AMETHYST

Assessment of changes in MEdiTerranean HYdro-resources in the South:
river basin Trajectories

Future Evolution of Water Resources over North Africa

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2 CESBIO, Toulouse
3 IRSTEA, Aix en Provence
4 MERCATOR, Toulouse
5 ENSAT, Tunis, Tunisia
6 IIS, Univ. Tokyo

Context :

Mediterranean is a so-called ***climate change hotspot region*** in CMIP5 runs :

- moderate →
    - for RCP4.5 by mid-century
- strong →
    - under higher forcing levels (RCP8.5)
    - near the end of the 21st century (feedbacks)

Diffenbaugh and Giorgi (2012)

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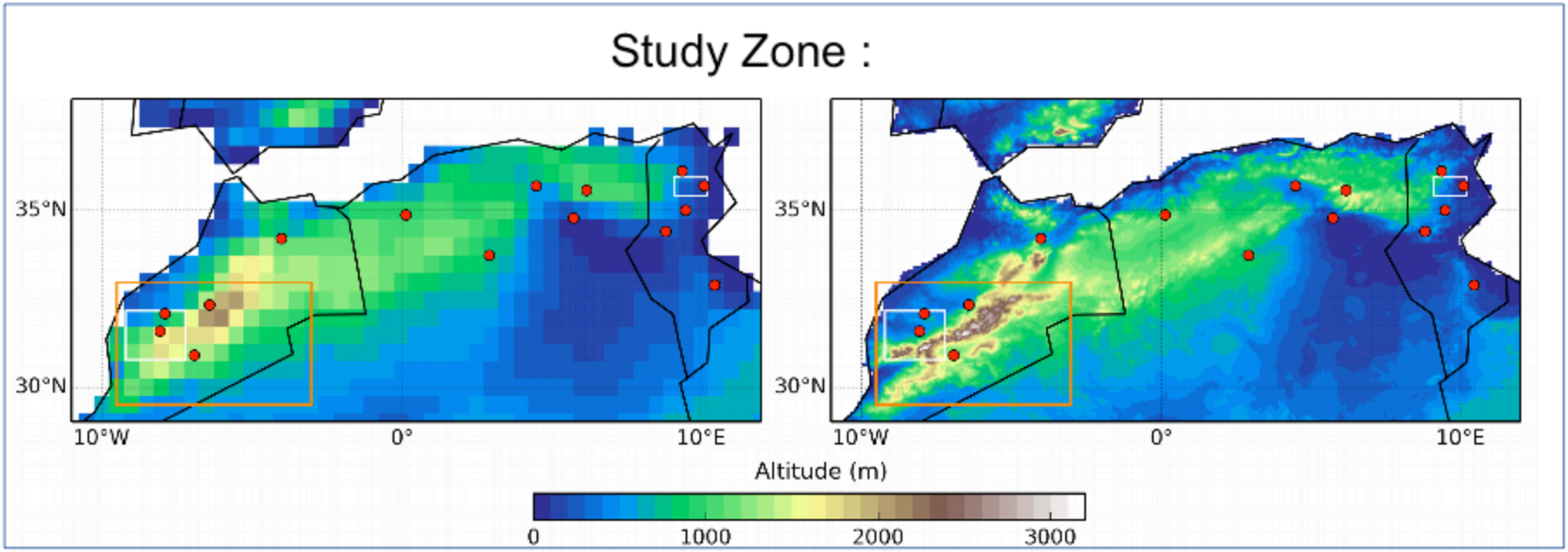

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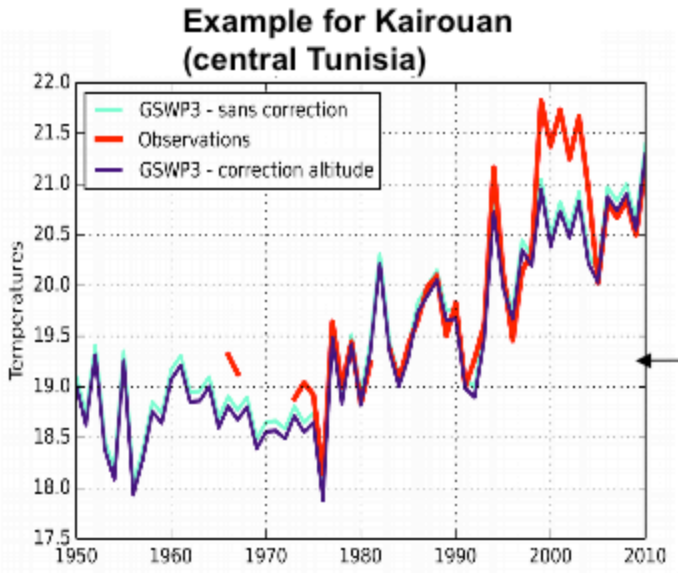
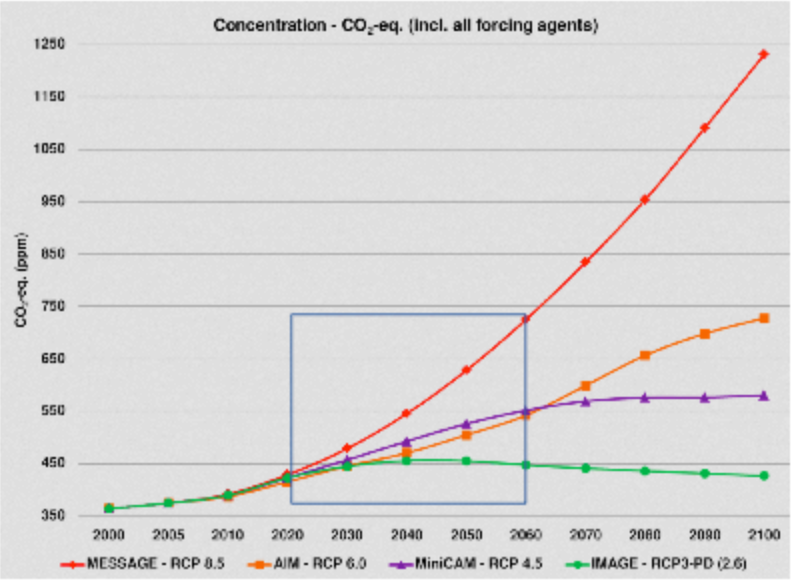


- Significant demographic changes
- Limited water resources
- Water being exported via agriculture
- Already significant warming

- **Objectives** :
  - Study the projected water resource evolution for the *Horizon 2050*
  - **Method :** Use several climate scenarios, 2 RCP projections, 2 standard statistical methods (*futurization*), Impacts using an LSM → ISBA-SURFEX

- Med-CORDEX database:
  - Core runs : 50 km resolution,
  - Historical (1986-2005): forced by ERA-Interim
  - Future : RCP4.5 and RCP8.5, Time slices : 2021-2040 et 2041-2060



Regional Climate Models used:

- **CNRM** Météo-France
- **LMD** Laboratoire de Météorologie Dynamique, IPSL
- **CMCC** Centro Euro-Mediterraneo sui Cambiamenti Climatici

Futurisation of climate data:

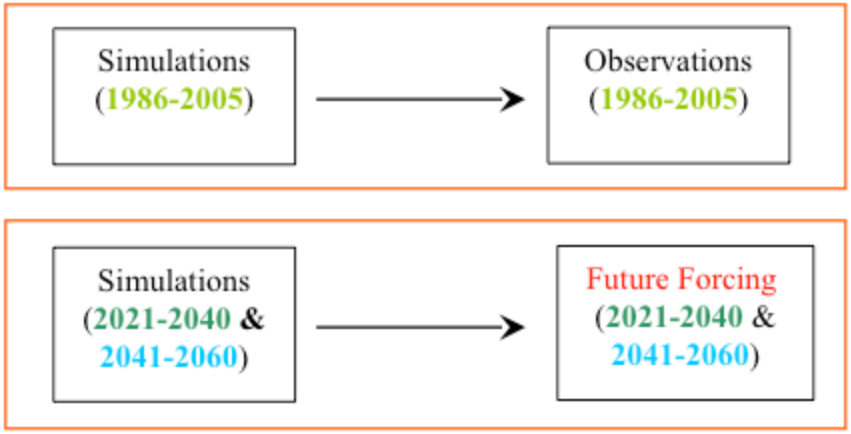
Reference Meteorological Variables : **GSWP3**

(H. Kim et al., Reanalysis at 0.5°)

- *Futurize* air temperature and precipitation
- Modified : Specific humidity (RH constant) & CO2

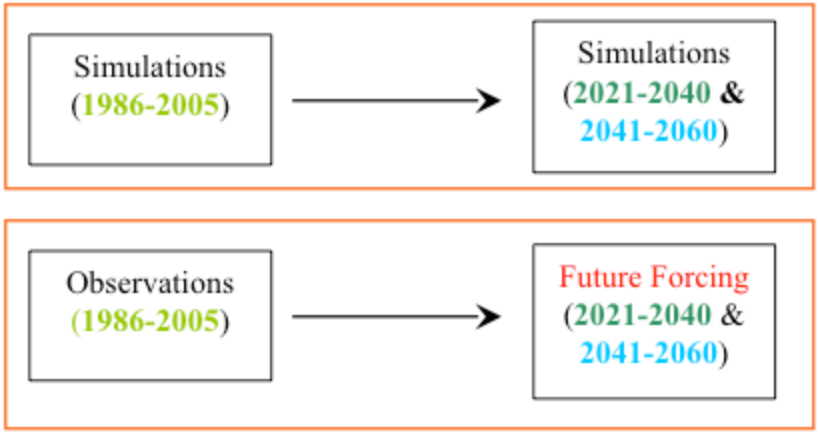
Quantile-quantile

De-bias past model simulations using observations/reference and apply to future simulation



Perturbation

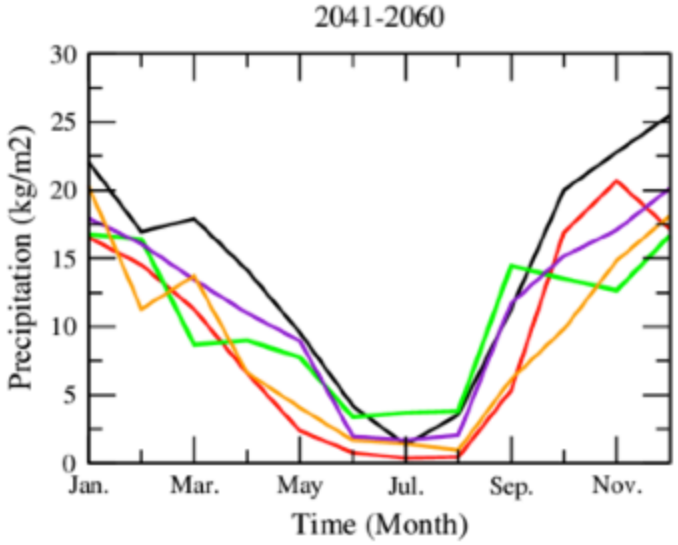
Predicted evolution (change) by a model applied to observations (or reference)

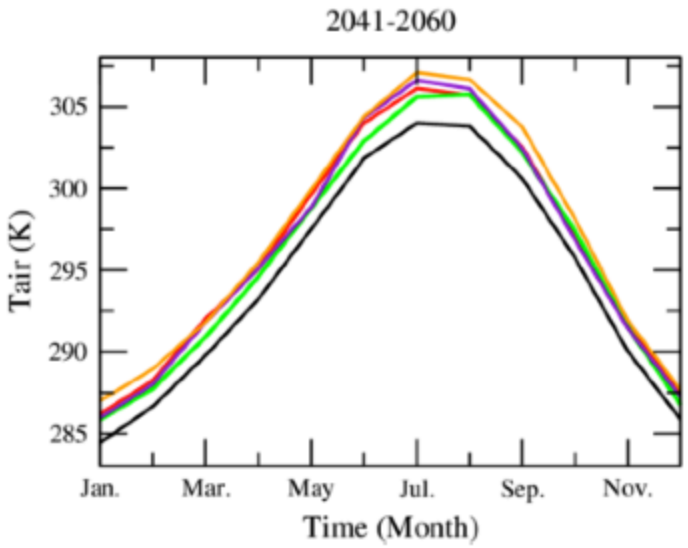


Futurisation of climate data:

