A-Priori Parameter Differences and Their Impact on Distributed Hydrologic Modeling Using SAC-SMA

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Overview

- Background
- Applications
- Results
- Conclusions
Parameter requirements for hydrologic modeling

- Lumped modeling
  - uniform value for a basin
  - relative easier to be optimized by manual and/or automatic calibration methods as compare to distributed modeling
  - less work
Parameter requirements for hydrological modeling

- Distributed modeling
  - requires gridded parameter estimation
  - more difficult to calibrate than for lumped case
Need for *a priori* parameter estimation procedures for distributed modeling

- available observed data cannot support calibration of unique model parameter for individual grid cell
- good initial parameters estimation is important in keeping parameter consistency across regions/basins
Use measured soil property data and land cover data to estimate *a-priori* model parameters

- Improve initial estimates of conceptual model parameters
- Constrain calibration so that parameter adjustment occurs within a range of values to maintain conceptual consistency
- Provide physically consistent spatially variable parameters in smaller basins for flood modeling
Available Land Cover Data
- Global Land Cover Characterization (GLCC) data
- The 2001 National Land Cover Data Set (NLCD)

Available Soil Data

The Natural Resources Conservation Service of the USDA has established three soil geographic data bases and related soil maps
- Soil Survey Geographic (SSURGO) data base
- State Soil Geographic (STATSGO) data base
- National Soil Geographic (NATSGO) data base
Soil Data

- **NATSGO:**
  - scale is 1:5000K
  - used primarily for national and regional resource appraisal and planning

- **STATSGO:**
  - scale is 1:250K
  - polygon size is about 100-200 km²

- **SSURGO:**
  - scale is 1:24K
  - polygon size is about 20 km²
  - partially available for CONUS; will be completed in 2008
Demonstration of scale difference between STATSGO and SSURGO
The Model and Parameters:

- SAC-SMA: the rainfall runoff component used in HL-RDHM, research distributed hydrologic model developed in the NWS Hydrology Lab.
- 16 parameter grids need to be provided.
## List of SAC-SMA Parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
<th>Unit</th>
<th>Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UZTWM</td>
<td>The upper layer tension water capacity</td>
<td>mm</td>
<td>10–300</td>
</tr>
<tr>
<td>2</td>
<td>UZFWM</td>
<td>The upper layer free water capacity</td>
<td>mm</td>
<td>5–150</td>
</tr>
<tr>
<td>3</td>
<td>UZK</td>
<td>Interflow depletion rate from the upper layer free water storage</td>
<td>day⁻¹</td>
<td>0.10–0.75</td>
</tr>
<tr>
<td>4</td>
<td>ZPERC</td>
<td>Ratio of maximum and minimum percolation rates</td>
<td>day⁻¹</td>
<td>5–350</td>
</tr>
<tr>
<td>5</td>
<td>REXP</td>
<td>Shape parameter of the percolation curve</td>
<td></td>
<td>1–5</td>
</tr>
<tr>
<td>6</td>
<td>LZTWM</td>
<td>The lower layer tension water capacity</td>
<td>mm</td>
<td>10–500</td>
</tr>
<tr>
<td>7</td>
<td>LZFSM</td>
<td>The lower layer supplemental free water capacity</td>
<td>mm</td>
<td>5–400</td>
</tr>
<tr>
<td>8</td>
<td>LZFPM</td>
<td>The lower layer primary free water capacity</td>
<td>mm</td>
<td>10–1000</td>
</tr>
<tr>
<td>9</td>
<td>LZSK</td>
<td>Depletion rate of the lower layer supplemental free water storage</td>
<td>day⁻¹</td>
<td>0.01–0.35</td>
</tr>
<tr>
<td>10</td>
<td>LZPK</td>
<td>Depletion rate of the lower layer primary free water storage</td>
<td>day⁻¹</td>
<td>0.001–0.05</td>
</tr>
<tr>
<td>11</td>
<td>PFREE</td>
<td>Percolation fraction that goes directly to the lower layer free water storages</td>
<td></td>
<td>0.0–0.8</td>
</tr>
<tr>
<td>12</td>
<td>PCTIM</td>
<td>Permanent impervious area fraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>ADIMP</td>
<td>Maximum fraction of an additional impervious area due to saturation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>RIVA</td>
<td>Riparian vegetarian area fraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>SIDE</td>
<td>Ratio of deep percolation from lower layer free water storages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>RSERV</td>
<td>Fraction of lower layer free water not transferable to lower layer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Objective estimation procedure that can produce spatially consistent and physically realistic values for 11 of the 16 SAC-SMA parameters

- **STATSGO** + Assumed spatially constant “pasture or range land use” under “fair” hydrologic conditions, (Koren et al. 2000, 2003)
- **STATSGO** + Spatially variable land use land cover data
- **SSURGO** + Spatially variable land use land cover data, (Anderson et al., 2005, Zhang et al., 2008)
Applications

SAC-SMA Parameter: UZTWM

STATSGO + Uniform LULC

UZTWM

10 - 35
35 - 59
59 - 84
84 - 109
109 - 134
134 - 158
158 - 183
No Data

STATSGO + LULC

Forest Cover

SSURGO + LULC

Forest cover increases upper zone tension water
Applications

Percentage Change as Compared to STATSGO+uniform LULC: UZTWM

<table>
<thead>
<tr>
<th>Change (%)</th>
<th>Uniform - Variable</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>-43 to -150</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>-149 to -71</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>-70 to -31</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>-30 to -16</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>-15 to -1</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>0 to 15</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>16 to 100</td>
<td>uniform</td>
<td></td>
</tr>
<tr>
<td>No Data</td>
<td>uniform</td>
<td></td>
</tr>
</tbody>
</table>

Forest cover increases upper zone tension water

STATSGO + LULC

SSURGO + LULC

Forest Cover
### Study Basins

<table>
<thead>
<tr>
<th>No.</th>
<th>Short Name</th>
<th>Station Name</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SPRI NGT</td>
<td>Flint Creek at Springtown, AR</td>
<td>37</td>
</tr>
<tr>
<td>2</td>
<td>WSILO</td>
<td>Sager Creek near West Siloam Springs, OK</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>CHRISTI</td>
<td>Peacheater Creek at Christie, OK</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>CAVESP</td>
<td>Osage Creek near Cave Springs, AR</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>DUTCH</td>
<td>Baron Fork at Dutch Mills, AR</td>
<td>105</td>
</tr>
<tr>
<td>6</td>
<td>KNSO2</td>
<td>Flint Creek near Kansas, OK</td>
<td>285</td>
</tr>
<tr>
<td>7</td>
<td>ELMSP</td>
<td>Osage Creek near Elm Springs, AR</td>
<td>337</td>
</tr>
<tr>
<td>8</td>
<td>POWELL</td>
<td>Big Sugar Creek near Powell, MO</td>
<td>365</td>
</tr>
<tr>
<td>9</td>
<td>SAVOY</td>
<td>Illinois River at Savoy, AR</td>
<td>433</td>
</tr>
<tr>
<td>10</td>
<td>LANAG</td>
<td>Indian Creek near Lanagan, MO</td>
<td>619</td>
</tr>
<tr>
<td>11</td>
<td>ELDO2</td>
<td>Baron Fork at Eldon, OK</td>
<td>795</td>
</tr>
<tr>
<td>12</td>
<td>BLUO2</td>
<td>Blue River near Blue, OK</td>
<td>1233</td>
</tr>
<tr>
<td>13</td>
<td>SLOA4</td>
<td>Illinois River South of Siloam Springs, AR</td>
<td>1489</td>
</tr>
<tr>
<td>14</td>
<td>WTTO2</td>
<td>Illinois River near Watts, OK</td>
<td>1645</td>
</tr>
<tr>
<td>15</td>
<td>TIFM7</td>
<td>Elk River at Tiff City, MO</td>
<td>2258</td>
</tr>
<tr>
<td>16</td>
<td>TALO2</td>
<td>Illinois River near Tahlequah, OK</td>
<td>2484</td>
</tr>
</tbody>
</table>
Applications

SAC-SMA Parameter within Study Basins: UZTWM

-STATSGO-

-STATSGO+LULC-

-SSURGO-

Forest Map

Applications
Applications

SAC-SMA Parameter within Study Basins: UZTWM

Percentage Change as Compared to STATSGO+uniform LULC

Forest Cover

change (%)

-43 - -150
-149 - -71
-70 - -31
-30 - -16
-15 - -1
0 - 15
16 - 100
No Data
Applications

Percentage Changes of Averaged SAC-SMA Parameters

CONUS Averaged

Averaged for multi-basins
**Results**

$R_m$: Modified correlation coefficient. It is calculated by reducing normal correlation coefficient by the ratio of the standard deviations of the observed and simulated hydrographs.

Overall
Results

Event-based Statistics
Peak Error and Peak Time Error
Comparison of flow simulations for TALO2 (2484 km²)

- Observed
- STATSGO-uniform lulc
- STATSGO+lulc
- SSURGO
Comparison of flow simulations for WSI LO (49 km²)

- Observed
- STATSGO-uniform lulc
- STATSGO+lulc
- SSURGO
Comparison of flow simulations for SPRI NGT (37 km²)

- Observed
- STATSGO-uniform lulc
- STATSGO+lulc
- SSURGO
Conclusions

- Use of land cover data and higher resolution soil data results in different \textit{a-priori} SAC-SMA parameters.

- Overall simulation results for three sets of \textit{a-priori} parameters are similar.

- The effect of using higher resolution soil data and land use land cover data is different between smaller basins and larger basins. Improvements are mainly for smaller basins when SSURGO data are used. Generally similar results for large basins for three sets of a priori parameters.

- Improvement from using detailed soil data is greater than using gridded land cover data.

- Results suggest that the SSURGO based parameters are preferable for smaller scale applications.