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# EVALUATION OF THE ADVANTAGES OF THE CONTINUOUS SAC-SMA MODEL OVER AN EVENT API MODEL

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## 1. INTRODUCTION

One of the key elements of the Advanced Hydrologic Prediction Service (AHPS) proposed by the National Weather Service (NWS) is the Sacramento Soil Moisture Accounting (SAC-SMA) model. Through AHPS, the NWS River Forecast Centers (RFCs) will be able to expedite the calibration and implementation of the SAC-SMA model as a replacement for event Antecedent Precipitation Index (API) models. Calibrated SAC-SMA models will help improve the accuracy of RFC forecasts because in many areas of application the API models are based on regional empirical relationships rather than specific basin properties. Also as part of AHPS, some RFC's will be re-calibrating the SAC-SMA model for specific basin characteristics to replace those parameter sets initially derived from regionalized parameters. Recently, advances have been made in the estimation of initial SAC-SMA parameters from soils information available from the Natural Resources Conservation Service (NRCS) (Koren et al, 1999). These advances should help expedite the application and calibration of the SAC-SMA.

The purpose for the present work is to evaluate the gains realized by implementing and calibrating the SAC-SMA. Simulations from a calibrated SAC-SMA are compared to those from the API model as well as those from a SAC-SMA model with regionalized parameters. Both the API and SAC-SMA models are forecast models and can be used in conjunction with user-specified modifications to account for non-standard conditions and to keep the model on track. Such modifications include the ability to change model states, precipitation forcing, runoff volume and baseflow volume. The SAC-SMA has been compared to other models in forecast mode in several other studies (Hogue, T.S., (1999), Miller et. al (1995), and Sokolowski and Younger, (1995). For this study, it was decided to remove the human element and compare the models in simulation mode over many years. In order to accomplish this, the event API model was run with a constant baseflow.

## 2. DESCRIPTION OF THE SAC-SMA and API MODELS

The SAC-SMA was initially developed by Burnash et. al, (1973). It is a conceptual model that represents the active soil profile as a system of two layers, each having a tension water and one or more free water components or reservoirs. In the upper layer, precipitation initially encounters the tension water reservoir, in which water is held and can only be removed by evaporation. Once the upper zone tension water fills, excess precipitation encounters the upper zone free water reservoir. Here, the water is able to percolate to the lower zones or move laterally as interflow. Any precipitation in excess of the upper zone tension and free water zones enters the channel system as fast responding surface runoff. As in the upper zone, there is a tension water reservoir in the lower zone. Once percolated water fills this lower zone tension water storage, water moves to two free water reservoirs. Outflow from these two storages forms short and long-term baseflow. Each time step, the outflows and excesses from the different reservoirs is summed to make a total channel volume contribution. Interested readers can also refer to Burnash (1995) for additional information.

The standard API model is based on empirical relationships linked through a coaxial graphical relationship. The model is event based, non-linear and lumped. It generates storm runoff based on antecedent moisture conditions, a seasonality function, storm duration and total precipitation. Storm runoff is then added to baseflow and snow melt to produce a final river discharge.

## 3. METHODOLOGY

Three basins were selected for the initial phase of this study, which is ongoing. Table 1 presents relevant data for each of the test basins.

| River | NWS Identifier | Drainage Area in sq. km. |
|---|---|---|
| Cedar Cr. near Bussey, Iowa | BSSI4 | 967.7 |
| West Breast Cr. near Dallas, Ia | DLLI4 | 885.8 |
| Conasauga R. near Tilton, Ga. | TLNG1 | 1779.3 |

Calibrated parameters for the SAC-SMA and API models were obtained for basins BSSI4 and DLLI4. The simulation period spanned 40 years for BISS4 and 38 years for DLLI4. Time series of precipitation and

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temperature were used as forcing for both models, which were run at a 6 hr time step. Simulations were compared to observed mean daily flow from the U.S. Geological Survey. Examination of the observed streamflow records revealed that baseflow contribution to the hydrograph was minimal. Therefore, it was a reasonable assumption in these basins to assume a small, constant baseflow for the API model throughout the simulation period.

Basin TLNG1 was used to evaluate the performance of the SAC-SMA given calibrated parameters and those derived by applying parameter sets from nearby calibrated basins.

Two statistics were computed to evaluate the performance of the SAC-SMA and the API models in all tests. The first is a hydrograph shape error, which is the root mean square error of the simulated response versus observed discharge. The second statistic is a peak error. The shape error was computed for 4 flow intervals for each of the basins, while the peak error was computed as a combined statistic for both basins.

TABLE 2. Shape Error and Peak Error in CMS for Study Basins BSSI4 and DLLI4: SAC-SMA vs API.

| | Flow Interval cms | Error SAC-SMA | Error API | Percent Improvement |
|---|---|---|---|---|
| BISS4 | 0-5 | 3.4 | 3.8 | 10.5 |
| | 5-100 | 21.7 | 23.0 | 5.7 |
| | 100-above | 88.4 | 116.7 | 24.3 |
| | 350-above | 219.9 | 306.6 | 28.3 |
| DLLI4 | 0-5 | 3.0 | 2.7 | -11.1 |
| | 5-100 | 21.6 | 20.3 | -6.4 |
| | 100-above | 100.2 | 120.8 | 17.1 |
| | 350-above | 145.7 | 308.6 | 52.8 |
| Both | 0-5 | 3.2 | 3.3 | 1.5 |
| | 5-10 | 21.7 | 21.7 | 0.0 |
| | above 100 cms | 94.3 | 118.8 | 20.6 |
| | above 350 cms | 182.8 | 307.6 | 40.6 |
| | Peaks | 88.6 | 115.8 | 23.5 |

