

Study of the evolution of the water resources in semi-arid regions of North Africa during the 20th Century : Focus on the Tensift and Merguellil basins



C. Szcypta, A. Boone, Le Moigne, P., Gascoin, S., Martin, E.



HyMex Drought Workshop



AMETHYST

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

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

- {
- Global scale
 - 0.5° , 3h, 1901-2010
 - NCEP-RA
(H. Kim, U. Tokyo)



Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

- {
- Global scale
 - 0.5° , 3h, 1901-2010
 - NCEP-RA
(H. Kim, U. Tokyo)



Obs. SYNOP



Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3



Study of forcing
evolution
(1901-2010)

- 
- Temperatures
 - Precipitation

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

Study of forcing
evolution
(1901-2010)

Evaluation of the
SURFEX simulations
- water budget

-
- Total Soil water storage
 - layer soil moisture
 - Evapotranspiration
 - Snowcover

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

Study of forcing
evolution
(1901-2010)

Evaluation of the
SURFEX simulations
- water budget

- Total Soil water storage
- layer soil moisture
- Evapotranspiration
- Snowcover

→ **GRACE**

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

Study of forcing
evolution
(1901-2010)

Evaluation of the
SURFEX simulations
- water budget

- Total Soil water storage
- layer soil moisture
- Evapotranspiration
- Snowcover

**Produit
ESA-CCI**

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3



Study of forcing
evolution
(1901-2010)



Evaluation of the
SURFEX simulations
- water budget

- Total Soil water storage
- layer soil moisture
- Evapotranspiration
- Snowcover

→ **GLEAM**

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

Study of forcing
evolution
(1901-2010)

Evaluation of the
SURFEX simulations
- water budget

- Total Soil water storage
- layer soil moisture
- Evapotranspiration
- Snowcover



**Snow
cover
fraction
MODIS**

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3



Study of forcing
evolution
(1901-2010)



Evaluation of the
SURFEX simulations
- water budget



Water budget
evolution
(1901-2010)

Modeling the water resource evolution

Projet Interest : Large scale « Integrated modeling approach»

Objective :

- Study of the past evolution of the water resources and projections for 2050
- Setup of a distributed modeling chain (Forcing – LSM)



Forcing evaluation :
GSWP3

Study of forcing
evolution
(1901-2010)

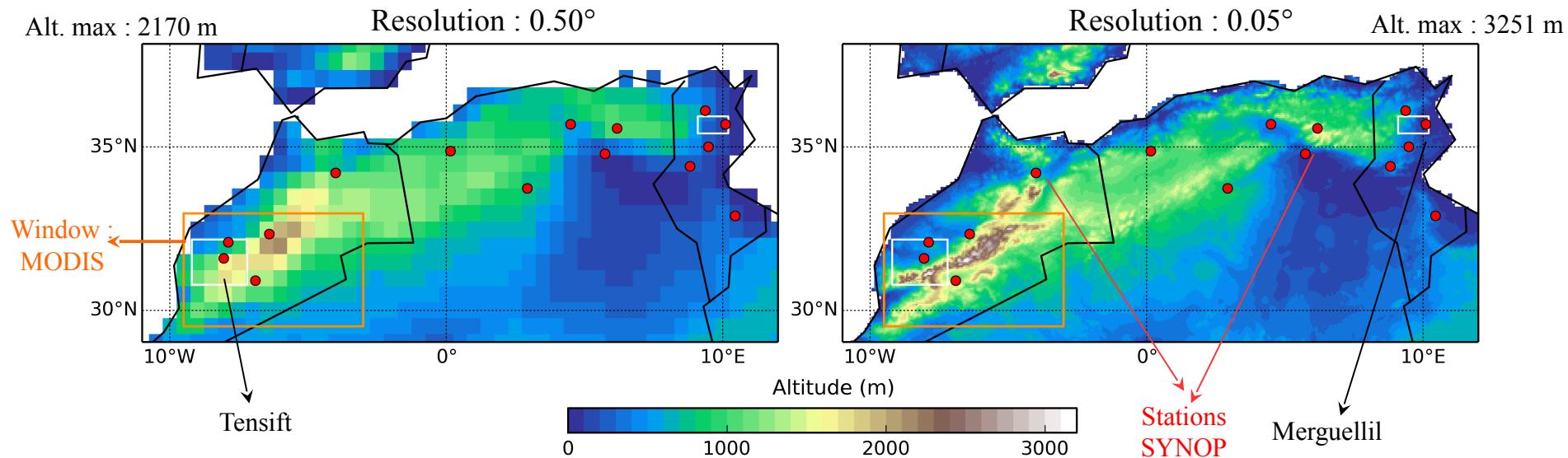
Evaluation of the
SURFEX simulations
- water budget

