HYDRO TECHNICAL NOTE - 3

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HYDROLOGIC
RESEARCH
LABORATORY

TSFP VERSION 2 USER'S MANUAL

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OFFICE
OF
HYDROLOGY

NATIONAL
WEATHER
SERVICE

NOAA

HYDROLOGIC RESEARCH LABORATORY
NATIONAL WEATHER SERVICE, NOAA
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T S F P   V E R S I O N   2

T: Time Series Analysis

S: State Space Modeling

F: Forecasting

P: Parameter Search

U S E R 'S   M A N U A L

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ADDENDUM -- HYDRO TECHNICAL NOTE 3

- T S F P Version 2 User's Manual -

The purpose of this addendum is to document the necessary changes in the input card stream of the computer program TSFP so that it can handle cases with model noise spectral density matrix Q dependent linearly on the observed input. Thus, insert the following after card no. 20 on page 13.

Card No.	Format	Variable Name	Description
Note: The following two cards are read only when INDIN > 0.			
20.1	1X,I5	INDRP	Index to define whether the Q-diagonal elements are proportional or inversely proportional to the observed input. INDRP ≥ 0 - Proportional INDRP < 0 - Inversely proportional
	F8.0	QPOR	Fraction denoting the time between current input observation time and previous input observation time where the input is interpolated, for use in the Q-INPUT relationship. It holds QPOR = 0 - Previous time QPOR = 1 - Current time
20.2	1X,5E12.5	W	Coefficients of proportionality in the expression: $D_i = \sum_{j=1}^{INPT} (W_{ji} \cdot U_j)$ where D_i is the square root of the ith diagonal Q-element if INDRP ≥ 0, or D_i is the inverse of the square root of the ith diagonal Q-element if INDRP < 0. The jth input is represented by U_j. The coefficients W_{ji} are read row-wise.

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SECTION 1

INTRODUCTION

This report provides documentation of the TSFP computer program, Version 2. Version 1 of the program was created at the Massachusetts Institute of Technology, Ralph M. Parsons Laboratory, under U.S. Government Contract No. NA80AA-H-00044. Version 2 was developed at the Hydrologic Research Laboratory of the National Weather Service when the author was a National Research Council - NOAA Research Associate. The new version is considerably expanded to include additional displays and statistics that aim at improved analysis of the user supplied models. In addition, effort was directed to make TSFP a self-contained program. Thus, Version 2 of the program does not rely on IMSL library subroutines.

Development of Version 2 was done on a PR1ME/750 computer, PRIMOS operating system. The program, on option, uses the DISSPLA library subroutines, installed in the PR1ME/750, to produce pen-plotter plots.

The TSFP User's Manual contains the following information about Version 2:

(1) Description of program operations (Section 2).

(2) Input data format for the program options (Section 3).

(3) Description of TSFP output (Section 3).

(4) Charts of the subroutine network for each TSFP option (Section 4).

(5) Descriptions of all subroutines used by TSFP (Section 5).

(6) Instructions to users on incorporation of their own data and subroutines into the TSFP subroutine network (Section 6).

Appendix A of the Version 2 Manual contains the User's Manual for Version 1 of the program.

SECTION 2

DESCRIPTION OF TSFP PROGRAM OPERATIONS

The TSFP program is written in FORTRAN IV. It consists of four generic subroutines: A TSFP-parameters read subroutine, PMSC; a problem specific input data subroutine, RDT1; an execution subroutine, EX; and a printout and display subroutine, OUTT. Each subroutine is called once, in the order listed above. Information is passed among the subroutines via five TSFP-arrays: a parameter array, PM; a descriptions array, IDSCR; an input data array, TSIN; an output array, TSOUT; and an auxiliary, statistical output array, TSTAT. PM contains values of the TSFP program options and parameters as well as of the user's model parameters. IDSCR stores the alphanumeric descriptions of the input-output data. TSIN contains the data necessary to run the user-specified model. TSOUT contains output generated by TSFP based on the operation activated by the user. TSTAT stores the statistical output of the TSFP program when the parameter search operation is activated.

The TSFP program was developed to serve as a research tool and is therefore not an operational program for applications.

The program operations are:

(1) Time Series Analysis (T)

Performs, on option, time series multivariate statistics computation and multiple linear regression for a vector of input time series.

(2) State Space Modeling (S)

Produces, on option, forecasts from a user-supplied model in state space form, with or without a statistical filter, using vector input and vector output time series. The continuous-discrete form of the Extended Kalman Filter is used.

(3) Forecasting (F)

Produces extended forecasts (for more than one time-step in the future) from a user-supplied model in state space form, complemented by a statistical filter, using vector input and vector output time series.

(4) Parameter Search (P)

Produces two-dimensional printer plots of the contours of several objective functions in a user-specified parameter domain and for a user-supplied model in state space form.

In addition to the main TSFP program units, four subroutines have been developed: FLOWS, PRECS, FLOWZ, and PRECZ. In these subroutines, the equations describing the state space form of: (1) the Station

Precipitation model and (2) the Integrated Hydrometeorological model (see Georgakakos and Bras, 1982) have been encoded. A fifth subroutine, RDT1, has been developed to read the input data (meteorological and hydrological data) that drive the above mentioned models.

Currently, the dimensions of the state variable arrays permit a maximum of 20 state variables and 5 observation variables in the user-supplied models. A maximum of 15 input variables is allowed. Twenty time series can be used with the time series analysis option. For covariance propagation in state space modeling, the arrays allow matrices with a maximum of 400 elements.

A maximum of 1500 time steps can be handled by the program. Thus time series with 1500 or fewer elements can be processed. This corresponds approximately to 1 year of 6-hourly observations.

The program allows for processing of non-adjacent time-periods. The array dimensions of Version 2 allow for a maximum of 10 such periods.

SECTION 3

INPUT-OUTPUT DATA

The sequence of the input cards and the relevant variable names and formats are given for the various operations.

The following cards are common to all operations:

Card No.	Format	Variable Name	Description
1	72A1	IDSCR	The run title. It appears at the top of every page of TSFP output.

Note: The following card allows for some preprocessing of the data.

Card No.	Format	Variable Name	Description
2	1X,I5	MTSNO	Number of time series to be used in the run. (Max = 20.)
	I5	IENDC	Total number of dates to be scanned when locating the periods of record to be used in the current run. (Max = 10,000.)
	I5	IAVER	Number of dates of record for which data will be averaged when time averages will be used as elements of the input time series.

Note: The following group of cards gives the initial and final dates for each of NOPER continuous periods of record that will combine to give the run period.

Card No.	Format	Variable Name	Description
3	1X,I5	NOPER	Number of continuous periods of record that constitute the run period. (Max = 10.)
4	1X,I5	IPER(1)	Initial year and month of the continuous period of record (YYMM).
	I5	IPER(2)	Initial day and hour of the continuous period of record (DDHH).
	I5	IPER(3)	Final year and month of the continuous period of record (YYMM).

Card No.	Format	Variable Name	Description
	I5	IPER(4)	Final day and hour of the continuous period of record (DDHH).

Note: Card 4 is repeated NOPER times.

Card No.	Format	Variable Name	Description
5	1X,I5	IOPER	Operation indicator: IOPER = 1 - Operation: T = 2 - : S = 3 - : F = 4 - : P

3.1 Time Series Analysis Operation Input

When the indicator IOPER takes the value of 1, the following cards are read:

Card No.	Format	Variable Name	Description
6	1X,I5	NU	Write statements unit for TSFP output.
	I5	LREGAN	Time series analysis option LREGAN = 0 - Time series multivariate statistics = 1 - Multiple linear regression
	I5	MTOT	Number of time series to be used in the current run. (Max = 20.)
	I5	NDTEND	Number of data points in each time series. It should be the same for all time series in the current run. (Max = 1500.)
	I5	IMUL	Regression indicator. IMUL = 0 - Program will perform regression. = 2 - Explanatory variables will be lagged one time step with respect to the dependent variable.

Card No.	Format	Variable Name	Description
	I5	IMRPR	If regression is active (i.e., LREGAN = 1 and IMUL > 0 IMRPR = 0 - Parameter estimation > 0 - Prediction with specified parameters Otherwise, set IMRPR to 0.
	F8.0	ZABSNT	Value to indicate a missing data point in the record.
7	1X,5E12.5	CVUNT	Time series units - conversion for display purposes.
8	1X,25A1	IDSCR	Description of the time series.
	1X,20A1	IDSCR	Units of the time series.
	1X,6A1	IDSCR	Symbol of the time series to be used for TSFP printout.

Note: Card 8 is repeated MTSNO times.

Note: The next 2 cards are necessary only when the multiple linear regression option has been selected.

Card No.	Format	Variable Name	Description
9	1X,I5	IPRD	If positive, printer plot of observations and predictions is produced.
	I5	ISV	If positive, the predictions of the multiple linear regression are saved in file ISV.
10	1X,10I5	ISQNO	Order numbers of the time series that participate in the multiple linear regression, the dependent time series read last. These numbers are used to locate the time series in the list of the MTSNO time series read in.

Note: The following card is read when the regression prediction indicator IMRPR is greater than 0.

Card No.	Format	Variable Name	Description
11	1X,5E12.5	X	Prespecified regression parameters and regression constant (read last) when regression prediction with prespecified parameters is active. The parameters are read in the same order as in ISQNO.

Note: The following two cards provide information to be printed as headings in the TSFP output displays.

12	1X,36A1	IXDSC	Description of the X-axis in displays of predictions and observations. For time series, use: "TIME STEP NUMBER".
13	1X,50A1	IALP1	Heading in the multivariate statistics operation printout. Suggested: "TIME SERIES MULTIVARIATE STATISTICS".

3.2 S, F, P Operations Input

When the indicator IOPER takes the values 2, 3, and 4, the following cards are read:

Card No.	Format	Variable Name	Description
6	1X,I5	IOPFC	Display graphics option: 1 - Hardcopy output 2 - Screen display >2 - No pen-plotter graphics
	I5	IWGHT	Option to specify the accuracy weights in the integration of the user supplied system of differential equations: 1 - Equal weights Other - Input weights (See DERYY, Card 11 on p.10.)
	I5	IPLOP	Detailed printout option for all time steps: 0 - No printout 1 - Detailed printout

Card No.	Format	Variable Name	Description
7	1X,E12.5	TOLINT	Bound on accuracy in the integration of model differential equations.
	E12.5	SUBS	Number of subdivisions of the time step for integration (real).
	E12.5	CFVMX	Maximum coefficient of variation for statistical linearization.
8	1X,I5	NU	Write statements unit for TSFP printout.
	I5	ICOR	If positive, filtering of the noise and state estimation is performed.
	I5	NXFORC	Number of extended forecast steps. (Max = 6.)
	I5	NDTEND	Number of time steps for the current run, including initial condition. (Max = 1500.)
	I5	N	Number of state variables in the user-supplied state space form model. (Max = 20.)
	I5	INPT	Number of input variables in the user-supplied state space form model. (Max = 15.)
	I5	M	Number of observation variables in the user-supplied state space form model. (Max = 5.)
9	1X,E12.5	DT1	Forecast time step. The Station Precipitation model uses a time step of 3600 seconds, while the Integrated Hydrometeorological model uses a time step of one 6-hour period.
	E12.5	CNV1	Conversion factor to display time dimensions.

Card No.	Format	Variable Name	Description
	E12.5	ZABSNT	Number to indicate a missing value.
	E12.5	PORZ	Fraction of the current input values used in the user-supplied model to compute the response. (1-PORZ) corresponds to the one time-step lagged input variables.
10	1X,I5	IPRCV	If positive, covariance propagation is performed.
	I5	IRSDPL	If positive, residual time series are displayed.
	I5	IRSDPD	If positive, displays of observations and predictions result.
	I5	INMES	If positive, display the normalized residual time series.
	I5	NOUTPM	Number of user defined "physical quantities" for which time series are to be displayed.
	I5	NSTPRD	If positive, display predicted state means, standard deviations, and selected state correlations.
	I5	NCORX	Number of selected state correlation coefficients to be displayed.
	I5	NSTEST	If positive, display estimated state means, standard deviations, and NCORX state correlations.
	I5	NFLTR	If positive, display filter gains and the standard deviation of the innovations sequence.
	I5	NLINE	If positive, display the eigenvalues of the linearized system. Currently equal to 0.

Card No.	Format	Variable Name	Description
10a	1X,I5	IPDPL	If positive, display sample probability distributions vs. a normal distribution with sample mean and variance. Currently equal to 0.
	I5	IHSPL	Display histograms of 1) predicted residuals normalized by the predicted response mean and 2) observations together with predictions. Currently equal to 0.
	I5	ISTVR	If positive, display standardized variates of input and output time series.

Note: The following card is read only if the integration weights indicator IWGHT (Card 6 on p.7) is not equal to 1.

Card No.	Format	Variable Name	Description
11	1X,5E12.5	DERYY	Read N weights for the integration of the user supplied differential equations. If covariance differential equations are involved, the state equations are weighted by 0.5 and the covariance ones by 0.5. The weights are normalized internally. Thus the user need only input numbers that indicate relative magnitude.
12	1X,I5	NMPARM	Number of user's model parameters, including option indicators, if any.
	I5	LCOPT	Number of user's model options.
	I5	NLCQPM	Number of parameters related to the specification of the model noise spectral density matrix Q. If n is the order of the state vector, this number is equal to: $1 + \frac{n \cdot (n+1)}{2}$, under the condition in Card No. 20.

Card No.	Format	Variable Name	Description
	I5	NLCRPM	Number of parameters related to the specification of the observations noise covariance matrix R. If m is the order of the observations vector, then a) if the variances in R depend linearly on the observed output, $NLCRPM = 2+m^2+\frac{m\cdot(m+2)}{2}$, b) if no linear dependence exists, $NLCRPM = 1+\frac{m\cdot(m+2)}{2}$. See also Card Nos. 22, 23, 24.
13	1X,I5	IIOCPL	If positive, complete statistical analysis (CSA) of observed input and observed output time series (TS) is performed.
	I5	IISCPL	If positive, CSA of observed input and simulated output TS is performed.
	I5	IIRCPL	If positive, CSA of observed input and predicted residuals TS is performed.
	I5	IOSCPL	If positive, CSA of observed output and simulated output TS is performed.
	I5	IORCPL	If positive, CSA of observed output and predicted residuals TS is performed.
	I5	IRESCP	If positive, CSA of the residual TS is performed.
	I5	INCPL	If positive, CSA of the normalized residual TS is performed.
	I5	NLTPM	If positive, CSA of the TS of the first NLTPM of the NOUTPM "physical quantities" is performed.
	I5	NCOEFF	If positive, the least squares performance indices: 1) coefficient of efficiency

Card No.	Format	Variable Name	Description
			2) coefficient of determination 3) coefficient of persistence 4) coefficient of extrapolation are computed for the forecast lead time of one time step.
	I5	IMXLK	If positive, the log-likelihood function is computed. The log-likelihood function is displayed only for the parameter search option (IOPER=4).

Note: CSA of several time series consists of computing, for each time series: time averages, time coefficients of variation, time skewness and kurtosis coefficients, time cross-correlations between time series, and time autocorrelations.

Note: The following two cards are read only when the parameter search operation P (IOPER=4), is active.

Card No.	Format	Variable Name	Description
14	1X,I5	IMDRSP	If positive, two-dimensional contour plots of the user-supplied model response statistics are produced in addition to the contours related to the residuals statistics.
	I5	NP1	Number of values of the ordinate parameter to be used in the search.
	I5	NP2	Number of values of the abscissa parameter to be used in the search.
	I5	ILP1	Identifier for the ordinate parameter.
	I5	ILP2	Identifier for the abscissa parameter.
15	1X,E12.5	P1LO	Lowest value of the ordinate parameter to be considered in the two-dimensional search.

Card No.	Format	Variable Name	Description
	E12.5	P1UP	Highest value of the ordinate parameter to be considered in the two-dimensional search.
	E12.5	P2LO	Lowest value of the abscissa parameter to be considered in the two-dimensional search.
	E12.5	P2UP	Highest value of the abscissa parameter to be considered in the two-dimensional search.
16	1X,10I5	MDOP	User's model options.
17	1X,5E12.5	PARM	User's model parameter values.
18	1X,5E12.5	X	Initial state mean vector.

Note: The following seven cards are read only when the covariance propagation option is active (IPRCV > 0).

Card No.	Format	Variable Name	Description
19	1X,5E12.5	X	Initial standard deviations of the state variables. The initial state covariance matrix is assumed diagonal.
20	1X,I5	INDIN	If positive, the diagonal elements of the model noise spectral density matrix Q depend linearly on the observed input. Currently, it is equal to 0.
21	1X,5E12.5	X	Square roots of the diagonal elements of the model noise spectral density matrix Q.

Note: The following four cards will be read only when the filtering option is active (ICOR > 0).

Card No.	Format	Variable Name	Description
22	1X,I5	INDOB	If positive, the diagonal elements of the observations noise covariance matrix R depend linearly on the observed output.

Note: The following two cards are read only when INDOB > 0.

Card No.	Format	Variable Name	Description
23	1X,I5	INDRP	Index to define whether the R-diagonal elements are proportional or inversely proportional to the observed output.

Card No.	Format	Variable Name	Description
			INDRP > 0 - Proportional INDRP < 0 - Inversely Proportional
24	1X,5E12.5	W	Coefficients of proportionality in the expression: $D_i = \sum_{j=1}^{M} (W_{ji} \cdot Z_j)$ where D_i is the square root of the ith diagonal R-element if INDRP > 0, or D_i is the inverse of the square root of the ith diagonal R-element if INDRP < 0. The jth output is represented as Z_j. The coefficients W_{ji} are read row-wise.
25	1X,5E12.5	X	Square root of the constant part of the R-diagonal elements.

Note: The following cards contain descriptions and headings to be used in the TSFP printout.

Card No.	Format	Variable Name	Description
26	1X,4A1	IDSCR	Units of the time variable for displays.
27	1X,25A1	IDSCR	Description of the time series for the user-supplied model.
	1X,20A1	IDSCR	Units of the time series for the user-supplied model.
	1X,6A1	IDSCR	Symbol to be used in TSFP displays for the time series for the user-supplied model.
	1X,12A1	IDSCR	Description of the type of the time series for the user-supplied model. It can be: "FORECASTED" or "OBSERVED"

Note: Card 27 is repeated for all input, and then for all output time series.

Card No.	Format	Variable Name	Description
28	1X,25A1	IDSCR	Comments regarding the continuous period of record.

Note: Card 28 is repeated for all the continuous periods of record (NOPER times).

