAT (/I3,' THE ',A8,' STEP IS TO BE SKIPPED. ',10A4)
    6 FORMAT (/I3,' THE ',A8,' STEP IS TO PRODUCE OUTPUT. ',10A4)
    7 FORMAT (/I3,' THE ',A8,' STEP IS NOT TO PRODUCE OUTPUT. ',10A4)
      END
```

```
IDENTIFICATION DIVISION.
PROGRAM-ID. INCDTE.
AUTHOR. KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
    AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
    SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
    NORTH CENTRAL REGION.
INSTALLATION. THE KANSAS STATE UNIVERSITY COMPUTING CENTER.
DATE-WRITTEN. JUL 25,1973.
DATE-COMPILED.
REMARKS. THIS SUBROUTINE INCREMENTS A DATE FIELD, SIGNALING
    CONTROL BREAKS IF THE MONTH OR YEAR VALUES CHANGE.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SOURCE-COMPUTER. IBM-360-F50.
OBJECT-COMPUTER. IBM-360-F50.
DATA DIVISION.
WORKING-STORAGE SECTION.
01  DATE, PICTURE IS 9(6), USAGE IS DISPLAY.
01  YYMMDD REDEFINES DATE.
    02  YEAR, PICTURE IS 99, USAGE IS DISPLAY.
    02  MONTH, PICTURE IS 99, USAGE IS DISPLAY.
    02  DAY, PICTURE IS 99, USAGE IS DISPLAY.
01  TABLE-VALUES.
    02  JAN, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.
    02  FEB, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 28.
    02  MAR, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.
    02  APR, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 30.
    02  MAY, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.
```

```
           02  JUN, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 30.
           02  JUL, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.
           02  AUG, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.
           02  SEP, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 30.
           02  OCT, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.
           02  NOV, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 30.
           02  DEC, PICTURE IS 99, USAGE IS COMP-3, VALUE IS 31.

       01  LENGTH-OF-MONTH-TABLE REDEFINES TABLE-VALUES.
           02  TABLE-ENTRY OCCURS 12 TIMES.
               03  LENGTH-OF-MONTH, PICTURE IS 99, USAGE IS COMP-3.

       LINKAGE SECTION.

       77  NOWDTE, PICTURE IS S9(9), USAGE IS COMP.

       77  INDYR, PICTURE IS S9(9), USAGE IS COMP.

       77  INDMO, PICTURE IS S9(9), USAGE IS COMP.


       PROCEDURE DIVISION USING NOWDTE, INDYR, INDMO.


       010-NOTE.
           NOTE ********************************************************
           *   RESET THE LOGICAL INDICATORS AND INCREMENT THE DATE.*
           *************************************************************

       010-UPDATE.
           MOVE 0 TO INDYR, INDMO.
           ADD 1 TO NOWDTE.
           MOVE NOWDTE TO DATE.
           IF DAY IS GREATER THAN LENGTH-OF-MONTH (MONTH) GO TO
               020-NEW-MONTH, ELSE GOBACK.


       020-NOTE.
           NOTE ********************************************************
           *   SET THE NEW-MONTH INDICATOR AND UPDATE THE MONTH.   *
           *************************************************************

       020-NEW-MONTH.
           MOVE +1 TO INDMO.
           MOVE 1 TO DAY.
           ADD 1 TO MONTH.
           IF MONTH IS LESS THAN 13 MOVE DATE TO NOWDTE, GOBACK,
               ELSE NEXT SENTENCE.

       030-NOTE.
           NOTE ********************************************************
           *   SET THE NEW-YEAR INDICATOR AND UPDATE THE YEAR.     *
           *************************************************************
```

```
030-NEW-YEAR.
    MOVE +1 TO INDYR.
    MOVE 1 TO MONTH.
    IF YEAR IS EQUAL TO 99 MOVE 0 TO YEAR, ELSE ADD 1 TO YEAR.
    MOVE DATE TO NOWDTE.
    GOBACK.
```

