Hydrological impacts of climate change in North African countries

Main results of the CLIHMAG project (2013-2016)

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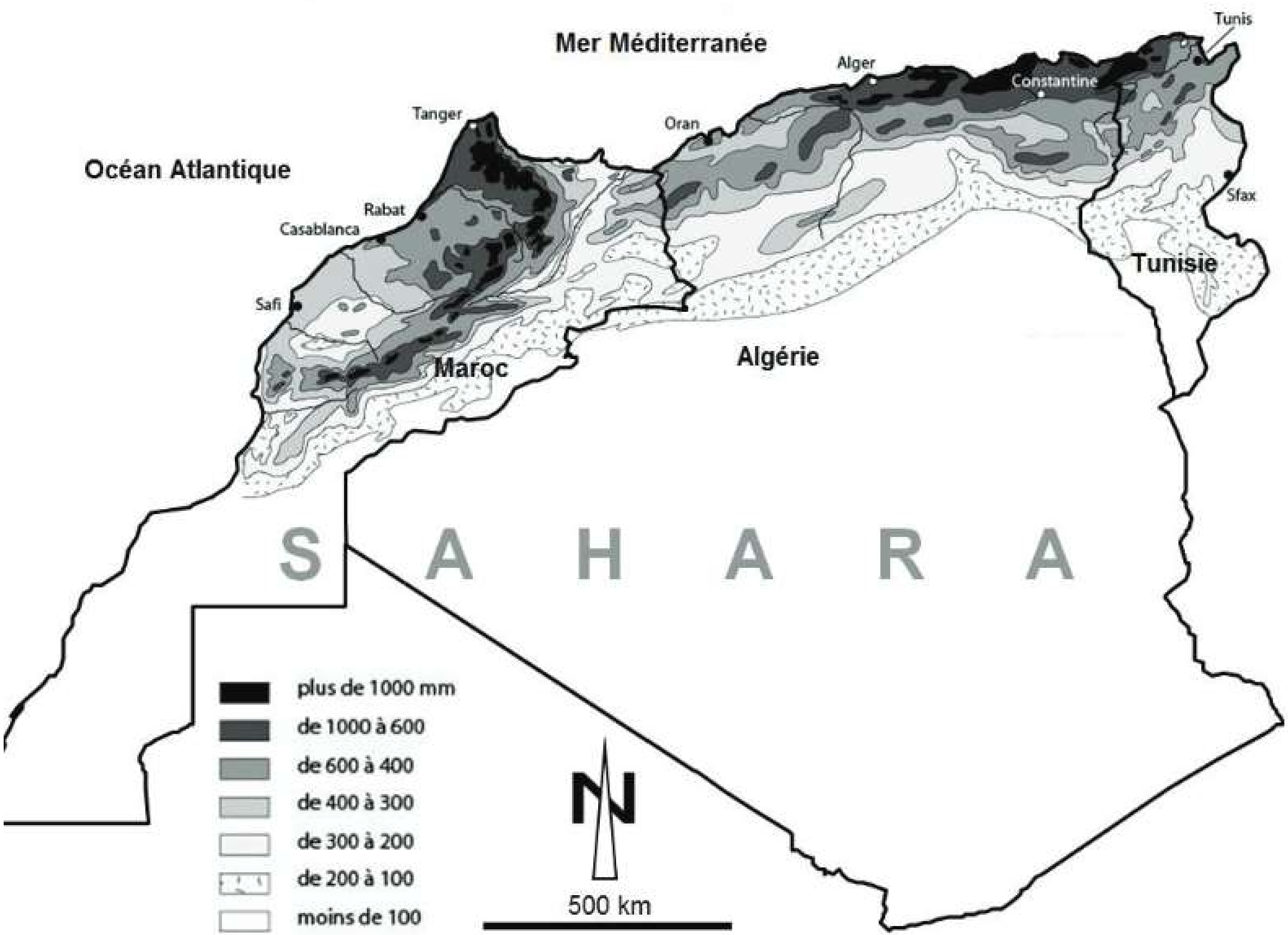
1- Regional context
2- Climate scenarios
3- Hydrological scenarios
4- Case study in Morocco

1- Regional context

Spatial variability of precipitation



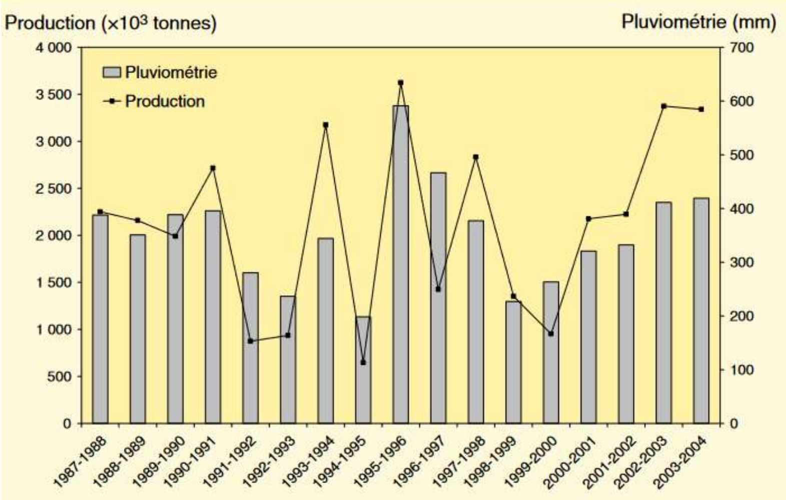
High vulnerability to climatic conditions

Impacts of precipitation variability

Levels of dams and reservoirs

Rain fed cultures (95%)

