Using the HEC-HMS Model for Evaluating Climate Change Impact on Water Resources at the Basin Scale in the Arab Region

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Hydrological modeling

The following models were selected to simulate hydrological process over the Arab region:

- **HYPE model** *(HYdrological Predictions for the Environment)*
- **HBV model** *(Hydrologiska Byråns Vattenbalansavdelning)*
- **VIC model**
- **HEC-HMS**
• HEC-HMS, HEC-HMS is GIS-based semidistributed rainfall-runoff model developed by Hydrologic Engineering Centre (HEC) of United States Army Corps of Engineers (USACE),
HEC-HMS

HEC-HMS Model setup consists of 4 main model components:

• basin model,
• meteorologic model,
• control specifications and
• input data (time series, paired data and gridded data).
Basin Model

- Basin model handles the infiltration loss and base flow computations, and rainfall runoff transformation process.
Meteorologic Model

- Meteorologic model is the major component that is responsible for the definition of the meteorologic boundary conditions for the subbasins. It includes precipitation, evapotranspiration and snowmelt methods.

- Output from RCM will be used as input in this model.
Hec-GeoHMS

- Hec-GeoHMS: is an ArcGIS extension developed by the U.S. Army Corps of Engineers (USACE)
- Hec-GeoHMS is used for computing the flow direction, flow accumulation, stream delineation, watershed delineation, drainage network derivation
Loss method

soil moisture accounting (SMA) method, were selected because it allows for a long-term continuous simulation of hydrologic processes.
soil moisture accounting (SMA)
Input data
precipitation data

precipitation time series (daily data) •
Input data

- Land use data
- Soil data
- Topographic data
- Streamflow Data (for model calibration and validation)
Evapotranspiration data

- Temperature
- Relative humidity
- Wind speed
- Solar radiation
Input data

- Location of important features such as reservoirs or diversions
- Reservoir characteristics: rating curves, spillway
- Reservoirs use and regulation
Test basins

test basins were selected from different area in the Arab region to evaluate and calibrate the selected models

- Mejerda watershed – Tunisia
- Wadi Dayqah - Sultanate of Oman
- Nahr el Kabir Al-Junoubi–Syria
- Nile river
- Euphrates river
Medjerda River (Tunisia)
Basin Area = 22070 km$^2$
Discharge data
Rainfall data
# Extreme floods

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Q (m³/s)</td>
<td>1610</td>
<td>1790</td>
<td>2060</td>
<td>1780</td>
<td>1700</td>
<td>981</td>
<td>980</td>
<td>1490</td>
<td>1410</td>
<td>3500</td>
<td>1300</td>
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</table>
Wadi Dayqah basin, Oman

located 60 km southeast of Muscat
Basin area = 1870 km²
Rainfall data

Time series daily rainfall data collected from six stations
Discharge data

Time series daily discharge data collected from the four stations
Extreme floods:

- **The flood of June 2007**: On 5-6 June 2007, Oman was subjected to the strongest tropical cyclone ever been recorded on its recent history since 1890.
  - The peak flow at the site during the tropical Cyclone was estimated to be of the order of 10,000 m³/sec;
Nahr el Kabir Al-Junoubi

The Nahr el Kabir Al-Junoubi constitutes the Lebanese Syrian borders
Nahr el Kabir Al-Junoubi

- The total water shed area (within Lebanon and Syria) is about 990 km² of which 295 km² lies in Lebanon.
Discharge data

Mean monthly river flow in Al Kaber Al Janobi Basin in MCM/month

- Al Kaber Al Janobi 2 - Al Dabosia
- Al Kaber Al Janobi 1 - Al Arida
- Al Arous

Map showing river flow in Lebanon and Syria with marked hydrostations.
Rainfall data

Time series rainfall data were collected from the three stations.
AL-Lith valley

- Located in the western part of Saudi Arabia along the Red Sea coast and is about 300 km south of Jeddah.
- Area = 3000 km²
AL-Lith valley
Land use map
Soil map
Rainfall station
Hydrometric station
Model calibration
Mejerda basin—Tunisia
Topology

Gulf of Tunsia

Value
- High: 1624
- Low: 0

- watershed boundary
- international border
- coastal line

Kilometers
Soil map

Gulf of Tunsia

Texture:
- Loam
- Sandy clay loam
- Clay
- Loam
- Sand loam
- Sandy clay loam
- Sandy loam