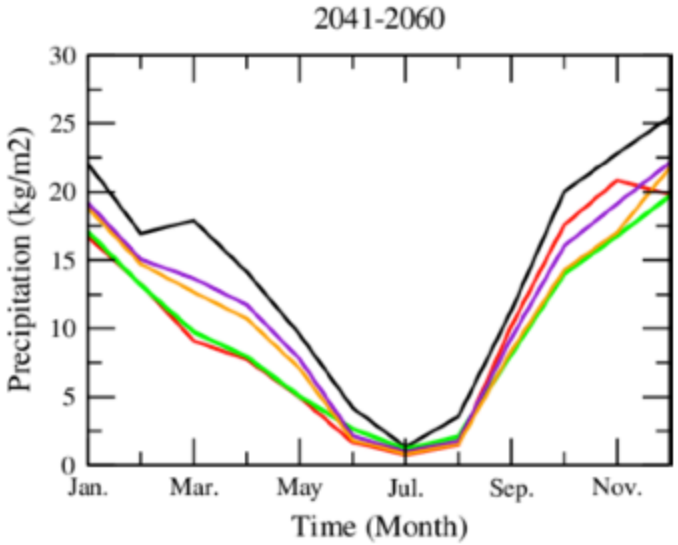
Horizon 2050, RCP8.5

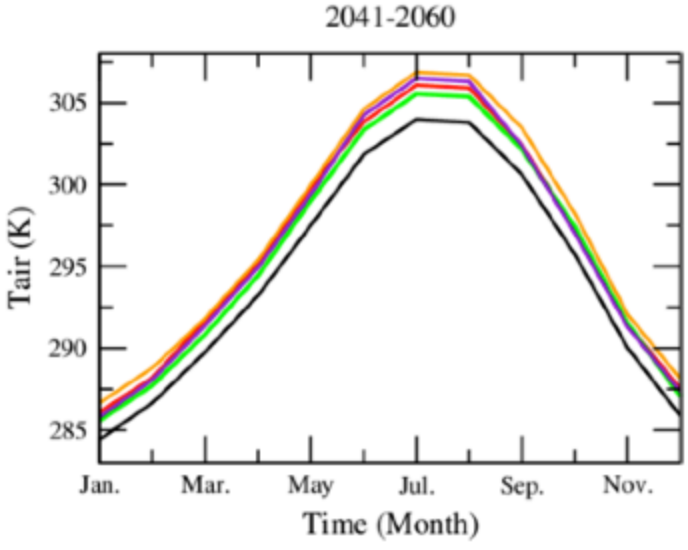
Quantile-quantile





Perturbation

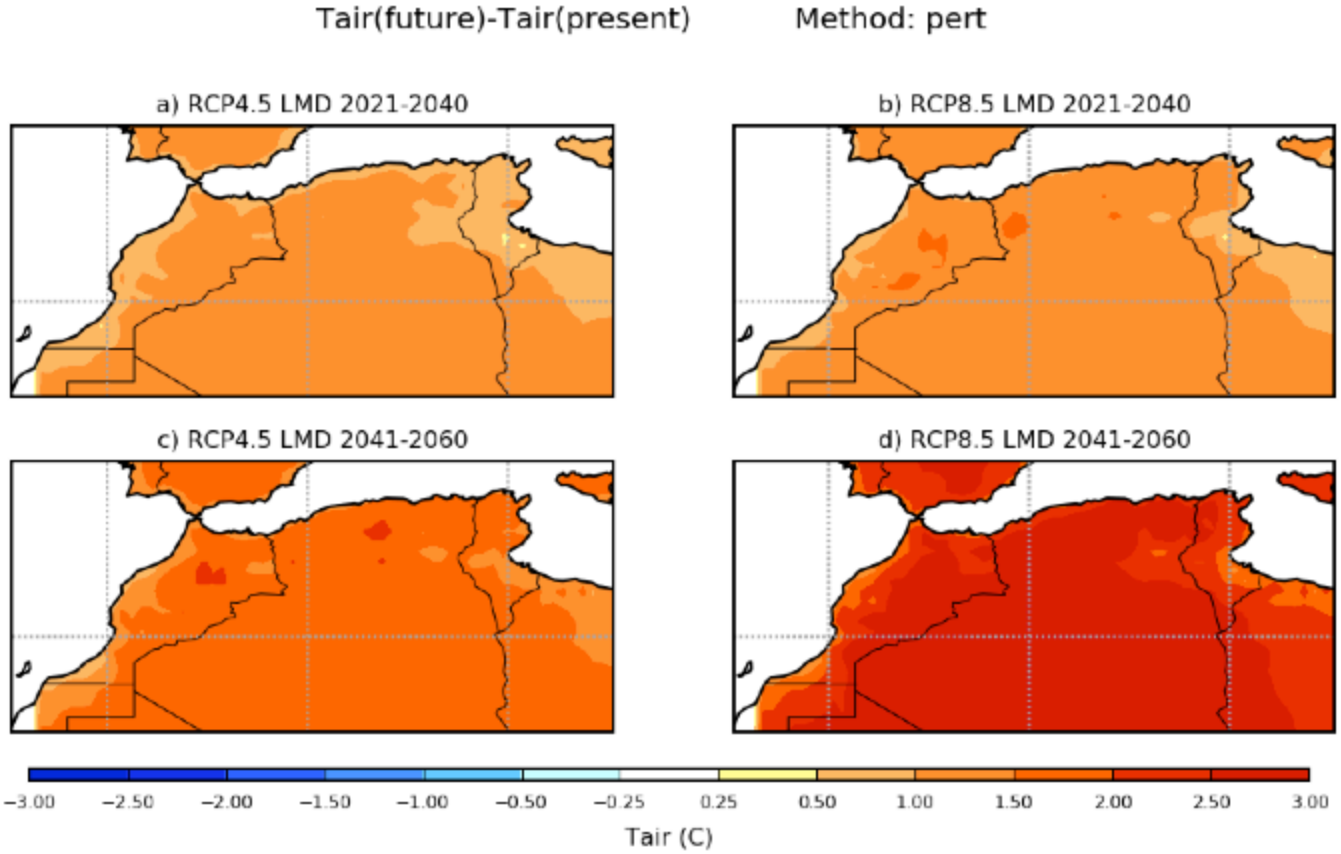




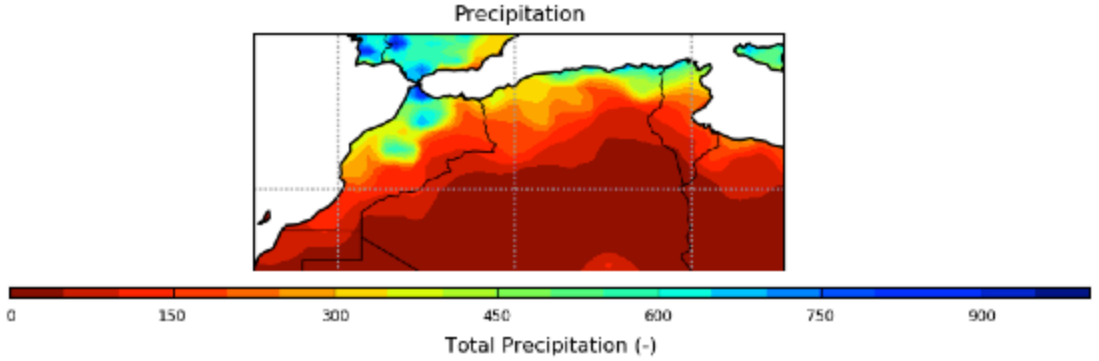
METEO FRANCE

Futurisation of climate data:

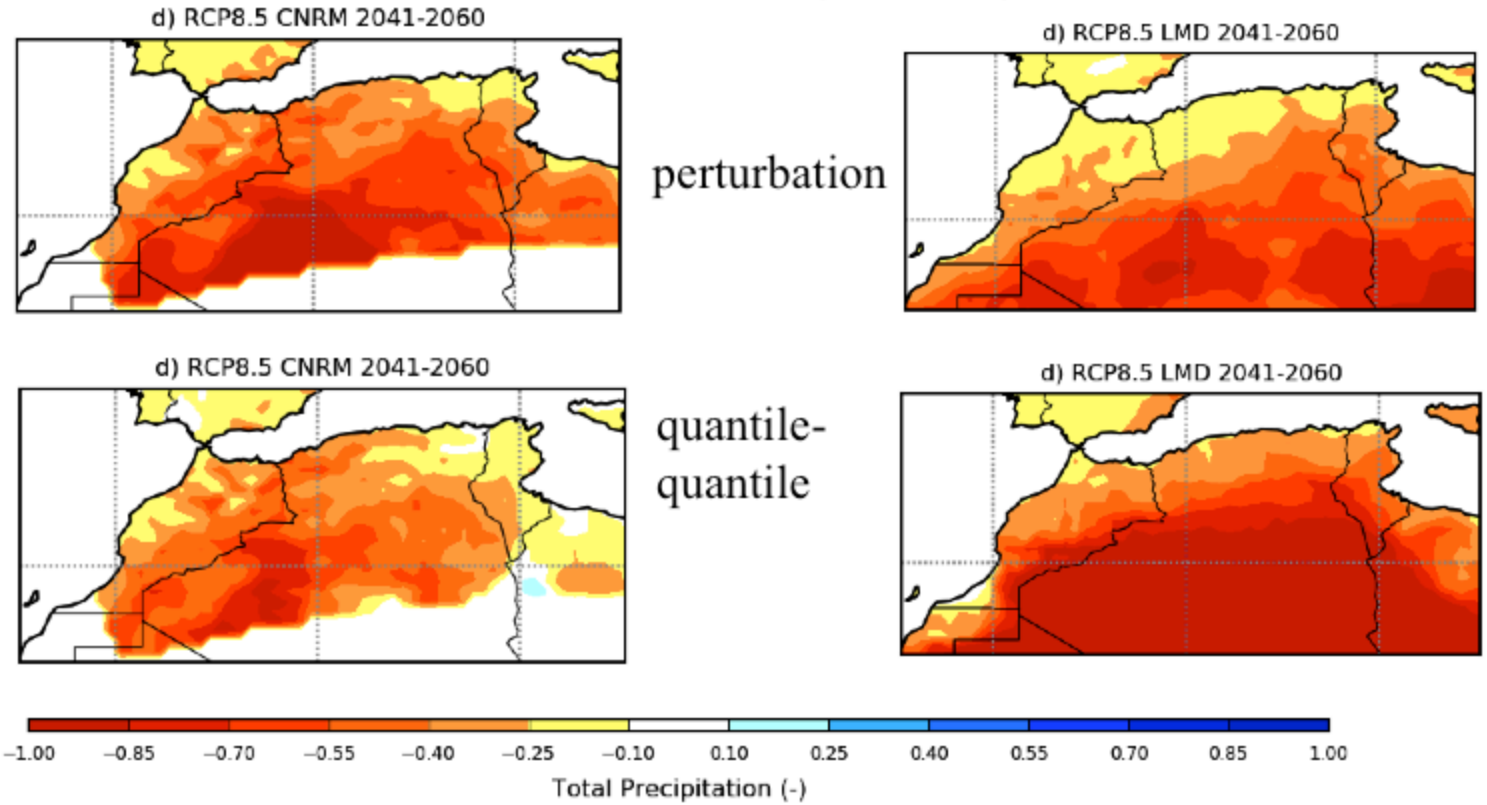
Example for LMD :
All models have similar spatially « flat » pattern and dT….