Relation between annual rainfall and wheat productivity

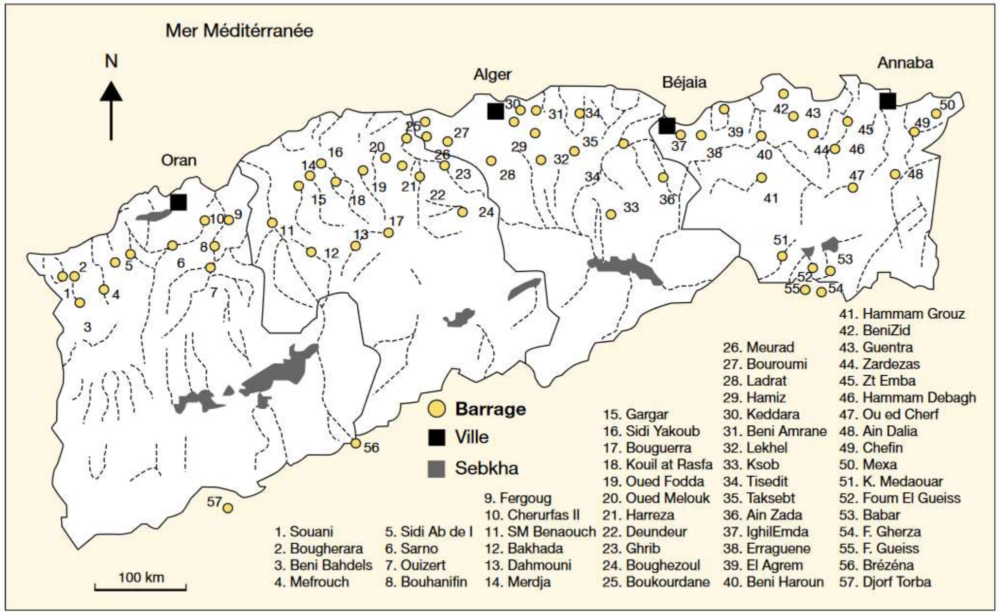


2007 drought in Morocco : – 76% wheat production compared to 2006

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%



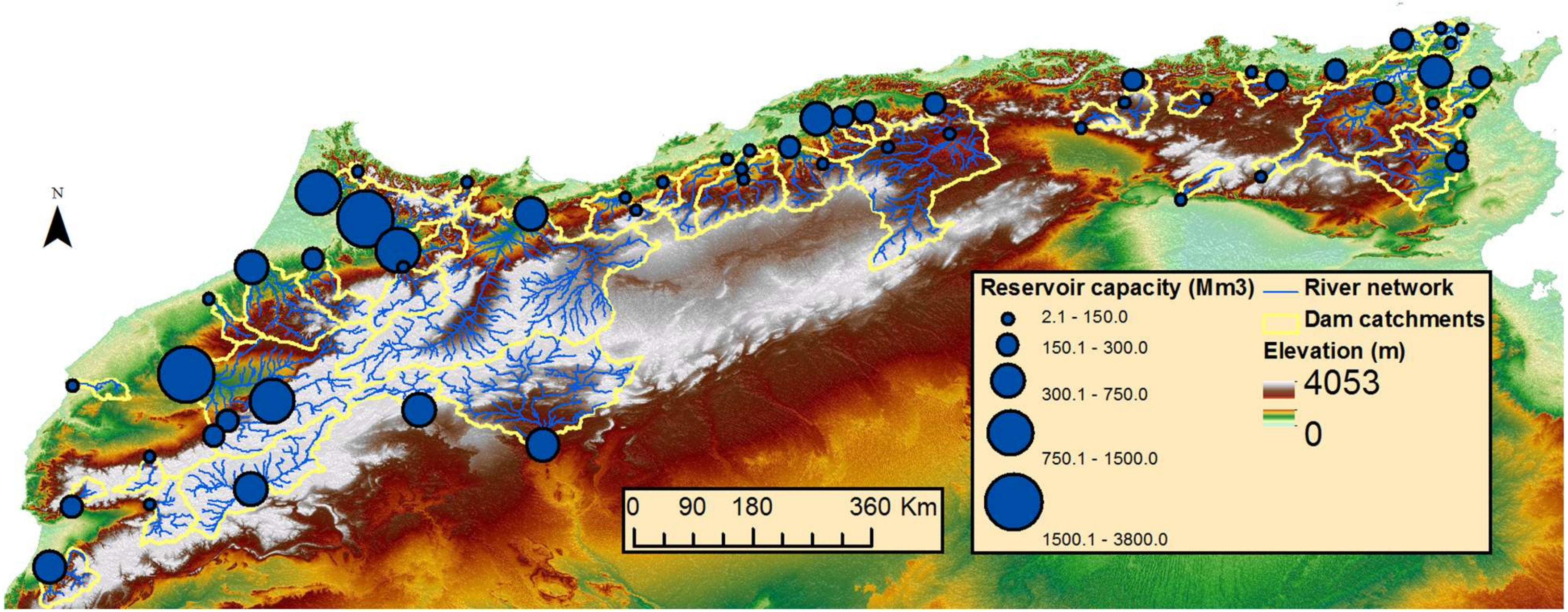
Rimini et al. 2003

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

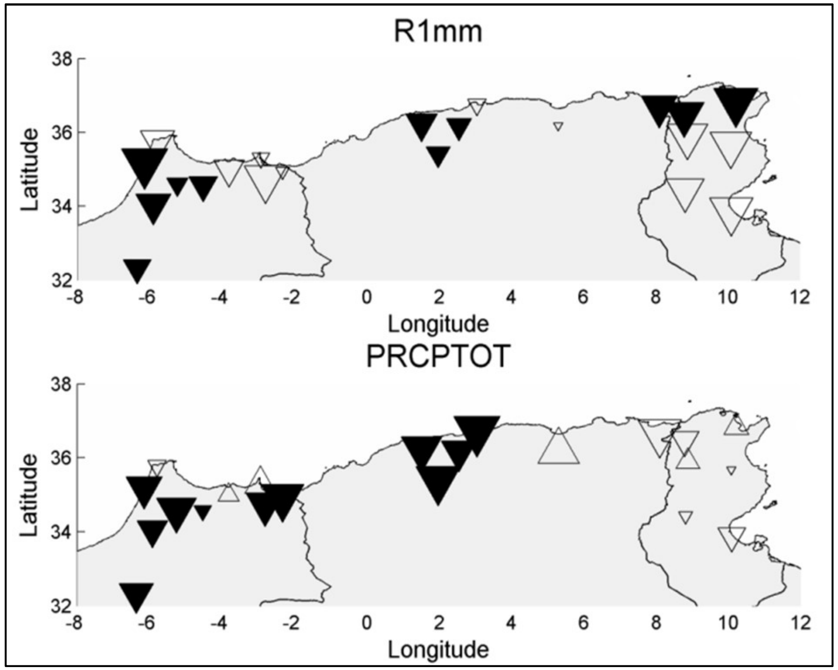


52 basins with a contributing area larger than 100km²

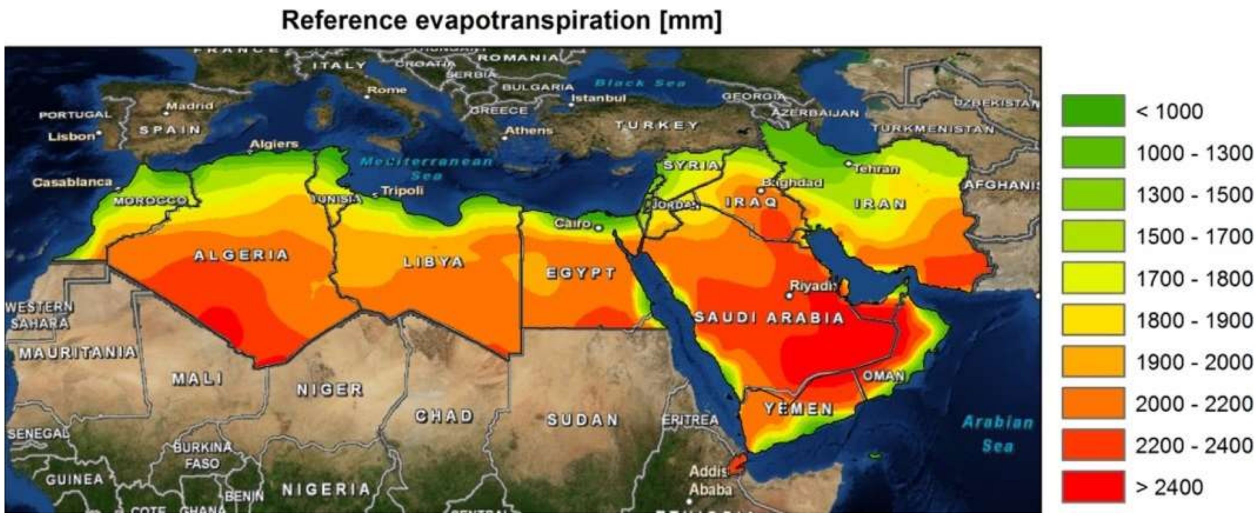
=> Crucial for the economy, they are basis for the study