```
C
C      ...............................................................
C
C         SUBROUTINE
C            INCDAY, MODEL 1, VERSION 1.
C
C         PROGRAMMER
C            KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C            AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C            SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C            NORTH CENTRAL REGION.
C
C         INSTALLATION
C            KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C            USING FORTRAN IV COMPILER G, LEVEL 21.
C
C         PURPOSE
C            TO INCREMENT A DATE COUNTER AND SET AN INDICATIOR IF THE
C            YEAR HAS CHANGED.
C
C         USAGE
C            CALL INCDAY (NOWYR,NOWDAY,INDYR)
C
C         DESCRIPTION OF PARAMETERS
C            NOWYR  - THE YEAR NUMBER OF THE LAST DATE.
C            NOWDAY - THE DAY NUMBER OF THE LAST DATE.
C            INDYR  - A LOGICAL INDICATOR SET TO .TRUE. ONLY IF THE
C                     YEAR NUMBER CHANGES.
C
C         REMARKS
C            THIS SUBROUTINE MAY BE USED TO INCREMENT EITHER CALENDAR
C            OR CLIMATIC DATES.
C
C         SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C            NONE
C
C         METHOD
C            THE DAY COUNTER IS CYCLED FROM 1 THROUGH 365. FEB 29 IS
C            IGNORED.
C
C      ...............................................................
C
      SUBROUTINE INCDAY (NOWYR,NOWDAY,INDYR)
      LOGICAL INDYR
C
C     RESET THE NEW-YEAR INDICATOR.
C
      INDYR=.FALSE.
C
C     INCREMENT THE DAY NUMBER
C
      NOWDAY=NOWDAY+1
      IF (NOWDAY.LT.366) GO TO 10
C
```

```
C     INCREMENT THE YEAR COUNTER.
C
      INDYR=.TRUE.
      NOWDAY=1
      NOWYR=NOWYR+1
C
C     RETURN TO THE CALLING PROGRAM WITH THE NEW VALUES.
C
   10 RETURN
      END
```

```
IDENTIFICATION DIVISION.
PROGRAM-ID. INTEGR.
AUTHOR. KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
    AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
    SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
    NORTH CENTRAL REGICN.
INSTALLATION. THE KANSAS STATE UNIVERSITY COMPUTING CENTER.
DATE-WRITTEN. JUL 28,1973.
DATE-COMPILED.
REMARKS. THIS SUBROUTINE SETS A BINARY FIELD EQUAL TO THE
    VALUE OF A ZONED-DECIMAL FIELD.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SOURCE-COMPUTER. IBM-360-F50.
OBJECT-COMPUTER. IBM-360-F50.
DATA DIVISION.
WORKING-STORAGE SECTION.
77  SUBROUTINE-NAME, PICTURE IS X(8), VALUE IS 'INTEGR  '.
01  ERROR-MESSAGE.
    02  FILLER, PICTURE IS X(36), VALUE IS
            'NON-NUMERIC CHARACTER IN ARGUEMENT: '.
    02  ERROR-FIELD, PICTURE IS X(4).
    02  FILLER, PICTURE IS X(16), VALUE IS '.'.
LINKAGE SECTION.
77  EXTERNAL-INTEGER, PICTURE IS 9999, USAGE IS DISPLAY.
```

```
 77  BINARY-INTEGER, PICTURE IS S9(9), USAGE IS COMP.



 PROCEDURE CIVISION USING EXTERNAL-INTEGER, BINARY-INTEGER.


 010-NOTE.
     NOTE *****************************************************
     *   CHECK THE ZONED-DECIMAL FIELD TO INSURE THAT IT      *
     *   CONTAINS ONLY VALID DIGITS. THEN PERFORM THE         *
     *    CCNVERSION.                                         *
     ***********************************************************

 010-CCNVERT.
     IF EXTERNAL-INTEGER IS NOT NUMERIC
         MOVE EXTERNAL-INTEGER TO ERROR-FIELD,
         CALL 'ABEND' USING SUBROUTINE-NAME, ERROR-MESSAGE,
     ELSE MOVE EXTERNAL-INTEGER TO BINARY-INTEGER.
     GOBACK.
```

