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THE BART EXPERIMENT

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ABSTRACT. The BART (Bay Area Regional Temperature) Experiment attempts to objectively forecast temperatures at seven locales in the San Francisco Bay Area by statistical means. Also, the experiment demonstrates the value of AFOS in providing local forecast aids. The method of least squares and a type of screening regression were used to create sets of seasonal forecast equations. Forecasts of daily maximum and minimum temperature at seven stations in northern and central California that are forecast points for the MOS (Model Output Statistics) technique plus the date/time group of the forecast serve as predictors for the BART equations. The average reduction of predictand variance by the BART equations was 85 percent for maximum temperature forecasts and 67 percent for minimum temperature forecasts. The mean standard error of estimate of the predictand was 3 degrees Fahrenheit. Appendices containing FORTRAN IV programs developed during the experiment and the AFOS procedure which obtains the temperature forecasts are also presented.

I. INTRODUCTION

A variety of climates exists in the San Francisco Bay Area, due to varied topography and prevailing onshore winds. These climates range from maritime to continental in character, all within the space of a few miles. Accordingly, spatial temperature variations can be marked, especially in afternoons during the dry season. As a result, forecasting temperatures for Bay Area cities can be difficult.

Objective forecasts of daily maximum and minimum temperature are made for nine locations in northern and central California via the MOS technique. (These locations will be referred to as "MOS stations" henceforth.) The MOS temperature forecasts are usually modified by the San Francisco WSFO. Temperature forecasts for other locales or "non-MOS stations" are made by the San Francisco WSFO. These latter forecasts have been subjective, the basis for these predictions being climatology, persistence, and forecaster experience. Therefore, an objective method of making temperature forecasts at non-MOS stations seemed worthwhile, especially when viewed in terms of the recent retirement of experienced personnel and the advent of forecaster cross-training.

An experiment was devised to produce an objective method based on statistical climatology. It was called the BART experiment (or "BART" for short) since the experiment's test area was a zone lying within 50 miles of San Francisco and San Pablo Bays.

Although BART's prime function was to provide an objective aid to forecast daily temperature extremes at non-MOS stations, it had a second, yet equally important, purpose. The experiment was also intended to show the value of AFOS as a source of computation and information which can greatly assist the forecaster. It was hoped that BART would create enough interest in field personnel so that similar aids would be developed.

BART's end result was several sets of polynomial equations which can be quickly solved by an AFOS minicomputer. The predictor in each BART equation is the predicted daily maximum (or minimum) temperature at one or more MOS stations in northern and central California. The MOS and non-MOS stations used in the BART experiment are listed below:

MOS STATIONS		NON-MOS STATIONS	
CODE	NAME	CODE	NAME
FAT	Fresno Air Terminal	HLL	Hollister
OAK	Oakland Airport	LVK	Livermore
RBL	Red Bluff	RWC	Redwood City
SAC	Sacramento Executive Airport	SFB	San Francisco Fed. Bldg.
SFO	San Francisco Intl. Airport	SJC	San Jose
SMX	Santa Maria Airport	STS	Santa Rosa
SCK	Stockton Airport	WNC	Walnut Creek.

Figures 1a and 1b show the locations of these stations.

Work on BART commenced in 1977 but did not begin in earnest until late 1978. BART began to roll once a research minicomputer housed at the National Weather Service's Western Region Headquarters was commissioned. This AFOS minicomputer allows Western Region personnel to develop, test, and debug programs without needlessly tying up their station's AFOS system.

II. PROCEDURE

Input for BART consisted of a random sample of observation days drawn from a 20-year population (December 1950 - November 1970). Each observation day contained an observed minimum and maximum temperature for each MOS and non-MOS station. A total of 396 days, out of a possible 7305, were selected for study. The sample dates were chosen so that each season contained 99 observation days. The seasons were defined as follows:

Winter -- December-February
Spring -- March-May
Summer -- June-August
Autumn -- September-November.

The sample data were verified then read into appropriate data files. Each data file contained one season's worth of maximum or minimum temperatures.

File data were grouped into columns and rows--the columns headed by station names; the rows by observation dates. These files, a portion of which is shown in Figure 2a, were stored in the development computer.

Each file's contents were then subjected to statistical testing to ensure that the sample data compared favorably to the population from which they were drawn. The seasonal mean temperature for each station was compared to its corresponding population mean by way of a two-tailed hypothesis test. In every case, the null hypothesis was satisfied at the 0.02 significance level. In other words, the sample temperatures were representative of their population.

The next step in the experiment was to select the degree of polynomial to be used for the BART equations. The polynomial's degree had to be large enough to significantly reduce predictand variance; yet, small enough to use computer time and disk storage efficiently.

The characteristic polynomial was selected by first rearranging each file's station temperatures in ascending order (see Figure 2b). Then the resultant data set of each MOS (predictor) station was compared, in turn, to those of the non-MOS (predictand) stations in the same file. This was done by means of scatter diagrams, an example of which is shown in Figure 3. The characteristic distribution curve which emerged from these diagrams was a cubic, expressed symbolically by

$$y = A_0 + A_1x + A_2x^2 + A_3x^3, \tag{1}$$

where A_0, A_1, A_2, and A_3 are coefficients, x is the predictor, and y the predictand.

The method of least squares was used to determine the reduction of variance achieved by using a cubic. In this case, predictor and predictand data came from the files containing temperatures arranged in ascending order by station (see Figure 2b). The reduction of variance by each MOS/non-MOS station pair is

$$RV = 1 - \frac{S^2_{y\cdot x}}{S^2_y}, \tag{2}$$

where $S^2_{y\cdot x}$, the square of the standard error of estimate of y on x, is

$$S_{y\cdot x} = \frac{\Sigma y^2 - A_0\Sigma y - A_1\Sigma xy - A_2\Sigma x^2 y - A_3\Sigma x^3 y}{N - 4} \tag{3}$$

and S^2_y, the predictand variance is

$$S^2_y = \frac{\Sigma y^2 - (\Sigma y)^2/N}{N - 1}. \tag{4}$$

In equations 3 and 4, N represents the number of x-y data pairs.

In all cases, more than 91 percent of the variance was accounted for by the cubic; in most cases, that figure was better than 98 percent. Also, the computer was able to solve the cubic equations efficiently while keeping the results free of truncation error. Consequently, the least-square cubic was selected to be the characteristic BART equation.

The next task in the BART experiment was to derive the operational BART equations. This was done by a FORTRAN IV program which alternately used the method of least squares and a type of screening regression to arrive at a solution. The program and the attendant flowchart can be found in Appendix A. Input data for the program were from the files arranged by type of extreme, season, station, and observation date (see Figure 2a).

The predictor for each equation was a term based on the forecast temperature at one or more MOS stations. The number of MOS stations incorporated into the term was the number which reduced the variance at the non-MOS station in question to the greatest possible extent. The general form of this term is:

$$x = \frac{B_1 x_1 + B_2 x_2 + \cdots + B_m x_m}{B_1 + B_2 + \cdots + B_m} = \frac{\sum_{k=1}^{m} B_k x_k}{\sum_{k=1}^{m} B_k}, \qquad (5)$$

where the subscripts 1,2, ···, m represents MOS stations, x_k is the forecast temperature at MOS station k, and B_k is the reduction of variance at the non-MOS station in question by MOS station k <u>before</u> any screening regression occurs. The reduction of variance was used for the coefficients in equation 5, since the temperature at the MOS station nearest to the non-MOS station in question may not correlate as highly as a more distant MOS station.

Each use of screening regression was after the generation of values for A_0, A_1, A_2, A_3, the standard error of estimate ($S_{y \cdot x}$), and the reduction of variance by the method of least squares for each predictor/predictand combination. The first use of screening regression selected the MOS station whose data set caused the largest reduction of variance of the non-MOS station's data set. Each subsequent use of screening regression involved the use of data from a MOS station not previously selected. The data set of this MOS station, in combination with the predictor (or predictors) already chosen, caused the greatest additional reduction of the predictand's variance.

Once the maximum possible reduction of variance was achieved, the predictor term described by equation 5 could be substituted into the least-square cubic, thus, creating the operational BART equation. Substituting T_m for x, TM_k for x_k, and RV_k for B_k, the predictor term could be expressed as:

$$T_m = \frac{\sum_{k=1}^{m} RV_k TM_k}{\sum_{k=1}^{m} RV_k}. \qquad (5a)$$

The upper limit of the summation, m, represents the number of MOS stations (and uses of screening regression) needed to cause the greatest possible reduction of the non-MOS station's variance. TM_1, TM_2, •••, TM_m all had the same observation date.

Equation 1 could now be written as the operational BART equation, namely,

$$y = T_x = A_0 + T_m(A_1 + T_m((A_2 + T_m(((A_3))))))), \qquad (6)$$

where A_0, A_1, A_2, and A_3 are coefficients from m uses of screening regression, T_x is the predicted temperature at the non-MOS station, and T_m is the predictor term described by equation 5a. Sample output from the least squares/screening regression process and the resultant BART equation are shown in Figure 4.

The final step in the BART experiment was to devise a program which could solve the BART equations and run in the local AFOS system. This FORTRAN IV program was successfully developed in early 1979 and is now operational at the San Francisco WSFO. This program and its flowchart comprises Appendix B.

III. PROGRAM USE

Program input, execution, and output are handled by an AFOS procedure 1/ appropriately entitled "BART". The "BART" procedure is detailed in Appendix C.

Input is supplied to the program by means of a preformat (see Figure 5a). The date/time group of the forecast and the predicted extreme temperatures for the next three 12-hour forecast periods at each MOS station are typed into the preformat. Program execution begins once the input data have been entered and verified.

During execution, the program reads data from selected disk files. Each file, identified by season and type of temperature extreme, contains seven data sets: each data set contains variables which define the coefficients in equations 5a and 6. An example of this file is shown in Figure 6.

The date inserted into the input preformat determines which disk files are read. For example, a spring date will cause the files containing spring data to be opened then read into the program.

Extreme temperatures derived by the repeated solution of the BART equations are displayed in an output message. This message is a matrix consisting of three columns--one per 12-hour forecast period and seven rows--one for each non-MOS station. An example of the output message is shown in Figure 7.

1/ An AFOS procedure is an in-house routine which retrieves and displays AFOS products and programs in a specific sequence or at specific times.

The output message's contents are governed by the time of the forecast that was entered into the input preformat. For example, a time between 0730 GMT and 1929 GMT will place predicted maximum temperatures for each non-MOS station in the columns headed by the first and third forecast periods; predicted minima will be put in the second period. The converse will be true if the input time is between 1930 GMT and 0729 GMT.

IV. ACCURACY OF THE BART EQUATIONS

The reduction of predictand variance by the BART equations should measure the contribution of seasonal climatology in the temperature forecasting process. The minimum temperature equations reduced predictand variance an average of 67 percent; seasonal values ranged from 75 percent in the winter to 58 percent in the summer. The corresponding values for the maximum temperature equations are higher--the average reduction of variance being 85 percent, with seasonal averages ranging from 89 percent in the autumn to 82 percent in the summer and winter. (Refer to Table 1 and Figure 8 for details.) The lower values of the reduction of variance with respect to season and non-MOS station stem from the alteration of climatological temperature patterns by marine intrusions and sharp frontal zones. Sampling errors probably had a negative effect. However, the effects of the "normal" marine layer should be accounted for by the BART equations, because of their climatological roots.

