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MODELING WINTER STORMS OVER ARIZONA

Final Report
Volume III

APPENDIX B:

Estimation of Winter Precipitation on the Mogollon Rim With a Simple Local-Scale Model

Prepared for
Arizona Department of Water Resources
Under IGA-0-AG-30-08290

September 1995

U.S. DEPARTMENT OF THE INTERIOR
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The Bureau of Reclamation has adapted an orographic precipitation model to produce useful estimates of daily precipitation at grid points spaced at 5 or 10 km over the Mogollon Rim in Arizona. The model also integrates the precipitation to yield water volume for the Salt and Verde watersheds. The model should be useful in planning future cloud seeding experiments, developing seeding suspension criteria, constructing daily weather forecasts necessary for seeding operations, and designing and performing the evaluation of cloud seeding effects on precipitation and streamflow. Additionally, model generated grid point precipitation can be employed as input to a physical hydrologic model that estimates daily runoff. This report describes the model computer code and its operation.

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U.S. Department of the Interior
Mission Statement

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1. MODEL COMPUTER PROGRAM DESCRIPTION AND OPERATION

1.1 Introduction

The appendix consists of a general description of principal components of the computer code for the orographic precipitation model that was originally developed by Rhea (1978). The model was adapted for application to the Mogollon Rim of Arizona and the computer code reflects this adaptation. No discussion of model theory is included in this appendix. Individuals interested in those details should consult Rhea (1978). Chapter 3, Volume I of the report related to this appendix and Medina (1991) contain some discussion on technical aspects of the model.

1.2 General Features of the Model Code

The model code consists of program LLWC and 10 subroutines listed in tables 1.1 and 1.2. Program LLWC performs various calculations, including grid-point precipitation estimation, and controls model input and output through calls to the various subroutines. The LLWC code also initializes a number of model constants and switches.

Table 1.1. – Model input subroutines.

Subroutine	Primary function
RDSTNS	Reads or rotates precipitation point locations
RDUPAIR	Reads and prepares the interpolated upper air data for model use
READ36	Deals with the terrain elevation data
GETDATA	Prepares the upper air data for program LLWC
FILINTP	Determines applicable border points and gridlines

Table 1.2. – Model output subroutines.

Subroutine	Primary function
STOREP	Stores precipitation estimates for other model use
PRNTSTN	Interpolates for station precipitation and sums and prints amounts for each station
ROTAT10	Rotates precipitation grids and sums precipitation over desired periods
FRSTSTR	Writes precipitation grids to file
WTRSHED	Integrates precipitation over designated watersheds and writes to file

1.3 Program LLWC

Program LLWC is the main program of the model. It contains various labeled and unlabeled commons through which information is transferred to and from the subroutines. It is in program LLWC that border point soundings are tested for moisture adequacy to perform precipitation calculations. The code contains loops within which precipitation is calculated at each grid point and line-by-line. The principal functions of LLWC include the following:

a. LLWC initializes a number of constants and switches including:

Constant	Definition
GRAV	Gravitational acceleration constant
R	Gas constant for dry air

Switch	Function
DURF	Duration factor. When set (= 1.), the summation period is 12 h per sounding. If set (= 0.5), the period is 6 h.
IFRSTM	Switch set (= 1) to tell subroutine RDUPAIR to open files that contain interpolated soundings. It is reset (= 0) for subsequent calls.
IBUFFSW	Switch set (= 0) tells subroutine READ36 to open a file containing terrain elevations and read them into an array. When set (= 1), READ36 reads a row of elevations.
IGRID	Switch set (= 0) on initial pass tells subroutine RDSTNS to read precipitation station names, coordinates and elevations. Thereafter, the switch is set (= 100) in the Arizona version so that RDSTNS rotates station coordinates to agree with THETA.

b. With a couple of exceptions, LLWC opens all input/output files. Given in table 1.3 is a listing of these files with respective functions. Some of the file names are currently hard-coded. For those not hard-coded, the user is prompted to supply a name of choice.

Table 1.3. Input and output files opened in main program LLWC.