29	1X,40A1	IDSCR	Information regarding the topographic location of the data collection point.
30	1X,40A1	IDSCR	User's model title (without the word "model").
31	1X,25A1	IDSCR	Description of user's model parameter.
	1X,20A1	IDSCR	Units of user's model parameter.
	1X,6A1	IDSCR	Symbol to be used in TSFP displays for user's model parameter.

Note: Card 31 is repeated for all user's model options and parameters (NMPARM times).

32	1X,25A1	IDSCR	Description of user's model state variable.
	1X,20A1	IDSCR	Units of user's model state variable.
	1X,6A1	IDSCR	Symbol to be used in TSFP displays for user's model state variable.

Note: Card 32 is repeated for all user's model state variables (N times).

Note: The following 13 cards are read only when operation S is active (IOPER = 2).

33	1X,36A1	IXDSC	10X, "TIME STEP NUMBER"
34	1X,36A1	IYDSC1	10X, "STATE CORRELATIONS"
35	1X,36A1	IYDSC2	2X, "FILTER GAINS FOR THE STATE"
36	1X,36A1	IYDSC3	"FILTER INNOVATIONS ST. DEVIATION OF"
37	1X,36A1	IYDSC4	2X, "EIGEN VALUES OF LINEARIZED SYSTEM"
38	1X,36A1	IYDSC5	2X, "STANDARDIZED TIME SERIES"
39	1X,36A1	IALP1	12X, "INPUT-OUTPUT STATISTICS"

Card No.	Format	Variable Name	Description
40	1X,36A1	IALP2	10X, "INPUT-PREDICTIONS STATISTICS"
41	1X,36A1	IALP3	11X, "INPUT-RESIDUALS STATISTICS"
42	1X,36A1	IALP4	9X, "OUTPUT-PREDICTION STATISTICS"
43	1X,36A1	IALP5	10X, "OUTPUT-RESIDUALS STATISTICS"
44	1X,36A1	IALP6	15X, "RESIDUALS STATISTICS"
45	1X,36A1	IALP7	9X, "NORMALIZED RESIDUALS STATISTICS"
46	1X,36A1	IALP8	3X, "USER'S MODEL PHYSICAL QUANTITIES STATISTICS"

Note: The following eight cards are read only when operation F (IOPER = 3) is active.

Card No.	Format	Variable Name	Description
33	1X,25A1	IALP1	"EFFICIENCY COEFFICIENT"
34	1X,25A1	IALP2	"DETERMINATION COEFFICIENT"
35	1X,25A1	IALP3	5X, "SLOPE ESTIMATE"
36	1X,25A1	IALP4	3X, "INTERCEPT ESTIMATE"
37	1X,25A1	IALP5	2X, "SLOPE STANDARD ERROR"
38	1X,25A1	IALP6	"INTERCEPT STANDARD ERROR"
39	1X,25A1	IALP7	"PERSISTENCE COEFFICIENT"
40	1X,25A1	IALP8	"EXTRAPOLATION COEFFICIENT"

Note: The following 13 cards are read only when operation P (IOPER = 4) is active.

Card No.	Format	Variable Name	Description
33	1X,60A1	IALP1	14X, "ABSOLUTE PROPORTIONAL MEAN ERROR"
34	1X,60A1	IALP2	16X, "PROPORTIONAL STANDARD ERROR"
35	1X,60A1	IALP3	2X, "PROPORTION OF LAG-1 CORRELATION UNEXPLAINED BY THE MODEL"

Card No.	Format	Variable Name	Description
36	1X,60A1	IALP4	13X,"ABSOLUTE NORMALIZED RESIDUAL ERROR"
37	1X,60A1	IALP5	13X, "STANDARD NORMALIZED RESIDUAL ERROR"
38	1X,60A1	IALP6	9X, "LAG-1 CORRELATION OF NORMALIZED RESIDUALS"
39	1X,60A1	IALP7	9X, "TIME AVERAGE VALUES OF PHYSICAL QUANTITIES"
40	1X,60A1	IALP8	4X, "TIME COEFFICIENT OF VARIATION OF PHYSICAL QUANTITIES"
41	1X,60A1	IALP9	18X, "LOG-LIKELIHOOD FUNCTION"
42	1X,60A1	IALP10	7X, "ABSOLUTE PROPORTIONAL ERROR IN THE OUTPUT MEAN"
43	1X,60A1	IALP11	2X, "ABSOLUTE PROPORTIONAL ERROR IN THE OUTPUT STND DEVIATION"
44	1X,60A1	IALP12	"ABSOLUTE PROPORTIONAL ERROR IN THE OUTPUT LAG-1 CORRELATION"
45	1X,60A1	IALP13	10X, "MODEL-SYSTEM OUTPUT CROSS-CORRELATION"

In addition to the above given sequence of input cards, the user supplies a subroutine to read the data (time series) necessary for the TSFP operation in use.

For the Station Precipitation (SP) model and the Integrated Hydrometeorological (IH) model in Georgakakos and Bras (1982), the time series data are read in subroutine RDT1.

For the Station Precipitation model:

Format	Variable Name	Description
I4	NDT1	Year and month of the current values read (YYMM).
I4	NHR1	Day and hour of the current values read (DDHH).
F7.3	P	Station pressure reading in mm Hg.

Format	Variable Name	Description
I3	IT	Station air-temperature reading in degrees F.
I3	ITD	Station dewpoint termperature reading in degrees F.
I3	ITW	Station wet-bulb temperature reading in degrees F.
F7.3	PI	Station precipitation rate reading in inches/hour.

For the Integrated Hydrometeorological model:

Format	Variable Name	Description
1X,I4	NDT1	Year and month of the current values read (YYMM).
I4	NHR1	Day and hour of the current values read (DDHH).
F7.3	P	Station pressure reading in hundredths of an inch Hg.
I3	IT	Station air-temperature reading in degrees F.
I3	ITD	Station dewpoint temperature reading in degrees F.
E12.5	PI	Six-hourly mean areal precipitation reading in mm/6-hours.
E12.5	Q	Six-hourly outflow discharge rate in mm/6-hours.
E12.5	EVD	Six-hourly mean areal potential evapotranspiration rate in mm/6-hours.

Subroutine RDT1 converts temperature input to degrees K and pressure input to kg/(m • sec^2). For the SP model, precipitation rate is converted to [mm/hour] units.

Printed output from the TSFP program is produced in subroutine OUTS. The format of the first page of program and active operation identification printout is the same for all operations. The user-supplied run title is printed on every page of output. The last page, containing array storage information and virtual CPU time estimates, also has the same format for all TSFP operations.

Description of the printed output for each TSFP operation is given next.

3.3 Time Series Analysis Operation Output

The first page of printout contains the following information about the time series:

- Description
- Units
- Symbols
- Total number of data points

Other output depends on the option selected.

Multivariate statistics option:

- Time averages
- Time coefficients of variation
- Time skewness and kurtosis coefficients
- Complete table of cross-correlations between concurrent values of the various time series and up to lag-9 autocorrelation for each time series.

Multiple linear regression option with parameter estimation:

- Standard deviation of the one-step-ahead predicted residuals
- Estimates of regression parameters and associated standard errors
- t and F statistics
- Printer plots of the predicted and observed time series

(Note: Whenever there are values missing in the input time series, a message with the number of missing values and the time step on which they occur is printed.)

Multiple linear regression option with prediction:

- Printer plots of the predicted and observed time series
- Complete statistical analysis (CSA) or prediction residuals

3.4 S,F,P Operations Output

The following items are contained in the output for each of the three operations -- S, F, and P:

- Input and output time series descriptions, units, symbols, and types (observed-forecasted).
- Information on data records used in the run (dates defining periods of record, topographical locations of data collection points).
- User's model parameters descriptions, units, symbols, and values.
- User's model states descriptions, units, symbols, and initial values.
- The initial state covariance matrix, the model error spectral density matrix, and the observations error covariance matrix.

Additional output for the State Space Modeling Operation:

- Printer plots of the predictions and observations.
- Mean, standard deviation, and skewness coefficient of the residual time series.
- Least squares performance indices (coefficients of efficiency, determination, persistence, and extrapolation). See Georgakakos and Bras, 1982.

Additional output for the Forecasting Operation (for extended forecasts up to a maximum lead time specified by the user and not greater than six time steps):

- Least squares performance indices (coefficients of efficiency, determination, persistence, and extrapolation).
- Mean and standard deviation of the residuals.

Additional output for the Parameter Estimation Operation:

- Two-dimensional contours corresponding to the performance indices (absolute proportional average error, proportional standard error, cross-correlation coefficient, and log-likelihood function). See Georgakakos and Bras, 1982.

SECTION 4

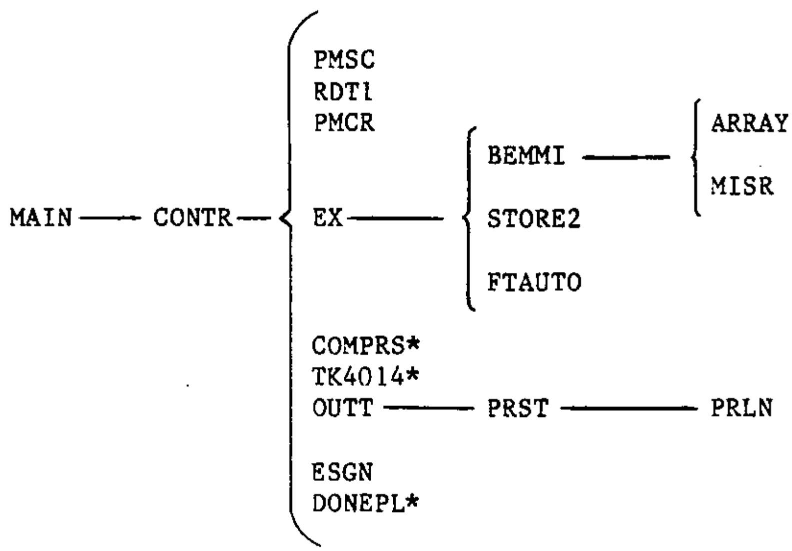
TSFP SUBROUTINE NETWORK

The sequence of the subroutine calls is given next for the various operations of the TSFP program. Also included are the subroutine call-networks related to the Station Precipitation and the Integrated Hydro-meteorological models documented in Georgakakos and Bras, 1982. The order in which the subroutines are called in the following charts is from left to right. Multiple calls to the same subroutine are not shown.

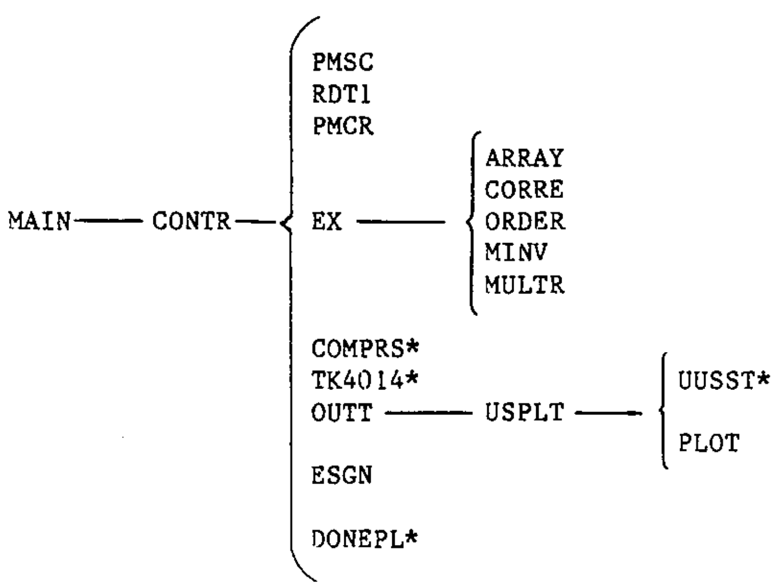
Subroutines identified with an asterisk link the TSFP program to the DISSPLA library package on the PRIME computer, for the construction of pen-plotter plots. They can be removed or replaced when the program is transferred to another system.

1) TIME SERIES ANALYSIS OPERATION

(a) Multivariate Statistics Option



(b) Multiple Linear Regression



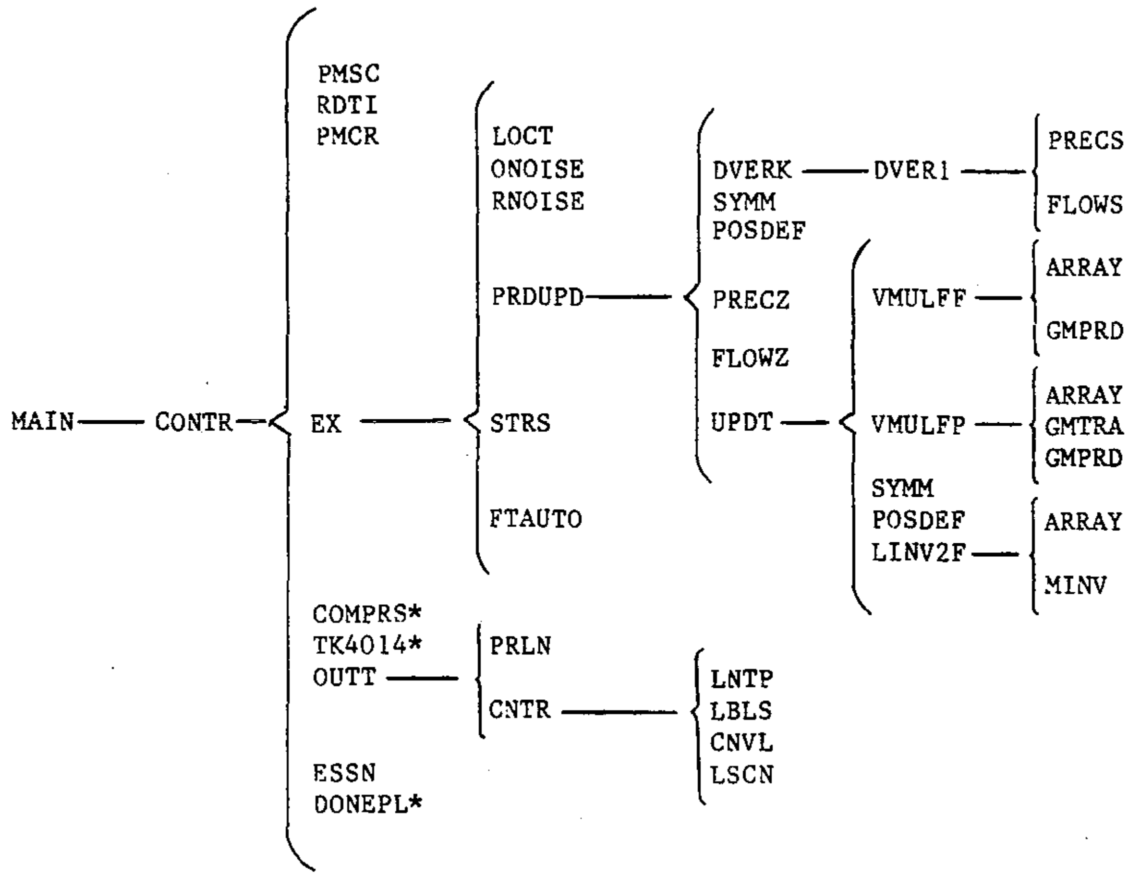
2) STATE SPACE MODELING OPERATION

- MAIN — CONTR
  - PMSC
  - RDT1
  - PMCR
  - EX
    - LOCT
    - QNOISE
    - RNOISE
    - PRDUPD
      - DVERK — DVER1
        - PRECS
        - FLOWS
      - SYMM
      - POSDEF
      - PRECZ
      - FLOWZ
      - UPDT
        - VMULFF
          - ARRAY
          - GMPRD
        - VMULFP
          - ARRAY
          - GMTRA
          - GMPRD
        - SYMM
        - POSDEF
        - LINV2F
          - ARRAY
          - MINV
    - STRS
    - BEMMI
      - ARRAY
      - MISR
    - STORE2
    - FTAUTO
    - COFF
      - ARRAY
      - CORRE
      - ORDER
      - MINV
      - MULTR
  - COMPRS*
  - TK4014*
  - OUTT
    - PRLN
    - USPLT
      - UUSST*
      - PLOT
    - PRST — PRLN
  - ESGN
  - DONEPL*

3) FORECASTING OPERATION

- MAIN
  - CONTR
    - PMSC
    - RDTI
    - PMCR
    - EX
      - LOCT
      - ONOISE
      - RNOISE
      - PRDUPD
        - DVERK
          - DVER1
            - PRECS
            - FLOWS
        - SYMM
        - POSDEF
        - PRECZ
        - FLOWZ
        - UPDT
          - VMULFF
            - ARRAY
            - GMPRD
          - VMULFP
            - ARRAY
            - GMTRA
            - GMPRD
          - SYMM
          - POSDEF
          - LINV2F
            - ARRAY
            - MINV
      - STRS
      - COFF
        - ARRAY
        - CORRE
        - ORDER
        - MINV
        - MULTR
    - COMPRS*
    - TK4014*
    - OUTT
      - PRLN
    - ESGN
    - DONEPL*

4). PARAMETER SEARCH OPERATION



5) STATION PRECIPITATION MODEL SUBROUTINES

- PRECS
  - EFFUN
    - MIXRAT
    - NTN3 — DRPT — MIXRAT
    - NEWTON — FUNCT
    - NTN2
  - V12F
  - DERINP
  - VRPR
    - VMULFF
      - ARRAY
      - GMPRD
    - VMULFP
      - ARRAY
      - GMTRA
      - GMPRD

- PRECZ
  - EFFUN
    - MIXRAT
    - NTN3 — DRPT — MIXRAT
    - NEWTON — FUNCT
    - NTN2
  - VPNF
  - DERINP

6) INTEGRATED HYDROMETEOROLOGICAL MODEL SUBROUTINES

- FLOWS
  - EFFUN
    - MIXRAT
    - NTN3 — DRPT — MIXRAT
    - NEWTON — FUNCT
    - NTN2
  - VPNF
  - V12F
  - DERU
  - VRPR
    - VMULFF
      - ARRAY
      - GMPRD
    - VMULFP
      - ARRAY
      - GMTRA
      - GMPRD

- FLOWZ
  - EFFUN
    - MIXRAT
    - NTN3 — DRPT — MIXRAT
    - NEWTON — FUNCT
    - NTN2
  - VPNF
  - DERU

SECTION 5

DESCRIPTION OF TSFP SUBROUTINES

Each subroutine appearing on the TSFP subroutine-network charts is described in the following. The information given in each case consists of:

- a short description of the operation performed by the subroutine
- a list of variables that serve as arguments in the subroutine, with a description of each one, and
- a list of the COMMON blocks needed.