Water budget
evolution
(1901-2010)

FINAL Objective :

Perturb GSWP3 with climate scenarios from MED-Cordex and drive SURFEX to simulate the evolution of water resources up to 2050

Study Area and Altitude gradients



Résolution 0.5° : smoothed topography

→ underestimation of snowfall, overestimation of air temperature

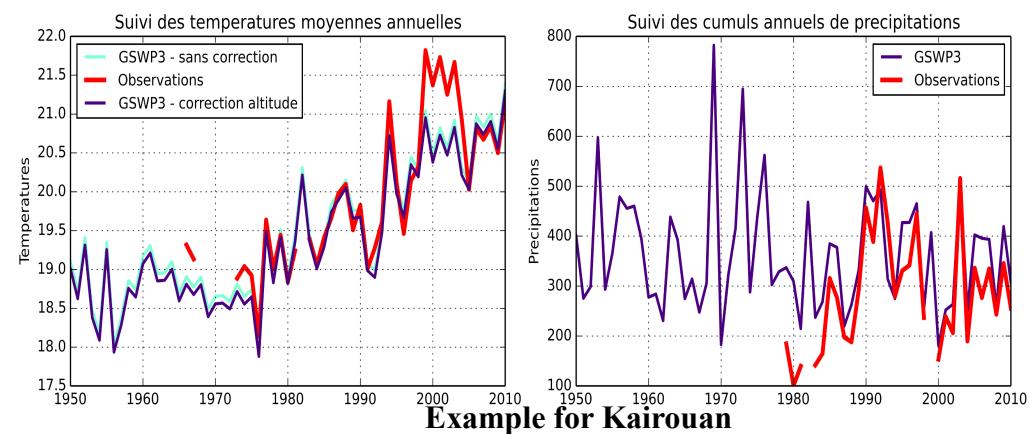
Elevation Bands used : explicit - 13 simulations

- ± 2 STD ; $\pm 5/3$ STD ; $\pm 4/3$ STD ; ± 1 STD ; $\pm 2/3$ STD ; $\pm 1/3$ STD and avg
- Modify model input only (*Ta, Snowf-Rainf, Psfc*)