Input files	Function
ARZPCP.STA (UNIT = 4)	Contains precipitation station information
ARZSHED.STA (UNIT = 10)	Contains watershed descriptions
WSINFO.DTA (UNIT = 9)	Unformatted temporary file used by the model for temporary storage.
Output files	Function
User prompted (UNIT = 8)	Contains detailed results of individual model runs.
User prompted (UNIT = 24)	Contains, for each sounding, the individual station precipitation values computed (13 of them) and the mean (column 1) for 11 stations, in a format compatible with software that computes correlations.
PCPDST1.OUT (UNIT =16)	Contains results as in unit 24 but for 8 stations used in the Arizona study.
PCPDST2.OUT (UNIT =17)	Contains results as in unit 24 but for 5 stations used in the Arizona study.
PCPMST1.OUT (UNIT = 19)	Contains the computed monthly precipitation values for each of 8 stations.
PCPMST2.OUT (UNIT = 20)	Contains the computed monthly precipitation values for each of 5 stations.
PCPDVOL.OUT (UNIT = 15)	Contains for each sounding the volume precipitation calculated for each watershed described in ARZSHED.STA.
PCPMVOL.OUT (UNIT = 18)	Contains the computed monthly volume precipitation of each watershed in ARZSHED.STA.

Important controlling processing provided by program LLWC is given in the following:

1. Reads from a file, watershed area descriptions for which the model will calculate volume precipitation.

2. Calls subroutine RDSTNS for obtaining precipitation station information.

3. Processes within a major loop where ultimately, precipitation is calculated.

4. Calls subroutine RDUPAIR to obtain interpolated upper air data.

5. Calls subroutine READ36 to get terrain elevation information.

6. Calls RDSTNS to rotate precipitation station coordinates into current THETA framework.

7. Calls subroutine FILINTP to determine interpolation border points.

8. Tests whether the sounding at each selected border point contains adequate moisture for a full model run. If all are dry, processing proceeds to the next period.

9. Calls subroutine STOREP in cases where some border points are moist and others are dry, to store zero values for grid points applicable to dry border points.

10. Calls subroutine GETDATA which determines a number of factors including the top of the blocked or dead layer, the unlifted cloud top and the vertical displacement factors for the various layers.

11. Proceeds with processing gridline by gridline. Calls are made to subroutine STOREP after each gridline is completed to store computed values.

12. Calls subroutine PRNTSTN to write precipitation station values to output files and perform seasonal summations.

13. Calls subroutine ROTAT10 to rotate the precipitation grid to 270° format.

14. Skips code originally developed for various print options on other computers. Code remains as background information for future model uses.

15. Calls subroutine FRSTSTR to write the precipitation grid to a designated file for future printing or processing.

16. Calls subroutine WTRSHED to compute the volume precipitation and mean water depth for each watershed and write results to designated files.

1.4 Model Subroutines

1.4.1 ***Subroutine RDSTNS***. – On the first call of subroutine RDSTNS, a test of IGRID which was initialized at (= 0), leads to the reading of precipitation station names, elevations, and positions on the 270° oriented 10-km grid. Station coordinates are determined within a grid-point reference system where the origin is position (1,1) and is the southwestern-most grid point on the 270° grid. Thus, a station's position could be, for example, (15.5,32.7) so that XVAL = 15.5 and YVAL = 32.7, meaning that the station is located between the 15th and 16th gridlines in the familiar x-direction and between the 32nd and 33rd gridlines in the familiar y-direction. It is noted that the distance of the station from the y-axis would be 145 km since the origin is (1,1) rather than the familiar (0,0). Similarly, the distance from the x-axis would be 317 km.

Precipitation stations are counted as the information is read. The number of stations is stored in MAXPNT. Other subroutines use MAXPNT as a limit to some processing.

Subroutine RDSTNS establishes some grid size constants, based on the value of IGRID, that are used by program LLWC. Four constants set are:

Constant	Definition
DELX	Distance between grid points (in ft).
MAXX	Maximum number of grid points in the x-direction in the 270° grid.
MAXY	Maximum number of gridlines in the 270° grid.
GRIDFTR	A constant used in subroutines RDSTNS and ROTAT10 in the rotation of grids.

Subsequent calls to subroutine RDSTNS are for rotation of precipitation station coordinates. Subroutine RDSTNS contains a rotation algorithm that rotates precipitation station coordinates into the coordinate system dictated by the upper air winds (THETAN indicates the elevation grid to be used).

1.4.2 ***Subroutine READ36***.– Subroutine READ36 reads the terrain elevation data. There are 36 files with elevations. On the initial call to READ36, the switch IBUFFSW which previously has been set (= 0) tells READ36 to read the elevation data specified by THETAN into array IGRELV. The switch IBUFFSW is then set (= 1) for subsequent calls to READ36 for the same sounding. In the subsequent calls, READ36 obtains a gridline of elevations in each call. Upon obtaining the last line of elevation, IBUFFSW is reset (= 0) for a new sounding.