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

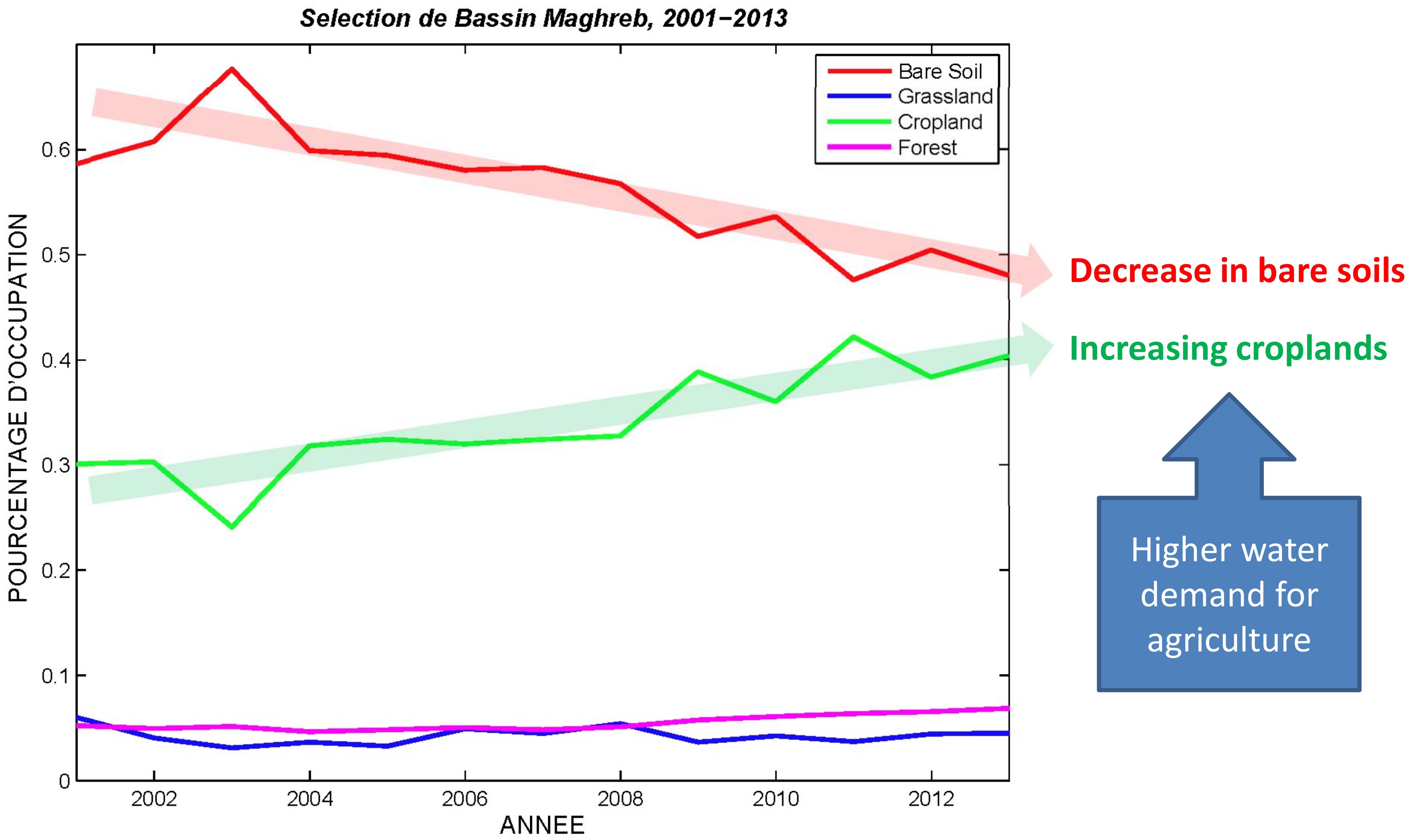


Stations with a **regionally significant** decrease in the frequency of wet days (R1mm) and precipitation totals (PRCPTOT) (Tramblay et al., 2013 NHESS)



Terink et al 2013

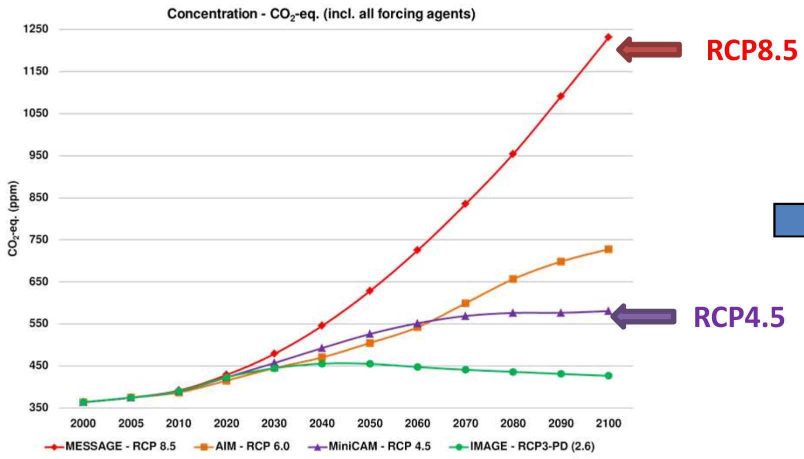
Changing land cover

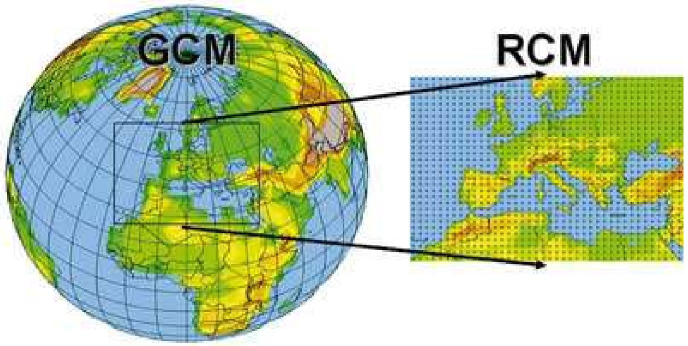


MODIS land cover analysis, L. Jarlan

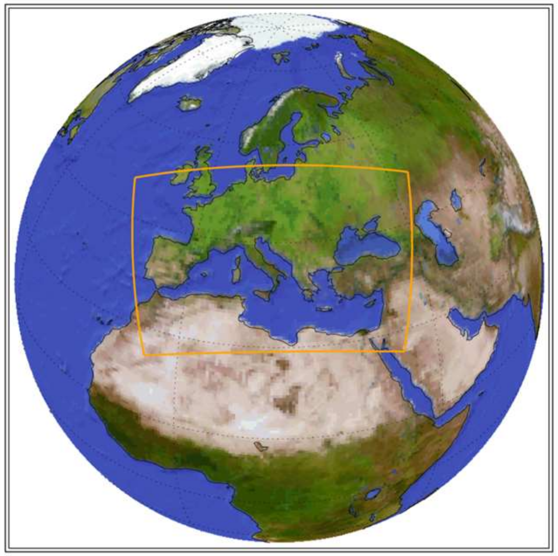
2-Regional climate scenarios

Regional climate simulations



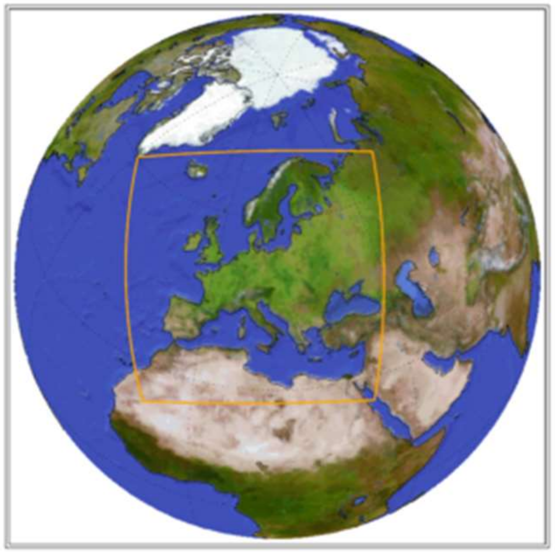


Med-CORDEX



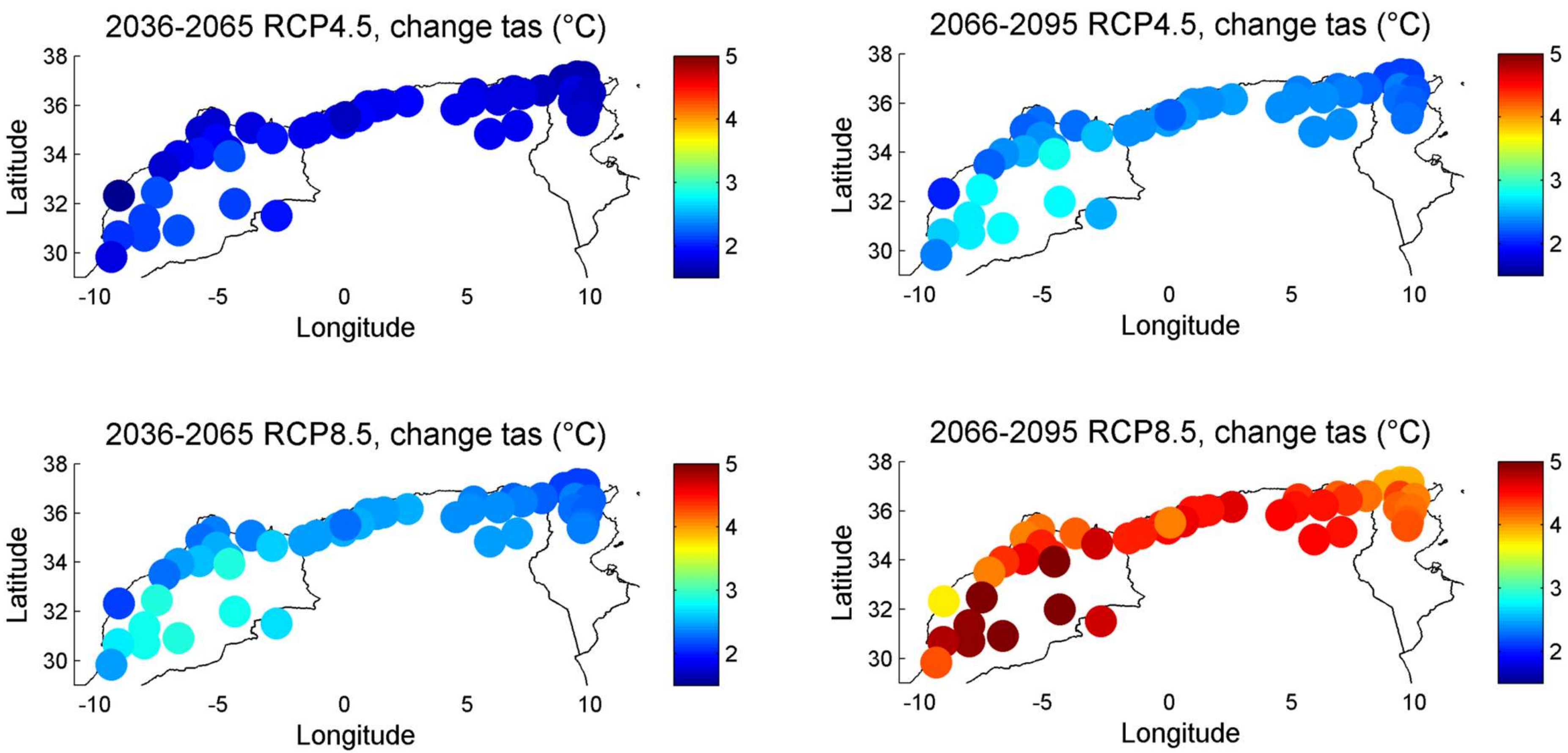
12km and 50km simulations (2 and 5 model runs, 5 GCM)

Euro-CORDEX



12km simulations (11 model runs, 5 GCM)

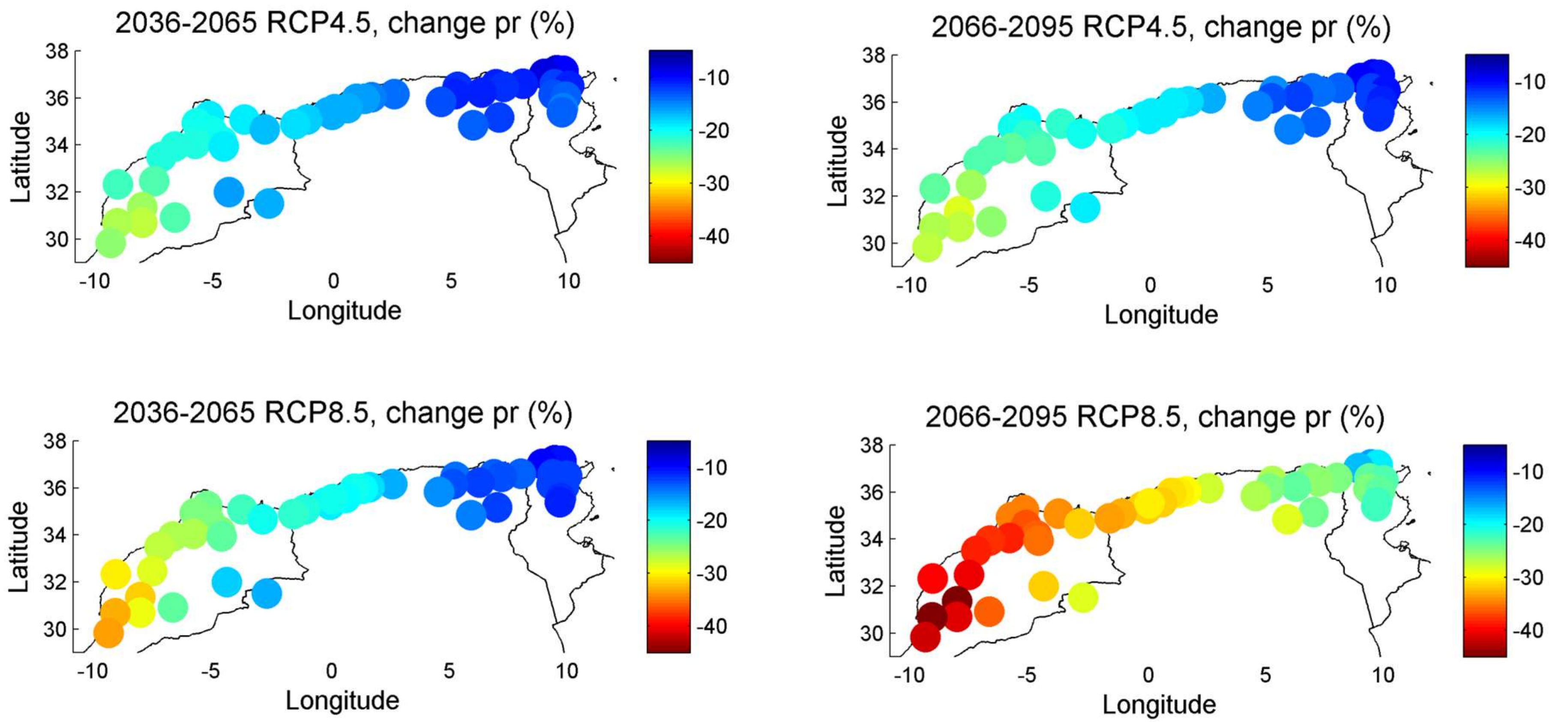
Temperature changes for 2036-2065 and 2066-2095



Tramblay et al., 2018

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

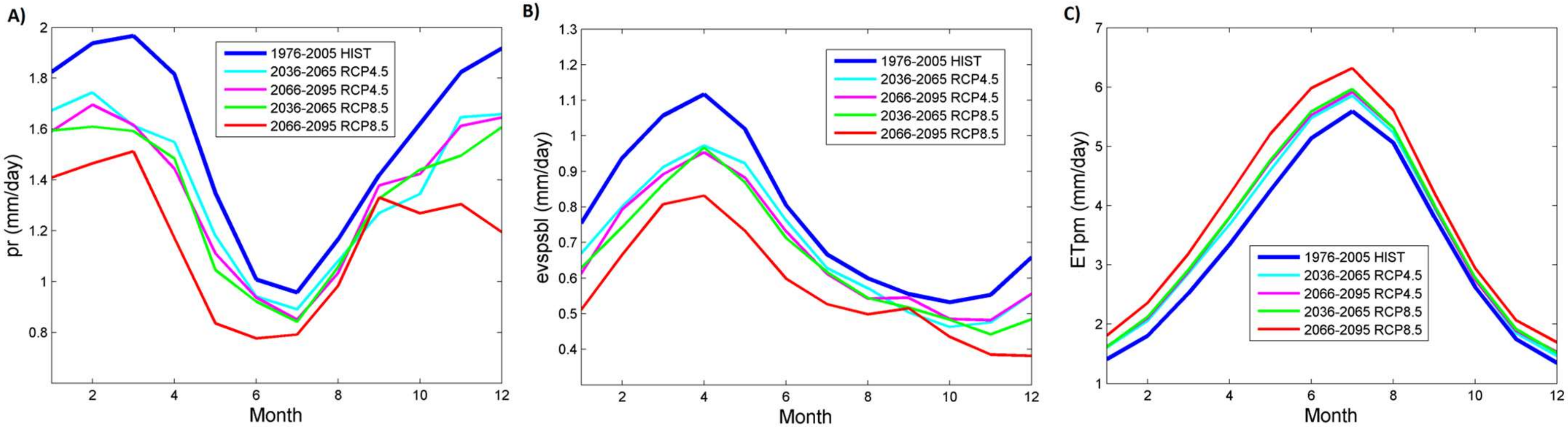
Precipitation changes for 2036-2065 and 2066-2095



Tramblay et al., 2018

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

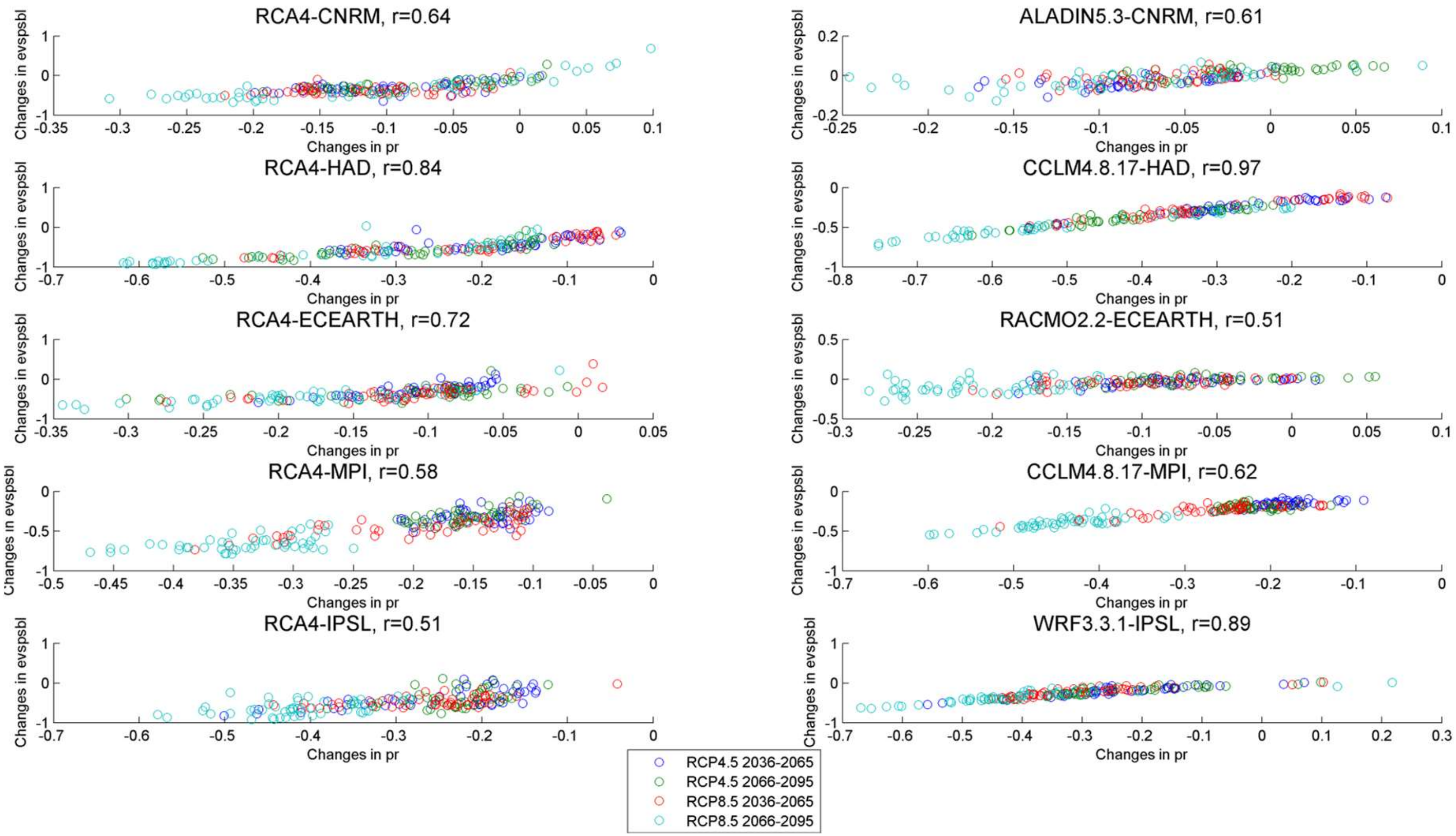
Seasonal cycles of precipitation (a), actual (b) and reference (c) evapotranspiration



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 of a strongly water-limited environment

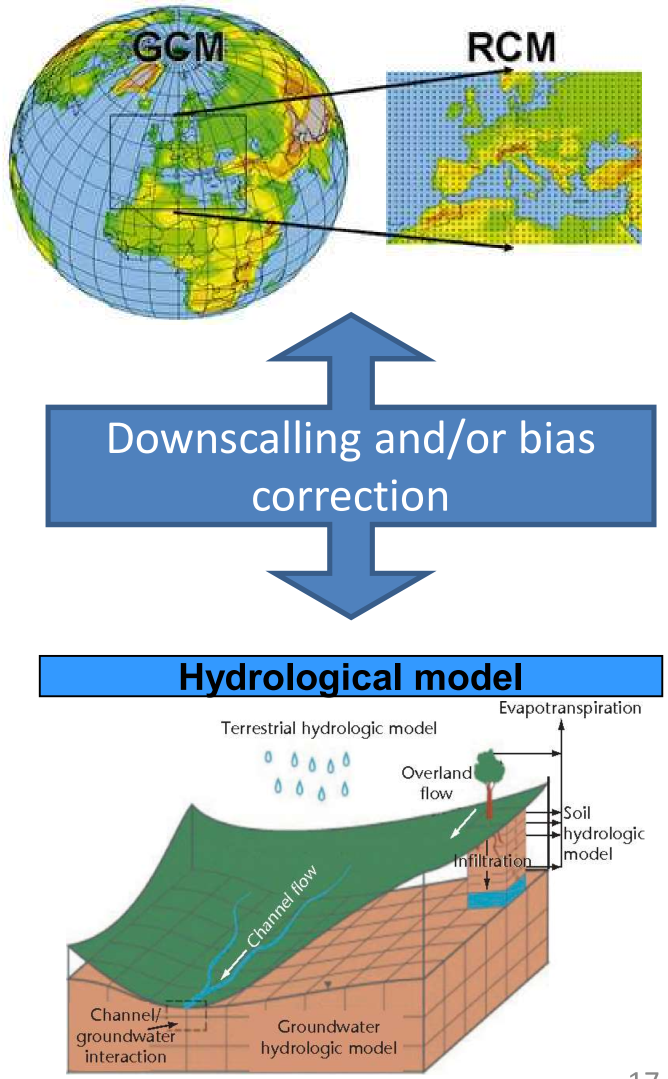
Tramblay et al., 2018

3-Hydrological scenarios

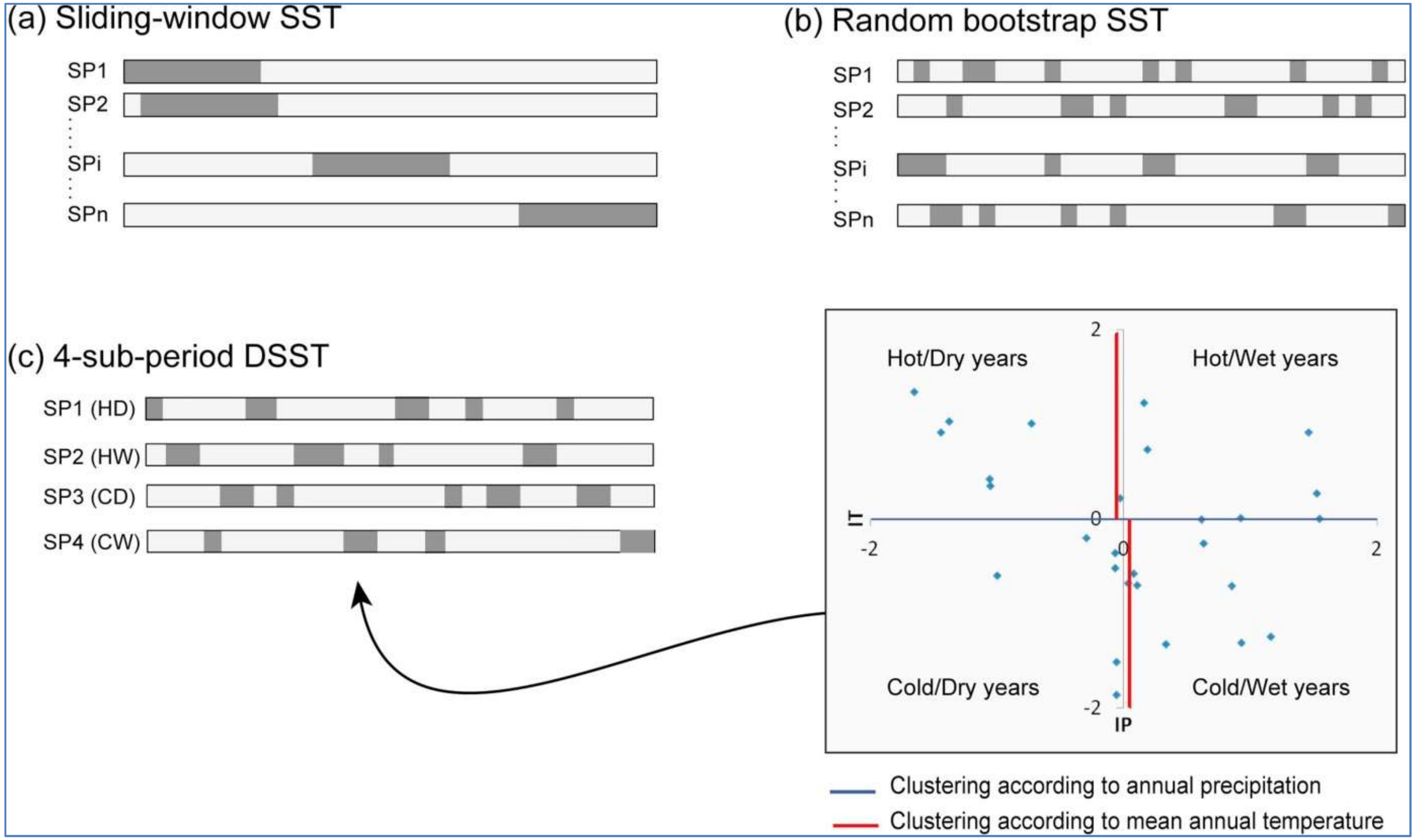
Methods for analyzing climate change impacts on hydrology

Uncertainties:

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



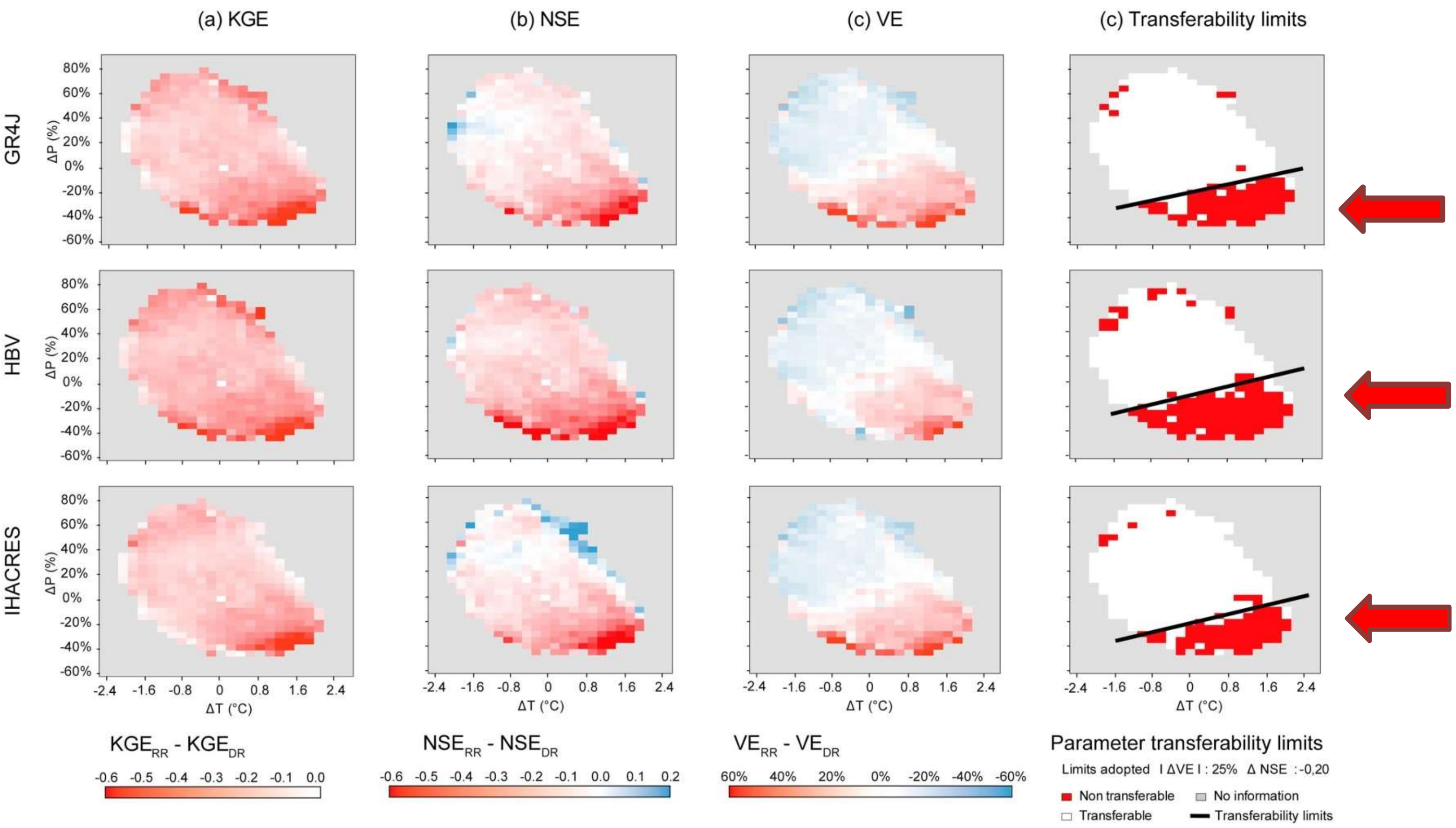
A framework to validate downscaling and hydrological models



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 and planning

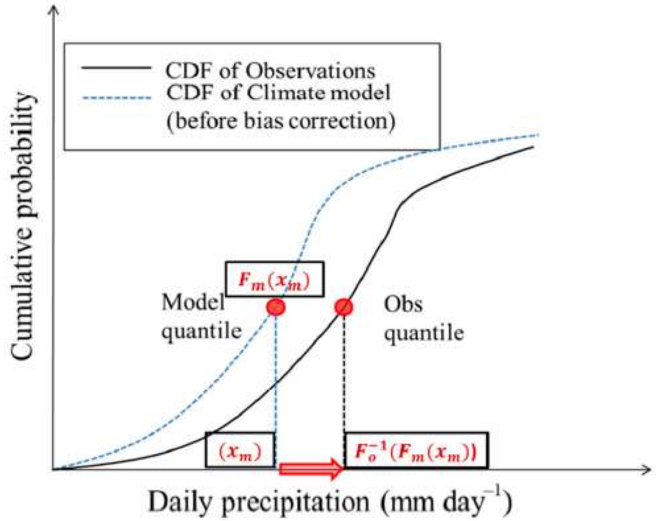


For climate conditions resembling to the most pessimistic scenarios, the daily models are unable to reproduce river runoff => monthly water balance models are preferred

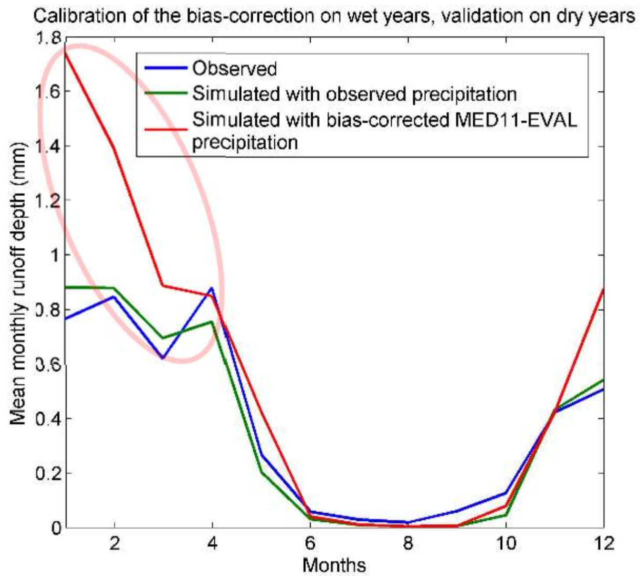
Dakhlaoui et al., 2017, 2019

Validation of bias-correction methods in Maghreb

A very common approach in hydrological impact studies is to bias-correct the outputs of RCM simulations



The standard method of quantile-mapping was found inefficient in semi arid areas with a large number of dry days

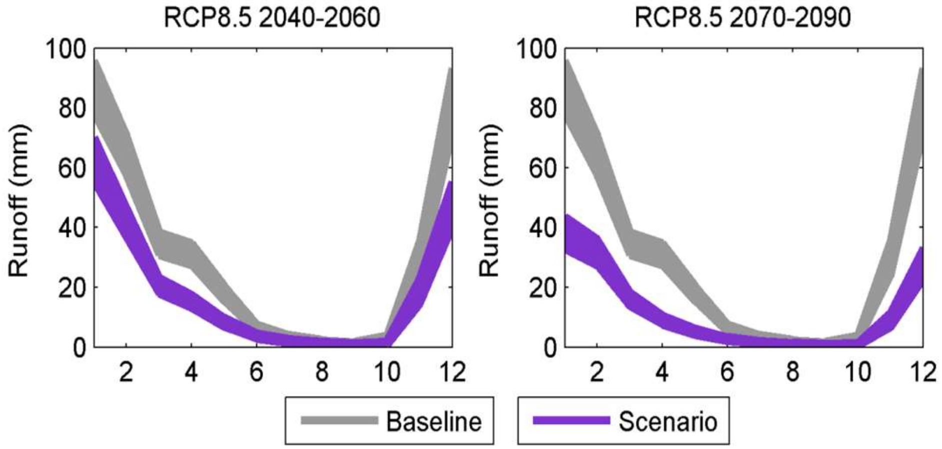


Tramblay et al. 2013

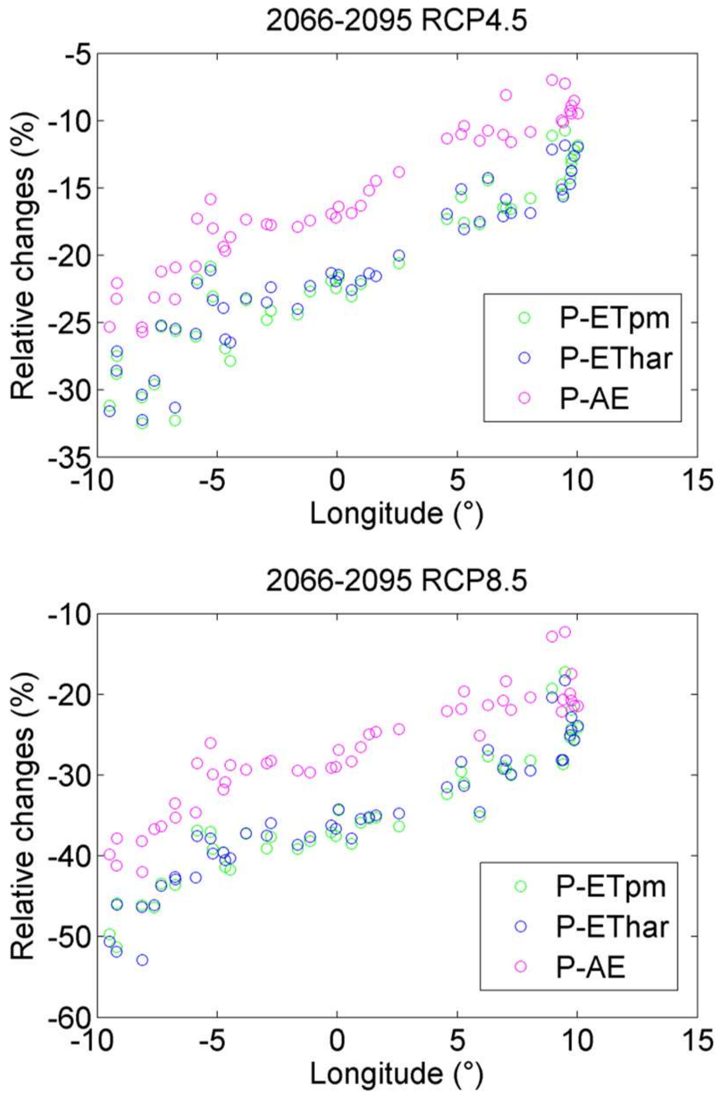
Proposition of a robust quantile perturbation method to overcome these limitations (Tramblay et al. 2013)

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

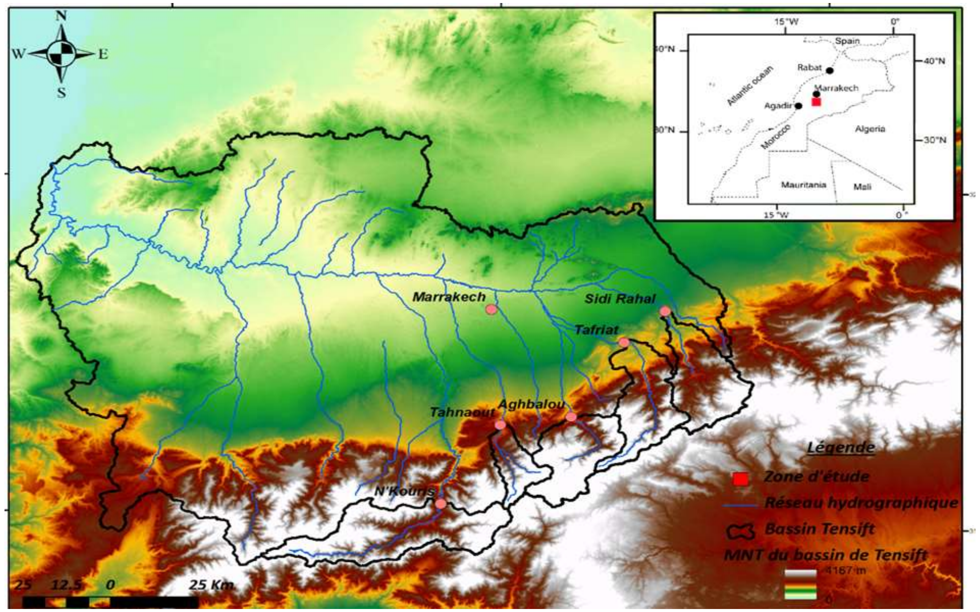
4-Case study in Morocco

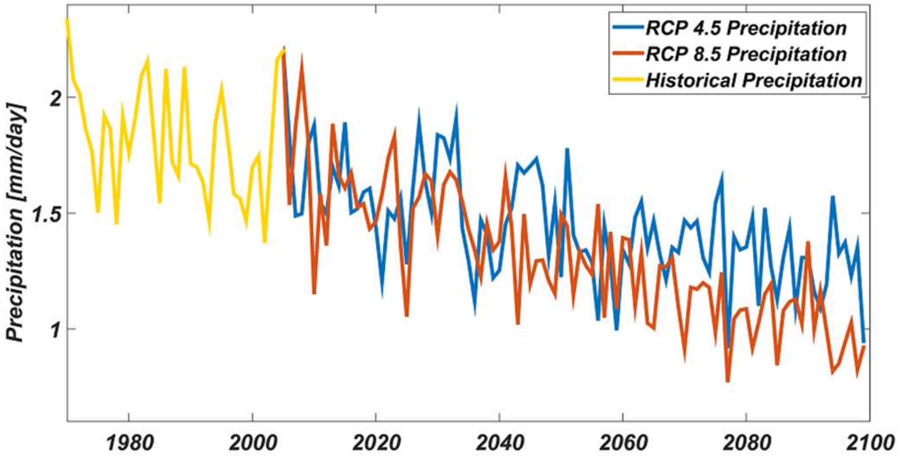
The Tensift bassin south of Morocco

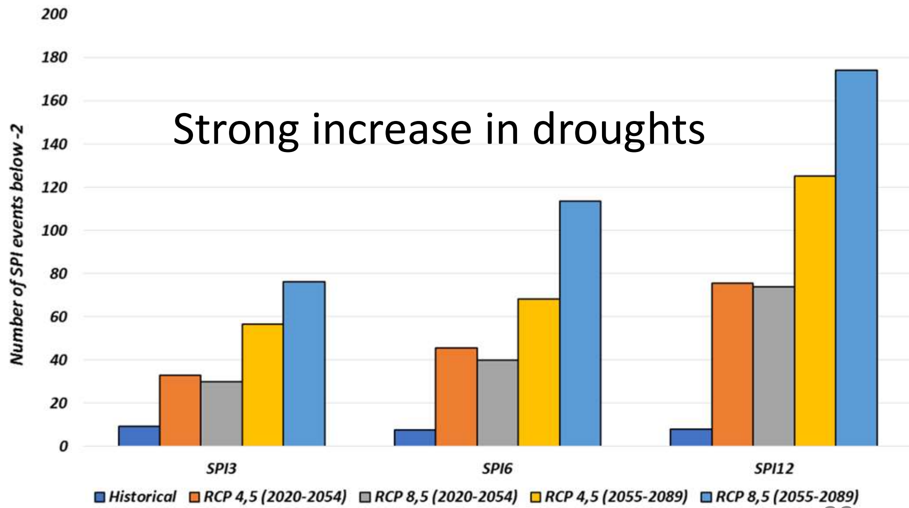
Semi-arid area already facing water stress

Importance of agricultural activities and tourism (city of Marrakech)

Strongest signal in North Africa for precipitation reduction

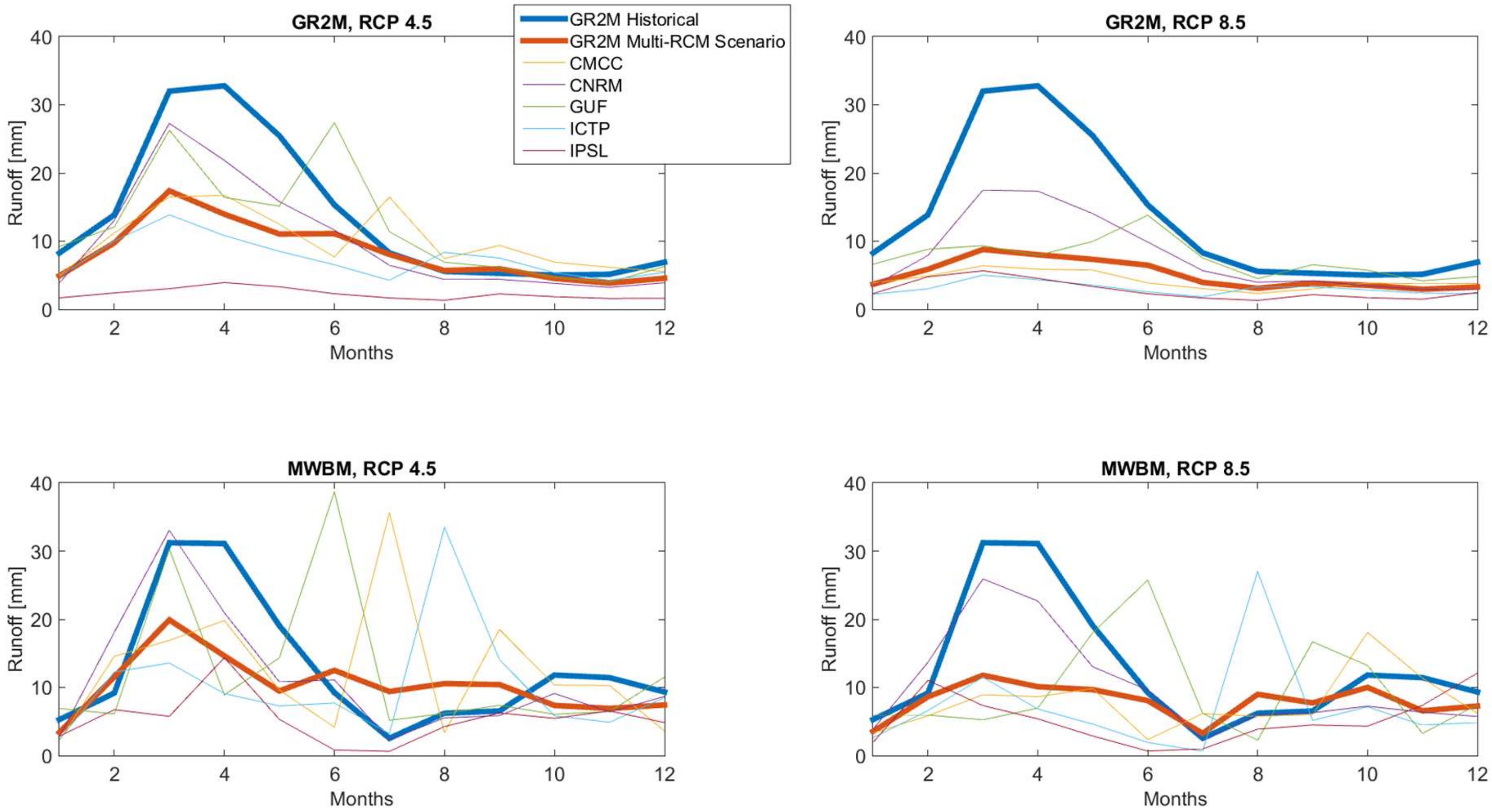






Zkhiri et al. 2019

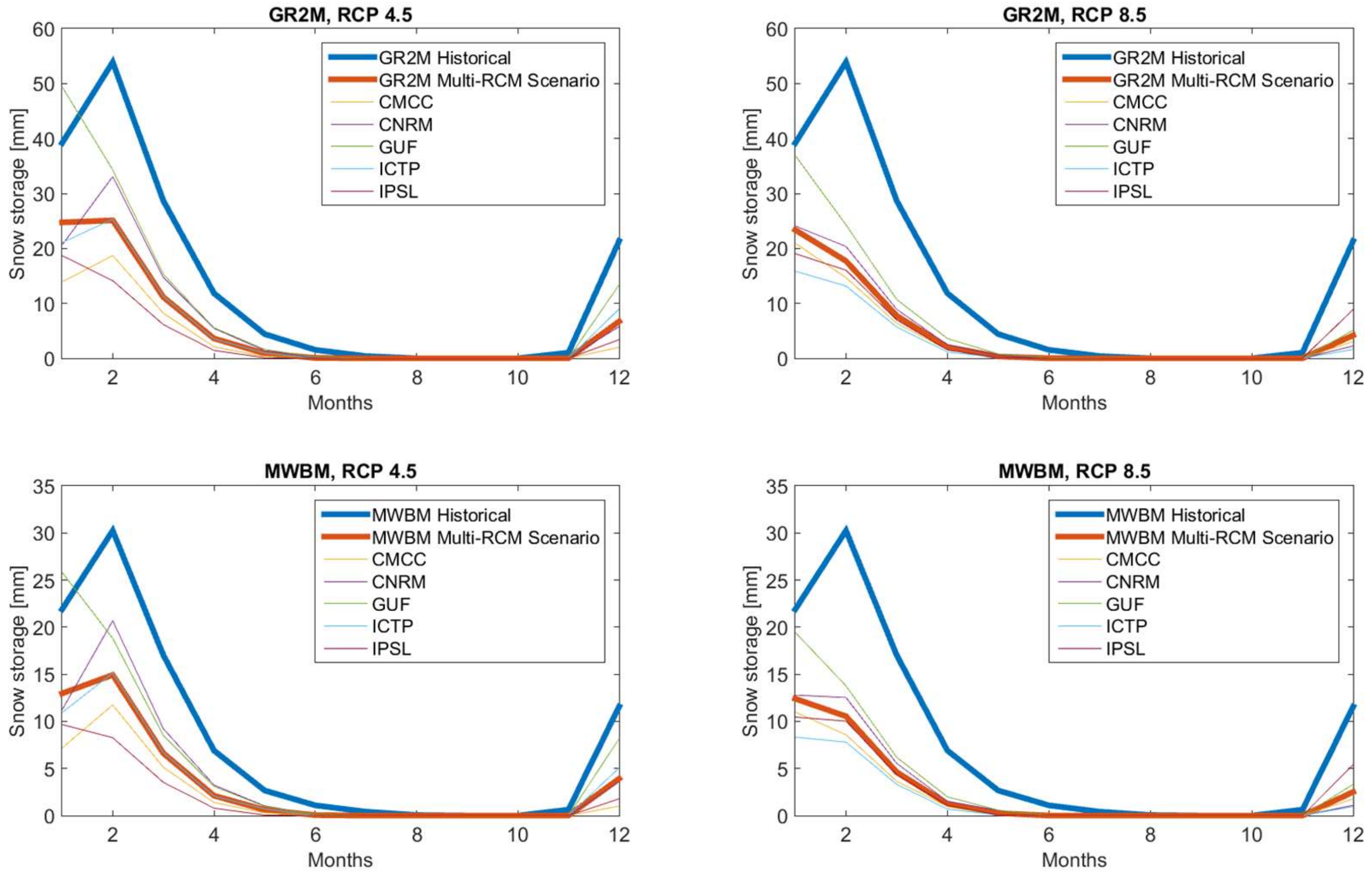
Hydrological runoff projections



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, in particular for Morocco
- There is a strong need for adaptation strategies and to develop monitoring and forecasting systems for droughts

Contributions :
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Khaoula Klouz (Master)
Mahdi Khalki (Master)
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References

Dakhlaoui H., Ruelland D., Tramblay Y., 2019. A bootstrap-based differential split-sample test to assess the transferability of conceptual rainfall-runoff models under past and future climate variability. Journal of Hydrology 575, 470-486

Zkhiri W., Tramblay Y., Hanich L., Jarlan L., Ruelland D., 2019. Spatiotemporal characterization of current and future droughts in the High-Atlas basins (Morocco). Theoretical and Applied Climatology 135, 593-605

Tramblay Y., Jarlan L., Hanich L., Somot S., 2018. Future scenarios of surface water resources availability in North African dams. Water Resources Management 32(4), 1291-1306.

Dalkhlaoui H., Ruelland D., Tramblay Y., Bargaoui Z., 2017. Evaluating the robustness of conceptual rainfall-runoff models under climate variability in northern Tunisia. Journal of Hydrology 550, 201-217

Filahi S., Tramblay Y., Mouhir L., Diaconescu E.P., 2017. Projected changes in temperature and precipitation in Morocco from high-resolution regional climate models. International Journal of Climatology 37(14), 4846-4863

Marchane A., Jarlan L., Boudhar A., Tramblay Y., Hanich L., 2016. Linkages between Snow Cover, temperature and rainfall and the North Atlantic Oscillation over Morocco. Climate Research 69, 228-338

Tramblay Y., Ruelland D., Hanich L., Dakhlaoui H. Hydrological impacts of climate change in North African countries. In : Thiébault S. (ed.), Moatti Jean-Paul (ed.). The Mediterranean region under climate change : a scientific update. Marseille : IRD ; AllEnvi, 2016, p. 295-302. (Synthèses). ISBN 978-2-7099-2219-7

Foughali A., Tramblay Y., Bargaoui Z., Carreau J., Ruelland D., 2015. Hydrological modeling in North Tunisia with regional climate model outputs: performance evaluation and bias-correction in present climate conditions. Climate, 3(3), 459-473

Bargaoui Z., Tramblay Y., Lawin E., Servat E., 2014. Seasonal precipitation variability in regional climate simulations over Northern basins of Tunisia. International Journal of Climatology 34, 235-248.

Tramblay Y., Ruelland D., Somot S., Bouaicha R., Servat E., 2013. High-resolution Med-CORDEX regional climate model simulations for hydrological impact studies: a first evaluation of the ALADIN-Climate model in Morocco. Hydrology and Earth System Sciences 17, 3721-3739