The subroutines are divided into three groups. Group A is the group of subroutines pertaining to the TSFP program, group B is the group pertaining to the Station Precipitation and Integrated Hydrometeorological models of Georgakakos and Bras (1982), and group C is the group of subroutines (marked with asterisks in the previous charts) which link TSFP to the DISSPLA library.

The subroutines are in alphabetical order within each group.

For details on the DISSPLA library, the reader is referred to: "Display Integrated Software System and Plotting Language, User's Manual Version 9.0," published by Integrated Software Systems Corporation, San Diego, California.

For easy reference, a list of contents precedes the subroutine descriptions.

A) TSFP Intrinsic Subroutines

ARRAY (MODE, I, J, N, M, S, D)

Description:

ARRAY converts a data array from single to double dimension or vice versa. It is used to link the TSFP program subroutines which have double dimension arrays and the SSP library based subroutines, which operate on single dimension arrays of data. It is based on subroutine ARRAY of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

MODE (INPUT)	Code indicating type of conversion: 1 - from single to double dimension; 2 - from double to single dimension
I (INPUT)	Number of rows in data matrix.
J (INPUT)	Number of columns in data matrix.
N (INPUT)	Number of rows in the DIMENSION statement for the matrix D.
M (INPUT)	Number of columns in the DIMENSION statement for the matrix D.
S (INPUT/OUTPUT)	If MODE = 1, this is an input vector which contains the elements of a data matrix of size I x J. Column (I+1) of the data matrix follows column I, etc. If MODE = 2, this vector is output, representing a data matrix of size I x J containing its columns consecutively. The length of S is IJ = I * J.
D (INPUT/OUTPUT)	If MODE = 1, this matrix of size N x M is output, containing a data matrix of size I x J in the first I rows and J columns. If MODE =2, this N x M matrix is input containing a data matrix of size I x J in the first I rows and J columns.

Note that the vector S can be the same location as matrix D.

COMMON Blocks:

None.

BEMMI (XX, N, M, IX, XMEAN, V, A, INCD, IER)

Description:

BEMMI is the driver subroutine for the computation of multivariate time series statistics. It sets the code for missing values to -999999., and converts the two-dimensional array that holds the time series values to one-dimensional, for processing by the statistics subroutine MISR. Upon return from MISR it converts the time series holding array to a two-dimensional one.

Argument List:

XX (INPUT)	A two-dimensional array holding the time series. Thus, XX(I,J) is the Ith element of the Jth time series.
N (INPUT)	Number of values in each time series including missing value indicators.
M (INPUT)	Number of time series to be processed. Up to 20 are allowed.
IX (INPUT)	First dimension of the XX array.
XMEAN (OUTPUT)	Vector holding the time average of the time series.
U (OUTPUT)	Vector dimensioned (3,20), holding in: V (1,I) the standard deviation of the Ith time series; V (2,I) the skewness coefficient of the Ith time series; V (3,I) the kurtosis coefficient of the Ith time series.
A (OUTPUT)	Vector storing the product-moment correlation coefficients. Only the upper triangular portion of the full matrix is stored.
INCD (OUTPUT)	Number of pairs of observations used in computing the elements of matrix A.
IER (OUTPUT)	Error code. For no error it takes the value of 0. See the argument list of subroutine MISR for complete description.

COMMON Blocks:

None.

CNTR (IMXMN, NPRM, X1C, X2C, YC, N1, N2, PARM, ITITLE, NV, IIDATA, IDMPAR, IDMPRM, IDMTLE)

Description:

CNTR creates a printer-plot of a two-dimensional function, in the space defined by the user. It also prints on the same page values and descriptions of other variables remaining constant. Nine contours of the two-dimensional function are plotted, labeled by the numbers 1 to 9. The extremum of the function with the plot-space is labeled by 0 and its value is printed together with the values of the two variables that yield the extremum. A key to the contour values is also printed.

The user supplies the coordinate arrays X1C and X2C with the coordinates of the points where the function values are known. The subroutine linearly interpolates in space and determines the function values at the grid points of a grid-network with 31 ordinate and 31 abscissa values. Those values are the one used for the contour plot. If the value of the variable IDSSPL (located in the COMMON block PLOTT) is less than or equal to 2, the subroutine CNTRP is called to produce pen-plotter contour-plots based on the DISSPLA package.

Argument List:

IMXMN (INPUT)	Index to specify whether the two-dimensional function has a minimum (-1) or maximum (+1) in the plot-space.
NPRM (INPUT)	Number of parameters that remain constant for the plot under construction.
X1C (INPUT)	Array storing the ordinates of the function.
X2C (INPUT)	Array storing the abscissas of the function.
YC (INPUT)	Two-dimensional array holding the function values. In YC (I,J), I corresponds to the ordinate and J to the abscissa.
N1 (INPUT)	Number of ordinate values for which the function values are known.
N2 (INPUT)	Number of abscissa values for which the function values are known.
PARM (INPUT)	Array that stores the parameters that remain constant for the plot under construction.

ITITLE (INPUT)	Array that holds the descriptions of the plot variables, the plot labels, and descriptions of the parameters that remain constant for the plot under construction. The run description, with 72 characters, is followed by the ordinate and abscissa descriptions, with 10 characters each, and then the descriptions of the constant parameters are stored, with 10 characters each.
NU (INPUT)	Unit number of the output file to which TSFP output is directed.
IIDATA (INPUT)	Dimension of the array X1C.
IDMPAR (INPUT)	Dimension of the array X2C. The array YC is dimensioned as YC (IDMPAR, IDMPAR).
IDMPRM (INPUT)	Dimension of the constant-parameters array PARM.
IDMTLE (INPUT)	Dimension of the character array ITITLE.

COMMON Blocks:

PLOTT.

CNVL (Y, IS1, IS2, OPT, IOPT1, IOPT2, VL, IMXMN)

Description:

CNVL determines the extremum of the function in the plot-space and, based on the function characteristics, the values of the 9 contours to be used in the function contour plotting. The contour values are determined based on the following steps:

- Determine the maximum absolute function differences for the coordinate directions originating from the predetermined extremum (4 differences).

- Eliminate the directions where no change occurs and take the geometric mean of the function differences for the rest of the directions.

- Determine the maximum difference between the geometric mean and the difference in each direction. If the max difference is greater than the geometric mean in absolute value, allow for two extra contour lines in that direction.

- Determine the contour values by dividing the geometric mean by 9 (or by 7 if two contour lines are allowed in any direction as in above step) and then using

  $$VL(I) = OPT \pm I * DELTA.$$

  OPT is the extremum value, I is the contour sequence number (from 1 to 9) and DELTA is the quotient of the geometric mean by 9 (or 7). VL(I) is the value of the Ith contour. Plus is used when OPT is a minimum and minus when it is a maximum.

Argument List:

Y (INPUT)	Two-dimensional function whose contours are to be plotted.
IS1 (INPUT)	The number of ordinate values for which the function is known.
IS2 (INPUT)	The number of abscissa values for which the function is known.
OPT (OUTPUT)	The function extremum.
IOPT1 (OUTPUT)	The sequence number of the ordinate where the extremum occurs.
IOPT2 (OUTPUT)	The sequence number of the abscissa where the extremum occurs.

VL (OUTPUT)	Array that holds the 9 contour values.
IMXMN (INPUT)	Index to determine whether the function has a minimum (-1) or a maximum (+1).

COMMON Blocks:

None.

COFF (N, LAG, OBS, PRED, COE1, COE2, COE3, COE4, PRM, STPRM, IIDATA)

Description:

COFF computes the least squares performance indices: coefficient of efficiency, coefficient of determination, coefficient of persistence, and coefficient of extrapolation, for a certain forecast lead time in the future. The various coefficients are defined in the following:

$$\text{- Coefficient of efficiency} = \frac{\Sigma\,[Q_o(i) - \bar{Q}_o]^2 - \Sigma\,[Q_o(i) - Q_p(i)]^2}{\Sigma\,[Q_o(i) - \bar{Q}_o]^2}$$

$$\text{- Coefficient of determination} = 1 - \frac{\Sigma\,[Q_o(i) - Q_e(i)]^2}{\Sigma\,[Q_o(i) - \bar{Q}_o]^2}$$

$$\text{- Coefficient of persistence} = 1 - \frac{\Sigma\,[Q_o(i) - Q_p(i)]^2}{\Sigma\,[Q_o(i) - Q_o(i-j)]^2}$$

$$\text{- Coefficient of extrapolation} = 1 - \frac{\Sigma\,[Q_o(i) - Q_p(i)]^2}{\Sigma\,[Q_o(i) - Q_\ell(i)]^2}$$

where: Σ is the symbol of summation with counting index starting at 1 and ending at the total number of values in each time series; $Q_o(i)$ is the observed time series; $\bar{Q}_o$ is the time average of $Q_o(i)$; $Q_p(i)$ is the time series predicted by the user's model; $Q_e(i)$ is the estimated time series that results from the regression line of Q_o on Q_p; $Q_o(i-j)$ is the observed time series lagged j time steps, where $j \cdot \Delta t$ is the forecast lead time; and $Q_\ell(i)$ is the predicted time series that results from the straight line fitted to the two most recent observations.

Argument List

N (INPUT)	Total number of values in the observed and predicted time series to be used in the computation of the least squares performance indices.
LAG (INPUT)	The forecast lead time.
OBS (INPUT)	Vector that stores the observed time series.
PRED (INPUT)	Vector that stores the predicted time series.
COE1 (OUTPUT)	Coefficient of efficiency.
COE2 (OUTPUT)	Coefficient of determination.
COE3 (OUTPUT)	Coefficient of persistence.
COE4 (OUTPUT)	Coefficient of extrapolation.
PRM (OUTPUT)	Vector of dimension 2, storing the slope and intercept of the regression line of Q_o on Q_p.
STPRM (OUTPUT)	Vector of dimension 2, storing the standard deviations of the slope and intercept of the regression line of Q_o on Q_p.
IIDATA (INPUT)	Dimension of the vectors OBS and PRED.

COMMON Blocks:

LREGR.

CONTR (IDIMPM, PM, IDIMSC, IDSCR, IMDTSI, TSIN, IDMTSO, TSOUT, IDMTST, TSTAT)

Description

CONTR is the TSFP program control subroutine. It calls the input-data supplying routines PMSC and RDT1, the execution subroutine EX, and the printout subroutine OUTT. It calls the PR1ME/750 (PR1MOS operating system) intrinsic timing function CTIM$ that determines the CPU time used by the various program operations. Upon transfer of the program to another computer system, the timing subroutine should be accordingly changed.

Argument List:

IDIMPM (INPUT)	Dimension of the TSFP parameter array PM.
PM (INPUT)	Array where all options and parameters of the program TSFP are stored.
IDIMSC (INPUT)	Dimension of the description array IDSCR.
IDSCR (INPUT)	Array where all the parameter and input data descriptions related to the chosen TSFP operation are stored.
IDMTSI (INPUT)	Dimension of the raw data array TSIN.
TSIN (INPUT)	Array where the raw input data related to the chosen TSFP operation are stored.
IDMTSO (INPUT)	Dimension of the TSFP output array TSOUT.
TSOUT (OUTPUT)	Array where output time series and statistical performance indices are stored.
IDMTST (INPUT)	Dimension of the auxiliary statistical array TSTAT.
TSTAT (OUTPUT)	Array where the statistics of the parameter search operation are temporarily stored before they are transferred to the TSOUT array.

COMMON Blocks

ALPNU1, ALPNU2, INP1, IDTES, TSNO, MUCH, RDIN, DIME, DIME1, CNVTS, NOINTG, ACCR, SUBDV, PLOTT, VARAC, IRER.

CORRE (N, M, IO, X, XBAR, STD, RX, R, B, D, T)

Description:

CORRE computes means, standard deviations, sums of cross-products of deviations, and correlation coefficients of several time series. It is based on subroutine CORRE of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

N (INPUT)	Number of observations for each time series ($N > 2$).
M (INPUT)	Number of time series ($M > 1$).
IO (INPUT)	Option code for input data. Set to 1.
X (INPUT)	Matrix (N x M) holding the time series.
XBAR (OUTPUT)	Vector of the means of the time series.
STD (OUTPUT)	Vector of the standard deviations of the time series.
RX (OUTPUT)	Matrix (M x M) holding sums of cross-products of deviations from means.
R (OUTPUT)	Upper triangular portion of the (M x M) matrix of correlation coefficients.
B (OUTPUT)	Vector storing the diagonal of the matrix of sums of cross-products of deviations from means.
D (OUTPUT)	Auxiliary storage vector of length M.
T (OUTPUT)	Auxiliary storage vector of length M.

COMMON Blocks:

None.

DVERK (NDIM, FCT, PRMT1, Y, PRMT2, TOL, IHLF, PRMT, AUX)

Description:

DVERK is the driver subroutine for the integration of a system of first order ordinary differential equations given initial conditions. It fills arrays PRMT (integration interval parameter array) and DERY (array of integration-error weights), and then calls the integrator subroutine DVER1.

Argument List:

NDIM (INPUT)	Number of differential equations to be integrated.
FCT (INPUT)	The name of an external input subroutine. It computes the right hand sides of the system to be integrated. For details see the argument list of subroutine DVER1.
PRMT1 (INPUT)	Lower bound of integration interval.
Y (INPUT/OUTPUT)	On input it holds the initial values. On output it holds the vector of dependent variables computed at intermediate points X.
PRMT2 (INPUT)	Upper bound of integration interval. Upon return, PRMT2 is stored in PRMT1.
TOL (INPUT)	Upper error bound for the integration. See description of PRMT(4) in subroutine DVER1.
IHLF (OUTPUT)	Number of bisections of the initial increment. For more details see the argument list of subroutine DVER1.
PRMT (OUTPUT)	Integration parameters array used by subroutine DVER1. For detailed description, see argument list of subroutine DVER1.
AUX (OUTPUT)	An auxiliary storage array used by subroutine DVER1. It has 16 rows and NDIM columns.

COMMON Blocks:

SUBDV, STATN.

DVER1 (PRMT, Y, DERY, NDIM, IHLF, FCT, OUTP, AUX)

Description:

DVER1 determines the solution of a system of first order ordinary differential equations with given initial values. Evaluation is done using a fourth order predictor-convector method that uses 4 preceding points for computation of a new vector of the dependent variables. For computation of starting values a fourth order Runge-Kutta method is used. The subroutine automatically adjusts the increment during the whole computation by halving or doubling. The procedure terminates and returns if 1) more than 10 bisections of the initial increment are necessary to get satisfactory accuracy, 2) initial increment is equal to 0 or has wrong sign, 3) the whole integration interval is worked through. The subroutine is based on the SSP library subroutine HPCG (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

PRMT (INPUT/OUTPUT) Vector of dimension > 5 which specifies the parameters of the interval and of accuracy and which serves for communication between output subroutine OUTP (furnished by the user) and subroutine DVER1. Except for PRMT(5), the components are not destroyed by subroutine DVER1, and they are:

- PRMT(1): Lower bound of interval (INPUT).
- PRMT(2): Upper bound of interval (INPUT).
- PRMT(3): Initial increment of independent variable (INPUT).
- PRMT(4): Upper error bound (INPUT). If absolute error is greater than PRMT(4), increment is halved. If increment is less than PRMT(3) and absolute error less than PRMT(4)/50, increment is doubled. The user may change PRMT(4) by means of subroutine OUTP.
- PRMT(5): Subroutine DVER1 initializes PRMT(5) to 0 (OUTPUT). If the user wants to terminate DVER1 at any output point, he has to change PRMT(5) to nonzero by means of subroutine OUTP.

Y (INPUT/OUTPUT) On input, Y holds the initial values. On output, it is the vector of dependent variables computed at intermediate points X.

DERY (INPUT/OUTPUT) On input, it is the vector of error weights. Sum of components must equal 1. On output, it is the vector of derivatives which correspond to function values Y at point X.

NDIM (INPUT)	Number of differential equations to be integrated.
IHLF (OUTPUT)	Number of bisections of the initial increment. If IHLF > 10, DVER1 returns with IHLF = 11. Values IHLF = 12 or IHLF = 13 appear if PRMT(3) = 0 or if the sign of PRMT(3) is not the same as the sign of [PRMT(2) - PRMT(1)], respectively.
FCT (INPUT)	The name of an <u>external</u> input subroutine. It computes the right hand sides (DERY) of the system for given values of X and Y. Its parameter list must be X, Y, DERY. The subroutine should not destroy X and Y. Examples are subroutines PRECS and FLOWS for the differential equations of the Station Precipitation and Integrated Hydrometeorological models of Georgakakos and Bras (1982).
OUTP (INPUT)	The name of an <u>external</u> output subroutine supplied by the user. Its parameter list must be X, Y, DERY, IHLF, NDIM, PRMT. None of these parameters (except, if necessary PRMT(4), PRMT(5), ...) should be changed by OUTP. If PRMT(5) is changed to a non-zero value, DVER1 terminates.
AUX (OUTPUT)	An auxiliary storage array with 16 rows and NDIM columns.

<u>COMMON Blocks</u>:

None.

ESGN (NU, XK1, XK2, XK3, XK4)

Description:

ESGN prints the last page of output of the TSFP program: the TSFP end-sign; the virtual CPU time used by the input, execution, and output routines; and the prespecified and actually used storage space for the main program arrays (parameter input array, PM; data input array, TSIN; output array, TSOUT; and auxiliary statistical array, TSTAT).

Argument List:

NU (INPUT)	Unit number of the file to which TSFP output is directed.
XK1 (INPUT)	Virtual CPU time used by the TSFP parameter input subroutines in minutes.
XK2 (INPUT)	Virtual CPU time used by the TSFP data input subroutines in minutes.
XK3 (INPUT)	Virtual CPU time used by the TSFP execution subroutines in minutes.
XK4 (INPUT)	Virtual CPU time used by the TSFP output subroutines in minutes.

COMMON Blocks:

DIME, DIME1.

EX (IDIMPM, PM, IDIMTS, TSIN, IDMTSO, TSOUT, IDMTST, TSTAT)

Description:

EX is the execution subroutine of the TSFP program. It computes the TSOUT-array elements to be passed to the output subroutine OUTT, for each program operation. TSOUT contains output time series and statistical performance measures.

Argument List:

IDIMPM (INPUT)	Dimension of the TSFP parameter array PM.
PM (INPUT)	Array where all options and parameters of the program TSFP are stored.
IDIMTS (INPUT)	Dimension of the raw data array TSIN.
TSIN (INPUT)	Array where the raw input data related to the chosen TSFP operation are stored.
IDMTSO (INPUT)	Dimension of the TSFP output array TSOUT.
TSOUT (OUTPUT)	Array where output time series and statistical performance indices are stored.
IDMTST (INPUT)	Dimension of the auxiliary statistical array TSTAT.
TSTAT (OUTPUT)	Array where the statistics of the parameter search operation are temporarily stored before they are transferred to the TSOUT-array.