1.4.3 ***Subroutine FILINTP***. – Subroutine FILINTP deals with determination of the border points that apply to the sounding under study and the gridlines assigned to each selected border point. This subroutine employs THETAN and IGRID to determine how many and which border points apply to each sounding. It determines the subscript number of each selected border point and the gridline subscript number of the last gridline (of the group assigned) applicable to each border point.

1.4.4 ***Subroutine GETDATA***. – In the Arizona version of the model, subroutine GETDATA performs the following four functions:

a. Determines the top of the blocked or dead layer. Criteria employed are that a layer is considered blocked or dead if the layer mean wind is less than 2.5 m/s or dT/dP (T and P represent temperature and pressure, respectively) is less than 0.4 °K/50 mb. The subroutine initially tests the lowest layer and progresses upward, ceasing with the first layer that violates the criteria. The pressure, temperature, wind speed, and height of the top of the highest dead layer are stored for later use.

b. Determines the cloud top by testing from the highest layer for layer-mean relative humidity of at least 65 percent (60% for Arizona) that is not undercut by a layer with less than 50 percent (45% for Arizona) layer-mean relative humidity.

c. Calculates vertical displacement factors for the cloud-top streamline. Factors are determined based on the stability class selected by comparing the temperature difference of the 700- and 500-mb levels with the difference according to the wet adiabatic lapse rate. In the Arizona version a small enhancement of the factors over the Colorado version of the code is inserted in an attempt to better model the light precipitation events over the Mogollon Rim. The model computes the cloud-top streamline displacement, Δh_T, by the equation:

$$\Delta h_T = k(\Delta h_o)$$

where:

k = displacement factor
Δh_o = surface streamline displacement (which follows the terrain or the top of the dead layer, whichever is highest)

The displacement of the cloud-top streamline is set (= 0) for soundings where an inversion exists above cloud top. For stable cases, the enhancement factor is set (= 0.5) except when cloud top is at 700 or 750 mb, then it is set (= 0.8). In neutral stability cases, it is set (= 0.9), except when cloud top is at 700 or 750 mb, then it is set (= 0.95). If the factor is (≥ 0.9), then over the highest terrain, it is reset (= 1.2) to simulate convection.

d. Prepares sounding data for use by program LLWC. The program code develops averages of the principal variables, such as temperature and relative humidity, to mid-layer values (layers are generally 50-mb layers).

Other computer code in GETDATA presents the option for employing crystal trajectories and variable thickness layers. Currently, this code is not usable in Arizona. Rhea did not include this capability in the working Colorado version as it required still more detailed study to determine its feasibility (personal communication with Rhea). It was felt that expending resources to incorporate these capabilities in the Arizona version was not warranted. Because of Arizona's terrain and climate conditions, improvement in model performance is more likely by adding physics for better handling convection. However, Rhea's code for trajectory capabilities has been left in the Arizona version. Processing simply routes around this code.

1.4.5 Subroutine STOREP. – Upon completion of precipitation computations for a gridline, subroutine STOREP is called to store estimates for each grid point for later use. This subroutine also stores, in separate arrays, precipitation values that are on either side of terrain points on the gridline being processed for which the model is to develop precipitation estimates. Stored values from a couple gridlines for a terrain point will be used later in the interpolation to estimate the precipitation.

1.4.6 *Subroutine PRNTSTN*. – The subroutine PRNTSTN is called to compute the precipitation for each selected terrain position, using the stored values for the surrounding grid points. This subroutine also sums the precipitation over a selected time for each site and stores these values for later use. In each model run, an average is computed for 11 Mogollon Rim sites for which the model develops precipitation. Individual sounding results are written to several different files by PRNTSTN, including those assigned to units 8 and 24. The file corresponding to unit 24 stores individual sounding results for 13 stations and the mean of 11 selected from the 13. PRNTSTN also provides for the writing of precipitation for the 13 stations (includes the 11 stations) to files PCPDST1.OUT and PCPDST2.OUT, with 8 and 5 stations, respectively for easy user viewing. Finally, the 13 station precipitation results, as well as their accumulating amounts, go to unit 8, printed in column format. Results sent to unit 24 can be read by another program developed for computing correlations versus corresponding gauge measurements.

