Hydrological impacts of climate change in North African countries

Main results of the CLIHMAG project (2013-2016)

Yves Tramblay[1], Denis Ruelland[1], Lahoucine Hanich[2], Zoubeida Bargaoui[3], Hammouda Dakhlaoui[3], Samuel Somot[4]

[1] HydroSciences Montpellier (Univ. Montpellier, CNRS, IRD), France
[2] Faculty of Geosciences, University Cadi Ayyad, Marrakech, Morocco
[3] LMHE, ENIT, Tunisia
[4] CNRM, Météo France, France

1-Regional context

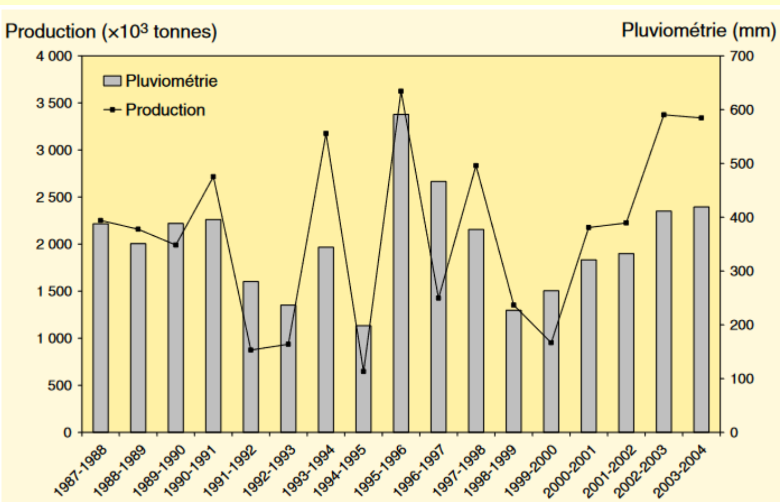
High vulnerability to climatic conditions

Impacts of precipitation variability

Levels of dams and reservoirs

Rain fed cultures (95%)

Relation between annual rainfall and wheat productivity



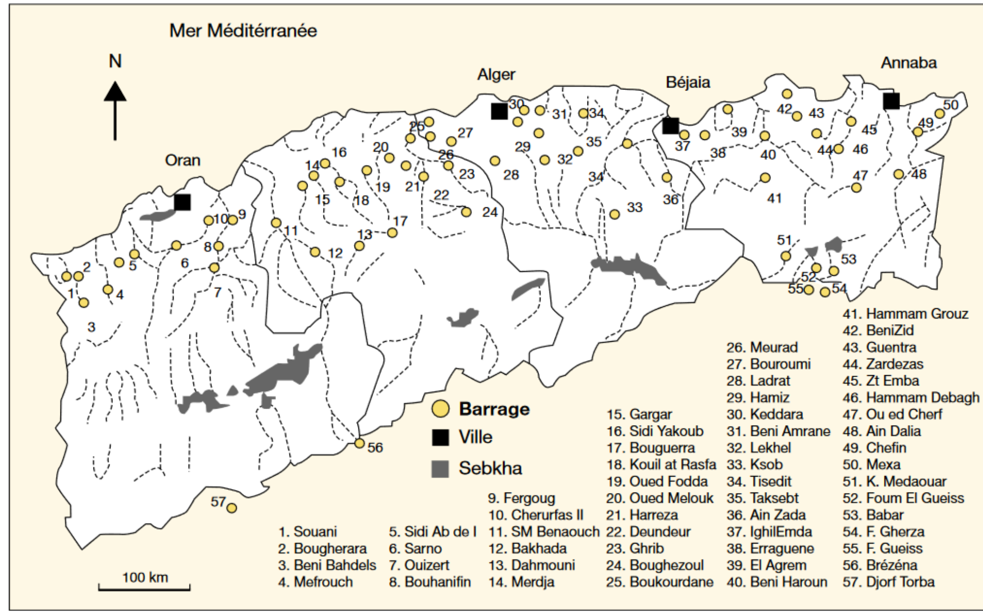
2007 drought in Morocco : – 76% wheat production compared to 2006

Balaghi et al., 2007

The importance of dams in North Africa

Country	Level of mobilization of surface water resources (in 2012)
Algeria	75%
Morocco	85%
Tunisia	90%

Dams in Algeria



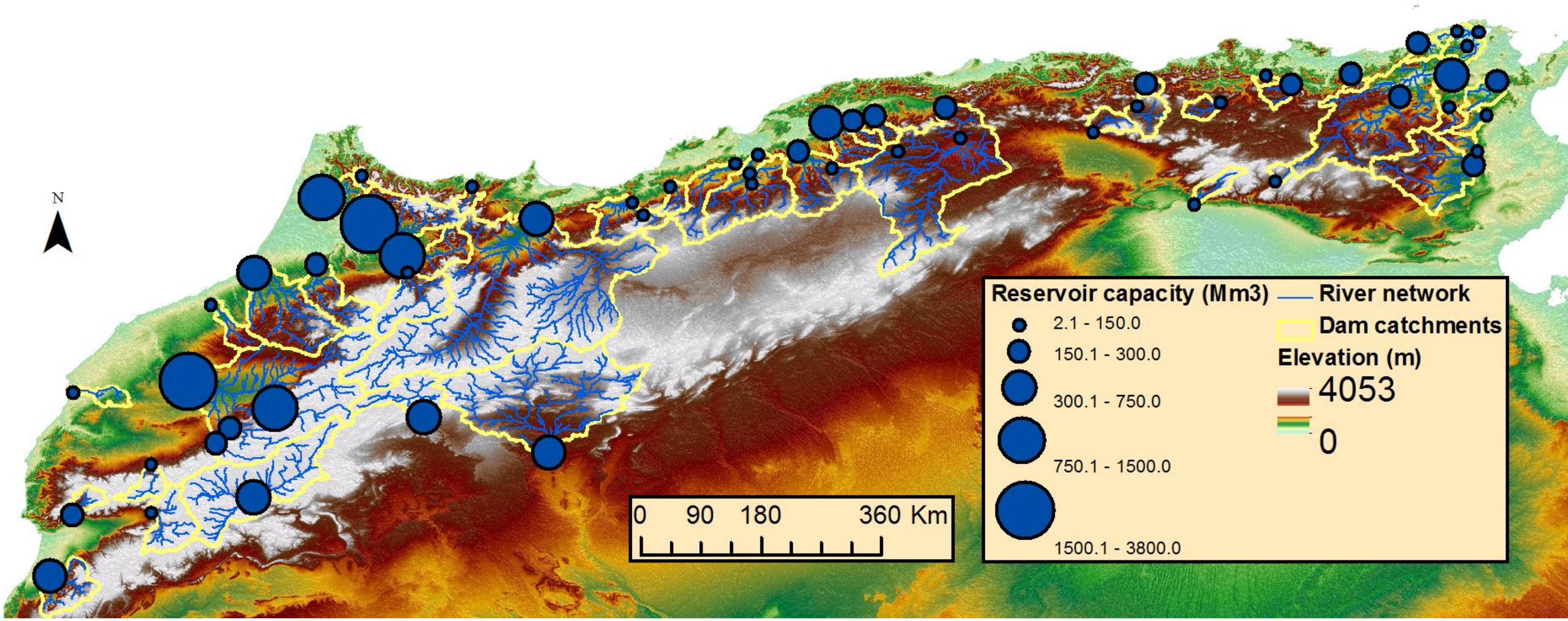
Rimini et al. 2003

Traditional irrigation systems: dalou (dwells), khettaras (underground drainage systems), seguias (open derivation channels)

Starting in 1870 with the French colonization, construction of large dams mostly for irrigation (agriculture)