The standard error of estimate of the BART equations is about 3.0 degrees F. for both maximum and minimum temperature equations (see Table 2). The actual absolute error will, of course, be larger than the standard error of estimate, since the inability to perfectly forecast temperatures at the MOS stations will create a second error source.

V. FUTURE PLANS AND CONCLUSION

A comprehensive verification program under way at the San Francisco WSFO should provide an estimate of the total error resulting from BART; hence, the worth of BART as a forecast tool. One year's worth of forecasts will be verified before any future work on BART is undertaken.

If BART proves worthwhile, then logical future steps would be:

1. To increase the number of non-MOS stations in the Bay Area and use the same predictors. This step would put more resolution in the zone and local forecasts.

2. To expand the test area to all of northern and central California. This would require data from the MOS stations in Oregon, Nevada, and southern California.

3. To rederive the existing BART equations using the entire population as a data base. This may allow the equations to be derived on a monthly rather than a seasonal basis, which should improve predictor/predictand correlation. Magnetic tapes from the NOAA Office of Hydrology would have to be obtained for this phase of the experiment.

If BART does nothing else, at least it shows that AFOS can add a new dimension to field forecasting by means of in-house execution of computer programs. BART also shows the value of having a development computer. Forecasters can now fully use their education and training to develop local routines which will benefit them and the public they serve. It is hoped that the BART experiment will encourage others to develop similar techniques.

VI. ACKNOWLEDGMENTS

This study came to fruition through the help I received from many people. Specific recognition and gratitude goes to my wife, Mary, for her patience and proofreading, the Western Region staff for their instruction and counsel and Harry Hassel and Charlie Roberts, San Francisco WSFO for their encouragement along the way.

VII. BIBLIOGRAPHY

AFOS Instructor Staff, 1978: Training Guide for AFOS Operators. AFOS Training Program, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Silver Spring, Maryland, 275 pp. (approx.).

Glahn, Harry R., and Dale A. Lowry, 1972: The Use of Model Output Statistics (MOS) in Objective Weather Forecasting. Journal of Applied Meteorology, Vol. 11, No. 8, American Meteorological Society, Boston, Mass., p 1203-1211.

Lipschutz, Seymour, and Arthur Poe, 1978: Theory and Problems of Programming with FORTRAN. Schaum's Outline Series, McGraw-Hill Book Company, New York, N. Y., 314 pp.

Panofsky, Hans A., and Gleen W. Brier, 1958: Some Applications of Statistics to Meteorology. College of Mineral Industries, The Pennsylvania State University, University Park, Pa., 224 pp.

Scientific Services Division Staff, National Weather Service Western Region, 1978: Handouts and Course Notes from the 1978 AFOS Workshop. National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Salt Lake City, Ut., 100 pp. (approx.) (unpublished material).

Spiegel, Murray R., 1961: Theory and Problems of Statistics. Schaum's Outline Series, McGraw-Hill Book Company, New York, N. Y., 359 pp.

Walts, Dennis S., and Larry O. Pochop, 1977: Operational Objective Temperature Forecasts at Non-MOS Stations. Monthly Weather Review, Vol. 105, No. 1, American Meteorological Society, Boston, Mass., pp 3-8.

Webb, Morris, S., Jr., and Lawrence A. Hughes, 1975: Objective Temperatures from MOS. NOAA Technical Attachment NWSTA CR 75-12, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Kansas City, Mo., 3 pp.

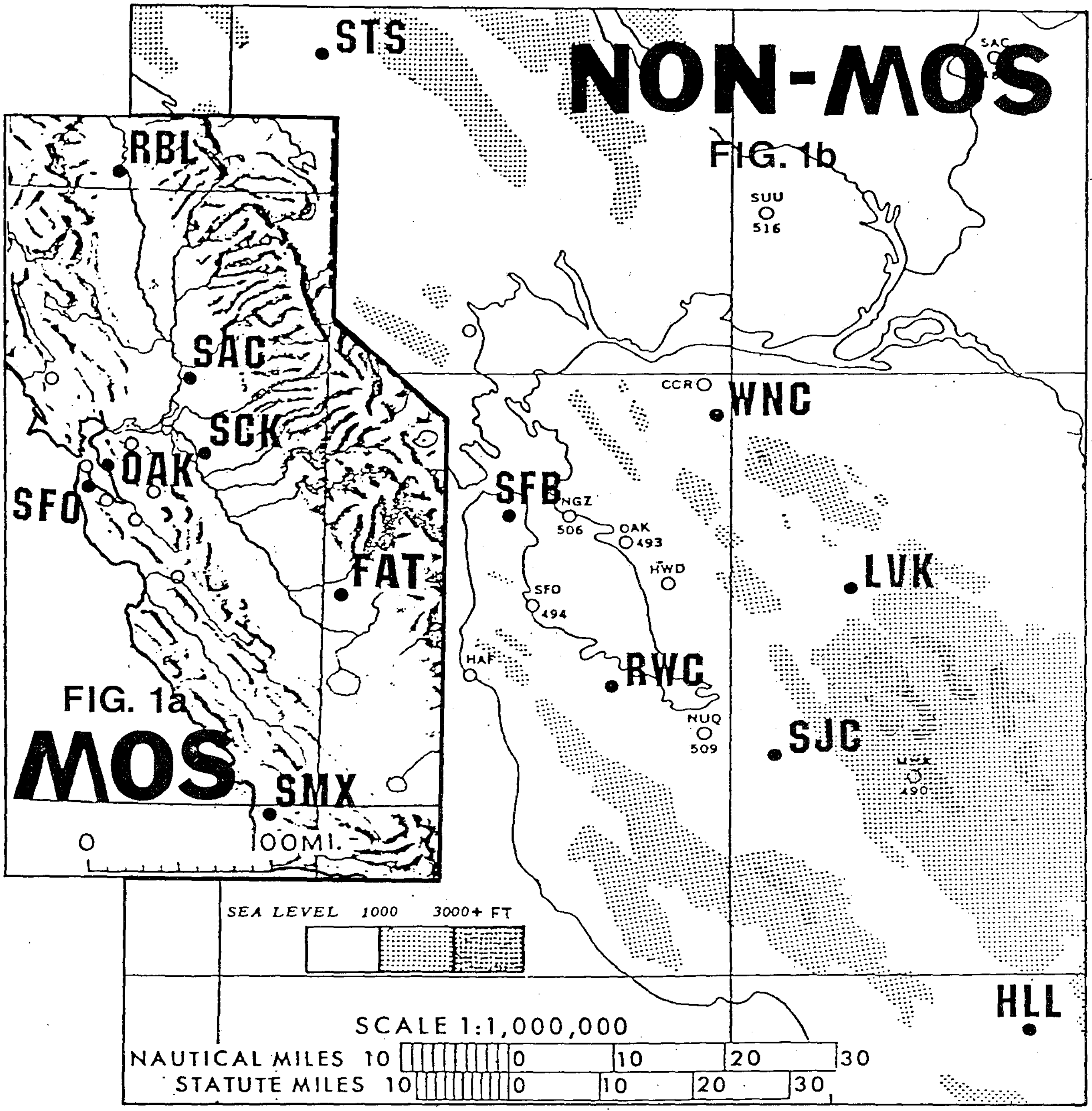


Figure 1a. Location of MOS Stations Used in the BART Experiment.

Figure 1b. Location of Non-MOS Stations Used in the BART Experiment.

SAMPLE DATA FILE

TYPE 3TXJJA (Maximum temperature -- Summer)

	DATE	HLL 01	LVK 02	RWC 03	SFB 04	SJC 05	STS 06	WNC 07	FAT 08	OAK 09	RBL 10	SAC 11	SFO 12	SMX 13	SCK 14
01	061551	74.	92.	78.	63.	82.	74.	79.	98.	73.	98.	87.	74.	70.	88.
02	061951	68.	82.	76.	63.	73.	68.	72.	88.	72.	97.	83.	70.	67.	80.
03	070851	91.	104.	90.	66.	90.	93.	103.	100.	75.	106.	102.	71.	70.	100.
04	072151	73.	90.	80.	61.	81.	83.	88.	95.	71.	105.	91.	69.	68.	90.
05	072651	75.	97.	78.	63.	83.	82.	95.	100.	74.	100.	96.	68.	70.	94.
06	081251	80.	100.	88.	67.	87.	90.	100.	99.	80.	99.	95.	79.	72.	96.
07	082251	77.	77.	79.	62.	75.	67.	70.	91.	67.	89.	78.	70.	72.	82.
08	082451	73.	88.	75.	60.	76.	80.	91.	90.	70.	97.	90.	67.	69.	87.
09	061352	76.	76.	68.	60.	69.	71.	70.	80.	65.	76.	75.	64.	69.	79.
10	062152	75.	80.	76.	59.	73.	82.	78.	83.	65.	85.	93.	64.	68.	85.
11	062352	73.	71.	71.	62.	69.	74.	69.	81.	65.	78.	74.	62.	69.	76.
12	062552	67.	72.	72.	64.	73.	78.	72.	78.	66.	83.	82.	68.	65.	82.
13	070252	94.	101.	96.	82.	95.	96.	99.	98.	91.	101.	97.	88.	70.	102.
14	070552	84.	96.	85.	64.	84.	87.	91.	100.	75.	100.	96.	71.	70.	99.
15	071952	81.	95.	79.	65.	84.	86.	95.	99.	75.	103.	98.	71.	71.	100.
16	072652	96.	102.	78.	63.	84.	84.	94.	101.	75.	104.	98.	69.	76.	101.
17	061253	75.	73.	71.	65.	71.	71.	71.	79.	69.	75.	75.	66.	72.	79.
18	070853	99.	103.	95.	71.	94.	97.	100.	101.	87.	101.	100.	75.	82.	103.
19	071753	90.	80.	80.	65.	85.	80.	85.	100.	74.	105.	95.	76.	72.	98.
20	072153	79.	96.	80.	61.	85.	87.	94.	105.	73.	105.	103.	70.	73.	105.

Figure 2a. Portion of a Data File whose Station Temperatures are Arranged According to Observation Date.

ARRAYED DATA FILE

TYPE 33TXJJA (Maximum temperature -- Summer)

HLL	LVK	RWC	SFB	SJC	STS	WNC	FAT	OAK	RBL	SAC	SFO	SMX	SCK
63.	64.	66.	56.	68.	66.	67.	73.	60.	75.	73.	59.	61.	75.
66.	71.	68.	56.	68.	67.	69.	77.	62.	75.	74.	61.	63.	76.
66.	71.	68.	58.	69.	68.	69.	78.	63.	76.	75.	62.	63.	78.
67.	71.	68.	58.	69.	69.	70.	78.	63.	76.	75.	62.	64.	78.
68.	72.	70.	59.	69.	71.	70.	79.	63.	78.	75.	63.	64.	79.
70.	72.	71.	59.	70.	71.	70.	80.	64.	79.	77.	64.	65.	79.
70.	72.	71.	59.	71.	72.	71.	80.	64.	79.	78.	64.	65.	79.
70.	73.	72.	59.	73.	72.	71.	81.	64.	80.	78.	64.	66.	79.
71.	73.	73.	59.	73.	73.	72.	81.	64.	81.	78.	64.	67.	79.
71.	75.	73.	60.	73.	74.	72.	82.	65.	81.	78.	64.	67.	80.
71.	75.	73.	60.	73.	74.	72.	83.	65.	81.	80.	64.	67.	80.
72.	75.	74.	60.	73.	74.	73.	83.	65.	81.	80.	64.	67.	80.
73.	75.	74.	60.	73.	74.	73.	83.	65.	81.	81.	65.	67.	80.
73.	75.	74.	60.	73.	74.	73.	83.	65.	82.	81.	65.	67.	82.
73.	75.	75.	60.	73.	74.	74.	83.	65.	83.	81.	65.	68.	82.
73.	76.	75.	61.	74.	75.	74.	85.	66.	83.	81.	66.	68.	82.
73.	76.	75.	61.	74.	75.	75.	85.	66.	83.	82.	66.	68.	82.
73.	77.	75.	61.	74.	75.	76.	86.	66.	83.	82.	66.	68.	82.
73.	77.	75.	61.	74.	76.	76.	86.	66.	84.	82.	67.	68.	82.
73.	77.	76.	61.	74.	77.	76.	86.	66.	84.	83.	67.	68.	82.