COMMON Blocks:

DIME1, LREGR, PARAS, OUTS, INPUS, LINS, NOINTG, ACCR, SUBDV, PLOTT, VARAC, ERIND, IRER.

FTAUTO (A, N, L, K, ISW, AVER, VAR, R, AR, PAR, WKAREA)

Description:

FTAUTO computes the average, the variance, the autocovariance and the autocorrelations of an input time series. It is based on subroutine AUTO of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

A (INPUT)	Array holding the input time series whose statistics will be determined.
N (INPUT)	Length of vector A.
L (INPUT)	Autocovariance and autocorrelation are calculated for lags of 1, 2, .., L. (Max L = 9.)
K (INPUT)	Maximum number of partial autocorrelations computed. Currently equal to 0.
ISW (INPUT)	Option index. If greater than or equal to 3 the autocorrelations are computed.
AVER (OUTPUT)	Time series average.
VAR (OUTPUT)	Time series variance.
R (OUTPUT)	Time series autocovariances vector of length L.
AR (OUTPUT)	Time series autocorrelations vector of length L.
PAR (OUTPUT)	Time series partial autocorrelations vector. Currently not computed.
WKAREA (OUTPUT)	Auxiliary storage array.

COMMON Blocks:

None.

GMPRD (A, B, R, N, M, L)

Description:

GMPRD computes the product of two general matrices. It is based on subroutine GMPRD of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

A (INPUT)	Name of first input matrix.
B (INPUT)	Name of second input matrix.
R (OUTPUT)	Name of the product matrix.
N (INPUT)	Number of rows in A.
M (INPUT)	Number of columns in A and rows in B.
L (INPUT)	Number of columns in B.

COMMON Blocks:

None.

GMTRA (A, R, N, M)

Description:

GMTRA computes the transpose of matrix A and stores it in matrix R. It is based on subroutine GMTRA of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

A (INPUT)	Matrix to be transposed.
R (OUTPUT)	The transpose of A.
N (INPUT)	Number of rows of A and columns of R.
M (INPUT)	Number of columns of A and rows of R.

COMMON Blocks:

None.

LBLS (XINTP, X1, IS1, IC1)

Description:

LBLS determines the abscissa parameter values for labeling the abscissa axis in the contour plot.

Argument List:

XINTP (OUTPUT)	Array that holds the abscissa parameter values to be printed as labels of the abscissa axis.
X1 (INPUT)	Array that holds the abscissa coordinates of the function whose contours are to be plotted.
IS1 (INPUT)	Total number of the abscissa coordinates stored in X1 array.
IC1 (OUTPUT)	Total number of the abscissa values to be used for labeling the abscissa axis.

COMMON Blocks:

None.

LINV2F (A, N, IA, AINV, D, IER)

Description:

LINV2F is the driver subroutine for the inversion of matrix A to produce matrix AINV. It converts A to single dimension, calls the inversion subroutine MINV, and recovers the two-dimensional inverse from the single dimensional one produced by MINV.

Argument List:

A (INPUT)	Matrix to be inverted.
N (INPUT)	Order of matrix A.
IA (INPUT)	Number of rows in the DIMENSION statement for A.
AINV (OUTPUT)	The resulting inverse of A.
D (OUTPUT)	Determinant of A.
IER (OUTPUT)	Error code. 0 - no error. 1 - zero determinant.

COMMON Blocks:

None.

LNTP (X1, X2, Y1, Y2, N, YINTP, XINTP)

Description:

LNTP computes coordinate values for the plot grid points by linearly interpolating between successive coordinate values for which the function is known. It also interpolates the function values to obtain function values for the plot grid points.

Argument List:

X1 (INPUT)	The initial coordinate value where the value of the function is known.
X2 (INPUT)	The final coordinate value where the value of the function is known.
Y1 (INPUT)	The initial function value known, corresponding to coordinate X1.
Y2 (INPUT)	The final function value known, corresponding to coordinate X2.
N (INPUT)	Number of interpolation points for which coordinate and function values need to be determined in the intervals (X1, X2) and (Y1, Y2) respectively.
YINTP (OUTPUT)	Array that holds the interpolated function values.
XINTP (OUTPUT)	Array that holds the interpolated coordinate values.

COMMON Blocks:

None.

LOCT (K, INPT, NOBSER, NDTEND, TSIN, IDMTSI, Z, IDMOBS)

Description:

LOCT locates input values from the input time series array, TSIN, given: the time step sequence number, K; the total number of the input variables, INPT; the total number of time steps of the current operation, (NDTEND+1). The current and previous input values for each input variable are located and stored in XINPS-array and passed through the COMMON block labeled INPUS to the rest of the program. Given the total number NOBSER of the observation variables, the subroutine also locates the current observation vector Z residing in the TSIN array.

Argument List:

K (INPUT)	The sequence number of the current time step.
INPT (INPUT)	The total number of input time series (to the user's model).
NOBSER (INPUT)	The total number of output time series (from the user's model).
NDTEND (INPUT)	The total number of time steps in the current operation for which predictions will be produced by TSFP.
TSIN (INPUT)	Array where the raw input data related to the chosen TSFP operation are stored.
IDMTSI (INPUT)	Dimension of the TSFP data input array TSIN.
Z (OUTPUT)	Vector that stores the observations of the user's model output variables for the current time step. It is called the observations vector in a state space formulation.
IDMOBS (INPUT)	Dimension of the vector Z. Currently it is set to 5.

COMMON Blocks:

INPUS.

LSCN (J, LINEND, IS1, VL, Y, ILINE, MARK4, MARK6, ICTLB, OPT)

Description:

LSCN determines the contour crossings of the J-th plot line. If the optimum value of the function is on the current line, it also determines the optimum position. The contour symbols at the appropriate position are stored in the array ILINE. Note that if, due to discretization, two contours pass from the same position, only the symbol of the contour closer to the extremum is printed.

Argument List:

J (INPUT)	Sequence number of the current line for which the contour crossings are determined.
LINEND (INPUT)	Characters in one plot-line.
IS1 (INPUT)	Total number of abscissa values for the current plot.
VL (INPUT)	Array that holds the value of the function in each one of the 9 contours to be plotted.
Y (INPUT)	Two-dimensional array holding the function values in the plot-space.
ILINE (OUTPUT)	Array that holds the characters to be printed in one plot line.
MARK4 (INPUT)	Character: "*"
MARK6 (INPUT)	Character: "0"
ICTLB (INPUT)	Array that holds the 9 characters from 1 to 9 that will label the contours.
OPT (INPUT)	Extremum of the function in the plot space.

COMMON Blocks:

None.

MINV (A, N, D, L, M)

Description:

MINV inverts a matrix. It uses the standard Gauss-Jordan method. The determinant is also calculated. A zero determinant indicates that the matrix is singular. It is based on subroutine MINV of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

A (INPUT/OUTPUT)	On input it is the matrix to be inverted. On output it stores the inverse.
N (INPUT)	Order of matrix A.
D (OUTPUT)	Determinant of A.
L (OUTPUT)	Auxiliary storage vector of length N.
M (OUTPUT)	Auxiliary storage vector of length N.

COMMON Blocks:

None.

MISR (NO, M, X, CODE, XBAR, STD, SKEW, CURT, RN, N, A, B, S, IER)

Description:

MISR computes means, standard deviations, skewness and kurtosis, correlation coefficients, regression coefficients, and standard errors of regression coefficients when there are missing data points. The user identifies the missing data by means of a numeric code. Those values having this code are skipped in computing statistics. In the case of the correlation coefficients, any pair of values is skipped if either one of them is missing. The subroutine is based on the SSP library subroutine MISR (IBM SYSTEM/360, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

NO (INPUT)	Number of observations
M (INPUT)	Number of time series.
X (INPUT)	One-dimensional array of size (NO x M) holding the time series.
CODE (INPUT)	Vector of length M holding a numeric missing data code. Any observation for a given variable having a value equal to the code will be dropped for the computations.
XBAR (OUTPUT)	Vector containing the time-average of the time series.
STD (OUTPUT)	Vector containing the standard deviations of the time series.
SKEW (OUTPUT)	Vector containing skewness.
CURT (OUTPUT)	Vector containing kurtosis.
R (OUTPUT)	Array storing the product moment correlation coefficients. Only the upper triangular portion of the full matrix of correlations is stored in R.
N (OUTPUT)	Array storing the number of pairs of observations used in computing the elements in R.
A (OUTPUT)	Array of dimension (M x M) holding intercepts (A) of regression lines of the form Y = A + BX. The first subscript of this matrix refers to the dependent variable. For example, A(1,3) contains the intercept of the regression line for two variables where variable 1 is independent and variable 3 is dependent. Matrix A is stored in vector form.

B (OUTPUT)	Array of dimension (M x M) holding regression coefficients (B) corresponding to the values of intercepts contained in the output matrix A.
S (OUTPUT)	Array of dimension (M x M) holding the standard errors of the regression coefficients in matrix B.
IER (OUTPUT)	Error code: = 0: No error. = 1: One variable has two or less non-missing data elements. = 2: Variance for one of the variables is less than 1.E-20.

COMMON Blocks:

None.

MULTR (N, K, XBAR, STD, D, RX, RY, ISAVE, B, SB, T, ANS)

DESCRIPTION:

MULTR performs a multiple linear regression analysis for a dependent variable and a set of independent variables. It is based on subroutine MULTR of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

N (INPUT)	Number of observations in time series.
K (INPUT)	Number of independent variables in the regression [N > (K + 1)].
XBAR (INPUT)	Vector of means of all time series.
STD (INPUT)	Vector of standard deviations of all time series.
D (INPUT)	Vector storing the diagonal of the matrix of sums of cross-products of deviations from means for all variables.
RX (INPUT)	Array of dimension (K x K) holding the inverse of intercorrelations among independent variables.
RY (INPUT)	Vector of length K holding intercorrelations of independent variables with the dependent variable.
ISAVE (INPUT)	Vector of length (K + 1) holding subscripts of independent variables in ascending order. In location (K + 1) it stores the subscript of the dependent variable.
B (OUTPUT)	Vector of regression coefficients.
SB (OUTPUT)	Vector of standard errors of regression coefficients.
T (OUTPUT)	Vector of length K containing T-values.
ANS (OUTPUT)	Vector of length 10: ANS (1) is the intercept, ANS (2) is the multiple correlation cofficient, ANS (3) is the standard error of estimate, ANS (4) is the sum of squares attributable to regression, ANS (5) is the number of degrees of freedom associated with ANS (4), ANS (6) is the mean square of ANS (4),

ANS (7) is the sum of squares of deviations from
        regression,
ANS (8) is the number of degrees of freedom
        associated with ANS (7),
ANS (9) is the mean square of ANS (7),
ANS (10) is the F-value.

COMMON Blocks:

None.

ORDER (M, R, NDEP, K, ISAVE, RX, RY)

Description:

ORDER constructs from a larger matrix of correlation coefficients a subset matrix of intercorrelations among independent variables and intercorrelations of independent variables with the dependent variable. This subroutine is normally used in the performance of multiple regression analysis. It is based on subroutine ORDER of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

M (INPUT)	Number of variables and order of matrix R.
R (INPUT)	Matrix of correlation coefficients. Only the upper triangular portion is stored by column in R.
NDEP (INPUT)	The subscript number of the dependent variable.
K (INPUT)	Number of independent variables to be included in the forthcoming regression (K > 1).
ISAVE (INPUT/OUTPUT)	Vector of length (K + 1) containing, in ascending order, the subscript numbers of K independent variables to be included in the forthcoming regression. Upon return, the vector stores at location (K + 1) the subscript number of the dependent variable.
RX (OUTPUT)	Matrix (K x K) storing intercorrelations among independent variables to be used in forthcoming regression.
RY (OUTPUT)	Vector of length K containing intercorrelations of independent variables with the dependent variable.

COMMON Blocks:

None.

OUTT (IDIMPM, PM, IDMTSI, TSIN, IDIMSC, IDSCR, IDMTSO, TSOUT)

Description:

OUTT is the output subroutine of the TSFP program. It creates displays of time series and prints statistics for all TSFP operations. It recovers the necessary values from the TSOUT-array.

Argument List:

IDIMPM (INPUT)	Dimension of the TSFP parameter array PM.
PM (INPUT)	Array where all options and parameters of the program TSFP are stored.
IDMTSI (INPUT)	Dimension of the raw data array TSIN.
TSIN (INPUT)	Array where the raw input data related to the chosen TSFP operation are stored.
IDIMSC (INPUT)	Dimension of the TSFP descriptions array IDSCR.
IDSCR (INPUT)	Array where all variable descriptions of the TSFP program are stored.
IDMTSO (INPUT)	Dimension of the TSFP output array TSOUT.
TSOUT (INPUT)	Array where output time series and statistical performance indices are stored.

COMMON Blocks:

STRR2, ALPNU1, ALPNU2, PLOTT, PROUT, LEGN, INP1, ACCR, SUBDV, VARAC, IRER.

PLOT (NO1, A, N, M, NL, NS, NU, ICHAR, II)

Description:

PLOT plots up to 9 cross-variables versus a base variable. It is based on subroutine PLOT of the SSP library (IBM SYSTEM/360 Scientific Subroutine Package, Version III, Programmer's Manual, Fifth Edition, August 1970, GH20-0205-4).

Argument List:

NO1 (INPUT)	Character array with the description of the plot and the axis labels. The plot description can be up to 72 characters long. The description of the base variable is stored in locations 73 to 108 and the general description of the cross-variables is stored in locations 109 to 144.
A (INPUT)	Matrix of data to be plotted. First column represents the base variable and successive columns are the cross-variables.
N (INPUT)	Number of rows in matrix A.
M (INPUT)	Number of columns in matrix A.
NL (INPUT)	Number of lines in the plot. If 0 is specified, 50 lines are used.
NS (INPUT)	Code for sorting the base variable data in ascending order 0 - sorting is not necessary 1 - sorting is necessary
NU (INPUT)	Unit number of the output file to which TSFP printout is directed.
ICHAR (INPUT)	Array of up to 9 user defined symbols to be used in plotting the cross-variables. If the first character in ICHAR is blank, then the symbols 1 to 9 are used.
II (INPUT)	Indicator to signal detailed printout of the plotted values 0 - no detailed printout 1 - detailed printout

COMMON Blocks:

None.

PMCR (IDIMPM, PM)

Description:

PMCR corrects the date and total time-step number in the PM-array for the case of pre-averaging of the raw input data.

Argument List:

IDIMPM (INPUT)	Dimension of the TSFP parameter array PM.
PM (INPUT/OUTPUT)	Array where all options and parameters of the TSFP program are stored.

COMMON Blocks:

IDTES, MUCH.

PMSC (ND, IDIMPM, PM, IDIMSC, IDSCR)

Description:

PMSC reads the TSFP program parameters and options together with the associated descriptions. Description of the format can be found in the Input-Output section of this document. The options and parameters read are stored in the TSFP parameter array PM. The descriptions are stored in the IDSCR-array.

Argument List:

ND (INPUT)	Unit for the read statements.
IDIMPM (INPUT)	Dimension of the TSFP parameter array PM
PM (OUTPUT)	Array where all options and parameters of the program TSFP are stored.
IDIMSC (INPUT)	Dimension of the TSFP descriptions array IDSCR.
IDSCR (OUTPUT)	Array where all variable descriptions of the program TSFP are stored.

COMMON Blocks:

ALPNU1, ALPNU2, IDTES, TSNO, RDIN, DIME1, CNVTS, INP1, NOINTG, ACCR, SUBDV, PLOTT, VARAC, MUCH.

POSDEF (IDMSTA, N, CX)

Description:

POSDEF enforces positive definiteness on a covariance matrix. The negative diagonal elements of the covariance matrix are assigned positive values equal to their absolute values. The diagonal elements are not allowed to assume values less than a lower bound of 1.E-8. The off-diagonal elements are adjusted so that correlations in the interval (-1,1) result.

Argument List:

IDMSTA (INPUT)	Dimension of the square covariance matrix.
N (INPUT)	Actual order of the covariance matrix.
CX (INPUT/OUTPUT)	Covariance matrix.

COMMON Blocks:

None.

PRDUPD (N, M, IMXLK, NU, X, CX, IDMSTA, Q, IDMOBS, Z, R, ICOR, GAIN, CINOV, TMXLK, DCINOV, RES, RESN, TEND, X1, CX1, IPRCV, ZABSNT, PORZ)

Description:

PRDUPD performs 1) integration of the user's model (stochastic) dynamic equations and 2) updating at each time step when an observations vector Z is available. The continuous dynamics - discrete observations Extended Kalman Filter is used. The user's model differential equations are supplied by the user. For example, subroutines PRECS and FLOWS are supplied for the case of the Station Precipitation model and the Integrated Hydrometeorological model of Georgakakos and Bras, 1982. If the stochastic model option ICOR is positive, the program forms the noise covariance matrices Q and R and performs Extended Kalman Filtering (e.g., Gelb, 1974). During the propagation step in the case of a stochastic model, the system of equations:

$$\frac{d\,X(t)}{dt} = f(X(t),t);\; X(t_o) = X_o \qquad (1)$$

and

$$\frac{d\,P^-(t)}{dt} = \left.\frac{d\,f(u(t),t)}{du}\right|_{u=X} \cdot P^-(t) + P^-(t) \cdot \left(\left.\frac{d\,f(u(t),t)}{du}\right|_{u=X}\right)^T + Q(t);$$

$$P^-(t_o) = P_o^- \qquad (2)$$

is integrated simultaneously. In the case of a deterministic model only (1) is integrated. The n-dimensional vector $X(t)$ is the state mean vector, $f(\cdot)$ is an n-dimensional vector function, $P^-(t)$ is the (n x n) predicted state covariance matrix, and $Q(t)$ is the (n x n) system noise covariance parameter matrix. The derivative of the vector function f with respect to the state mean vector is evaluated at the solution of Equation (1). The equations for updating are given in subroutine UPDT. If a parameter search operation is selected, the subroutine computes the data dependent component of the log-likelihood function, when the user choses the log-likelihood as a performance index. The propagation step, in a filtering sense, is performed by the integrator subroutine DVERK. Updating is performed by subroutine UPDT. The necessary observation equations of the state space form are provided by the user. For example, the subroutines PRECZ and FLOWZ are supplied for the case of the Station Precipitation model and the Integrated Hydrometeorological model of Georgakakos and Bras, 1982.

Argument List:

N (INPUT)	Number of state variables in the user-supplied model.
M (INPUT)	Number of outputs in the user-supplied model.

IMXLK (INPUT) — If positive, the program will compute the log-likelihood function when a parameter search operation is selected.