Strong impact of dam silting, reducing the capacity of reservoirs

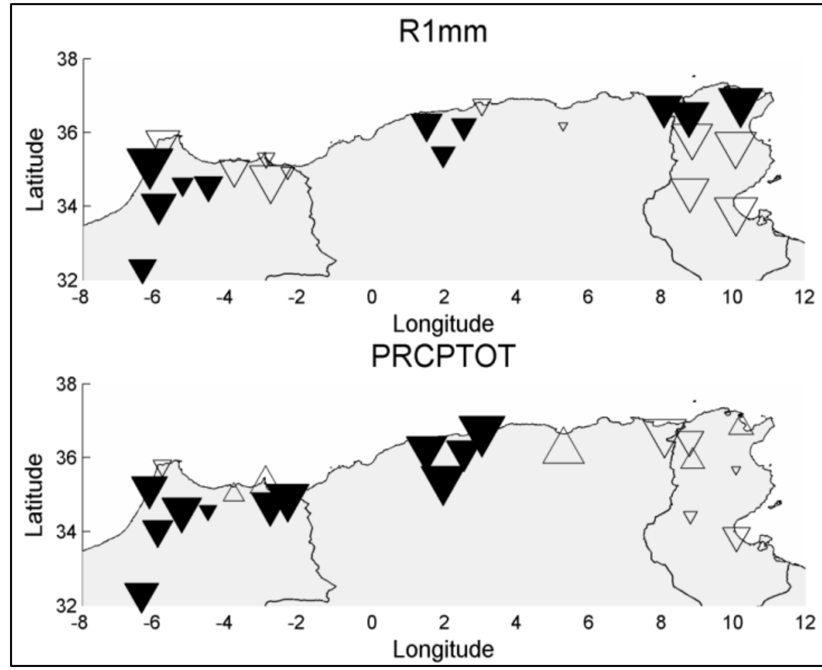
Largest dams of north Africa



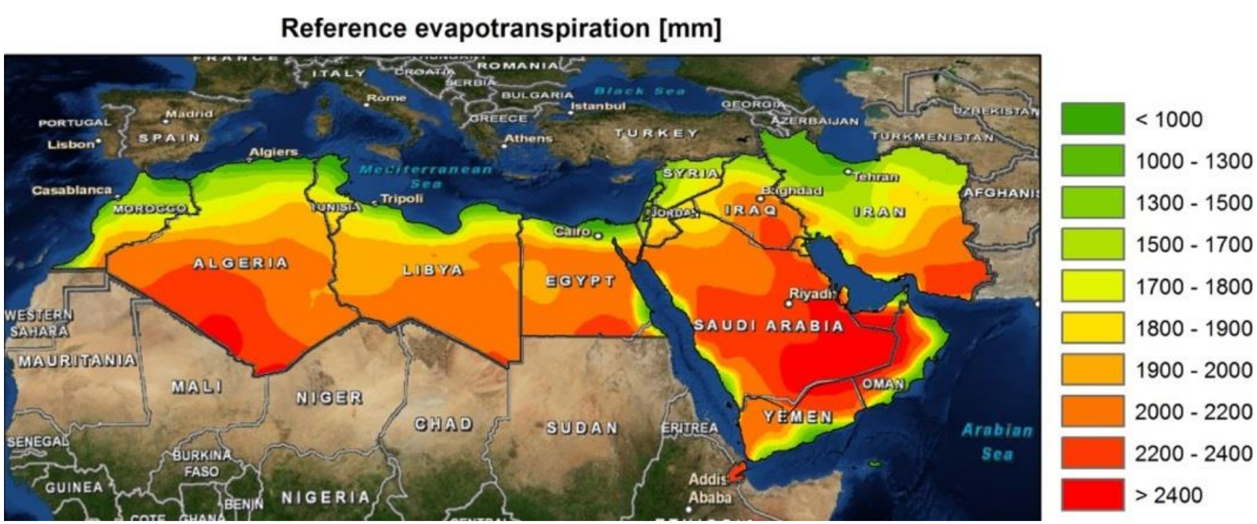
52 basins with a contributing area larger than 100km²

Historical trends

- Decrease in precipitation totals (PRCPTOT), driven by a decrease of the number of rainy days (R1mm)
- High evapotranspiration rates, increasing along with temperature

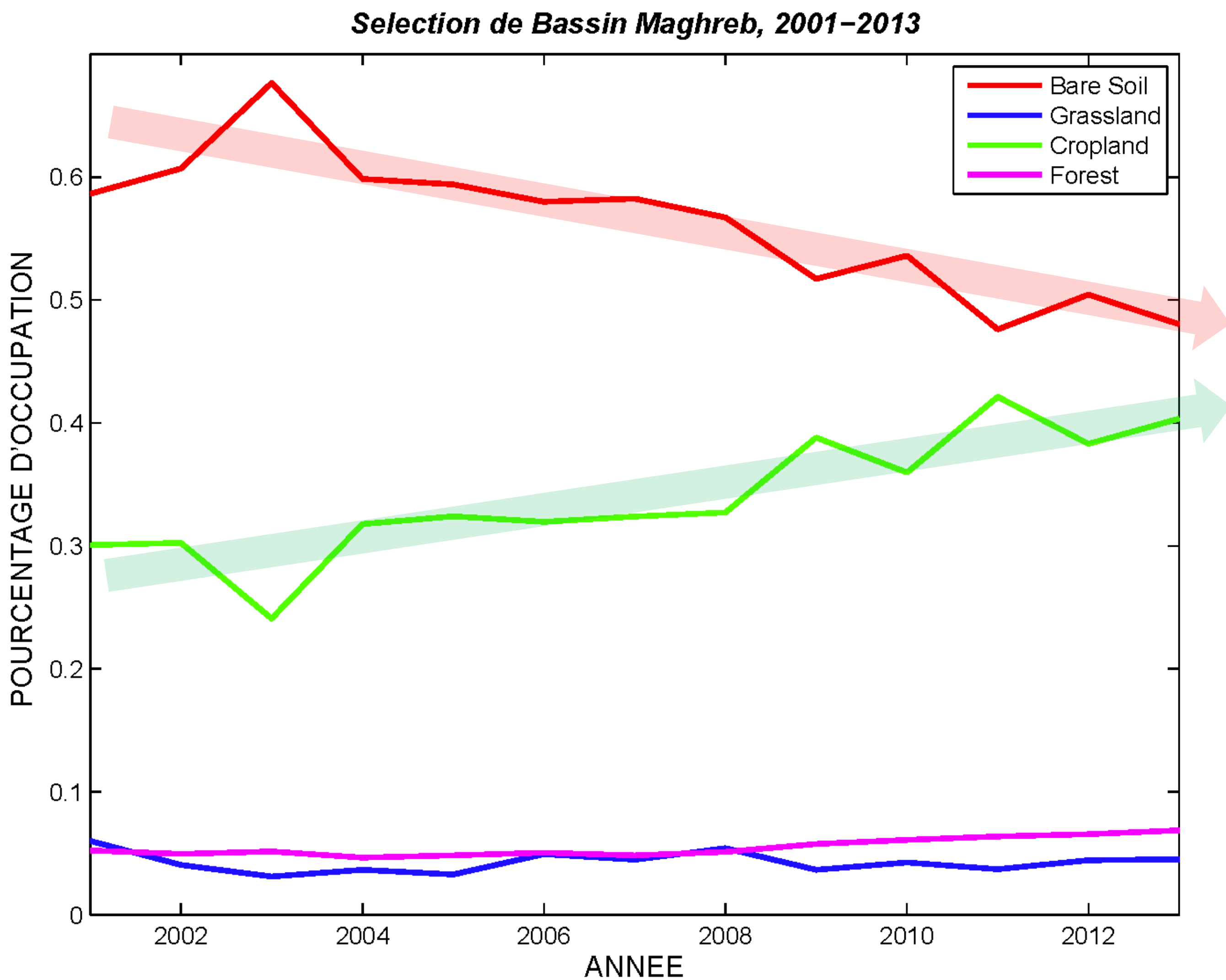


Stations with a **regionally significant** decrease in the frequency of wet days (R1mm) and precipitation totals (PRCPTOT) (Tramblay et al., 2013 NHESS)



Terink et al 2013

Changing land cover



Decrease in bare soils

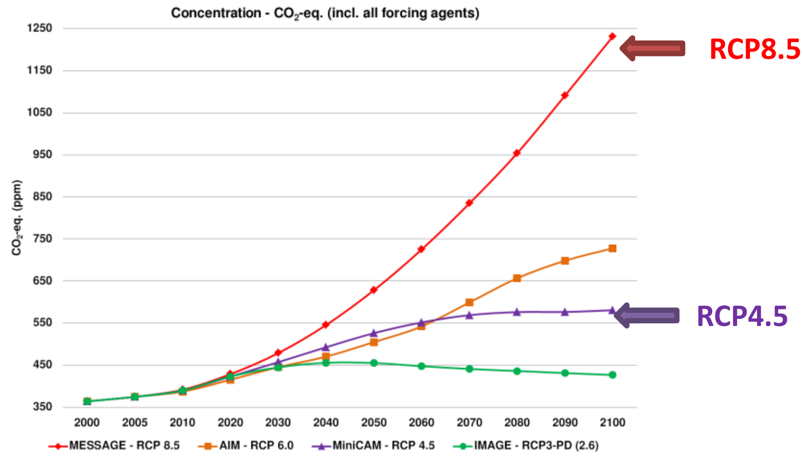
Increasing croplands

Higher water demand for agriculture

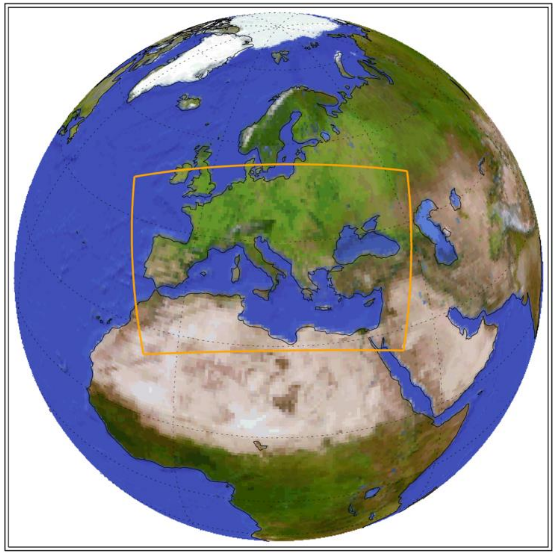
MODIS land cover analysis, L. Jarlan

2-Regional climate scenarios

Regional climate model simulations

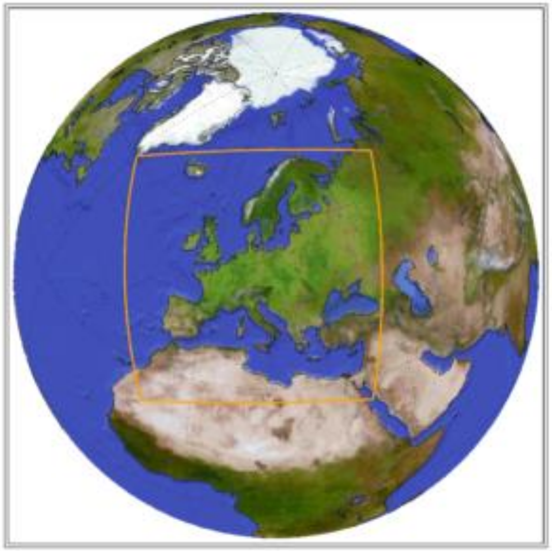


Med-CORDEX



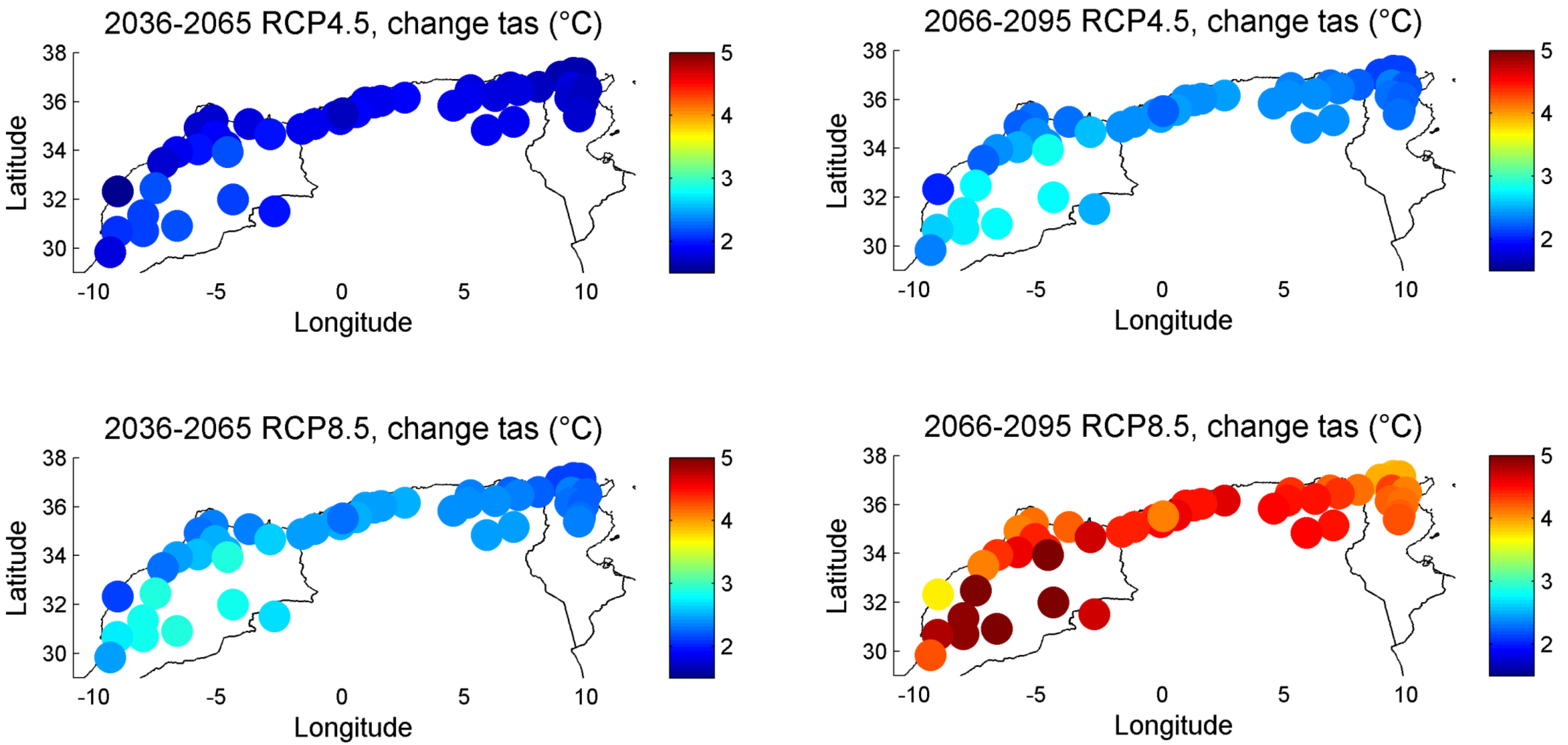
12km and 50km simulations (2 and 5 model runs, 5 GCM)

Euro-CORDEX



12km simulations (11 model runs, 5 GCM)

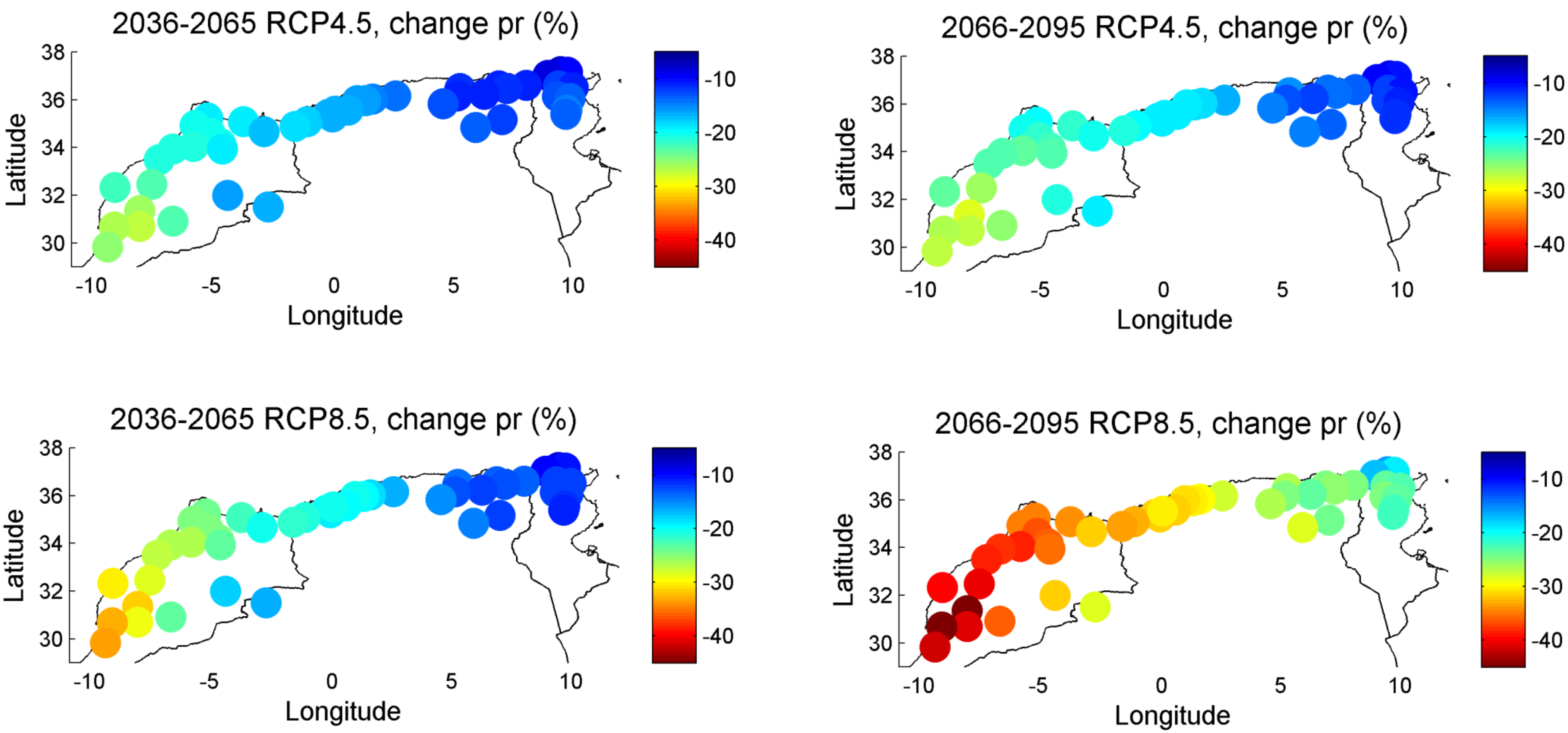
Temperature changes for 2036-2065 and 2066-2095



Tramblay et al., 2018

Uniform temperature increase, depending on the time window and emission scenario

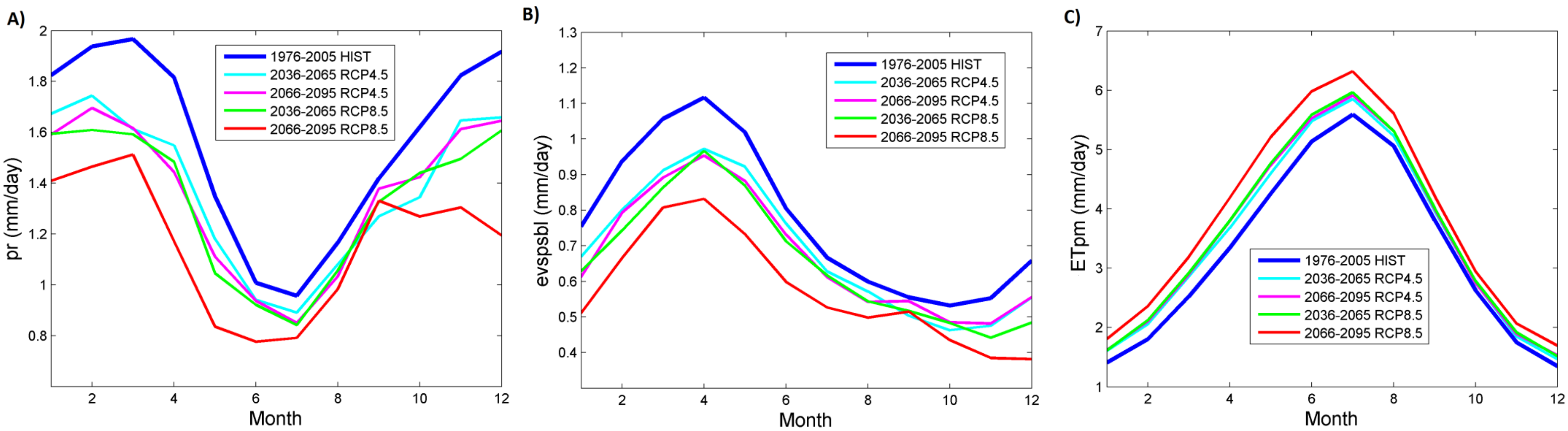
Precipitation changes for 2036-2065 and 2066-2095



Tramblay et al., 2018

Decrease in precipitation following a East (-) to West (---) gradient

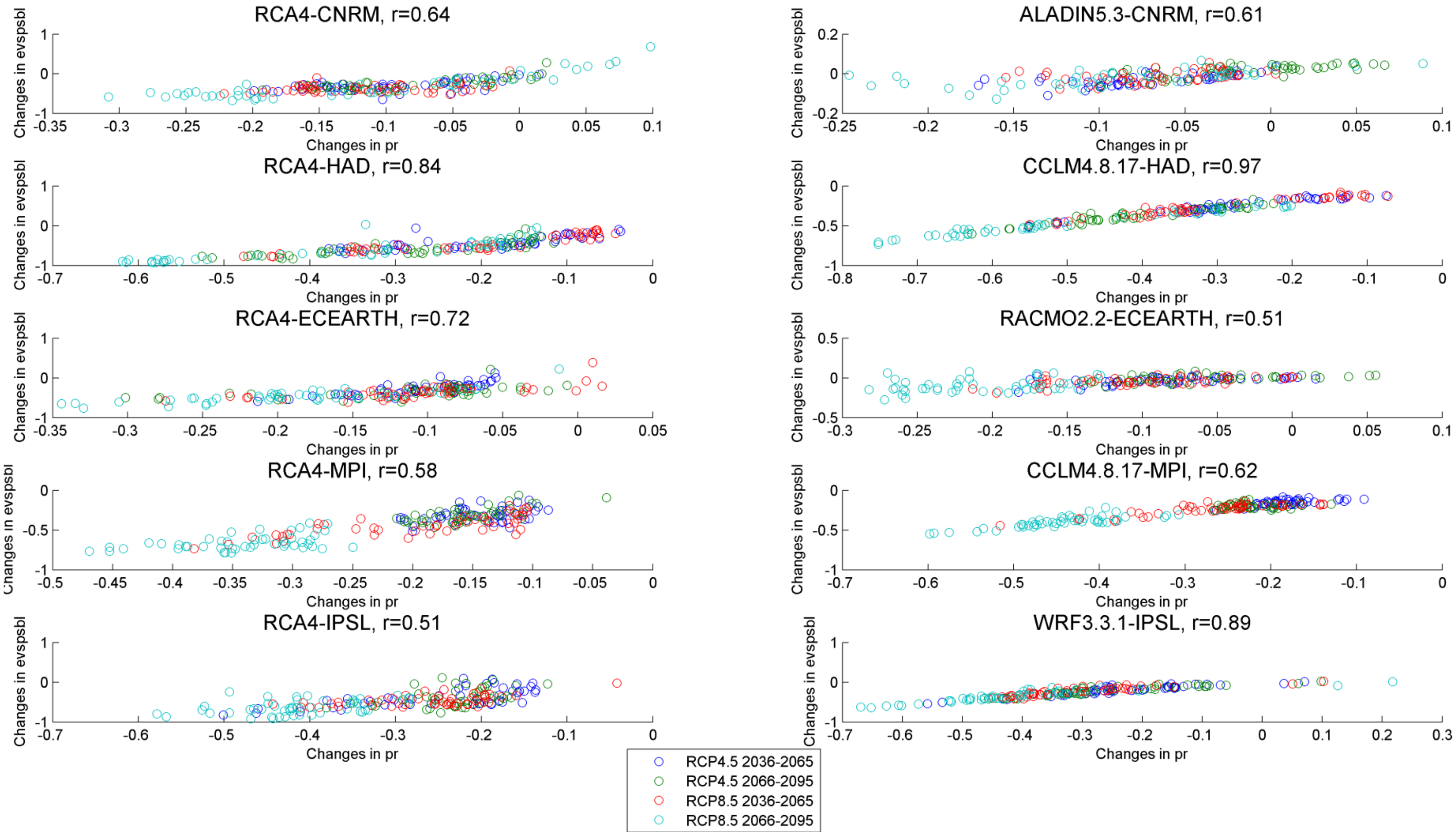
Seasonal cycles of precipitation (a), actual (b) and reference (c) evapotranspiration over North Africa



1. **Reduction of precipitation mainly in spring**
2. **Decrease of actual (real) evapotranspiration, linked to limited moisture availably (precipitation)**
3. **Increase in reference (potential) evapotranspiration mainly during summer**

Tramblay et al., 2018

Dependence of precipitation and evapotranspiration changes



High correlation of precipitation and evapotranspiration changes, typical in a strongly water-limited environment

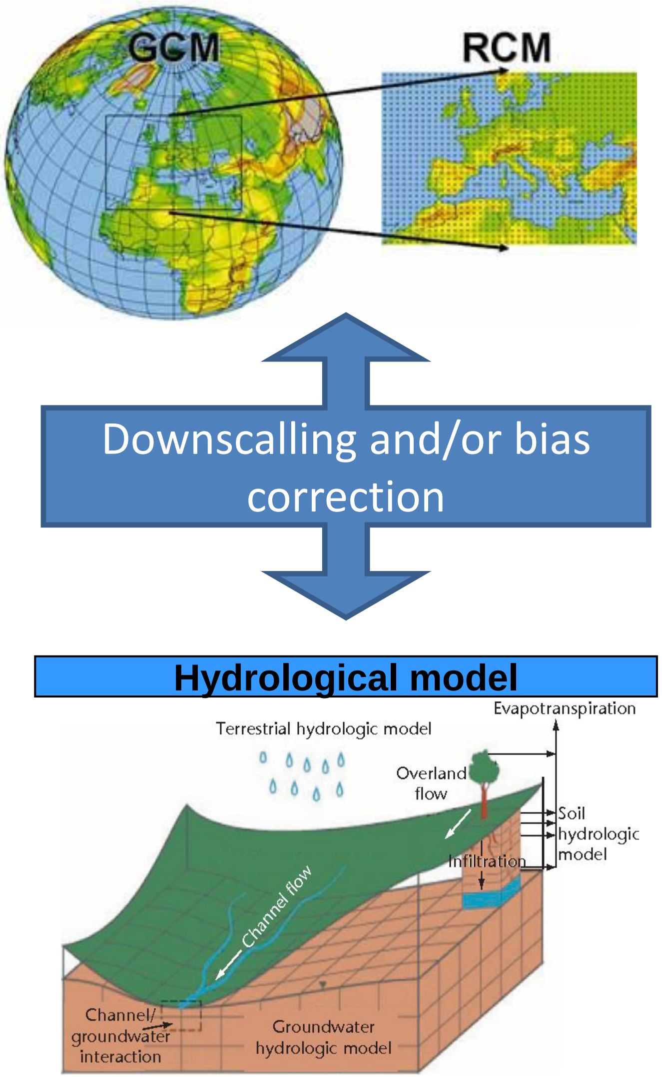
Tramblay et al., 2018

3-Hydrological scenarios

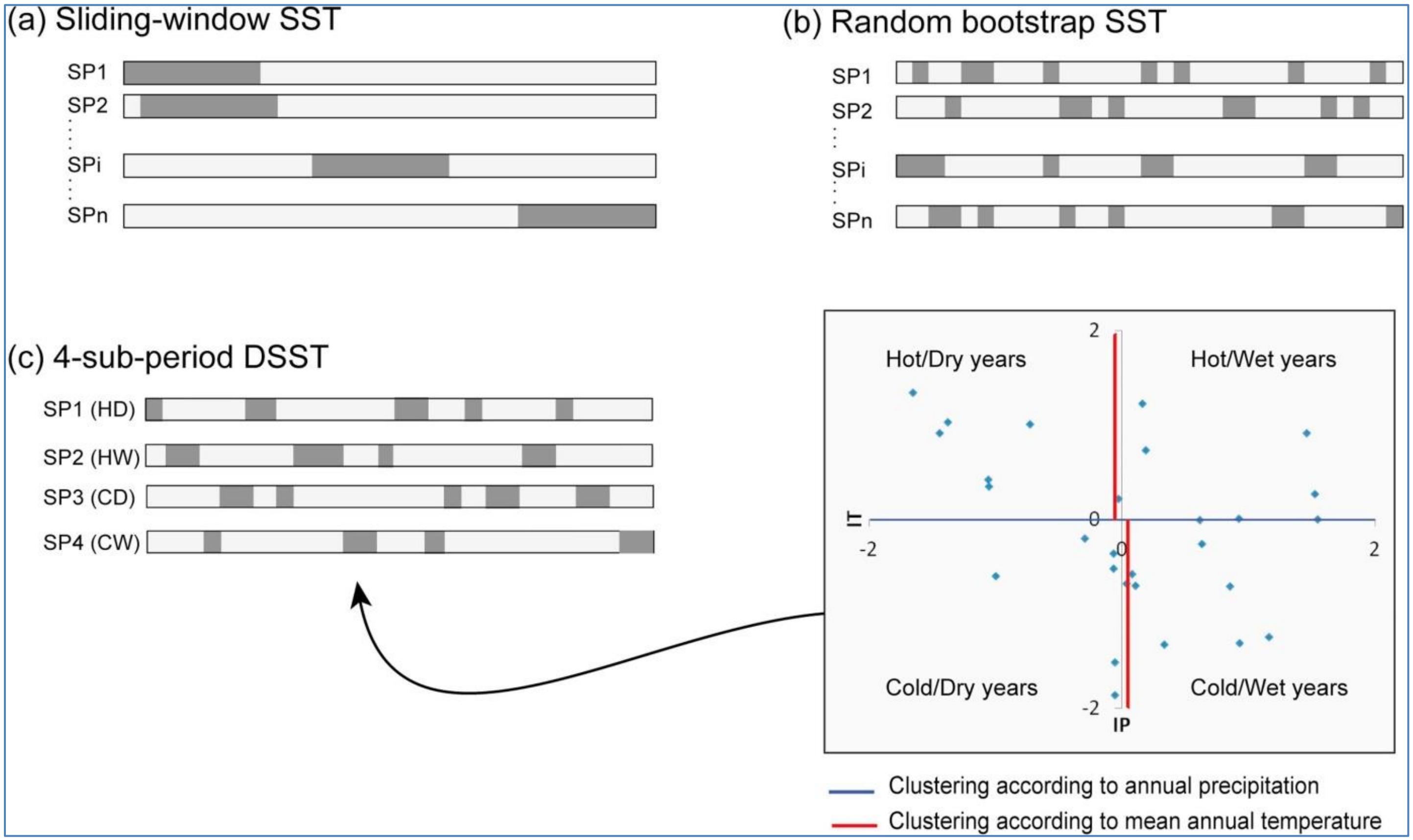
Methods for analyzing climate change impacts on hydrology

Uncertainties:

- Climate scenarios
- Downscaling and bias-correction methods
- Validity of the hydrological model outside of its calibration domain



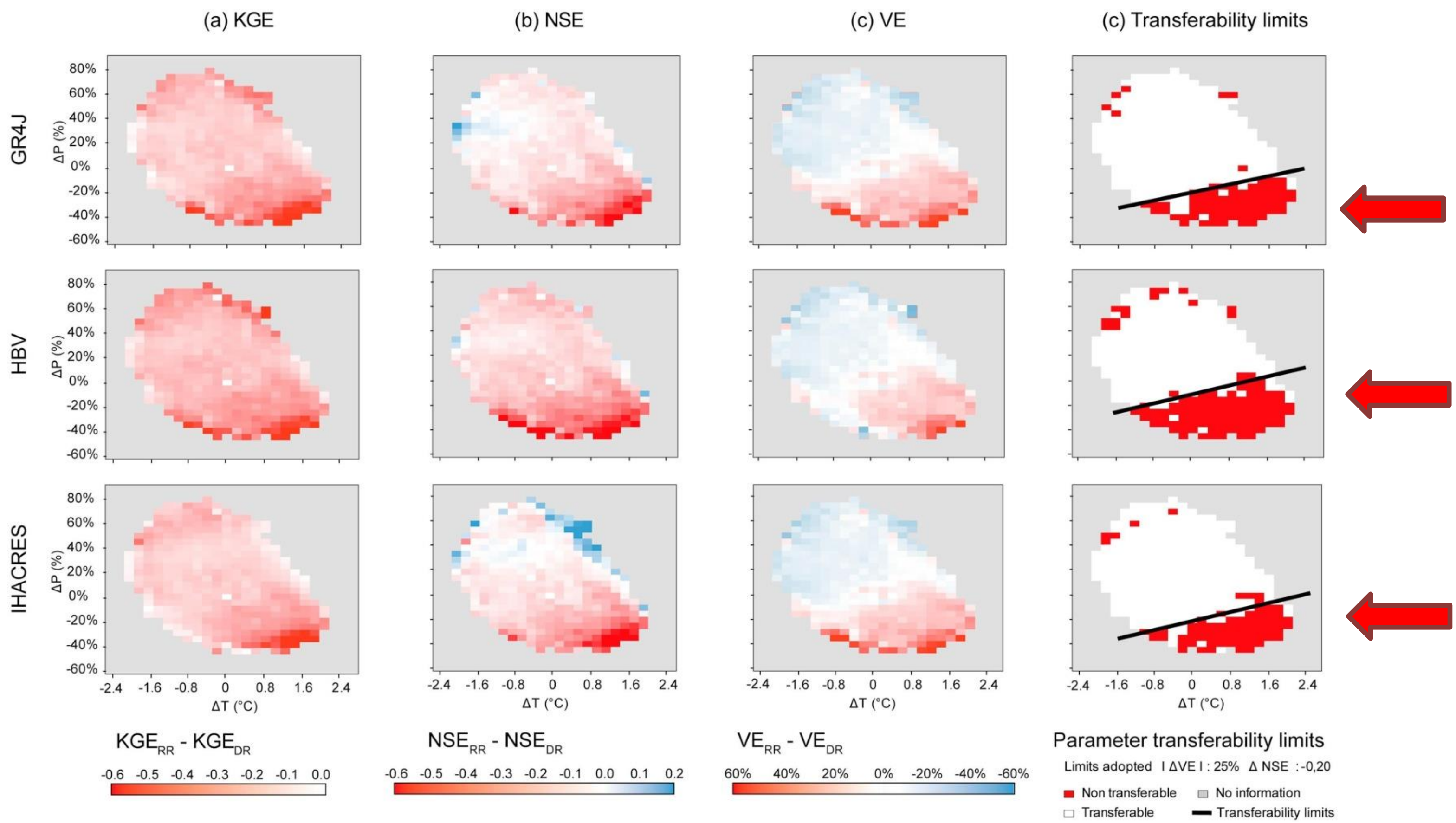
A framework to validate downscaling and hydrological models



A cross-validation method to validate downscaling methods and hydrological model parameters

Dakhlaoui et al., 2017, 2019

Limits of applicability of standard hydrological models currently used in water resources management an planning

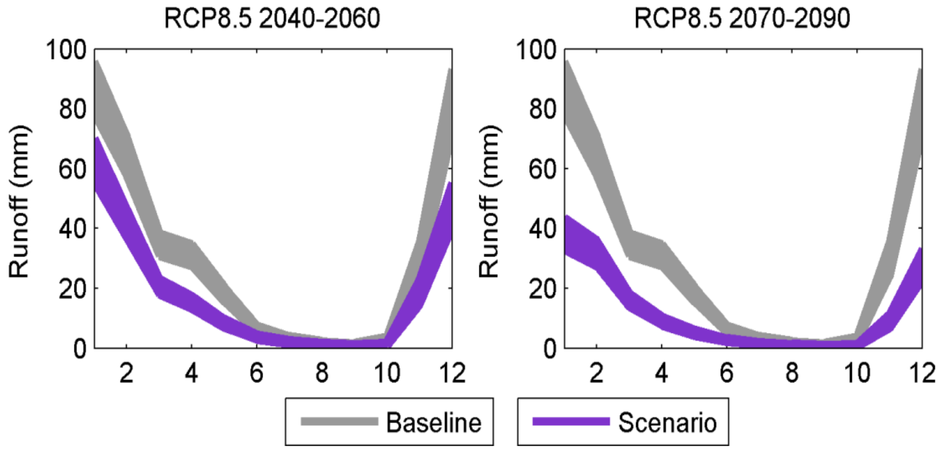


For climate conditions resembling to the most pessimistic scenarios, the daily models are unable to reproduce river runoff => monthly water balance models are preferred

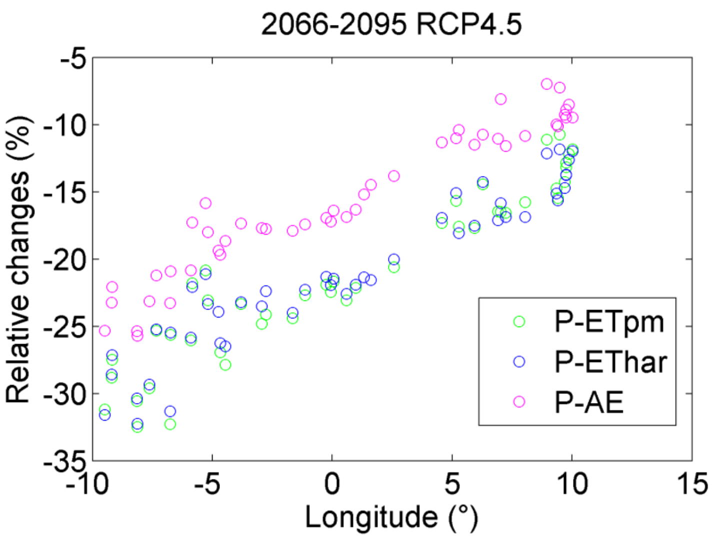
Dakhlaoui et al., 2017, 2019

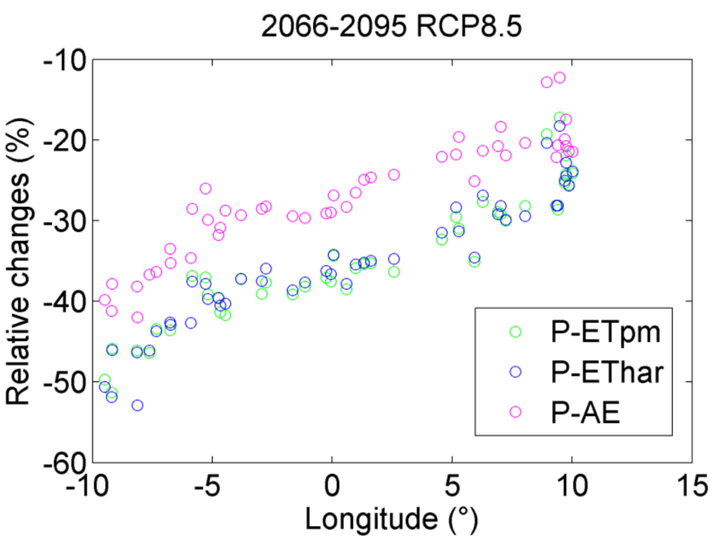
Future reduction of surface runoff in Maghreb bassins

Regional trends towards a reduction of net precipitation, whatever the method and climate scenario



Makhazine Dam, North Morocco





Tramblay et al., 2018

Tramblay et al., 2016

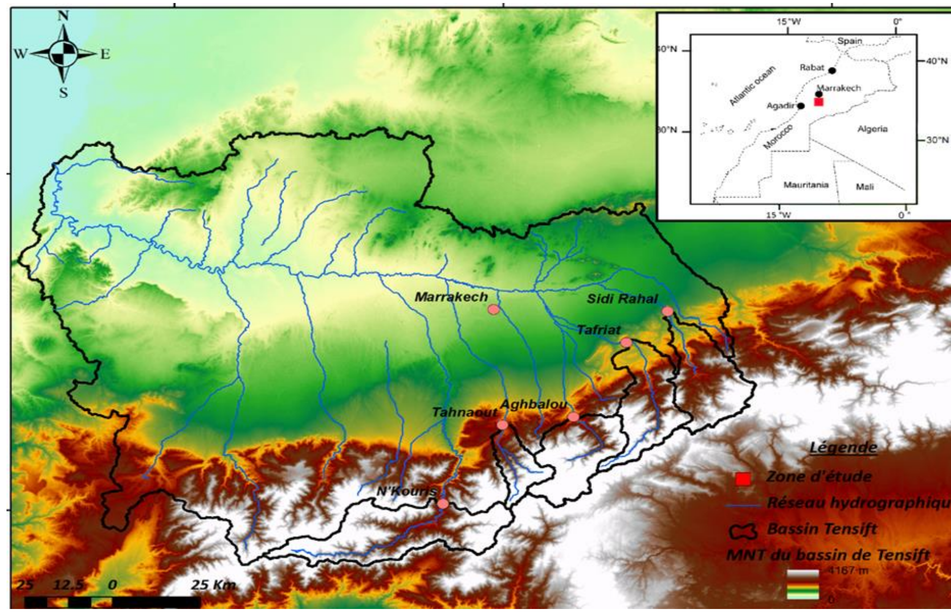
4-Case study in Morocco

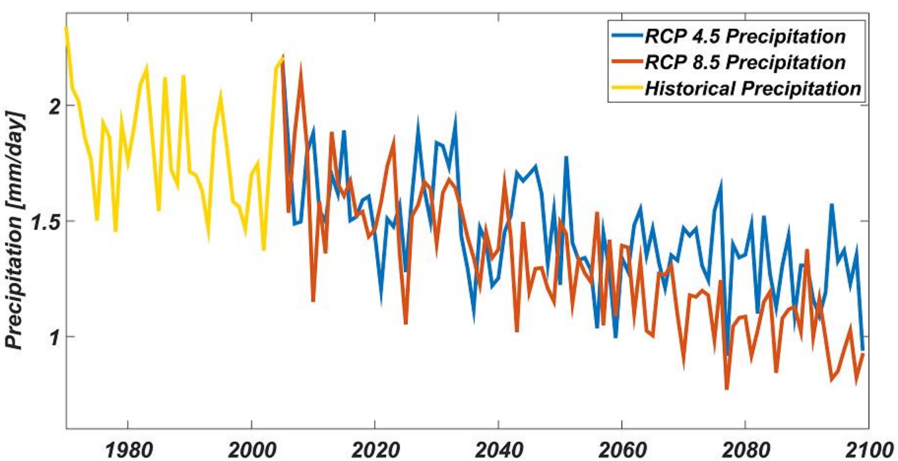
The Tensift bassin south of Morocco

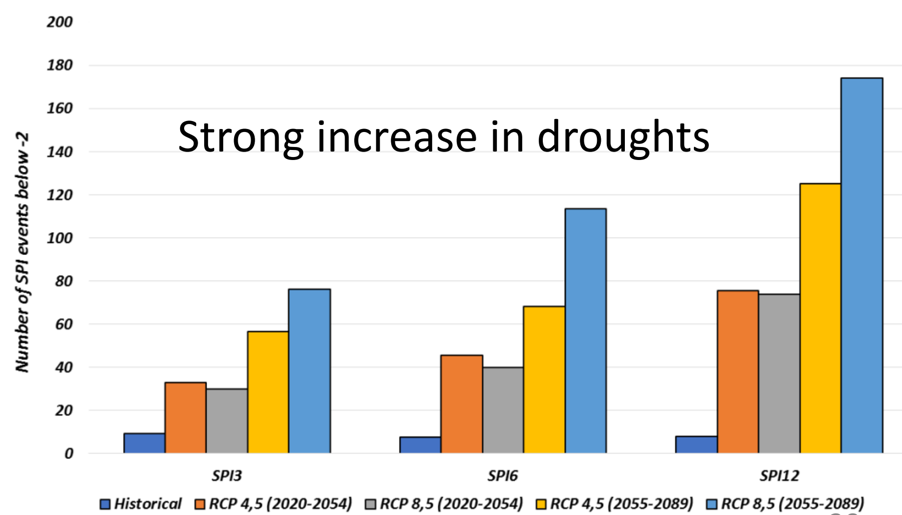
Semi-arid area already facing water stress

Importance of agricultural activities and tourism (city of Marrakech)

Strongest signal in North Africa for precipitation reduction

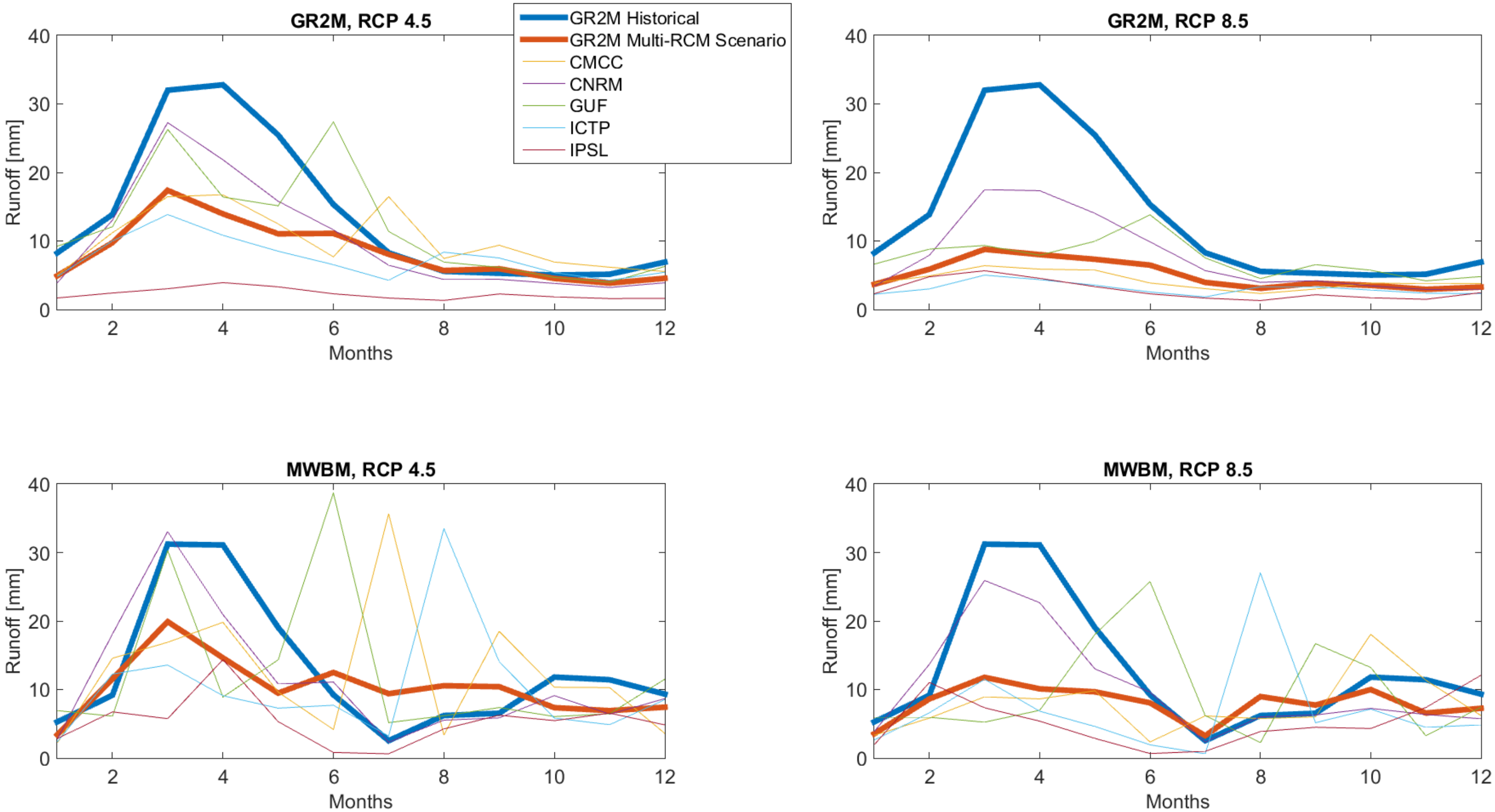






Zkhiri et al. 2019

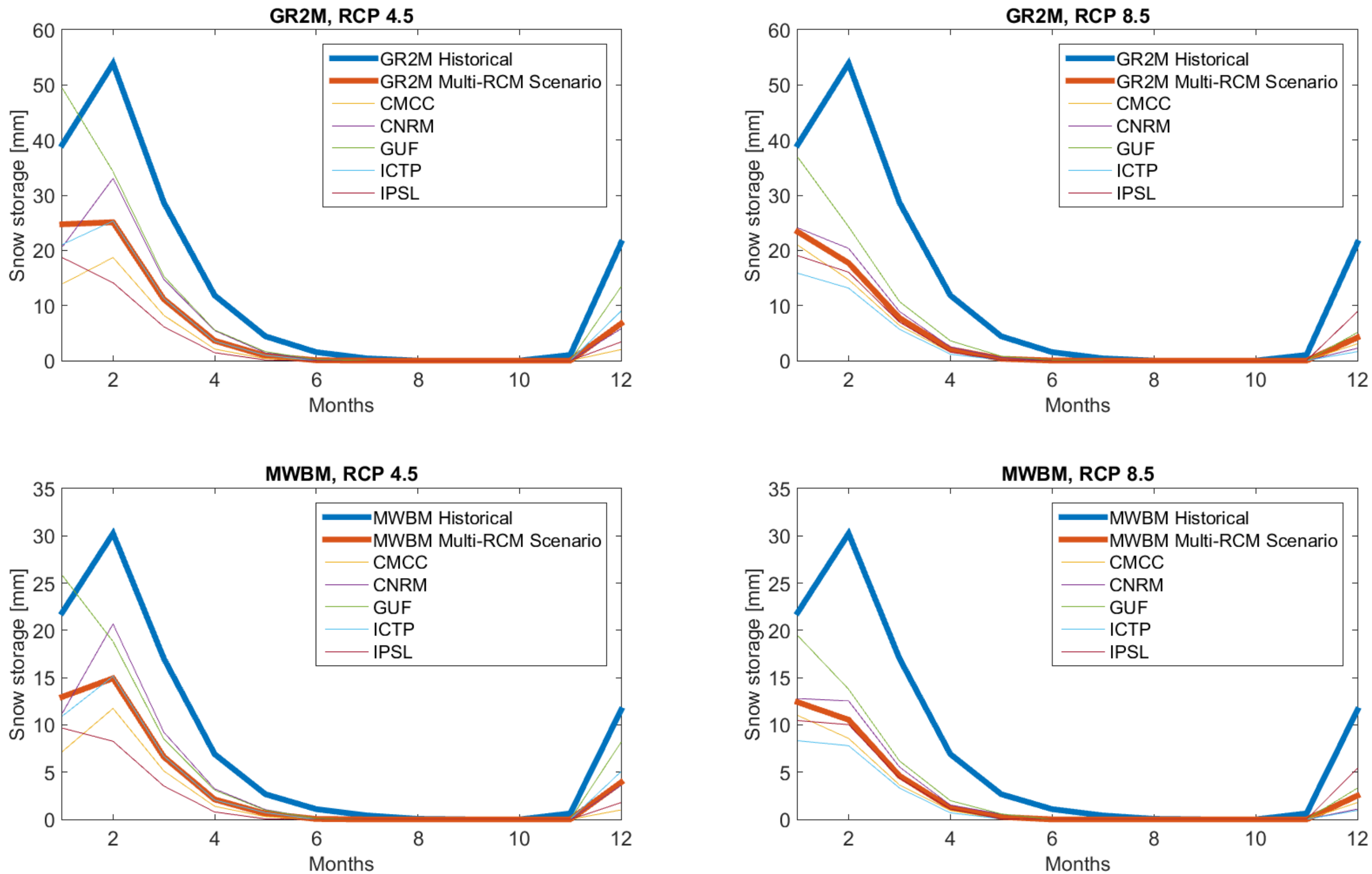
Hydrological runoff projections



Strong reduction of surface runoff from the Atlas mountain in spring

Marchane et al. 2017

Snow storage projections



The depletion of surface water resources is strongly linked to the decrease of snow amounts (without considering future water use)

Marchane et al. 2017

Concluding remarks

- North African countries are already facing water stress
- Historical trends and future scenarios indicate a reduction of surface water resources, with the most important reduction in Morocco
- There is a strong need for adaptation strategies and to develop monitoring and forecasting systems for droughts

Contributions :
Hammouda Dakhlaoui (postdoc), Wiam Zkhiri (Phd), Ahmed Marchane (PhD), Mehdi Amraoui (Master), Khaoula Klouz (Master), Mahdi Khalki (Master), Albin Lacroix (Master), Asma Foughali (Master)

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