GSWP3 Forcing Evaluation

- 14 SYNOP stations located within the study zone
- Period covered: 1980 - 2010

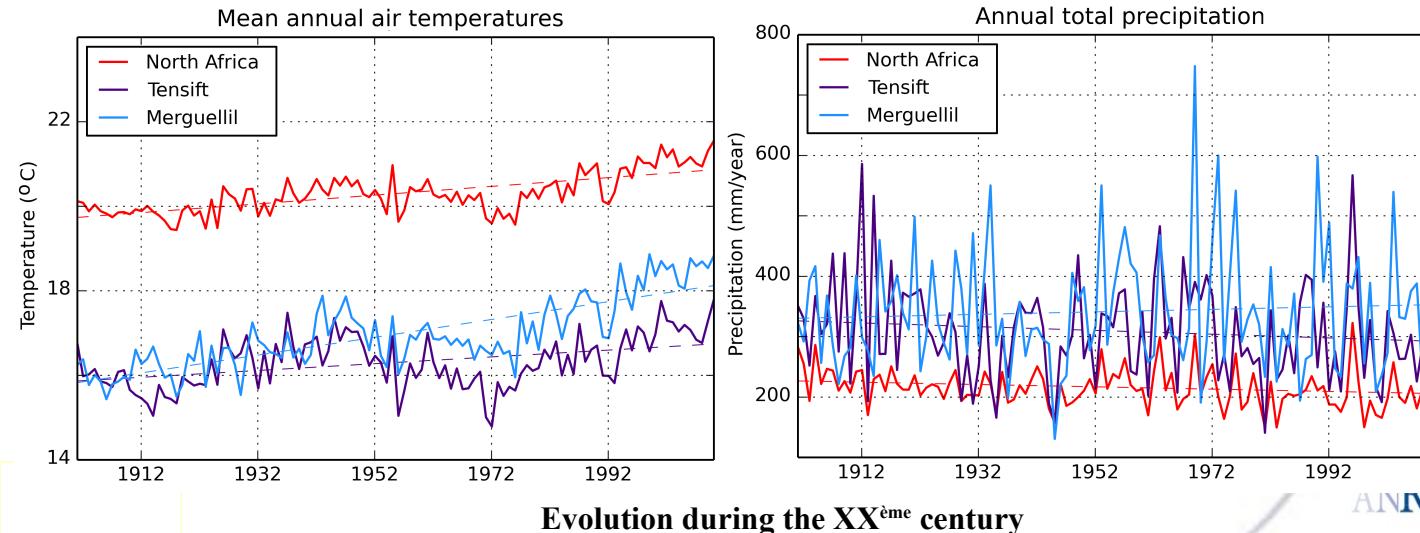
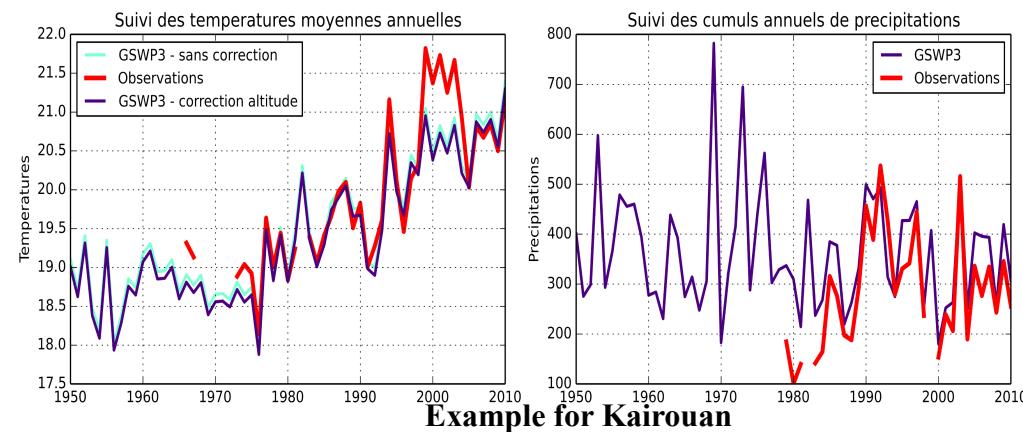
Variable	r (mon)	r (day)	bias
Temperature	0.99	0.92	0.22
Precipitation	0.74	0.08	-9.18%
Rel. Humidity	0.87	0.63	-3.45%



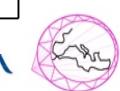
GSWP3 Forcing Evaluation

- 14 SYNOP stations located within the study zone
- Period covered: 1980 - 2010

Variable	r (mon)	r (day)	bias
Temperature	0.99	0.92	0.22
Precipitation	0.74	0.08	-9.18%
Rel. Humidity	0.87	0.63	-3.45%

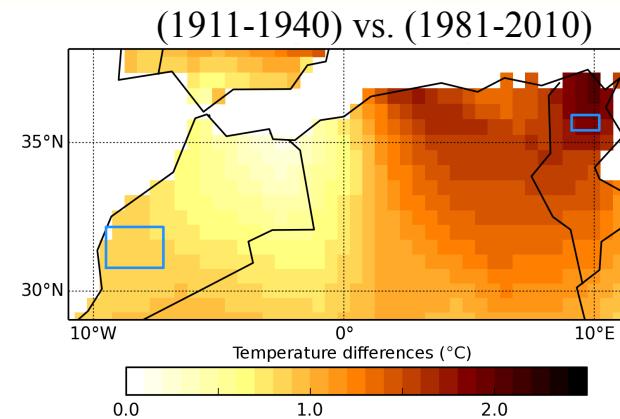
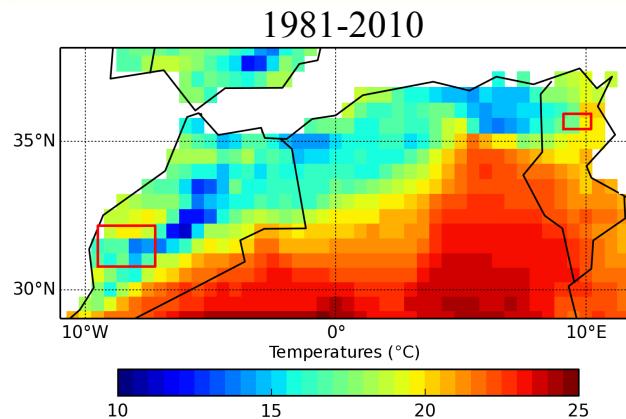