```
C
C     ..........................................................
C
C        SUBROUTINE
C           ABEND, MODEL 1, VERSION 1.
C
C        PROGRAMMER
C           KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
C           AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
C           SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
C           NORTH CENTRAL REGION.
C
C        INSTALLATION
C           KANSAS STATE UNIVERSITY COMPUTING CENTER'S IBM 360/50
C           USING FORTRAN IV COMPILER G, LEVEL 21.
C
C        PURPOSE
C           TO WRITE AN ERROR MESSAGE AND TO CAUSE AN ABNORMAL
C           TERMINATION OF PROCESSING FOR THE CALLING JOB STEP AND
C           THE SKIPPING OF ALL SUBSEQUENT JOB STEPS.
C
C        USAGE
C           CALL ABEND (NAME,MSG)
C
C        DESCRIPTION OF PARAMETERS
C           NAME    - AN EIGHT-CHARACTER LITERAL CONTAINING THE NAME
C                     OF THE CALLING PROGRAM OR SUBROUTINE.
C           MSG     - A 56-CHARACTER LITERAL CONTAINING THE MESSAGE
C                     TO BE PRINTED BEFORE THE ABNORMAL TERMINATION.
C
C        REMARKS
C           A COMPLETE EXPLANATION OF THE ERROR MESSAGE MAY OFTEN
C           BE FOUND THE USER'S MANUAL OF THE KANSAS AGRICULTURAL
C           EXPERIMENT STATION WEATHER DATA LIBRARY.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE LITERALS ARE SIMPLY PRINTED IN AN ERROR MESSAGE.
C           ABNORMAL TERMINATION IS CAUSED BY REFERENCING A WORD IN
C           STORAGE WHICH DOES NOT EXIST.
C
C     ..........................................................
C
      SUBROUTINE ABEND (NAME,MSG)
      INTEGER NULL(2),IMPOSS/1000000000/,NAME(2),MSG(14)
C
C     WRITE THE ERROR MESSAGE.
C
      WRITE (6,1) NAME,MSG
C
C     CAUSE AN ABNORMAL TERMINATION BY REFERENCING A STORAGE LOCATION
C     WHICH DOES NOT EXIST.
```

```
C
      NULL(IMPOSS)=0
      STOP
C
C     ..........................................................
C
    1 FORMAT ('1    (ROUTINE ',2A4,' HAS CALLED FOR A 240 ABEND ',
     1   'BECAUSE OF THE FOLLOWING CONDITION:'/7X,14A4/
     1   4X,'IF FURTHER INFORMATION IS REQUIRED, PLEASE CONSULT ',
     1   'THE USER''S GUIDE OF THE KANSAS'/4X,'AGRICULTURAL  ',
     1   'EXPERIMENT STATION WEATHER DATA LIBRARY.)')
      END
```

```
IDENTIFICATION DIVISION.
PROGRAM-ID. RDREC.
AUTHOR. KENNETH I. LAWS, RESEARCH ASSISTANT WITH THE KANSAS
     AGRICULTURAL EXPERIMENT STATION WEATHER DATA LIBRARY,
     SUPPORTED BY PROJECT NC-94: CLIMATIC RESOURCES OF THE
     NORTH CENTRAL REGION.
INSTALLATION.  THE KANSAS STATE UNIVERSITY COMPUTING CENTER.
DATE-WRITTEN. JUN 13,1974.
DATE-COMPILED. (INSERTED BY COMPILER).
REMARKS.  THIS IS MODEL 1, VERSION 5, OF SUBROUTINE RDREC.
     IT READS A STANDARD 1009 WEATHER DATA CARD AND RETURNS
     THE DATE, MAX AND MIN TEMPERATURES, AND PRECIPITATION.
     BLANK RECORDS AND THOSE FOR FEBRUARY 29 ARE IGNORED.
     RECORDS WILL BE DUMPED UNTIL ONE HAS A DATE AT LEAST AS
     GREAT AS THE VALUE OF IDATE IN THE CALL STATEMENT.

ENVIRONMENT DIVISION.

CONFIGURATION SECTION.
SOURCE-COMPUTER. IBM-370-158.
OBJECT-COMPUTER. IBM-370-158.