Futurisation of climate data:

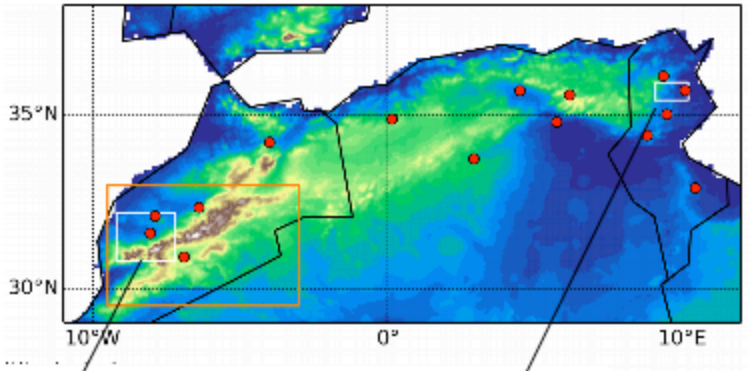


Precipitation (Rel-diffs)

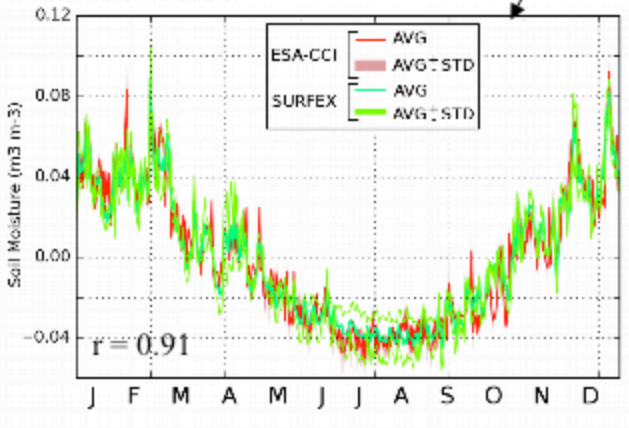


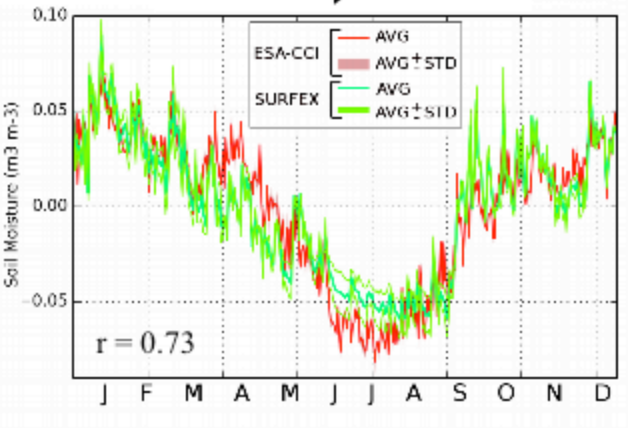
Simulations : Recent Past

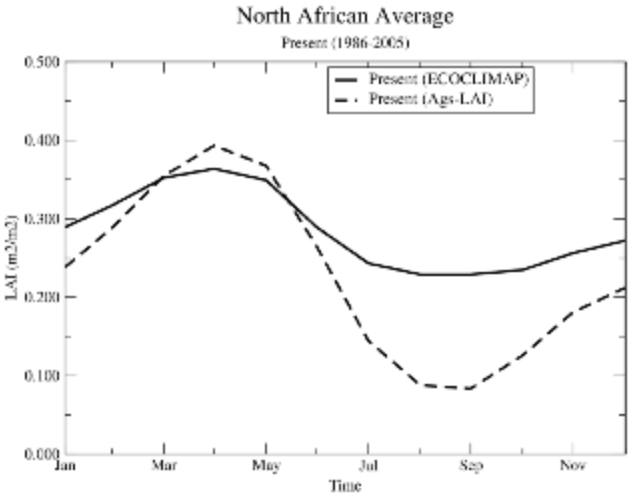
Simulations with SURFEX :
Comparisons with ESA-CCI, GRACE, GLEAM,...(AMETHYST WP report….)



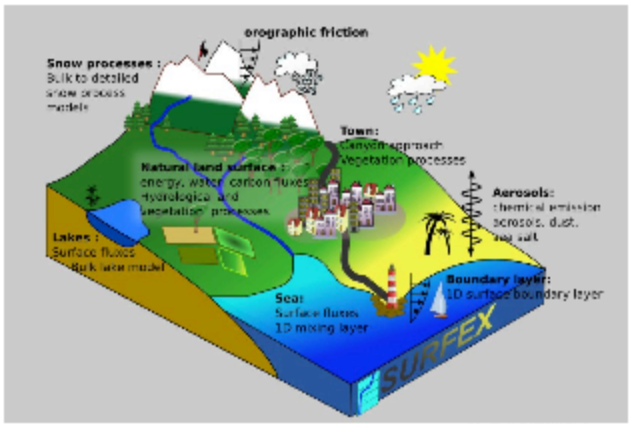
SURFEX vs. ESA-CCI (1991-2010)
Daily superficial soil moisture anomalies



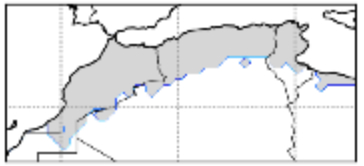




SURFEX-simulated monthly-average LAI

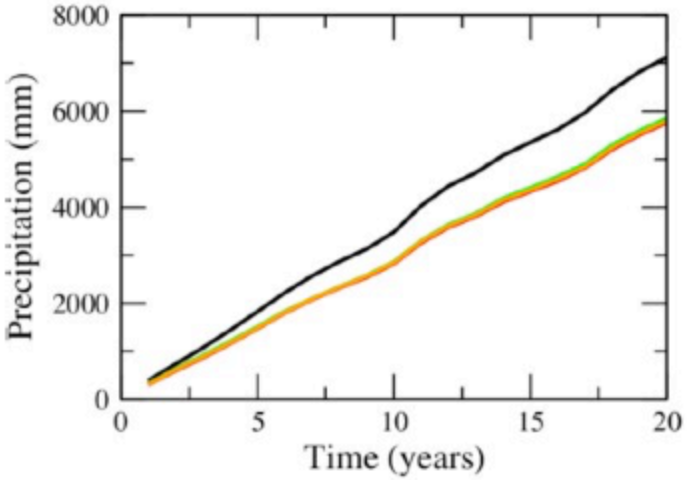


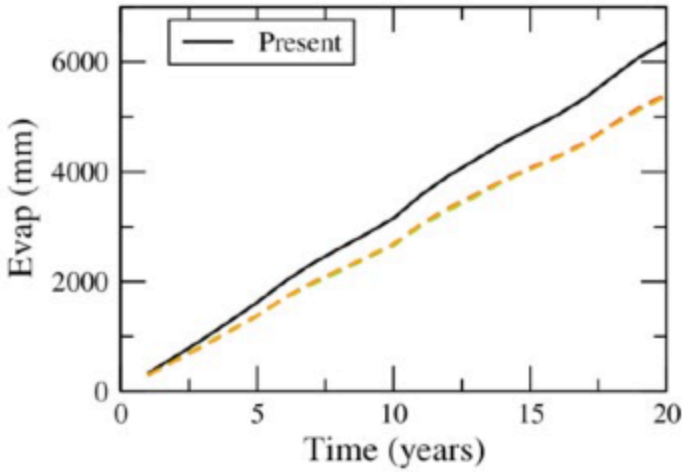
Simulated Impact :

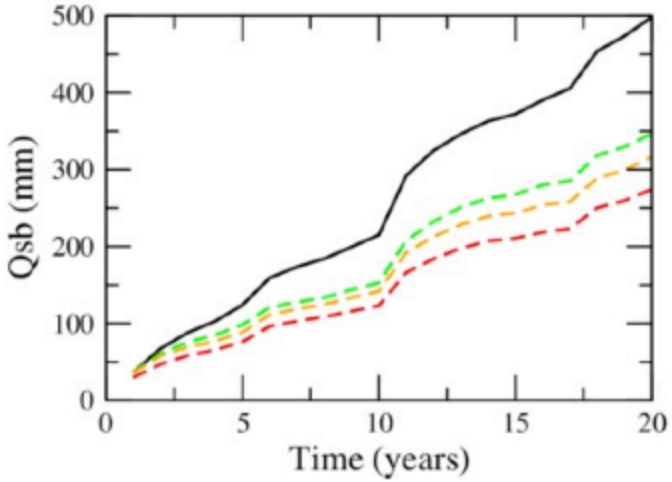


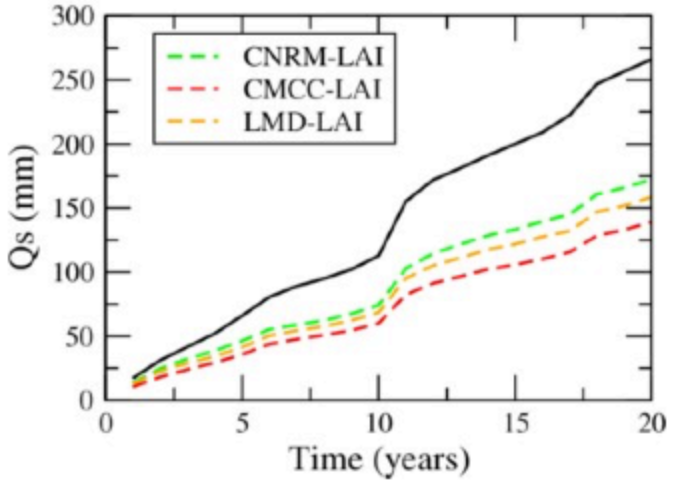
RCP8.5 1986-2005 vs 2041-2060

Method: pert

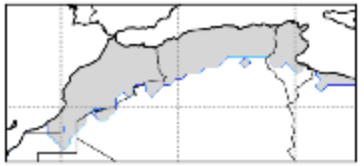






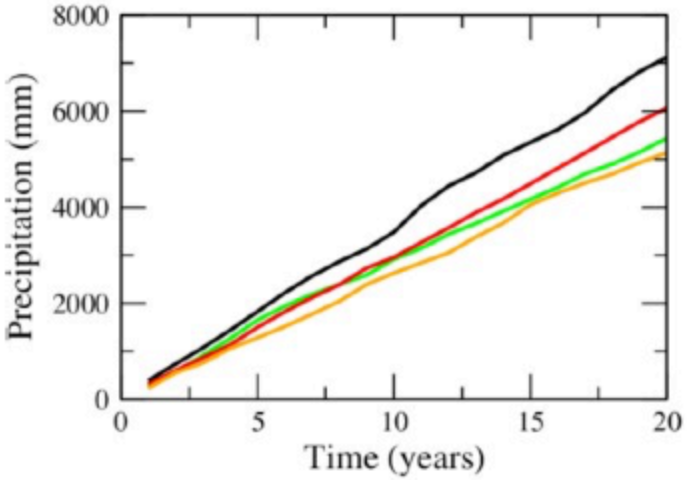


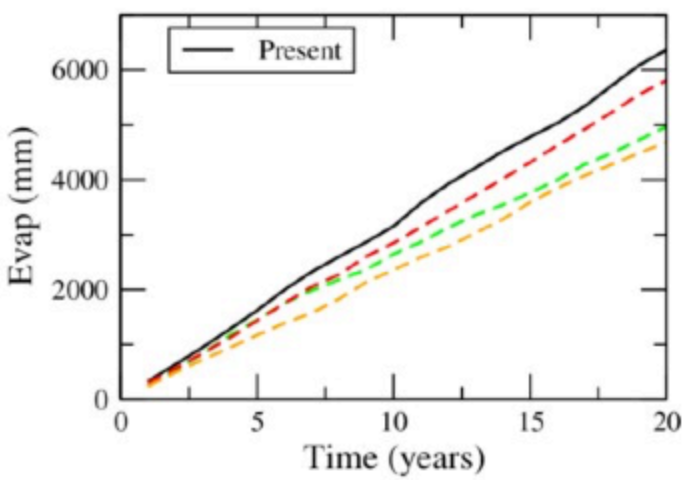
Simulated Impact :