NU (INPUT) — Unit number of the file to which TSFP output is directed.

X (INPUT/OUTPUT) — The initial condition of the state mean vector at the beginning of the current time step. Upon return from the subroutine, X stores the updated state mean vector at the end of the current time step.

CX (INPUT/OUTPUT) — The initial condition of the state covariance matrix at the beginning of the current time step. Upon return from the subroutine, CX stores the updated state covariance matrix at the end of the current time step.

IDMSTA (INPUT) — Dimension for vectors and matrices related to the state variables. In TSFP, Version 2, IDMSTA is set equal to 20.

Q (INPUT) — The system-noise spectral density matrix used by the continuous dynamics - discrete observations Extended Kalman Filter.

IDMOBS (INPUT) — Dimension for vectors and matrices related to the user's model output variables. In TSFP, Version 2, it is set equal to 5.

Z (INPUT) — Vector that stores the observations of the user's model output variables for the current time step. It is called the observations vector in a state space formulation.

R (INPUT) — The observations-noise covariance matrix used by the continuous dynamics - discrete observations Extended Kalman Filter.

ICOR (INPUT) — Index to indicate (if positive) that filtering of the noise and state estimation is performed.

GAIN (OUTPUT) — The Extended Kalman Filter Gain matrix (see Gelb, 1974).

CINOV (OUTPUT) — The innovations covariance matrix.

TMXLK (OUTPUT) — The observations dependent component of the log-likelihood function.

DCINOV (OUTPUT) — The determinant of the innovations covariance matrix.

RES (OUTPUT)	The residuals vector. Each element is defined as the observation minus the corresponding prediction.
RESN (OUTPUT	The normalized residuals vector, whose components are the components of the vector RES divided by the corresponding diagonal element of the innovations covariance matrix.
TEND (INPUT)	The duration of the time step used in the integration of the stochastic model equations during the propagation step.
X1 (OUTPUT)	The predicted state mean vector at the end of the current time step.
CX1 (OUTPUT)	The predicted state mean covariance matrix at the end of the current time step.
IPRCV (INPUT)	Index to denote (if positive) that covariance propagation is performed. Note that if ICOR is positive, IPRCV should be positive too.
ZABSNT (INPUT)	Value to denote a missing data value in the input time series.
PORZ (INPUT)	A fraction less than or equal to one, to determine the time in the current time step that the input is evaluated, to be used in the computation of the model observation equation.

COMMON Blocks:

LINS, LINZ, INDXS, PARAS, INPUS, OUTS, SYSNS, PINP, NOINTG, ACCR, SUBDV, VARIA, OBSNS, STATN, VARAC, ERIND.

PRLN (N, IDIMSC, NU, IDSCR, X, IDIMX, NHRZ)

Description:

PRLN prints one row of a matrix with a description of each element in the row. A maximum of 7 elements can be printed per line of output.

Argument List:

N (INPUT)	Number of elements in the row to be printed.
IDIMSC (INPUT)	Dimension of array (IDSCR) that holds the description of the elements to be printed.
NU (INPUT)	Unit number of the file to which TSFP output is directed.
IDSCR (INPUT)	Array that holds the description of the elements to be printed.
X (INPUT)	Array that holds the elements of the matrix to be printed.
IDIMX (INPUT)	Dimension of the X array.
NHRZ (INPUT)	Indicator to specify that a description of the row to be printed will be included in the printout, at the beginning of the row of elements. No descriptions is printed when NHRZ = 0. When positive, it also indicates the location in the IDSCR array of the characters of the row description.

COMMON Blocks:

None.

PRST (NU, IDIMSC, IDIMTS, IDMLE, INDAUT, ITMAL, IDIMAL, IDIMX, X, MINTS, INITS, TSOUT, IDSCR, U, LAG)

Description:

PRST prints time series statistics. Thus, time averages, time standard deviations, time skewness coefficients, and time kurtosis coefficients are printed. In case of multiple time series, the lower diagonal portion of the time cross-correlation matrix is also printed. On option, the autocorrelation coefficients for each input time series are displayed. The maximum lag for the autocorrelations is taken as the greatest integer equal to or less than $\{\frac{NTIME}{10}\}$, where NTIME is the number of values in the shorter time series. In any case the maximum lag cannot be greater than 9.

Argument List:

NU (INPUT)	Unit number of the file to which TSFP output is directed.
IDIMSC (INPUT)	Dimension of the TSFP descriptions array IDSCR.
IDIMTS (INPUT)	Dimension of the TSFP output array TSOUT.
IDMLE (INPUT)	Second dimension of the statistical array U(3, IDMLE). It is equal to the maximum number of state variables allowed in TSFP. For the current version it is equal to 20.
INDAUT (INPUT)	Index to activate printout of autocorrelations. = 0: No printout of autocorrelation. > 0: Printout of autocorrelations.
ITMAL (INPUT)	Array that stores the descriptions of the time series whose statistics are printed. Up to six characters are allowed for each time series.
IDIMAL (INPUT)	Dimension of ITMAL array. Currently equal to 1160.
IDIMX (INPUT)	Dimension of the array X. Currently a maximum of 1500 values are allowed in X.
X (OUTPUT)	Auxiliary array that stores the values that will be printed in one line of output.
MINTS (INPUT)	Number of time series whose statistics will be printed by subroutine PRST.
INITS (INPUT)	Beginning from location INITS, the statistics to be printed by the subroutine PRST are stored in TSOUT array.

TSOUT (INPUT) — Array where output time series and statistical performance indices are stored.

IDSCR (INPUT) — Array where all variable descriptions of the TSFP program are stored.

U (INPUT) — Auxiliary two-dimensional array storing:

U(1,J): Standard deviation of the jth time series.

U(2,J): Skewness coefficient of the jth time series.

U(3,J): Kurtosis coefficient of the jth time series.

LAG (INPUT) — The maximum lag for which autocorrelations will be printed for each time series.

COMMON Blocks:

None.

QNOISE (INPT, IDMSTA, PARZ, A, N, Q)

Description:

QNOISE determines the elements of the system-noise covariance parameter matrix Q retrieving information from the input parameter array PARZ. This subroutine is called at each time step since it allows for a time dependent Q matrix. The diagonal elements of Q can be linear functions of the observed input values or of the inverses of the observed input values at each time step. In Version 2 of the TSFP program, the Q matrix is taken as diagonal.

Argument List:

INPT (INPUT)	The total number of input time series (to the user's model).
IDMSTA (INPUT)	Dimension of the matrix Q. It is the maximum number of state variables allowed by the current version of TSFP. In Version 2 it is equal to 20.
PARZ (INPUT)	Array supplying the necessary parameters to specify matrix Q for the current time-step.
A (OUTPUT)	Two-dimensional, auxiliary matrix for temporary storage. It is dimensioned as A (IDMSTA,IDMSTA).
N (INPUT)	Number of state variables in the user's model.
Q (OUTPUT)	The system-noise covariance parameter matrix used by the continuous dynamics - discrete observations Extended Kalman Filter.

COMMON Blocks:

INPUS.

RNOISE (Z, IDMOBS, PARZ, A, IDIMTP, M, R)

Description:

RNOISE determines the elements of the observations-noise covariance matrix R, retrieving information from the input parameter array PARZ. This subroutine is called at each time step, since it allows for a time dependent R matrix. The diagonal elements of R can be linear functions of the observed output values or of the inverses of the observed output values at each time step. In Version 2 of the TSFP program, the R matrix is taken as diagonal.

Argument List:

Z (INPUT)	Vector that stores the observations of the user's model output variables for the current time step. It is called the observations vector in a state space formulation.
IDMOBS (INPUT)	Dimension of the square matrix R. It is equal to the maximum number of output variables allowed by the current version of TSFP for a user specified model. In Version 2 it is equal to 5.
PARZ (INPUT)	Array supplying the parameters necessary for specifying matrix R for the current time-step.
A (OUTPUT)	Two-dimensional auxiliary array for temporary storage.
IDIMTP (INPUT)	Dimension of the square matrix A. In Version 2 it is set equal to 20.
M (INPUT)	Total number of the user's model output variables.
R (OUTPUT)	The observations-noise covariance matrix used by the continuous dynamics - discrete observations Extended Kalman Filter.

COMMON Blocks:

None.

STORE2 (IDIMTS, IDIM2, IDIM1, MTOT, IXOUT, TSOUT, XME, U, AA)

Description:

STORE2 stores the means, standard deviations, third and fourth moments, and correlation coefficients in the output array TSOUT for MTOT time series.

Argument List:

IDIMTS (INPUT)	Dimension of the output array TSOUT.
IDIM2 (INPUT)	Dimension of the array AA, equal to at least: $\frac{MTOT \cdot (MTOT+1)}{2}$.
IDIM1 (INPUT)	Dimension of the array XME and second dimension of the array U. Equal to at least MTOT.
MTOT (INPUT)	Number of time series.
IXOUT (INPUT/OUTPUT)	Current storage location in array TSOUT.
TSOUT (INPUT/OUTPUT)	TSFP program output array.
XME (INPUT)	Array storing the means.
U (INPUT)	Array dimensioned as U(3,IDIM1) storing the standard deviations, skewness coefficients, and kurtosis coefficients for all the time series.
AA (INPUT)	Array holding the upper triangular portion of the cross-correlation matrix of the time series.

COMMON Blocks:

None.

STRS (INCR, N, IPCV, X, CX, IDIMX, NCORX, ICORX, TEMP, TSOUT)

Description:

STRS stores in the TSFP output array TSOUT the following:

- The elements of the state mean vector.
- The standard deviations of the state variables.
- A prespecified number, NCORX, of state correlation coefficients based on their identifying indices stored in pairs in the ICORX-array and corresponding to the upper diagonal part of the covariance matrix.

Argument List:

INCR (INPUT/OUTPUT)	On input it is the current location in the TSOUT array where the storage of values begins. On output from the subroutine is the location in the TSOUT array of the last value stored.
N (INPUT)	Number of state variables.
IPCV (INPUT)	Index to activate (if positive) covariance propagation operations.
X (INPUT)	State mean vector.
CX (INPUT)	State covariance matrix.
IDIMX (INPUT)	Dimension of the square matrix CX. In TSFP Version 2 it is set equal to 20.
NCORX (INPUT)	Number of state correlations to be stored.
ICORX (INPUT)	Vector where the indices defining the correlations are stored in pairs. Thus, if correlation between states 1 and 3 is stored, the indices 1 and 3 are stored sequentially in vector ICORX.
TEMP (OUTPUT)	Auxiliary square matrix of dimension IDIMX used for temporary storage.
TSOUT (INPUT/OUTPUT)	Array where output time series and statistical performance indices are stored.

COMMON Blocks:

None.

STVR (N, IDIMX, X)

Description:

STVR computes a standardized time series from an input time series. Standardization of each value consists of subtraction of the mean of the time series and division by the standard deviation of the time series.

Argument List:

N (INPUT)	Number of values in time series to be standardized.
IDIMX (INPUT)	Dimension of the array that holds the time series.
X (INPUT/OUTPUT)	On input X holds the time series to be standardized. On output it holds the standardized time series.

COMMON Blocks:

None.

SYMM (IDMSTA, N, CX)

Description:

SYMM enforces symmetry on a covariance matrix. Each off-diagonal element assumes the value defined by the average of the initial values that it and its symmetric element have.

Argument List:

IDMSTA (INPUT)	Dimension of the square covariance matrix.
N (INPUT)	Actual order of the covariance matrix.
X (INPUT/OUTPUT)	Covariance matrix.

COMMON Blocks:

None.

UPDT (IDMSTA, IDMOBS, N, M, X, CX, X1, CX1, Z, R, GAIN, GINOV, H, TEMP2, DET, NU)

Description:

UPDT computes the Extended Kalman Filter update equations for each time step:

$$Q_{IN} = HP^{-}H^{T} + R$$

$$K = P^{-} H^{T} Q_{IN}^{-1}$$

$$P^{+} = [I-KH] \; P^{-} \; [I-KH]^{T} + KRK^{T}$$

$$\hat{X}^{+} = \hat{X}^{-} + K (Z - H \cdot \hat{X}^{-})$$

where Q_{IN} is the (M x M) covariance matrix of the innovations sequence $(Z - H\hat{X}^{-})$; H is the (M x N) observations gradient matrix; P^{-}, P^{+} are the (N x N) predicted and updated state covariance matrices; R is the (M x M) covariance matrix of the observations noise; K is the (N x M) filter gain matrix; I is the (N x N) unit matrix; $\hat{X}^{-}$, $\hat{X}^{+}$ are the N-dimensional predicted and updated state mean vectors; and Z is the M-dimensional observation vector. In some cases, the observations gradient matrix H results from linearization of the model observation equation that is non-linear in the state. For details on the Extended Kalman Filter the reader is referred to Gelb, 1974.

Argument List:

IDMSTA (INPUT)	Dimension of the state vector.
IDMOBS (INPUT)	Dimension of the observations vector.
N (INPUT)	Number of state variables.
M (INPUT)	Number of observation variables in vector Z.
X (OUTPUT)	Updated state mean vector $\hat{X}^{+}$.
CX (OUTPUT)	Updated state covariance matrix P^{+}.
X1 (INPUT)	Predicted state mean vector $\hat{X}^{-}$.
CX1 (INPUT)	Predicted state covariance matrix P^{-}.

Z (INPUT)	Innovations sequence $(Z - H\hat{X}^{-})$.
R (INPUT)	Observations noise covariance matrix.
GAIN (OUTPUT)	Filter gain matrix K.
CINOV (OUTPUT)	Innovations covariance matrix Q_{IN}.
H (INPUT)	Observations gradient matrix.
TEMP2 (OUTPUT)	Inverse of the innovations covariance matrix Q_{IN}^{-1}.
DET (OUTPUT)	Determinant of the innovations covariance matrix.
NU (INPUT)	Unit number of the file to which TSFP output is directed.

COMMON Blocks:

None.

USPLT (X, Y, IY, N, M, INC, ITITLE, RANGE, ICHAR, IOPT, IMAG4, IER)

Description:

USPLT is the driver subroutine for plotting up to 9 cross-variables versus a base variable. It calls subroutine PLOT to create printer plots. If the variable IDSSPL of the COMMON block PLOTT is less than or equal to 2, it also calls subroutine UUSST, which, by linking TSFP to the DISSPLA library, creates pen-plotter plots.

Argument List:

X (INPUT)	Values of the base variable, not necessarily sorted in ascending order.
Y (INPUT)	Two-dimensional array holding values of the cross-variables. Each cross-variable corresponds to one column in Y.
IY (INPUT)	Number of rows in the DIMENSION statement of Y.
N (INPUT)	Number of rows in Y.
M (INPUT)	Number of cross-variables used by subroutine UUSST.
INC (INPUT)	Auxiliary variable used by subroutine UUSST.
ITITLE (INPUT)	Character array holding the plot description in characters 1 to 72, the cross-variables general description in characters 73 to 108 and the base variable description in characters 109 to 144.
RANGE (INPUT)	Auxiliary array of dimension 4 used by subroutine UUSST.
ICHAR (INPUT)	Character array holding the plot symbol for each cross-variable. If the first character of ICHAR is blank then the symbols 1 to 9 are the plot symbols.
IOPT (INPUT)	Auxiliary variable used by subroutine UUSST.
IMAG4 (INPUT)	Auxiliary variable used by subroutine UUSST.
IER (OUTPUT)	Error code presently set to 0.

COMMON Blocks:

STR14, LEGN, PLOTT, PROUT.

VMULFF (A, B, N, M, L, IA, IB, R, IR, IER)

Description:

VMULFF is the driver subroutine for the multiplication of matrix A by matrix B to produce matrix R. It converts A and B from double to single dimension, calls the multiplication subroutine GMPRD and then recovers double dimension matrices from A, B, and R.

Argument List:

A (INPUT)	First matrix of the product.
B (INPUT)	Second matrix of the product.
N (INPUT)	Number of rows in A.
M (INPUT)	Number of columns in A and rows in B.
L (INPUT)	Number of columns in B.
IA (INPUT)	Number of rows in the DIMENSION statement of A.
IB (INPUT)	Number of rows in the DIMENSION statement of B.
R (OUTPUT)	Product of A by B.
IR (INPUT)	Number of rows in the DIMENSION statement of R.
IER (OUTPUT)	Error code, presently set to 0.

COMMON Blocks:

None.

VMULFP (A, B, N, L, IA, IB, R, IR, IER)

Description:

VMULFP is the driver subroutine for the multiplication of matrix A by the matrix B-transpose to produce matrix R. It converts A and B to single dimension, calls subroutine GMTRA to transpose B, calls subroutine GMPRD to multiply A by B-transpose, and restores two-dimensional matrices A, B, and R.

Argument List:

A (INPUT)	First matrix of the product.
B (INPUT)	Matrix to be transposed and pre-multiplied by A.
N (INPUT)	Number of rows in A.
L (INPUT)	Number of columns in A and B.
M (INPUT)	Number of rows in B.
IA (INPUT)	Number of rows in the DIMENSION statement of A.
IB (INPUT)	Number of rows in the DIMENSION statement of B.
R (OUTPUT)	Product of A by B-transpose.
IER (OUTPUT)	Error code, presently set to 0.

COMMON Blocks:

None.

FLOWS (T, Y, DY)

Description:

FLOWS computes the right hand side of the first-order ordinary differential equations that describe the time evolution of the state mean vector of the Integrated Hydrometeorological model of Georgakakos and Bras (1982). When the variable IPRCV in COMMON block INDXS is positive, FLOWS also computes the right hand sides of the first-order ordinary differential equations that describe the time evolution of the state covariance matrix for the Integrated Hydrometeorological model. When input uncertainty is included in the latter case, FLOWS calls the subroutine that computes the component of the system noise covariance Q that is due to input uncertainty. For details on the model equations the reader is referred to Georgakakos and Bras (1982).

Argument List:

T (INPUT)	Current time.
Y (INPUT)	Array that stores the state-mean vector and (in the case of a stochastic model) the state-covariance matrix elements, column-wise.
DY (OUTPUT)	Array that stores the time derivatives of the state-mean vector and state-covariance matrix elements.

COMMON Blocks:

INPUS, PARAS, OUTS, LINS, INDXS, SYSNS, PREF, PINP, VARIA, PRMU1, PRMU2, PRMU3, PRMU4, PRMU5, PRMU6, VARAC.

FLOWZ (X1, Z, RES, PARZ, IDMSTA, IDMOBS)

Description:

FLOWZ computes the vector observation equation of the state space formulation of the Integrated Hydrometeorological model developed by Georgakakos and Bras (1982). In the case of filtering, it also computes the component of the observations noise covariance matrix R that is due to input uncertainty.

