Regional Initiative for the Assessment of Climate Change Impacts on Water Resources & Socio-Economic Vulnerability in the Arab Region
Integrated Assessment

Building Capacity for Accessing Disruptive Technologies for Improved Water Resources Management under Climate Change
Beirut, 14-15 January 2020
Intergovernmental Mandates calling for & supporting Climate Change Assessment in the Arab Region

- Arab Ministerial Declaration on Climate Change CAMRE 2007
- Arab Economic and Social Summit Resolution on Climate Change & Water Project 2009
- ACSAD Board of Directors Resolution 2013
- APCM is under new Arab Ministerial Council for Meteorology & Climate

Environment
Foreign Affairs & Planning
Water
Meteorology
Agriculture
Objective: To assess the impact of climate change on freshwater resources in the Arab Region through a consultative regional initiative that scientifically identifies the socio-economic and environmental vulnerability caused by climate change impacts on water resources based on regional specificities.

Purpose: To provide a common platform for assessing, addressing and informing response to climate change impacts on freshwater resources in the Arab region by serving as the basis for dialogue, priority setting and policy formulation on climate change at the regional level.
Pillars of Work

REGIONAL KNOWLEDGE HUB

INTEGRATED ASSESSMENT

Climate Change Impact Assessment

Climate Change Vulnerability Assessment

CAPACITY BUILDING & INSTITUTIONAL STRENGTHENING

AWARENESS RAISING & INFORMATION DISSEMINATION
Integrated Assessment

GCM: Global Climate Modelling
RCM: Regional Climate Modelling
RHM: Regional Hydrological Modeling
VA: Vulnerability Assessment
IM: Integrated Mapping
When examining Regional Climate Modelling and Hydrological modelling outputs, consider:

1) What **scale** of outputs do you need?
2) Which **Essential Climate Variables** are you interested in?
3) What **Domain** to use or draw upon for regional climate modelling?
4) Which **Climate Scenario** is of interest to your work?
5) Can you allocate the time needed to consider an **Ensemble** of projections for quantifying the range of uncertainty?
6) What **Time Intervals** do you need? Daily; Monthly; 10-year; 20-year; mid-century; end-century

And ultimately, do you need ready-made **outputs (projections) or inputs (dataset)** for use in other models?
1- Scale: Computing Climate Variables

REF: http://stratus.astr.ucl.ac.be/textbook/chapter3_node8.html
Computing Climate Variables:
Scale Improving Over Time

Source: IPCC, 2007; Met Office, 2011

RICCAR RCM Outputs
now at 50x50 km & 25x25 km
Mashreq to be at 10 km²

Source: IPCC, 2007; Met Office, 2011
**2- Essential Climate Variables: Generated per Grid Box**

**Atmosphere**
- **Surface**
  - Precipitation
  - Pressure
  - Radiation budget
  - Temperature
  - Water vapour
  - Wind speed and direction

- **Upper-air**
  - Earth radiation budget
  - Lightning
  - Temperature
  - Water vapor
  - Wind speed and direction

- **Atmospheric Composition**
  - Aerosols
  - Carbon dioxide, methane and other greenhouse gases
  - Clouds
  - Ozone
  - Precursors for aerosols and ozone

**Land**
- **Hydrosphere**
  - Groundwater
  - Lakes
  - River discharge

- **Cryosphere**
  - Glaciers
  - Ice sheets and ice shelves
  - Permafrost
  - Snow

- **Biosphere**
  - Above-ground biomass
  - Albedo
  - Evaporation from land
  - Fire
  - Fraction of absorbed photosynthetically active radiation (FAPAR)
  - Land cover
  - Land surface temperature
  - Leaf area index
  - Soil carbon
  - Soil moisture

**Ocean**
- **Physical**
  - Ocean surface heat flux
  - Sea ice
  - Sea level
  - Sea state
  - Sea surface currents
  - Sea surface salinity
  - Sea surface stress
  - Sea surface temperature
  - Subsurface currents
  - Subsurface salinity
  - Subsurface temperature

- **Biogeochemical**
  - Inorganic carbon
  - Nitrous oxide
  - Nutrients
  - Ocean colour
  - Oxygen
  - Transient tracers

- **Biological/ecosystems**
  - Marine habitats
  - Plankton

- **Anthroposphere**
  - Anthropogenic Greenhouse gas fluxes
  - Anthropogenic water use

---

Essential Climate Variables (ECV) datasets provide the empirical evidence needed to understand and predict the evolution of climate

3-Domain: IPCC Regional Domains (2010)

From R.K Kolli, WMO
RICCAR EGM #2 (Beirut, 2010)
Figure AI.3: Overview of the SREX, ocean and polar regions used.

SREX: Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
CORDEX Domains (2012)
Coordinated Regional Climate Downscaling Experiment

Arctic

NARCCAP
ENSEMBLES
RCMIP

Antarctic

CLARIS
### CORDEX-MENA Working Group

- Preliminary RCM Ensemble Meeting (Brussels, 2013)
- First **CORDEX MENA-CA Meeting** (Nicosia, November 2014)
- Organized by CORDEX (WMO) with SMHI & Hosted by The Cyprus Institute.

**Attending or Interested Centers:**

<table>
<thead>
<tr>
<th>Center</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Abdulaziz University (KAU)</td>
<td>KSA</td>
</tr>
<tr>
<td>King Abdullah University of Science and Technology (KAUST)</td>
<td>KSA</td>
</tr>
<tr>
<td>Istanbul Technical University</td>
<td>Turkey</td>
</tr>
<tr>
<td>Bogazici University</td>
<td>Turkey</td>
</tr>
<tr>
<td>Cairo University</td>
<td></td>
</tr>
<tr>
<td>Jet Propulsion Laboratory (USA)</td>
<td></td>
</tr>
<tr>
<td>Max Plank Institute for Chemistry (Germany)</td>
<td></td>
</tr>
<tr>
<td>Italian Aerospace Research Center (CIRA)</td>
<td></td>
</tr>
<tr>
<td>Qatar Meteorology Department</td>
<td></td>
</tr>
<tr>
<td>SMHI</td>
<td></td>
</tr>
<tr>
<td>ACSAD</td>
<td></td>
</tr>
<tr>
<td>Maroc Meteo</td>
<td></td>
</tr>
<tr>
<td>The Cyprus Institute</td>
<td></td>
</tr>
<tr>
<td>WMO</td>
<td></td>
</tr>
<tr>
<td>ESCWA</td>
<td></td>
</tr>
</tbody>
</table>

*CORDEX is the Coordinated Regional Climate Downscaling Experiment of the World Climate Research Program*
Spatial boundaries of the geographical regions used in the IPCC 5th Assessment Report (AR5) (2014)

http://www.ipcc-data.org/guidelines/pages/ar5Regions.html
4- Climate Scenarios
Special Report on Emission Scenarios (SRES) - SRES used in IPCC AR4 (2007)

A1
- Rapid economic growth,
- Global population peaks in mid-century
- Rapid introduction of new and more efficient technologies.

A2
- High population growth,
- Slow economic development
- Slow technological change.

B1
- Rapid economic growth,
- Global population peaks in mid-century
- More rapid introduction of new and more efficient technologies.

B2
- Intermediate economic growth,
- Intermediate population growth,
- Local technological solutions.

Average 1.8°C Temp increase Scenario

Average 3.4°C Temp increase Scenario

Source: ESCWA, 2009
Representative Concentration Pathways (RCPs) Scenarios used in IPCC AR5

Graph adapted from: Meinshausen et al., 2010
5- Regional Climate Modeling as Core Component

Different GCMs

Ensemble Average used to reduce uncertainty at level of RCMs & RHMs

Ensembles compare findings of different RCMs & RHMs applied for same RCP & Domain

At least 3 projections for the same scenario to generate an Ensemble

Extreme Climate Events from RCM
## RCM Ensemble Matrix

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA4</td>
<td>ERA-INTERIM</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>RCA4</td>
<td>EC-Earth</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>50</td>
</tr>
<tr>
<td>RCA4</td>
<td>EC-Earth</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>RCA4</td>
<td>CNRM-CM5</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>50</td>
</tr>
<tr>
<td>RCA4</td>
<td>GFDL-ESM2M</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>RCA4</td>
<td>GFDL-ESM2M</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>25</td>
</tr>
<tr>
<td>HIRAM</td>
<td>GFDL-ESM2M</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>REMO</td>
<td>MPI-ESM-LR</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
</tbody>
</table>

For RICCAR Report (2017), MENA/Arab Domain presented for Reference period; Mid-Century; End-Century, but data is available for customized domains & for daily/monthly/customized time periods via RICCAR Regional Knowledge Hub
RICCAR Impact Assessment: Selected Results
Temperature in the region is increasing and is expected to continue to increase until the end of the century.
Temperature Ensembles through a Seasonal Lens

- **Winter**
  - RCP 8.5 Ensemble
  - RCP 4.5 Ensemble

- **Summer**
  - RCP 8.5 Ensemble
  - RCP 4.5 Ensemble

Depends on which future (which climate scenario) one plans against.
Precipitation trends are largely decreasing across the region until the end of the century, though limited areas expected to exhibit an increase in the intensity & volume of precipitation.

From RICCAR RCM ensemble outputs
## Extreme events indices

<table>
<thead>
<tr>
<th>Extreme temperature indices</th>
<th>Extreme precipitation indices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Index</strong></td>
<td><strong>Full name</strong></td>
</tr>
<tr>
<td>SU</td>
<td>Number of summer days</td>
</tr>
<tr>
<td>SU35</td>
<td>Number of hot days</td>
</tr>
<tr>
<td>SU40</td>
<td>Number of very hot days</td>
</tr>
<tr>
<td>TR</td>
<td>Number of tropical nights</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Maximum length of dry spell (CDD)

RCP 4.5

RCP 8.5
Regional Climate Modeling to Hydrological Modeling

Different GCMs

Bias Correction of RCM Projections needed before data can be used for water & agricultural modeling

Same RCP

Ensembles used to reduce uncertainty at level of RCMs & RHMs

Ensembles aggregate findings of different RCMs & RHMs applied for same RCP & Domain

VIC
HYPE
HEC-HMS
Models Used

27
Mean change in Annual Runoff

Comparison between 2 hydrological models based on SMHI modeling outputs: Hydrological Predictions for the Environment (HYPE) and Variable Infiltration Capacity (VIC)

2 Models; 2 RCPs
Mean change in Annual Runoff

2 Models; 2 RCPs
Mean change in Annual Evapotranspiration
Mean change in Annual Evapotranspiration
Locations of subdomains identified for hydrological analysis

Most details in the RICCAR Main Report's Technical Annex and RKH
Climate Impacts on Transboundary Water Resources: Euphrates River

Upper Euphrates River
(1986-2005) : (2081-2100)

<table>
<thead>
<tr>
<th>Variable</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>2.3°C</td>
<td>4.8°C</td>
</tr>
<tr>
<td>Precip.</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Runoff</td>
<td>-2%</td>
<td>-12%</td>
</tr>
</tbody>
</table>
Climate Impacts on Transboundary Water Resources: Upper Tigris

Upper Tigris River: Seasonal Temperature (RCM output)

Upper Tigris River: Extreme Climate Indicators:
- Consecutive Dry Days
- Consecutive Wet Days (RCM output)
Climate Impacts on Transboundary Water Resources: Upper Tigris

Upper Tigris River: Monthly precipitation (mm/day) for mid-century and end-century (RHM output)

FIGURE 118
Mean change in monthly precipitation for mid-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 119
Mean change in monthly precipitation for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period

FIGURE 127
Mean change in annual runoff over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

Upper Tigris River: Runoff (RHM output)
Climate Impacts on Transboundary Water Resources: Jordan River

for a three-member ensemble of RCP 4.5 projections and three-member ensemble of RCP 8.5 projections for the Jordan River
Integrated Vulnerability Assessment: Selected Results
RICCAR Vulnerability Assessment Components

- EXPOSURE (0.50)
- SENSITIVITY (0.50)
  - POTENTIAL IMPACTS (0.50)
  - ADAPTIVE CAPACITY (0.50)
- VULNERABILITY

RICCAR, based on IPCC AR4, 2007
Preparation of a Vulnerability Index:

- **Per Sector**
  - Contains all indicators identified to assess a given sectors
  - Attribution of weights for each indicator dependent on impact chains and expert judgment
  - As sector level, aggregated by component: Exposure, Sensitivity, Adaptive Capacity

- **Overall Vulnerability**
  - Aggregates vulnerability of each sector to generate an Overall VA
  - Supports identification of VA Hotspots

Slide graphics: adelphi
Source of maps: ACSAD, SMHI
## Vulnerability Assessment

<table>
<thead>
<tr>
<th>SECTORS</th>
<th>SUBSECTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Water availability</td>
</tr>
<tr>
<td>Biodiversity and Ecosystems</td>
<td>Area covered by forests&lt;br&gt;Area covered by wetlands</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Water available for crops&lt;br&gt;Water available for livestock</td>
</tr>
<tr>
<td>Infrastructure and Human Settlements</td>
<td>Inland flooding area</td>
</tr>
<tr>
<td>People</td>
<td>Water available for drinking&lt;br&gt;Health conditions due to heat stress&lt;br&gt;Employment rate for the agricultural sector</td>
</tr>
</tbody>
</table>
Vulnerability Assessment Impact Chain
Water Availability

**Exposure** (0.50)
- **RCM**
  - Change in temperature (0.17)
  - Change in precipitation (0.17)
- **RIHM**
  - Change in runoff (0.17)
  - Change in evapotranspiration (0.17)

**Extreme Events Indices**
- Change in maximum length of dry spell (0.16)
- Change in maximum length of wet spell (0.10)

**Sensitivity** (0.50)
- **Population** (0.50)
  - Population density (0.14)
  - Total renewable water available per capita (0.59)
  - Water consumption per capita (0.13)
  - Share of water consumption in agriculture (0.13)
  - Refugee population (0.10)
- **Natural** (0.26)
  - Land use/land cover (0.27)
  - Soil storage capacity (0.25)
  - Degradation of vegetation cover (0.26)
  - Wetlands (0.22)
- **Man-made** (0.24)
  - Urban extent (0.47)
  - Areas served by dams (0.53)

**Potential Impact** (0.50)
- **Knowledge & Awareness** (0.19)
  - E-Government development (0.33)
  - Tertiary enrollment (0.32)
  - Adult literacy rate (0.35)
- **Technology** (0.16)
  - Number of scientific and technical journal articles (0.46)
  - Information and communication technologies index (0.54)
- **Infrastructure** (0.50)
  - Water & sanitation (0.50)
    - Fossil groundwater (0.17)
    - Access to improved water (0.17)
    - Access to improved sanitation (0.16)
    - Area equipped for irrigation (0.16)
- **Economic Resources** (0.11)
  - GDP per capita (0.36)
  - DDA (0.30)
  - Food imports as % of merchandise exports (0.34)

**Vulnerability Assessment**
- **Environment** (0.50)
  - Environment performance index (1.0)
- **Equity** (0.09)
  - Female-to-male literacy ratio (0.51)
  - Migrants/refugees index (0.49)

**Adaptive Capacity** (0.50)
- **Institutions** (0.10)
  - Governance index (0.54)
  - Disaster risk reduction committees (0.46)
- **Knowledge & Awareness** (0.19)
  - E-Government development (0.33)
  - Tertiary enrollment (0.32)
  - Adult literacy rate (0.35)

**Riccar**
Regional initiative for the assessment of Climate Change impacts on Water Resources and socio-economic vulnerability in the Mediterranean Region.
Water Availability Vulnerability

**Scenario**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Low Vulnerability</th>
<th>Moderate Vulnerability</th>
<th>High Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP 4.5 Mid-century</td>
<td>0%</td>
<td>57%</td>
<td>43%</td>
</tr>
<tr>
<td>RCP 8.5 Mid-century</td>
<td>0%</td>
<td>48%</td>
<td>52%</td>
</tr>
<tr>
<td>RCP 4.5 End-century</td>
<td>0%</td>
<td>52%</td>
<td>48%</td>
</tr>
<tr>
<td>RCP 8.5 End-century</td>
<td>0%</td>
<td>43%</td>
<td>57%</td>
</tr>
</tbody>
</table>
Lebanese Agricultural Sector Vulnerability Assessment
Report Launched – September 2017
Climate Change Adaptation Manual:
Five sector modules drawing on RICCAR outputs were developed by ESCWA in close cooperation with the following leading organizations:

1. **Environment** module with UNEP/ROWA;
2. **Agriculture** module with ACSAD and GIZ;
3. **Health** module with WHO;
4. **Human settlements** (on water supply/sanitation) with ACWUA;
5. **Economic Development** module by ESCWA

A joint introductory chapter by ESCWA render the 5 modules a manual. Five workshops were held with stakeholders from each sector to finalize the modules.

**RICCAR used to inform other publications**
Thank You

www.riccar.org
www.unescwa.org/our-work/climate-change