Regional Hydrological Modelling Setup & Preliminary Outputs - for Sub-Regions of the Mena/Arab Domain

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Swedish Meteorological and Hydrological Institute (SMHI)
Regional Hydrological Modelling over the Arab Region is a key component of RICCAR.
Within RICCAR, hydrological models are being used to assess climate change impacts on hydrological regimes over the Arab Region

Large-scale hydrological models are used to comply with the regional approach – thus regional hydrological modelling

The regional hydrological models are driven by outputs from the RCM projections to produce regional hydrological projections

Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)
We do not expect to produce perfect representation of river flows at local scales, but rather …

-reasonable representation of hydrological processes over regional scales

-**consistent** approach with similar level of detail over entire region

-focus on **signal** for future hydrological **change**

-provides regional overview to **identify** trends and most areas that would potentially warrant more detailed study
Assessing Climate Change impacts on hydrological systems
A number of hydrological models were reviewed and 3 were chosen for application

2 at SMHI

1 at ACSAD
**HYPE Model:** Hydrological Predictions for the Environment:

- Aimed at catchment-scale water and nutrient modeling
- Process-based (water and nutrients)
- Components: soils, rivers, lakes and reservoirs
- Daily time-step
- Spatial discretization: soil & landuse classes
- Management: dam regulation, irrigation, and fertilization
- Developed 2005 to 2008 at SMHI, based on the widely applied HBV concept

- S-HYPE (Sweden, Q, N & P)
- Balt-HYPE (Baltic Sea basin, Q, N & P)
- E-Hype (Europe, Q, N & P)
- LPB-HYPE (La Plata Basin, Q)
- Arctic-HYPE (Arctic, Q)
- MENA-HYPE (Middle East, Northern Africa, Q)
- Niger-HYPE (Niger River, Q)
- In-HYPE (Indian subcontinent, Q)
VIC Model

Variable Infiltration Capacity Macroscale Hydrologic Model

worldwide applications

http://www.hydro.washington.edu/Lettenmaier/Models/VIC/index.shtml
Input data

- Precipitation
- Temperature
- Evaporation
- Elevation data (mainly for defining watershed)
- Soil type
- Land use (special interest could be irrigated areas)
- Large lakes, surface area
- Rating curves
- Dams, reservoirs and its use / regulation
- Diversions / bifurcations - ie, different paths than given by topography

Desired data

- Groundwater, major aquifers
- Lengths of rivers
- River flow measurements (almost a requirement)
- Water level measurements
- Information on soil depth
- Etc.

Regional datasets have mostly been used

*Because that is what is available!*

Local knowledge important!
Hydrological Modelling

*Working with test basins*

Test basin calibration allowed us to make the initial choice of parameters for application to the Arab Region.
Some 30,000 subbasins
average size 650 km²
VIC Model Setup

Gridded 25 x 25 km
Grid box area 625 km$^2$
Hydrological simulations
- historical climate

HYPE Model results
Hydrological Modelling

Runoff - present

Annual runoff in mm/yr – 1981-2000
Annual runoff in mm/yr – 1981-2000
Hydrological Modelling

Evapotranspiration - present

Annual evapotranspiration in mm/yr – 1981-2000
Hydrological simulations
- Using future climate projections
Assessing Climate Change impacts on hydrological systems

Global emissions scenarios → Global Climate modelling → Regional Climate modelling → Hydrological Modelling → Analysis of Impacts

Can we go directly from RCM to hydrological model?
Assessing Climate Change impacts on hydrological systems

Can we go directly from RCM to hydrological model?
Assessing Climate Change impacts on hydrological systems

Requires an interface to overcome RCM biases
Direct input of Prec. & Temp. from RCM control period: 1961-1990

Example from Torpshammer River Basin in Sweden
(Observations & RCA-ECHAM5) - RCM overestimates precipitation
**Bias-corrected** input of Prec. & Temp. from RCM control period: 1961-1990

Example from Torpshammer River Basin in Sweden

(Observations & RCA-ECHAM5) - **RCM overestimates** precipitation
Bias Correction – Arab Region

For CORDEX–Mena domain, RCA Model tends to underestimates precipitation
Applying Bias Corrections

- Identify RCM biases using comparison to present climate for both precipitation and temperature.
- Use a tested technique to identify corrections needed.
- Apply corrections to full RCM time series, including future climate.
- Make impact simulations with corrected time series.
- Assumes that the bias being corrected is systematic and is the same for both present and future climate!
Regional Hydrological Modelling over the Arab Region is a key component of RICCAR

Future Hydrological Projections
Creating Future Hydro Projection Ensembles

Control period

3 Hydro runs
1986-2005

Future period - Change

3 Hydro runs
2081-2100

Hydro Ensemble

Hydro Ensemble

Hype Hydro Model: 3 projections (Summer)

Runoff - RCP 8.5
Future Projections - Summer

Hydro Models: 3-member ensemble

Runoff - RCP 4.5
Future Projections - Summer

Hydro Models: 3-member ensemble

Runoff - RCP 8.5
Future Projections - Winter

Hydro Models: 3-member ensemble

Runoff - RCP 4.5
Future Projections - Winter

Hydro Models: 3-member ensemble

Runoff - RCP 8.5
Future climate projections

Sub-regions
Moroccan Highlands

**Sub-region Summary of projected changes**

<table>
<thead>
<tr>
<th>RCP</th>
<th>Future Period</th>
<th>2m Temp (°C)</th>
<th>Prec (%)</th>
<th>Hype Runoff (%)</th>
<th>Vic Runoff (%)</th>
<th>Hype High Flow (100-yr) (%)</th>
<th>Hype Low Flow (&lt;20th perc) (days)</th>
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3-member ensemble  *Preliminary!*
Jordan River

Sub-region Summary of projected changes

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<th>2m Temp (°C)</th>
<th>Prec (%)</th>
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3-member ensemble Preliminary!
## Senegal River

### Sub-region Summary of projected changes

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3-member ensemble  **Preliminary!**
Sana’a River

Sub-region Summary of projected changes

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<th>Prec (%)</th>
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3-member ensemble Preliminary!
Summary

• Much effort has been put into setting up hydrological modelling and adapting bias correction techniques

• We are currently analysing results from RHMs

• We are still assessing how best to present and use this information

• We will likely find some surprises along the way!