INPUT-OUTPUT SECTION.
FILE-CONTROL.
     SELECT RECORD-FILE, ASSIGN TO UT-S-FT09F001.

DATA DIVISION.

FILE SECTION.
FD   RECORD-FILE,
     LABEL RECORDS ARE STANDARD,
     BLOCK CONTAINS 0 RECORDS.
01   CARD-IMAGE, PICTURE X(80).
```

```



WORKING-STORAGE SECTION.

77  DUMP-MARKER, PICTURE X(44), VALUE
        'SUBROUTINE RDREC WORKING-STORAGE BEGINS HERE'.

77  FILE-STATUS, PICTURE X, VALUE '0'.
    88  FILES-ARE-OPEN VALUE IS '1'.

77  BLANK-LINE, PICTURE X(121), VALUE SPACES.

01  LCGICAL-CODES.
    05  TRUE-VALUE, PICTURE S9(9), USAGE IS COMP, VALUE +1.
    05  FALSE-VALUE, PICTURE S9(9), USAGE IS COMP, VALUE ZERO.

01  TEMPERATURE-CODES.
    05  ABSENT-TEMP-CODE, PICTURE S9(9), USAGE COMP, VALUE +99

01  PRECIPITATION-CODES.
    05  TRACE-PRECIP-CODE, USAGE IS COMP-1, VALUE -1.0E-06.
    05  DELAYED-PRECIP-CODE, USAGE IS COMP-1, VALUE IS -2.0E-0
    05  ABSENT-PRECIP-CODE, USAGE IS COMP-1, VALUE IS -3.0E-06.
    05  INVALID-PRECIP-CODE, USAGE IS COMP-1, VALUE -1.0E-06.

01  MONTH-LENGTHS.
    05  JAN-JUN, PICTURE 9(12), VALUE 312831303130.
    05  JUL-DEC, PICTURE 9(12), VALUE 313130313031.

01  MONTH-TABLE REDEFINES MONTH-LENGTHS.
    05  LENGTH-OF-MONTH OCCURS 12 TIMES, PICTURE 99.

01  RECORD-IMAGE.
    05  IDENTIFIER.
        10  STATE, PICTURE S99.
        10  SITE, PICTURE S9(4).
        10  DATE-IMAGE.
            15  YEAR, PICTURE S99.
            15  DAY-OF-YEAR.
                20  MONTH, PICTURE S99.
                20  DAY, PICTURE S99.
            15  FILLER REDEFINES DAY-OF-YEAR, PICTURE X(4).
                88  FEB-29 VALUE IS '0229'.
                88  MAR-1 VALUE IS '0301'.
        10  DATE REDEFINES DATE-IMAGE, PICTURE S9(6).
        10  STATE-DIVISION, PICTURE S9.
            88  PM-OBSERVATION VALUES ARE +0 THRU +9.
    05  MAX-TEMP, PICTURE S999.
    05  FILLER REDEFINES MAX-TEMP, PICTURE XXX.
        88  ABSENT-MAX VALUE IS '   '.
    05  FILLER REDEFINES MAX-TEMP.
        10  MAX-SIGN, PICTURE X.
            88  VALID-MAX-SIGN VALUES ARE '-', '0', '1'.
```

