Application of SWAT in a Mountainous Region in Turkey using Remote Sensing Data

Bilal Peker, Dr. Arda Sorman

Eskisehir Technical University, Turkey
Department of Civil Engineering

15-19 July 2019 - Vienna, Austria

Contact: ismailbilalpeker@eskisehir.edu.tr
OUTLINE

1. Motivation of the Study
2. Study Area
3. Data Sources & Base Model Setup
4. Snow Parameters Fitting using Remote Sensing Data
5. Automatic Flow Calibration & Validation
6. Snow Validation using Ground Stations
7. Conclusions & Recommendations
Motivation of the Study

There are several successful SWAT model applications in Turkey, however, all is about water quality, agricultural management and non-point source pollution control at low elevated snowless areas.

The mountainous and snow-dominated watersheds are selected for this work, therefore snow-melt process is very important for the study area.

Remote sensing data is used for the more preferable model setup in the study.
Study Area

- Turkey is a peninsula surrounded on 3 sides by the sea.
- Average elevation of Turkey > 1100 m, snow is frequent.
- Most transboundary rivers are fed by snowmelt.
Two headwater basins of the Euphrates River, named as Karasu and Murat.

<table>
<thead>
<tr>
<th>Basin Name</th>
<th>Karasu</th>
<th>Murat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area</td>
<td>2800 km²</td>
<td>5900 km²</td>
</tr>
<tr>
<td>Hypsometric Elevation</td>
<td>2100 m</td>
<td>2100 m</td>
</tr>
<tr>
<td>Min. Elevation</td>
<td>1675 m</td>
<td>1559 m</td>
</tr>
<tr>
<td>Max. Elevation</td>
<td>3156 m</td>
<td>3516 m</td>
</tr>
</tbody>
</table>
Data Sources

- **HRU Definition Data**
  - DEM (SRTM, 90x90 m) (3 Slope Classes for each basin)
  - Land Use (Corine, 1:100 000)
  - Soil (FAO, 1:5 000 000)

- **Climate Data**
  - Turkish Met. Office (Precipitation & Max./Min. Temperature)
  - CFSR (Relative Humidity, Solar Radiation & Wind Speed)

- **Calibration & Validation Data**
  - Turkish Hydro. Office (Discharge & Snow Ground Stations)
  - MODIS (Cloud-Filtered Snow-covered Images)
GAGE STATIONS (Rainfall, Temperature, Stream, Snow)
# Base Model Setup

<table>
<thead>
<tr>
<th></th>
<th>Karasu</th>
<th>Murat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface</td>
<td>ArcSWAT 2012.10_4.19</td>
<td></td>
</tr>
<tr>
<td>Subbasin Threshold Area</td>
<td>5 000 Ha</td>
<td>10 000 Ha</td>
</tr>
<tr>
<td>HRU Threshold (Soil/LU/Slope)</td>
<td>0/0/0 (%)</td>
<td>0/0/0 (%)</td>
</tr>
<tr>
<td>Subbasin Number</td>
<td>41</td>
<td>45</td>
</tr>
<tr>
<td>HRU Number</td>
<td>462</td>
<td>663</td>
</tr>
<tr>
<td>Elevation Band Number</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Warm up</td>
<td>1999-2001 (3 yrs)</td>
<td>2000-2001 (2 yrs)</td>
</tr>
<tr>
<td>Calibration Period</td>
<td>2002-2007 (6 yrs)</td>
<td>2002-2007 (6 yrs)</td>
</tr>
<tr>
<td>Validation Period</td>
<td>2008-2011 (4 yrs)</td>
<td>2008-2011 (4 yrs)</td>
</tr>
</tbody>
</table>
PROCEDURE

Snow parameters should not be calibrated simultaneously with other parameters. (Abbaspour et al., 2017)

1) ADJUSTMENT OF SNOW PARAMETERS (WITH MODIS) (SNOW CALIBRATION)
- Conversion SWAT SWE outputs to basin-scale from HRU-scale & comparison with snow cover area as a chart
- Visualizing SWAT SWE outputs & comparison with MODIS images as a map