1.4.7 *Subroutine ROTAT10*. – The subroutine ROTAT10 rotates calculated precipitation grids whose orientation was based on THETAN (determined by the 700-mb winds at INW and TUS), to 270° (oriented) grids of precipitation. It also performs a summation of precipitation grids over a desired period specified by placement of 999999 at the end of the last sounding of the period, for each sounding station such as DRA, INW, and TUS in the case of Arizona (if using only one sounding station as input to the model, the 999999 would be inserted similarly). The procedure employed by ROTAT10 to develop the 270° precipitation grid is $1/D^2$ interpolation from the precipitation grid developed based on THETAN.

The parameters IXLIM and IYLIM are passed via the call to ROTAT10. The IXLIM is set to 48 (columns) and the IYLIM to 51 (rows), corresponding to the dimensions in grid points of the 270° grid. Use of these parameters allows for some flexibility in the use of this subroutine with different domain sizes such as may be employed in modeling for another geographical area. However, the array sizes are currently hard coded and many changes may need to be made to model another geographical area.

1.4.8 *Subroutine FRSTSTR (MSTR, IXLIM, IYLIM)*. – The sole purpose of subroutine FRSTSTR is to print the 270° precipitation grid. To restrict the precipitation values to 8-1/2-in-width paper, the format statement allows the writing of only 26 values per line. With MSTR = 1, a call to FRSTSTR is made for each line of the grid to print the first 26 values, then, with MSTR = 2, an additional set of calls to FRSTSTR is made to print the remainder of each line. One can then physically arrange the two grid pieces to display the complete 48*51 point grid. By altering the input into the array, *P*, which is printed in the calls to FRSTSTR, it is possible to write results for each sounding or for sums determined over some selected period. Control for this process is contained in the several nested loops that lead to calls to FRSTSTR.

1.4.9 *Subroutine WTRSHED (IXLIM, IYLIM)*. – The subroutine WTRSHED integrates calculated precipitation over a specified area which may correspond to a watershed, thus producing volume precipitation which can in turn be compared with measured streamflow. Precipitation values are obtained from array PSUM(,). Thus, to obtain a monthly sum of volume precipitation, for example, the monthly precipitation values for each grid point must be loaded into PSUM(,). The summation of the grid-point precipitation is accomplished elsewhere. WTRSHED simply integrates in space the contents in PSUM(,), determines the areal average depth, and writes individual sounding results to units 8 and 15 and period summation results to unit 18. The writing to unit 18 is keyed by the presence of 999999s in the sounding data file. WTRSHED employs a conversion factor of 2058.32 to yield units of acre-feet. Precipitation in PSUM(,) is in inches.

The calculations by WTRSHED are made for each watershed described in an input file. The code allows for computations for up to 30 watersheds. Identification of individual watersheds is read by an unformatted read of unit 9, a scratch file into which was written by program LLWC, the watershed identification, watershed number, and for each grid point that is part of the watershed, the position coordinates (of each grid point) and a weighting factor. The latter indicates what portion of the 10-km square surrounding a grid point is included in the watershed under study.

1.4.10 *Subroutine RDUPAIR*. – The subroutine RDUPAIR deals with the acquisition, manipulation, and assignment of interpolated sounding data to specific border points of the model grid. In particular, the current Arizona version accomplishes the following.

a. The subroutine reads the interpolated sounding data from three files in the order, DRA, INW, and TUS, or from a single file if a single sounding is to be run. In the case of three soundings, a model run requires that all three soundings be available date and time matched. When soundings are missing, computer code in the subroutine enables skipping data, as necessary, until a match of soundings is found. Sounding data for each station must have been interpolated to 50-mb levels and stored in proper order and format in the sounding files. More discussion on sounding data preparation is given in section 1.5.3.

b. RDUPAIR uses a system of weights and assignments applied to the DRA, INW, and TUS soundings to determine the 10 border point soundings. The weights have been determined by use of $1/D^2$, where D represents distance from a designated origin. From the latter, position coordinates have been determined for each border point and the three sounding stations. The coordinate system, which is different from the familiar model coordinate system, employs as the ordinate (y-axis), a north-south line passing through DRA and as the abscissa (x-axis), an east-west line passing through the southern border of the 10-km grid. In this coordinate system, one unit equals 100 km. The position coordinates are contained in data statements labeled XPSTN and YPSTN. The weights are contained in data statements labeled WF1, WF2, and WF3. The use of the weights and assignments for each border point is based on knowledge and experience of winter storms in Arizona. Comment statements in RDUPAIR indicate how the weights and assignments are applied. In the case of a single sounding run, all border points are filled with the sounding at hand.

c. The subroutine determines the value of THETAN which specifies the particular (wind direction) elevation grid applicable to the soundings under study. Currently, THETAN is calculated as the average of the 700-mb winds for INW and TUS. In a single sounding run, THETAN would be set to that sounding's 700-mb wind direction.

d. RDUPAIR computes the wind component in the direction of THETAN at all levels for DRA, INW, and TUS, or for a single sounding when operating in that mode.

e. The subroutine loads determined sounding data into arrays for subsequent model use. Pressure is placed in PRESURE(,), pressure height in PHGT(,), temperature in TEMPR(,), relative humidity in RELH(,), wind direction in WDIR(,), and wind speed in WSPD(,).

1.5 Model Input Data Requirements

1.5.1 ***Precipitation station specification.*** – The model estimates precipitation at specified locations between grid points as well as at grid points. To obtain precipitation at points other than grid points, a description of the location of desired points is necessary to identify surrounding grid points for interpolation.

A file must be developed that contains, for each precipitation station, a listing of station number, name, elevation in ft, and position coordinates. The latter must be stated such that the x-coordinate value is given first, followed by the y-coordinate value. The read statement for Arizona stations is given below, followed by file contents employed in the modeling. The read statement is located in subroutine RDSTNS.

```
      READ (4, 8001) ISTNNO(N), (NMPOINT(I,N),I=1,5), ELEV(N),
     *                XVAL, YVAL
8001  FORMAT (A4,2X,5A4,F6.0,2F6.2)
```

```
.00
 001   FORT VALLEY        7347.  13.30  45.40
 002   FLAGSTAFF          7006.  14.00  44.20
 003   HAPPY JACK RS      7480.  16.25  39.80
 004   BLUE RIDGE RS      6810.  18.95  38.20
 005   CHEVELON RS        7006.  20.75  37.40
 006   HEBER RS           6590.  24.10  36.00
 007   SHOW LOW CITY      6400.  29.20  34.30
 008   PINE TOP FISH HAT  8180.  29.90  32.80
 009   HAWLEY LAKE        8180.  31.50  31.40
 010   GREER              8490.  34.10  31.80
 011   ALPINE             8050.  37.00  29.90
 012   MT LEMMON          7794.  22.20  14.20
 013   CHIRICAHUA NM      5300.  35.55   9.50
999999
```

The first record of file ARZPCP.STA contains the value, .00, which is read by LLWC and used as a factor for altering the precipitation efficiency relationship. A value of .00 leaves the relationship unaltered. A value of 0.2, for example, leads to an enhancement of the relationship's results by 20 percent. Testing in many runs for Arizona indicated that in the current model configuration, .00 produces better results.

Succeeding records of file ARZPCP.STA contain precipitation station number, such as 001; station name, such as FORT VALLEY; elevation, such as 7347 ft; and station location. The latter locates a station, for example, between the 13th and 14th grid columns and the 45th and 46th rows of the 270° grid [recall that the extreme southwest grid point has coordinates of (1,1)]. The model will process up to 150 stations.

1.5.2 ***Watershed specification.*** – Each watershed must be fully described within the model coordinate system in order to calculate volume precipitation. As in the case of precipitation stations, a file is written that contains the required descriptions. This file is read by LLWC. Essentially, a watershed description consists of a number of records, each containing a watershed name and number, and the coordinates and weights of up to 10 grid points (fewer grid points may result for the last record of a watershed). The coordinates in watershed descriptions are listed in reverse order to precipitation sites; that is, the y-value is listed first followed by the x-value. For each grid point, the weight used accounts for the fractional areal amount of the 10-km square in which the grid point is centered, that is contained in the watershed. The fractional amount is denoted in the record for each grid point, placed following the grid-point coordinates.

Given below is the read statement for watershed descriptions followed by the first record of the file, ARZSHED.STA, which contains the descriptions for the Salt and Verde watersheds.

```
READ(10,8001) ICDCODE, ISHED, (JY(I), JX(I), P(I), I=1,10)

8001    FORMAT(A4,I3,10(2I2,F3.2))
```

ARZ1 12420010242104624220502516020251704625180302519065252009725211002522067

The variable, ICDCODE, represents the abbreviated name given the watershed being described, ISHED represents the watershed number (as in the first, second, etc. listed), JY(I) and JX(I) are the coordinates in the grid-point coordinate system.