Kilometers
Agriculture is the main land use
Curve Number Grid

Gulf of Tunsia

Curve number

VALUE
0 - 50
50-70
70-80
80-85
85- 100

Kilometers
The monthly evapotranspiration was estimated based using the **penman-Monteith method** using the cropwat program.
• Daily rainfall records are available for the period 1/9/1950 to 31/12/2005.
• Daily flow discharges record at GARDIMAOU DRE station are available for the period 1/9/1965 to 31/12/2000 but there is some discontinuity in the record.
The observations in the time-period (1975 to 1985) were used for calibrating the model and the data from the time-period (1997 to 1999) was used to independently evaluate the model.
Sensitivity analysis

The following parameters

• Soil maximum infiltration rate
• Soil percolation
• Groundwater water percolation

were identified to be sensitive parameters
these parameters were taken into consideration in the calibration
the automated calibration procedure in HEC-HMS uses an iterative method to minimize an objective function,
Objective functions

- Percentage error in simulated volume (PEV) objective function with the univariate gradient method was used to calibrate the HMS model.
Result of the optimization
Comparison of observed and simulated stream flow for the calibrated period
Model Validation
Model Validation

Model validation was used to determine the effectiveness of the calibrated parameters in predicting the flow discharges for the period 1/9/1997 - 31/12/1999.
Whole basin
Using measured rainfall data-1980-2000

<table>
<thead>
<tr>
<th>P</th>
<th>E</th>
<th>Q</th>
<th>R</th>
<th>Q/p</th>
<th>E/P</th>
<th>R/p</th>
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<tbody>
<tr>
<td>mm/year</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>426.6</td>
<td>298.2</td>
<td>89.0</td>
<td>8.1</td>
<td>20.9</td>
<td>69.9</td>
<td>1.9</td>
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</table>
WADI DAYQAH - SULTANATE OF OMAN

located 60 km southeast of Muscat
Model calibration
Model calibration

Basin Area = 1105 km²
### Objective Function Results for Trial "Trial 1"

**Project:** TYYIN  
**Optimization Trial:** Trial 1

Start of Trial: 15Jan1992, 00:00  
End of Trial: 02Jan1996, 00:00  
Compute Time: 09Dec2013, 00:37:57  
Basin Model: omanallbasin  
Meteorologic Model: Met 1  
Control Specifications: soha_control

#### Objective Function at Basin Element "W310"

Start of Function: 15Jan1992, 00:00  
End of Function: 02Jan1996, 00:00  
Type: Percent Error in Volume  
Value: 0.0

**Volume Units:**  
- [ ] MM  
- [ ] 1000 M3

<table>
<thead>
<tr>
<th>Measure</th>
<th>Simulated</th>
<th>Observed</th>
<th>Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (MM)</td>
<td>98.90</td>
<td>81.37</td>
<td>17.53</td>
<td>21.54</td>
</tr>
<tr>
<td>Peak Flow (M3/S)</td>
<td>430.6</td>
<td>315.0</td>
<td>115.6</td>
<td>36.7</td>
</tr>
<tr>
<td>Time of Peak</td>
<td>27Dec1995, 06:00</td>
<td>27Dec1995, 00:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of Center of Mass</td>
<td>21May1995, 00:48</td>
<td>05Oct1994, 16:43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Model Validation
Validation from the whole basin
### Summary Results for Subbasin "W310"

**Project:** omanallbasin  
**Simulation Run:** Run 1  
**Subbasin:** W310  
**Start of Run:** 15 Jan 1983, 00:00  
**End of Run:** 31 Dec 2006, 00:00  
**Compute Time:** 09 Dec 2013, 01:14:24  
**Basin Model:** omanallbasin  
**Meteorologic Model:** Met 1  
**Control Specifications:** soha_control

#### Computed Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Discharge</td>
<td>758.2 (M3/S)</td>
</tr>
<tr>
<td>Total Precipitation</td>
<td>2812.51 (MM)</td>
</tr>
<tr>
<td>Total Loss</td>
<td>2633.46 (MM)</td>
</tr>
<tr>
<td>Total Excess</td>
<td>179.05 (MM)</td>
</tr>
<tr>
<td>Date/Time of Peak Discharge</td>
<td>04 Dec 2006, 00:00</td>
</tr>
<tr>
<td>Total Direct Runoff</td>
<td>179.05 (MM)</td>
</tr>
<tr>
<td>Total Baseflow</td>
<td>0.00 (MM)</td>
</tr>
<tr>
<td>Discharge</td>
<td>179.05 (MM)</td>
</tr>
</tbody>
</table>