Argument List:

X1 (INPUT)	The predicted state vector at the time an observation becomes available.
Z (INPUT)	The current observations of the precipitation and flow rates.
RES (OUTPUT)	Array that stores the residuals that result from the subtraction of the forecasted precipitation and flow rates from the observed ones.
PARZ (INPUT)	A fraction less than or equal to one, used to determine the time within the current time step that the input is evaluated; to be used in the computation of the Integrated Hydrometeorological model observation equations.
IDMSTA (INPUT)	State vector dimension, equal to 20.
IDMOBS (INPUT)	Observations vector dimension, equal to 5.

COMMON Blocks:

INPUS, PARAS, LINZ, PREF, OUTS, INDXS, VARIA, OBSNS, PRMU1, PRMU2, PRMU3, PRMU4, VARAC.

PRECS (T, Y, DY)

Description:

PRECS computes the right hand side of the first-order ordinary differential equation that describes the time evolution of the state mean vector of the Station Precipitation model of Georgakakos and Bras (1982). When the variable IPRCV in COMMON block INDXS is positive, PRECS also computes the right hand side of the first-order ordinary differential equation that describes the time evolution of the Station Precipitation model state covariance. When input uncertainty is included in the latter case, PRECS calls the subroutine that computes the component of the system noise variance Q that is due to input uncertainty. For details on the model equations, the reader is referred to Georgakakos and Bras (1982).

Argument List:

T (INPUT)	Current time.
Y (INPUT)	State mean and (for a stochastic model) state variance vector.
DY (OUTPUT)	Vector that stores the time derivatives of the state mean and state variance.

COMMON Blocks:

INPUS, PARAS, OUTS, LINS, INDXS, SYSNS, SYSN1, PREF, PINP, PRMU1, PRMU2, PRMU3.

PRECZ (X1, Z, RES, PARZ, IDMSTA, IDMOBS)

Description:

PRECZ computes the observation equation of the state space formulation of the Station Precipitation model developed by Georgakakos and Bras (1982). In case of filtering, it also computes the component of the observations noise covariance matrix R that is due to input uncertainty.

Argument List:

X1 (INPUT)	The predicted state value at the time an observation becomes available.
Z (INPUT)	The current observed precipitation rate.
RES (OUTPUT)	The residual that results from the subtraction of the forecasted precipitation rate from the observed one.
PARZ (INPUT)	A fraction less than or equal to one, used to determine the time within the current time step that the input is evaluated; to be used in the computation of the Station Precipitation model observation equation.
IDMSTA (INPUT)	State vector dimension, equal to 20.
IDMOBS (INPUT)	Observations vector dimension, equal to 5.

COMMON Blocks:

INPUS, PARAS, LINS, LINZ, PREF, OUTS, INDXS, OBSNS, PRMU1, PRMU2, PRMU3, PRMU4.

RDT1 (IDMTSI, TSIN, NDT, IDIMPM, PM)

Description:

RDT1 reads the raw data for the chosen TSFP operation and for the Station Precipitation and Integrated Hydrometeorological models of Georgakakos and Bras (1982). The subroutine stores the data in the input data array TSIN. Description of the input format can be found in the Input-Output section of this document.

Argument List:

IDMTSI (INPUT)	Dimension of the raw data input array TSIN.
TSIN (OUTPUT)	Array where the raw input data related to the chosen TSFP operation are stored.
NDT (INPUT)	Unit number of device on which the raw input data is stored (tape, card reader, etc.)
IDIMPM (INPUT)	Dimension of the TSFP parameter array PM.
PM (INPUT)	Array where all options and parameters of the program TSFP are stored.

COMMON Blocks:

BIG2, INP1, IDTES, TSNO, MUCH, DIME1, CNVTS.

SUBROUTINES LINKING TSFP TO THE DISSPLA LIBRARY:

CNTRP: Driver subroutine for the generation of pen-plotter contour plots of a two-dimensional function in a user specified domain.

COMPRS: Opens the pen-plotter device for plotting.

DONEPL: Closes all the plotting devices after plots are completed.

TK4014: Prepares the terminal screen for on-line plotting.

UUSST: Driver subroutine for the generation of pen-plotter plots of one-dimensional functions.

SECTION 6

TSFP USAGE

This section illustrates the steps to be followed by a TSFP user for the incorporation of his data- and model-subroutines within the network of the TSFP subroutines.

The user can incorporate data through a data input subroutine similar to RDT1. A description of this subroutine is given in the previous section. It is required that the user include in his subroutine RDT1 the following COMMON blocks:

```
COMMON/INP1/IAVER, IENDC
COMMON/IDTES/NOPER, IPER (40)
COMMON/TSNO/MTSNO
COMMON/MUCH/NDTEND
COMMON/DIME1/IID1,IID2, IID3, IID4, IID5
COMMON/CNVTS/CVUNTS (20)
```

Inclusion of the above COMMON blocks is essential for communication with the rest of the TSFP program. The variables stored in the COMMON blocks are described in the following:

IAVER:	Number of dates for which data values are to be averaged, if any, before the TSFP uses the input data.
IENDC:	Total number of dates to be scanned when locating the run periods.
NOPER:	Number of disjoint continuous periods of record that constitute the run.
IPER:	Array storing the dates of the run periods. Two locations are needed for a single date: YRMO and DAHR. The dates are stored as follows: INITIAL1, FINAL1, INITIAL2, FINAL2, where the numbers denote run periods. Up to 10 run periods are allowed.
MTSNO:	Total number of input time series ($\leq$ 20).
NDTEND:	Number of data points in each input time series ($\leq$ 1500) to be processed by TSFP.
IID1, IID2,IID3, IID4, IID5:	Actual storage locations occupied in the main TSFP arrays: PM, IDSCR, TSIN, TSOUT, TSTAT.

CVUNTS: Array storing values to convert units from TSFP internal units to output units that match the descriptions in IDSCR array. One location for each time series is allocated.

If the time series has been stored in a file as:

1st record	YRMO1,	DAHR1,	TS11,	TS21,	TS31,	. . .
2nd record	YRMO1,	DAHR2,	TS12,	TS22,	TS32,	. . .
•	•	•	•	•	•	
•	•	•	•	•	•	
nth record	YRMO2,	DAHRn,	TS1n,	TS2n,	TS3n,	. . .
•	•	•	•	•	•	
•	•	•	•	•	•	

then the already existing subroutine RDT1 can be used by changing only the read statements and the associated formats (pages 17 and 18).

Note that TSij in the above sequence represents the jth data value of the ith time series.

For state space modeling, parameter search, or forecasting, the user supplies, in addition to the input data subroutine RDT1, subroutines that contain dynamic and observation equations for their model, in state space form.

Suppose that the user has a model in the form:

$$\frac{d\,X(t)}{dt} = f(X(t),\ u(t),t);\ X(t_o) = X_o \qquad (6.1)$$

where X(t) is the n-dimensional state vector of the model, u(t) is the p-dimensional vector of inputs and t is the time variable. The initial time is denoted by t_o and the initial state by X_o. f(•) is an n-dimensional vector function.

In addition to Eq. (6.1), usually called the dynamics equation, the user has an equation that relates the state and input vectors to the observations of the system output (observation equation):

$$Z(t_k) = h(X(t_k),\ u(t_k),\ t_k);\ k = 1,2\ .\ .\ . \qquad (6.2)$$

where Z is the m-dimensional observations vector and h(•) is an m-dimensional vector function.

It is assumed that the observations $Z(t_k)$ occur at discrete points in time: t_1, t_2, . . .

In the case of a deterministic model, both IPRCV and ICOR (see Input-Output Data section) are zero, and the user applies a subroutine similar to PRECS or FLOWS with the right hand side of Eq. (6.1) built into it. The user also supplies a subroutine similar to PRECZ or FLOWZ with the equation:

$$RES(t_k) = Z(t_k) - h(X(t_k), u(t_k), t_k) \tag{6.3}$$

built into it. Note that Eq. (6.3) gives the difference between observed output and model predicted output, and is derived from Eq. (6.2).

It is suggested that the user use the names PRECS, PRECZ for the case of a scalar state variable and the names FLOWS, FLOWZ for the case of a vector state. Thus, no changes would need to be made to the main TSFP program.

In the case of a stochastic system, both IPRCV and ICOR are positive, and the system of Eqs. (6.1) and (6.2) becomes

$$\frac{d\,X(t)}{dt} = f(X(t), u(t), t) + W(t) \tag{6.4}$$

and

$$Z(t_k) = h(X(t_k), u(t_k), t_k) + V(t_k);\ k = 1,2, \ldots \tag{6.5}$$

with initial conditions $\hat{X}(t_o)$ and $P(t_o)$ for the state mean vector and the (n x n) state covariance matrix. $W(t)$ and $V(t_k)$ are n-dimensional and m-dimensional white noises.

The evolution of the state mean and covariance between observations [e.g., $Z(t_k)$,$Z(t_{k+1})$] is described by the vector differential equations:

$$\frac{d\,\hat{X}(t)}{dt} = f(\hat{X}(t), \hat{u}(t), t) \tag{6.6}$$

$$\frac{d\,P(t)}{dt} = \left(\frac{d\,f(y(t), \hat{u}(t), t)}{dy(t)}\bigg|_{y(t) = \hat{X}(t)}\right) \cdot P(t) + P(t) \cdot \left(\frac{d\,f(y(t), \hat{u}(t), t)}{dy(t)}\bigg|_{y(t) = \hat{X}(t)}\right)^T + Q(t) \tag{6.7}$$

where the derivatives in Eq. (6.7) are evaluated at the solution of Eq. (6.6), and upper case T denotes transpose. $\hat{u}(t)$ is the mean value of the input vector.

The user supplies the right hand sides of both Eqs. (6.6) and (6.7) in the subroutine PRECS or FLOWS.

Note that, following Georgakakos and Bras (1982), one can incorporate the uncertainty due to the input vector u(t) in Q(t) as follows:

$$Q(t) = Q'(t) + \frac{d\, f(\hat{X}(t), y(t), t)}{dy(t)}\Big|_{y(t) = \hat{u}(t)} \cdot Q_u(t) \cdot \left(\frac{d\, f(X(\hat{t}), y(t), t)}{dy(t)}\Big|_{y(t) = \hat{u}(t)}\right)^T \tag{6.8}$$

where Q'(t) is the generic white noise component, and $Q_u(t)$ is the matrix of input uncertainty that can be approximated as:

$$Q_u(t) = |t_{k+1} - t_k| \cdot Q_u(t_k) \tag{6.9}$$

with $Q_u(t)$ being the covariance matrix of the input variables.

The user subroutine PRECZ or FLOWZ will contain the right hand side of the equations:

$$RES\ (t_k) = Z(t_k) - h(\hat{X}(t_k), \hat{u}(t_k), t_k) \tag{6.10}$$

It will also compute the (m x n) observation gradient matrix $H(t_k)$ defined by:

$$H(t_k) = \frac{d\, h(y(t_k), \hat{u}(t_k), t_k)}{dy(t_k)}\Big|_{y(t_k) = \hat{X}(t_k)} \tag{6.11}$$

In addition, in the case of input uncertainty it will modify the generic white noise covariance matrix $R'(t_k)$ as:

$$R(t_k) = R'(t_k) + \frac{d\, h(\hat{X}(t_k), \hat{u}(t_k), t_k)}{dy(t_k)}\Big|_{y(t_k) = \hat{u}(t_k)} \cdot Q_u(t_k) \cdot \left(\frac{d\, h(\hat{X}(t_k), y(t_k), t_k)}{dy(t_k)}\Big|_{y(t_k) = \hat{u}(t_k)}\right)^T \tag{6.12}$$

When only covariance propagation is wanted (IPRCV > 0 but ICOR = 0) then PRECS or FLOWS are as described previously, while PRECZ or FLOWZ computes only the right hand side of Eq. (6.10).

For communication with the rest of the TSFP program, subroutine PRECS or FLOWS must contain the following COMMON blocks:

```
COMMON/INPUS/XINPS (30)
COMMON/PARAS/PARMS (100)
COMMON/OUTS/OUTPM (20)
COMMON/LINS/A (20,20)
COMMON/INDXS/IPRCV, ICOR, NU, N, M, DT
COMMON/SYSNS/Q (20,20)
COMMON/PINP/PORIN
```

The variables stored in the above given COMMON blocks are described in the following:

XINPS	Array that stores the mean values of the input variables for the current time step. The values are stored as: VALUE1I, VALUE1F, VALUE2I, VALUE2F, . . . where the numbers represent the various input variables and I, F, denote value at the beginning of current time step and value at the end of current time step respectively. Thus, two values are stored for each input variable.
PARMS	Parameter array, which stores the user's model parameters and options as they were read in by subroutine PMSC. See description in the Input-Output Data section.
OUTPM	Array that stores user defined "physical quantities" for later display or for statistical processing. The user defines the OUTPM array elements in subroutine PRECS (FLOWS) and in PRECZ (FLOWZ).
A	Array that stores the matrix of derivatives that appears in Eq. (6.7).
IPRCV, ICOR, NU, N, M, DT	The covariance propagation index, the filtering index, the unit number for the WRITE statements, the number of states, the number of observations, and the time interval between observations.
Q	The generic system white noise covariance matrix Q'(t) appearing in Eq. (6.8). The user, in subroutine PRECS (FLOWS), defines the matrix Q(t) on the left side of Eq. (6.8) in case of input uncertainty.

PORIN — A fraction less than or equal to one that defines the time within the current time step at which the input variables are to be evaluated by linear interpolation between VALUEI and VALUEF (see description of XINPS above).

Similarly, for communication with the rest of the TSFP program, subroutine PRECZ or FLOWZ must contain the following COMMON blocks:

```
COMMON/INPUS/XINPS (30)
COMMON/PARAS/PARMS (100)
COMMON/LINZ/H (5,20)
COMMON/OUTS/OUTPM (20)
COMMON/INDXS/IPRCV, ICOR, NU, N, M, DT
COMMON/OBSNS/RRR (5,5)
```

The new variables are defined as follows:

H — The observations gradient matrix of Eq. (6.11)

RRR — On input it is the generic observations white noise covariance matrix $R'(t_k)$ of Eq. (6.12). On output from PRECZ (FLOWZ) it is the total observations noise covariance matrix $R(t_k)$ of the left side of Eq. (6.12).

Note that when the user's model subroutines are named PRECS and PRECZ, then dummy subroutines FLOWS and FLOWZ must be supplied as follows:

```
SUBROUTINE FLOWS (T, Y, DY)
DIMENSION Y (420), DY (420)
RETURN
END
```

and

```
SUBROUTINE FLOWZ (X1, Z, RES, PARZ, IDMSTA, IDMOBS)
DIMENSION  X1 (IDMSTA), Z (IDMOBS), RES (IDMOBS)
RETURN
END
```

so that the loading of the program is complete. Similarly, if FLOWS and FLOWZ are used, then dummy subroutines PRECS and PRECZ are supplied (format as given above).

When the DISSPLA library is not available for complete loading, the user needs to supply dummy subroutines with names: CNTRP, COMPRS, TK4014, DONEPL, UUSST. The subroutines provided should be of the type:

```
SUBROUTINE  COMPRS
RETURN
END


SUBROUTINE  TK4014
RETURN
END


SUBROUTINE DONEPL
RETURN
END

SUBROUTINE CNTRP (I1, I2, X1, X2, Y, N1, N2, PARM, ITITLE, NU, IIDATA,
                  IDMPAR, IDMPRM, IDMTLE)
DIMENSION X1(31), X2(31), Y(31,31), ITITLE(1), PARM (IDMPRM)
RETURN
END

SUBROUTINE UUSST (X, Y, IY, N, M, INC, ITITLE, RANGE, ICHAR, IOPT,
                  IMAG4, IER)
DIMENSION X(1), Y(IY,20), ITITLE(1), RANGE(4), ICHAR(9), IMAG4(1)
RETURN
END
```

Obviously, none of the pen-plotter options should be used in such a case.

Upon transfer to a computer system other than PRIME/750, PRIMOS Operating System, the user should change the timing function CTIM$A to the new system-specific timing routine. CTIM$A is called by subroutine CONTR (see description of CONTR in the previous section).

REFERENCES

Gelb, A., ed. (1974), Applied Optimal Estimation, The MIT Press, Cambridge, Massachusetts, 374 pp.

Georgakakos, K. P. and R. L. Bras (1982), "A Precipitation Model and its Use in Real-Time River Flow Forecasting," Ralph M. Parsons Laboratory Hydrology and Water Resource Systems Report No. 286, Massachusetts Institute of Technology, Cambridge, Massachusetts, 298 pp.

APPENDIX A

- T S F P -

T: Time Series Analysis

S: State Space Modeling

F: Forecasting

P: Parameter Search

U S E R 'S M A N U A L

by

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National Weather Service
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SECTION 1

INTRODUCTION

This report provides documentation of the TSFP computer program developed at MIT, Ralph M. Parsons Laboratory, under U.S. Government Contract No. NA80AA-H-00044.

Description of the TSFP structure and capabilities is given in Section 2. The input data formats for the various program options are given in Section 3. In the same section, the output of TSFP is also described. Section 4 presents charts of the subroutine network for each TSFP operation.

SECTION 2

DESCRIPTION OF TSFP PROGRAM OPERATIONS

The TSFP program is written in FORTRAN IV. It relies heavily, at its current stage of development, on the International Mathematical Statistical Library (IMSL) subroutines. Development and testing of the program was done on a Honeywell 6180, Multics Operating System.

The program operations are:

(1) Time Series Analysis (T)

On option, time series multivariate statistics are computed and multiple linear regression for a vector of input time series are performed.

(2) State Space Modeling (S)

On option, forecasts are produced from a user-supplied model in state space form, with or without a statistical filter, using vector input and vector output time series. The continuous-discrete form of the filter is used.

(3) Forecasting (F)

Extended forecasts (for more than one time-step in the future) are produced from a user-supplied model in state space form, complemented by a statistical filter, using vector input and vector output time series.

(4) Parameter Search (P)

Two-dimensional printer plots of the contours of several objective functions in a user-specified parameter domain and for a user-supplied model in state space form are produced.

In addition to the main TSFP program units, two subroutines have been developed in which the equations describing the state space forms of (1) the Station Precipitation model and (2) the full Rainfall-Runoff model (see Georgakakos and Bras, 1982) have been encoded. A third subroutine has been developed to read the input data (meteorological and hydrological data) that drive the above mentioned models.

Currently, the dimensions of the state variable arrays permit a maximum of 13 state variables and 2 observations variables in the user-supplied models. Ten time series can be used with the time series analysis option.

This report documents Version 1 of the TSFP program.

SECTION 3

INPUT-OUTPUT DATA

The sequence of the input cards and the relevant variable names and formats are given for the various operations.