In the record given above, taken from file ARZSHED.STA, the following identifications are noted:

ARZ1———— abbreviated name of the watershed
1————— watershed number
24————— y-coordinate of the first grid point
20 ————— x-coordinate of the first grid point
010————— weight representing proportion of area surrounding a grid point that is contained in the watershed
24————— y-coordinate of the grid point located to the right of the first grid point
21————— x-coordinate of the second grid point
046————— weight for the second grid point (represents 0.46)

The last grid point of the record given above is the tenth of the record. Additional grid points pertaining to the watershed are identified on succeeding records in the same fashion until all points are identified. Generally, the identification starts with the southwestern-most grid point and proceeds eastward along the gridline until all involved grid points on that line are denoted. The process is repeated for each gridline until the watershed is fully identified and all watersheds are described.

1.5.3 *Sounding data preparation*. – The sounding data must be preprocessed to a form compatible with the requirements of the model. This preprocessing involves interpolation to 50-mb increments and, for each sounding, arrangement from highest pressure to lowest pressure, which for Arizona was from 900 to 300 mb in the case of DRA and TUS, and 850 mb to 300 mb for INW. Soundings are arranged chronologically in files, each sounding site to its file.

The sounding preparation process requires that a computer program such as Reclamation's ANAL be applied to the data. The program ANAL reads the raw sounding data, interpolates to desired increments, and writes results to a designated file. The inputs to ANAL are generally in a form produced by another program that reads tapes containing sounding data from national archives.

Application of ANAL to sounding data from Arizona produced the following three sample files. Each file contains data for a single sounding station.

File: DRA8412.DAT

```
       841212 0  DRA72387   33
895.0  1007.0   10.6  .619  240.0   5.0
850.0  1433.0    6.3  .718  231.0   6.0
800.0  1926.0    1.8  .937  221.0   6.0
750.0  2443.0   -2.7  .940  236.0   7.0
700.0  2988.0   -4.1  .449  262.0   8.0
650.0  3570.7   -6.3  .325  272.0   8.0
600.0  4192.8   -9.7  .272  273.0  11.0
550.0  4860.5  -12.1  .559  320.0  13.0
500.0  5583.0  -15.2  .399  343.0  24.0
450.0  6371.3  -20.6  .340  350.0  23.0
400.0  7232.0  -27.3  .499    1.0  32.0
350.0  8182.9  -33.0  .748    2.0  42.0
300.0  9253.0  -40.4  .120    4.0  54.0
999999
888888
```

File: INW8412.DAT

```
       841212 0  INW72374   33
844.6  1487.0    7.8  .758  310.0   3.0
800.0  1932.3    4.8  .840  245.1   8.0
750.0  2456.0     .5  .978  230.0  13.0
700.0  3007.0   -2.8  .993  238.0  16.0
650.0  3590.8   -6.4  .487  247.0  16.0
600.0  4213.9   -9.5  .298  248.0  19.0
550.0  4879.9  -13.7  .202  250.0  20.0
500.0  5596.0  -19.4  .657  243.0  20.0
450.0  6368.5  -25.8  .805  240.0  27.0
400.0  7212.0  -31.8  .289  243.0  31.0
350.0  8142.0  -39.4  .186  242.0  31.0
300.0  9184.0  -44.1  .004  243.0  27.0
999999
888888
```

File: TUS8412.DAT

```
       841212 0  TUS72274   33
900.0   966.8   17.2  .450  216.0   5.0
850.0  1450.0   11.8  .588  216.0   6.0
800.0  1954.0    7.4  .763  229.0   7.0
750.0  2482.0    2.0  .791  224.0   9.0
700.0  3037.0    -.1  .447  238.0  11.0
650.0  3626.7   -3.6  .345  237.0  12.0
600.0  4253.5   -8.9  .469  245.0  14.0
550.0  4921.9  -13.2  .417  246.0  25.0
500.0  5641.0  -18.2  .477  238.0  31.0
450.0  6421.5  -22.5  .287  232.0  37.0
400.0  7276.0  -28.7  .287  227.0  44.0
350.0  8218.2  -35.9  .308  220.0  51.0
300.0  9271.0  -44.0  .043  226.0  52.0
999999
888888
```

The 999999s of the next-to-last record are used to denote points at which the model is to write accumulated results. Arrays are then initialized for the next period of interest such as the next month. The 888888s are used to terminate the processing. In most of the modeling performed for Arizona, the 999999s were placed at the end of each month so the model would produce not only daily results, but also monthly totals.