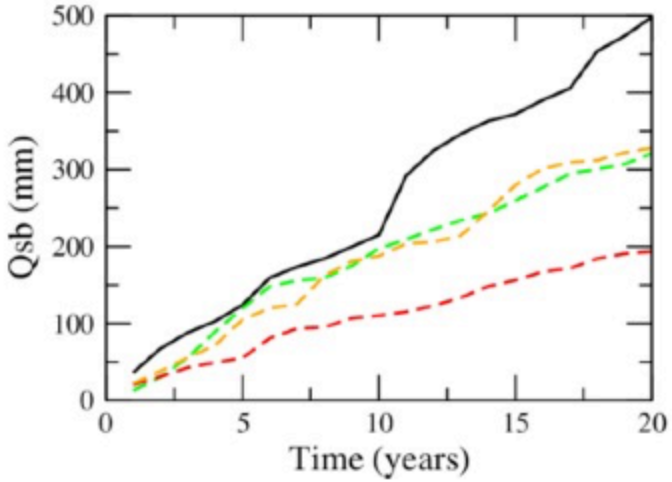


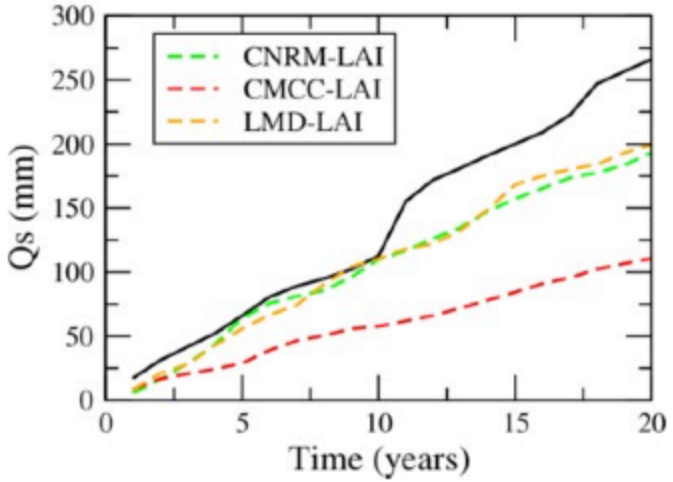
RCP8.5 1986-2005 vs 2041-2060

Method: q-q







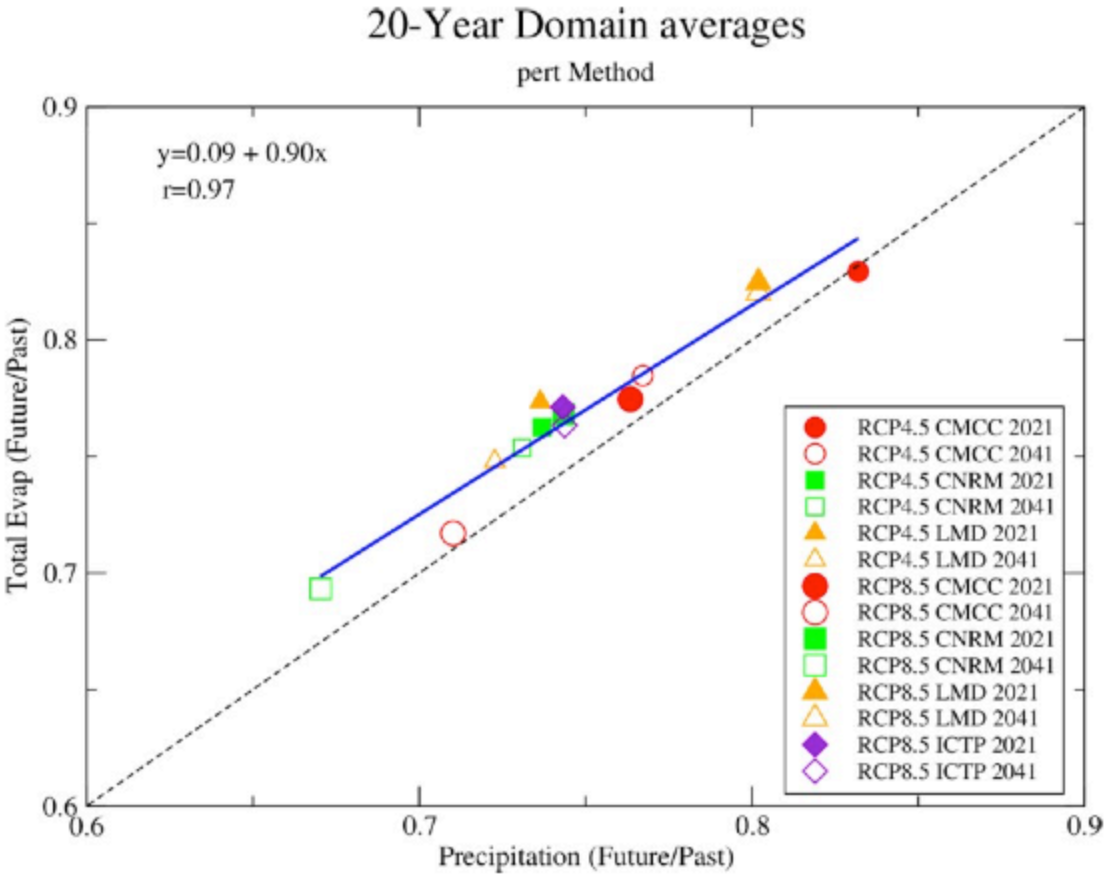


Simulated Impact :

Approximately 70 to 85 % of the Precipitation is Evaporated

Relationship between reduced rainfall and Evap is nearly linear (for both the perterbation and q-q, not shown, methods).

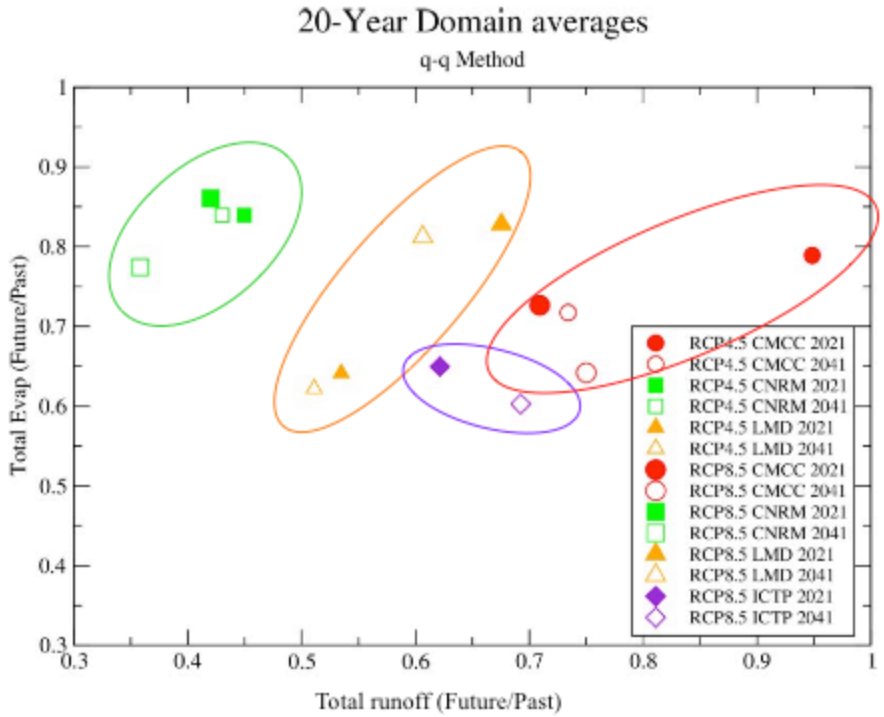
Total runoff is significantly reduced, but there is not a consistent statistical relationship with reduced Rainfall.

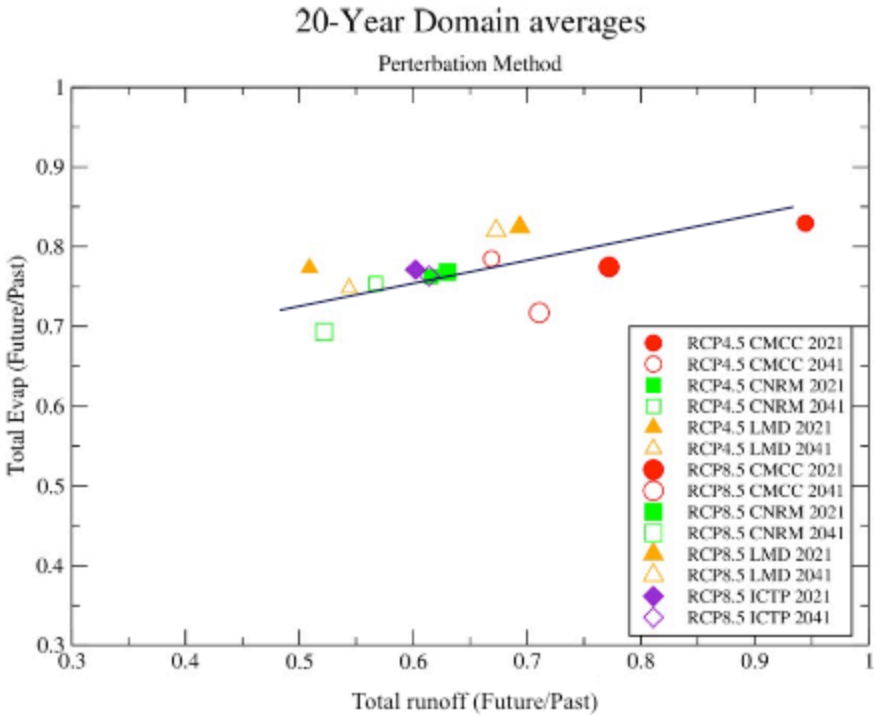


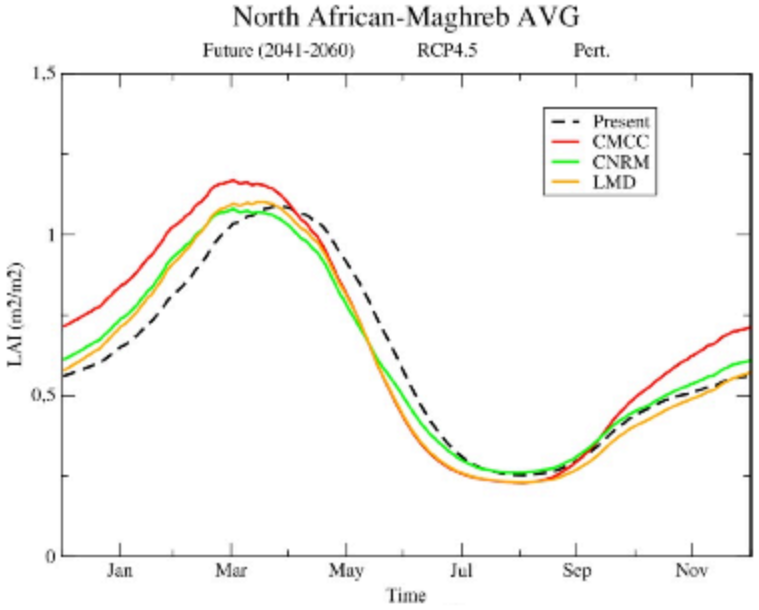
Simulated Impact :

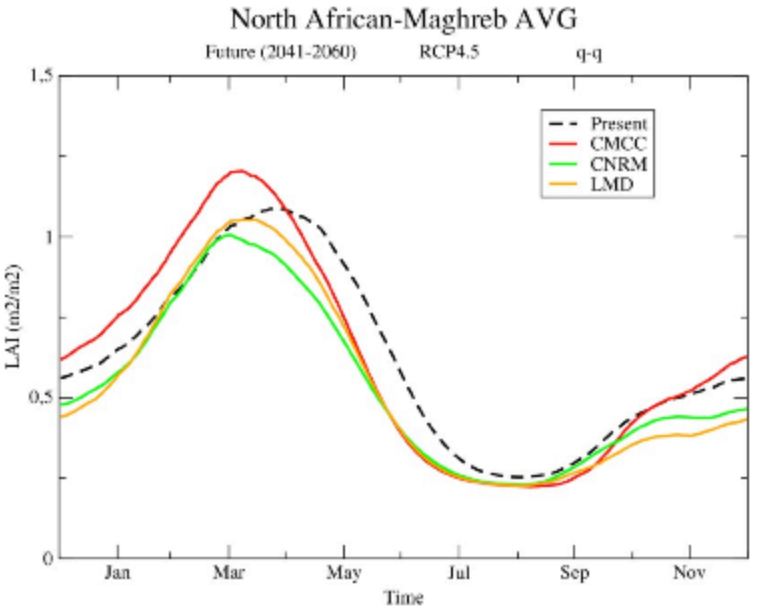
Perterbation :
runoff is reduced by ~30-40% on average, but considerable inter-model variation

Quantile-quantile:
AVG Reduction ranges from ~5% to 65 % → Rainfall forcing






North African-Maghreb AVG
Future (2041-2060) RCP4.5 Pert.
Present
CMCC
CNRM
LMD
LAI (m2/m2)
Time
Jan
Mar
May
Jul
Sep
Nov
0
0,5
1
1,5


North African-Maghreb AVG
Future (2041-2060) RCP4.5 q-q
Present
CMCC
CNRM
LMD
LAI (m2/m2)
Time
Jan
Mar
May
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Sep
Nov
0
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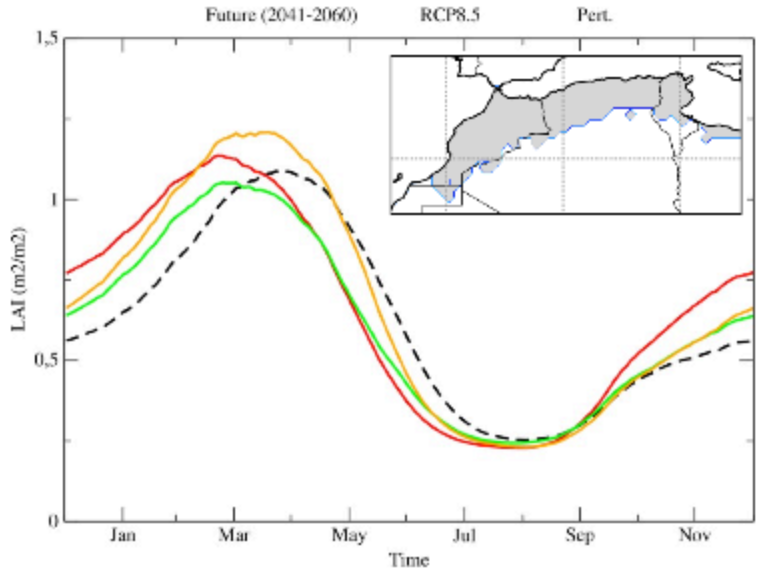
1,5