#### Observed Hydrograph at Gage Mazra

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Discharge</td>
<td>685.00 (M3/S)</td>
</tr>
<tr>
<td>Avg Abs Residual</td>
<td>0.90 (M3/S)</td>
</tr>
<tr>
<td>Total Residual</td>
<td>-27.44 (MM)</td>
</tr>
<tr>
<td>Date/Time of Peak Discharge</td>
<td>31 Mar 1997, 00:00</td>
</tr>
<tr>
<td>Total Obs Q</td>
<td>198.66 (MM)</td>
</tr>
</tbody>
</table>
Nahr el Kabir Al-Junoubi-Syria
Nahr el Kabir Al-Junoubi-Syria
Model calibration

Summary Results for Subbasin "W20"

Project: Arida2
Simulation Run: Run 1    Subbasin: W20

Start of Run: 01Jan1993, 00:00    Basin Model: basin1
End of Run: 30Dec1997, 00:00    Meteorologic Model: Met1
Compute Time: 07Dec2013, 20:11:11    Control Specifications: rrrrrrrr_control

Volume Units: MM    1000 M3

Computed Results
Peak Discharge: 348.5 (M3/S)    Date/Time of Peak Discharge: 08May1993, 00:00
Total Precipitation: 5512.00 (MM)    Total Direct Runoff: 2732.68 (MM)
Total Loss: 2779.32 (MM)    Total Baseflow: 1803.13 (MM)
Total Excess: 2732.68 (MM)    Discharge: 4535.81 (MM)

Observed Hydrograph at Gage Area
Peak Discharge: 43.63 (M3/S)    Date/Time of Peak Discharge: 01Apr1997, 00:00
Avg Abs Residual: 11.54 (M3/S)    Total Obs C: 4501.12 (MM)
Total Residual: -49.71 (MM)
Model Validation
# Summary Results for Subbasin "W20"

**Project:** Arida2  
**Simulation Run:** Run 1  
**Subbasin:** W20  
**Start of Run:** 01Jan1998, 00:00  
**End of Run:** 30Dec2000, 00:00  
**Compute Time:** 07Dec2013, 20:15:55  
**Basin Model:** basin1  
**Meteorologic Model:** Met 1  
**Control Specifications:** rrrrrrrr_control

### Volume Units:
- [ ] MM
- [ ] 1000 M3

## Computed Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Discharge</td>
<td>211.1 (M3/S)</td>
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<tr>
<td>Total Precipitation</td>
<td>3166.15 (MM)</td>
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<tr>
<td>Total Loss</td>
<td>1605.04 (MM)</td>
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<tr>
<td>Total Excess</td>
<td>1561.11 (MM)</td>
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<td>Date/Time of Peak Discharge</td>
<td>12Oct1999, 00:00</td>
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<tr>
<td>Total Direct Runoff</td>
<td>1561.08 (MM)</td>
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<tr>
<td>Total Baseflow</td>
<td>1081.48 (MM)</td>
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<tr>
<td>Discharge</td>
<td>2642.57 (MM)</td>
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### Observed Hydrograph at Gage Areda

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Peak Discharge</td>
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<td>Avg Abs Residual</td>
<td>10.80 (M3/S)</td>
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<tr>
<td>Total Residual</td>
<td>-209.96 (MM)</td>
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<tr>
<td>Date/Time of Peak Discharge</td>
<td>01Feb2000, 00:00</td>
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<tr>
<td>Total Obs Q</td>
<td>2852.52 (MM)</td>
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</table>

- 7%
Linking RCM data to HEC-HMS

- The outputs of the RCM are in NetCDF format.

What is NetCDF?

- **NetCDF** *(network Common Data Form)*
  
  A platform independent format for representing multi-dimensional array-orientated scientific data.
• HEC-HMS does not handle NetCDF data
ArcGIS tools
NetCDF to raster
Make netcdf Table

<table>
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<th>time</th>
<th>ta200</th>
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<td>220.4823</td>
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<td>1/2/2096 12:00:00 PM</td>
<td>218.2572</td>
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<td>3</td>
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<td>1/5/2096 12:00:00 PM</td>
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<td>1/6/2096 12:00:00 PM</td>
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Model builder
Climate change data

- Change in precipitation
Climate change data

Change in temperature

Absolute change in Temperature - rcp8.5 - 1986-2005_2081-2100

<table>
<thead>
<tr>
<th>Class</th>
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<td>3</td>
<td>3.1 - 3.4</td>
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<td>3.5 - 3.8</td>
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<td>4.3 - 4.6</td>
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<td>4.7 - 5</td>
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<td>8</td>
<td>5.1 - 5.4</td>
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<td>5.9 - 6.2</td>
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Thanks