The following cards are common to all operations:

Card No.	Format	Variable Name	Description
1	72A1	IDSCR	The run title. It appears at the top of every page of TSFP output.

Note: The following card allows for some preprocessing of the data.

Card No.	Format	Variable Name	Description
2	1X,I5	MTSNO	Number of time series to be used in the run. (Max = 20)
	I5	IENDC	Total number of dates to be scanned when locating the periods of record to be used in the current run.
	I5	IAVER	Number of dates of record for which data will be averaged when time averages will be used as elements of the input time series.

Note: The following group of cards gives the initial and final dates for each of NOPER continuous periods of record that will combine to give the run period.

Card No.	Format	Variable Name	Description
3	1X,I5	NOPER	Number of continuous periods of record that constitute the run period.
4	1X,I5	IPER(1)	Initial year and month of the continuous period of record (YYMM).
	I5	IPER(2)	Initial day and hour of the continuous period of record (DDHH).
	I5	IPER(3)	Final year and month of the continuous period of record (YYMM).

Card No.	Format	Variable Name	Description
	I5	IPER(4)	Final day and hour of the continuous period of record (DDHH).

Note: Card 4 is repeated NOPER times.

Card No.	Format	Variable Name	Description
5	1X,I5	IOPER	Operation indicator: IOPER = 1 – operation: T = 2 – : S = 3 – : F = 4 – : P

3.1 Time Series Analysis Operation Input

When the indicator IOPER takes the value of 1, the following cards are read:

Card No.	Format	Variable Name	Description
6	1X,I5	NU	Write statements unit for TSFP printout.
	I5	LREGAN	Time series analysis option: LREGAN = 0 – Time series multivariate statistics = 1 – Multiple linear regression
	I5	MTOT	Number of time series to be used in the current run (Max = 20).
	I5	NDTEND	Number of data points in each time series; common to all time series (Max = 1500).
	F8.0	ZABSNT	Value to indicate a missing data point in the record.
7	1X,5E12.5	CVUNT	Time series units – conversion for display purposes.
8	1X,25A1	IDSCR	Description of the time series.
	1X,20A1	IDSCR	Units of the time series.

Card No.	Format	Variable Name	Description
	1X,6A1	IDSCR	Symbol of the time series (used for TSFP printout).

Note: Card 8 is repeated MTSNO times.

Note: The next 2 cards are necessary only when the multiple linear regression option has been selected.

Card No.	Format	Variable Name	Description
9	1X,I5	IPRD	If positive, printer plot of observations and predictions is produced.
	I5	ISV	If positive, the predictions of the multiple linear regression are saved in file ISV.
10	1X,10I5	ISQNO	Order numbers of the time series that participate in the multiple linear regression, the dependent time series read last. These numbers are used to locate the time series in the list of the MTSNO time series read in.

Note: The following two cards provide information to be printed in the TSFP output as a heading in the displays.

Card No.	Format	Variable Name	Description
11	1X,36A1	IXDSC	Description of the X-axis in displays of predictions and observations. For time series, use: "TIME STEP NUMBER".
12	1X,50A1	IALP1	Heading in the multivariate statistics option printout. Suggested: "TIME SERIES MULTIVARIATE STATISTICS".

3.2 S, F, P Operations Input

When the indicator IOPER takes the values 2, 3, and 4, the following cards are read:

Card No.	Format	Variable Name	Description
6	1X,I5	NU	Write statements unit for TSFP printout.

Card No.	Format	Variable Name	Description
	I5	ICOR	If positive, filtering of the noise and state estimation is performed.
	I5	NXFORC	Number of extended forecast steps (Max = 6).
	I5	NDTEND	Number of time steps in the current run, including initial condition.
	I5	N	Number of state variables in the user-supplied state space form model (Max = 20).
	I5	INPT	Number of input variables in the user-supplied state space form model (Max = 15).
	I5	M	Number of observation variables in the user-supplied state space form model (Max = 5).
7	1X,E12.5	DT1	Forecast time step. The station precipitation model uses a time step of 3600 seconds while the full Rainfall-Runoff model uses a time step of one 6-hour period.
	E12.5	CNV1	Conversion factor to display time dimensions.
	E12.5	ZABSNT	Number to indicate a missing value.
	E12.5	PORZ	Fraction of the current input values used in the user-supplied model to compute the response. (1-PORZ) corresponds to the one time-step lagged input variables.
8	1X,I5	IPRXC	If positive, covariance propagation is performed.
	I5	IRSDPL	Indicator of residual displays. Currently, it is equal to 0.

Card No.	Format	Variable Name	Description
	I5	IRSDPD	Indicator of observations and predictions displays. Currently, it is equal to 1.
	I5	INMES,NOUTPM, NSTPRD,NCORX, NSTEST,NFLTR, NLINE,IPDPL, IHSPL,ISTVR	Display indicators. Currently, they are all equal to 0.
9	1X,I5	NMPARM	Number of user's model parameters, including option indicators, if any.
	I5	LCOPT	Number of user's model options.
	I5	NLCQPM	Number of parameters related to the specification of the model noise spectral density matrix Q.
	I5	NLCRPM	Number of parameters related to the specification of the observations noise covariance matrix R.
10	1X,10I5	IIOCPL,IISCPL, IIRCPL,IOSCPL, IORCPL,IRESCP, INCP,NLTPM, NCOEF,IMXLK	Statistical analysis indicators. Currently, the only nonzero ones are IRESCP and NCOEF, for residuals statistics and least squares performance measures computations respectively. They take the value of 1. All others should be set to 0.

Note: The following two cards are read only when the parameter search, operation P (IOPER=4), is active.

Card No.	Format	Variable Name	Description
11	1X,I5	IMDRSP	If positive, two-dimensional contour plots of the user-supplied model response statistics are produced in addition to the contours related to the residuals statistics.
	I5	NP1	Number of values of the ordinate parameter to be used in the search.

Card No.	Format	Variable Name	Description
	I5	NP2	Number of values of the abscissa parameter to be used in the search.
	I5	ILP1	Identifier for the ordinate parameter.
	I5	ILP2	Identifier for the abscissa parameter.
12	1X,E12.5	P1LO	Lowest value of the ordinate parameter to be considered in the two-dimensional search.
	E12.5	P1UP	Highest value of the ordinate parameter to be considered in the two-dimensional search.
	E12.5	P2LO	Lowest value of the abscissa parameter to be considered in the two-dimensional search.
	E12.5	P2UP	Highest value of the abscissa parameter to be considered in the two-dimensional search.
13	1X,10I5	MDOP	User's model options.
14	1X,5E12.5	PARM	User's model parameter values.
15	1X,5E12.5	X	Initial state mean vector.

Note: The following seven cards are read only when the covariance propagation option is active (IPRCV > 0).

Card No.	Format	Variable Name	Description
16	1X,5E12.5	X	Initial standard deviations of the state variables. The initial state covariance matrix is assumed diagonal.
17	1X,I5	INDIN	If positive, the diagonal elements of the model noise spectral density matrix Q depend linearly on the observed input. Currently, it is equal to 0.
18	1X,5E12.5	X	Square root of the diagonal elements of the model noise spectral density matrix Q.

Card No.	Format	Variable Name	Description

Note: The following four cards will be read only when the filtering option is active (ICOR > 0).

Card No.	Format	Variable Name	Description
19	1X,I5	INDOB	If positive, the diagonal elements of the observations noise covariance matrix R depend linearly on the observed output.

Note: The following two cards are only read when INDOB > 0.

Card No.	Format	Variable Name	Description
20	1X,I5	INDRP	Index to define whether the R-diagonal elements are proportional or inversely proportional to the observed output. INDRP > 0 - proportional INDRP < 0 - inversely proportional
21	1X,5E12.5	W	Coefficients of proportionality in the expression: $D_i = \sum_{j=1}^{M} (W_{ji} \cdot Z_j)$ where D_i is the square root of the ith diagonal R-element, if INDRP > 0, or D_i is the inverse of the square root of the ith diagonal R-element, if INDRP < 0. The jth output is represented as Z_j. The coefficients W_{ji} are read row-wise.
22	1X,5E12.5	X	Square root of the constant part of the R-diagonal elements.

Note: The following cards contain descriptions and headings to be used in the TSFP printout.

Card No.	Format	Variable Name	Description
23	1X,4A1	IDSCR	Units of the time variable for displays.
24	1X,25A1	IDSCR	Description of the input time series for the user-supplied model.

Card No.	Format	Variable Name	Description
	1X,20A1	IDSCR	Units of the input time series for the user-supplied model.
	1X,6A1	IDSCR	Symbol of the input time series for the user-supplied model (used in TSFP displays).
	1X,12A1	IDSCR	Description of the type of the input time series for the user-supplied model. It can be: "FORECASTED" or "OBSERVED"

Note: Card 24 is repeated for all input time series, and then for all output time series.

Card No.	Format	Variable Name	Description
25	1X,25A1	IDSCR	Comments regarding the first continuous period of record.

Note: Card 25 is repeated for all the continuous periods of record (NOPER times).

Card No.	Format	Variable Name	Description
26	1X,40A1	IDSCR	Information regarding the topographic location of the data collection point.
27	1X,40A1	IDSCR	User's model title (without the word "model").
28	1X,25A1	IDSCR	Description of the user's model parameter.
	1X,20A1	IDSCR	Units of the user's model parameter.
	1X,6A1	IDSCR	Symbol of the user's model parameter for TSFP displays.

Note: Card 28 is repeated for all user's model options and parameters (NMPARM times).

Card No.	Format	Variable Name	Description
29	1X,25A1	IDSCR	Description of the user's model state variable.
	1X,20A1	IDSCR	Units of the user's model state variable.

Card No.	Format	Variable Name	Description
	1X,6A1	IDSCR	Symbol of the user's model state variable for TSFP displays.

Note: Card 29 is repeated for all user's model state variables (N times).

Note: The following 13 cards are read only when operation S is active (IOPER = 2).

Card No.	Format	Variable Name	Description
30	1X,36A1	IXDSC	10X, "TIME STEP NUMBER"
31	1X,36A1	IYDSC1	10X, "STATE CORRELATIONS"
32	1X,36A1	IYDSC2	2X, "FILTER GAINS FOR THE STATE"
33	1X,36A1	IYDSC3	"FILTER INNOVATIONS ST. DEVIATION OF"
34	1X,36A1	IYDSC4	2X, "EIGEN VALUES OF LINEARIZED SYSTEM"
35	1X,36A1	IALP1	12X, "INPUT-OUTPUT STATISTICS"
36	1X,36A1	IALP2	10X, "INPUT-PREDICTIONS STATISTICS"
37	1X,36A1	IALP3	11X, "INPUT-RESIDUALS STATISTICS"
38	1X,36A1	IALP4	9X, "OUTPUT-PREDICTION STATISTICS"
39	1X,36A1	IALP5	10X, "OUTPUT-RESIDUALS STATISTICS"
40	1X,36A1	IALP6	15X, "RESIDUALS STATISTICS"
41	1X,36A1	IALP7	9X, "NORMALIZED RESIDUALS STATISTICS"
42	1X,36A1	IALP8	3X, "USER'S MODEL PHYSICAL QUANTITIES STATISTICS"

Note: The following eight cards are read only when operation F (IOPER = 3) is active.

Card No.	Format	Variable Name	Description
30	1X,25A1	IALP1	"EFFICIENCY COEFFICIENT"
31	1X,25A1	IALP2	"DETERMINATION COEFFICIENT"

Card No.	Format	Variable Name	Description
32	1X,25A1	IALP3	5X, "SLOPE ESTIMATE"
33	1X,25A1	IALP4	3X, "INTERCEPT ESTIMATE"
34	1X,25A1	IALP5	2X, "SLOPE STANDARD ERROR"
35	1X,25A1	IALP6	"INTERCEPT STANDARD ERROR"
36	1X,25A1	IALP7	"PERSISTENCE COEFFICIENT"
37	1X,25A1	IALP8	"EXTRAPOLATION COEFFICIENT"

Note: The following 13 cards are read only when operation P (IOPER = 4) is active.

Card No.	Format	Variable Name	Description
30	1X,60A1	IALP1	14X, "ABSOLUTE PROPORTIONAL MEAN ERROR"
31	1X,60A1	IALP2	16X, "PROPORTIONAL STANDARD ERROR"
32	1X,60A1	IALP3	2X, "PROPORTION OF LAG-1 CORRELATION UNEXPLAINED BY THE MODEL"
33	1X,60A1	IALP4	13X,"ABSOLUTE NORMALIZED RESIDUAL ERROR"
34	1X,60A1	IALP5	13X, "STANDARD NORMALIZED RESIDUAL ERROR"
35	1X,60A1	IALP6	9X, "LAG-1 CORRELATION OF NORMALIZED RESIDUALS"
36	1X,60A1	IALP7	9X, "TIME AVERAGE VALUES OF PHYSICAL QUANTITIES"
37	1X,60A1	IALP8	4X, "TIME COEFFICIENT OF VARIATION OF PHYSICAL QUANTITIES"
38	1X,60A1	IALP9	18X, "LOG-LIKELIHOOD FUNCTION"
39	1X,60A1	IALP10	7X, "ABSOLUTE PROPORTIONAL ERROR IN THE OUTPUT MEAN"
40	1X,60A1	IALP11	2X, "ABSOLUTE PROPORTIONAL ERROR IN THE OUTPUT STND DEVIATION"

Card No.	Format	Variable Name	Description
41	1X,60A1	IALP12	"ABSOLUTE PROPORTIONAL ERROR IN THE OUTPUT LAG-1 CORRELATION"
42	1X,60A1	IALP13	10X, "MODEL-SYSTEM OUTPUT CROSS-CORRELATION"

In addition to the above given sequence of input cards, the user supplies a subroutine to read the data (time series) necessary for the TSFP operation in use.

For the Station Precipitation (SP) model and the full Rainfall-Runoff (RR) model of Georgakakos and Bras (1982), the time series data are read in subroutine RDT1.

For SP:

Format	Variable Name	Description
I4	NDT1	Year and month of the current values read (YYMM).
I4	NHR1	Day and hour of the current values read (DDHH).
F7.3	P	Station pressure reading in mm Hg.
I3	IT	Station air-temperature reading in degrees F.
I3	ITD	Station dewpoint termperature reading in degrees F.
I3	ITW	Station wet-bulb temperature reading in degrees F.
F7.3	P1	Station precipitation rate reading in inches/hour.

For RR:

Format	Variable Name	Description
1X,I4	NDT1	Year and month of the current values read (YYMM).
I4	NHR1	Day and hour of the current values read (DDHH).
F7.3	P	Station pressure reading in mm Hg.

Format	Variable Name	Description
I3	IT	Station air-temperature reading in degrees F.
I3	ITD	Station dewpoint temperature reading in degrees F.
I3	ITW	Station wet-bulb temperature reading in degrees F.
E12.5	P1	Six-hourly mean areal precipitation reading in mm/6-hours.
E12.5	Q	Six-hourly outflow discharge rate in mm/6-hours.
E12.5	EVD	Six-hourly mean areal potential evapotranspiration rate in mm/6-hours.

Subroutine RDT1 converts temperature input to degrees K and pressure input to kg/(m • sec^2). For the SP model, precipitation rate is converted to mm/hour units.

Printed output from the TSFP program is produced in subroutine OUTS. The format of the first page of program and active operation identification printout is the same for all operations. The user-supplied run title is printed on every page of output. The last page containing array storage information and virtual CPU time estimates also has the same format for all TSFP operations.

Description of the printed output for each TSFP operation is given on the next page.

3.3 Time Series Analysis Operation Output

• First, a page of time series description, units, and symbols is printed together with the total number of data points in the time series.

• Additional output for the multivariate statistics option: Time averages, time coefficients of variation, time skewness and kurtosis coefficients are printed. The complete table of cross-correlations between concurrent values of the various time series and up to lag-9 autocorrelation for each time series are also printed.

• Additional output for the multiple linear regression option: The standard deviation of the one-step-ahead predicted residuals, estimates of the regression parameters and the associated standard errors, and printer plots of the predicted and observed time series are printed. Whenever there are values missing in the input time series, a message is printed with the number of missing values and the time step on which they occur.

3.4 S,F,P Operations Output

• The following printout is common to all three operations:

Input and output time series descriptions, units, symbols, and types (observed-forecasted).

Information on the periods of record used in the run (dates--topographical location).

User's model parameters descriptions, units, symbols, and values.

User's model states descriptions, units, symbols, and initial values.

The initial state covariance matrix, the model error spectral density matrix, and the observations error covariance matrix.

• For the State Space Modeling Operation, printer plots of the predictions and observations are produced. In addition, the mean, standard deviation, and skewness coefficient of the residual time series, and the least squares performance indices (coefficients of efficiency, determination, persistence, and extrapolation) are printed. (See Georgakakos and Bras, 1982.)

• For the Forecasting Operation, the least squares performance indices (coefficients of efficiency, determination, persistence, and extrapolation) are printed for extended forecasts up to a maximum lead time specified by the user.

• For the Parameter Estimation Operation, two-dimensional contours corresponding to the performance indices (absolute error, proportional average error, proportional standard error, and cross-correlation coefficient) are printed. (See Georgakakos and Bras, 1982.)

SECTION 4

TSFP SUBROUTINE NETWORK

The sequences of the subroutine calls are given on the following pages for the various operations of the TSFP program. Also included are the subroutine call-networks related to the Station Precipitation and the Rainfall-Runoff models documented in Georgakakos and Bras, 1982. The order in which the subroutines are called in the following charts is from left to right. Multiple calls to the same subroutine are not shown.

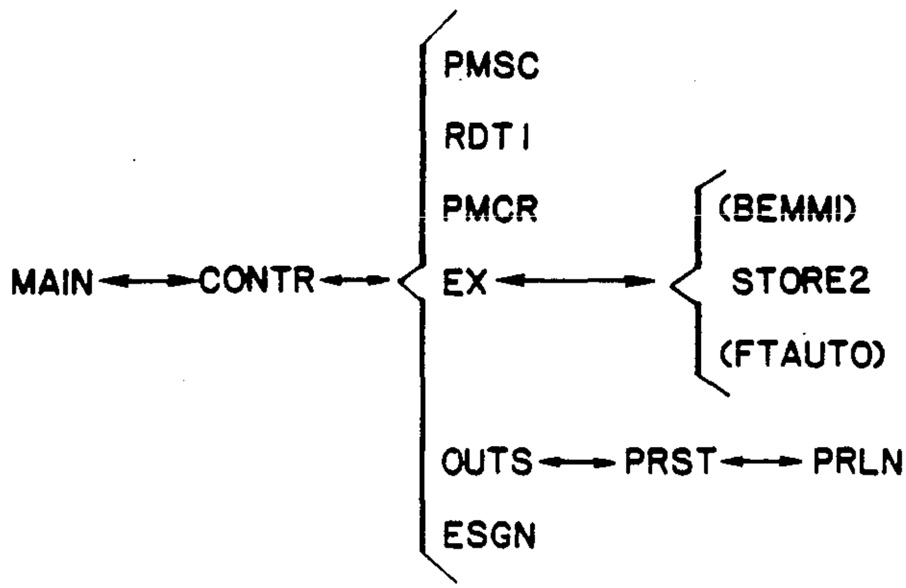
Subroutines whose names are enclosed in parentheses belong to the International Mathematical Statistical Library (IMSL). Documentation of those subroutines is given in "IMSL Library Reference Manual," 1980, Edition 8, published by IMSL, Inc., Houston, Texas.