Future (2041-2060) RCP8.5 Pert.
LAI (m2/m2)
Time
Jan
Mar
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Sep
Nov
0
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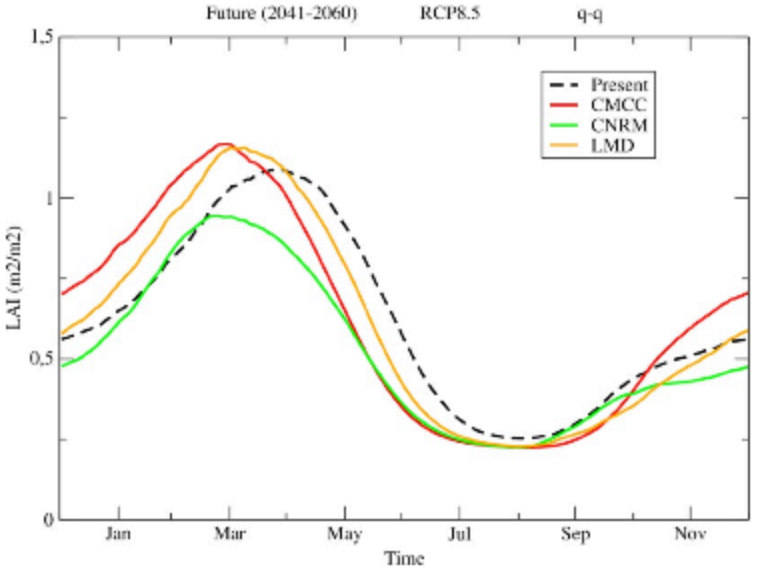
1
1,5


Future (2041-2060) RCP8.5 q-q
Present
CMCC
CNRM
LMD
LAI (m2/m2)
Time
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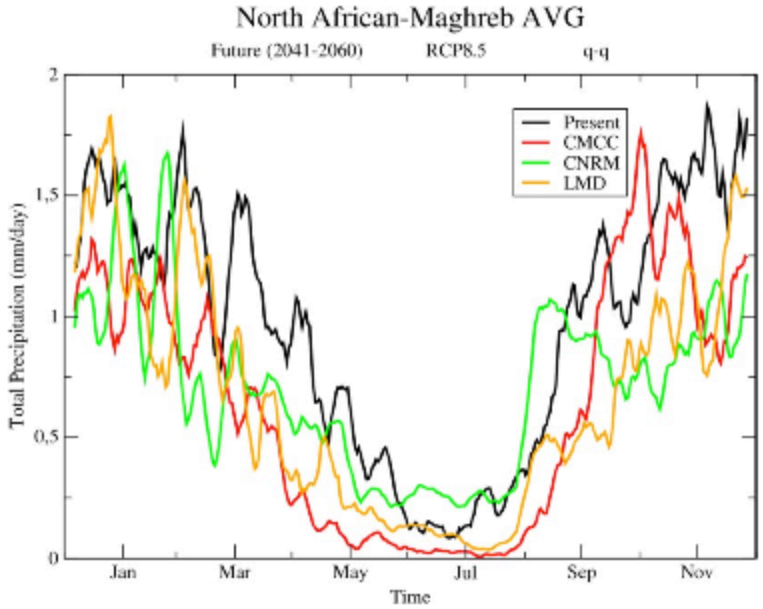
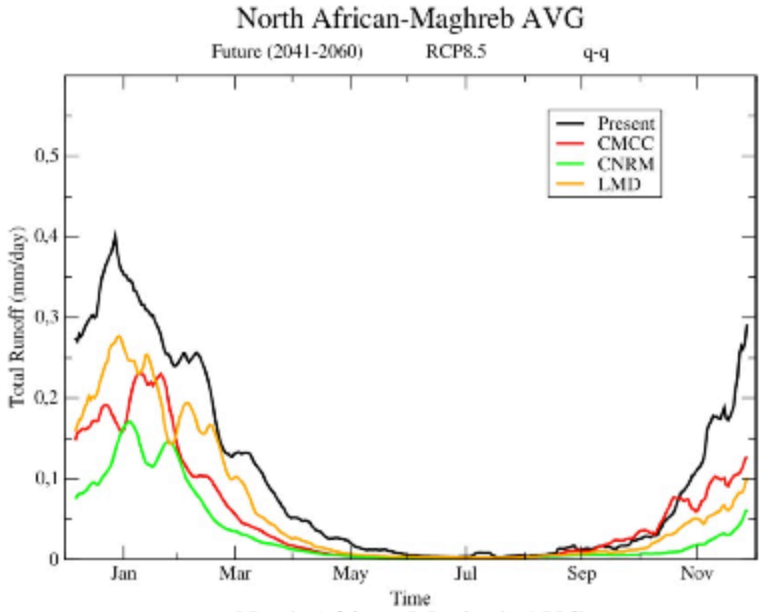
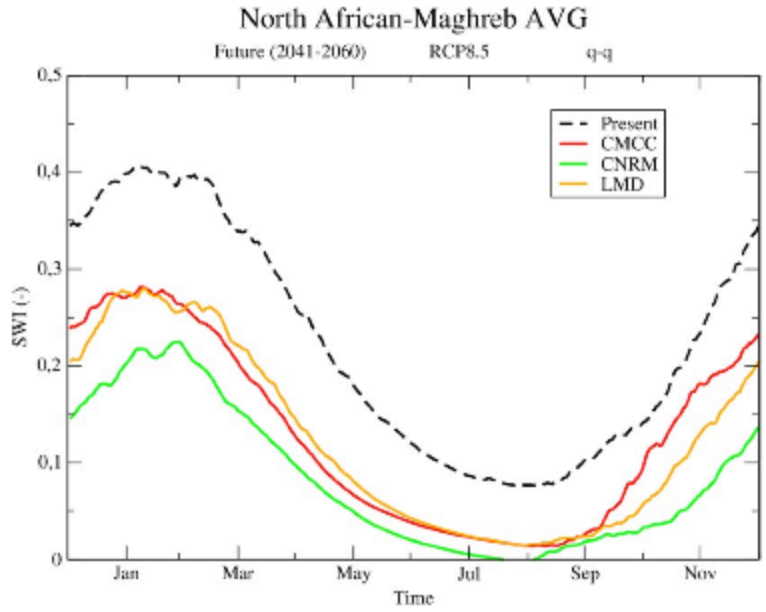
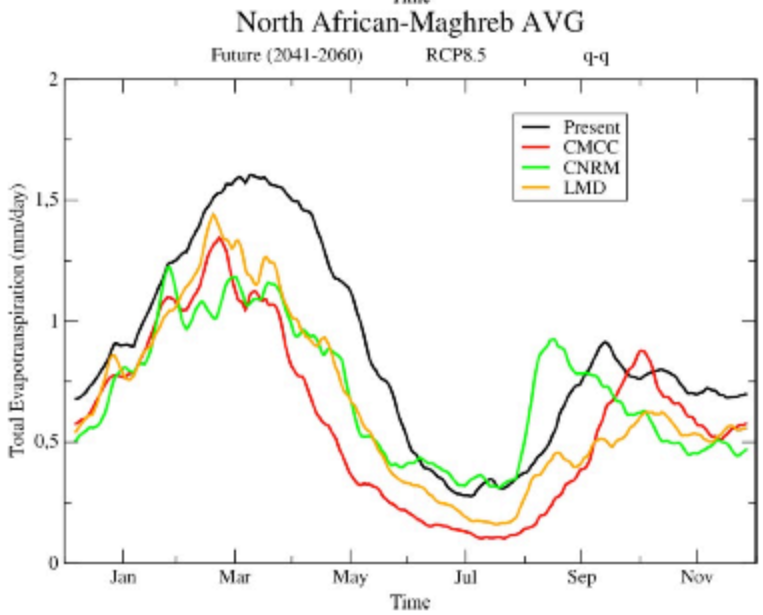
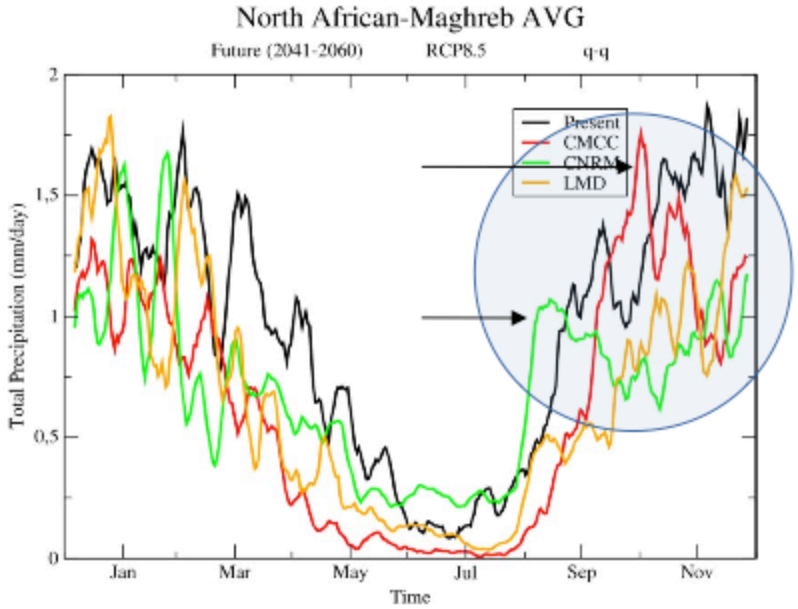

North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
CNRM
LMD
Total Precipitation (mm/day)
Time
Jan
Mar
May
Jul
Sep
Nov


North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
CNRM
LMD
Total Runoff (mm/day)
Time
Jan
Mar
May
Jul
Sep
Nov


North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
CNRM
LMD
SWI (-)
Time
Jan
Mar
May
Jul
Sep
Nov


North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
CNRM
LMD
Total Evapotranspiration (mm/day)
Time
Jan
Mar
May
Jul
Sep
Nov


