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Regional projections: How climate change affects transboundary water resources – RICCAR Highlights

UNITED NATIONS
الاسكوا
ESCWA

Carol Chouchani Cherfane
RICCAR Coordinator
Chief, Water Resources Section
Climate Change and Natural Resource Sustainability Cluster
UN Economic and Social Commission for Western Asia (ESCWA)

Regional workshop on Enhancing transboundary water cooperation in the MENA region - progress, challenges and opportunities
Beirut, 3-4 March 2020

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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

Arab Permanent Committee for Meteorology
Resolutions
2012, 2013, 2014, 2015, 2016

APCM is under new
Arab Ministerial Council for Meteorology & Climate

ESCWA Ministerial Session
Resolutions on Climate Change
*2008, 2012, 2014, 2016, 2018, 2019**

Arab Ministerial Water Council
Resolutions
2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019

ACSAD Board of Directors
Resolution
2013

Environment | Foreign Affairs & Planning | Water | Meteorology | Agriculture

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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.

Assessment | **Adaptation** | **Mitigation** | **Negotiations**

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RICCAR Partnerships

UNITED NATIONS
الاسكوا
ESCWA

UN environment

WMO

ACSAD

LAS

SMHI

UNESCO
United Nations Educational, Scientific and Cultural Organization
Cairo Office

UNITED NATIONS UNIVERSITY
UNU-INWEH

FAO
FIAT PANIS

Sweden
Sverige
SWEDISH INTERNATIONAL DEVELOPMENT COOPERATION AGENCY

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ACCWaM

UNDRR
UN Office for Disaster Risk Reduction

CORDEX/MENA Domain housed at The Cyprus Institute

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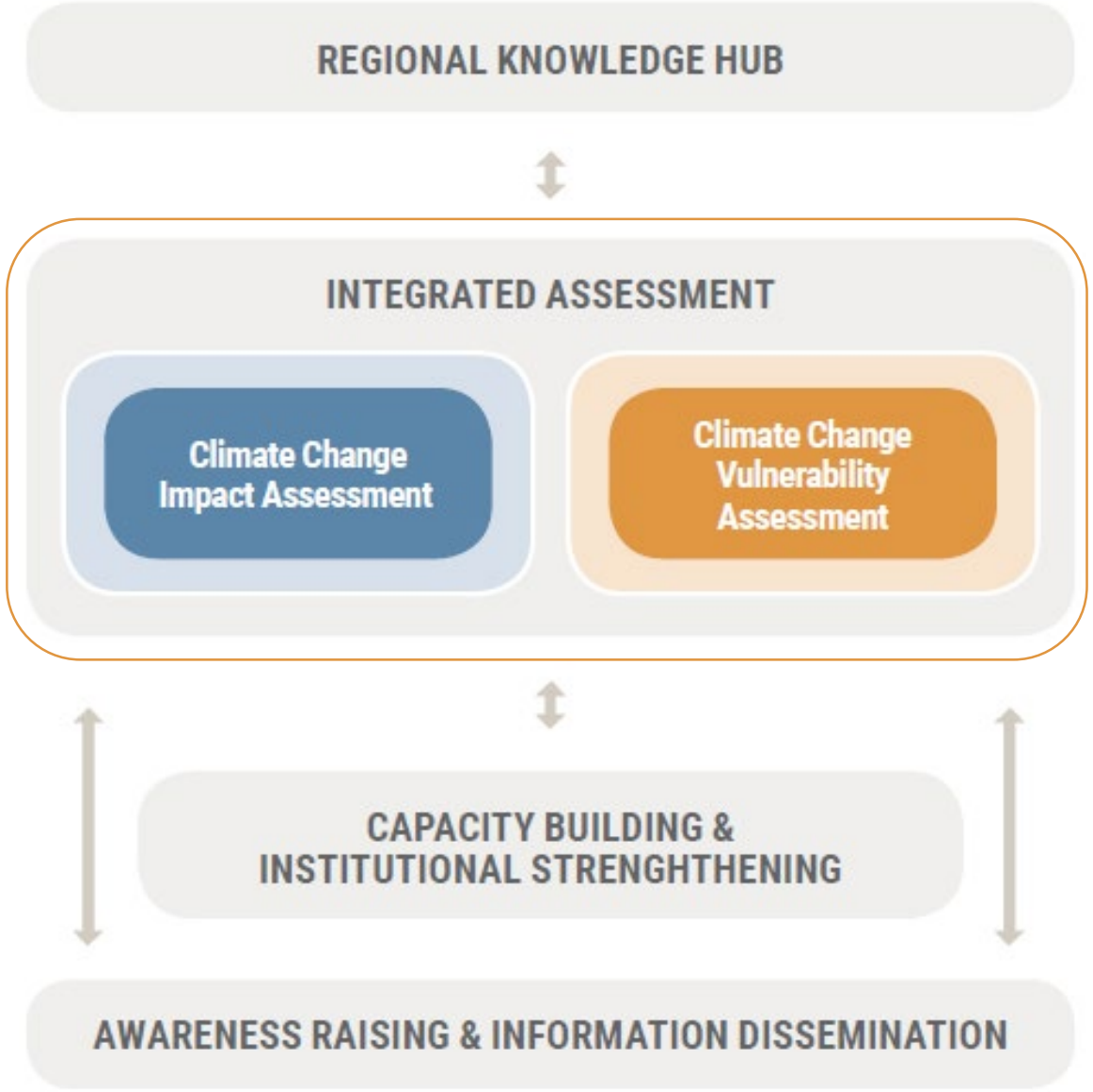
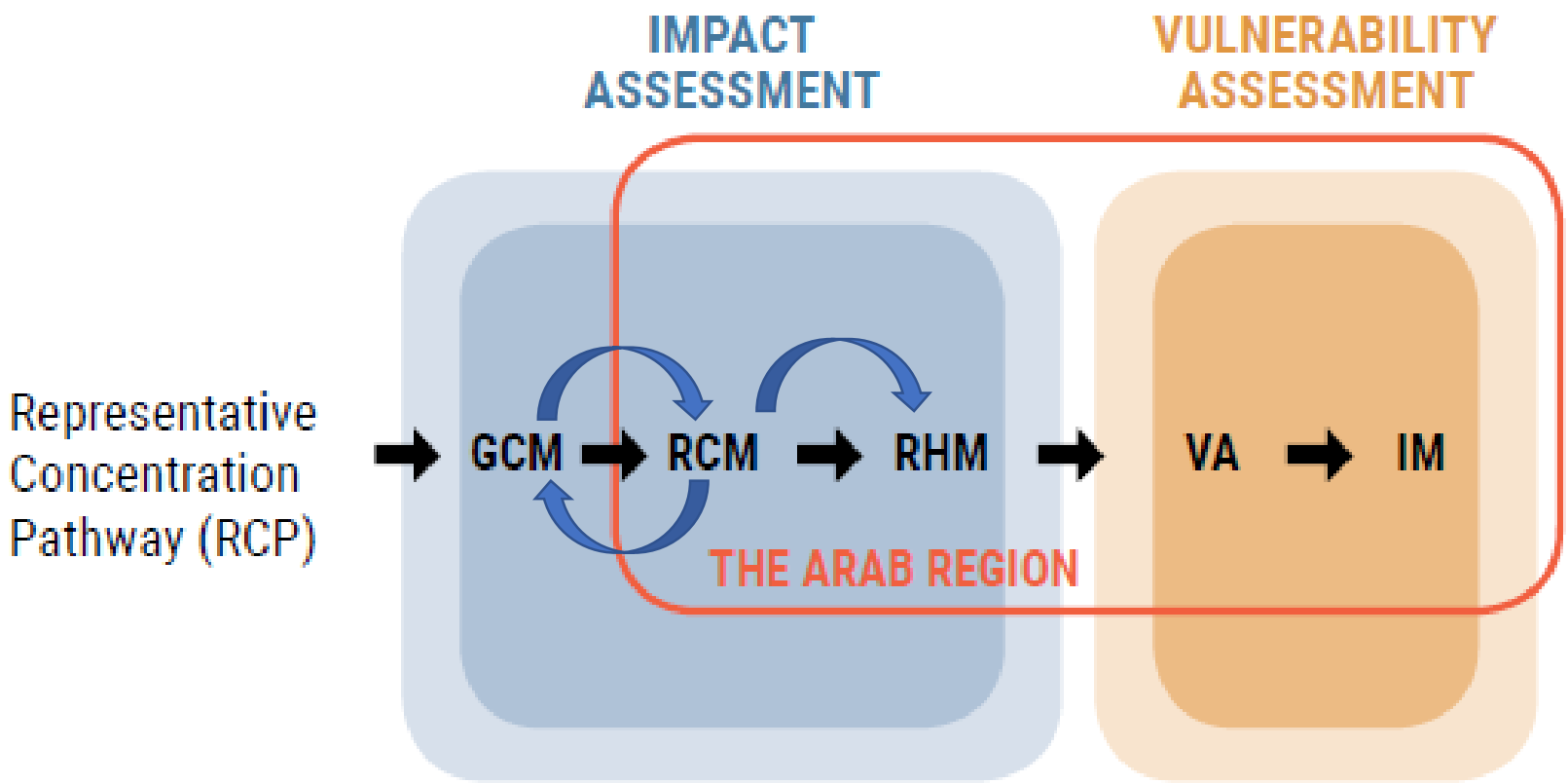
Pillars of Work



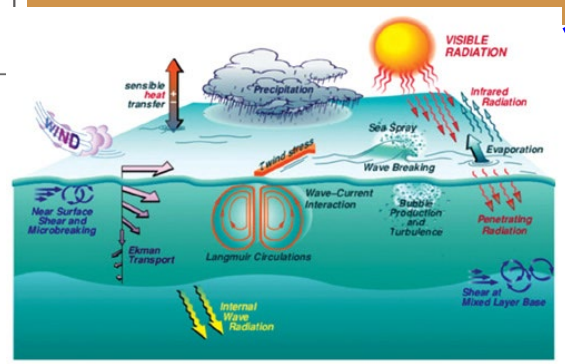
Integrated Assessment

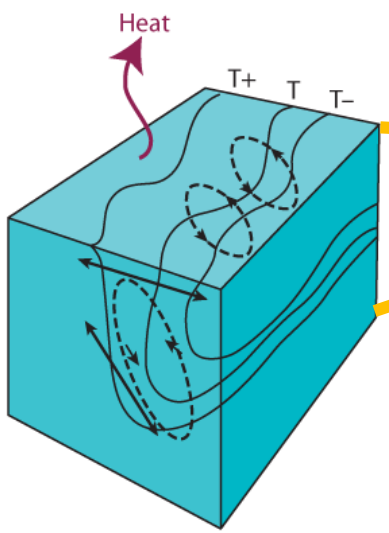


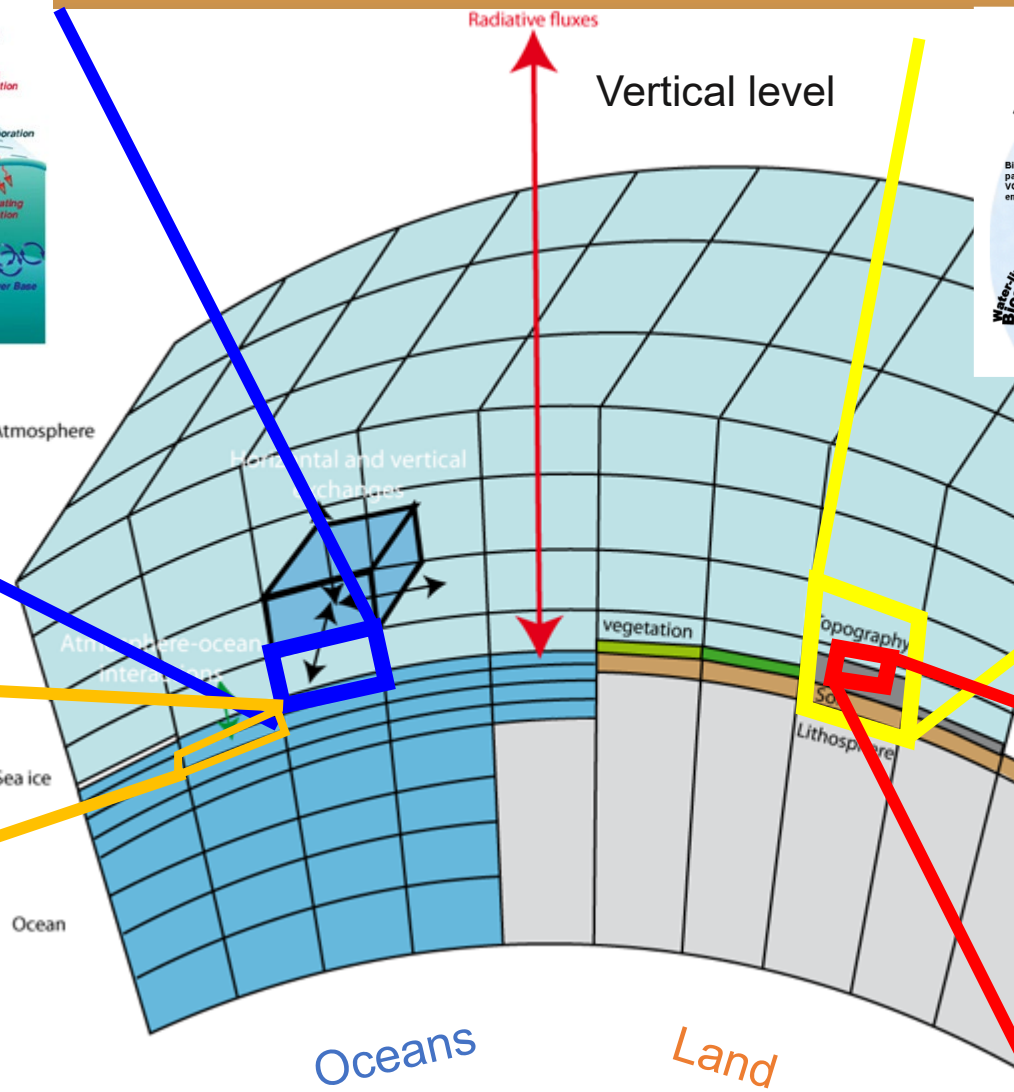
GCM: Global Climate Modelling
RCM: Regional Climate Modelling
RHM: Regional Hydrological Modeling

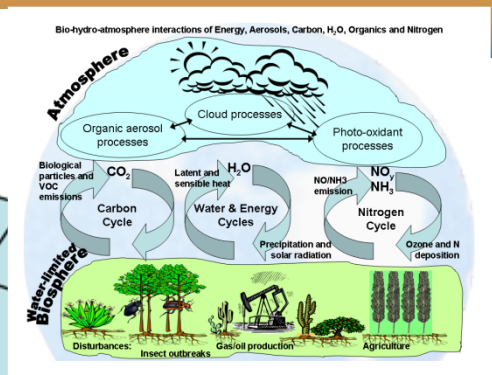
VA: Vulnerability Assessment
IM: Integrated Mapping

Computing Climate Variables

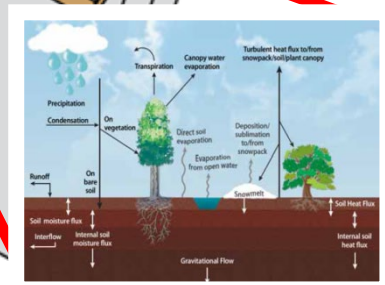








Atmosphere



REF: http://stratus.astr.ucl.ac.be/textbook/chapter3_node8.html
http://www.nesl.ucar.edu/LAR/2007/strategic-priorities/sp2/index.php

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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

Anthroposphere
- Anthropogenic Greenhouse gas fluxes
- Anthropogenic water use

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

RICCAR RCMs are land-based models and do not generate Oceanic Variables

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

https://gcos.wmo.int/en/essential-climate-variables/table

Computing Climate Variables:
Scale Improving Over Time

IPCC FAR 1990

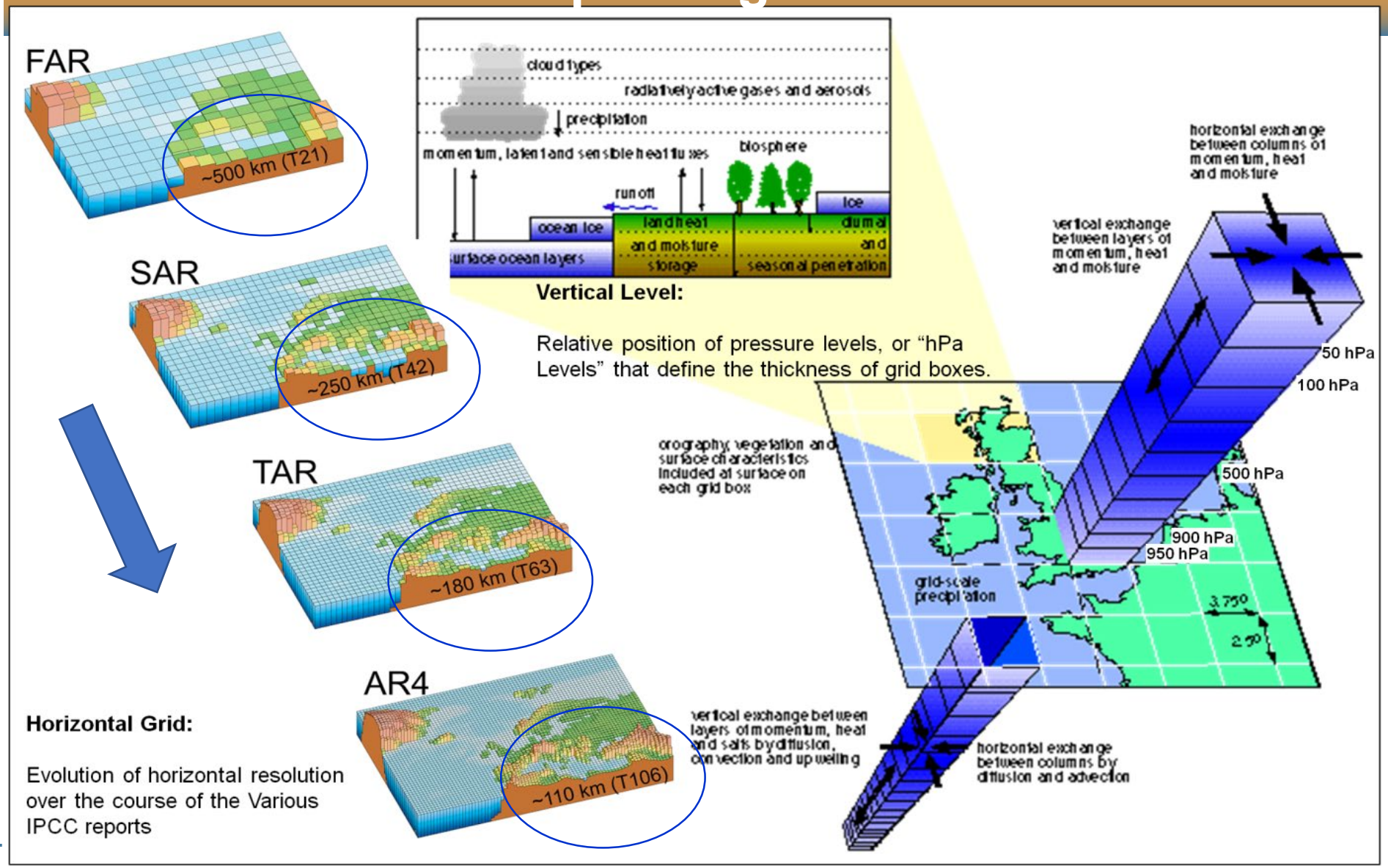
SAR 1995

TAR 2001

AR4 2007

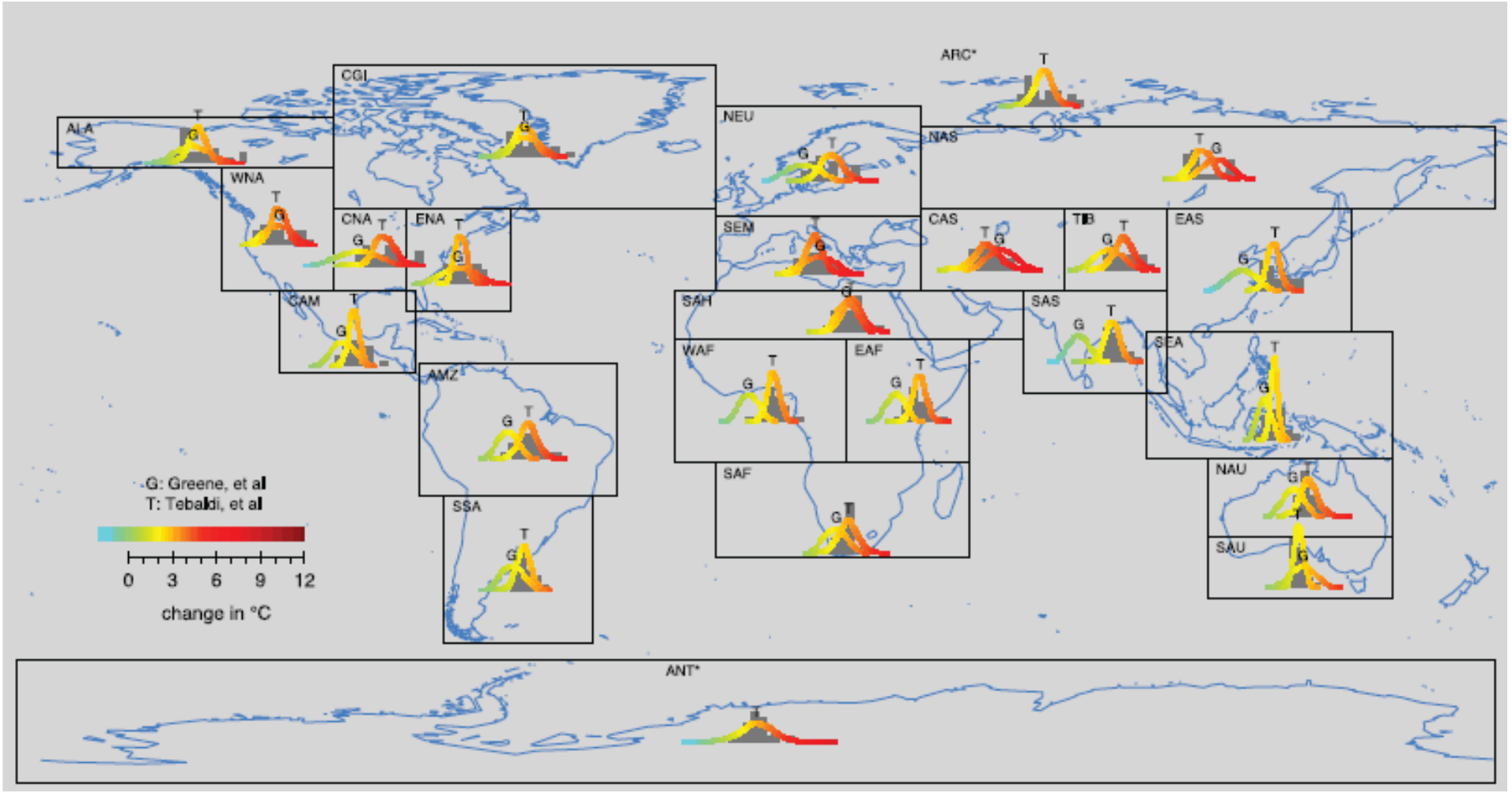
AR5 in 2014

AR6 in 2021/2022



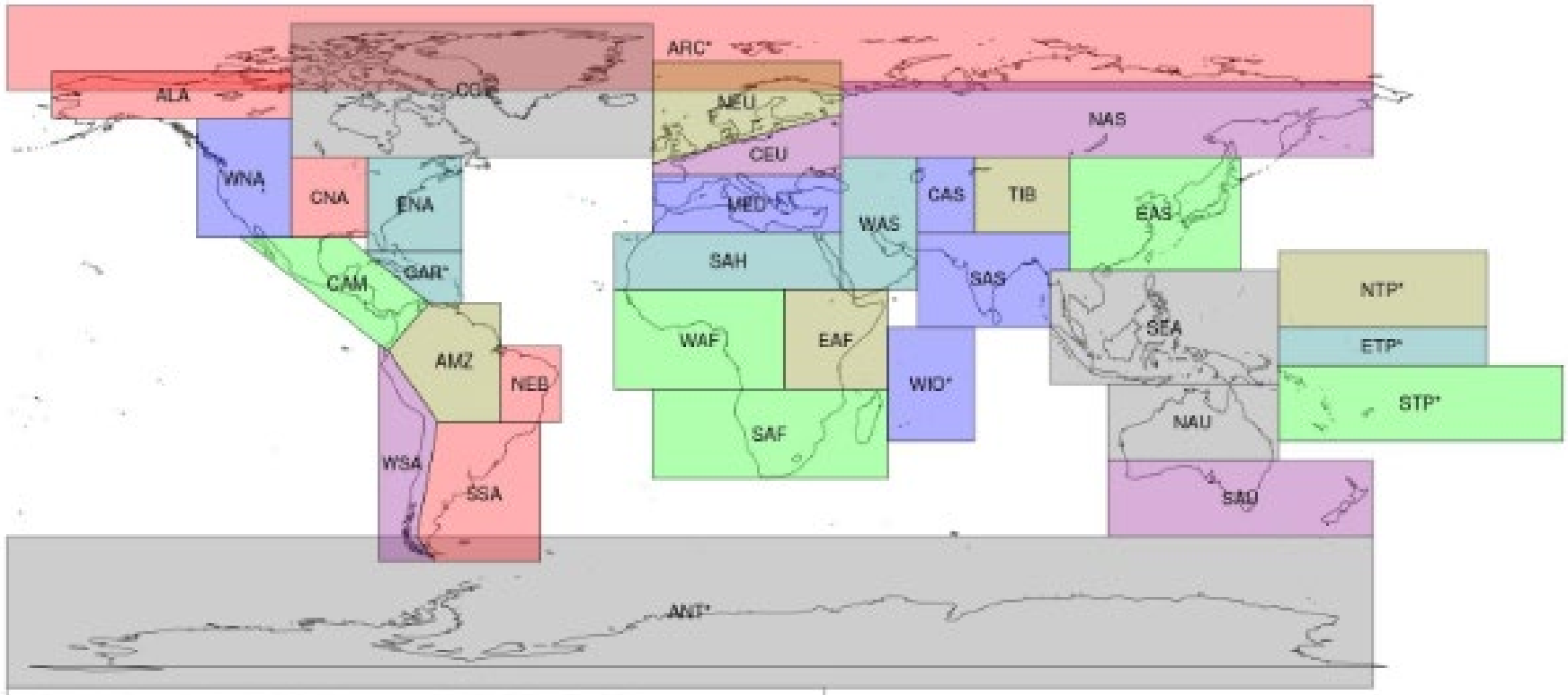
Source: IPCC, 2007; Met Office, 2011

Domain: IPCC Regional Domains (2010)



From R.K Kolli, WMO
RICCAR EGM #2 (Beirut, 2010)

IPCC Regional Domains (2014)



ALA : Alaska/N.W. Canada [ALA:1]
AMZ : Amazon [AMZ:7]
CAM : Central America/Mexico [CAM:6]
CAR* : small islands regions Caribbean
CAS : Central Asia [CAS:20]
CEU : Central Europe [CEU:12]
CGI : Canada/Greenland/Iceland [CGI:2]
CNA : Central North America [CNA:4]
EAF : East Africa [EAF:16]
EAS : East Asia [EAS:22]
ENA : East North America [ENA:5]
MED : South Europe/Mediterranean [MED:13]
NAS : North Asia [NAS:18]
NAU : North Australia [NAU:25]
NEB : North-East Brazil [NEB:8]
NEU : North Europe [NEU:11]
SAF : Southern Africa [SAF:17]
SAH : Sahara [SAH:14]
SAS : South Asia [SAS:23]
SAU : South Australia/New Zealand [SAU:26]
SEA : Southeast Asia [SEA:24]
SSA : Southeastern South America [SSA:10]
TIB : Tibetan Plateau [TIB:21]
WAF : West Africa [WAF:15]
WAS : West Asia [WAS:19]
WNA : West North America [WNA:3]
WSA : West Coast South America [WSA:9]
ANT* : Antarctica
ARC* : Arctic
NTP* : Pacific Islands region[2]
STP* : Southern Topical Pacific
ETP* : Pacific Islands region[3]
WIO* : West Indian Ocean

Spatial boundaries of the geographical regions used in the IPCC 5th Assessment Report (AR5) (2014)

http://www.ipcc-data.org/guidelines/pages/ar5_regions.html

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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.

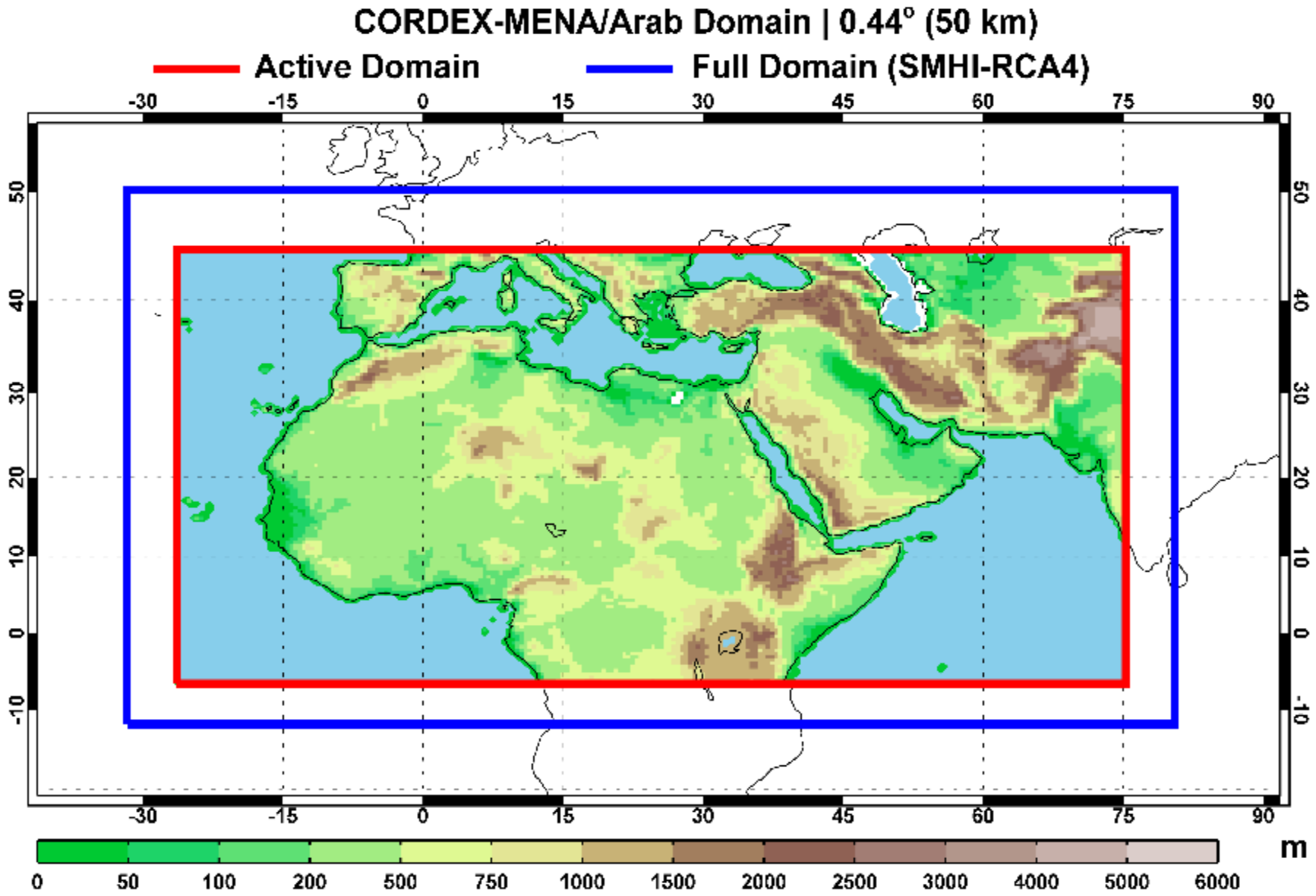
Attending or Interested Centers:

- King Abdulaziz University (KAU) - KSA
- King Abdullah University of Science and Technology (KAUST) - KSA
- Istanbul Technical University (Turkey)
- Bogazici University (Turkey)
- Cairo University
- Jet Propulsion Laboratory (USA)
- Max Plank Institute for Chemistry (Germany)
- Italian Aerospace Research Center (CIRA)
- Qatar Meteorology Department

- SMHI
- ACSAD
- Maroc Meteo
- The Cyprus Institute
- WMO
- ESCWA

CORDEX is the Coordinated Regional Climate Downscaling Experiment of the World Climate Research Program

MENA/Arab Domain (2013)



Boundary conditions explicitly framed to capture the climate change dynamics affecting the headwaters of the **Tigris, Euphrates and Nile Basins**

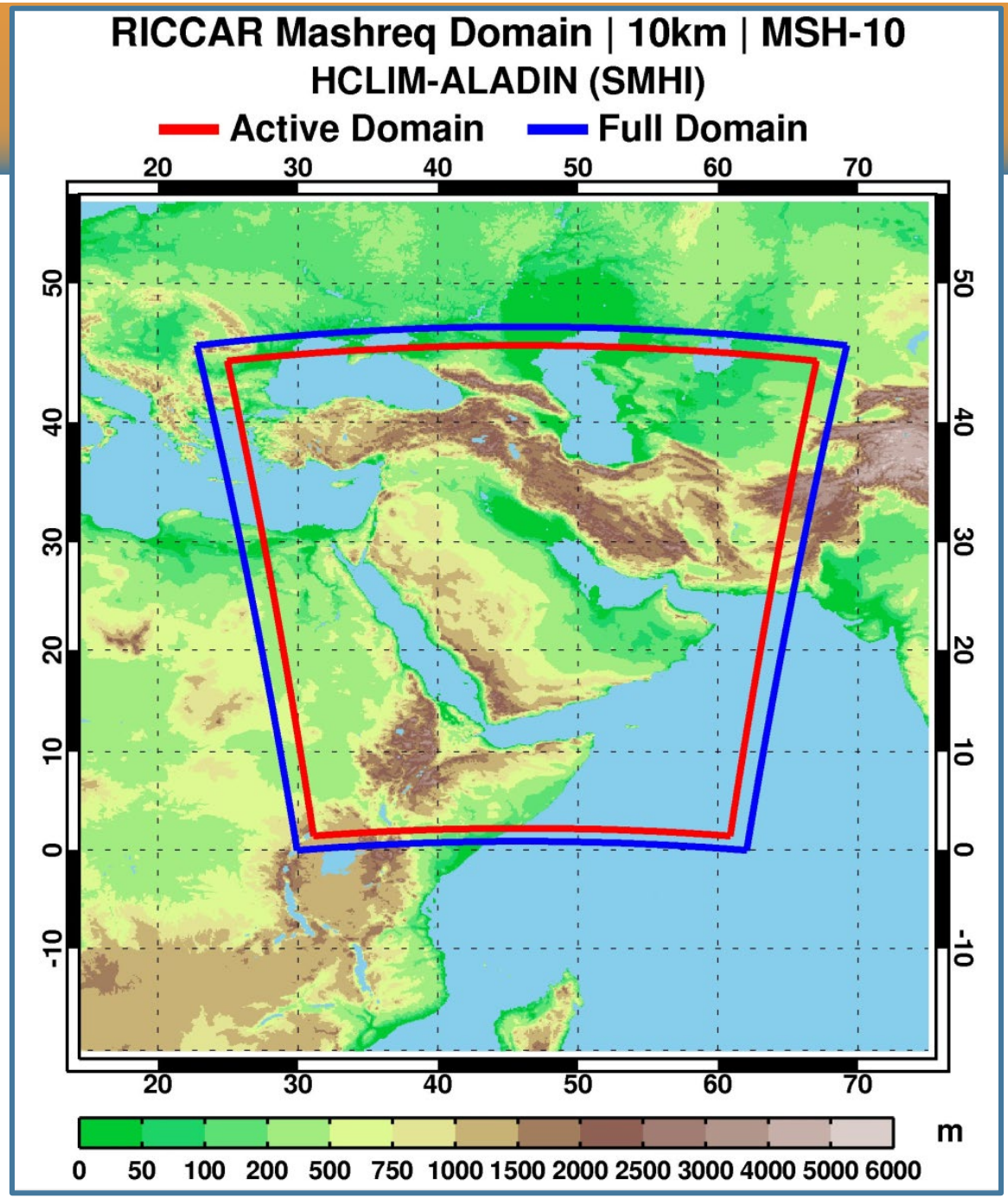
Mashreq Domain

MENA/Arab Domain
Regional Climate Modeling Projections available at 50x50 km & 25x25 km

