Hydrologic Calibration of the SWAT Model for African River Basins using GRACE data

Hua Xie¹, Laurent Longuevergne², Claudia Ringler³, Bridget Scanlon⁴, Tingju Zhu⁵

¹Postdoctoral Fellow, International Food Policy Research Institute, Washington D.C., USA
²Postdoctoral Fellow, Department of Geological Sciences, Jackson School of Sciences, University of Texas at Austin, TX, USA
³Senior Research Fellow, International Food Policy Research Institute, Washington D.C., USA
⁴Senior Research Scientist, Bureau of Economic Geology, Jackson School of Geosciences, University of Texas at Austin, TX, USA
⁵Senior Scientist, International Food Policy Research Institute, Washington D.C., USA
Agricultural Water Management Solutions

- Identify promising investment options for smallholder irrigation in Sub-Saharan Africa and South Asia.
Data challenges in the development of SWAT applications for Sub-Saharan Africa and South Asia

- HydroSHED
- Harmonized world soil database v 1.1
- Global land cover 2000 & Spatial allocation model
- Global lakes and wetlands database
- Global runoff data centre (GRDC) database
- GRACE

Elevation

Soil

Land cover

Lakes, wetlands and reservoirs

SWAT GIS Interface

SWAT-SSA&SA

Climate

River discharge

Total water storage variation

Model application
Gravity Recovery and Climate Experiment (GRACE)

• A twin satellite system in GRACE mission

Distance between two satellites $\rightarrow$ Earth’s gravity field & mass distribution variation $\rightarrow$ Total water storage variation

• Total water storage variation
  
  — Snow/ice
  — groundwater
  — soil water
  — surface water (in rivers, lakes, wetlands and reservoirs)

• Errors in GRACE data processing
  
  — Measurement error
  — Aliasing error
  — Leaky error
SWAT-Tanzania model

- Area: $1.15 \times 10^6$ km$^2$
- subbasins: 63
GRDC stations

Source: Global Runoff Data Centre (GRDC)
Calculation of the total water storage variations (TWSV) in SWAT modeling

\[ V_{\text{total}} = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 \]

- \( V_{\text{total}} \) — the total water storage
- \( V_1 \) — the water storage in snow pack
- \( V_2 \) — the water storage in soil profile
- \( V_3 \) — the groundwater storage in aquifers
- \( V_4 \) — the water storage in river channel
- \( V_5 \) — the delayed released surface runoff
- \( V_6 \) — the water storage in lakes and reservoirs

\[ \text{TWSV} = V_{\text{total}} - \overline{V_{\text{Total}}} \]
Mass correction

Mass correction was made to remove the effects of the large lakes in GRACE data processing.
Filtering and zonation

0.5° × 0.5°

Interior north
Costal north
Interior south
Costal south
Irrigation

— Irrigation was not simulated in SWAT-SSA (Sub-Saharan Africa) model, but will be modeled in SWAT-SA (South Asia) model
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN2_1</td>
<td>SCS curve number for open grassland with sparse shrubs</td>
</tr>
<tr>
<td>CN2_2</td>
<td>SCS curve number for deciduous woodland</td>
</tr>
<tr>
<td>CN2_3</td>
<td>SCS curve number for closed deciduous forest</td>
</tr>
<tr>
<td>CN2_4</td>
<td>SCS curve number for deciduous shrubland with sparse tree</td>
</tr>
<tr>
<td>CN2_5</td>
<td>SCS curve number for closed grassland</td>
</tr>
<tr>
<td>CN2_6</td>
<td>SCS curve number for cropland</td>
</tr>
<tr>
<td>ESCO</td>
<td>Soil evaporation compensation factor</td>
</tr>
<tr>
<td>GW_DELAY</td>
<td>Groundwater delay (days)</td>
</tr>
<tr>
<td>GW_REVAP</td>
<td>Groundwater “revap” coefficient</td>
</tr>
<tr>
<td>ALPHA_BF</td>
<td>Baseflow alpha factor (days)</td>
</tr>
<tr>
<td>REVAPMN</td>
<td>Threshold depth of water in the shallow aquifer for &quot;revap&quot; to occur (mm H₂O)</td>
</tr>
<tr>
<td>GWQMN</td>
<td>Threshold depth of water in the shallow aquifer required for groundwater flow to occur (mm H₂O)</td>
</tr>
<tr>
<td>SURLAG</td>
<td>Surface runoff lag coefficient</td>
</tr>
<tr>
<td>SOL_AWC</td>
<td>Available water capacity of the soil layer (mm H₂O/mm soil)</td>
</tr>
<tr>
<td>SOL_Z</td>
<td>Depth from soil surface to bottom of layer (mm)</td>
</tr>
<tr>
<td>SOL_HC</td>
<td>Soil saturated hydraulic conductivity (mm/Hr)</td>
</tr>
</tbody>
</table>
Calibration results

**Interior north**

**Costal north**

**Interior south**

**Costal south**
Calibration results

Station 1286900

Station 1289450
Future work

• To complete the calibration of the SWAT model for entire Sub-Saharan Africa and South Asia

• Uncertainty analysis
Thanks & Questions?