North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
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Total Precipitation (mm/day)
Time
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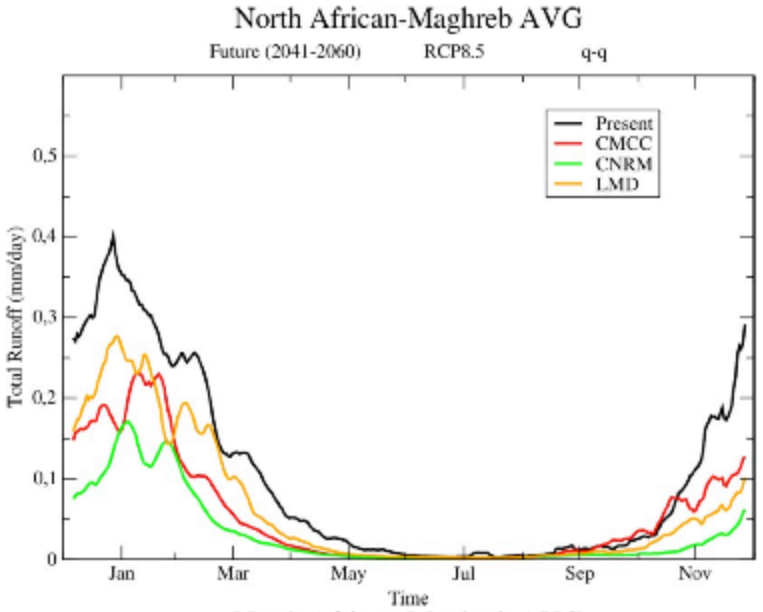
North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
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Total Runoff (mm/day)
Time
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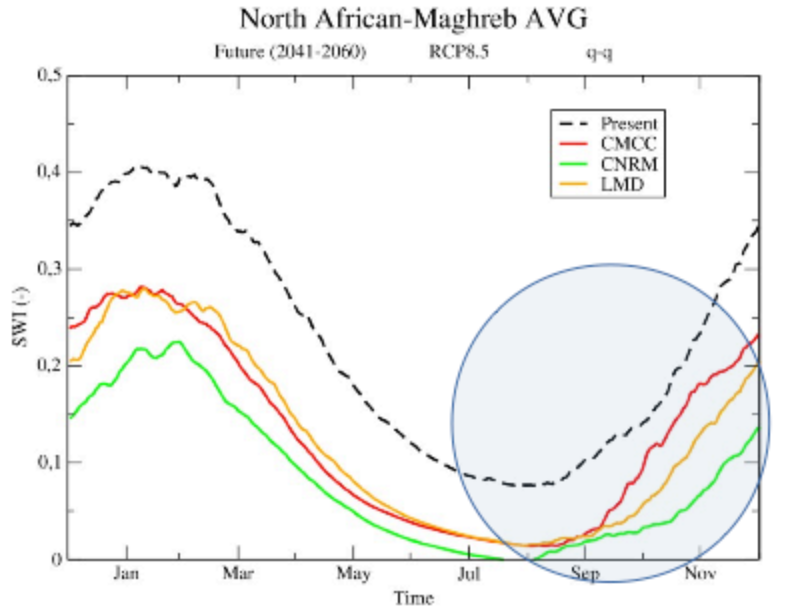
North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
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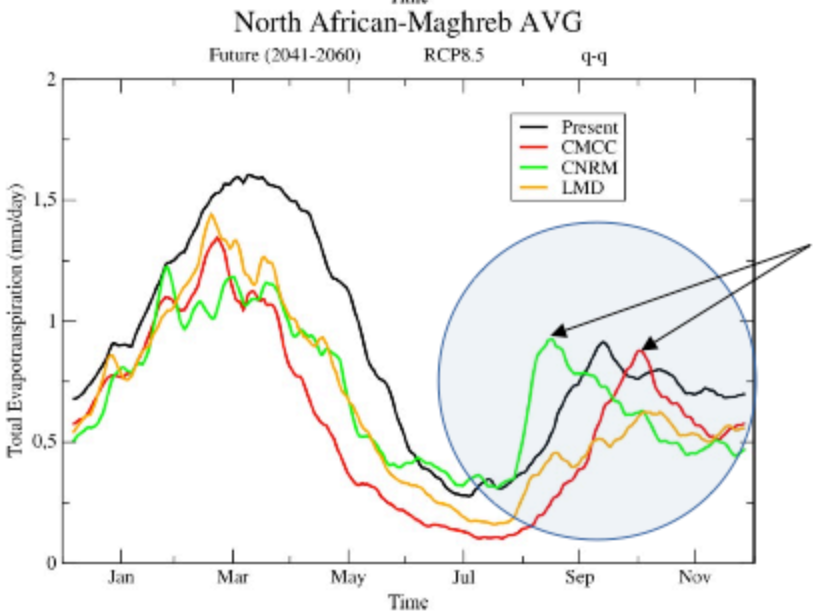
North African-Maghreb AVG
Future (2041-2060) RCP8.5 q-q
Present
CMCC
CNRM
LMD
Total Evapotranspiration (mm/day)
Time
Jan
Mar
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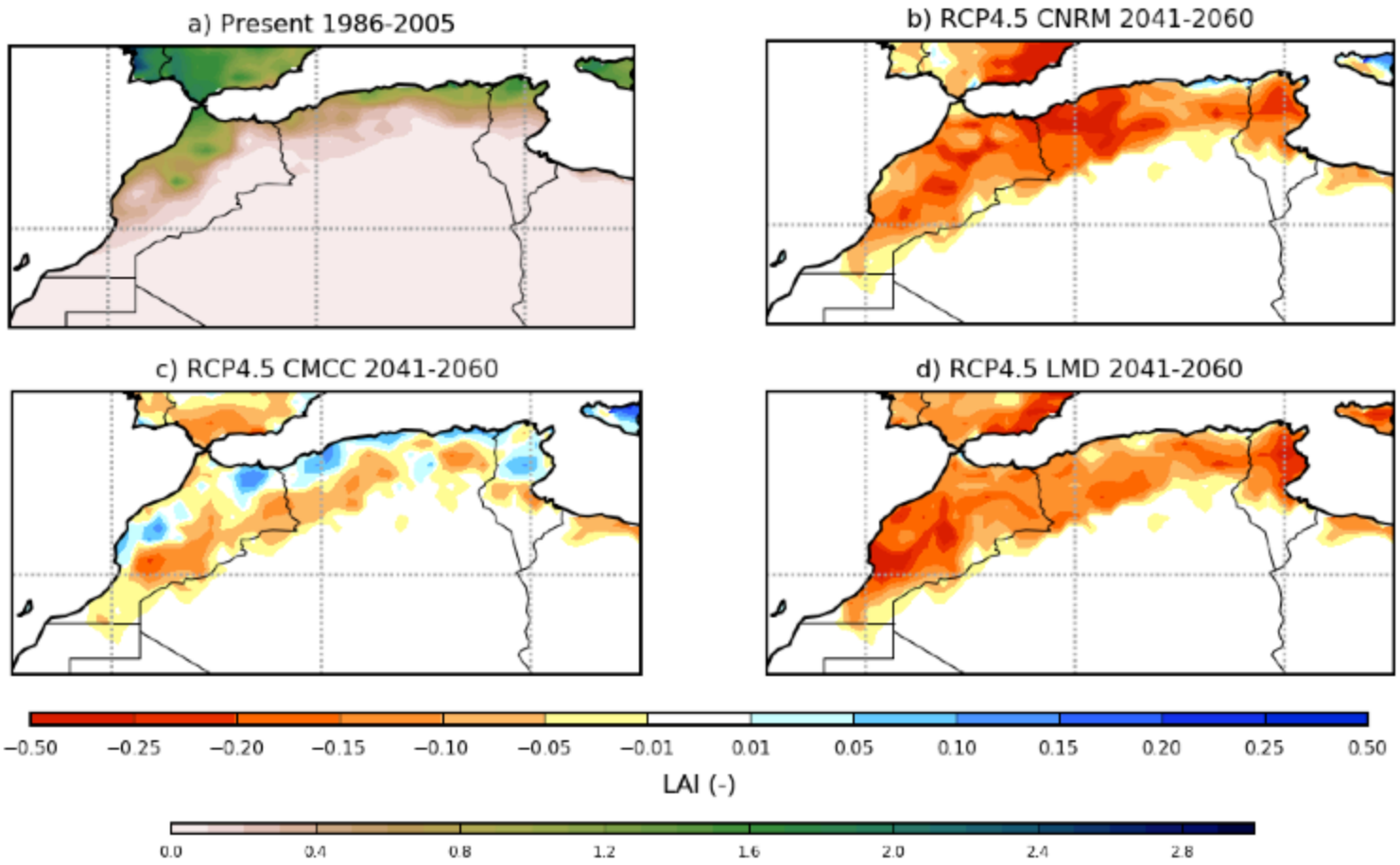
Simulated Impact :

Relative Changes in LAI :

Method: q-q



Conclusions

- Air temperature increases quite consistent and over entire region, Precipitation drops, but less agreement (notably annual cycle) among RCMs
- Evapotranspiration and runoff both reduced : E is reduced similarly to rainfall, but the runoff is ~ an order of magnitude lower : large differences but 30 % reduction on average→ source for aquifer recharge, reservoirs and irrigation
- Growing season shifted (earlier) by nearly 1 month….adaptation
- Epot increases as Tair, less runoff → implications for irrigation (and human) needs
- Impact models (using this forcing) indicate possible aquifer collapse for Tensift before the end of the century possible (Le Page et al., 2017)
- What scaling methods to use ?

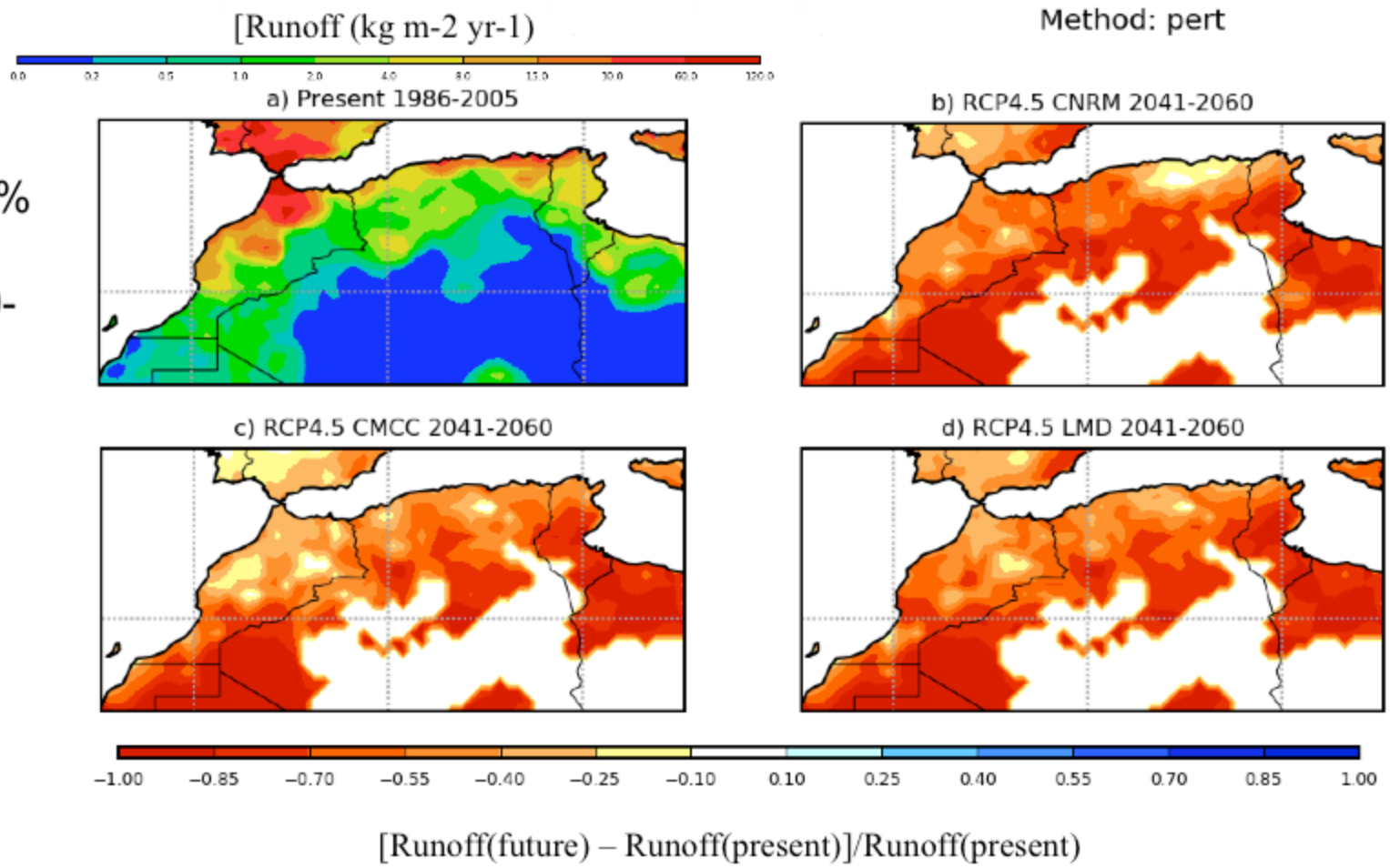
Coming up : CORDEX high res RCMs...(but no hi-res REF!)

- Communication of these results to water management...

Simulated Impact :

Tensift:10-85 % less

Merguellil : 40-85 % less



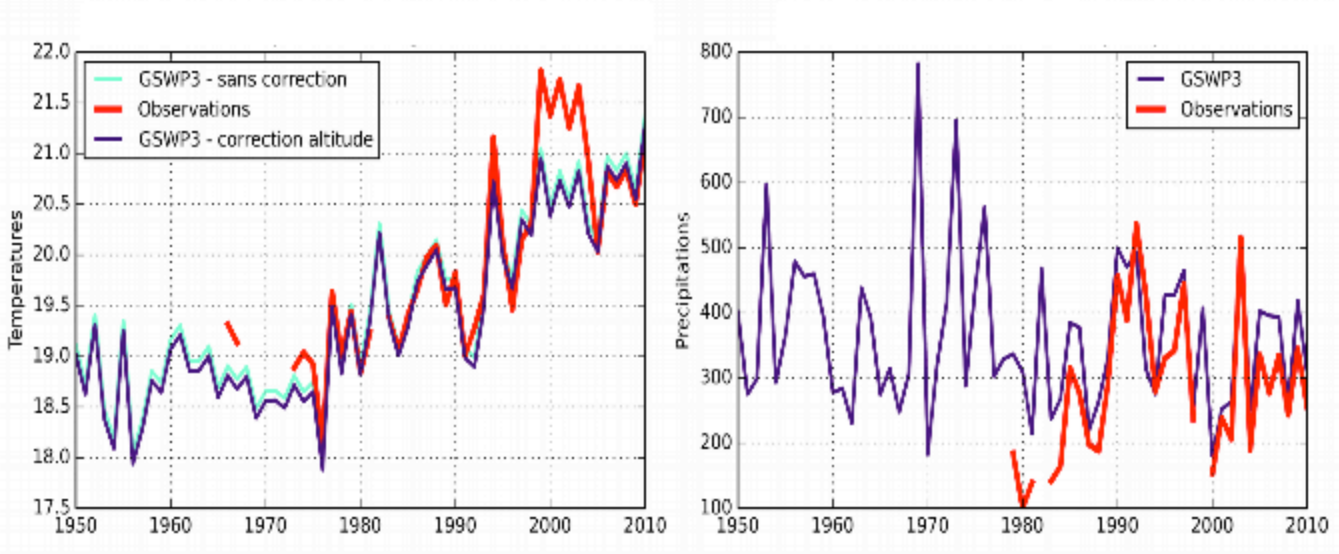
Futurisation of climate data:

Evaluation of Reference Data:
Comparison between GSWP3 data and station data

- 14 sites
- ~1960s-2010

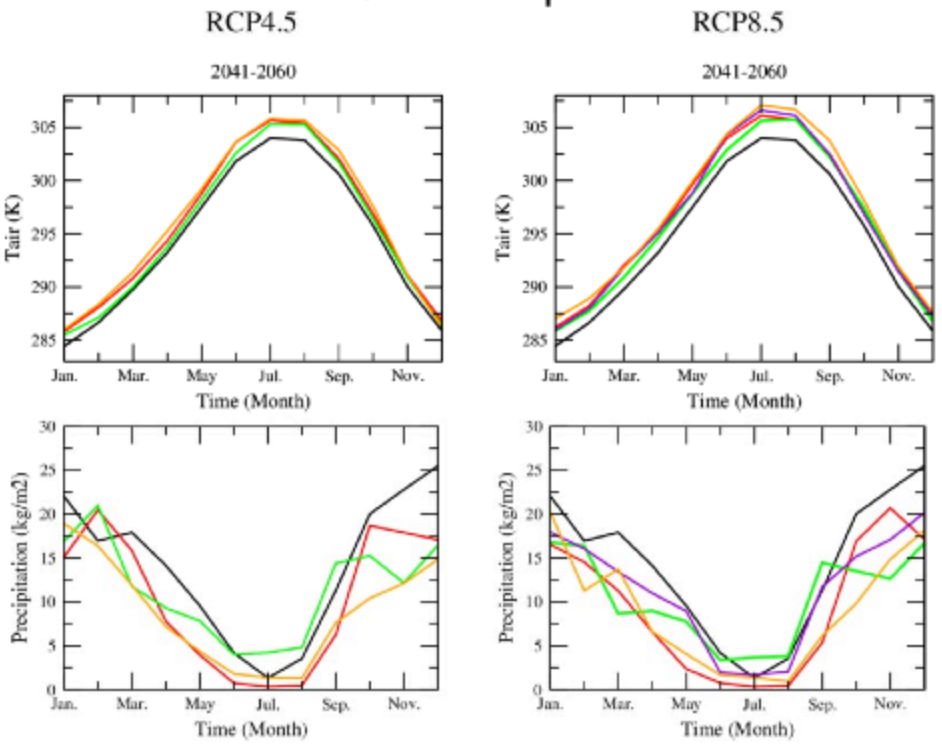
	r (monthly)	r (daily)	Biais
Temperature avg	0.99	0.92	0.22 °C
Temperature std			1.04 °C
Precipitation avg	0.74	0.08	- 9.18 %
Precipitation std			14.59 %
Rel. humidity avg	0.87	0.63	- 3.45 %
Rel. humidity std			9.38 %

Example for Kairouan (central Tunisia)

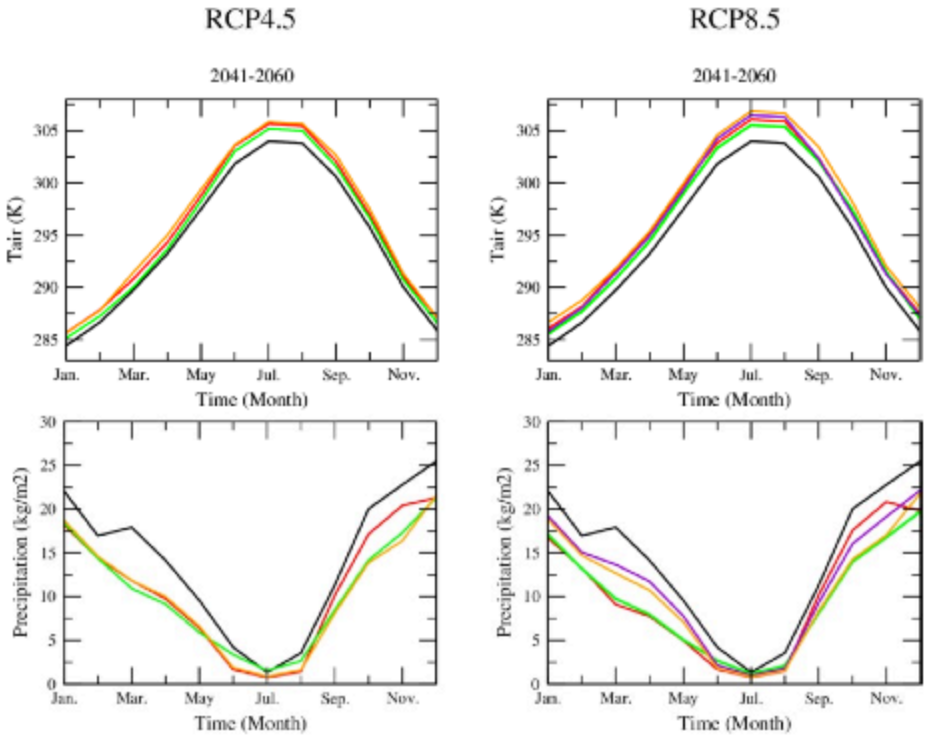


Temperature and Precipitation : Horizon 2050

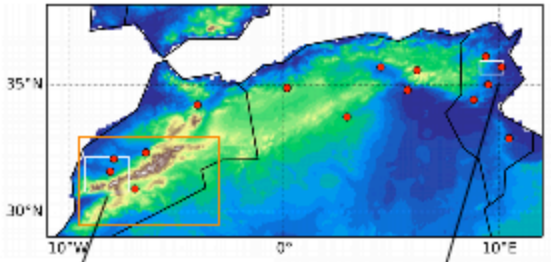
Quantile-quantile



Perterbation

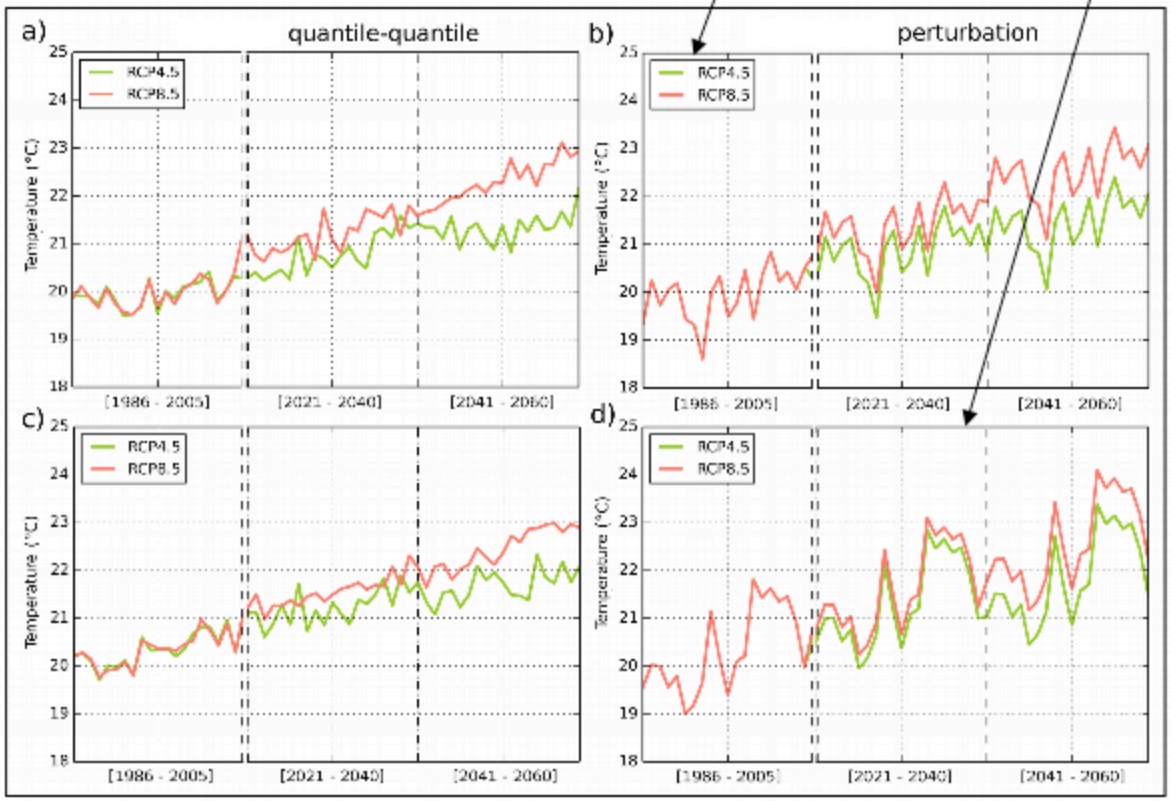


Example of scaling methods for two sub-zones :

