PRMS San Joaquin Model Update

November 14, 2018

Nathan Burley, P.E.
Angelique Fabbiani-Leon, P.E.
Water Resources Engineers
Overview

• Introduction
• San Joaquin Watershed
• Calibration Steps/Completed Portions
• Streamflow Calibration and Issues
• Review Calibration
• Closing Remarks
Introduction

Precipitation-Runoff Modeling System (PRMS)
- Deterministic, distributed-parameter, energy budget model
- Determines streamflow through hydrologic processes represented mathematically to coordinate together

Calibrated for April-July (A-J) Runoff
- California Department of Water Resources (DWR) Snow Surveys Section provides A-J runoff forecasts, referenced by major reservoir operators
- PRMS calibrated to A-J runoff forecasts

San Joaquin (SJ) PRMS Model Contracted Development
- SJ PRMS development is contracted work with GEI Consultants and first DWR PRMS model not developed by USGS

Educational Opportunity
- Working with GEI in the SJ PRMS development → greater opportunities to learn the mechanics of PRMS → continual improvements for the model
- Learning the fundamentals → applicable to other PRMS model development
PRMS Development Steps

1) Climate Data Collection
   - Collect climate data from data sources
   - QC climate data
   - Format to .data files for PRMS input

2) FNF Data Collection
   - Collect streamflow data
   - QC streamflow data
   - Review areas not covered by observed data
   - Format to .data files for PRMS input

3) Hydrologic Response Unit (HRU) Development
   - Develop list of basin physical characteristic layers to compose HRU network
   - Review HRU network and aggregate heavily delineated areas

4) Climate Data Distribution
   - Climate data distribution method from GEI
   - Review climate distributed network

5) Calibration
   - LUCA
   - 4 Round process
   - Shuffled Complex Evolution (SCE)

6) Validation
   - Select validation points to review calibrated results
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San Joaquin Watershed

*Drainage area: 1,675 sq mi
*Median runoff: 1.45 MAF
*Snowmelt basin
*Upstream Stor: 610 TAF
*Hydropower
*Limited gages
*Rainshadows
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## Calibration Steps (GEI)

<table>
<thead>
<tr>
<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
<th>Round 4</th>
</tr>
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<tbody>
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<td>Monthly Mean</td>
<td>UCLA SWE Data</td>
<td>Mean Monthly/Seasonal Flow</td>
<td>Daily Flow</td>
</tr>
<tr>
<td>Solar Radiation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Objective Function

- **Round 1**: Sum of the absolute difference in the logarithms of observed and simulated solar radiation
- **Round 2**: Normalized Root Mean Square Error
- **Round 3**: Sum of the Absolute Values of the Normalized Residuals
- **Round 4**: Normalized Root Mean Square Error
## Calibration Parameters

<table>
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<td></td>
<td></td>
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<td>Radiation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Round 1:
- dday_intcp
- radadj_intcp
- tmax_index

### Round 2:
- freeh2o_cap
- potet_sublime
- tmax_allrain
- tmax_allsnow
- Rad_trncf

### Round 3:
- Adjmax_rain
- Imperv_stor_max
- Pref_flow_den
- Smidx_coef
- Smidx_exp
- Snowinfil_max
- Soil_moist_max
- Soil_rechr_max

### Round 4:
- Carea_max
- Cecn_coef
- Fastcoef_lin
- Fastcoef_sq
- Gwflow_coef
- Gwsink_coef
- Gwstor_init
- Jh_coef
- Radadj_slope
- Sat_threshold
- Slowcoef_lin
- Slowcoef_sq
- Soi2gw_max
- Ssr2gw_exp
- Ssr2gw_rate
- Ssstor_init
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## Parameters Calibrated from GEI List

<table>
<thead>
<tr>
<th>Parameter Names (Pars_Names)</th>
<th>Lower Limit* (bl)</th>
<th>Upper Limit* (bu)</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>imperv_stor_max</td>
<td>0.0</td>
<td>0.1</td>
<td>Inches</td>
<td>Max impervious area retention storage for each HRU</td>
</tr>
<tr>
<td>pref_flow_den</td>
<td>0.0</td>
<td>1.0</td>
<td>Decimal Fraction</td>
<td>Fraction of the soil zone where preferential flow occurs for each HRU</td>
</tr>
<tr>
<td>smidx_coef</td>
<td>0.001</td>
<td>0.06</td>
<td>Decimal Fraction</td>
<td>Coefficient in non-linear contributions area algorithm for each HRU</td>
</tr>
<tr>
<td>smidx_exp</td>
<td>0.1</td>
<td>0.5</td>
<td>(1/inch)</td>
<td>Exponent in non-linear contributing area algorithm for each HRU</td>
</tr>
<tr>
<td>snowinfil_max</td>
<td>0.0</td>
<td>20.0</td>
<td>Inches</td>
<td>Max snow infiltration per day for each HRU</td>
</tr>
<tr>
<td>soil_moist_max</td>
<td>0.001</td>
<td>10.0</td>
<td>Inches</td>
<td>Max available water holding capacity of capillary reservoir from land surface</td>
</tr>
<tr>
<td>soil_rechr_max</td>
<td>0.001</td>
<td>5.0</td>
<td>inches</td>
<td>Max storage for soil recharge zone</td>
</tr>
</tbody>
</table>

* Based on ‘PRMS Manual_Version4.pdf’
Monthly/Seasonal Flow Error Calculation*

Objective Function in Calibration

(1) Annual Mean Water Volumes
(2) Mean Monthly Water Volumes
(3) Monthly Mean Water Volumes

Normalized Root Mean Square Error (NRMSE):

\[ NRMSE = \left( \frac{\sum_{n=1}^{n_{\text{step}}} (MSD(n) - SIM(n))^2}{\sum_{n=1}^{n_{\text{step}}} (MSD(n) - MN)^2} \right)^{1/2} \]

Equation for \( OF_{\text{ann}}, OF_{\text{mnmmtn}}, OF_{\text{mthmn}} \)


\( MSD, SIM, \) and \( MN \) are the measured, simulated, and mean value.
General Calibration Steps

Loop 1  Each HRU in calibration group
Loop 2  Run Shuffled Complex Evolution (SCE), global optimization method (~75 simulations), for each HRU

1. Calibration group selected with corresponding observed data
2. Calibration parameters determined from parameter file
3. SCE for calibration parameters; recording error for each iteration
4. Sorted error for best calibration parameter listing → update parameter file
5. Loop for next HRU
Calibration Simulation Time

• ~75 simulations for each HRU in the calibration group

• Run time: ~1.3 simulation/minute
  • With 75 simulations: ~57 minutes for each HRU

• Example: Calibration Group 3
  • Total Number HRUs: 51
  • ~48 Hours to run
Initial Issues with Streamflow Calibration Parameters

Issue in initialized values:

1. According to ‘PRMS Manual_Version4.pdf’ the:
   - ‘soil_moist_max’ >= ‘soil_rechr_max’
   - ‘soil_moist_init’ < ‘soil_moist_max’
   - ‘soil_rechr_init’ < ‘soil_rechr_max’ <= ‘soil_moist_max’

Solution:

1. Script updates parameter values for ‘soil_moist_init’ and ‘soil_rechr_int’ when ‘soil_moist_max’ and ‘soil_rechr_max’ random generator assigns a number less than.
   - After the simulation returns the ‘soil_moist_init’ and ‘soil_rechr_int’ to the original values assigned
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Base Flow Example

Calibration Group: 2
Original Simulation Flow, Calibrated Simulation Flow, Observed Flow

Observed Flow
Original PRMS Simulation Flow
Calibrated PRMS Simulation Flow
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Closing Remarks

• Continuing calibration work for the additional calibration groups
• Work towards reducing computation time for calibration runs
Questions?

Nathan Burley, P.E.
Water Resources Engineer
(916) 574-2350
Nathan.Burley@water.ca.gov

Angelique Fabbiani Leon, P.E.
Water Resources Engineer
(916) 574-2369
Angelique.Fabbiani-Leon@water.ca.gov
Calibration Step 3—Streamflow Volume

The calibration data set used for the third step was measured streamflow from USGS gaging station 11266500. Four parameters were calibrated when using the $xyz\_dist$ module, while two were calibrated when using the $ide\_dist$ module (table 3-5).

The streamflow volume objective function ($OF_{sv}$) is the sum of three objective functions: (1) annual mean water volumes ($OF_{ann}$), (2) mean monthly water volumes ($OF_{mnum}$), and (3) monthly mean water volumes ($OF_{mthmn}$) according to:

$$OF_{sv} = OF_{ann} + OF_{mnum} + OF_{mthmn},$$  \hspace{1cm} (3-2)

where $OF_{ann}$, $OF_{mnum}$, and $OF_{mthmn}$ are computed by using the normalize root mean square error ($NRMSE$) according to:

$$NRMSE = \left( \frac{\sum_{n=1}^{nstep} (MSD(n) - SIM(n))^2}{\sum_{n=1}^{nstep} (MSD(n) - MN)^2} \right)^{1/2}$$  \hspace{1cm} (3-3)

where $nstep$ is the total number of time steps, and $MSD$, $SIM$, and $MN$ are the measured, simulated, and mean values associated with $OF_{ann}$, $OF_{mnum}$, or $OF_{mthmn}$ respectively.
Higher Flow Example

Calibration Group: 2
Original Simulation Flow, Calibrated Simulation Flow, Observed Flow

Observed Flow
Original PRMS Simulation Flow
Calibrated PRMS Simulation Flow