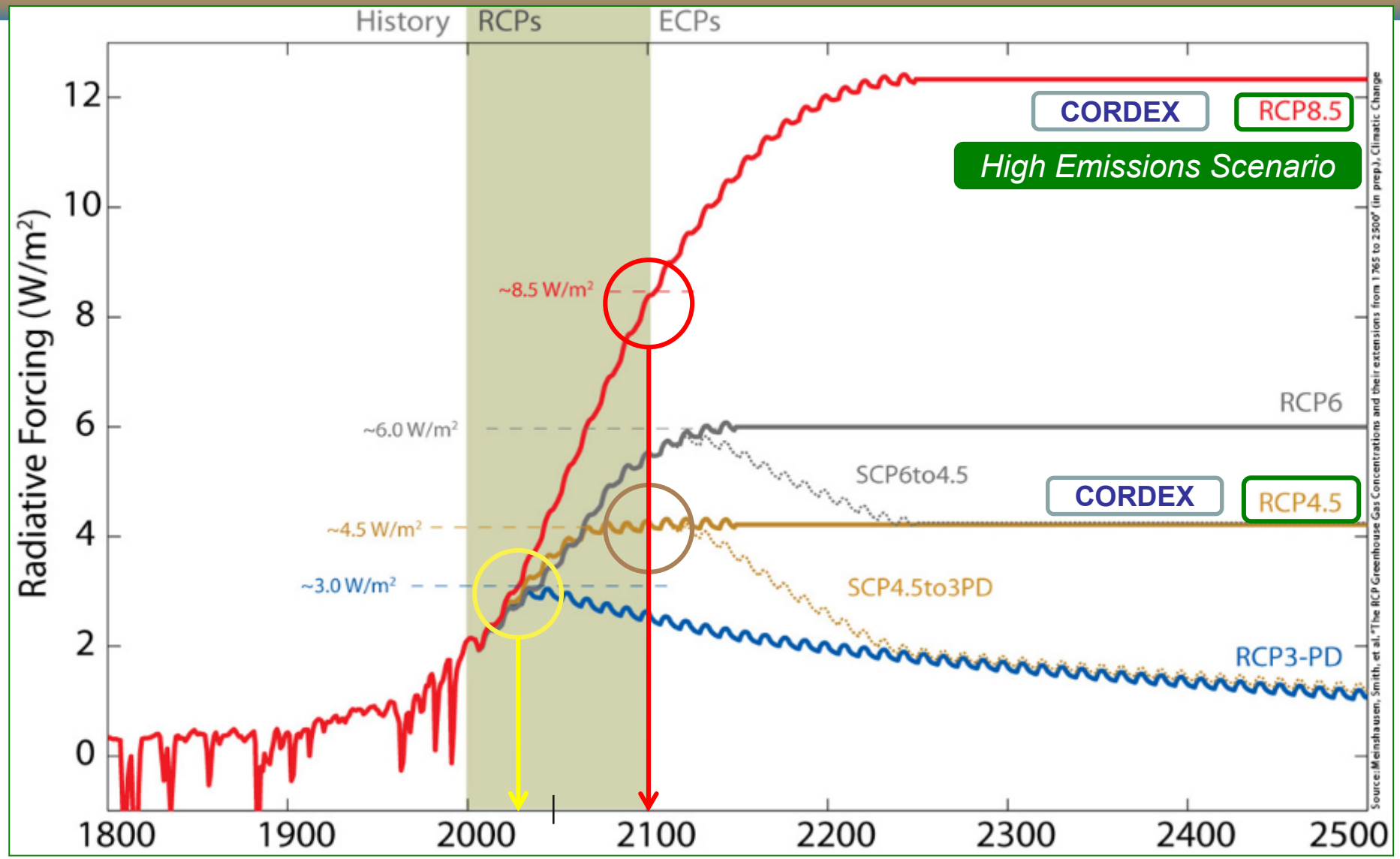
New!

Mashreq Domain
being generated at 10 x 10 km

Usable data is area within the red boundary



Representative Concentration Pathways (RCPs)
Scenarios used in IPCC AR5



Graph adapted from: Meinshausen et al.,2010

Regional Climate Modeling & Hydrological Modeling under RICCAR

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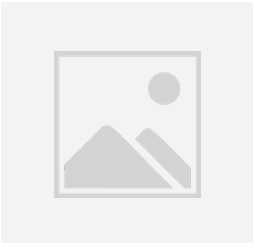
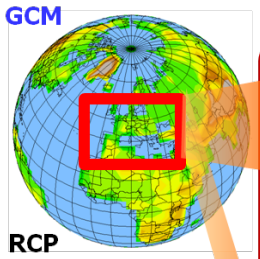
GCM ensembles used by IPCC

Different GCMs



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

General Circulation Model GCM)

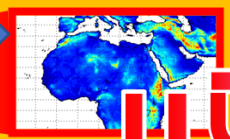


GCMs at
300 km x 300 km

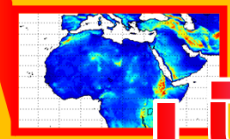
Ensemble Average used to reduce uncertainty at level of RCMs & RHMs

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

Regional Climate Model (RCM)

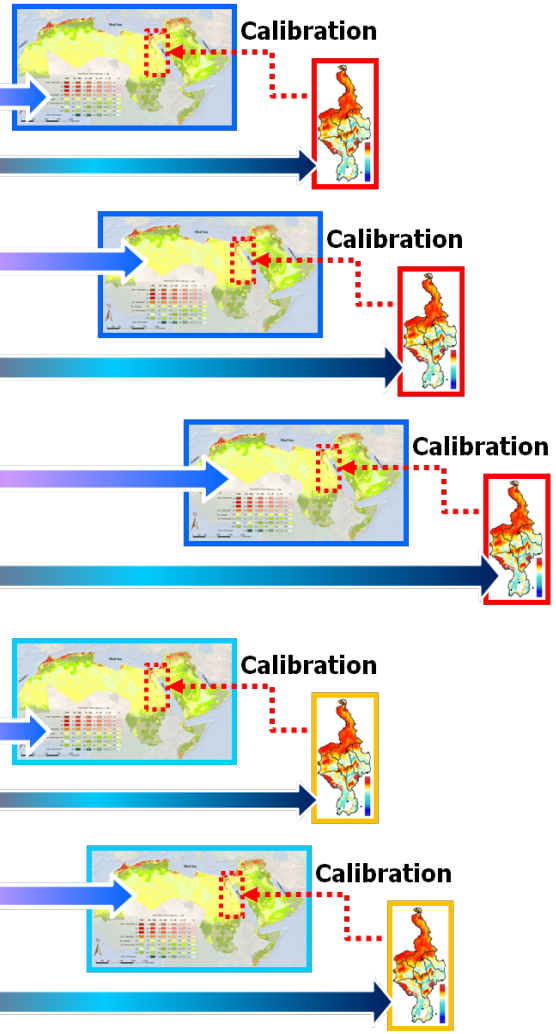


50km x 50km



25km x 25km

Regional Hydrological Model (RHM)



Extreme Climate Events

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RICCAR Impact Assessment: Selected Results

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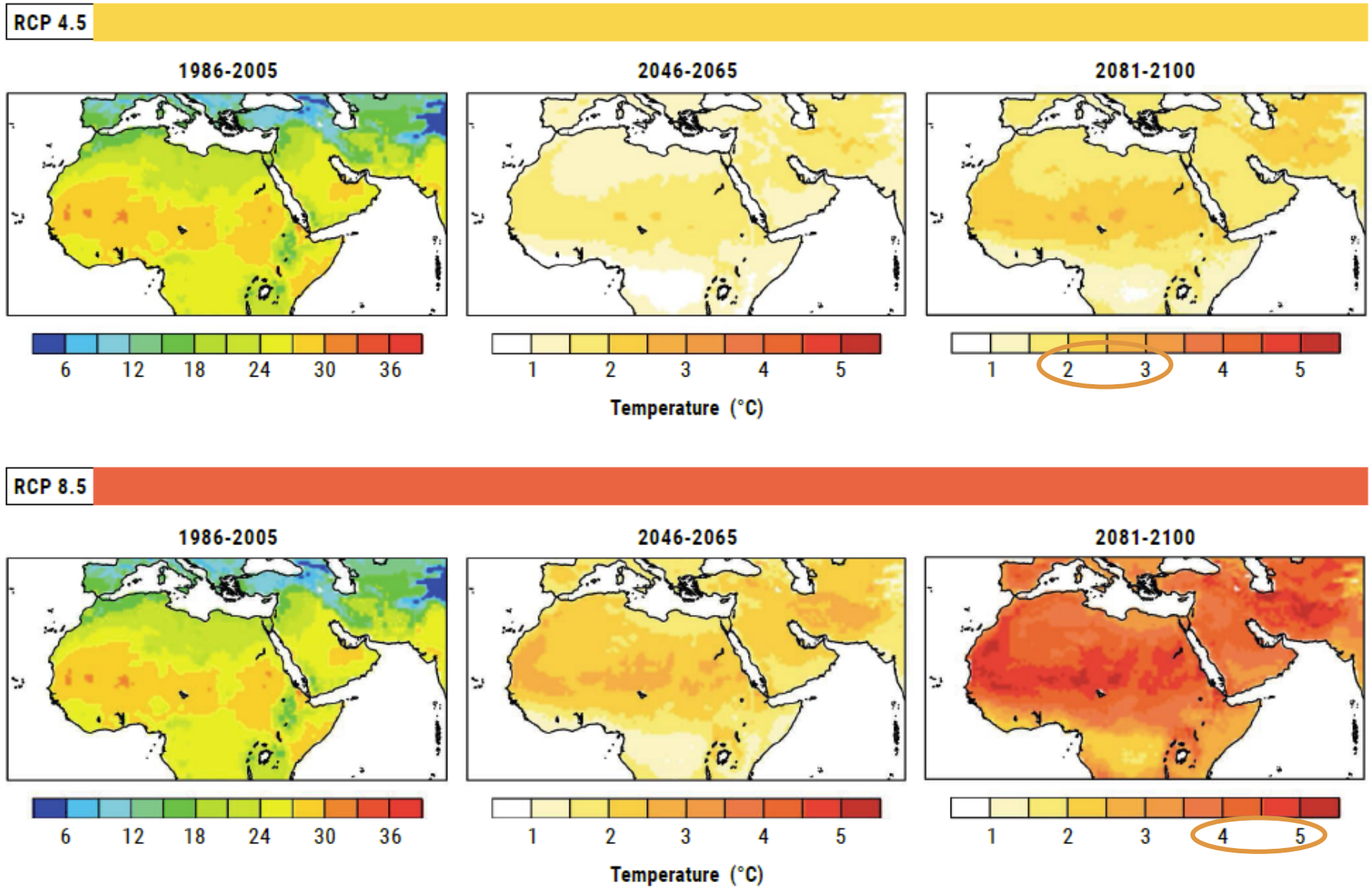
Temperature in the region is increasing and is expected to continue to increase until the end of the century.



Temperature Ensembles through a Seasonal Lens

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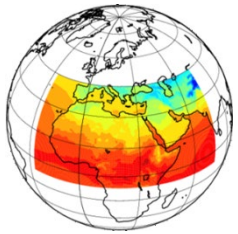
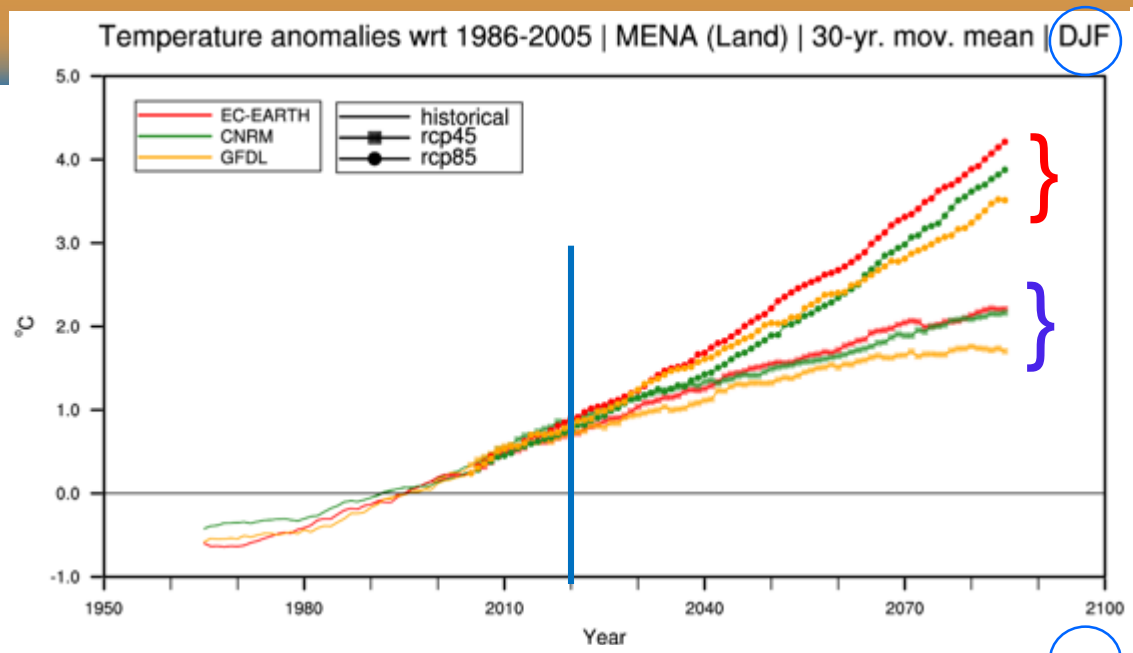


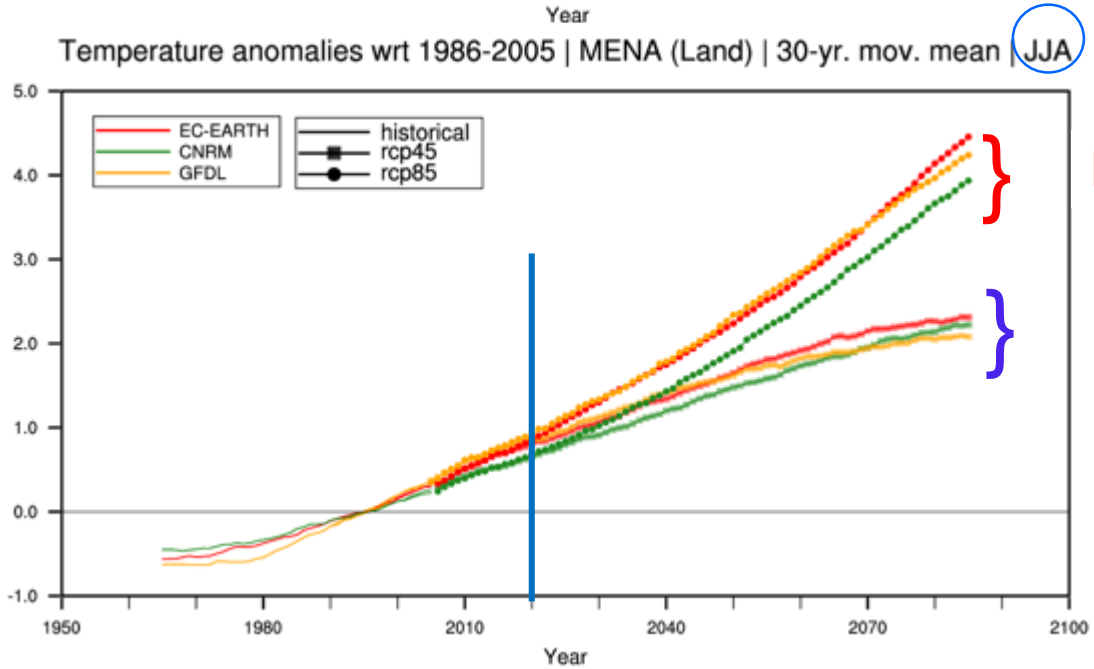
Winter



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

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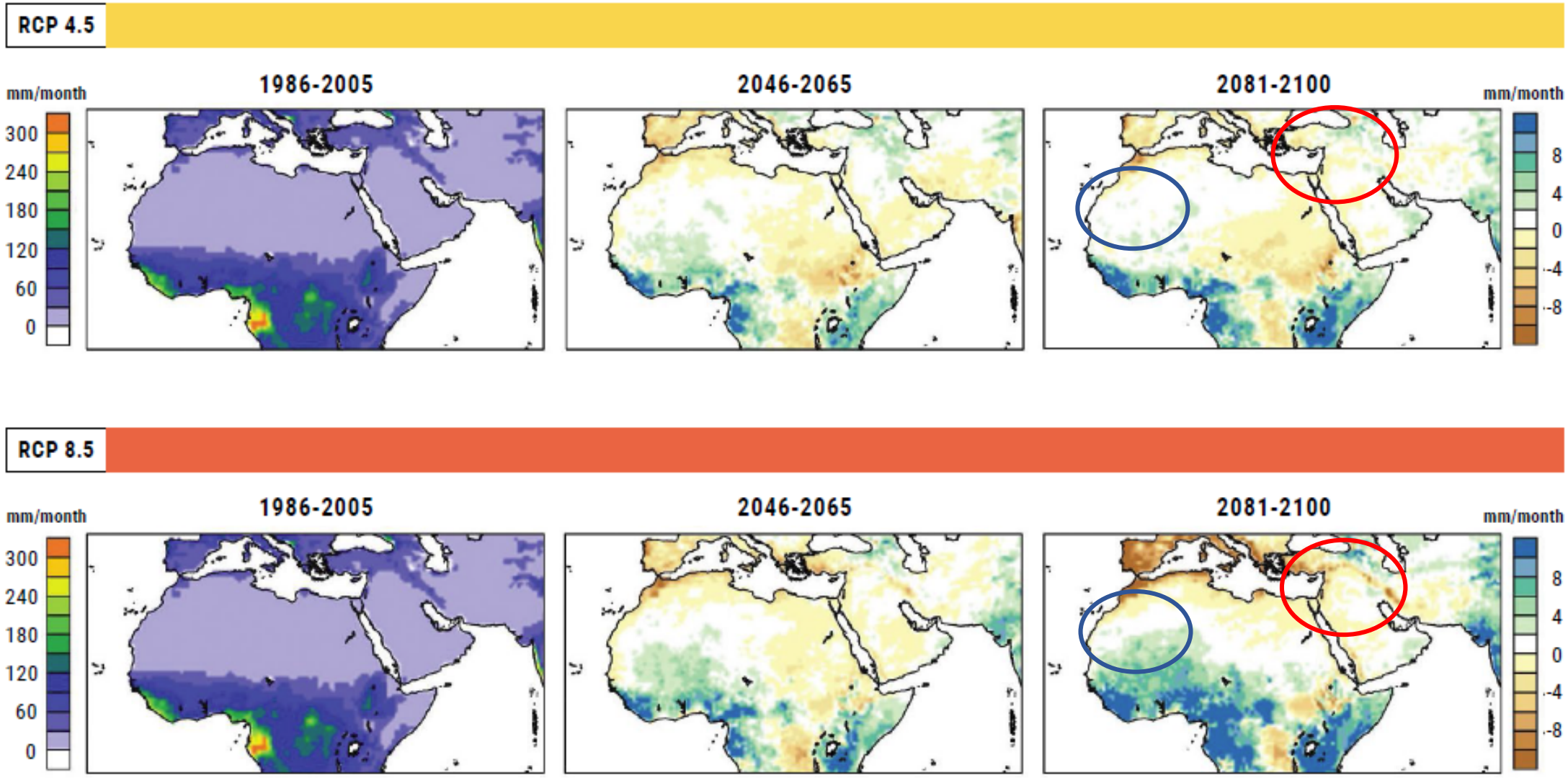
Precipitation trends are largely decreasing across the region until the end of the century, though limited areas expected to exhibit an increase in the intensity & volume of precipitation.



From RICCAR RCM ensemble outputs

Extreme events indices

Extreme temperature indices		Extreme precipitation indices	
Index	**Full name**	**Index**	**Full name**
SU	Number of summer days	CDD	Maximum length of dry spell
SU35	Number of hot days	CWD	Maximum length of wet spell
SU40	Number of very hot days	R10	Annual count of 10 mm precipitation days
TR	Number of tropical nights	R20	Annual count of 20 mm precipitation days
		SDII	Simple precipitation intensity index

Maximum length of dry spell (CDD)

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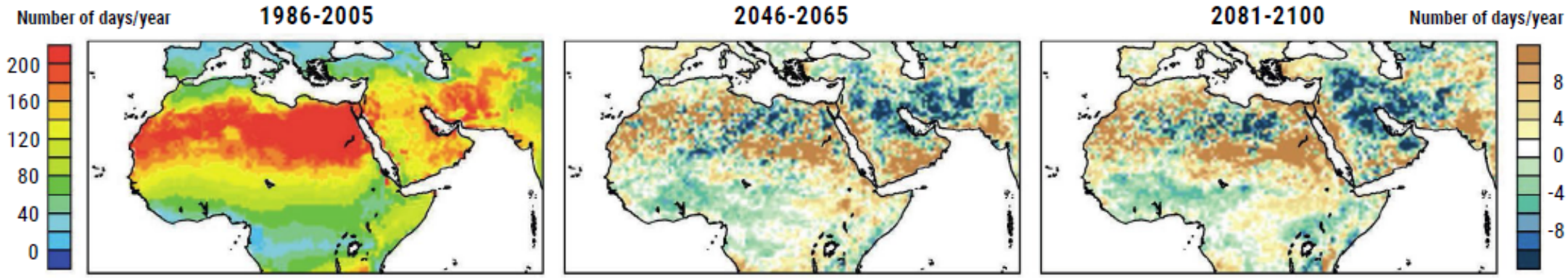
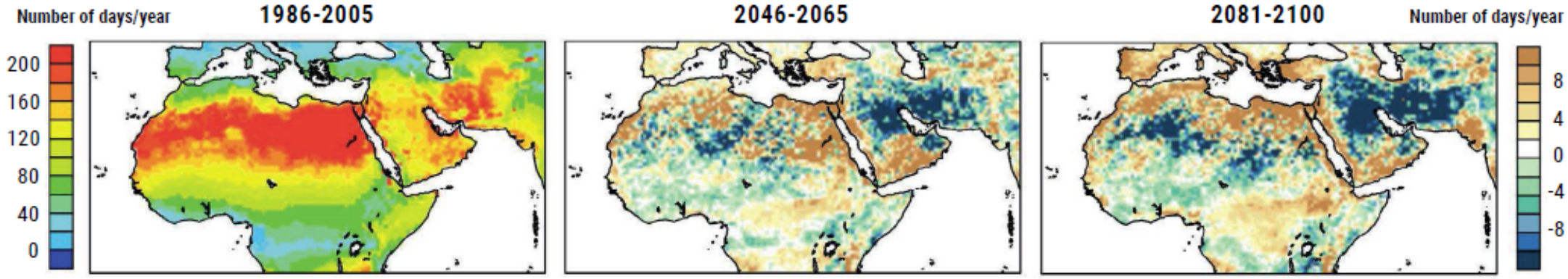
RCP 4.5



RCP 8.5



Regional Climate Modeling to Hydrological Modeling

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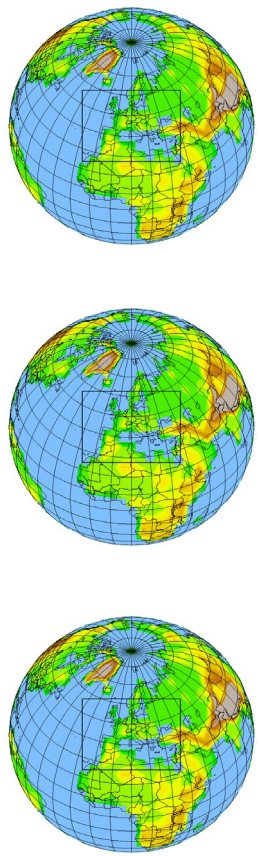
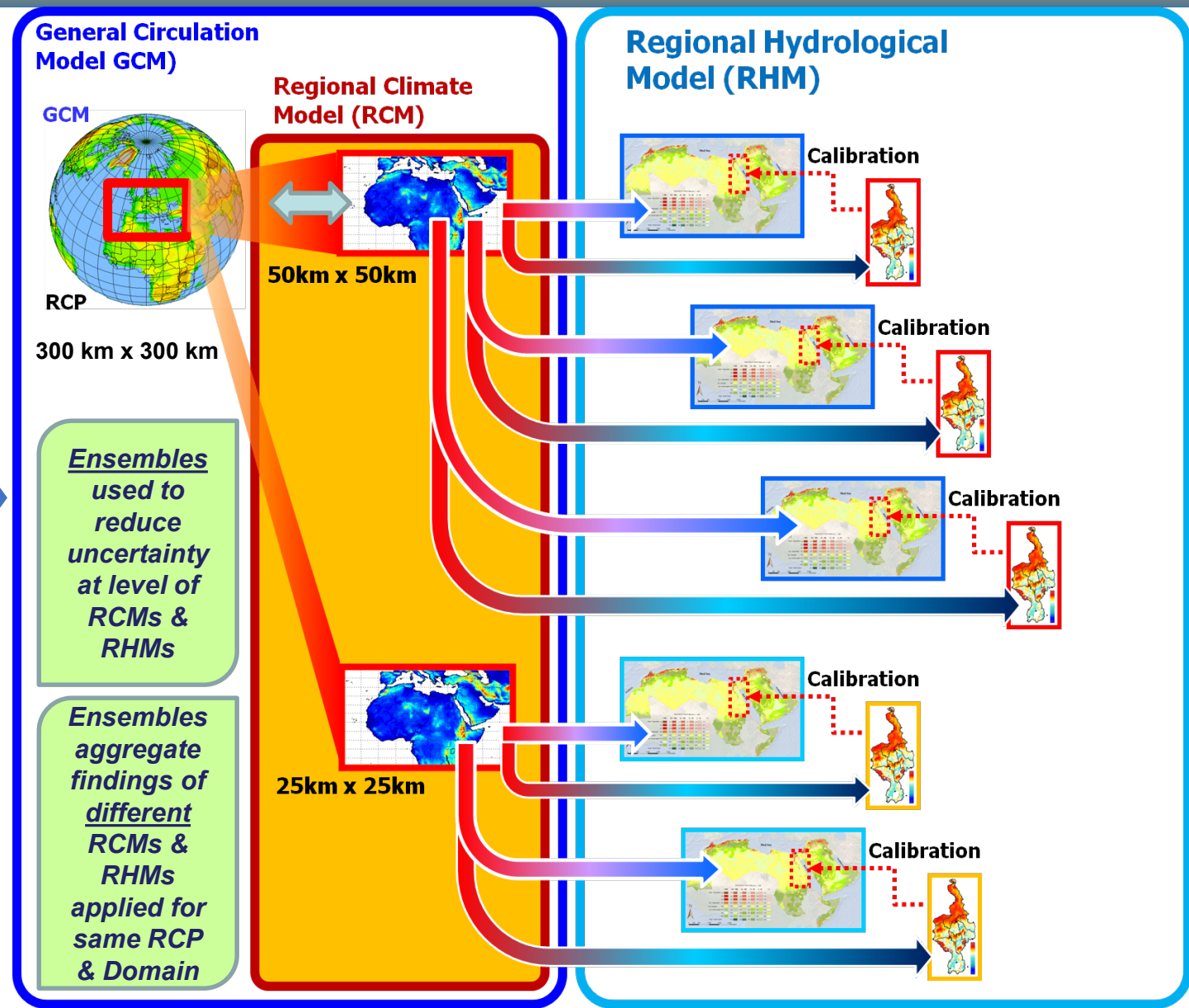
Bias Correction **of RCM Projections needed before data can be used for water & agricultural modeling**

Different GCMs



Same RCP



VIC
HYPE
HEC-HMS
Models Used

Mean change in Annual Runoff

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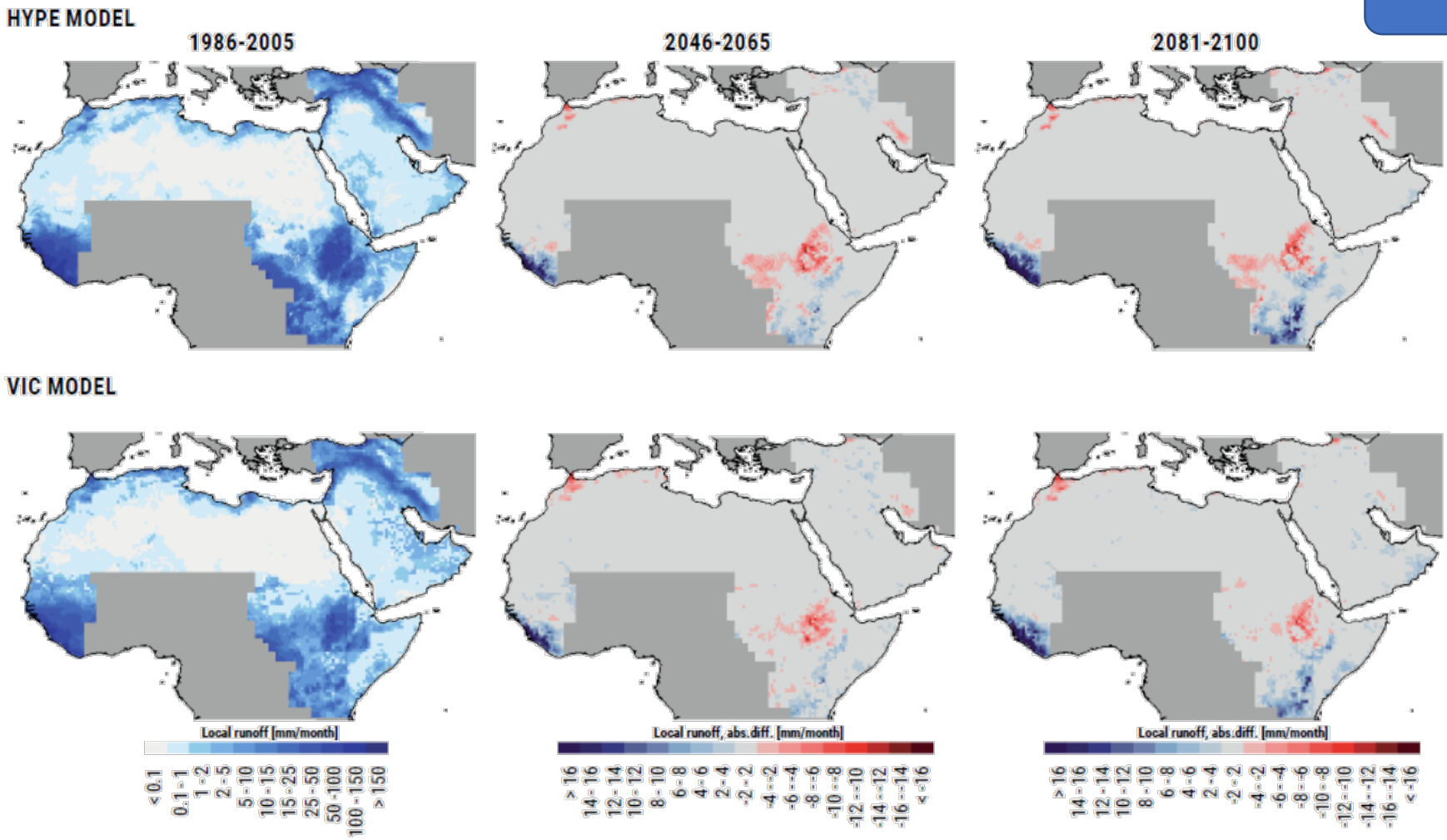
RCP 4.5

2 Models; 2 RCPs



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

Mean change in Annual Runoff

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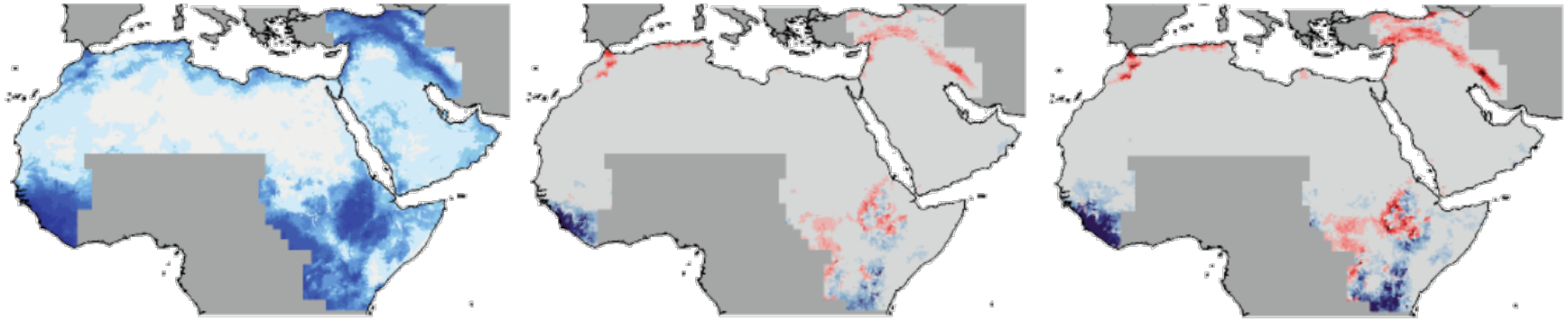
2 Models; 2 RCPs

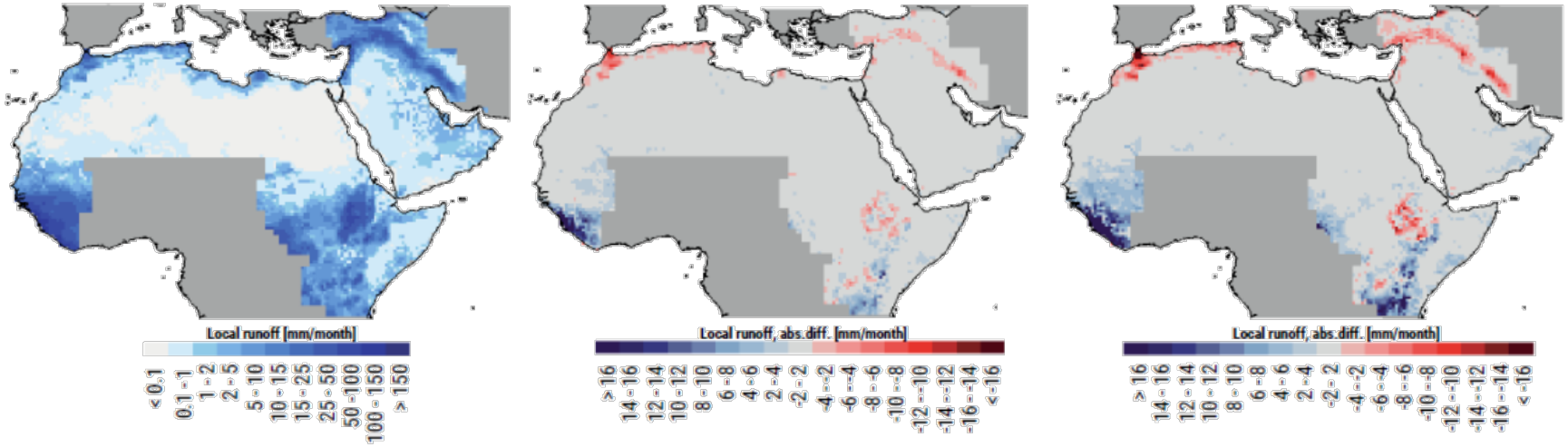
RCP 8.5

HYPE MODEL

1986-2005 | 2046-2065 | 2081-2100



VIC MODEL



Mean change in Annual Evapotranspiration

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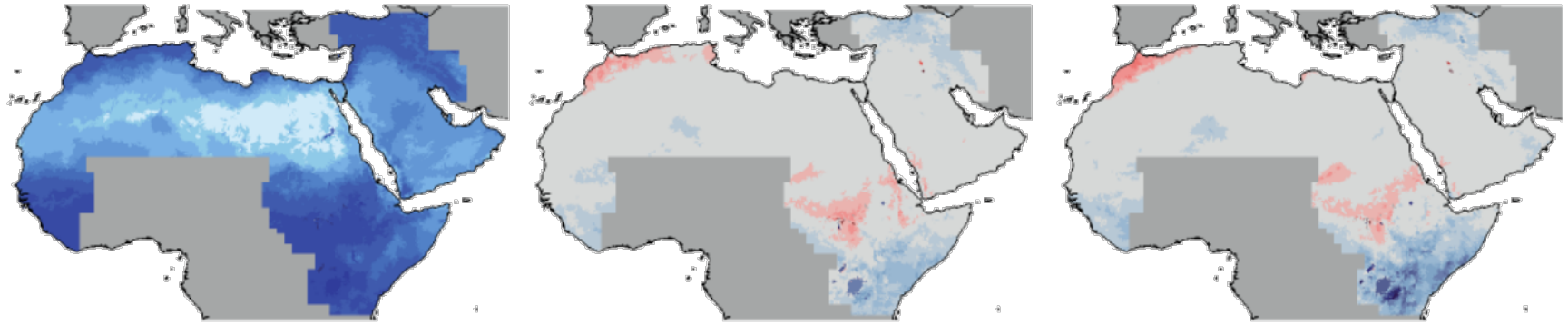
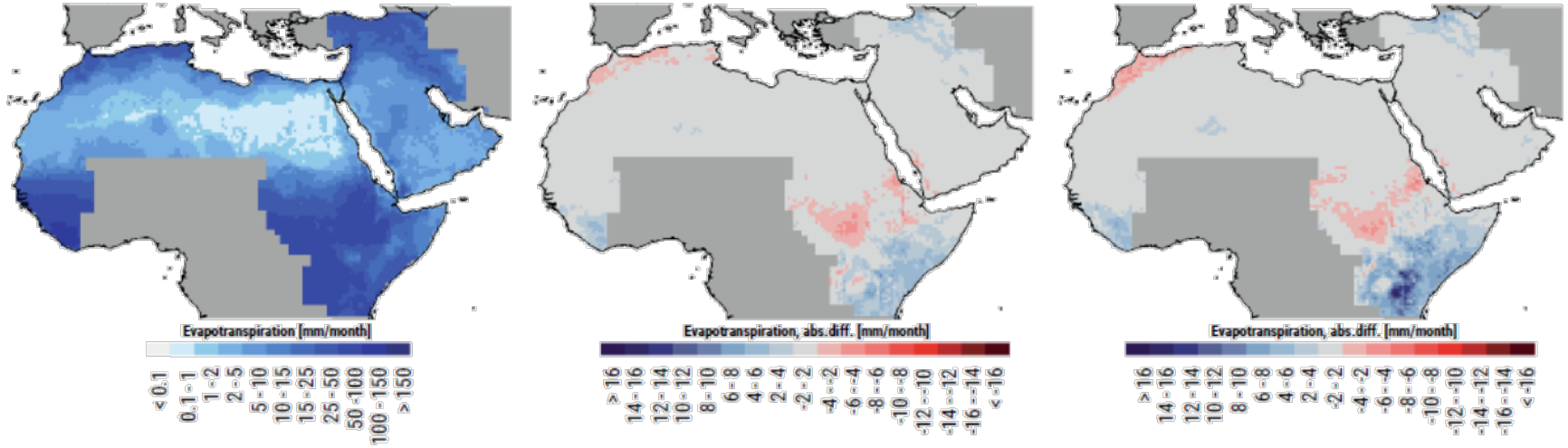
RCP 4.5

HYPE MODEL

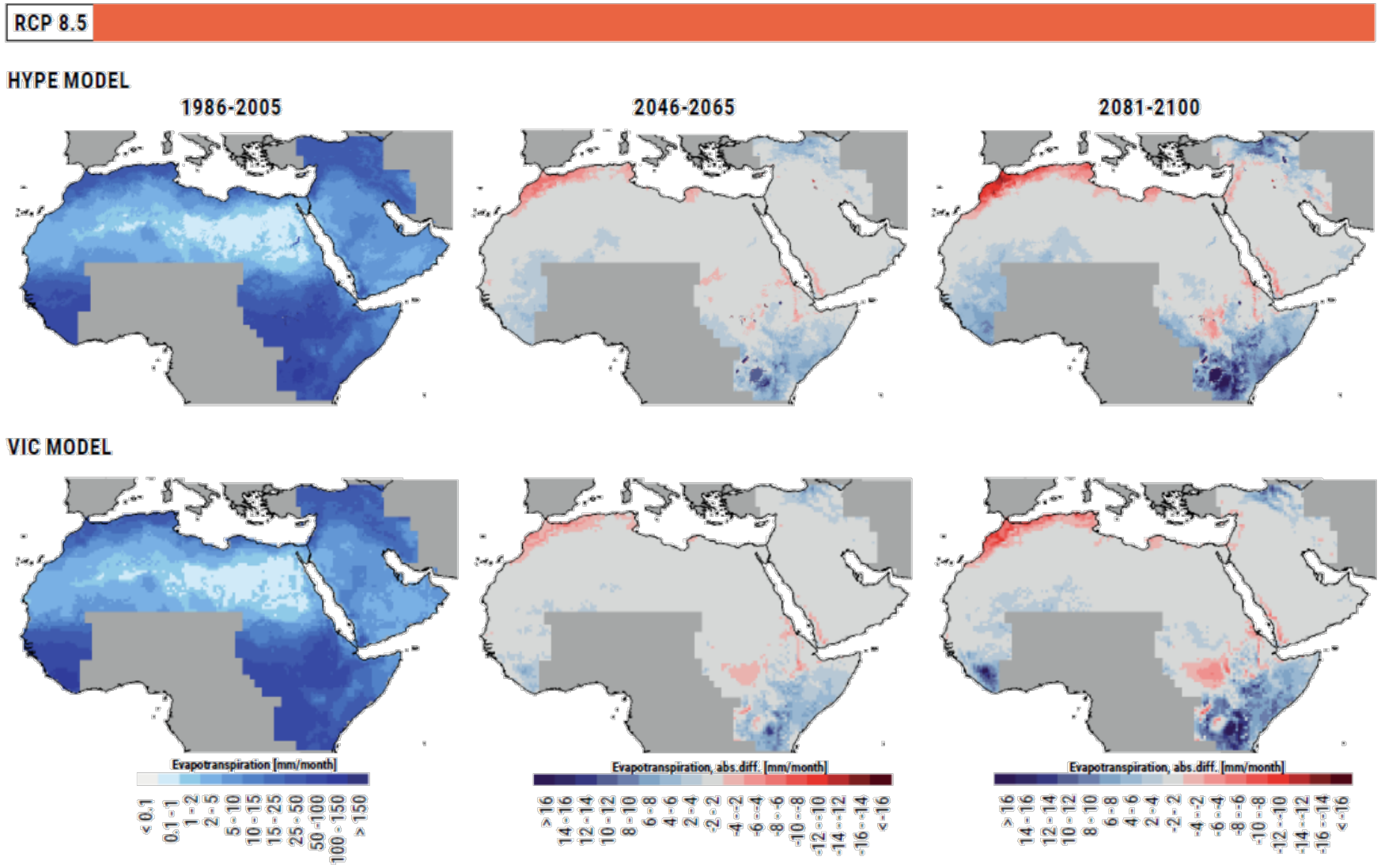
1986-2005 | 2046-2065 | 2081-2100



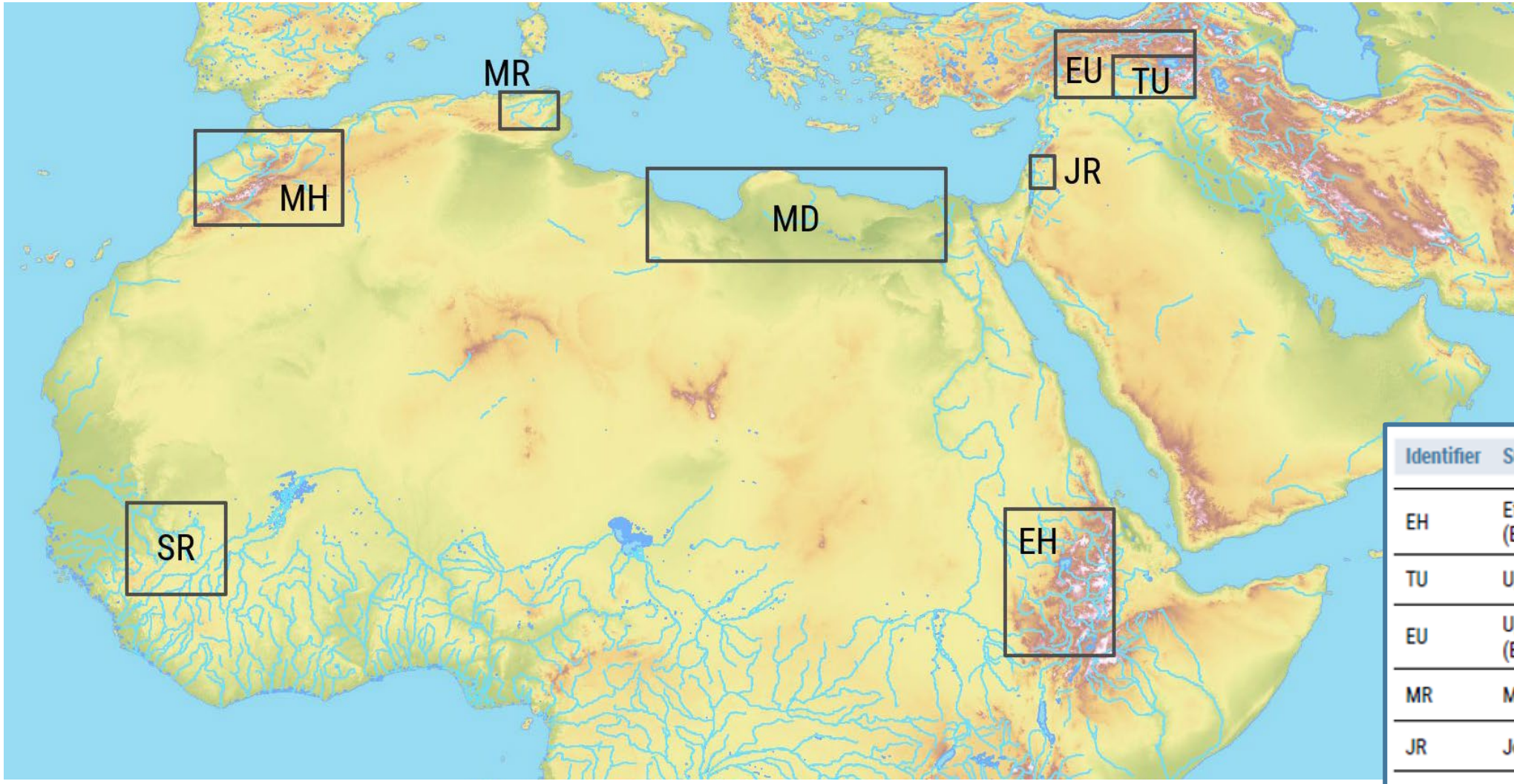
VIC MODEL



Mean change in Annual Evapotranspiration



Locations of subdomains identified for hydrological analysis



*See RICCAR Main Report, **Technical Annex** and Regional Knowledge Hub*

Identifier	Subdomain Name
EH	Ethiopian Highlands (Blue Nile Headwaters)
TU	Upper Tigris (Tigris River Headwaters)
EU	Upper Euphrates (Euphrates River Headwaters)
MR	Medjerda River
JR	Jordan River
SR	Senegal River Headwaters

Climate Impacts on Transboundary Water Resources: Euphrates River

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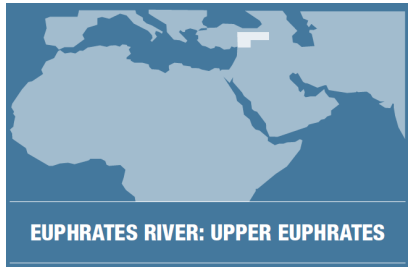


FIGURE 140
Mean change in annual temperature over time for ensemble of three RCP 4.5 and RCP 8.5 projections

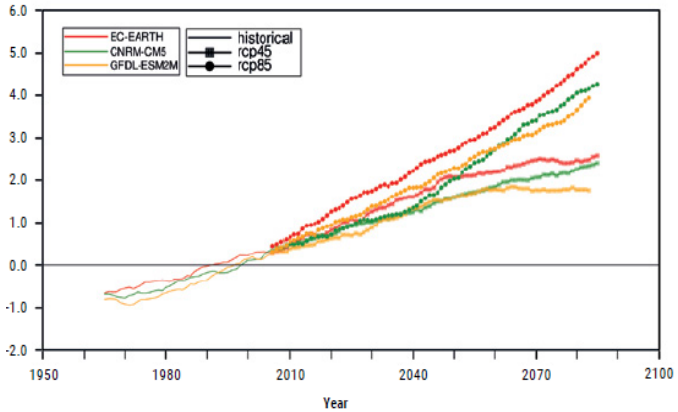
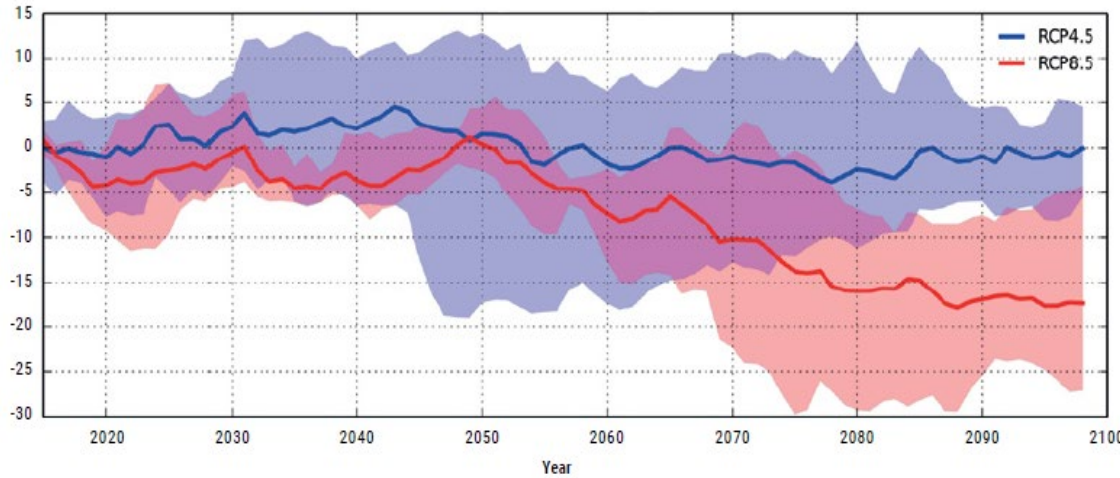
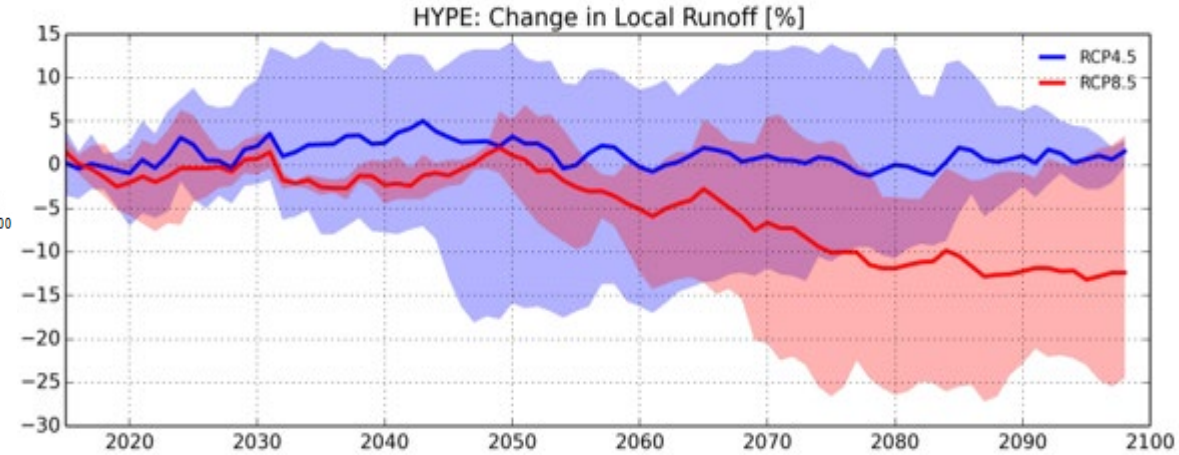


FIGURE 160
Mean change in annual discharge over time for ensemble of three RCP 4.5 and RCP 8.5 projections using HYPE model





Upper Euphrates River

(1986-2005) : (2081-2100)

Variable	RCP4.5	RCP8.5
Temp.	2.3°C	4.8°C
Precip.	3%	0%
Runoff	-2%	-12%

Climate Impacts on Transboundary Water Resources: Upper Tigris

Upper Tigris River:
Seasonal Temperature
(*RCM output*)

FIGURE 111
Mean change in seasonal temperature (April-September) over time for ensemble of three RCP 4.5 and RCP 8.5 projections

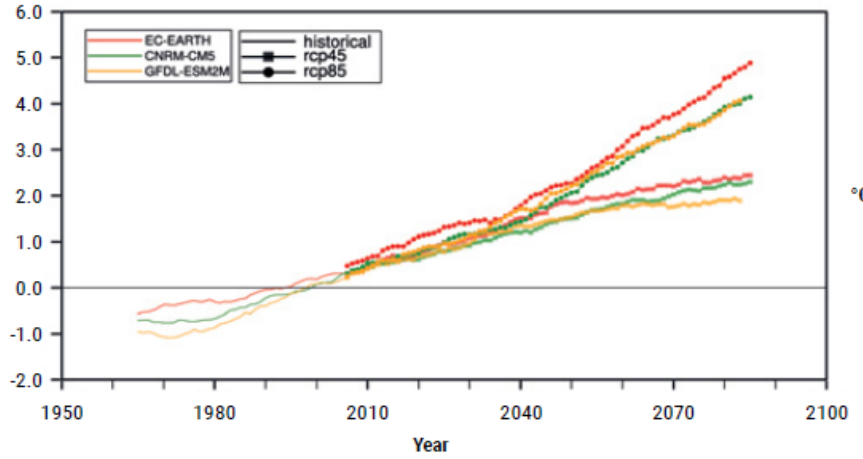
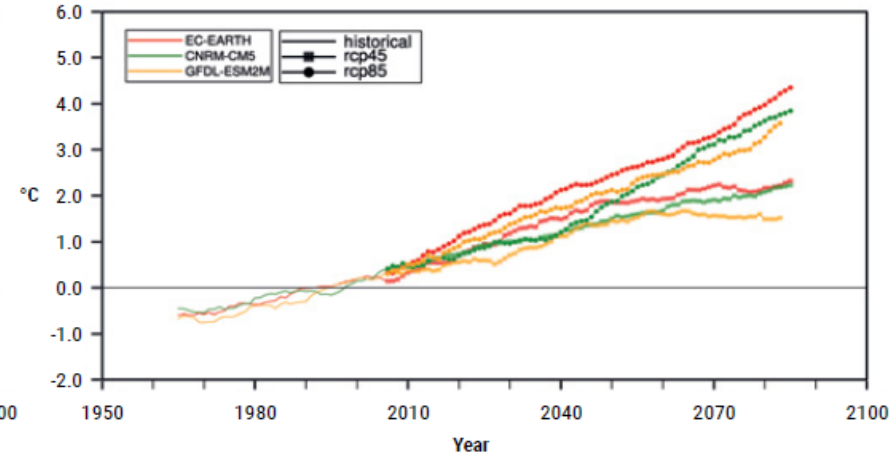


FIGURE 112
Mean change in seasonal temperature (October-March) over time for ensemble of three RCP 4.5 and RCP 8.5 projections



Upper Tigris River:
Extreme Climate Indicators:
Consecutive Dry Days
Consecutive Wet Days
(*RCM output*)

FIGURE 123
Mean change in CDD over time for ensemble of three RCP 4.5 and RCP 8.5 projections

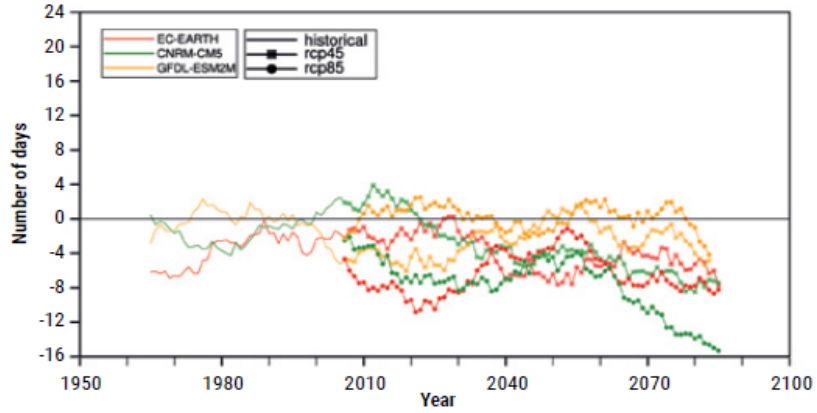
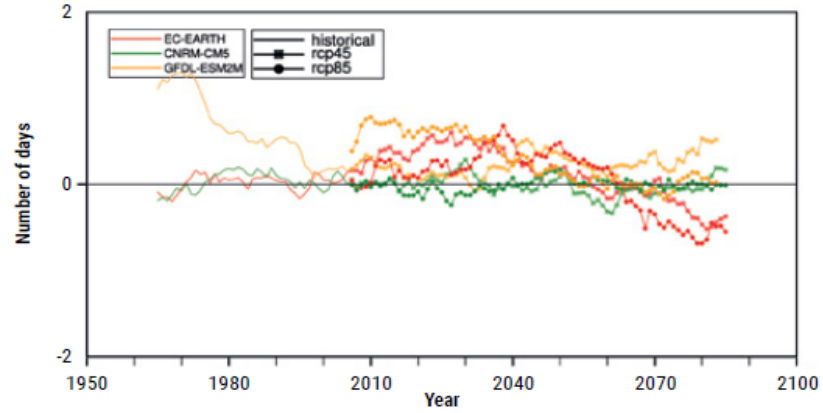


FIGURE 124
Mean change in CWD over time for ensemble of three RCP 4.5 and RCP 8.5 projections



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

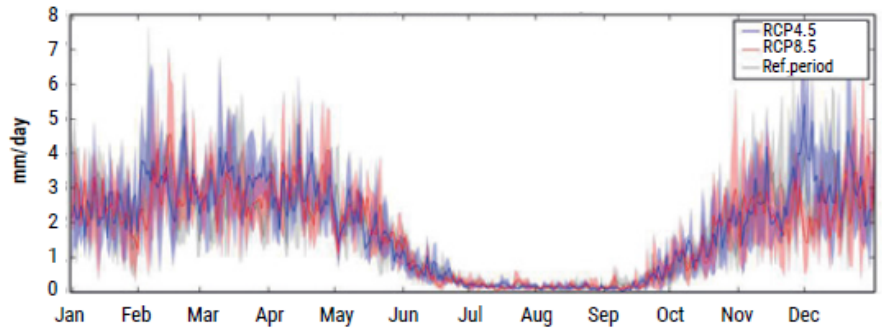
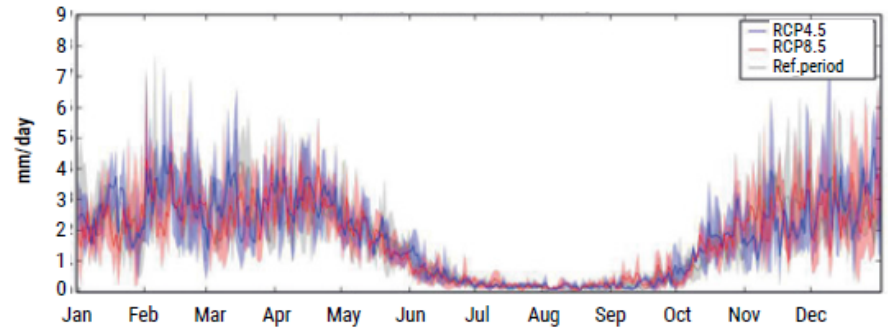
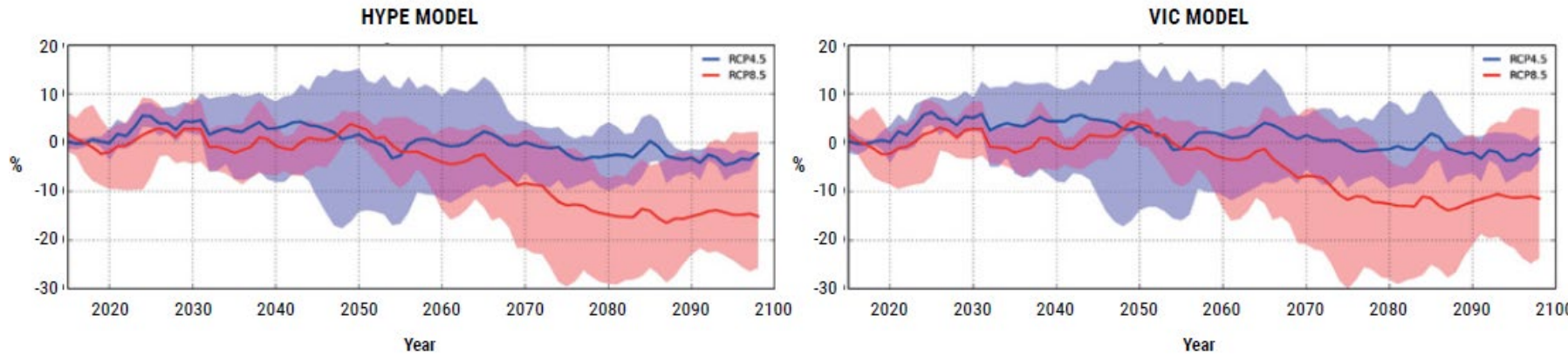


FIGURE 119
Mean change in monthly precipitation for end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period



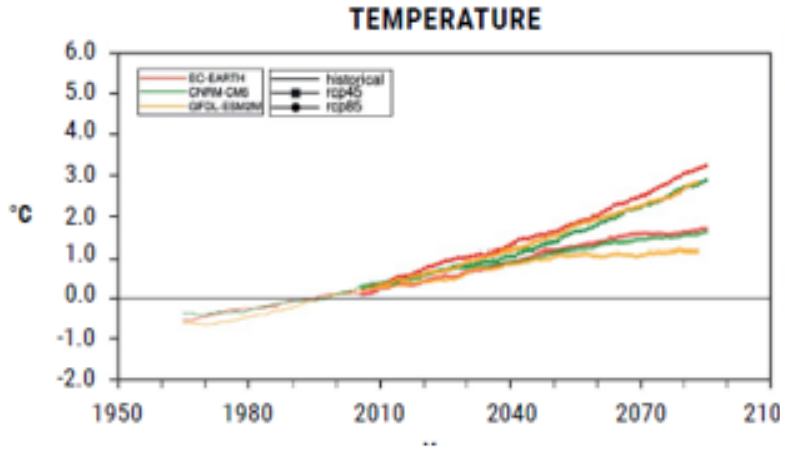
Upper Tigris River:
Runoff
(*RHM output*)

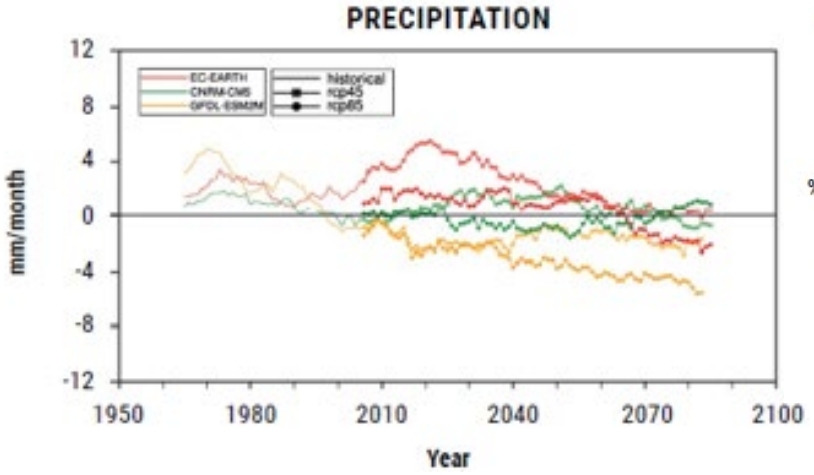
FIGURE 127
Mean change in annual runoff over time for ensemble of three RCP 4.5 and RCP 8.5 projections using two hydrological models

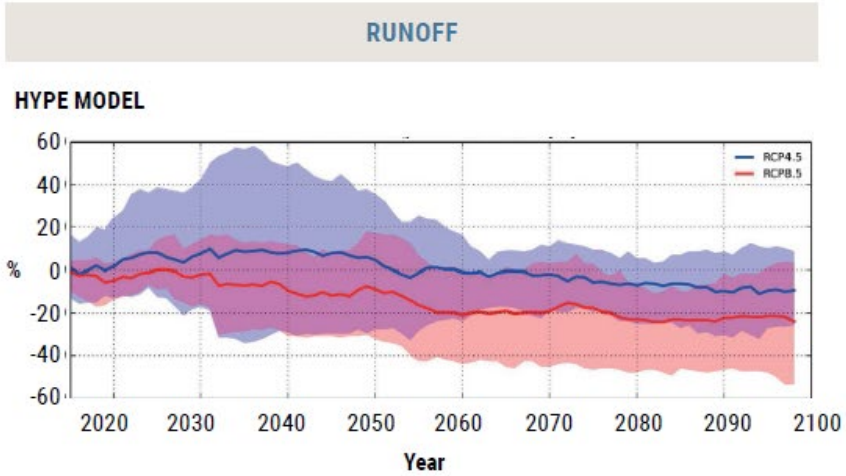


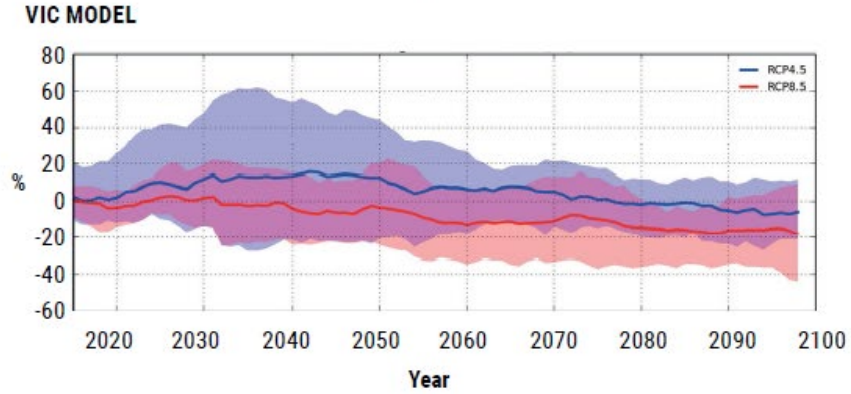
Climate Impacts on Transboundary Water Resources: Jordan River

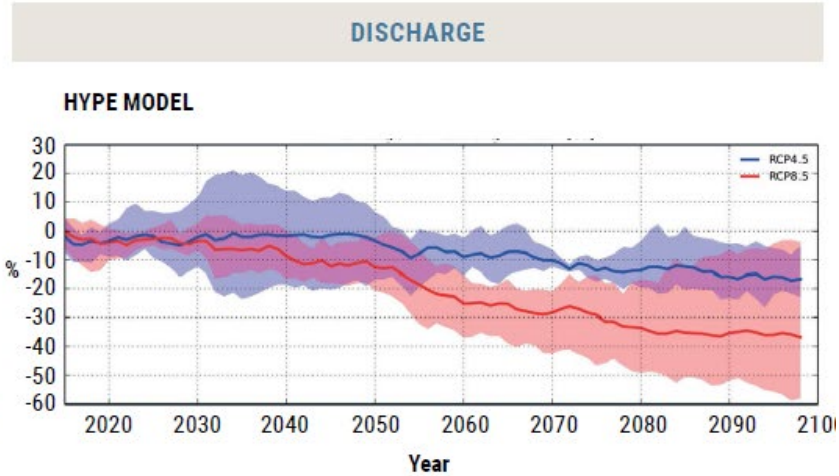
For three-member ensemble of **RCP 4.5 projections** and three-member ensemble of **RCP 8.5 projections** for the Jordan River











*New **Mashreq Domain** projections will generate a 6-member ensemble for RCP 8.5 and support further surface & groundwater analysis*

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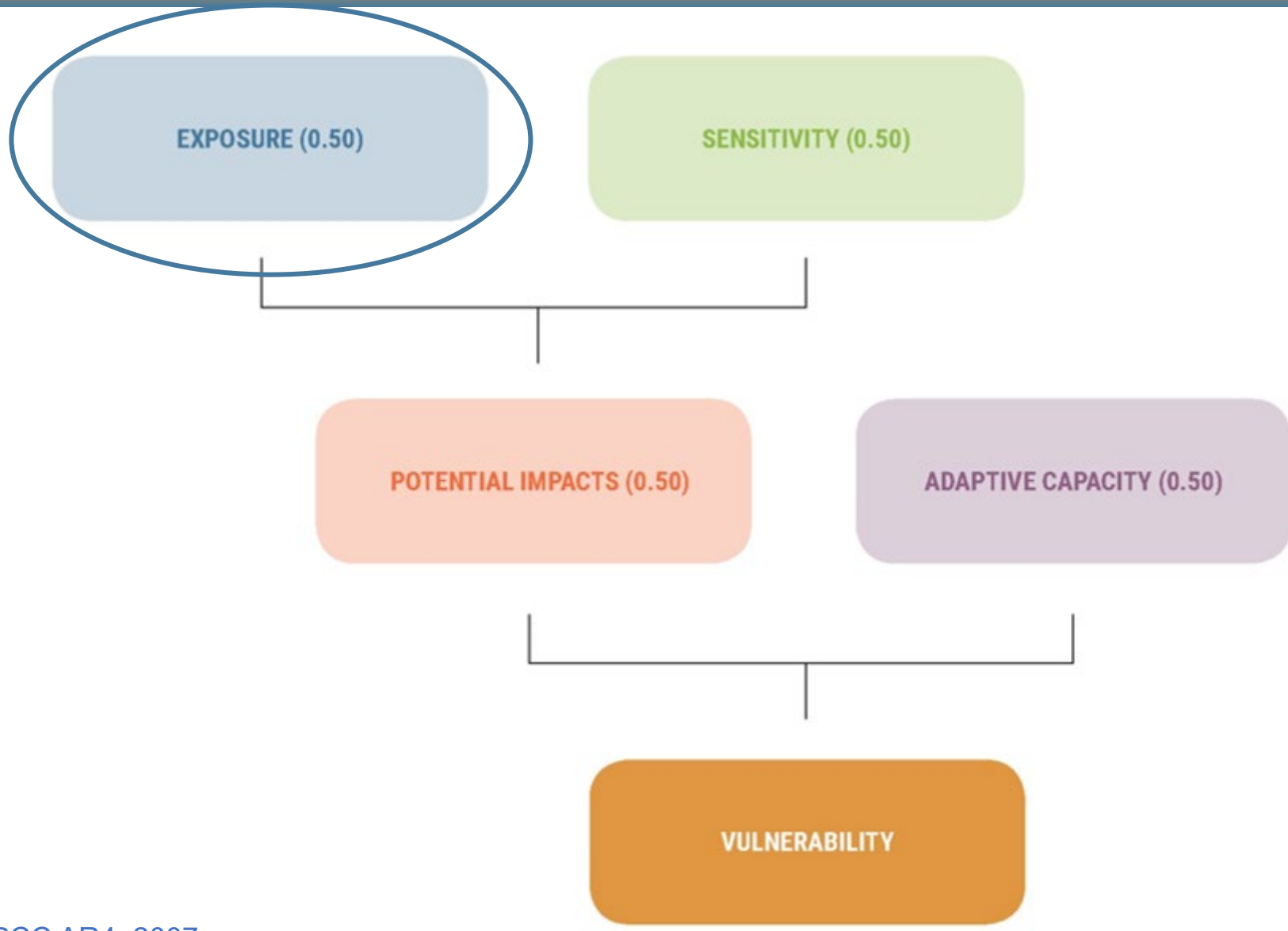
Integrated Vulnerability Assessment: Selected Results

RICCAR Vulnerability Assessment Components



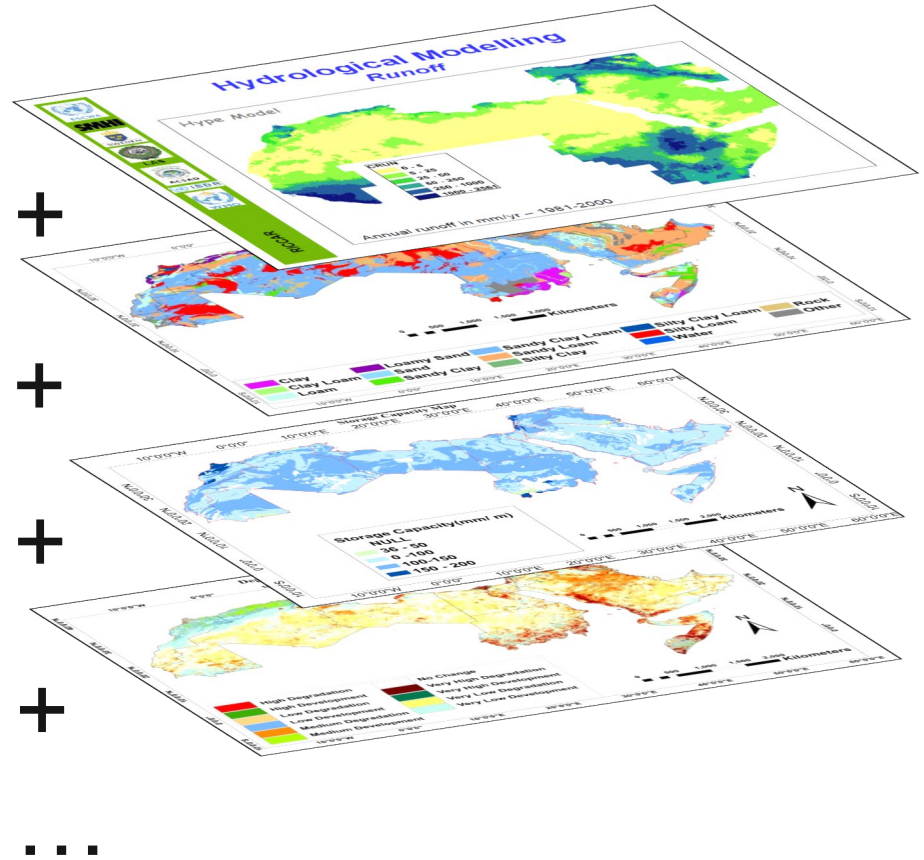
RICCAR, based on IPCC AR4, 2007

Overall Vulnerability

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



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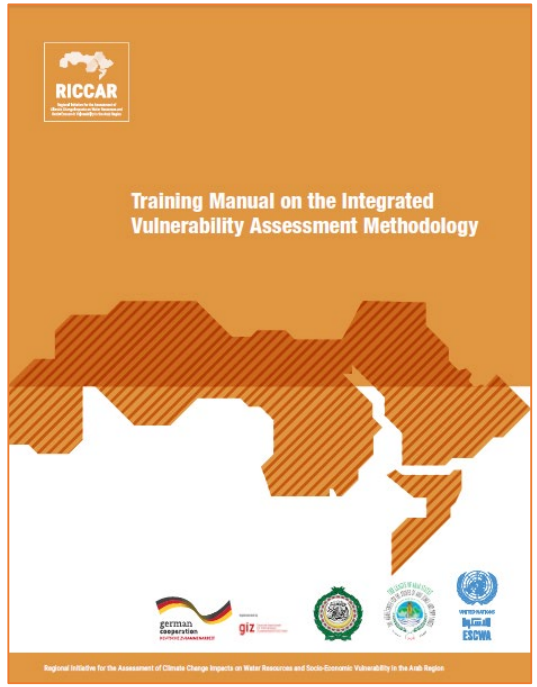
Slide graphics: adelphi
Source of maps: ACSAD, SMHI

Vulnerability Assessment

SECTORS	SUBSECTORS
Water	Water availability
Biodiversity and Ecosystems	Area covered by forests Area covered by wetlands
Agriculture	Water available for crops Water available for livestock
Infrastructure and Human Settlements	Inland flooding area
People	Water available for drinking Health conditions due to heat stress Employment rate for the agricultural sector



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Vulnerability Assessment Impact Chain
Water Availability

EXPOSURE (0.50)

RCM
- Change in temperature (0.17)
- Change in precipitation (0.17)

RHM
- 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 (0.16)

6 Exposure indicators

SENSITIVITY (0.50)

POPULATION (0.50)
- Population density (0.14)
- Total renewable water available per capita (0.50)
- 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)

MANMADE (0.24)
- Urban extent (0.47)
- Areas served by dams (0.53)

10 Sensitivity indicators

POTENTIAL IMPACT (0.50)

VULNERABILITY ASSESSMENT

ADAPTIVE CAPACITY (0.50)

KNOWLEDGE & AWARENESS (0.10)
- E-Governement development (0.33)
- Tertiary enrollment (0.32)
- Adult literacy rate (0.35)

TECHNOLOGY (0.10)
- Number of scientific and technical journal articles (0.46)
- Information and communication technologies index (0.54)

INSTITUTIONS (0.10)
- Governance index (0.54)
- Disaster risk reduction committees (0.46)

INFRASTRUCTURE (0.50)

WATER & SANITATION (0.50)
- Areas served by dams (0.17)
- Installed desalination capacity per capita (0.17)
- Fossil groundwater (0.17)
- Access to improved water (0.17)
- Access to improved sanitation (0.16)
- Area equipped for irrigation (0.16)

ENVIRONMENT (0.50)
- Environment performance index (1.0)

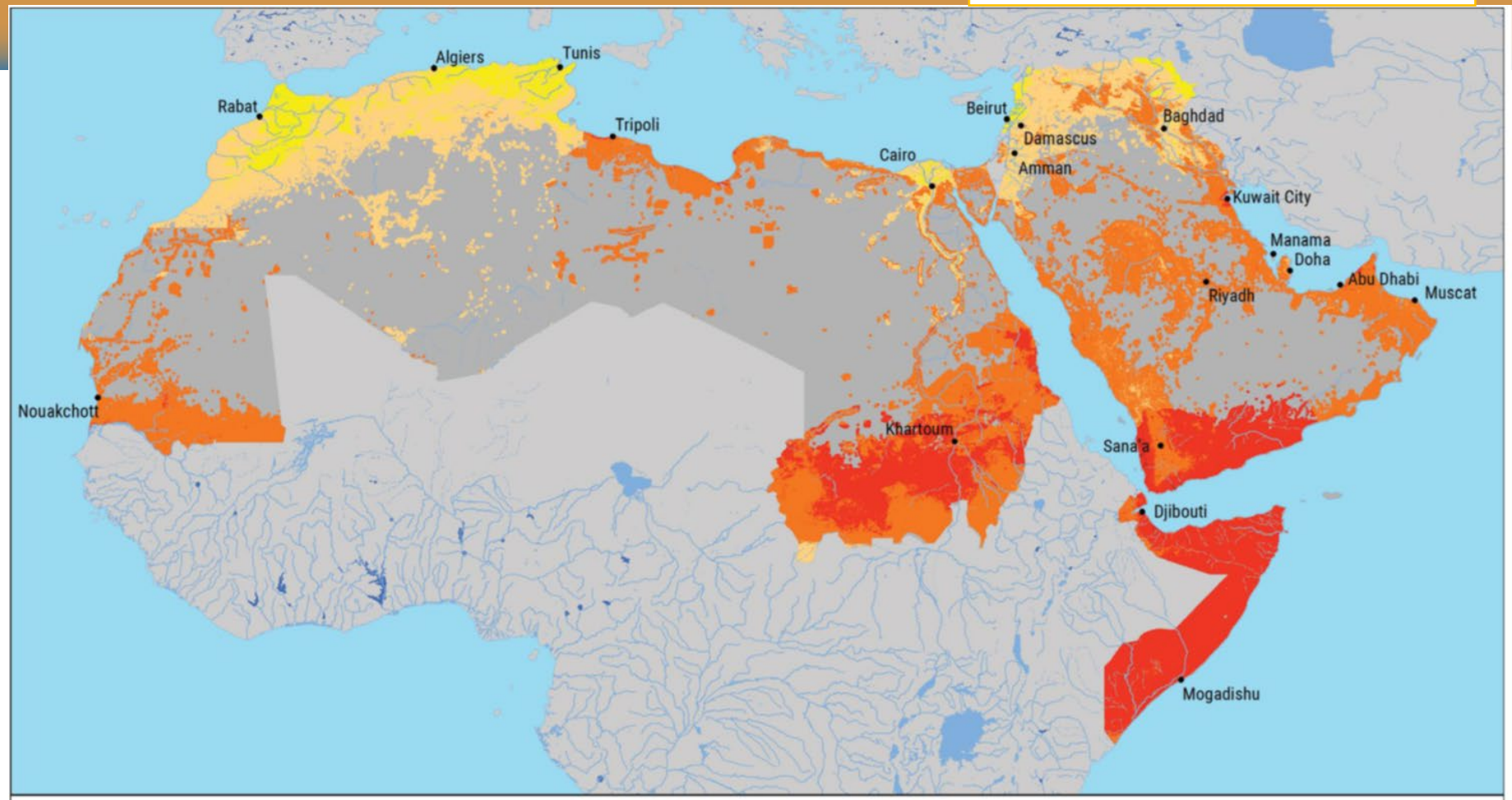
ECONOMIC RESOURCES (0.11)
- GDP per capita (0.36)
- ODA (0.30)
- Food imports as % of merchandise exports (0.34)

EQUITY (0.09)
- Female-to-male literacy ratio (0.51)
- Migrants/refugees index (0.49)

20 Adaptive Capacity indicators

WATER AVAILABILITY VULNERABILITY

Reference Period
(1986-2005)



WATER: WATER AVAILABILITY

VULNERABILITY: REFERENCE PERIOD

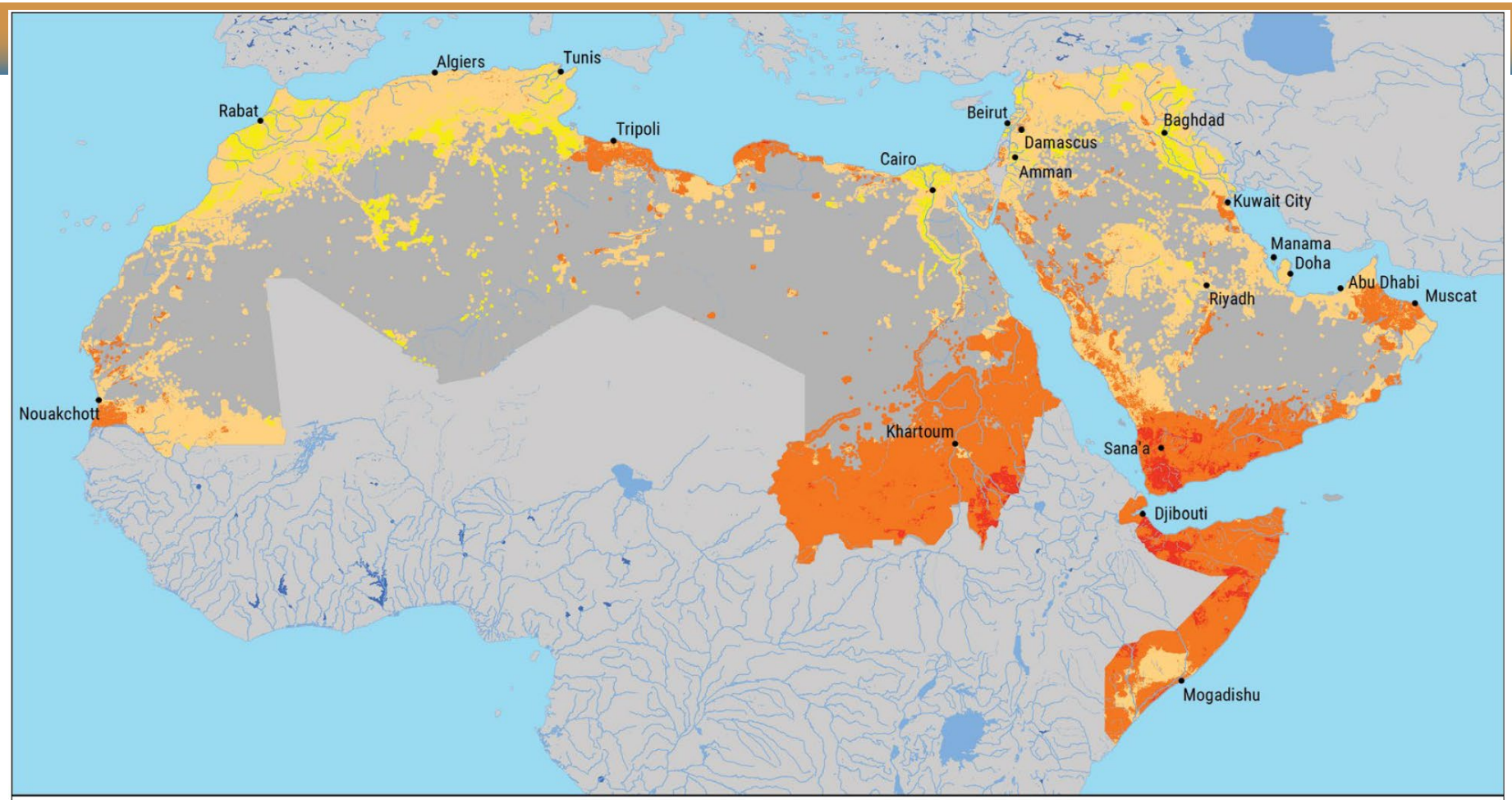
Legend

- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability — High Vulnerability

WATER AVAILABILITY VULNERABILITY

Mid-Century RCP 4.5



WATER: WATER AVAILABILITY

VULNERABILITY: RCP4.5 MID-CENTURY (2046-2065)

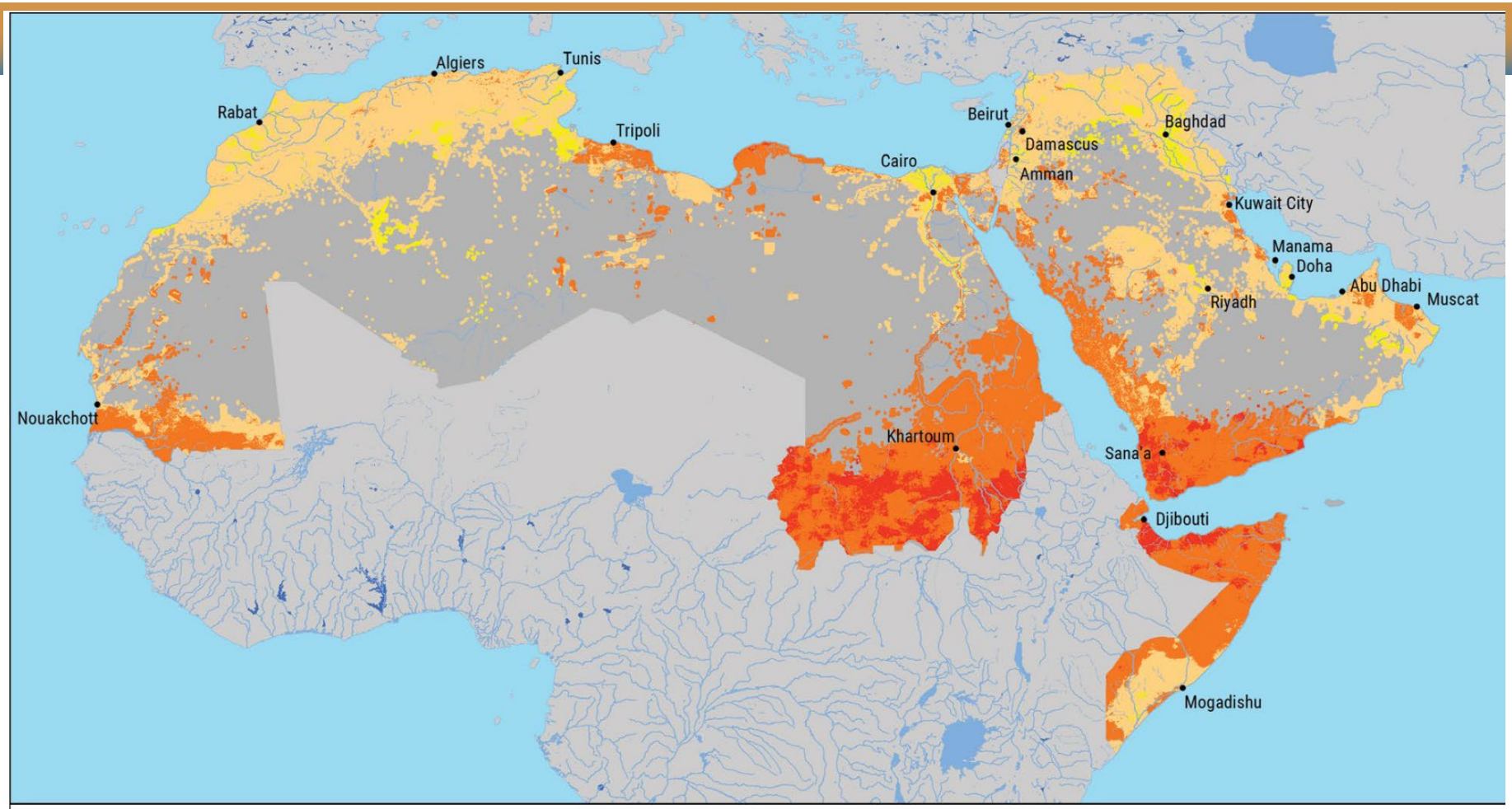
Legend

- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability — High Vulnerability

WATER AVAILABILITY VULNERABILITY

End-Century RCP 4.5



WATER: WATER AVAILABILITY

VULNERABILITY: RCP4.5 END-CENTURY (2081-2100)

Legend

- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability — High Vulnerability

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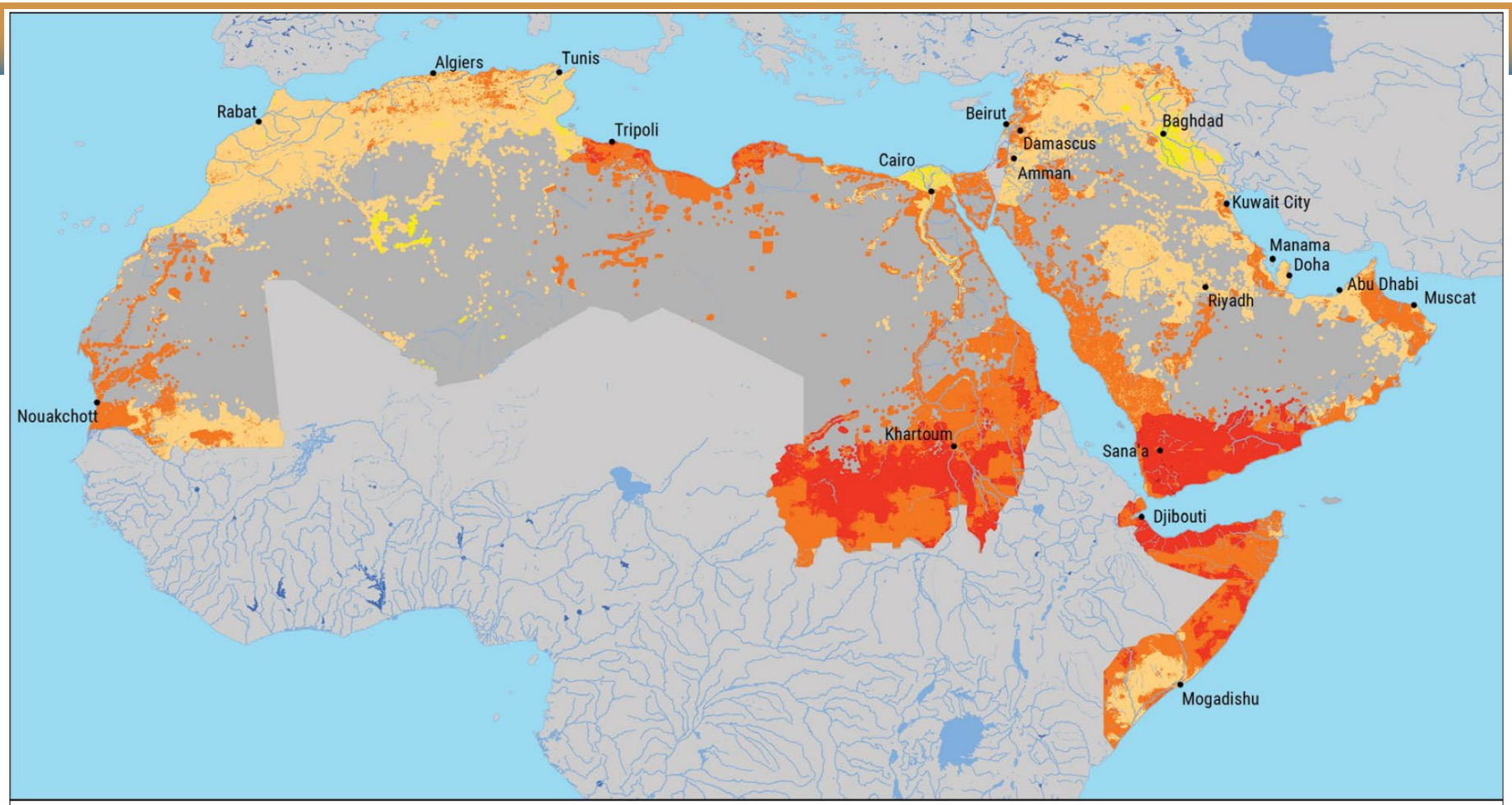
WATER AVAILABILITY VULNERABILITY

End-Century RCP 8.5



WATER: WATER AVAILABILITY

VULNERABILITY: RCP8.5 END-CENTURY (2081-2100)

Legend

- Lakes
- Reservoirs
- Rivers
- Intermittent rivers
- Major cities
- Area not relevant to subsector

Low Vulnerability — High Vulnerability

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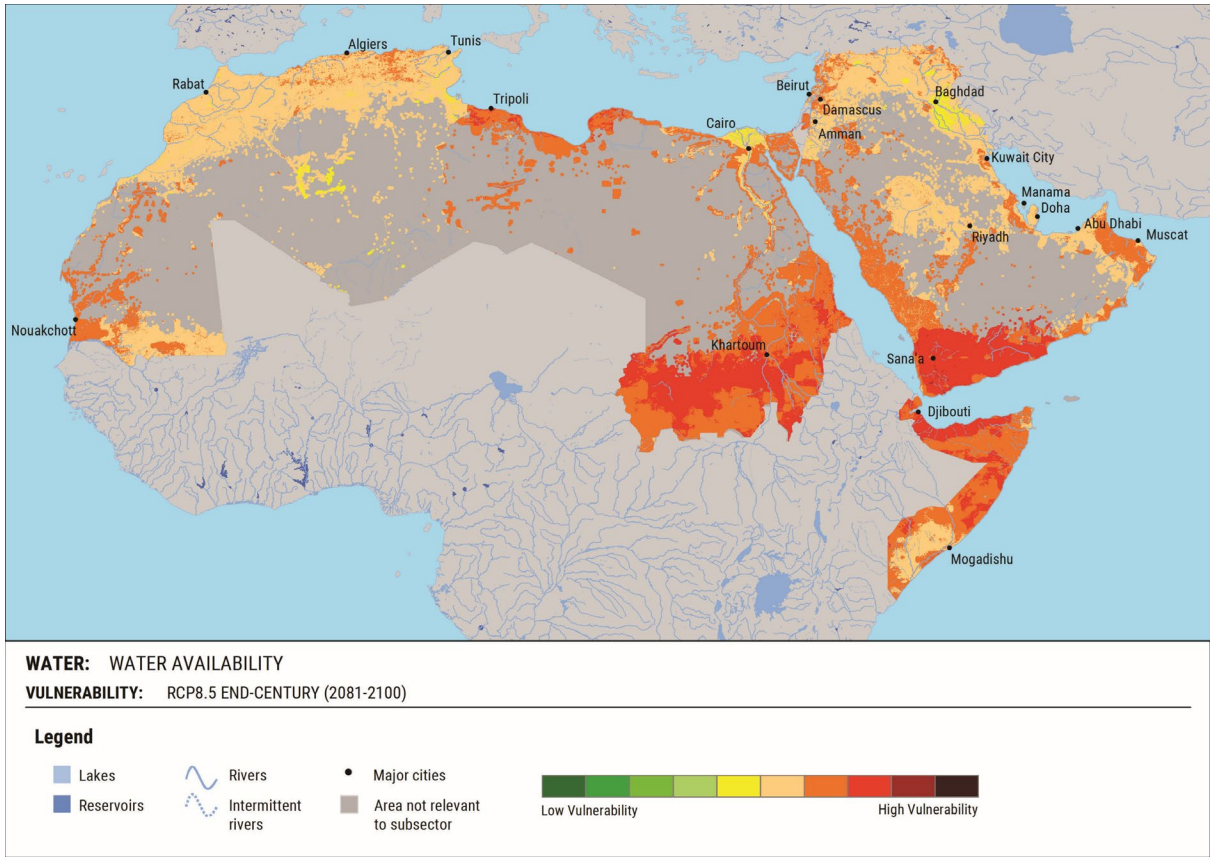
Water Availability Vulnerability



Scenario	Percentage of study area		
	Low Vulnerability	Moderate Vulnerability	High Vulnerability
RCP 4.5 Mid-century	0%	57%	43%
RCP 8.5 Mid-century	0%	48%	52%
RCP 4.5 End-century	0%	52%	48%
RCP 8.5 End-century	0%	43%	57%

Lebanese Agricultural Sector Vulnerability Assessment

…could be replicated at a basin-level in collaboration will all riparian states

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FIGURE 7: Change in temperature compared to the reference period at mid-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

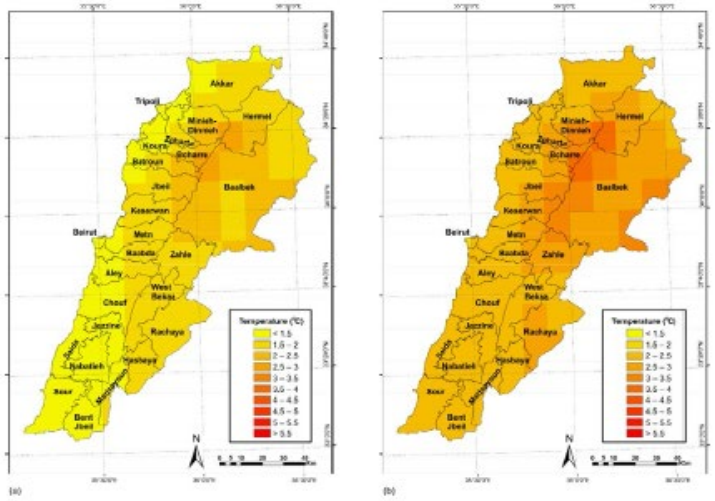


FIGURE 8: Change in temperature compared to the reference period at end-century for (a) RCP4.5 and (b) RCP8.5 (0.11° grid resolution)

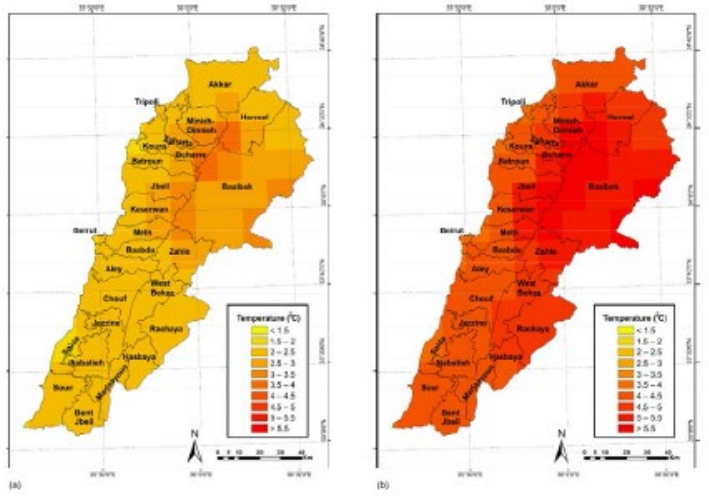


FIGURE 21: Vulnerability at mid-century for (a) RCP4.5 and (b) RCP8.5

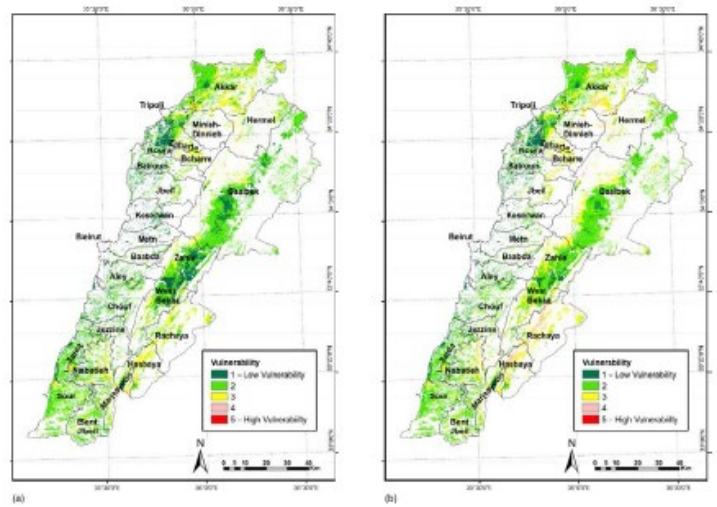


FIGURE 22: Vulnerability at end-century for (a) RCP4.5 and (b) RCP8.5

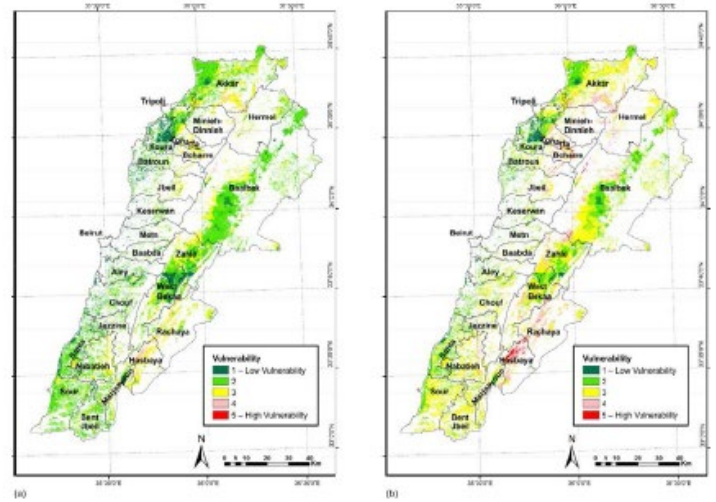


FIGURE 24: Vulnerability hotspots for end-century RCP8.5

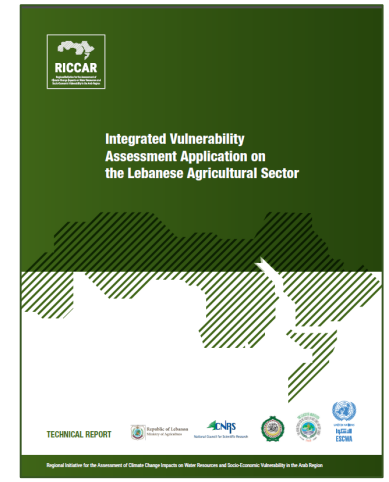
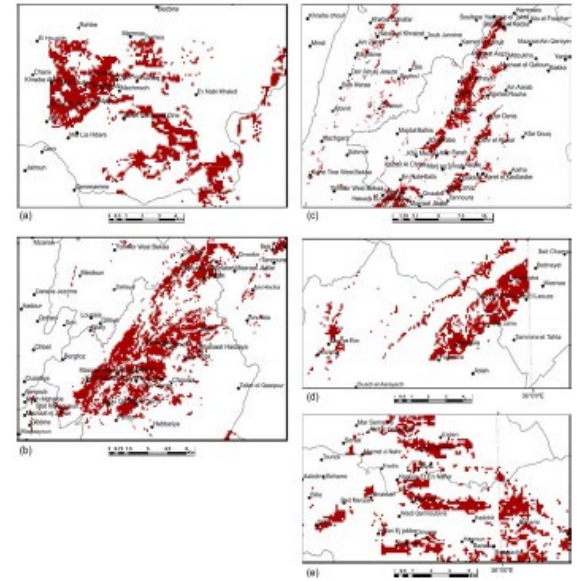


FIGURE 25: Selected vulnerability hotspots for end-century RCP8.5 in (a) Akkar, (b) Hasbaya, (c) Rachaya, (d) Baalbek and Zahle, and (e) Zgharta and Bcharre



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RICCAR Publication Series

ARAB CLIMATE CHANGE ASSESSMENT REPORT

BOOKLET

TECHNICAL NOTES

MANUAL

TECHNICAL REPORTS

RICCAR used to inform other publications

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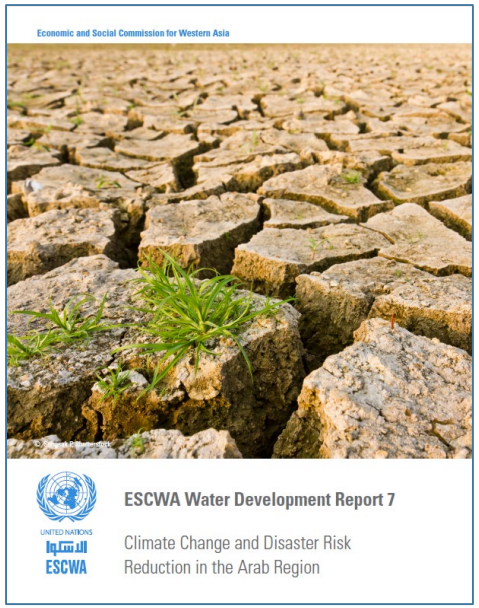
Climate Change Adaptation Manual:

Five sector modules drawing on RICCAR outputs were developed by ESCWA in close cooperation with the following leading organizations:

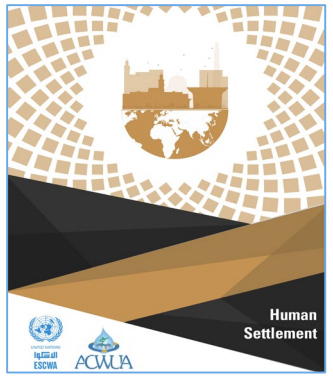
1. **Environment** module with UNEP/ROWA;
2. **Agriculture** module with ACSAD and GIZ;
3. **Health** module with WHO;
4. **Human settlements** (on water supply/sanitation) with ACWUA;
5. **Economic Development** module by ESCWA

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.



Agricultural productivity case studies



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Thank You

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