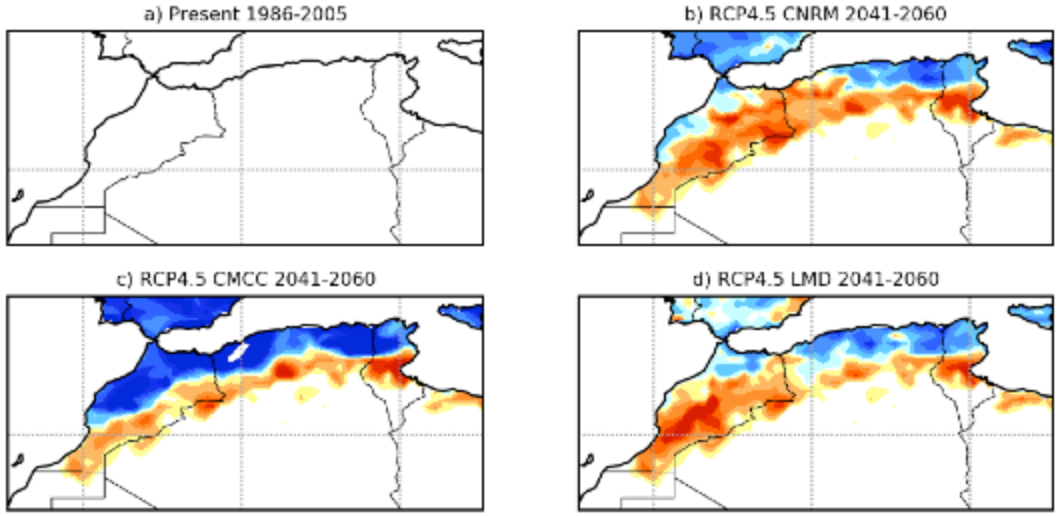


Marrakech

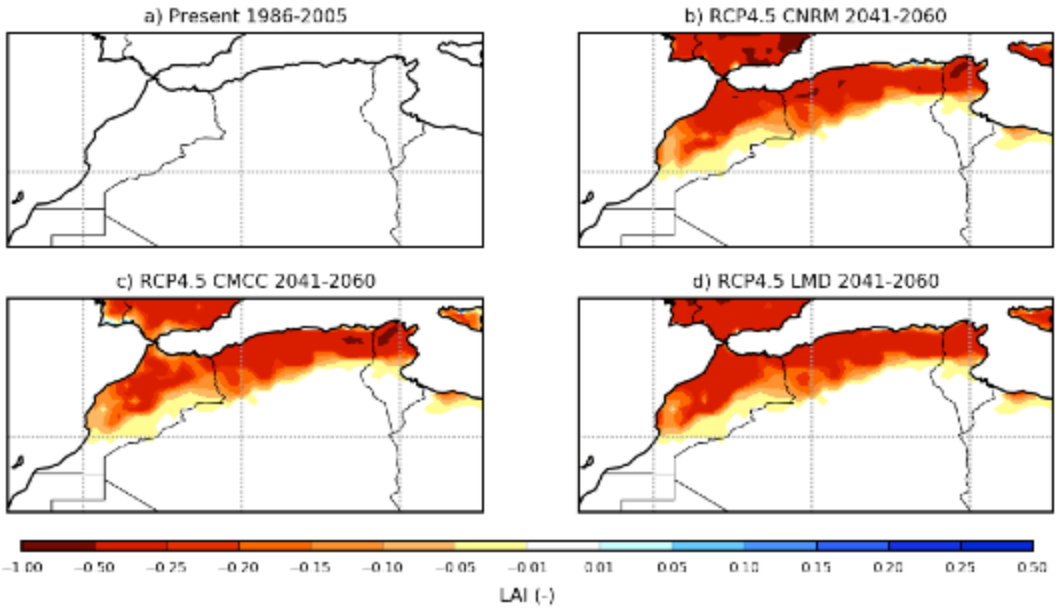
Kairouan



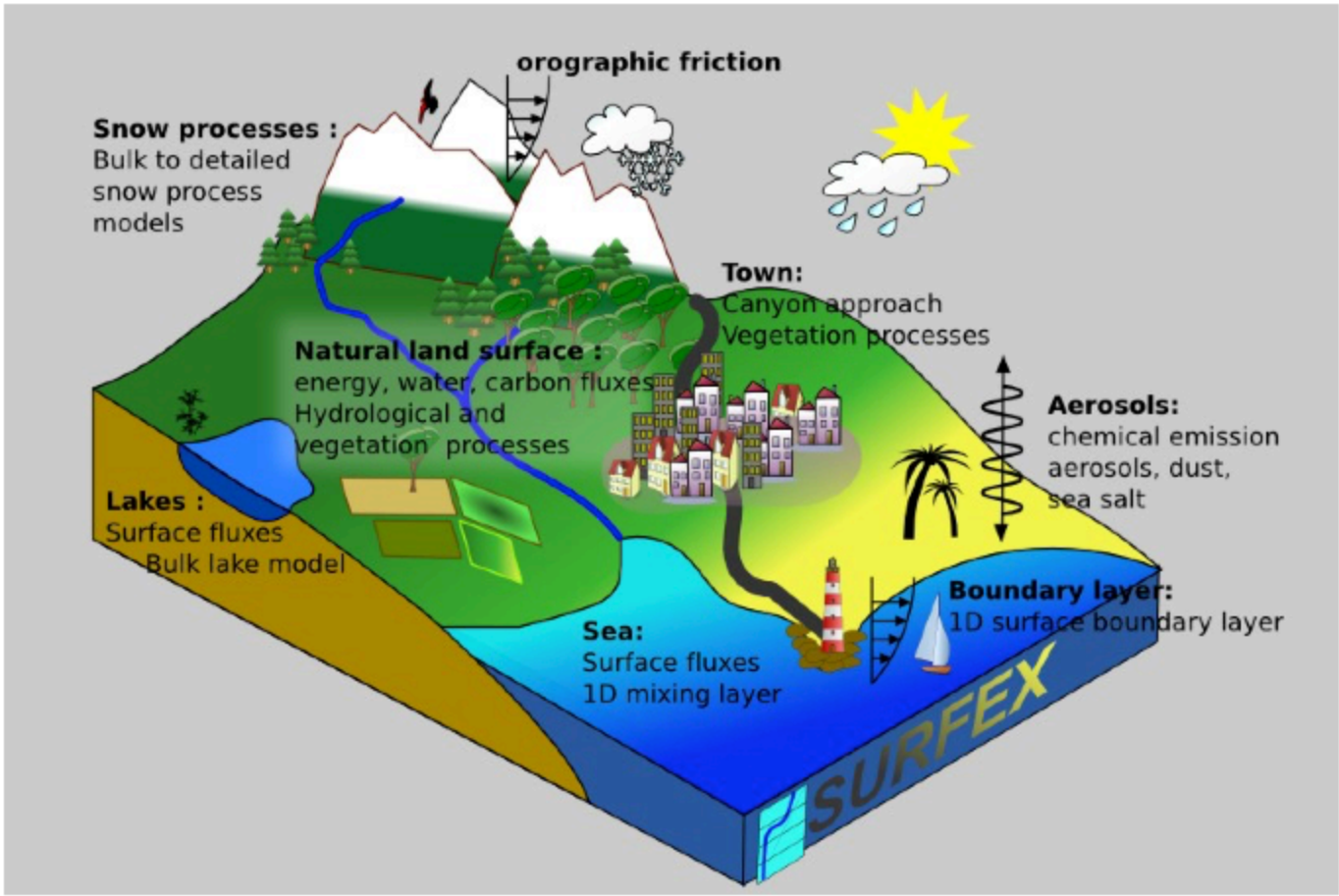
March

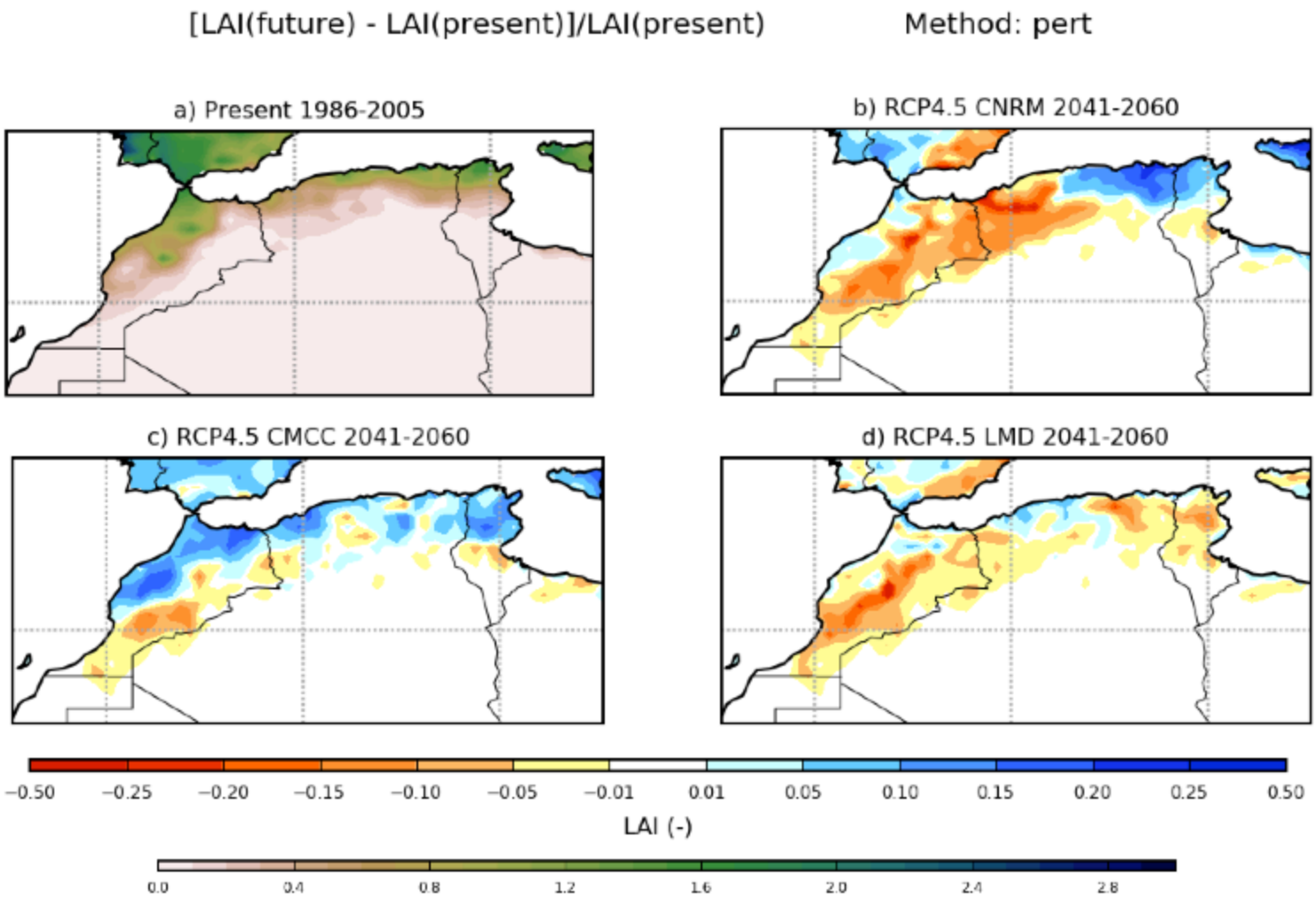

[LAI(future) - LAI(present)]/LAI(present)
Method: pert
a) Present 1986-2005
b) RCP4.5 CNRM 2041-2060
c) RCP4.5 CMCC 2041-2060
d) RCP4.5 LMD 2041-2060

June

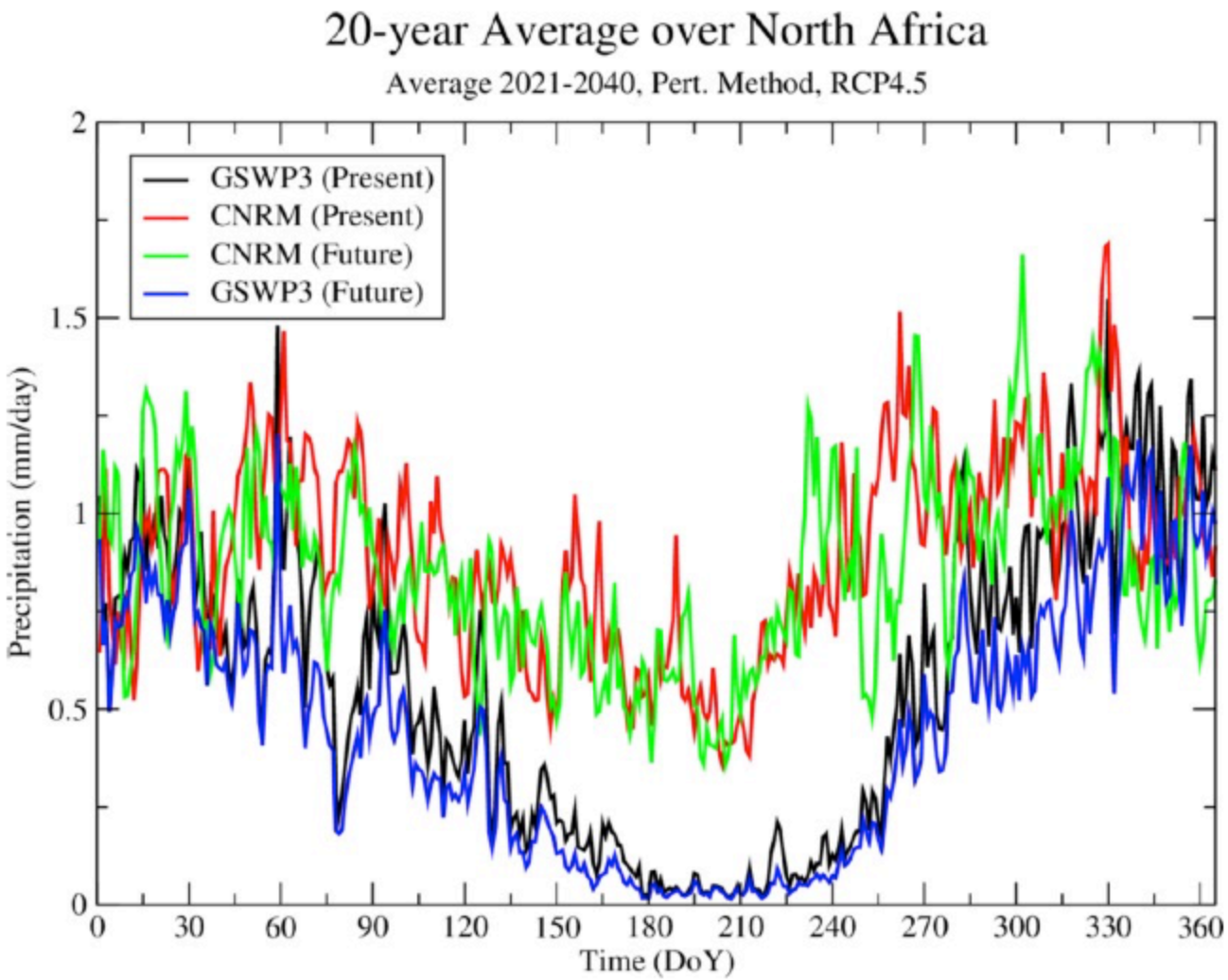

[LAI(future) - LAI(present)]/LAI(present)
Method: pert
a) Present 1986-2005
b) RCP4.5 CNRM 2041-2060
c) RCP4.5 CMCC 2041-2060
d) RCP4.5 LMD 2041-2060
−1.00 −0.50 −0.25 −0.20 −0.15 −0.10 −0.05 −0.01 0.01 0.05 0.10 0.15 0.20 0.25 0.50
LAI (-)

Land surface model : ISBA-SURFace EXternalisée (SURFEX)




[LAI(future) - LAI(present)]/LAI(present)
Method: pert
a) Present 1986-2005
b) RCP4.5 CNRM 2041-2060
c) RCP4.5 CMCC 2041-2060
d) RCP4.5 LMD 2041-2060
−0.50 −0.25 −0.20 −0.15 −0.10 −0.05 −0.01 0.01 0.05 0.10 0.15 0.20 0.25 0.50
LAI (-)
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8

Futurisation of climate data:



Futurisation of climate data: