USE OF NEW SSARR MODEL AUTOMATIC UPDATING PROCEDURE

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INTRODUCTION

In real-time hydrologic forecasting, it is highly important to have an easily applied correcting routine to use in adjusting model results to observed streamflow conditions. The scheme needs to produce results quickly, while being rigorous enough to ensure that the adjusted hydrograph has the proper shape to begin the forecast session. From its inception, the SSARR model has been designed with a careful marriage between model complexity and ease of use in real-time forecasting. The idea of applying an automatic adjustment technique to make model results match observed conditions was an important part of this design from the start.

INITIAL SSARR ADJUSTMENT ROUTINE

The SSARR model has used a simple adjustment routine as a part of the model for more than 20 years. The initial method simply adjusted the moisture input (precipitation and snowmelt) to force the model to match endpoint observed streamflow. The user specifies the factors to apply to the moisture input (0.5 to 2.0, in most cases) and the tolerance allowed to fit, 5% error or a specified flow value supplied by the hydrologist. The resulting adjusted hydrograph did not always match the observed flow throughout the whole adjustment period. In addition, if heavy rain or significant melt occurred in the last period of adjustment, the correcting technique tended to over-adjust, producing an incorrect shape in the forecast period. Even considering these limitations, the simple adjustment routine has worked fairly well. Over the last five years, a considerable amount of time has been spent by the North Pacific Division Corps of Engineers and the Northwest River Forecast Center to produce an improved adjustment routine.

NEW SSARR ADJUSTMENT ROUTINE

Goal of Adjustment Technique

The goal of the adjustment scheme is to make the computed instantaneous conditions of the model match observed conditions at the end of the adjustment period. This is done by making small changes to lapse rate, temperature, and precipitation to make the computed hydrograph match the observed hydrograph. The rationale is that if the hydrographs match, the model state variables will best represent observed conditions. The adjustment scheme is currently limited to changing lapse rate, temperature, basin average temperature and basin average precipitation. The user specifies which of these parameters are candidates for adjustment, the adjustment increment for each, and the maximum number of increments of change allowed in any compute period. The goal is to make the minimum number of incremental adjustments so that the computed hydrograph will match the observed hydrograph within user-specified tolerance. All parameters are adjusted simultaneously.

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The Adjustment Cycle

The adjustment cycle follows these steps: (1) Process the basin through time to produce the unadjusted computed hydrograph. (2) Compile a tabulation of the estimate of difference for each time period. The estimate of difference is an estimate of the difference between the observed and computed hydrographs which potentially can be corrected by a change in moisture input. (3) Derive a set of trial adjustments to the parameters for each compute period. If the estimate of difference is already within error tolerance for a compute period, no adjustment is made. (4) If the maximum number of cycles (specified by user) has not been exceeded, and if changes have been made to adjustment time series, go back to step 1. If the maximum cycles have been made, or no additional adjustments were made in the last cycle, the adjustment procedure is complete.

The Objective Function

The objective function is the squared error between the observed and computed hydrographs. After the adjustment procedure is complete, the trial resulting in the smallest squared error is accepted as best. A table of attribution percents (in the form of a mass curve) is provided by the user. These percents represent the portion of the streamflow error in each future period which can be corrected by a change to generated runoff in the current period. If, for example, the table of attribution percents contains five points, the estimate of difference for period i is:

$$E_i=P_i(C_i-O_i)+P_{i+1}*C_{i+1}-O_{i+1})+...+P_{i+5}*(C_{i+5}-O_{i+5})$$

$$F_i=E_i*CF/(1-BFP_i/100)$$

Where:

i = compute period

P = from attribution table; it is the ratio of volume of runoff in a compute period to total volume of the hydrograph.

C = computed discharge

O = the observed discharge

BFP = baseflow percent; $(1-BFP/100)$ is the contribution to direct runoff.

E = cfs error attributed to input to runoff from this period.

CF = conversion factor: (CFS hours) $*CF$=basin-inches, $CF=1/645.33*area$

F = the estimate of difference in basin-inches of generated runoff.

The attribution percent table is a percentage description of a unit hydrograph. It is a relationship of time versus the percent of volume of the unit hydrograph that has passed up to that time. If, for example, 50% of the volume of the unit hydrograph is in the first six hours, 30% in the period from hour 6 to hour 12 and 20% in the period from hour 12 through hour 18, the accumulated percents are as follows:

HOUR	ACCUMULATED-PERCENT
6	50%
12	80%
18	100%

The attribute table (ZCT) is as follows: ZCT ATTR 2 650128018100. Since the shape of the hydrograph resulting from a unit of precipitation varies with the intensity of input, a family of curves relating intensity to attribution percents can be used. A three variable attribution table may be input with the ZCF or CF card format. The "Z" value is the input to direct runoff. "X" is hours and "Y" is accumulated percent, in percent of runoff through that hour. The attribution table can be derived by running the model with a unit of precipitation in the first compute period as demonstrated in appendix A of the SSARR handbook.