REFERENCES

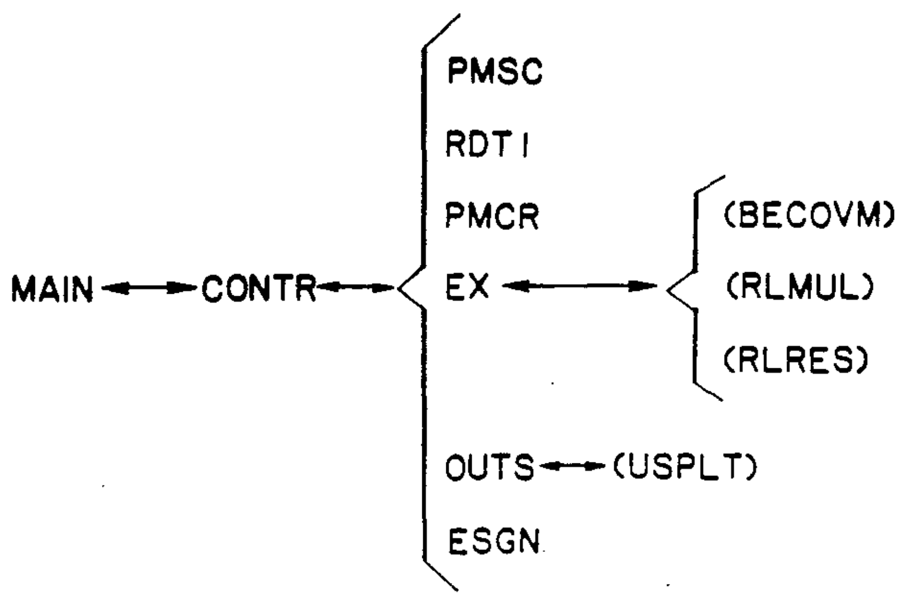
Georgakakos, K. P., and R. L. Bras (1982), "A Precipitation Model and its Use in Real-Time River Flow Forecasting," Ralph M. Parsons Laboratory Hydrology and Water Resource Systems Report No. 286, Massachusetts Institute of Technology, Cambridge, Massachusetts, 298 pp.

1) TIME SERIES ANALYSIS OPERATION

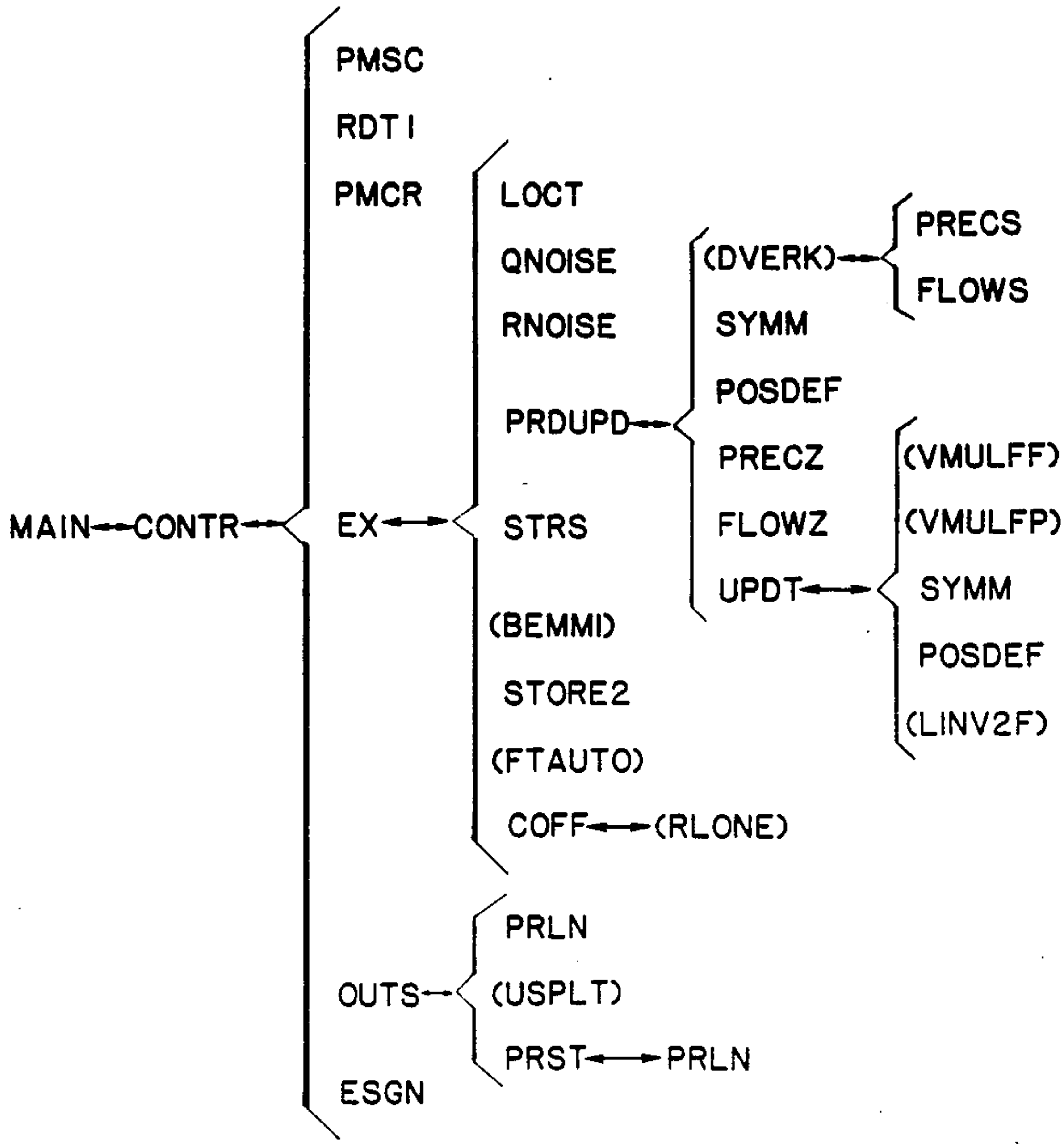
A) MULTIVARIATE STATISTICS OPTION



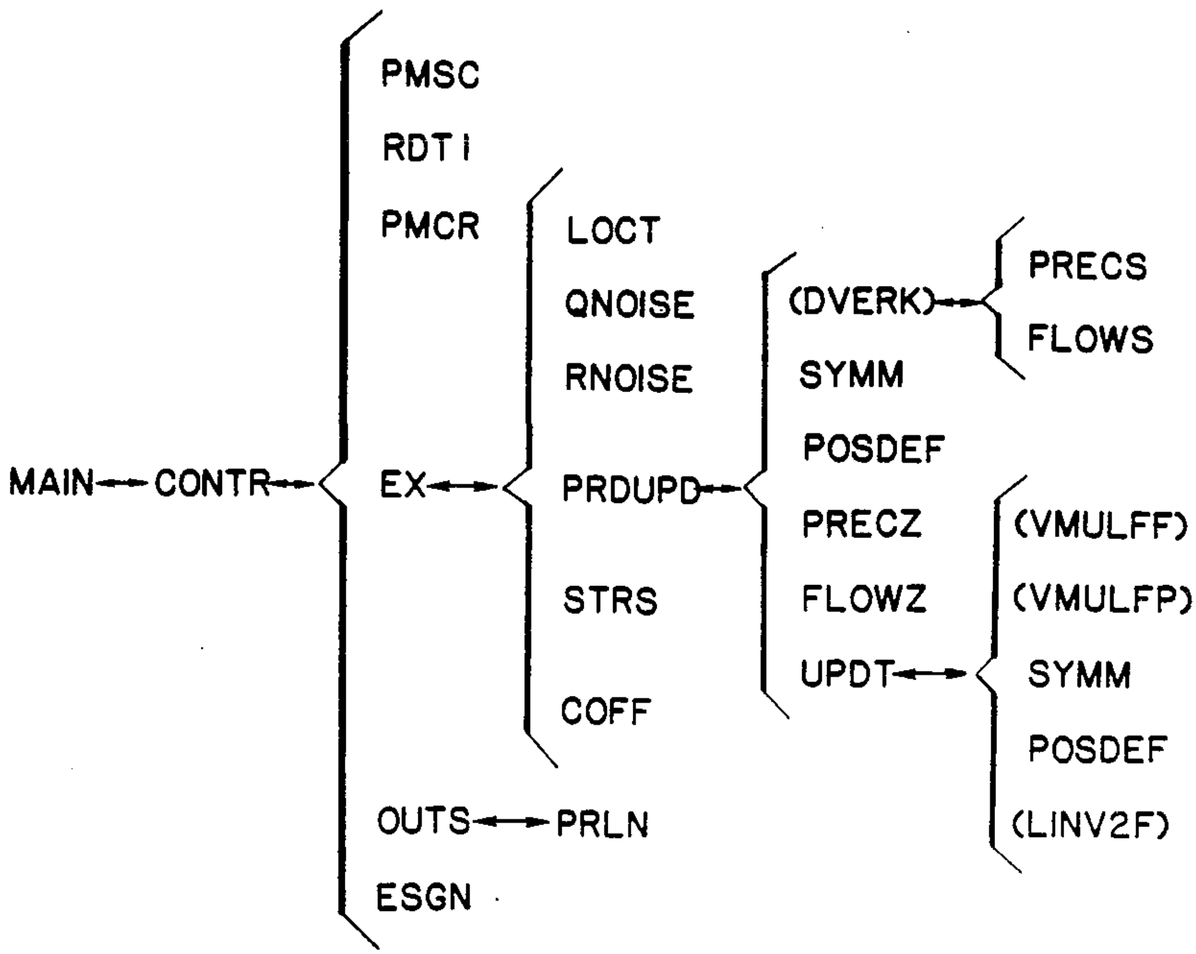
B) MULTIPLE LINEAR REGRESSION



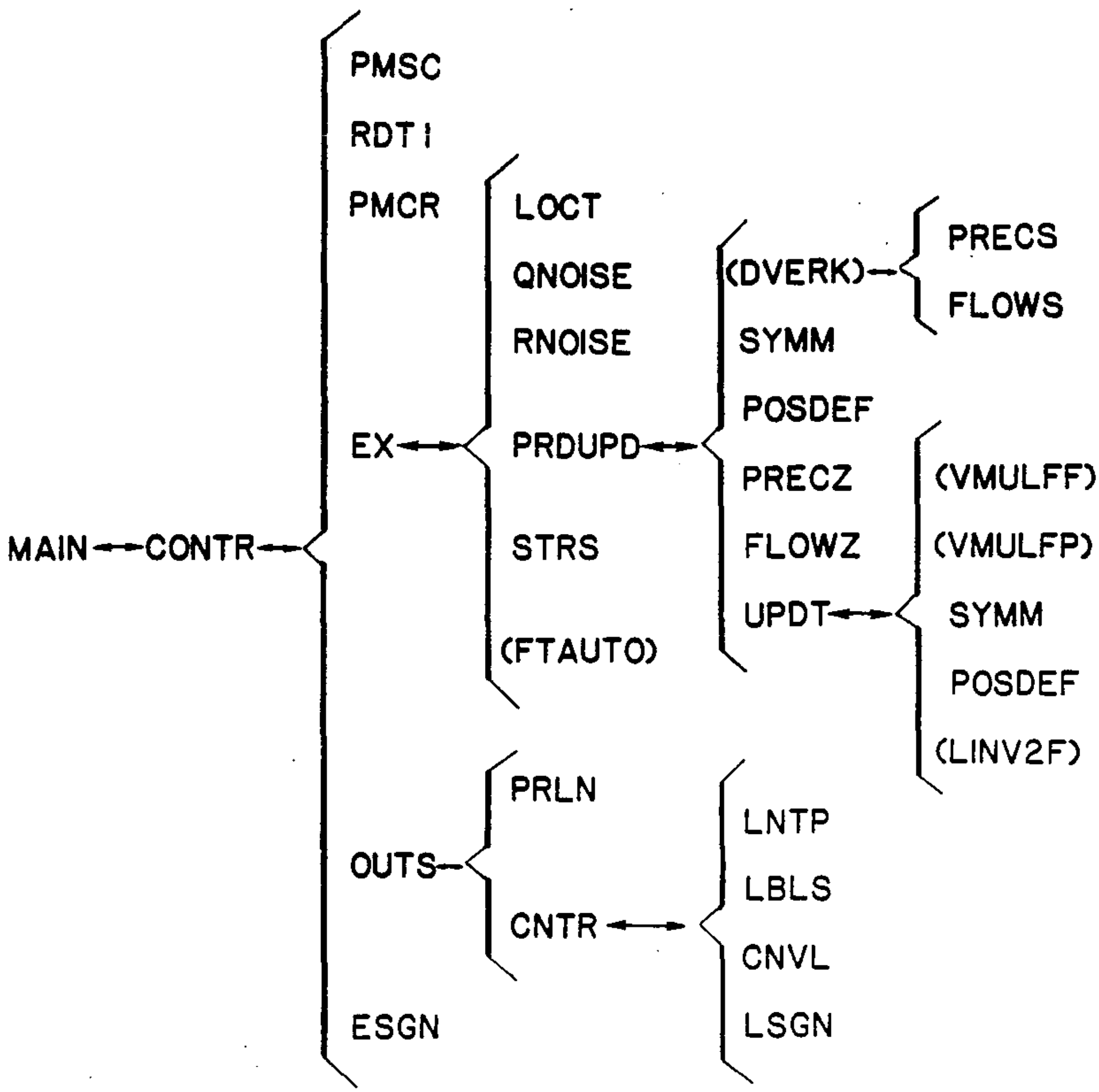
2) STATE-SPACE MODELING OPERATION



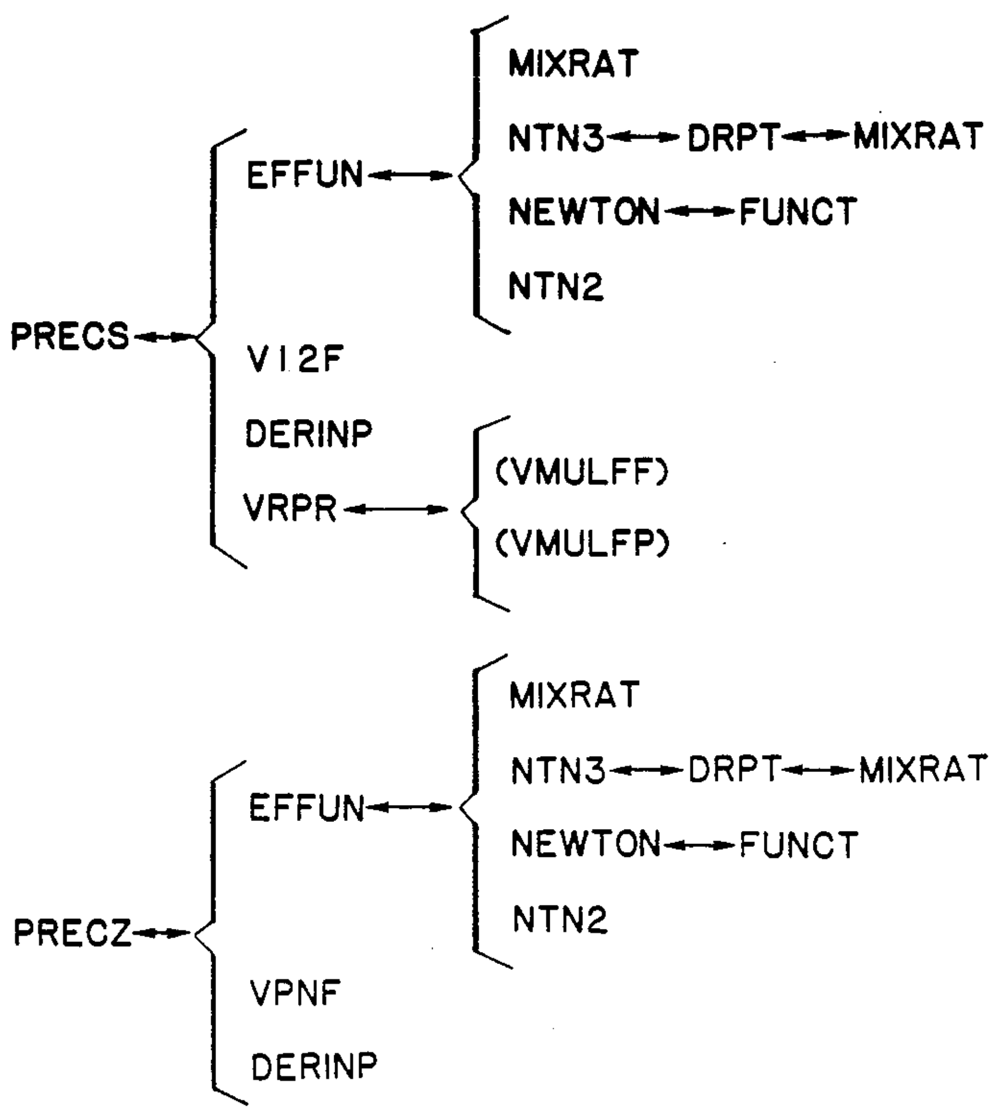
3) FORECASTING OPERATION



4) PARAMETER SEARCH OPERATION



5) STATION PRECIPITATION MODEL SUBROUTINES



6) FULL RAINFALL-RUNOFF MODEL SUBROUTINES

- FLOWS ↔
  - EFFUN ↔
    - MIXRAT
    - NTN3 ↔ DRPT ↔ MIXRAT
    - NEWTON ↔ FUNCT
    - NTN2
  - VPNF
  - VI2F
  - DERINP
  - VRPR ↔
    - (VMULFF)
    - (VMULFP)

- FLOWZ ↔
  - EFFUN ↔
    - MIXRAT
    - NTN3 ↔ DRPT ↔ MIXRAT
    - NEWTON ↔ FUNCT
    - NTN2
  - VPNF
  - DERINP