SENSITIVITY OF HSPF-ESTIMATED FLOW RATE TO TOPOGRAPHICAL PARAMETER VALUES
FOR A COASTAL WATERSHED IN MISSISSIPPI

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Introduction

• The modeling of watershed hydrology requires input from several types of databases.
• Digital elevation data are used at the beginning of the watershed modeling process to abstract the watershed physiographic features into a manageable number of parameters.
• Sensitivity analysis can be used to assess the influence of variables/parameters on the state of a modeled system.
• The analysis of sensitivity of state variables has been widely used in water resources modeling to quantify the reliability of the output or during the calibration process.
Objectives

• The purpose of this research is to identify how sensitive are flowrate estimations to perturbations in topographical parameters.
  - HSPF
  - Jourdan River catchment (coastal Mississippi)
Study area

- Jourdan River:
  - Located in the Saint Louis Bay watershed (Mississippi Gulf coast)
- Largest contributor of flow to the Saint Louis Bay
- Drains 882 sq. km
- Average flow: 24.5 cms
Watershed delineation, hydrological calibration

- The Jourdan River catchment was delineated using elevation data from the National Elevation Dataset (NED) in BASINS:
  - 30 Meter Resolution (1 arc-second)
- An HSPF application for Jourdan River was generated from within BASINS and calibrated for flow rate.
  - USGS station 02481570 at Santa Rosa for the period 1962-1966
- To isolate the effects of topography-related parameters during sensitivity analysis, the calibration was performed using parameters that are not related to topography:
  - LZSN: Lower zone nominal soil moisture storage
  - INFILT: Index to the infiltration capacity of the soil
  - UZSN: Upper zone nominal soil moisture storage
- Parameters that are mildly dependent on topography were also used
  - INTFW: Interflow inflow parameter
Methodology

Sensitivity analysis

- Normalized sensitivity coefficients
  - Represent the percentage change in the output variable resulting from a 1 percent change in each input variable
  - $S_{ij}$: normalized sensitivity coefficient for output $y_j$ (flow) to inputs $x_i$ (topographical parameters)
  - $x_i$: base value of input variable (calibrated model)
  - $\Delta x_i$: magnitude of input perturbation
  - $y_j$: base value of output variable (calibrated model)
  - $\Delta y_j$: sensitivity of output variable

\[
S_{ij} = \frac{\Delta y_j}{\frac{y_j}{\Delta x_i} x_i}
\]
Sensitivity analysis (cont’d)

- Sensitivity of flow rate estimations to perturbations in the following variables:
  - Length of the overland flow plane: LSUR
  - Slope of the overland flow plane: SLSUR
  - F-tables
    - Stream width (WID1),
    - Stream length (LEN2), and

- Strategy:
  - One-variable-at-a-time approach.
    - Percent perturbations to the variables included in this study were increased/decreased in: ±100%, ±50%, ±10% and ±1% from the base values.
    - The estimations of flow for the calibrated case were considered the base case.
    - The combination of small and big perturbations allowed identifying non-linear sensitivities.
    - Normalized sensitivity values were calculated for each perturbation.
HSPF variables

Used in sensitivity experiments

Stream Length LEN2

Max Elev

Min Elev

DEP1

SUB-BASIN AREA

NSUR

WID1

SLSUR

LSUR

HSPF variables

Used in sensitivity experiments

Stream Length LEN2

Max Elev

Min Elev

DEP1

SUB-BASIN AREA

NSUR

WID1

SLSUR

LSUR
Results

- Hydrological calibration (goodness of fit)

<table>
<thead>
<tr>
<th>Year</th>
<th>1963</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
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</thead>
<tbody>
<tr>
<td>Mean (observed) (m³/s)</td>
<td>2.84</td>
<td>8.93</td>
<td>5.27</td>
<td>11.03</td>
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<td>Mean (simulated) (m³/s)</td>
<td>2.85</td>
<td>8.83</td>
<td>4.95</td>
<td>12.13</td>
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<td>Coefficient of Determination ($r^2$)</td>
<td>0.84</td>
<td>0.51</td>
<td>0.73</td>
<td>0.81</td>
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<tr>
<td>Model Fit Efficiency (NS)</td>
<td>0.81</td>
<td>0.49</td>
<td>0.67</td>
<td>0.78</td>
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</tbody>
</table>
Results

- Moderate to low sensitivity
  - Normalized sensitivity statistics for LSUR and SLSUR