2) FLOW CALIBRATION & VALIDATION

3) SNOW VALIDATION (WITH GROUND STATIONS)
SWE (mm) – SCA (%) COMPARISON

- HRU-BASED SWE
- SUBBASIN-BASED SWE
- BASIN-BASED SWE

MODIS Snow Cover Area (SCA) (%)

Areal Percentage Weights

SWAT BASIN-SCALE SWE (mm) values are obtained daily.
EXAMPLE: MURAT BASIN 2004 HYDROLOGICAL YEAR

- **Start of snow session**
- **End of snow session**
- **Beginning of recession part**
VISUALIZATION PROCESS

SWAT SWE OUTPUTS ARE HRU-BASED AT EACH ELEVATION BAND.

DERIVATION OF SUB-SWE FOR EACH SUBBASINS AT EACH ELEVATION BAND

MURAT SUB-1

Reclassified 10 Elevation Classes

SWE Value for Each Elevation Band from SWAT .snw Output

.Snw output file

SNOW

THRESHOLD SWE

LAND
• VISUALIZATION PROCESS IS IMPLEMENTED FOR EACH SUBBASIN AND BASIN-SCALE SWE MAPS ARE OBTAINED.

• 7 DATES ARE SELECTED:

04 DECEMBER 2005 (ACCUMULATION PERIOD)
30 DECEMBER 2005 (~100% SNOW COVER)
30 MARCH 2006 (RANDOMLY)
08 APRIL 2006 (RECESSION PERIOD)
13 APRIL 2006 (RANDOMLY)
18 APRIL 2006 (RANDOMLY)
12 MAY 2006 (~0% SNOW COVER)
SWE THRESHOLD CAN CHANGE

BECAUSE SUBBASINS HAVE DIFFERENT ELEVATION RANGE AND ASPECT
Adjustment of Snow Parameters & Lapse Rates

<table>
<thead>
<tr>
<th>PARAMETER NAME</th>
<th>UNIT</th>
<th>FITTING VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFTMP</td>
<td>°C</td>
<td>1</td>
</tr>
<tr>
<td>SMTMP</td>
<td>°C</td>
<td>0.5</td>
</tr>
<tr>
<td>SMFMX</td>
<td>mm H₂O/°C-day</td>
<td>2.5</td>
</tr>
<tr>
<td>SMFMN</td>
<td>mm H₂O/°C-day</td>
<td>0.5</td>
</tr>
<tr>
<td>TIMP</td>
<td>unitless</td>
<td>1</td>
</tr>
<tr>
<td>SNOCOVMX</td>
<td>mm H₂O</td>
<td>55</td>
</tr>
<tr>
<td>SNO50COV</td>
<td>unitless</td>
<td>0.55</td>
</tr>
<tr>
<td>PLAPS</td>
<td>mm H₂O/km</td>
<td>175</td>
</tr>
<tr>
<td>TLAPS</td>
<td>°C/km</td>
<td>-5.5</td>
</tr>
</tbody>
</table>

These values are fixed as a result of the many trials according to the physical meaning and experiences from the previous studies at the study area.
**AUTO-CALIBRATION PROCEDURE**