The Adjustment Scheme

The "ADJUST" command card in the SSARR input stream contains controls for the adjustment procedure. These controls include designation of which parameters (lapse rate, temperature, and/or precipitation) are candidates for adjustment. Also specified are the amount of change (i.e., the increment) allowed for each parameter during a trial cycle, and the maximum number of increments of change allowed in any one compute period. There is also tolerance information to control closeness of fit. In addition, the "ADJUST" command specifies the total number of trial cycles allowed, and the "wet" constant to identify periods which have too much precipitation to allow the lapse rate to exceed 6.0c/1000m. The adjustment proceeds as shown below for each compute period, normally six hours for Columbia basin forecasting.

A. The first step. The first step is to derive the tolerance against which the estimate of difference is measured. If the absolute value of the estimate of difference is less than the tolerance, no adjustment for this compute period is necessary. The user specifies a maximum allowable error in terms of percent of "attributed observed" flow (typically 5 percent). The "attributed observed" flow is calculated in the same way as the estimate of difference; the series of attribution percents are multiplied by the current and future observed flows to arrive at the "attributed observed" flow for this period. The allowable-error-percent times this flow gives "maximum error". If the estimate of difference is smaller than the "maximum error", no adjustment for this period is necessary.

B. Undercompute. When the estimate of difference for a period is negative, more generated runoff is needed and the lapse rate should probably be lowered, the temperature raised, and or precipitation increased. Lapse rate is the first parameter checked by the adjustment scheme. If the user does not elect it as a candidate for adjustment, the scheme goes on to the next parameter (temperature). After adjusting lapse rate and estimating the effect of the adjustment, the effect is added to the estimate of difference to see if more correction is needed. Estimate the effect on moisture input of increasing temperature one increment. If the change does not exceed the error expressed by the estimate of difference, increase the temperature one increment. If the temperature has been increased by the maximum number of increments, no further temperature adjustments are allowed. After adjusting temperature and estimating the effect of the adjustment, the effect is subtracted from the estimate of difference to see if more correction is needed. The maximum amount of change to precipitation during a single trial cycle is 10% of observed precipitation for a period, taken in whole increments. Estimate the effect on moisture input by increasing precipitation by one increment. If the change does not exceed the error, increase the precipitation by one increment. No further adjustments to precipitation will be made if the maximum number of increments have been reached.

C. Overcompute. If the estimate of difference is positive, less generated runoff is needed and the lapse rate should be raised, the temperature lowered, and/or precipitation reduced. Again, lapse rate is the first parameter checked by adjustment scheme. Estimate the change to moisture input of raising lapse rate one increment. If the change does not exceed the error expressed by the estimate of difference, adjust lapse rate one increment. After adjusting lapse rate and estimating the effect of the adjustment, the effect is subtracted from the estimate of difference to see if more correction is needed. Again, the temperature is decreased one increment at a time until the maximum number of increments have been used. Finally, if adjustments to lapse rate and temperature have not reduced the error difference sufficiently, precipitation is decreased one increment at a time to decrease the computed error difference.

D. Iterative procedure. After the completion of one time period of adjustment, a new error difference is computed and the same process described above is repeated on the reduced error for the next time period. The maximum number of iterations allowed on a backup period defaults to four. However, present operational use suggests that a more realistic number of iterations is 10. In operational practice, the hydrologist runs the automatic adjustment on the backup period and either accepts the adjusted results or make manual adjustments, interactively, to the observed data or state variables and reruns the adjustment procedure.

EXAMPLE OF APPLICATION OF NEW ADJUSTMENT SCHEME ON AN OREGON COASTAL BASIN

During the winter forecast season (1987-88), the new adjustment scheme was tested on an Oregon coastal basin that derives streamflow primarily from rainfall runoff. Figure 1 illustrates the application of the procedure during one rain event. The unadjusted hydrograph was consistently higher than the observed hydrograph throughout the adjustment period. Note that the adjustment procedure reduced almost every period of precipitation prior to the peak, while in the recession period, precipitation increments were added to the observed precipitation. The overall fit of the observed and adjusted hydrographs is quite good. A few additional comments about the test results are in order.

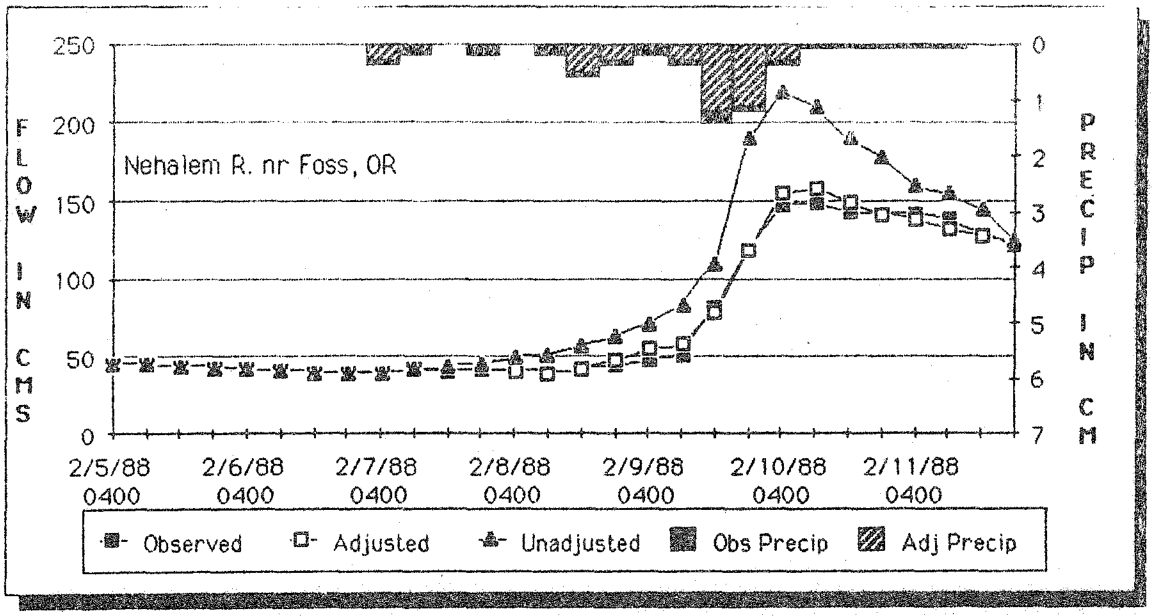

Figure 1. New Adjustment Routine Applied On A Rain Runoff Basin

Note that in the recession period precipitation increments were added where the mean basin precipitation input to the model had initially been zero. There is some question whether adding precipitation to periods of zero input is appropriate. The observed streamflow was extracted directly from the CROHMS database and supplied to the adjustment scheme to perform the error analysis. This exercise pointed up the need for an interactive routine in the SSARR model to quickly correct erroneous streamflow values before the adjustment process is started. In flood forecasting, the time required for correcting streamflows and performing the adjustment routine must be minimized.

Finally, if the hydrologist decides that adjustments to the lapse rate, temperature and precipitation did not produce a satisfactory result, changes to some of the state variables may be initiated. These could be changes to soil moisture levels, snow covered area, melt rate or other initial conditions. After these adjustments, the automatic adjustment routine would be run to fit the model results to the observed hydrograph. Experience to date indicates that the need to adjust state variables is relatively infrequent.

<u>EXAMPLES OF APPLICATION OF NEW ADJUSTMENT SCHEME ON A SNOWMELT BASIN - THE ILLECILLEWAET RIVER</u>

This past summer, a hydrologic model testing workshop was held at the University of British Columbia, sponsored by the World Meteorological Organization. One of the basins studied in the workshop was the Illecillewaet River in British Columbia. The new SSARR adjustment scheme was used during this workshop and one year serves to illustrate well the use of the new adjustment scheme on a snowmelt basin.

Figure 2 shows the first ten days of the selected event which has a sharply peaked hydrograph produced by a combination of rainfall and snowmelt. The unadjusted hydrograph had the timing of the peak represented accurately, but missed the peak by a significant amount. The adjustment scheme operated on the input data, making small changes to the precipitation and temperature values. A total of 1.6 centimeters of rain was added to the storm, four days preceding the storm peak. Additionally, 5.5 degrees C were added to the temperature input two days prior to the peak. This combination produced more rainfall runoff and more rain melt. The end results was an excellent fit of the hydrograph.