<table>
<thead>
<tr>
<th></th>
<th>-100%</th>
<th>-50%</th>
<th>-10%</th>
<th>-1%</th>
<th>1%</th>
<th>10%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSUR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>0.005683</td>
<td>0.00565</td>
<td>0.004041</td>
<td>0.004454</td>
<td>0.004475</td>
<td>0.004111</td>
<td>0.003549</td>
<td>0.003064</td>
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<tr>
<td>Minimum</td>
<td>-0.36719</td>
<td>-0.25194</td>
<td>-0.25194</td>
<td>-0.81301</td>
<td>-0.38911</td>
<td>-0.21318</td>
<td>-0.16667</td>
<td>-0.13178</td>
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<tr>
<td>Maximum</td>
<td>0.071429</td>
<td>0.07309</td>
<td>0.09901</td>
<td>0.990099</td>
<td>0.884956</td>
<td>0.097087</td>
<td>0.04878</td>
<td>0.036364</td>
</tr>
<tr>
<td>SLSUR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>-0.00958</td>
<td>-0.0031</td>
<td>-0.00313</td>
<td>-0.00443</td>
<td>-0.00288</td>
<td>-0.00212</td>
<td>-0.00169</td>
<td>-0.00139</td>
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<tr>
<td>Minimum</td>
<td>-0.15758</td>
<td>-0.04636</td>
<td>-0.09709</td>
<td>-0.88496</td>
<td>-0.91743</td>
<td>-0.09901</td>
<td>-0.02857</td>
<td>-0.02</td>
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<td>Maximum</td>
<td>0.37785</td>
<td>0.147287</td>
<td>0.116279</td>
<td>0.389105</td>
<td>0.408163</td>
<td>0.116279</td>
<td>0.096899</td>
<td>0.075581</td>
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</tbody>
</table>

- LSUR: length of the overland flow plane
- SLSUR: slope of the overland flow plane
- For both variables:
  - Average normalized sensitivity values are less than 1%
  - Mode (most frequent value) of normalized sensitivity equals 0.0
Results

- Medium to high sensitivity
  - (F-tables: stream width and stream length)

<table>
<thead>
<tr>
<th>STREAM WIDTH</th>
<th>-100%</th>
<th>-50%</th>
<th>-10%</th>
<th>-1%</th>
<th>1%</th>
<th>10%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.03007</td>
<td>-0.02221</td>
<td>0.017884</td>
<td>0.417068</td>
<td>-0.47364</td>
<td>-0.07144</td>
<td>-0.03438</td>
<td>-0.0297</td>
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<tr>
<td>Minimum</td>
<td>-0.26829</td>
<td>-0.57757</td>
<td>-1.30081</td>
<td>-10.8911</td>
<td>-16.3424</td>
<td>-1.67315</td>
<td>-0.51685</td>
<td>-0.30808</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.524528</td>
<td>0.718784</td>
<td>1.733945</td>
<td>15.95331</td>
<td>10.89109</td>
<td>1.235521</td>
<td>0.370861</td>
<td>0.208609</td>
</tr>
<tr>
<td>STREAM LENGTH</td>
<td>-100%</td>
<td>-50%</td>
<td>-10%</td>
<td>-1%</td>
<td>1%</td>
<td>10%</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.02022</td>
<td>-0.01256</td>
<td>0.026739</td>
<td>0.425844</td>
<td>-0.46368</td>
<td>-0.06046</td>
<td>-0.02163</td>
<td>-0.0138</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.70743</td>
<td>-0.63789</td>
<td>-0.79365</td>
<td>-10.4265</td>
<td>-16.7315</td>
<td>-2.10117</td>
<td>-0.77043</td>
<td>-0.57012</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.218182</td>
<td>0.25641</td>
<td>1.128405</td>
<td>15.5642</td>
<td>11.38614</td>
<td>1.396648</td>
<td>0.614286</td>
<td>0.582524</td>
</tr>
</tbody>
</table>

- Average normalized sensitivity values bigger than 1%
  - Peak sensitivities for ± 1%
  - Non-linearity
Results

• Normalized sensitivity percentile values for Stream-Length and Stream Width
Conclusions

- HSPF-estimated flow is not very sensitive to LSUR (length of the overland flow plane) and SLSUR (slope of the overland flow plane).
  - Relative changes in flow estimations to perturbations to these variables are lower than 1% from the base values.
- The variables Stream Length and Stream Width produce significant percent changes on simulated flow when small changes (1%) are made to base values of those variables.
- 20% of those changes are at least greater than 1.5% reaching up to 16% change from the base values.
- Since stream length and stream width are highly dependant from the size and shape of the corresponding sub-catchment, the delineation of the watershed will drive the value of those variables.
Potential for research

• Future studies using other data
  ✷ Elevation:
    ▪ SRTM: 30-meter
    ▪ IFSAR: 5-meter
  ✷ Landuse
  ✷ Soil moisture

• Impact on hydrological simulation
  ✷ Flow
  ✷ Water quality
Acknowledgements

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