Two-Step Calibration Method for SWAT

Francisco Olivera, Ph.D.
Assistant Professor
Huidae Cho
Graduate Student

Department of Civil Engineering
Texas A&M University
College Station - Texas
Can we extract spatial information from temporal data?

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Assistant Professor
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Objective

- **Given:** A calibration routine that adjusts the terrain parameters independently for each sub-basin and HRU (i.e., extracts spatial information).

- **Hypothesis:** A model that can reproduce the system’s responses for a “long” period of time has the correct parameter spatial distribution.
Lake Lewisville Watershed

Area: 2500 km²

Period of record: 1987 – 1999
Lake Lewisville Watershed

Curve number
Calibration and validation

- Three-year warm-up period.
- Calibration periods:
  - One year: [1992-1994] + [1995]
  - ...
  - Six years: [1987-1989] + [1990-1995]
- Validation period:
  - Four years: [1993-1995] + [1996-1999]
- Calibration location
- Validation location
Calibration parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN2</td>
<td>SCS runoff curve number</td>
</tr>
<tr>
<td>SOL_AWC</td>
<td>Soil available water capacity (mm $H_2O$/mm soil)</td>
</tr>
<tr>
<td>ESCO</td>
<td>Soil evaporation compensation factor. Whenever the upper layer cannot meet the evaporative demand, SWAT extracts more soil water from the lower layer.</td>
</tr>
<tr>
<td>GWQMN</td>
<td>Threshold depth of water in the shallow aquifer required for return flow to occur (mm $H_2O$)</td>
</tr>
<tr>
<td>GW_REVAP</td>
<td>Groundwater “revap” coefficient. Revap is the process by which water moves into the overlying unsaturated zone from the shallow aquifer by the capillary fringe or deep-rooted plants.</td>
</tr>
<tr>
<td>REVAPMN</td>
<td>Threshold depth of water in the shallow aquifer for “revap” or percolation to the deep aquifer to occur (mm $H_2O$)</td>
</tr>
<tr>
<td>CH_K2</td>
<td>Effective hydraulic conductivity in main channel alluvium (mm/hr)</td>
</tr>
<tr>
<td>ALPHA_BF</td>
<td>Baseflow alpha factor (days) is a direct index of groundwater flow response to changes in recharge.</td>
</tr>
<tr>
<td>OV_N</td>
<td>Manning’s “n” value for overland flow</td>
</tr>
<tr>
<td>SLOPE</td>
<td>Average slope steepness (m/m)</td>
</tr>
<tr>
<td>SLSUBBSN</td>
<td>Average slope length (m)</td>
</tr>
</tbody>
</table>
Calibration levels

- **Watershed:** All sub-basin and HRU parameters are adjusted by applying one single parameter-change rule over the entire watershed.

- **Sub-basin:** All sub-basin and HRU parameters are adjusted by applying a different parameter-change rule in each subbasin. Follows watershed calibration.

- **HRU:** Each HRU parameter is adjusted differently. Follows sub-basin calibration.
Parameter-change rules

- **Method A (plus/minus):** 
  \[-0.05 < \alpha < 0.05\]

  \[P_{i+1} = P_i + (P_{\text{max}} - P_{\text{min}}) \alpha\]

- **Method B (factor):** 
  \[0.9 < \alpha < 1.1\]

  \[P_{i+1} = P_i + (P_i - P_{\text{min}}) \alpha\]

- **Method C (alpha):** 
  \[-0.5 < \alpha < 0.5\]

  \[P_{i+1} = P_i + (P_{\text{max}} - P_i) \alpha\]
Initial conditions

- Initial conditions for the iterative calibration process:
  - **Non-uniform**: parameter values based on land-use and soil-type data.
  - **Uniform**: average parameter values throughout the watershed … let the calibration process extract the spatial information.
Objective functions

- Sum of the square of the residuals (SSR)
  \[ SSR = \sum (Q_{\text{simulated}} - Q_{\text{observed}})^2 \]

- Sum of the absolute value of the residuals (SAR)
  \[ SSR = \sum |Q_{\text{simulated}} - Q_{\text{observed}}| \]

- No \( \log Q \) or \( Q \) in the denominator was used because some flows were zero.
Model efficiency

- Model efficiency was evaluated with the Nash-Sutcliffe coefficient:

\[
NS = 1 - \frac{\sum (Q_{\text{simulated}} - Q_{\text{observed}})^2}{\sum (Q - Q_{\text{observed}})^2} = 1 - \frac{\text{SSR}}{\sum (Q - Q_{\text{observed}})^2}
\]

where \( \overline{Q} \) is the long-term flow average (i.e., the predicted flows with “no model”).
The increase in NS between subbasin and watershed is small, and between HRU and subbasin is negligible.
The decrease in NS between subbasin and watershed is small, and between HRU and subbasin is negligible.
The increase in NS between subbasin and watershed is small, and between HRU and subbasin is negligible.
The increase in NS between subbasin and watershed is small, and between HRU and subbasin is negligible.
The NS values for the *factor* parameter-change-function are slightly lower than for the other functions.
Parameter change function

Validation // SSR // Distributed // 42

Number of years used in calibration

Nash-Sutcliffe coefficient

HGA
WGA
WGF
SGF
SGP
HGF
HGP
SGA
WGP
The NS values are not significantly affected by the initial assumed spatial variability.
The simulated hydrographs are fundamentally equal even though the initial conditions before the calibration were very different.
Parameter values

Same results were obtained from significantly different sets of initial parameters.
The NS values are not significantly affected by the initial assumed spatial variability.
The simulated hydrographs are fundamentally equal even though the assumptions during calibration were very different.
The initial assumed spatial variability does not make a significant difference; however, the watershed-based calibration is more accurate.
In validation over space and time, the watershed-based calibration with an average initial spatial variability has the highest NS values.
Spatial validation

Not even the watershed-based calibration using the spatial variability defined by the soil and land use data produces a good NS value.
Spatial and temporal validation

Not even the watershed-based calibration using the spatial variability defined by the soil and land use data produces a good NS value.
Discussions

- Dispersion is the hydrodynamic process by which some water particles flow faster than others. Because of dispersion, it is difficult to know exactly when and where a particle entered the system.
- The effect of dispersion (i.e., response width) increases proportionally to the square root of the flow time, while the effect of advection (i.e., location of the response centroid) increases linearly with the flow time.
- In small watersheds, dispersion "mixes" all responses (i.e., unit hydrographs); while in large watersheds, advection keeps responses "separate" (i.e., flow-time area diagrams).
Conclusions

- It was not possible to “extract hydrologic information from temporal data” for the 2,500-km² Lake Lewisville watershed.

- The effect of the spatial variability was small compared to the effect of hydrodynamic dispersive processes in the system.

- The number of years used for calibrating the model was fundamental for determining the parameter values.

- The parameter-change rule and the selected objective function did not significantly affect the calibration process.
Questions?