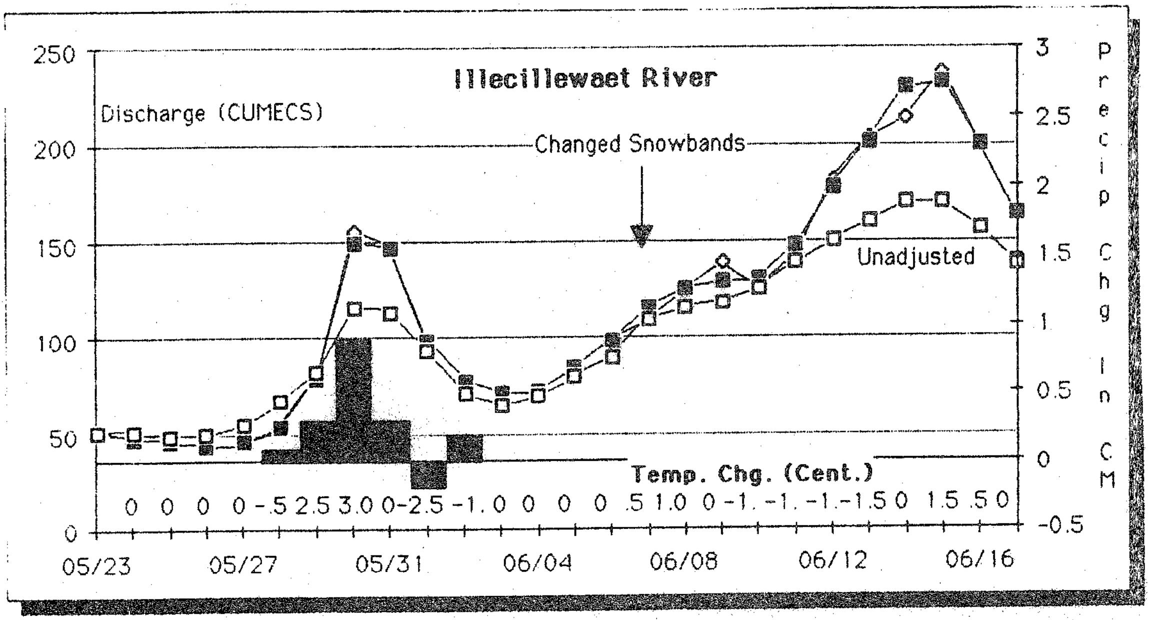

Figure 2. Example of SSARR Adjustment Scheme On a Snowmelt Basin

The second event on Figure 2 shows the application of the procedure on what was the snowmelt peak of the season. Precipitation during this event was minimal, while temperatures reached 23 to 25°C on several days. As can be noted on the hydrograph, the unadjusted hydrograph was not a very good fit with the observed. In addition, allowing the adjustment scheme to make the maximum change per computation period (10°C) would have produced maximum temperatures that would be unrealistically high. Further inspection of the SSARR zone model pointed up the fact that a snow band had gone bare two days before the snowmelt peak. The initial conditions for zone snow water equivalent were called up and water equivalent was added to the lower zones. The fit of the hydrograph after adjusting the zone snow water equivalent was excellent, with only minor changes to the temperature input.

CONCLUSION

The results of testing the new SSARR adjustment scheme on a rainfall runoff basin on the Oregon coast and on a snowmelt basin in British Columbia indicated that the technique if quite versatile, working equally well in both hydrologic regions. Small adjustments to temperature, precipitation and lapse rate seem to correct the hydrograph fit in the majority of cases. However, events will still occur when the hydrologist will need to change some of the model parameters such as soil moisture, zone snow water equivalent in order to achieve the best fit.

Another result from the WMO model test on the Bird Creek, Oklahoma basin, pointed up the need for a refinement to the adjustment scheme. The current procedure makes the estimate of differences based on a unit hydrograph; consequently, it tends to spread the correction to precipitation over the major part of the hydrograph, rather than making large changes to individual precipitation measurements. Therefore, it does not shift the timing of the precipitation very well. Several storms in the Bird Creek study indicated the need for a shift in timing of precipitation to improve the model fit. A step is now being added to the adjustment procedure to change the timing of precipitation when it is found that incremental adjustments to precipitation are not reducing the squared error term.

This procedure is currently being tested on several basins in daily forecasting. The forecaster reviews the automatic adjustment and either accepts the automatic fit or interactively operates the model to manually intervene if the automatic fit is not acceptable. Experience to date indicates that the need to manually intervene is relatively infrequent. The new adjustment scheme shows promise for full application in the entire forecast area.

REFERENCES

Davis, T. E., "Automatic Adjustment Algorithm in the SSARR Snowband Model", unpublished manuscript, October 1987, 10 pp.

U.S. Army Corps of Engineers, North Pacific Division, "SSARR Users Handbook", April 1986, 61 pp.