RICCAR Regional Climate Modelling and Hydrological Modelling Outputs Covering the MENA/Arab Domain

Phil Graham
Swedish Meteorological and Hydrological Institute (SMHI)

A core activity within RICCAR is to produce regionally downscaled future climate projections for the Arab Region

Present Climate From RCMs
CORDEX-MENA/Arab Ensemble Matrix

<table>
<thead>
<tr>
<th>RCM (Institute)</th>
<th>GCM</th>
<th>Historical</th>
<th>RCP2.6</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA4 (SMHI)</td>
<td>EC-Earth</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
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<td>RCA4 (SMHI)</td>
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<td>✔</td>
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</tr>
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<td>✔</td>
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<td>✔</td>
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<tr>
<td>Remo (CSC)</td>
<td>MPI-ESM</td>
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<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

- ✔ Completed
- ✔ Running
- ✔ Planned

Observed and simulated temperature (JJA)

2m Temperature (tas) | JJA | 1980-2004

- CRU-TS31
- UDEL301
- ERAINT
- RCA4 (ERAINT)
- RCA4 (EC-EARTH)
- RCA4 (CNRM-CM5)
- RCA4 (GFDL-ESM2M)
- REMO (MPI-ESM-LR)
- HIRAM (GFDL-ESM2M)
- EN3 (RGCMs)
- EN3 (SGCMs)

- a common cold bias in GCMs and in the GCM driven runs
**Observed and simulated temperature (DJF)**

2m Temperature (tas) | DJF | 1980-2004

- the cold bias becomes larger in winter compared to summer
- there is a need in bias correction

**Observed and simulated precipitation (JJA)**

Precipitation (pr) | JJA | 1980-2004

- RCA is too dry in central Africa while REMO and HiRAM are too wet over the Guinea coast
A core activity within RICCAR is to produce *regionally downscaled* future climate projections for the Arab Region.

**Future Climate Projections**

**CORDEX-MENA/Arab Ensemble Matrix**

<table>
<thead>
<tr>
<th>RCM (Institute)</th>
<th>GCM</th>
<th>Historical 1950-2005</th>
<th>RCP2.6 2006-2100</th>
<th>RCP4.5 2006-2100</th>
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<tbody>
<tr>
<td>RCA4 (SMHI)</td>
<td>EC-Earth 50km</td>
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<td>✔️</td>
<td>✔️</td>
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<tr>
<td>RCA4 (SMHI)</td>
<td>EC-Earth 25km</td>
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<tr>
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<td>GFDL-ESM-2 25km</td>
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✔️ Completed  ✔️ Running  ✔️ Planned
Projected Change in Temperature
Summarised over entire MENA Domain

2m Temperature (tas) anomalies wrt 1975-2004 | 11-yr. mov. mean | JJA |
MENA (MNA) 15W-60E 10N-35N

- RCA(EC-EARTH)
- RCA(GFDL)
- RCA(CRIMM)
- REMO(MPI)
- HIST
- RCP45
- RCP85

- in coming decades both RCP45 and RCP85 are similar
- RCM simulations follow their driving GCMs on continental scale

Future Projections - RCP 4.5

RCA4: 3-member ensemble

Temperature
Future Projections - RCP 8.5

Temperature

Future Projections - RCP 4.5

Precipitation
Future Projections - RCP 8.5

RCA4: 3-member ensemble

Precipitation

Future Projections - RCP 8.5

RCA4: 3-member ensemble

Precipitation - agreement on signal of change
Future climate projections

Sub-regions

Temperature Change

Atlas Mountains

Summer

Winter

Precipitation Change
Regional changes

Atlas Mountains, Winter

- an agreement between global and regional ensembles in temperature and precipitation projections

Temperature Change

Jordan River

Precipitation Change

Summer

Winter
Future climate projections

Extremes

Future Projections

ETCCDI
CC Indices

RCA4: 3-member ensemble

Maximum Length of Dry Spell (CDD)
Future climate projections

*a larger ensemble?*
The RICCAR initiative was founded to assess climate change impacts on water resources over the Arab Region.

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 hydrological projections provide an overview for the entire region using a *consistent approach* with similar level of detail applied overall. They thus provide *identification of overall trends* and areas that would potentially warrant more detailed study.

*Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)*
Assessing Climate Change impacts on hydrological systems

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

A number of hydrological models were reviewed and three were chosen for application
**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

Current applications
- 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)

**SMHI is also working with another hydrological model over the Arab Region**

**VIC Model**

Variable Infiltration Capacity
Macroscale Hydrologic Model

http://www.hydro.washington.edu/Lettenmaier/Models/VIC/index.shtml
ACSAD is working with a third hydrological model over the Arab Region

**HEC-HMS**

*HEC - Hydrological Modelling System*

- Hydrologic Cycle Components in HEC-HMS (circa 2008)

  - Rainfall, $P(t)$
  - Evaporation
  - Snowfall
  - Snowpack
  - Infiltration Loss
  - Land Surface and Vegetation
  - Runoff
  - Percolation Loss
  - Channels
  - Runoff
  - Discharge, $Q(t)$
  - Reservoirs

Hydrological Modelling

*Working with test basins*

Test basin calibration allowed us to make the initial choice of parameters for application to the Arab Region

- Medjerda
- Tigris-Euphrates
- Wadi Dayqah (Oman)
Hype Model Setup

Some 30,000 subbasins
average size 650 km²

Hydrological simulations
- historical climate
HYPE Model results
Hydrological Modelling

Runoff - present

Hype Model

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

Hype Model

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?

NO!

Assessing Climate Change impacts on hydrological systems

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Can we go directly from RCM to hydrological model?

NO!
Assessing Climate Change impacts on hydrological systems

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

Requires an interface to overcome RCM biases

Direct input of Prec. & Temp. from RCM control period: 1961-1990

HBV model runs for Torpshammer River Basin in Sweden
(Observations & RCA-ECHAM5) - RCM over-estimates precipitation
Scaling precipitation using a gamma-distribution approach

CDF of observations, raw RCA & scaled RCA precipitation
1961-1990 compared to RCA control period

Summer

Scaled (bias-corrected) input of Prec. & Temp. from RCM control period: 1961-1990

HBV model runs for Torpshammer River Basin in Sweden
(Observations & RCA-ECHAM5) - RCM over-estimates precipitation
Applying Bias Corrections

- Identify RCM biases using comparison to present climate
- 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**
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
### Sub-region Summary of projected changes

**Atlas Mountains** (annual)

<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>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>2046-2065</td>
<td>1.5</td>
<td>-9%</td>
<td>-24%</td>
<td>-27%</td>
<td>-25%</td>
<td>67</td>
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<tr>
<td>8.5</td>
<td>2046-2065</td>
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<td>-43%</td>
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<tr>
<td>4.5</td>
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<td>2.0</td>
<td>-11%</td>
<td>-23%</td>
<td>-30%</td>
<td>-11%</td>
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<tr>
<td>8.5</td>
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<td>4.4</td>
<td>-21%</td>
<td>-55%</td>
<td>-67%</td>
<td>-44%</td>
<td>157</td>
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</table>

*Preliminary!*

### Sub-region Summary of projected changes

**Jordan River** (annual)

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>4.5</td>
<td>2046-2065</td>
<td>1.5</td>
<td>-1%</td>
<td>-2%</td>
<td>6%</td>
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<td>-26%</td>
<td>-21%</td>
<td>-33%</td>
<td>36</td>
</tr>
</tbody>
</table>

*Preliminary!*
Summary

• Much effort has been put into setting up the RCM domain and producing climate projections
• Much effort has been put into setting up hydrological modelling and adapting bias correction techniques
• We are currently analysing results from both RCMs and RHMs
• We are still assessing how best to present and use these
• Such work needs to continue even beyond the scope of RICCAR!
• Is this a task for an ArabCOF?

In response to questions on climate portal ...

• climate4impact.eu/impactportal/general/index.jsp
• is-enes.climateimpact portal
• exploring climate model data
• IS-ENES climate and impact portal
• Welcome to the IS-ENES climate and impact portal, oriented towards climate change impact modellers, impact and adaptation consultants as well as other experts using climate change data.
• With you will find access to data and tools related to global climate models (GCMs) and regional climate model (RCMs) and downscaled higher resolution climate data. The portal provides data transformation tools for solving data to your needs and mapping & ordering available datasets.
• Guidelines on how to use climate scenarios, documentation on the climate system, frequently asked questions and examples in several impact and adaptation themes are presented and described, along with the steps required to go from GCM data to impact model input data.
• The climate impact portal is operational since 15 April 2014: read more.