**SWAT-CUP** is used for model calibration.

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Initial Range</th>
<th>Fitted Value MURAT</th>
<th>Fitted Value KARASU</th>
</tr>
</thead>
<tbody>
<tr>
<td>r_ CN2.mgt</td>
<td>-0.3 - 0.3</td>
<td>-0.28</td>
<td>-0.16</td>
</tr>
<tr>
<td>v_ ESCO.hru</td>
<td>0.7 - 1</td>
<td>0.73</td>
<td>0.75</td>
</tr>
<tr>
<td>r_ SOL_Z.sol</td>
<td>-0.3 - 0.3</td>
<td>-0.21</td>
<td>0.3</td>
</tr>
<tr>
<td>r_ SOL_K.sol</td>
<td>-0.3 - 0.3</td>
<td>-0.19</td>
<td>0.3</td>
</tr>
<tr>
<td>r_ SOL_AWC.sol</td>
<td>-0.3 - 0.3</td>
<td>0.29</td>
<td>0.19</td>
</tr>
<tr>
<td>v_ ALPHA_BF.gw</td>
<td>0.01 - 0.99</td>
<td>0.79</td>
<td>0.92</td>
</tr>
<tr>
<td>v_ GW_DELAY.gw</td>
<td>1 - 50</td>
<td>10.69</td>
<td>7.53</td>
</tr>
<tr>
<td>v_ GWQMN.gw</td>
<td>1 - 250</td>
<td>172.85</td>
<td>15.04</td>
</tr>
<tr>
<td>v_ RCHRG_DP.gw</td>
<td>0.2 - 0.5</td>
<td>0.36</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Determined sensitive parameters. *(One-at-a-time procedure, Abbaspour, 2013)*

Same for each basin model.  
1000 simulations for 2 iterations.
HYDROGRAPHS FOR KARASU BASIN

NSE: NASH-SUTCLIFFE EFFICIENCY

R²: COEFF. OF DETERMINATION

**CAL-DAILY**

Q-NSE: 0.64
R²: 0.63

**VAL-DAILY**

Q-NSE: 0.82
R²: 0.82

**CAL-MONTHLY**

Q-NSE: 0.74
R²: 0.75

**VAL-MONTHLY**

Q-NSE: 0.89
R²: 0.90
HYDROGRAPHS FOR MURAT BASIN

Q-NSE \[ R^2 \]

CAL-DAILY

Q: 0.73

R^2: 0.74

VAL-DAILY

Q: 0.67

R^2: 0.76

CAL-MONTHLY

Q: 0.83

R^2: 0.87

VAL-MONTHLY

Q: 0.76

R^2: 0.86

NSE: NASH-SUTCLIFFE EFFICIENCY

R^2: COEFF. OF DETERMINATION
SWE Validation

Snow Stations

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Elevation (m)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hacimahmut</td>
<td>1945</td>
<td>SUB 35</td>
</tr>
<tr>
<td>Yesildere</td>
<td>1935</td>
<td>SUB 9</td>
</tr>
<tr>
<td>Guzelyayla</td>
<td>2070</td>
<td>SUB 10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Elevation (m)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hacimomer</td>
<td>1865</td>
<td>SUB 8</td>
</tr>
<tr>
<td>Eleskirt</td>
<td>1780</td>
<td>SUB 11</td>
</tr>
<tr>
<td>Dogangun</td>
<td>1660</td>
<td>SUB 40</td>
</tr>
</tbody>
</table>
Snow Validation

TREND IS MATCHING
CONCLUSIONS

• SWAT was used for mountanious and snow-fed basins in Turkey.

• Before the model calibration, snow parameters were fitted with two methods that utilized with MODIS.

• Auto-calibration procedure was applied according to flow data and successful results were obtained.

• Calibrated model was validated for flow data and snow validation was done using the ground snow station data.

Models are ready for future studies!
**RECOMMENDATIONS**

**DIFFERENT ELEVATION BAND NUMBERS FOR EACH SUBBASIN**

- **SUB7**
  - Elevation: High 1706, Low 1647

- **SUB15**
  - Elevation: High 2280, Low 1626

- **SUB42**
  - Elevation: High 3291, Low 1606

Because subbasins have **DIFFERENT ELE. RELIEF, AREA AND SHAPE**

**ADJUSTMENT OF ELEVATION BAND RANGES INSTEAD OF AUTOMATIC VALUES**

**MORE DETAILED DISTRIBUTION OF SUBBASINS**
Thank you for your attention.

Contact: ismailbilalpeker@eskisehir.edu.tr

Eskisehir Technical University, Turkey
Department of Civil Engineering – Hydraulics Division