## 4. RESULTS

Table 2 presents the shape and peak error statistics for basins BISS4 and DLLI4. The peak error statistic was based on the total number of events for both basins. In Table 2, percent improvement is defined using equation 1:

$$\text{\% Improvement} = \frac{Error_{API} - Error_{SAC-SMA}}{Error_{API}} \qquad 1$$

It can be seen in Table 2 that the calibrated SAC-SMA provides substantial improvement over the API when run in simulation mode. In the lowest flow ranges for basin DLLI4, the SAC-SMA performed slightly worse than the API model. Figure 1 presents a typical case of the simulations generated by the SAC-SMA and the API models.

Shape error and peak error statistics were also computed for basin TLNG1. In these tests, simulations were generated using two parameter sets: calibrated specifically for TLNG1 and parameters derived by regionalization. Table 3 presents the results of these tests.

TABLE 3. Shape Errors and Peak Errors for TLNG1: Calibrated Parameters vs. Regionalized Parameters.

| Flow Interval cms | Error (cms) SAC-SMA Calibrated Parameters | Error(cms) SAC-SMA Regional Parameters | % Improvement |
|---|---|---|---|
| above 350 cms | 98.6 | 254.5 | 61.3 |
| above 400 cms | 101.4 | 282.2 | 64.1 |
| peaks > 450 cms | 87 | 307 | 71.7 |

It can be seen from the results in Table 3 that dramatic improvements can be realized when SAC-SMA is calibrated specifically to a basin rather than adopting parameters from nearby calibrated parameters.

## 5. SUMMARY

Streamflow simulations generated by a calibrated SAC-SMA model were compared to those produced from an API model. These tests work conducted in simulation mode with no forecaster updates or modifications. The simulations spanned nearly 40 years. Error statistics computed for these tests revealed that in pure simulation mode, the continuous SAC-SMA provides improvement in streamflow simulation accuracy. In addition, tests with basin TLNG1 showed that regionalized parameter sets can be improved upon through basin-specific calibration. Tests with other basins are planned.

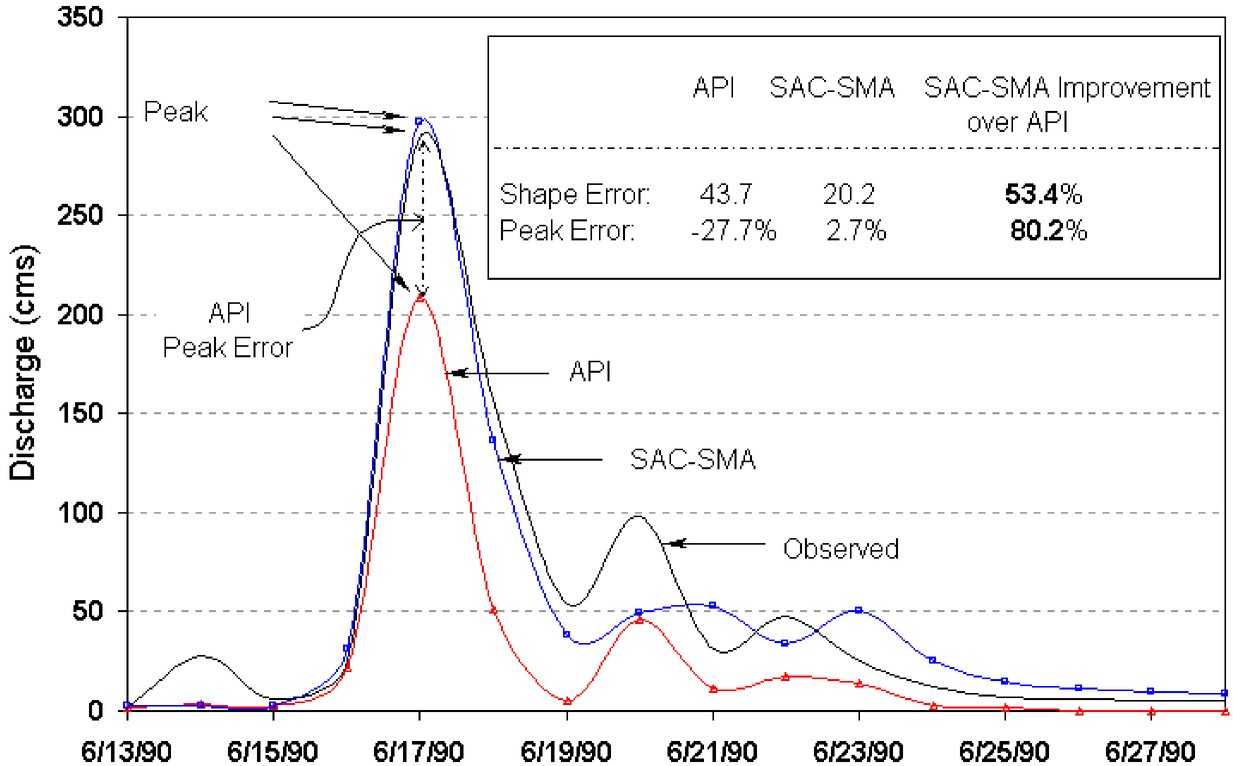


**Figure 1** Comparison of SAC-SMA and API Simulations for event of June, 1990

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