Figure 2b. Portion of the Data File Shown in Figure 2a, Except the Station Temperatures are Arranged in Ascending Order.

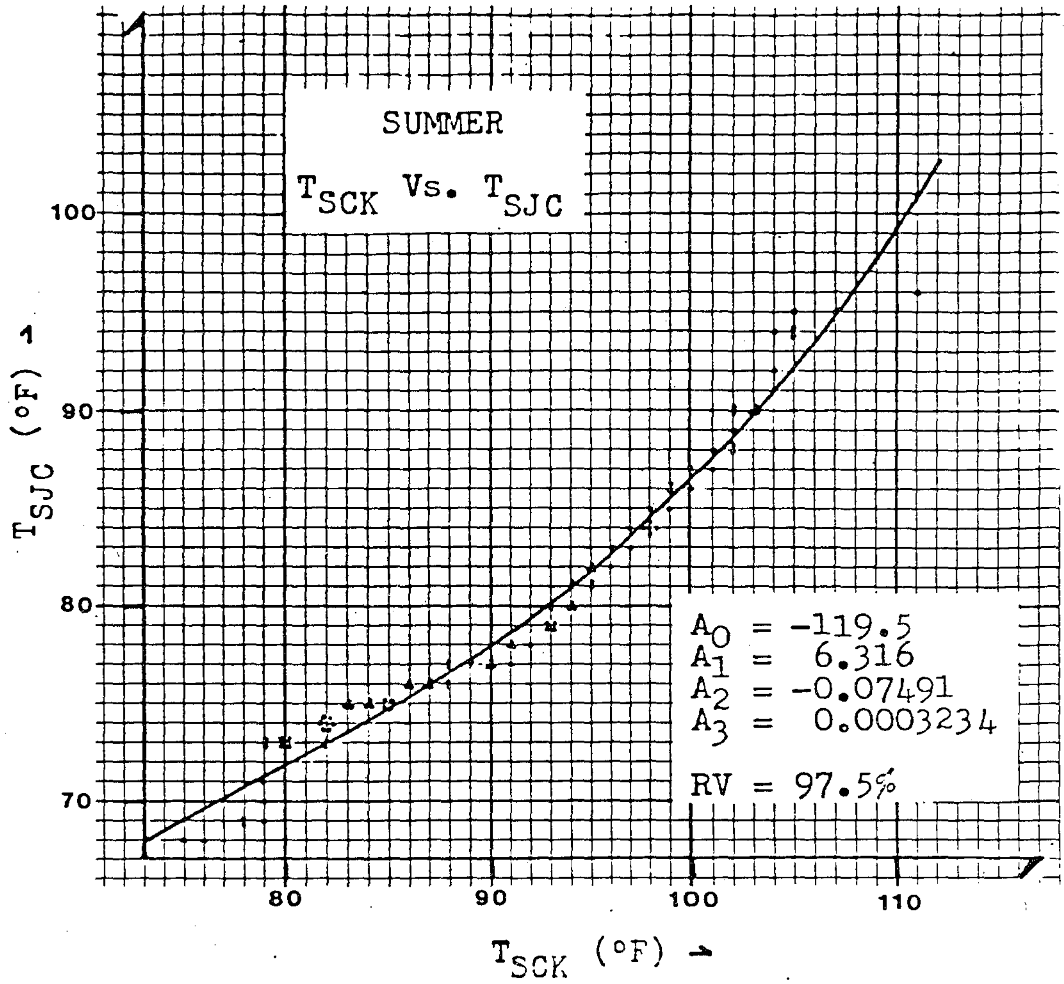


Figure 3. Sample Scatter Diagram Used to Help Determine the Characteristic Polynomial for the Operational BART Equations. In This Case, a Cubic Curve was Drawn Through Data Points Relating the Daily Maximum Temperature at Stockton (SCK) to the Daily Maximum Temperature at San Jose (SJC). The Numbers in the Lower Right-Hand Corner of the Diagram are the Coefficients Of and the Reduction of Variance By the Least Cubic Whose Curve is Shown in the Diagram.

... LEGEND ...

FILE IDENTIFICATION NUMBERS ...
1. MINIMUM TEMPERATURE -- WINTER
2. MAXIMUM TEMPERATURE -- WINTER
3. MINIMUM TEMPERATURE -- SPRING
4. MAXIMUM TEMPERATURE -- SPRING
5. MINIMUM TEMPERATURE -- SUMMER
6. MAXIMUM TEMPERATURE -- SUMMER
7. MINIMUM TEMPERATURE -- AUTUMN
8. MAXIMUM TEMPERATURE -- AUTUMN

NON-MOS STATION NUMBERS ...
1. HLL -- HOLLISTER
2. LVK -- LIVERMORE
3. RWC -- REDWOOD CITY
4. SFB -- SAN FRANCISCO - FEDERAL BLDG.
5. SJC -- SAN JOSE
6. STS -- SANTA ROSA
7. WNC -- WALNUT CREEK

MOS STATION NUMBERS ...
1. FAT -- FRESNO WSO
2. OAK -- OAKLAND WSO
3. RBL -- RED BLUFF WSO
4. SAC -- SACRAMENTO WSO - EXECUTIVE AIRPORT
5. SFO -- SAN FRANCISCO WSO - AIRPORT
6. SMX -- SANTA MARIA WSO - AIRPORT
7. SCK -- STOCKTON WSO - AIRPORT

THE FILE IDENTIFICATION NUMBER IS ... 6
THE NON-MOS STATION NUMBER IS 5
THE STANDARD DEVIATION OF NON-MOS STATION 5 IS 7.2

K	MOS STN	SYX	MAX RV	RV	A0	A1	A2	A3
1	7	3.5	0.76437	0.76437	159.6	-2.857	0.02593	-0.0000473
2	2	2.3	0.89879	0.71502	526.0	-17.348	0.21165	-0.0008103
3	5	2.2	0.90417	0.64199	677.0	-24.337	0.31433	-0.0012891
4	4	2.2	0.90565	0.73440	608.3	-20.314	0.24668	-0.0009453
5	6	2.3	0.89949	0.43941	731.4	-25.459	0.31657	-0.0012525
6	1	2.4	0.88788	0.57573	680.8	-22.623	0.27006	-0.0010201
7	3	2.6	0.87166	0.61102	590.4	-18.514	0.21123	-0.0007532

The BART equation for the data displayed above is

$$Tx_{SJC} = 608.3 - T_m(20.314 + T_m(0.24668 - T_m(0.0009453)))$$

where

$$T_m = \frac{0.76437Tx_{SCK} + 0.71502Tx_{OAK} + 0.64199Tx_{SFO} + 0.73440Tx_{SAC}}{0.76437 + 0.71502 + 0.64199 + 0.73440}$$

Figure 4. Sample Output from the Least Squares/Screening Regression Program along with the BART Equation Derived from the Output.

```
SFOMCP002
WOUS00 KSFO 281735
ENTER THE DATE/TIME GROUP IN THE SPACES BELOW.  TO INSURE THAT MAX
TEMPERATURES ARE PLACED IN THE FIRST FORECAST PERIOD, USE 10GMT FOR
THE TIME GROUP; FOR MIN TEMPERATURES IN THE FIRST PERIOD, USE 22GMT.

   MONTH [--]   DAY [--]   TIME [--]GMT

ENTER YOUR FORECAST OF MAX/MIN TEMPERATURES IN THE SPACES PROVIDED:

          STATION                    FORECAST PERIOD
                                   1ST    2ND    3RD
   RBL -- WSO RED BLUFF           [0--]  [0--]  [0--]
   SAC -- WSO SACRAMENTO          [0--]  [0--]  [0--]
   SCK -- WSO STOCKTON            [0--]  [0--]  [0--]
   FAT -- WSO FRESNO              [0--]  [0--]  [0--]
   OAK -- WSO OAKLAND             [0--]  [0--]  [0--]
   SFO -- WSO SAN FRANCISCO       [0--]  [0--]  [0--]
   SMX -- WSO SANTA MARIA         [0--]  [0--]  [0--]

POSITION THE CURSOR BETWEEN THE BRACKETS IN THE LOWER RIGHT-HAND
CORNER OF THE SCREEN THEN STRIKE THE "ENTER" KEY.
                                                                  [ ]
                                                              PAGE 01
```

Figure 5a. Preformat (AFOS Product SFOMCP002) Used to Enter Input Data into the Program which Solves the BART Equations.

```
SFOFRFSFO
WOUS00 KSFO 302339
ENTER THE DATE/TIME GROUP IN THE SPACES BELOW.  TO INSURE THAT MAX
TEMPERATURES ARE PLACED IN THE FIRST FORECAST PERIOD, USE 10GMT FOR
THE TIME GROUP; FOR MIN TEMPERATURES IN THE FIRST PERIOD, USE 22GMT.

   MONTH  07     DAY  30     TIME  22 GMT

ENTER YOUR FORECAST OF MAX/MIN TEMPERATURES IN THE SPACES PROVIDED:

          STATION                    FORECAST PERIOD
                                   1ST    2ND    3RD
   RBL -- WSO RED BLUFF            072    110    072
   SAC -- WSO SACRAMENTO           064    104    063
   SCK -- WSO STOCKTON             067    106    068
   FAT -- WSO FRESNO               072    107    072
   OAK -- WSO OAKLAND              058    077    057
   SFO -- WSO SAN FRANCISCO        053    072    053
   SMX -- WSO SANTA MARIA          054    075    053

POSITION THE CURSOR BETWEEN THE BRACKETS IN THE LOWER RIGHT-HAND
CORNER OF THE SCREEN THEN STRIKE THE "ENTER" KEY.

                                                              PAGE 01
```

Figure 5b. Example of an Input File (AFOS Product SFOFRFSFO). This File was Created by Entering Data into the Preformat Shown in Figure 5a.

... LEGEND ...