Temperature :
 + 0,9°C (Zone)
 + 0,8°C (Tensift)
 + 1,9°C (Merguellil)
Precip.
 - 10 mm/yr (Zone)
 - 16 mm/yr (Tensift)
 + 8 mm/yr (Merguellil)



AMETHYST

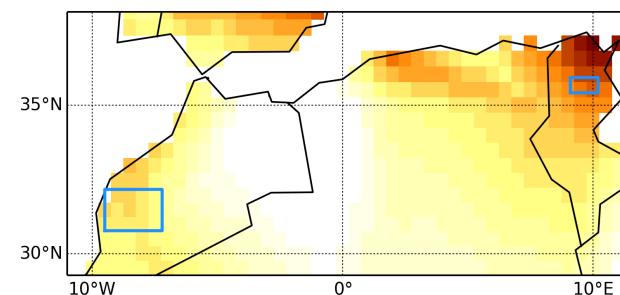
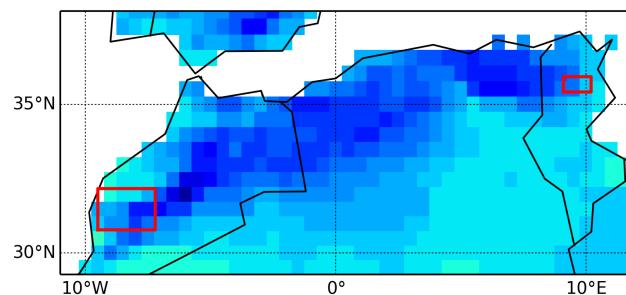
Evolution of the air temperature (1901-2010)



Annual

$\text{T}(\text{Tensift}) : + 0.8^{\circ}\text{C}$

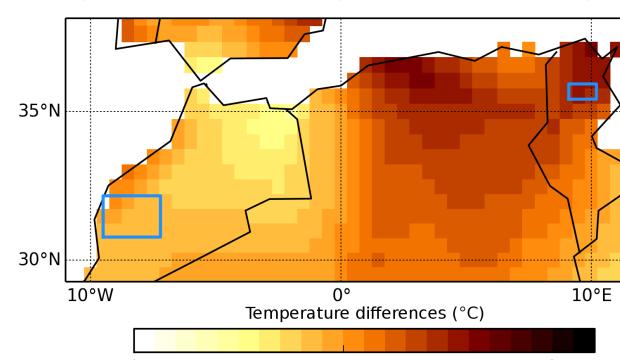
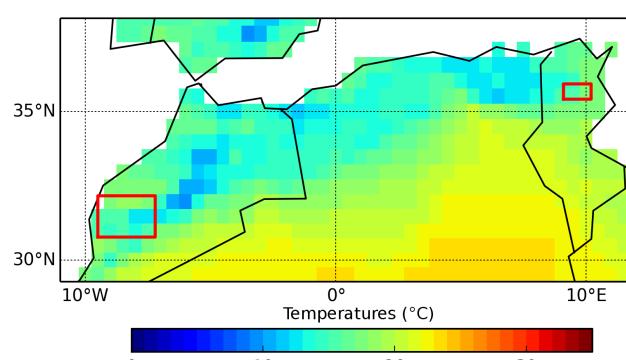
$\text{T}(\text{Merguellil}) : +1.9^{\circ}\text{C}$