The first record for each sounding contains the date and time of the sounding, followed by the three-character and five-digit station identifiers. An additional number follows, such as 33, that was of use in modeling another geographical area, but is of no relevance to Arizona. Succeeding records contain information for 6 variables of a sounding. Listed from left-to-right (as in the above samples) are pressure (mb), pressure height (m), temperature (°C), relative humidity (% in decimal form), wind direction (°), and wind speed (m/s), information required by the model.

The subroutine RDUPAIR opens the three sounding data files on the initial call. Thereafter, calls to RDUPAIR read the succeeding sounding in each of the files. Date and time comparisons are made and, depending on the outcome, additional soundings may be read until three time-matched soundings are available, one for each location. RDUPAIR provides data quality checking such that a model run is not performed until all three soundings consist of acceptable data. For model runs involving only one sounding as input, the data preparation is similar.

1.6 Model Program Operation

1.6.1 ***General comments.*** – The model has been adapted from operation on mainframe to minicomputers, to microcomputers. It is currently coded in FORTRAN 77 and the input/output is structured for operation on a microcomputer that has a hard disk, with available storage adequate to handle the input and output files which may contain several Mbytes. The model can be run on a PC-compatible microcomputer. For climatological studies involving many runs, the faster microcomputers are preferable. Runs involving soundings for 10 winters were accomplished in about 1.5 h of clock time on a 33 MHz machine. A model run for one sounding period can be accomplished in less than one minute on this type of machine that is equipped with a math coprocessor.

1.6.2 ***Subroutine library.*** – The model program is currently structured such that the necessary 10 subroutines, listed in tables 1.1 and 1.2, are inserted in a library entitled ARZWAT16.LIB, which is linked with the main program LLWC. This configuration facilitated performing code changes in the subroutines during model adaptation and testing for Arizona.

1.6.3 ***Input and output file requirements.*** – The Arizona version of the model, which uses sounding data from DRA, INW, and TUS, requires that three separate data files, each containing soundings for one sounding station, be available for calls from ARZWAT16. The files ARZPCP.STA and ARZSHED.STA containing the descriptions of precipitation stations and watersheds, respectively, must be available. Finally, the 36 files containing elevation information must also be available to the model program.

Regarding output, the model requests two output file names and then opens them. It also opens six other output files whose names are hard-coded in the main program. The names and contents of all of these files are discussed below in section 1.6.4. Hard-coding of output file names can easily be altered so that the operator is prompted for unique naming of the files.

1.6.4 *Performing a model run.* – Given below are the steps necessary to perform a model run. A listing of the prompts and respective answers in a typical run are given.

1. Make available to ARZWAT16, the sounding files to be run, ARZPCP.STA, ARZSHED.STA, and the 36 files with elevations.

2. Execute ARZWAT16.

PROMPTS AND ANSWERS IN A SAMPLE RUNNING OF ARZWAT16

Operator enters: ARZWAT16

Prompt: TYPE THE FILE NAME OF DETAILED RESULTS:

Operator enters: AZ78-88.OUT

Prompt: TYPE THE FILE NAME OF PRECIP STATION AVERAGE RESULTS:

Operator enters: AZ78-AVE.DAT

Prompt: GIVE THE STARTING AND ENDING DATES:

Operator enters: 781101,880430

Prompt: ENTER THE DRA SOUNDING DATA FILE NAME:

Operator enters: DRA78-88.DAT

Prompt: ENTER THE INW SOUNDING DATA FILE NAME:

Operator enters: INW78-88.DAT

Prompt: ENTER THE TUS SOUNDING DATA FILE NAME:

Operator enters: TUS78-88.DAT

Model responds to the screen:

781101 0 DRA
781101 0 INW
781101 0 TUS

NDATE = 781101 IEND = 880430

78110112 DRA
78110112 INW
78110112 TUS

Ndate = 781101 IEND = 880430

(The process continues.)

Given below are descriptions of the contents of each of the eight output files from a model run. The six files with hard-coded names are first described.

Output File	Contents
PCPDST1.OUT	Precipitation (in) for eight stations on the Mogollon Rim for easy user viewing on notebook-size paper.
PCPDST2.OUT	Precipitation for five additional stations (three on the Mogollon Rim plus two others to the south).
PCPMST1.OUT	Monthly precipitation (in) for each of the eight stations noted above.
PCPMST2.OUT	Monthly precipitation for each of the five stations noted above.
PCPDVOL.OUT	Integrated volume precipitation for each watershed described in the input file, ARZSHED.STA. In Arizona the watersheds were the Salt River and Verde River watersheds.
PCPMVOL.OUT	Monthly integrated volume precipitation for the Salt River and Verde River watersheds.
Name given to first file	Listing of the precipitation site names for which the model develops estimates, sounding date and time, information on the nature of the run (of use to those well versed on model technical details), current sounding and accumulating (for a specified period) station precipitation, and watershed volume precipitation. A sample of the output is given on figure 1.1. Accumulated grid point precipitation for the month is not given on the figure (because of difficulty in presentation on notebook size paper), but is also written to the output file in two formats, the first for subsequent development of graphics, and the second for easy user viewing.
Name given to second file	Mean precipitation for the 11 gauge sites on the Mogollon Rim, listed in the first column of the file, followed by 13 columns of precipitation for the 13 gauge locations of interest in the Arizona modeling. This file is constructed for input to a program that develops a correlation table for model estimates versus actual gauge measurements.

The precipitation grid written to an output file is constructed such that the first 26 columns of the 270° grid are written first, to accommodate some printers, followed by the remaining 22 columns. The user can "cut and paste" to view the grid as one would view a map. If the user chooses to become familiar with some of the model code, it is not difficult to modify the model output format.

It may be desirable to develop a precipitation grid for each day or each model run. A more complex version of subroutine RDUPAIR is available that does not require insertion of the 999999s to produce a precipitation grid. The user is prompted as to whether a grid is desired for each day for which the model is run. In this model version, the end of data or time period requested is determined and the effects of 888888s and 999999s are simulated. A single sounding run can also be performed with this version.

```
 001  FORT VALLEY                 7347.  13.30  45.40
 002  FLAGSTAFF                   7006.  14.00  44.20
 003  HAPPY JACK RS               7480.  16.25  39.80
 004  BLUE RIDGE RS               6810.  18.95  38.20
 005  CHEVELON RS                 7006.  20.75  37.40
 006  HEBER RS                    6590.  24.10  36.00
 007  SHOW LOW CITY               6400.  29.20  34.30
 008  PINE TOP FISH HAT           8180.  29.90  32.80
 009  HAWLEY LAKE                 8180.  31.50  31.40
 010  GREER                       8490.  34.10  31.80
 011  ALPINE                      8050.  37.00  29.90
 012  MT LEMMON                   7794.  22.20  14.20
 013  CHIRICAHUA NM               5300.  35.55   9.50
9999

RUN 790106 TIME - 0  700 WIND - 229.60  DURF FACTOR - 1.00  GRID - 220.  100  69
 TOP XTL LEVEL PRESSURE =    650.00      5
     3  3253.16      11
 TOP XTL LEVEL PRESSURE =    650.00      5
     2  3249.81      22
 TOP XTL LEVEL PRESSURE =    700.00      4
     1  3259.19      33
 -------- TOO DRY FOR PRECIP ------      10      51
 -------- TOO DRY FOR PRECIP ------       9      70
 FORT VALLEY               .21       5.39       5.39
 FLAGSTAFF                 .10       2.49       2.49
 HAPPY JACK RS             .13       3.33       3.33
 BLUE RIDGE RS             .00        .00        .00
 CHEVELON RS               .00        .00        .00
 HEBER RS                  .00        .00        .00
 SHOW LOW CITY             .00        .00        .00
 PINE TOP FISH HAT         .00        .00        .00
 HAWLEY LAKE               .00        .00        .00
 GREER                     .00        .00        .00
 ALPINE                    .00        .00        .00
 MT LEMMON                 .00        .00        .00
 CHIRICAHUA NM             .00        .00        .00
0 1   .00       .00 (volume precipitation for 1st watershed)
0 2   .01   5103.48 (volume precipitation for 2nd watershed)
```

Figure 1.1. – Sample model output. Contents of the first file for which the operator is prompted to supply a file name. The output includes precipitation station names for which the model develops estimates, some information on the nature of the run, precipitation in inches (first column) and millimeters (second column), and accumulating precipitation in millimeters (third column). Listed last is the volume precipitation in acre-feet.

2. REFERENCES

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Mission

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