```
                  88  NEGATIVE-MAX VALUE IS '-'.
              10  MAX-VALUE, PICTURE 99.
          05  MIN-TEMP, PICTURE S999.
          05  FILLER REDEFINES MIN-TEMP, PICTURE XXX.
              88  ABSENT-MIN VALUE IS '   '.
          05  FILLER REDEFINES MIN-TEMP.
              10  MIN-SIGN, PICTURE X.
                  88  VALID-MIN-SIGN VALUES ARE '-', '0', '1'.
                  88  NEGATIVE-MIN VALUE IS '-'.
              10  MIN-VALUE, PICTURE 99.
          05  OBS-TEMP, PICTURE S999.
          05  FILLER REDEFINES OBS-TEMP, PICTURE XXX.
              88  ABSENT-OBS VALUE IS '   '.
          05  FILLER REDEFINES OBS-TEMP.
              10  OBS-SIGN, PICTURE X.
                  88  VALID-OBS-SIGN VALUES ARE '-', '0', '1'.
                  88  NEGATIVE-OBS VALUE IS '-'.
              10  OBS-VALUE, PICTURE 99.
          05  PRECIPITATION, PICTURE S99V99.
          05  FILLER REDEFINES PRECIPITATION, PICTURE X(4).
              88  TRACE-PRECIP VALUE IS '000-'.
              88  DELAYED-PRECIP VALUE IS '00- '.
              88  ABSENT-PRECIP VALUE IS '    '.
              88  NO-PRECIP VALUES ARE '-   ', '-000'.
          05  SNOW-FALL, PICTURE S99V9.
          05  FILLER REDEFINES SNOW-FALL, PICTURE X(3).
              88  TRACE-SNF VALUE IS '00-'.
              88  NO-SNF VALUES ARE '-  ', '   '.
              88  DELAYED-SNF VALUE IS '0- '.
          05  FILLER REDEFINES SNOW-FALL.
              10  FILLER, PICTURE X.
              10  SNF-SIZE, PICTURE S9.
              10  FILLER REDEFINES SNF-SIZE, PICTURE X.
                  88  SNOW-OVER-100 VALUES ARE ' ' THRU 'R'.
              10  FILLER, PICTURE X.
          05  SNOW-DEPTH, PICTURE S999.
          05  FILLER REDEFINES SNOW-DEPTH, PICTURE XXX.
              88 TRACE-SND VALUE IS '00-'.
              88  NO-SND VALUES ARE '-  ', '   '.
          05  FILLER, PICTURE S9.
              88  EST-PRECIP VALUE IS -9.
          05  FILLER, PICTURE X.
          05  FILLER, PICTURE X.
              88  HAZE VALUE IS '1'.
          05  FILLER, PICTURE X.
              88  FOG VALUE IS '1'.
          05  FILLER, PICTURE X.
              88  DRIZZLE VALUE IS '1'.
          05  FILLER, PICTURE X.
              88  SLEET VALUE IS '1'.
          05  FILLER, PICTURE X.
              88  GLAZE VALUE IS '1'.
          05  FILLER, PICTURE X.
              88  THUNDER VALUE IS '1'.
```

```
           05  FILLER, PICTURE X.
               88  HAIL VALUE IS '1'.
           05  FILLER, PICTURE X.
               88  DUST VALUE IS '1'.
           05  FILLER, PICTURE X.
               88  BLOWING-SNOW VALUE IS '1'.
           05  FILLER, PICTURE X.
               88  WIND VALUE IS '1'.
           05  FILLER, PICTURE X.
               88  TORNADO VALUE IS '1'.
           05  FILLER, PICTURE X(18).
           05  WIND-MOVEMENT, PICTURE S999.
           05  FILLER REDEFINES WIND-MOVEMENT, PICTURE XXX.
               88  NO-MOVEMENT VALUE IS '   '.
               88  DELAYED-MOVEMENT VALUE IS '0- '.
           05  FILLER REDEFINES WIND-MOVEMENT.
               10  MOVEMENT-SIZE, PICTURE S9.
               10  FILLER REDEFINES MOVEMENT-SIZE, PICTURE X.
                   88  MOVEMENT-OVER-1000 VALUES ARE ' ' THRU 'R'.
               10  FILLER, PICTURE XX.
           05  EVAPORATION, PICTURE S9V99.
           05  FILLER REDEFINES EVAPORATION, PICTURE XXX.
               88  NO-EVAPORATION VALUE IS '   '.
               88  DELAYED-EVAPORATION VALUE IS '0- '.
           05  MAX-PAN, PICTURE S99.
           05  FILLER REDEFINES MAX-PAN.
               10  PAN-SIZE, PICTURE S9.
               10  FILLER REDEFINES PAN-SIZE, PICTURE X.
                   88  PAN-OVER-100 VALUES ARE ' ' THRU 'R'.
               10  FILLER, PICTURE X.
           05  MIN-PAN, PICTURE S99.
           05  FILLER, PICTURE X.
               88  INTERPOLATED-MAX VALUE IS ','.
           05  FILLER, PICTURE XX.
           05  FILLER, PICTURE X.
               88  INTERPOLATED-MIN VALUE IS ','.
           05  FILLER, PICTURE X.
               88  INTERPOLATED-PRECIP VALUE IS ','.
           05  CLIMATIC-WEEK, PICTURE S99.

       01  FILLER, PICTURE X(42), VALUE
               'SUBROUTINE RDREC WORKING-STORAGE ENDS HERE'.


       LINKAGE SECTION.

       77  INDEND, PICTURE S9(9), USAGE IS COMP.

       77  IDATE, PICTURE 9(9), USAGE IS COMP.

       77  IMAX, PICTURE S9(9), USAGE IS COMP.

       77  IMIN, PICTURE S9(9), USAGE IS COMP.

```

```
 77  PRECIP, USAGE IS COMP-1.



 PROCEDURE CIVISION USING INDEND, IDATE, IMAX, IMIN, PRECIP.


 010-CONTROL SECTION.

 010-COMMENT.
     NOTE ***********************************************************
     *   THIS SECTION CONTAINS THE MAIN LOGIC OF THE               *
     *   SUBROUTINE.                                               *
     ****************************************************************

 010-PROCESS-RECORD.
     IF FILES-ARE-OPEN NEXT SENTENCE, ELSE PERFORM
         020-OPEN-FILES.
     PERFORM 030-LOAD-RECORD.
     IF INDEND IS EQUAL TO TRUE-VALUE GOBACK.
     IF FEB-29 PERFORM 030-LOAD-RECORD, IF INDEND IS EQUAL
         TO TRUE-VALUE GOBACK.
     MOVE DATE TO IDATE.
     PERFORM 040-COPY-MAX-TEMP.
     PERFORM 050-COPY-MIN-TEMP.
     PERFORM 060-COPY-PRECIPITATION.
     GOBACK.



 020-OPEN-FILES SECTION.

 020-COMMENT.
     NOTE ***********************************************************
     *   OPEN THE INPUT FILE ON THE FIRST CALL TO THIS             *
     *   SUBROUTINE.                                               *
     ****************************************************************

 020-INITIALIZE.
     OPEN INPUT RECORD-FILE.
     MOVE '1' TO FILE-STATUS.


 030-LOAD-RECORD SECTION.

 030-COMMENT.
     NOTE ***********************************************************
     *   MOVE A NEW RECORD INTO THE WORK AREA, BUT GET             *
     *   ANOTHER IF THE FIRST IS BLANK. MAKE SURE THE DATE         *
     *   IS VALID.  GET ANOTHER IF THE DATE IS LESS THAN THE       *
     *   CALLING DATE.                                             *
     ****************************************************************

 030-LOAD.
```

```
     MOVE FALSE-VALUE TO INDEND.
     READ RECORD-FILE RECORD, AT END GO TO 030-END-OF-FILE.
     MOVE CARD-IMAGE TO RECORD-IMAGE.
     IF IDENTIFIER IS EQUAL TO ALL SPACES GO TO 030-LOAD.

030-CHECK-DATE.
     IF DATE IS NUMERIC GO TO 030-LOCATE.
     EXAMINE DATE-IMAGE REPLACING ALL SPACES BY ZEROS.
     IF DATE IS NUMERIC GO TO 030-LOCATE.
     MOVE IDATE TO DATE.
     ADD 1 TO DAY.
     IF DAY IS GREATER THAN LENGTH-OF-MONTH (MONTH) MOVE 1 TO
         DAY, ADD 1 TO MONTH.
     IF MONTH IS GREATER THAN 12 MOVE 1 TO MONTH, ADD 1 TO YEAR
     IF YEAR IS GREATER THAN 99 MOVE 0 TO YEAR.
     DISPLAY BLANK-LINE, '   (SUBROUTINE RDREC HAS REPLACED ',
         'A FAULTY DATE WITH ', DATE, ', THE DAY AFTER THE ',
         'INPUT DATE.)',

030-LOCATE.
     IF DATE IS LESS THAN IDATE GO TO 030-LOAD.
     GO TO 030-EXIT.