STN. NO.	MOS STATION	STN. NO.	NON-MOS STATION
1.	WSO RED BLUFF	1.	SAN FRANCISCO FOB
2.	WSO SACRAMENTO	2.	REDWOOD CITY
3.	WSO STOCKTON	3.	SAN JOSE
4.	WSO FRESNO	4.	HOLLISTER
5.	WSO OAKLAND	5.	WALNUT CREEK-CONCORD
6.	WSO SAN FRANCISCO	6.	LIVERMORE
7.	WSO SANTA MARIA	7.	SANTA ROSA

```
TYPE SUMMERMAX                                                          NON-MOS STN. NO.
5600000                                                                 (See Legend)
0.73962 0.73352 0.00000 0.00000 0.00000 0.00000 0.00000               1. (SFB)
 133.5   -3.061  0.03653 -0.0001011
6300000
0.63195 0.54545 0.00000 0.00000 0.00000 0.00000 0.00000               2. (RWC)
-295.4   12.634 -0.15077  0.0006444
A  3562000
B  0.76437 0.71502 0.64199 0.73440 0.00000 0.00000 0.00000            3. (SJC)
C   608.3 -20.314  0.24668 -0.0009453
7530000
0.63915 0.53785 0.58494 0.00000 0.00000 0.00000 0.00000               4. (HLL)
 487.0 -17.250  0.22471 -0.0009024
2530000
0.85466 0.56274 0.83122 0.00000 0.00000 0.00000 0.00000               5. (WNC)
 493.9 -16.933  0.21241 -0.0008226
3527160
0.85031 0.55066 0.82853 0.44365 0.75626 0.44260 0.00000               6. (LVK)
 265.2   -9.530  0.13368 -0.0005413
2500000
0.66015 0.58349 0.00000 0.00000 0.00000 0.00000 0.00000               7. (STS)
  35.4    0.151  0.00575 -0.0000059
R
```

$$Tx_{SJC} = 608.3 - T_m(20.314 + T_m(0.24668 - T_m(0.0009453)))$$

where

$$T_m = \frac{0.76437 Tx_{SCK} + 0.71502 Tx_{OAK} + 0.64199 Tx_{SFO} + 0.73440 Tx_{SAC}}{0.76437 + 0.71502 + 0.64199 + 0.73440}$$

Figure 6. A Sample Disk File (Labeled, "SUMMERMAX") whose Contents are used to Solve the General BART Equation for Each Non-MOS Station. For Example, Data in Rows A, B and C are used to Solve the Equation Displayed Below the File. Row A Contains MOS Station Numbers (See Legend) whose Temperatures are to be Read into the Equation; Row B Contains Values of RV_k; Row C Contains the Coefficients A_0, A_1, A_2 and A_3.

```
SFOOSOSRF
WOUS00 KSFO YYGGGG
OUTPUT FROM BAY AREA TEMPERATURE FORECAST ROUTINE
   STATION                             FORECAST PERIOD
                                      1ST    2ND    3RD
SAN FRANCISCO BAY AREA...
   SAN FRANCISCO FOB                   54.    66.    54.
   REDWOOD CITY                        58.    88.    58.
SANTA CLARA VALLEY...
   SAN JOSE                            60.    90.    59.
   HOLLISTER                           55.    91.    55.
EAST BAY INTERMEDIATE VALLEYS...
   WALNUT CREEK-CONCORD                59.   100.    59.
   LIVERMORE                           57.   102.    56.
SANTA ROSA PLAIN...
   SANTA ROSA                          53.    93.    52.
                                                                   PAGE 01
```

Figure 7. Sample Output Message from the Program Which Solves the BART Equations. Data From the Input File Shown in Figure 5b and the "SUMMERMAX" (See Figure 6) and "SUMMERMIN" Disk Files Produced the Results Displayed Above.

REDUCTION OF VARIANCE [PERCENT] ACHIEVED BY THE BART EQUATIONS

MINIMUM TEMPERATURE ...

SEASON	HLL	LVK	RWC	SFB	SJC	STS	LNC	ROW MEANS
	PREDICTAND STATION							
WINTER	73.7	62.8	84.5	73.6	79.1	76.5	76.8	75.3
SPRING	49.8	72.7	60.5	57.4	67.4	71.4	70.5	64.2
SUMMER	33.7	73.6	57.2	55.9	79.1	49.3	58.5	58.2
AUTUMN	59.3	80.2	75.7	52.1	80.9	68.1	77.6	70.6
COLUMN MEANS	54.1	72.4	69.5	59.8	76.6	66.3	70.9	67.1 = ANNUAL MEAN

MAXIMUM TEMPERATURE ...

SEASON	HLL	LVK	RWC	SFB	SJC	STS	LNC	ROW MEANS
	PREDICTAND STATION							
WINTER	79.4	73.0	84.7	89.4	84.5	80.8	79.9	81.7
SPRING	78.0	87.1	89.9	90.6	84.3	80.8	91.7	86.1
SUMMER	76.1	89.5	75.4	76.5	90.6	76.8	89.6	82.1
AUTUMN	84.6	88.7	85.2	87.2	92.5	86.7	94.3	88.5
COLUMN MEANS	79.6	84.6	83.8	85.9	88.0	81.3	88.9	84.6 = ANNUAL MEAN

Table 1

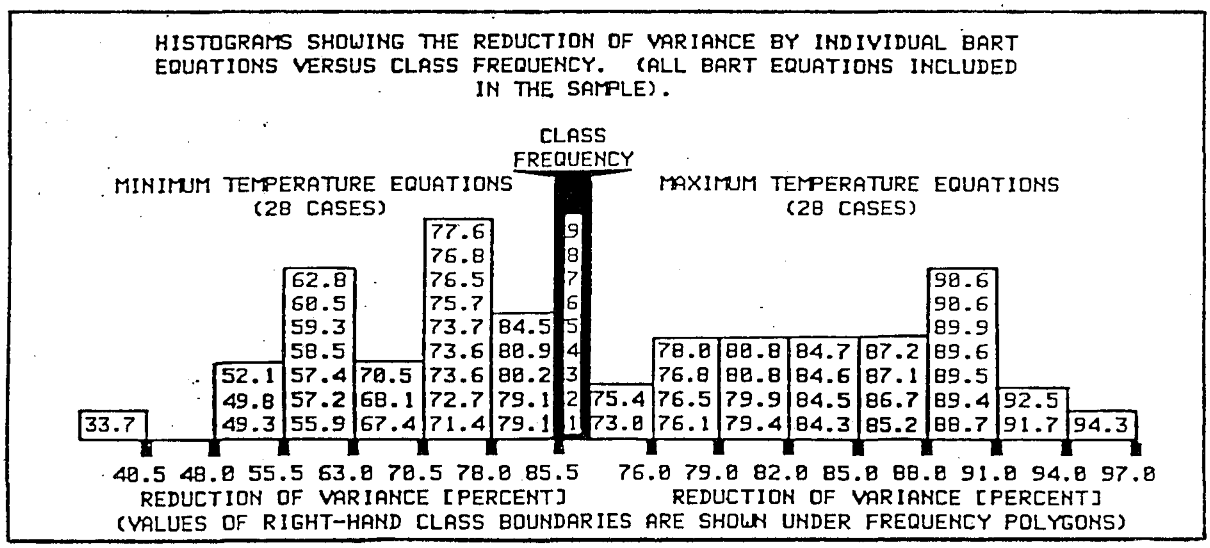


Figure 8

STANDARD ERROR OF ESTIMATE [DEG. F] OF EACH BART EQUATION

MINIMUM TEMPERATURE ...

SEASON	HLL	LVK	RWC	SFB	SJC	STS	WNC	ROW MEANS
WINTER	3.9	4.2	2.5	2.1	3.0	3.8	3.5	3.3
SPRING	4.1	3.0	3.1	2.0	2.8	3.0	3.3	3.0
SUMMER	3.4	2.4	2.8	1.5	1.7	2.5	3.0	2.5
AUTUMN	4.3	3.0	2.7	2.3	2.3	3.5	3.3	3.1
COLUMN MEANS	3.9	3.2	2.8	2.0	2.5	3.2	3.3	3.0 = ANNUAL MEAN

MAXIMUM TEMPERATURE ...

SEASON	HLL	LVK	RWC	SFB	SJC	STS	WNC	ROW MEANS
WINTER	3.2	3.3	2.2	1.8	2.5	3.2	2.9	2.7
SPRING	3.9	3.3	2.6	2.0	3.1	3.5	2.4	3.0
SUMMER	4.4	3.4	3.8	2.7	2.2	3.9	3.3	3.4
AUTUMN	3.9	4.1	3.4	2.8	2.4	4.2	2.8	3.3
COLUMN MEANS	3.9	3.5	3.0	2.3	2.6	3.7	2.9	3.1 = ANNUAL MEAN

Table 2

APPENDIX A

FLOWCHART AND

LISTING OF

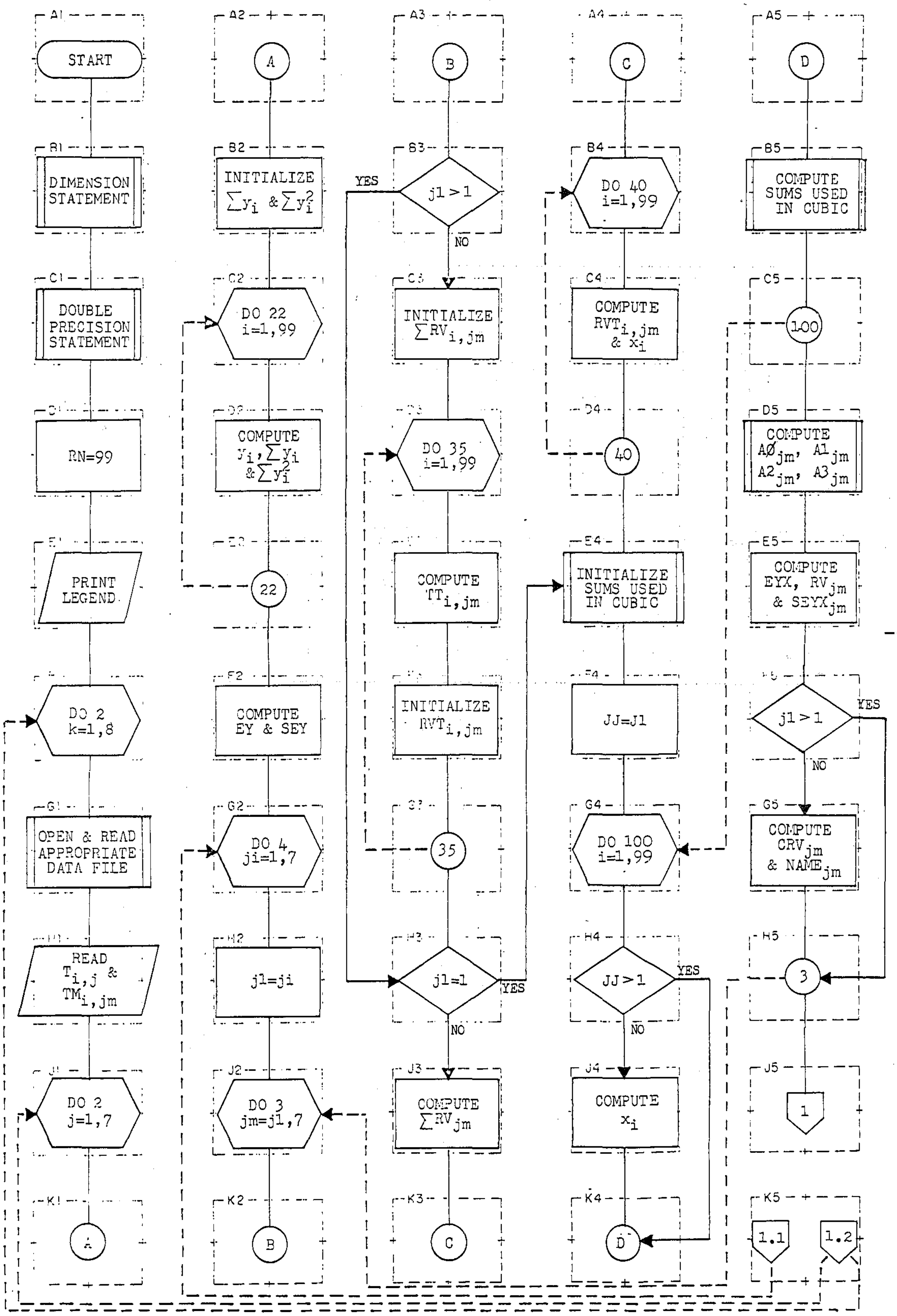
THE FORTRAN IV PROGRAM

USED TO DERIVE THE BART EQUATIONS

IBM Flowcharting Worksheet

Printed in U.S.A.
GX20-8021-2 U/M 050
Reprinted 5/75

Programmer: MORRIS S. WEBB, JR. Program No.: 9 Date: 03/11/79 Page: 1
Chart ID: -- Chart Name: MWBART009.FR FLOWCHART Program Name: MWBART009.FR



Fold under at dotted line.

Figure A1. Flowchart of the Program that Derived the BART Equations (Page 1 of 2).

IBM Flowcharting Worksheet

Printed in U.S.A.
GX20-8021-2 U/M 050
Reprinted 5/75

Programmer: MORRIS S. WEBB, JR. Program No.: 9 Date: 03/11/79 Page: 2

Chart ID: -- Chart Name: MWBART009.FR FLOWCHART Program Name: MWBART009.FR

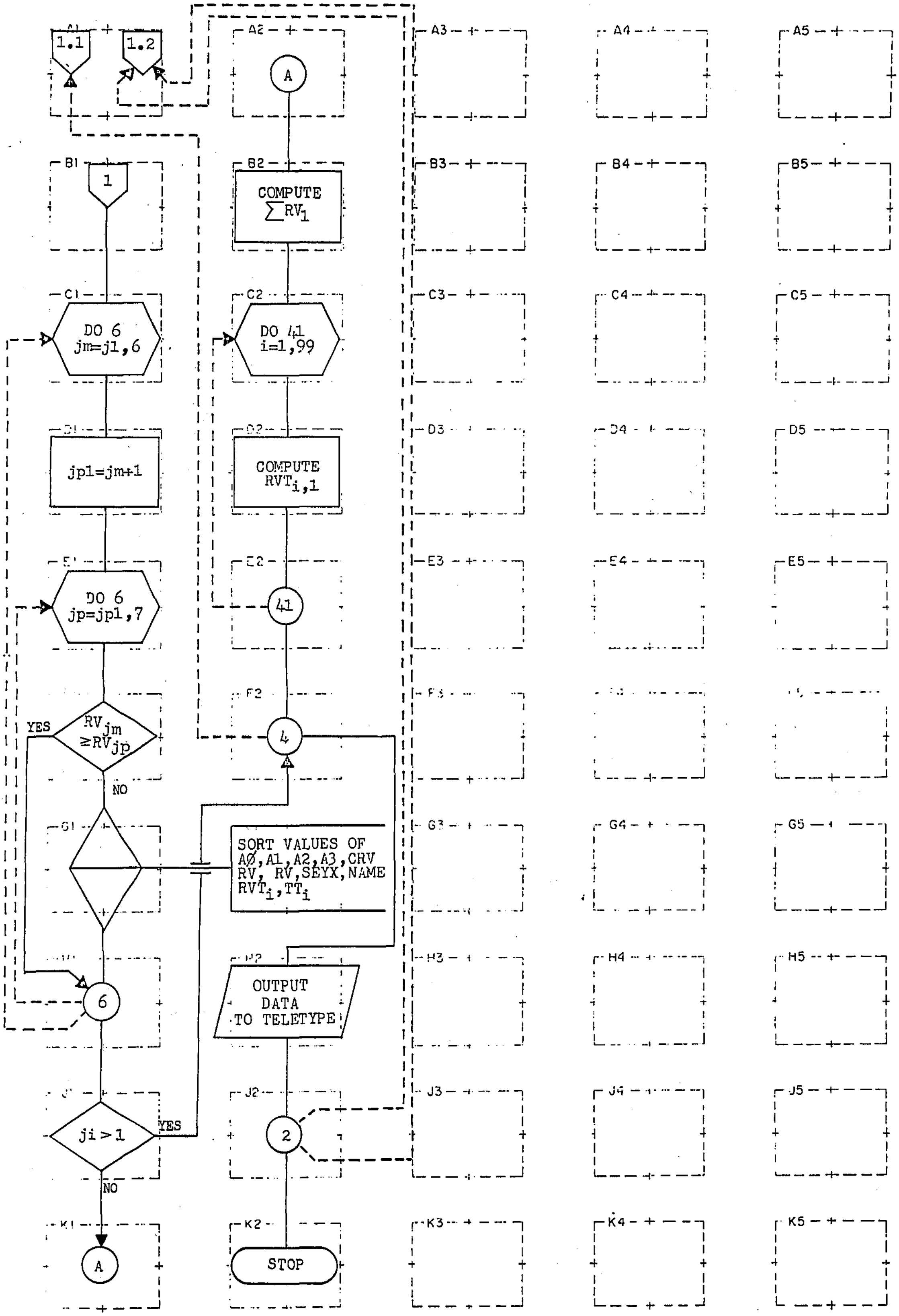


Figure A1 (Cont'd.). Flowchart of the Program that Derived the BART Equations (Page 2 of 2).

```
TYPE DP0F:SFD:MWBART009.FR
C   SCREENING REGRESSION USING LEAST SQUARE CUBIC -- FINAL RUN.
C   MORRIS S. WEBB, JR.; WSFO, SAN FRANCISCO, CA; 03/11/79.
C
      DIMENSION T(99,7),TM(99,7),CRV(7),RV(7),RVT(99,7),NAME(7)
      DIMENSION SUMRV(7),TRVT(99),TT(99,7),TTM(99)
      DOUBLE PRECISION Y(99),X(99),SY,SY2,SXY,SX2Y,SX3Y,
     1SX,SX2,SX3,SX4,SX5,SX6,X46X55,X36X45,X35X44,X26X35,X25X34,
     2X24X33,X234,X134,X124,X123,A0(7),A1(7),A2(7),A3(7),EYX,EY,RN,
     3SEY,SEYX(7),TA0,TA1,TA2,TA3,TSYX
      RN=9.9D1
      WRITE(10,9)
    9 FORMAT(1H0," ... LEGEND ..."//" FILE IDENTIFICATION NUMBERS ..."/
     1"   1. MINIMUM TEMPERATURE -- WINTER"/
     2"   2. MAXIMUM TEMPERATURE -- WINTER"/
     3"   3. MINIMUM TEMPERATURE -- SPRING"/
     4"   4. MAXIMUM TEMPERATURE -- SPRING"/
     5"   5. MINIMUM TEMPERATURE -- SUMMER"/
     6"   6. MAXIMUM TEMPERATURE -- SUMMER"/
     7"   7. MINIMUM TEMPERATURE -- AUTUMN"/
     8"   8. MAXIMUM TEMPERATURE -- AUTUMN"/)
      WRITE(10,10)
   10 FORMAT(" NON-MOS STATION NUMBERS ..."/
     1"   1. HLL -- HOLLISTER"/
     2"   2. LVK -- LIVERMORE"/
     3"   3. RWC -- REDWOOD CITY"/
     4"   4. SFB -- SAN FRANCISCO - FEDERAL BLDG."/
     5"   5. SJC -- SAN JOSE"/
     6"   6. STS -- SANTA ROSA"/
     7"   7. WNC -- WALNUT CREEK"//
     -" MOS STATION NUMBERS ..."/
     1"   1. FAT -- FRESNO WSO"/
     2"   2. OAK -- OAKLAND WSO"/
     3"   3. RBL -- RED BLUFF WSO"/
     4"   4. SAC -- SACRAMENTO WSO - EXECUTIVE AIRPORT"/
     5"   5. SFO -- SAN FRANCISCO WSO - AIRPORT"/
     6"   6. SMX -- SANTA MARIA WSO - AIRPORT"/
     7"   7. SCK -- STOCKTON WSO - AIRPORT"//)
```

Figure A2. FORTRAN IV Program that Derived the BART Equations (Page 1 of 5).

```
C  START OF THE "K" DO LOOP.
      DO 2 K=1,8
C  OPEN A FILE CONTAINING TEMPERATURE DATA.
      GO TO (11,12,13,14,15,16,17,18),K
   11 CALL OPEN (20,"DP0F:SFO:1TNDJF",1,IER,6665)
      GO TO 20
   12 CALL OPEN (20,"DP0F:SFO:1TXDJF",1,IER,6665)
      GO TO 20
   13 CALL OPEN (20,"DP0F:SFO:2TNMAM",1,IER,6665)
      GO TO 20
   14 CALL OPEN (20,"DP0F:SFO:2TXMAM",1,IER,6665)
      GO TO 20
   15 CALL OPEN (20,"DP0F:SFO:3TNJJA",1,IER,6665)
      GO TO 20
   16 CALL OPEN (20,"DP0F:SFO:3TXJJA",1,IER,6665)
      GO TO 20
   17 CALL OPEN (20,"DP0F:SFO:4TNSON",1,IER,6665)
      GO TO 20
   18 CALL OPEN (20,"DP0F:SFO:4TXSON",1,IER,6665)
   20 READ(20,21)(((T(I,J),J=1,7),(TM(I,JM),JM=1,7)),I=1,99)
   21 FORMAT(//(9X,14F4.0))
      CALL FCLOS (20)
C START OF THE "J" DO LOOP.
      DO 2 J=1,7
      SY=0.D0
      SY2=0.D0
      DO 22 I=1,99
      Y(I)=DBLE(T(I,J))
      SY=SY+Y(I)
      SY2=SY2+Y(I)**2
   22 CONTINUE
      EY=(SY2-SY**2/RN)/(RN-1.D0)
      SEY=DSQRT(EY)
C START OF THE "JI" DO LOOP.
      DO 4 JI=1,7
C START OF THE "JM" DO LOOP.
      J1=JI
      DO 3 JM=J1,7
      IF(J1.GT.1)GO TO 37
      SUMRV(JM)=0.0
      DO 35 I=1,99
      TT(I,JM)=TM(I,JM)
      RVT(I,JM)=0.0
   35 CONTINUE
   37 IF(J1.EQ.1)GO TO 30
      SUMRV(JM)=SUMRV(J1-1)+CRV(JM)
      DO 40 I=1,99
      RVT(I,JM)=RVT(I,J1-1)+CRV(JM)*TT(I,JM)
      X(I)=DBLE(RVT(I,JM)/SUMRV(JM))
   40 CONTINUE
```

Figure A2 (Cont'd.). FORTRAN IV Program that Dervied the BART Equations (Page 2 of 5).

```
C COMPUTE TERMS USED IN DETERMINING THE LEAST SQUARE CUBIC.
   30 SXY=0.D0
      SX2Y=0.D0
      SX3Y=0.D0
      SX=0.D0
      SX2=0.D0
      SX3=0.D0
      SX4=0.D0
      SX5=0.D0
      SX6=0.D0
      JJ=J1
      DO 100 I=1,99
      IF(JJ.GT.1)GO TO 101
      X(I)=DBLE(TT(I,JM))
  101 SXY=SXY+X(I)*Y(I)
      SX2Y=SX2Y+X(I)**2*Y(I)
      SX3Y=SX3Y+X(I)**3*Y(I)
      SX=SX+X(I)
      SX2=SX2+X(I)**2
      SX3=SX3+X(I)**3
      SX4=SX4+X(I)**4
      SX5=SX5+X(I)**5
      SX6=SX6+X(I)**6
  100 CONTINUE
C  COMPUTE THE REPETITIVE TERMS.
      X46X55=SX4*SX6-SX5**2
      X36X45=SX3*SX6-SX4*SX5
      X35X44=SX3*SX5-SX4**2
      X26X35=SX2*SX6-SX3*SX5
      X25X34=SX2*SX5-SX3*SX4
      X24X33=SX2*SX4-SX3**2
      X234=SX2*X46X55-SX3*X36X45+SX4*X35X44
      X134=SX*X46X55-SX3*X26X35+SX4*X25X34
      X124=SX*X36X45-SX2*X26X35+SX4*X24X33
      X123=SX*X35X44-SX2*X25X34+SX3*X24X33
C  COMPUTE THE ALPHA COEFFICIENTS.
      A0(JM)=(SY*X234-SXY*X134+SX2Y*X124-SX3Y*X123)
     1/(RN*X234-SX*X134+SX2*X124-SX3*X123)
      A1(JM)=((SY-A0(JM)*RN)*X35X44-(SXY-A0(JM)*SX)*X25X34+
     1(SX2Y-A0(JM)*SX2)*X24X33)/X123
      A2(JM)=((SY-A0(JM)*RN-A1(JM)*SX)*SX4-(SXY-A0(JM)*SX-
     1A1(JM)*SX2)*SX3)/X24X33
      A3(JM)=(SY-A0(JM)*RN-A1(JM)*SX-A2(JM)*SX2)/SX3
C  COMPUTE THE STANDARD ERROR OF ESTIMATE AND THE REDUCTION OF
C  VARIANCE.
      EYX=(SY2-A0(JM)*SY-A1(JM)*SXY-A2(JM)*SX2Y-A3(JM)*SX3Y)/(RN-4.D0)
      RV(JM)=1-SNGL(EYX/EY)
      SEYX(JM)=DSQRT(EYX)
      IF(J1.GT.1)GO TO 3
      CRV(JM)=RV(JM)
      NAME(JM)=JM
    3 CONTINUE
```

Figure A2 (Cont'd.). FORTRAN IV Program that Derived the BART Equations (Page 3 of 5).

```
C  START OF THE LOOP WHICH ARRANGES THE PREDICTOR STATIONS IN
C  DESCENDING ORDER (IN TERMS OF THE REDUCTION OF VARIANCE BETWEEN
C  THE PREDICTORS AND THE PREDICTAND).
      DO 6 JM=J1,6
      JP1=JM+1
      DO 6 JP=JP1,7
      IF(RV(JM).GE.RV(JP))GO TO 6
      TA0=A0(JM)
      TA1=A1(JM)
      TA2=A2(JM)
      TA3=A3(JM)
      TCRV=CRV(JM)
      TRV=RV(JM)
      TSUMRV=SUMRV(JM)
      TSYX=SEYX(JM)
      NAM=NAME(JM)
      DO 50 I=1,99
      TRVT(I)=RVT(I,JM)
      TTM(I)=TT(I,JM)
   50 CONTINUE
      A0(JM)=A0(JP)
      A1(JM)=A1(JP)
      A2(JM)=A2(JP)
      A3(JM)=A3(JP)
      CRV(JM)=CRV(JP)
      RV(JM)=RV(JP)
      SUMRV(JM)=SUMRV(JP)
      SEYX(JM)=SEYX(JP)
      NAME(JM)=NAME(JP)
      DO 51 I=1,99
      RVT(I,JM)=RVT(I,JP)
      TT(I,JM)=TT(I,JP)
   51 CONTINUE
      A0(JP)=TA0
      A1(JP)=TA1
      A2(JP)=TA2
      A3(JP)=TA3
      CRV(JP)=TCRV
      RV(JP)=TRV
      SUMRV(JP)=TSUMRV
      SEYX(JP)=TSYX
      NAME(JP)=NAM
      DO 6 I=1,99
      RVT(I,JP)=TRVT(I)
      TT(I,JP)=TTM(I)
    6 CONTINUE
      IF(J1.GT.1)GO TO 4
      SUMRV(1)=CRV(1)
      DO 41 I=1,99
      RVT(I,1)=CRV(1)*TT(I,1)
   41 CONTINUE
    4 CONTINUE
```

Figure A2 (Cont'd.). FORTRAN IV Program that Derived the BART Equations (Page 4 of 5).

```
C  OUTPUT DATA TO THE TELETYPE.
      WRITE(10,70)K,J,J,SEY,((JI,NAME(JI),SEYX(JI),RV(JI),CRV(JI),
     1A0(JI),A1(JI),A2(JI),A3(JI)),JI=1,7)
   70 FORMAT(/5X,"THE FILE IDENTIFICATION NUMBER IS ... ",I2/
     15X,"THE NON-MOS STATION NUMBER IS ....... ",I2/
     25X,"THE STANDARD DEVIATION OF NON-MOS STATION ",I1," IS",F5.1//
     35X,"LOOP MOS SYX  R.VAR. C.RVAR.",5X,"A0",6X,"A1",7X,"A2",9X,"A3"/
     45X," NO. STN"/(I8,I4,F5.1,2F8.5,F8.1,F8.3,F10.5,F12.7))
    2 CONTINUE
      STOP
      END
R
```

Figure A2 (Cont'd.). FORTRAN IV Program that Derived the BART Equations (Page 5 of 5).

APPENDIX B

FLOWCHART AND

LISTING OF

THE FORTRAN IV PROGRAM

USED TO SOLVE

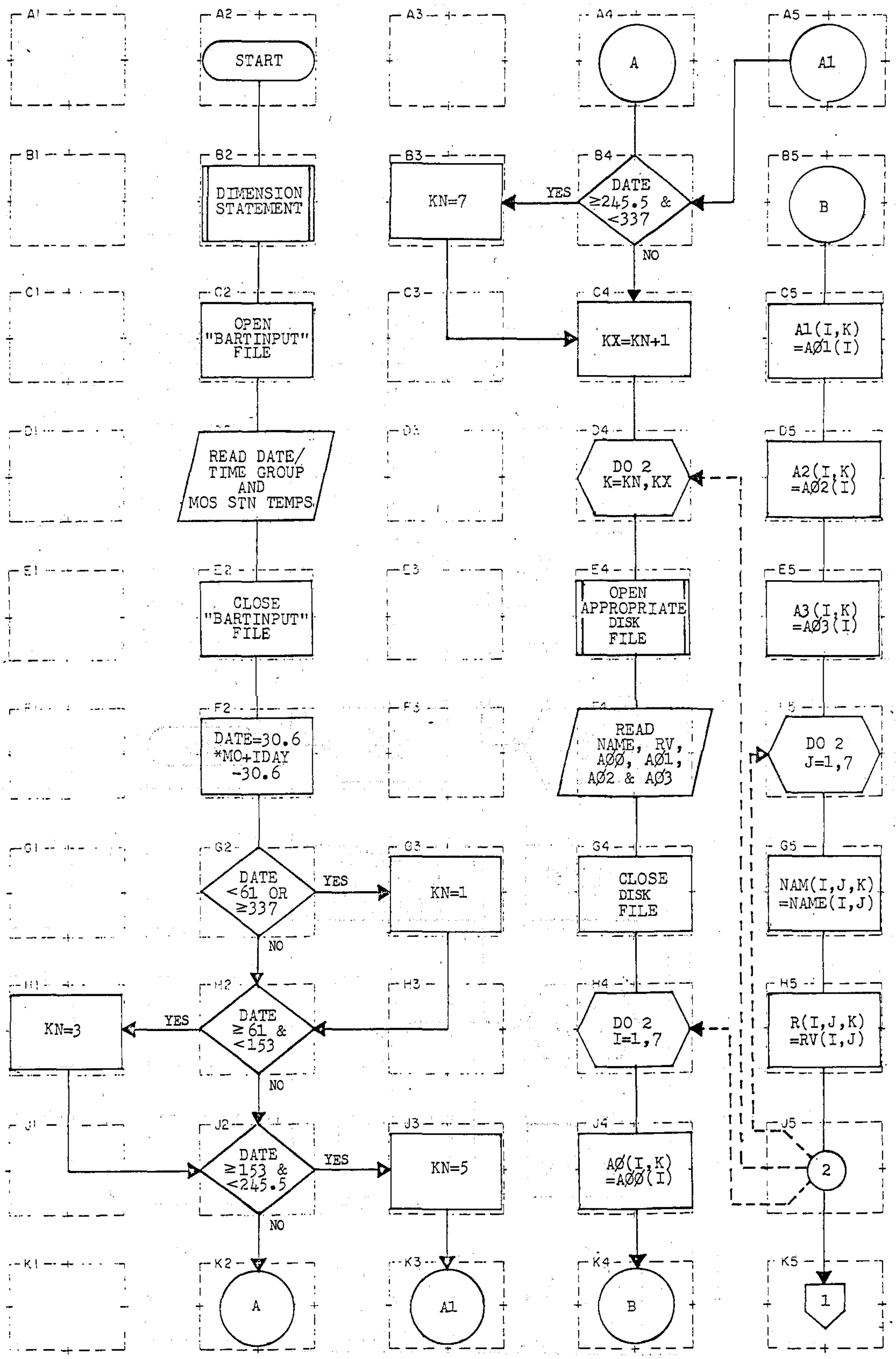
THE OPERATIONAL BART EQUATIONS

IBM Flowcharting Worksheet

GX20-8021-2 U/M 050
Reprinted 5/75

Programmer: MORRIS S. WEBB, JR. Program No.: 10 Date: 06/30/79 Page: 1

Chart ID: -- Chart Name: BART FLOWCHART Program Name: BART



Fold to here.

Fold under at dotted line.

Figure B1. Flowchart of the Program that Solves the Operational BART Equations (Page 1 of 2).

IBM Flowcharting Worksheet

GX20-8021-2 U/M 050
Reprinted 5/75

Programmer: MORRIS S. WEBB, JR. Program No.: 10 Date: 06/30/79 Page: 2
Chart ID: -- Chart Name: BART FLOWCHART Program Name: BART

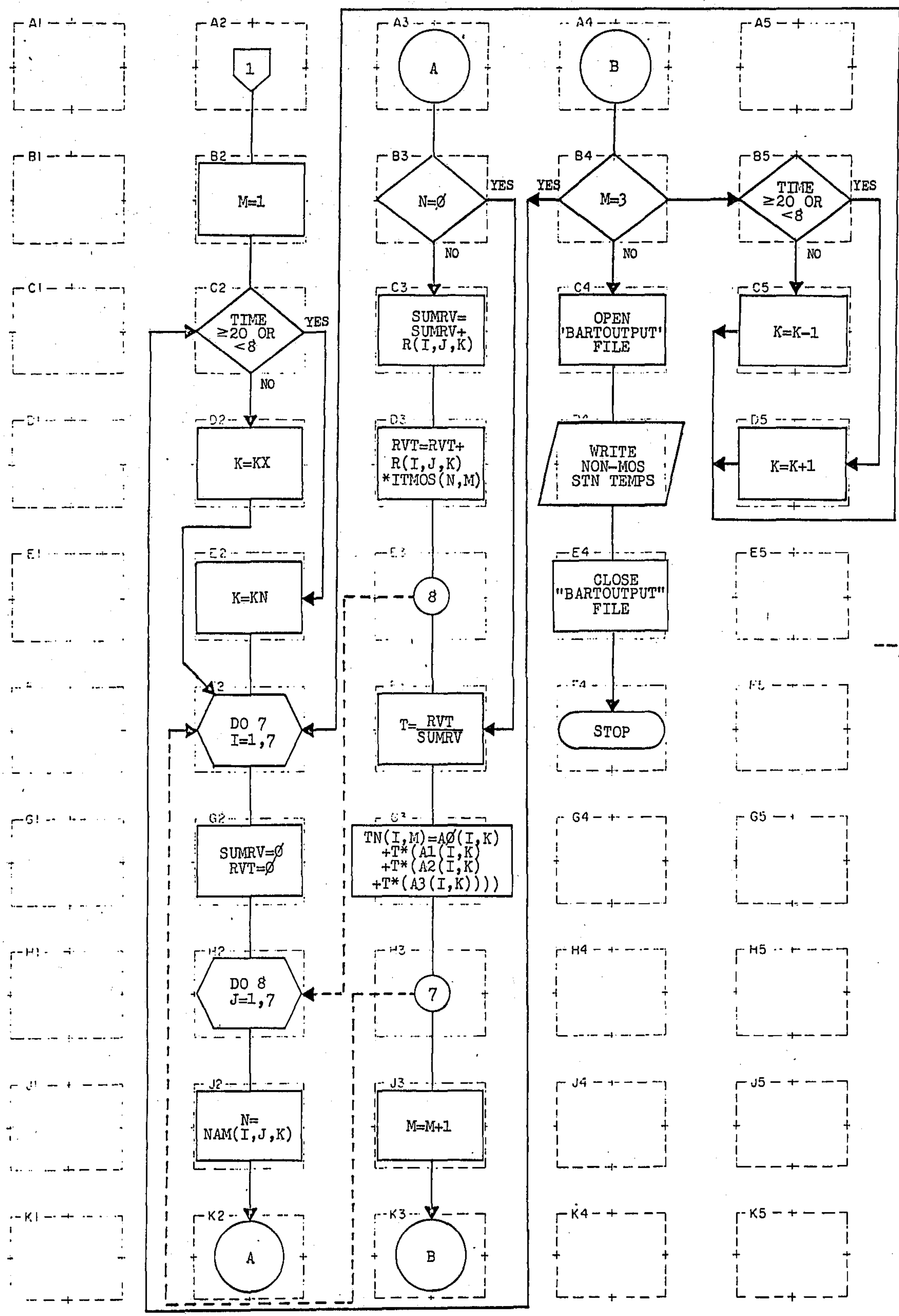


Figure B1 (cont'd.). Flowchart of the Program that Solves the Operational BART Equations (Page 2 of 2).

```
C  BART EXPERIMENT -- OPERATIONAL PROGRAM
C  MORRIS S. WEBB, JR.; WSFO, SAN FRANCISCO, CA; 06/30/79
      DIMENSION A00(7), A01(7), A02(7), A03(7), A0(7,8), A1(7,8)
      DIMENSION A2(7,8), A3(7,8), NAM(7,7,8), NAME(7,7), R(7,7,8)
      DIMENSION RV(7,7), ITMOS(7,3), TN(7,3)
      CALL OPEN (20,"BARTINPUT",1,IER,1259)
      READ (20,1) MO, IDAY, ITIME, ((ITMOS(I,J),J=1,3),I=1,7)
    1 FORMAT(/////10X,I2,9X,I2,10X,I2,4X//////(27X,3(4X,I3)))
      CALL FCLOS (20)
      DATE=30.6*FLOAT(MO)+FLOAT(IDAY)-30.6
      IF(DATE.LT.61..OR.DATE.GE.337.)KN=1
      IF(DATE.GE.61..AND.DATE.LT.153.)KN=3
      IF(DATE.GE.153..AND.DATE.LT.245.5)KN=5
      IF(DATE.GE.245.5.AND.DATE.LT.337.)KN=7
      KX=KN+1
      DO 2 K=KN,KX
         IF(K.EQ.1)CALL OPEN (21,"WINTERMIN",1,IER,693)
         IF(K.EQ.2)CALL OPEN (21,"WINTERMAX",1,IER,693)
         IF(K.EQ.3)CALL OPEN (21,"SPRINGMIN",1,IER,693)
         IF(K.EQ.4)CALL OPEN (21,"SPRINGMAX",1,IER,693)
         IF(K.EQ.5)CALL OPEN (21,"SUMMERMIN",1,IER,693)
         IF(K.EQ.6)CALL OPEN (21,"SUMMERMAX",1,IER,693)
         IF(K.EQ.7)CALL OPEN (21,"AUTUMNMIN",1,IER,693)
         IF(K.EQ.8)CALL OPEN (21,"AUTUMNMAX",1,IER,693)
         READ(21,3)(((NAME(I,J),J=1,7),(RV(I,J),J=1,7),A00(I),A01(I),
     1   A02(I),A03(I)),I=1,7)
    3    FORMAT(7I1/F7.5,6F8.5/F6.1,F8.3,F9.5,F11.7)
         CALL FCLOS (21)
         DO 2 I=1,7
            A0(I,K)=A00(I)
            A1(I,K)=A01(I)
            A2(I,K)=A02(I)
            A3(I,K)=A03(I)
            DO 2 J=1,7
               NAM(I,J,K)=NAME(I,J)
               R(I,J,K)=RV(I,J)
    2 CONTINUE
```

Figure B2. FORTRAN IV Program that Solves the Operational BART Equations (Page 1 of 2).

```
      M=1
    4 IF(ITIME.GE.20.OR.ITIME.LT.08)GO TO 5
      K=KX
      GO TO 6
    5 K=KN
    6 DO 7 I=1,7
          SUMRV=0.0
          RVT=0.0
          DO 8 J=1,7
              N=NAM(I,J,K)
              IF(N.EQ.0)GO TO 9
              SUMRV=SUMRV+R(I,J,K)
              RVT=RVT+R(I,J,K)*FLOAT(ITMOS(N,M))
    8     CONTINUE
    9     T=RVT/SUMRV
          TN(I,M)=A0(I,K)+T*(A1(I,K)+T*(A2(I,K)+T*(A3(I,K))))
    7 CONTINUE
      M=M+1
      IF(M-3)10,4,11
   10 IF(ITIME.GE.20.OR.ITIME.LT.08)GO TO 12
      K=K-1
      GO TO 6
   12 K=K+1
      GO TO 6
   11 CALL OPEN (22,"BARTOUTPUT",3,IER,645)
      WRITE (22,13)((TN(I,J),J=1,3),I=1,7)
   13 FORMAT(1H0,"SFOOSOSRF          EWOUS00 KSFO YYGGGG"//
     1"  OUTPUT FROM BAY AREA TEMPERATURE FORECAST ROUTINE"//
     25X,"STATION",21X,"FORECAST PERIOD"/32X,"1ST",4X,"2ND",4X,"3RD"/
     3"  SAN FRANCISCO BAY AREA..."/5X,"SAN FRANCISCO FOB",7X,3F7.0/
     45X,"REDWOOD CITY",12X,3F7.0/"  SANTA CLARA VALLEY..."/
     55X,"SAN JOSE",16X,3F7.0/5X,"HOLLISTER",15X,3F7.0/
     6"  EAST BAY INTERMEDIATE VALLEYS..."/
     75X,"WALNUT CREEK-CONCORD",4X,3F7.0/5X,"LIVERMORE",15X,3F7.0/
     8"  SANTA ROSA PLAIN..."/5X,"SANTA ROSA",14X,3F7.0/)
      CALL FCLOS (22)
      STOP
      END
R
```

Figure B2 (Cont'd.). FORTRAN IV Program that Solves the Operational BART Equations (Page 2 of 2).

APPENDIX C

THE "BART" AFOS PROCEDURE

```
SFOPCD002
WOUS00 KSFO 190841
   DISPLAY   MODE  ACC/OV    COMMAND
    (1-4)    (D/M) (R/A/O)   (ANY COMMAND; LAST LINE MUST BE END OR "NAME")
   -------   ----- -------   ----------------------------------------------
01    1        D      R        DSP:BARTINFO.00
02                             WCHR T
03    1        D      R        FTP(RBL,SAC,SCK,FAT)
04                             PAUSE 01
05    1        D      A        FTP(OAK,SFO,SMX)
06                             WCHR I
07    1        D      R        DSP:BARTINFO.01
08                             PAUSE 01
09    1        D      A        DSP:BARTINFO.02
10                             PAUSE 02
11    2        D      R        DSP:BARTINFO.01
12    1        D      R        WCHR S
13                             SAVE:FRFSFO DP0:BARTINPUT
14                             PAUSE 05
15    1        D      R        DSP:BARTINPUT
16                             WCHR R
17    2        D      R        FRFSFO
18                             PAUSE 02
   DISPLAY   MODE  ACC/OV    COMMAND
    (1-4)    (D/M) (R/A/O)   (ANY COMMAND; LAST LINE MUST BE END OR "NAME")
   -------   ----- -------   ----------------------------------------------
19    1        D      R        DSP:BARTINFO.03
20                             PAUSE 01
21                             RUN:BART
22                             PAUSE 20
23                             STORE:DP0:BARTOUTPUT SFOOSOSRF
24                             PAUSE 05
25    1        D      R        OSOSRF
26                             PAUSE 01
27    1        D      A        DSP:BARTINFO.04
28                             END
29
30
31
32
33
34
35
36
37
38
                                                                     PAGE 02
```

Figure C1. List of Steps and Console Commands in the "BART" Procedure.

WOUS00 KSFO 242142

HELLO! WELCOME TO THE "BART" PROCEDURE — A PROCEDURE WHICH COMPUTES DAILY MAXIMUM AND MINIMUM TEMPERATURES FOR SELECTED STATIONS IN THE SAN FRANCSICO BAY AREA FOR WHICH MOS TEMPERATURE FORECASTS ARE NOT CURRENTLY MADE.

IF YOU ARE RUNNING THIS PROCEDURE FROM AN "AGG" OR "AGGG" CONSOLE, MAKE SURE THAT THE ZOOM BUTTON ON THE GDM CONSOLE ADJACENT TO YOUR ADM CONSOLE IS PUNCHED TO THE "1:1" POSITION. ALSO, CLEAR THE DISPLAY FROM THE SCREEN NEXT TO THE ONE IN FRONT OF YOU (ALPHANUMERIC DATA WILL BE DISPLAYED SHORTLY ON THE ADJACENT SCEEN).

NOW, PLEASE WRITE DOWN THE MOS TEMPERATURE FORECASTS FOR THE FIRST THREE FORECAST PERIODS AT THE FOLLOWING STATIONS:

1. RBL 2. SAC 3. SCK 4. FAT 5. OAK 6. SFO 7. SMX
(MOS TEMPERATURES SHOULD BE PROVIDED BY THE NEXT PROCEDURE STEP).

TRY TO IMPROVE ON MOS BY MAKING YOUR OWN TEMPERATURE FORECAST FOR THE FORECAST PERIODS AND STATIONS LISTED ABOVE. THIS INFORMATION WILL BE USED LATER ON IN THE PROCEDURE.

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Figure C2. Contents of the "BARTINFO.00" Disk File -- Obtained by Procedure Step 1.

MOS FCSTS FINAL POP F MAX/MIN 7/30/79 1200 GMT

DATE/GMT		31/12	01/00	01/12	02/00	02/12
RBL	POP 12	0	02	0	02	
	MN/MX	72	104	68	103	69
SAC	POP 12	0	0	0	0	
	MN/MX	63	103	59	99	60
SCK	POP 12	0	0	0	0	
	MN/MX	65	100	65	100	
FAT	POP 12	0	0	0	0	
	MN/MX	66	101	66	102	66
OAK	POP 12	0	0	0	0	
	MN/MX	58	73	56	70	
SFO	POP 12	0	0	0	0	
	MN/MX	55	78	55	72	56
SMX	POP 12	0	0	0	0	
	MN/MX	54	73	52	76	54

Figure C3. Display of MOS Temperatures for the Seven MOS Stations Used in the BART Experiment -- Obtained by Procedure Steps 3 and 5.

WOUS00 KSFO 241842

1. AFTER READING THE INSTRUCTIONS ON THIS PAGE, TYPE, M:002, THEN STRIKE THE [ENTER] KEY. (THE HEADER BLOCK SHOULD APPEAR ON THE SCREEN).

2. COMPLETE THE HEADER BLOCK AS FOLLOWS:
   PRODUCT CATEGORY [FRF]
   PRODUCT DESIGNATOR [SFO]
   ADDRESSEE [000]
MOVE THE CURSOR TO THE BOTTOM OF THE HEADER BLOCK THEN STRIKE [ENTER]. (THE BAY AREA TEMPERATURE FORECAST PREFORMAT SHOULD APPEAR ON THE SCREEN).

3. COMPLETE THE PREFORMAT THEN STRIKE [ENTER]. (THE MESSAGE, "PRODUCT SFOFRFSFO STORED", SHOULD APPEAR ON THE SCREEN).

4. AFTER STEP 3 IS COMPLETED, TYPE THE LETTER S AT THE BOTTOM OF THE SCREEN THEN STRIKE [ENTER] TO CONTINUE THE PROCEDURE.

WOUS00 KSFO 241856
(THE ABOVE INSTRUCTIONS ARE ALSO DISPLAYED ON THE SCREEN NEXT TO THIS ONE).

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Figure C4. Contents of the "BARTINFO.01" and "BARTINFO.02" Disk Files -- Obtained by Procedure Steps 7 and 9.

WOUS00 KSFO 302339
ENTER THE DATE/TIME GROUP IN THE SPACES BELOW. TO INSURE THAT MAX TEMPERATURES ARE PLACED IN THE FIRST FORECAST PERIOD, USE 10GMT FOR THE TIME GROUP; FOR MIN TEMPERATURES IN THE FIRST PERIOD, USE 22GMT.

MONTH 07 DAY 30 TIME 22 GMT

ENTER YOUR FORECAST OF MAX/MIN TEMPERATURES IN THE SPACES PROVIDED:

STATION	FORECAST PERIOD 1ST	2ND	3RD
RBL -- WSO RED BLUFF	072	110	072
SAC -- WSO SACRAMENTO	064	104	063
SCK -- WSO STOCKTON	067	106	068
FAT -- WSO FRESNO	072	107	072
OAK -- WSO OAKLAND	058	077	057
SFO -- WSO SAN FRANCISCO	053	072	053
SMX -- WSO SANTA MARIA	054	075	053

POSITION THE CURSOR BETWEEN THE BRACKETS IN THE LOWER RIGHT-HAND CORNER OF THE SCREEN THEN STRIKE THE "ENTER" KEY.

PAGE 01

Figure C5. Contents of the "BARTINPUT" Disk File -- Obtained by Procedure Steps 13 and 15.

WOUS00 KSFO 011804

THE BART PROGRAM IS NOW BEING EXECUTED. IT TAKES ABOUT TWENTY SECONDS TO RUN. WHILE YOU ARE WAITING, REFER TO THE TABLE BELOW:

THE TABLE LISTS THE PERCENTAGE OF VARIANCE ACCOUNTED FOR BY THE MAXIMUM AND MINIMUM TEMPERATURE EQUATIONS BEING SOLVED BY THE BART PROGRAM:

STATION	REDUCTION OF VARIANCE [%] BY THE MAX AND MIN TEMPEATURE EQUATIONS: WINTER		SPRING		SUMMER		AUTUMN	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
SAN FRANCISCO FOB	89	74	91	57	76	56	87	52
REDWOOD CITY	85	85	90	61	75	57	85	76
SAN JOSE	85	79	84	67	91	79	93	81
HOLLISTER	79	74	78	50	76	34	85	59
WALNUT CREEK-CONCORD	80	77	92	70	90	58	94	78
LIVERMORE	73	63	87	73	89	73	89	60
SANTA ROSA	81	77	81	71	77	49	87	68

PAGE 01

Figure C6. Contents of the "BARTINFO.03" Disk File -- Obtained by Procedure Step 19.

```
SFOOSOSRF
WOUS00 KSFO YYGGGG
OUTPUT FROM BAY AREA TEMPERATURE FORECAST ROUTINE
   STATION                       FORECAST PERIOD
                                1ST    2ND    3RD
SAN FRANCISCO BAY AREA...
   SAN FRANCISCO FOB             54.    66.    54.
   REDWOOD CITY                  58.    88.    58.
SANTA CLARA VALLEY...
   SAN JOSE                      60.    90.    59.
   HOLLISTER                     55.    91.    55.
EAST BAY INTERMEDIATE VALLEYS...
   WALNUT CREEK-CONCORD          59.   100.    59.
   LIVERMORE                     57.   102.    56.
SANTA ROSA PLAIN...
   SANTA ROSA                    53.    93.    52.
OUS00 KSFO 281844

THIS MARKS THE END OF THE "BART" PROCEDURE.  TEMPERATURES DERIVED
BY THE BART PROGRAM ARE STORED UNDER THE HEADER SFOOSOSRF.

FINIS
                                                                PAGE 01
```

Figure C7. Contents of the Output Message (AFOS Product SFOOSOSRF) -- Obtained by Procedure Steps 21, 23, and 25. The Contents of the "BARTINFO.04" Disk File -- Obtained by Procedure Step 27 -- are Displayed Below the Output Message.

NOAA Technical Memoranda NWSWR: (Continued)

92 Smoke Management in the Willamette Valley. Earl M. Bates, May 1974. (COM-74-11277/AS)

93 An Operational Evaluation of 500-mb Type Regression Equations. Alexander E. MacDonald, June 1974. (COM-74-11407/AS)

94 Conditional Probability of Visibility Less than One-Half Mile in Radiation Fog at Fresno, California. John D. Thomas, August 1974. (COM-74-11555/AS)

96 Map Type Precipitation Probabilities for the Western Region. Glenn E. Rasch and Alexander E. MacDonald, February 1975. (COM-75-10428/AS)

97 Eastern Pacific Cut-off Low of April 21-28, 1974. William J. Alder and George R. Miller, January 1976. (PB-250-711/AS)

98 Study on a Significant Precipitation Episode in Western United States. Ira S. Brenner, April 1976. (COM-75-10719/AS)

99 A Study of Flash Flood Susceptibility--A Basin in Southern Arizona. Gerald Williams, August 1975. (COM-75-11360/AS)

102 A Set of Rules for Forecasting Temperatures in Napa and Sonoma Counties. Wesley L. Tuft, October 1975. (PB-246-902/AS)

103 Application of the National Weather Service Flash-Flood Program in the Western Region. Gerald Williams, January 1976. (PB-253-053/AS)

104 Objective Aids for Forecasting Minimum Temperatures at Reno, Nevada, During the Summer Months. Christopher D. Hill, January 1976. (PB-252-866/AS)

105 Forecasting the Mono Wind. Charles P. Ruscha, Jr., February 1976. (PB-254-650)

106 Use of MOS Forecast Parameters in Temperature Forecasting. John C. Plankinton, Jr., March 1976. (PB-254-649)

107 Map Types as Aids in Using MOS PoPs in Western United States. Ira S. Brenner, August 1976. (PB-259-594)

108 Other Kinds of Wind Shear. Christopher D. Hill, August 1976. (PB-260-437/AS)

109 Forecasting North Winds in the Upper Sacramento Valley and Adjoining Forests. Christopher E. Fontana, Sept. 1976. (PB-273-677/AS)

110 Cool Inflow as a Weakening Influence on Eastern Pacific Tropical Cyclones. William J. Denney, November 1976. (PB-264-655/AS)

112 The MAN/MOS Program. Alexander E. MacDonald, February 1977. (PB-265-941/AS)

113 Winter Season Minimum Temperature Formula for Bakersfield, California, Using Multiple Regression. Michael J. Oard, February 1977. (PB-273-694/AS)

114 Tropical Cyclone Kathleen. James R. Fors, February 1977. (PB-273-676/AS)

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117 The Relative Frequency of Cumulonimbus Clouds at the Nevada Test Site as a Function of K-value. R. F. Quiring, April 1977. (PB-272-831)

118 Moisture Distribution Modification by Upward Vertical Motion. Ira S. Brenner, April 1977. (PB-268-740)

119 Relative Frequency of Occurrence of Warm Season Echo Activity as a Function of Stability Indices Computed from the Yucca Flat, Nevada, Rawinsonde. Darryl Randerson, June 1977. (PB-271-290/AS)

121 Climatological Prediction of Cumulonimbus Clouds in the Vicinity of the Yucca Flat Weather Station. R. F. Quiring, June 1977. (PB-271-704/AS)

122 A Method for Transforming Temperature Distribution to Normality. Morris S. Webb, Jr., June 1977. (PB-271-742/AS)

124 Statistical Guidance for Prediction of Eastern North Pacific Tropical Cyclone Motion - Part I. Charles J. Neumann and Preston W. Leftwich, August 1977. (PB-272-661)

125 Statistical Guidance on the Prediction of Eastern North Pacific Tropical Cyclone Motion - Part II. Preston W. Leftwich and Charles J. Neumann, August 1977. (PB-273-155/AS)

127 Development of a Probability Equation for Winter-Type Precipitation Patterns in Great Falls, Montana. Kenneth B. Mielke, February 1978. (PB-281-387/AS)

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130 Flash-Flood Procedure. Ralph C. Hatch and Gerald Williams, May 1978. (PB-286-014/AS)

131 Automated Fire-Weather Forecasts. Mark A. Mollner and David E. Olsen, September 1978. (PB-289-916/AS)

132 Estimates of the Effects of Terrain Blocking on the Los Angeles WSR-74C Weather Radar. R. G. Pappas, R. Y. Lee, and B. W. Finke, October 1978. (PB289767/AS)

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134 Solar Radiation. John A. Jannuzzi, November 1978. (PB291195/AS)

135 Application of a Spectrum Analyzer in Forecasting Ocean Swell in Southern California Coastal Waters. Lawrence P. Kierulff, January 1979. (PB292716/AS)

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138 A Simple Analysis/Diagnosis System for Real Time Evaluation of Vertical Motion. Scott Heflick and James R. Fors, February 1979. (PB294216/AS)

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143 The Depth of the Marine Layer at San Diego as Related to Subsequent Cool Season Precipitation Episodes in Arizona. Ira S. Brenner, May 1979.

144 Arizona Cool Season Climatological Surface Wind and Pressure Gradient Study. Ira S. Brenner, May 1979.

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