030-END-OF-FILE.
     MOVE TRUE-VALUE TO INDEND.

030-EXIT.
     EXIT.


040-COPY-MAX-TEMP SECTION.

040-COMMENT.
     NOTE ******************************************************
     *   THE MAX TEMP MUST BE CHECKED FOR SPECIAL CODES AND   *
     *   THEN BE CONVERTED TO A FORTRAN STYLE INTEGER.        *
     **********************************************************

040-MAX-TEMP.
     IF NOT VALID-MAX-SIGN OR MAX-VALUE IS NOT NUMERIC
         MOVE ABSENT-TEMP-CODE TO IMAX, GO TO 040-EXIT.
     IF NEGATIVE-MAX MOVE ZERO TO IMAX, SUBTRACT MAX-VALUE FROM
         IMAX, GO TO 040-EXIT.
     MOVE MAX-TEMP TO IMAX.

040-EXIT.
     EXIT.


050-COPY-MIN-TEMP SECTION.

050-COMMENT.
     NOTE ******************************************************
     *   THE MIN TEMP MUST BE CHECKED FOR SPECIAL CODES AND   *
```

```
     *   THEN BE CONVERTED TO A FORTRAN STYLE INTEGER.          *
     ************************************************************

050-MIN-TEMP.
     IF NOT VALID-MIN-SIGN OR MIN-VALUE IS NOT NUMERIC
         MOVE ABSENT-TEMP-CODE TO IMIN, GO TO 050-EXIT.
     IF NEGATIVE-MIN MOVE ZERO TO IMIN, SUBTRACT MIN-VALUE FROM
         IMIN, GO TO 050-EXIT.
     MOVE MIN-TEMP TO IMIN.

050-EXIT.
     EXIT.


060-COPY-PRECIPITATION SECTION.

060-COMMENT.
     NOTE *******************************************************
     *   THE PRECIPITATION MUST BE CHECKED FOR SPECIAL CODES *
     *   AND THEN BE CONVERTED TO A FORTRAN REAL*4 NUMBER.   *
     ************************************************************

060-PRECIPITATION.
     IF TRACE-PRECIP MOVE TRACE-PRECIP-CODE TO PRECIP,
         GO TO 060-EXIT.
     IF DELAYED-PRECIP MOVE DELAYED-PRECIP-CODE TO PRECIP,
         GO TO 060-EXIT.
     IF ABSENT-PRECIP MOVE ABSENT-PRECIP-CODE TO PRECIP,
         GO TO 060-EXIT.
     IF NO-PRECIP MOVE ZERO TO PRECIP, GO TO 060-EXIT.
     IF PRECIPITATION IS NOT NUMERIC GO TO 060-ERROR.
     MOVE PRECIPITATION TO PRECIP, GO TO 060-EXIT.

060-ERROR.
     DISPLAY BLANK-LINE, '   (SUBROUTINE RDREC HAS REPLACED ',
         'AN INVALID PRECIPITATION IN RECORD ', IDENTIFIER,
         ' .)'.
     MOVE INVALID-PRECIP-CODE TO PRECIP.

060-EXIT.
     EXIT.
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# A MODEL FOR THE SIMULATION OF KANSAS TEMPERATURE DATA

by

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B.A., Southwestern College, 1972

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AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Statistics

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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Models for weather data were explored using records for Manhattan, Kansas, from 1900 through 1970. Precipitation was found to be independent of antecedent conditions, but a covariance model for minimum and maximum daily temperatures proved satisfactory. Daily extreme temperatures were regressed on the occurrence of precipitation during the preceding day and the day of interest and on the deviations from normal of the preceding two temperatures. Interaction terms were found to be insignificant.

Parameter estimates are listed for nine Kansas stations. Harmonic analysis has been used to smooth the estimates. The Fourier coefficients are tabulated and mapped.

Simulation of Manhattan weather was attempted using randomly generated precipitation. The distribution of wet and dry days was found to be correct, but precipitation amounts were too uniform. This did not degrade the temperature simulation.