Winter

$\text{T}(\text{Tensift}) : + 0.6^{\circ}\text{C}$

$\text{T}(\text{Merguellil}) : +1.2^{\circ}\text{C}$

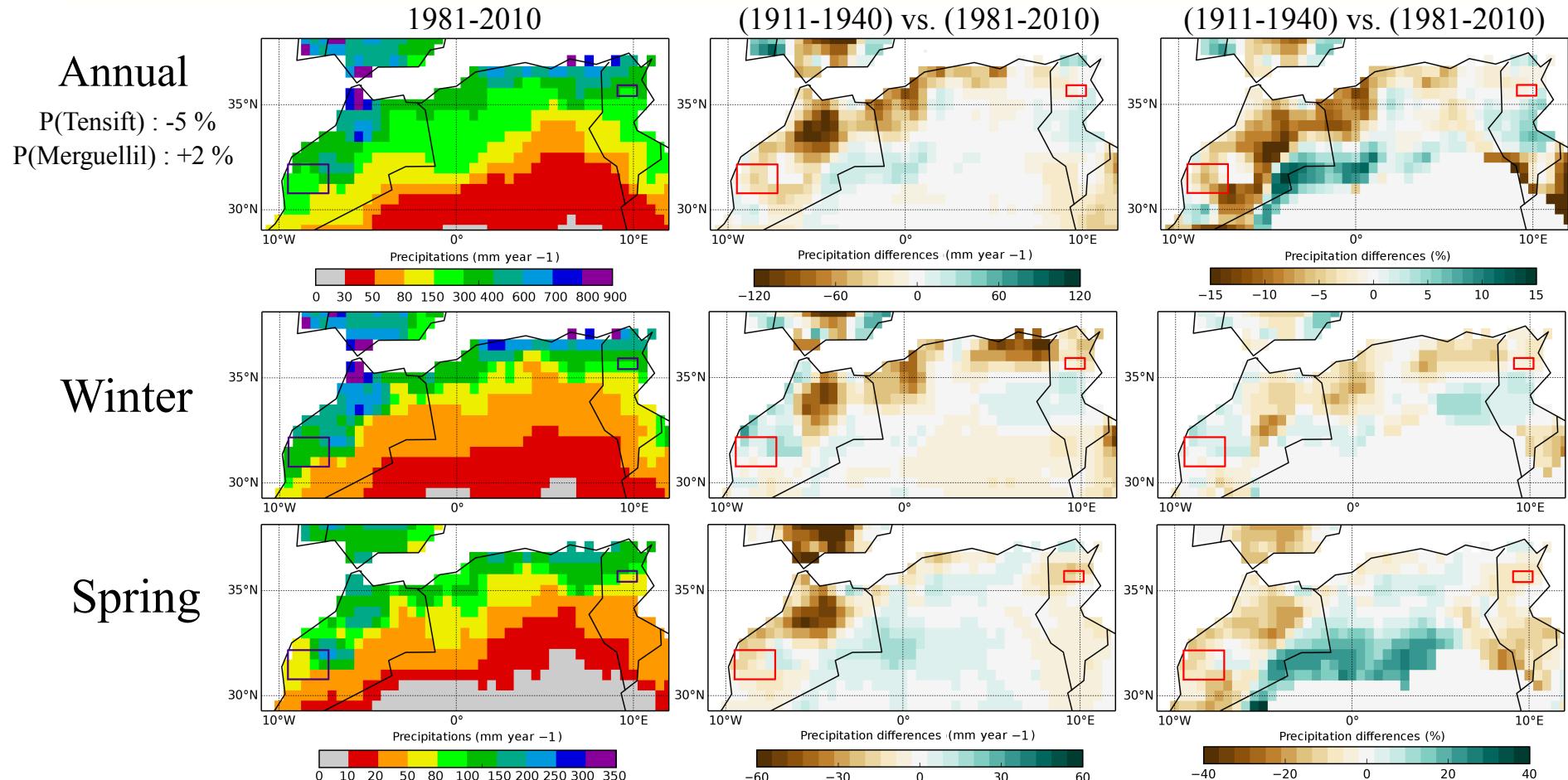


Spring

$\text{T}(\text{Tensift}) : + 0.9^{\circ}\text{C}$

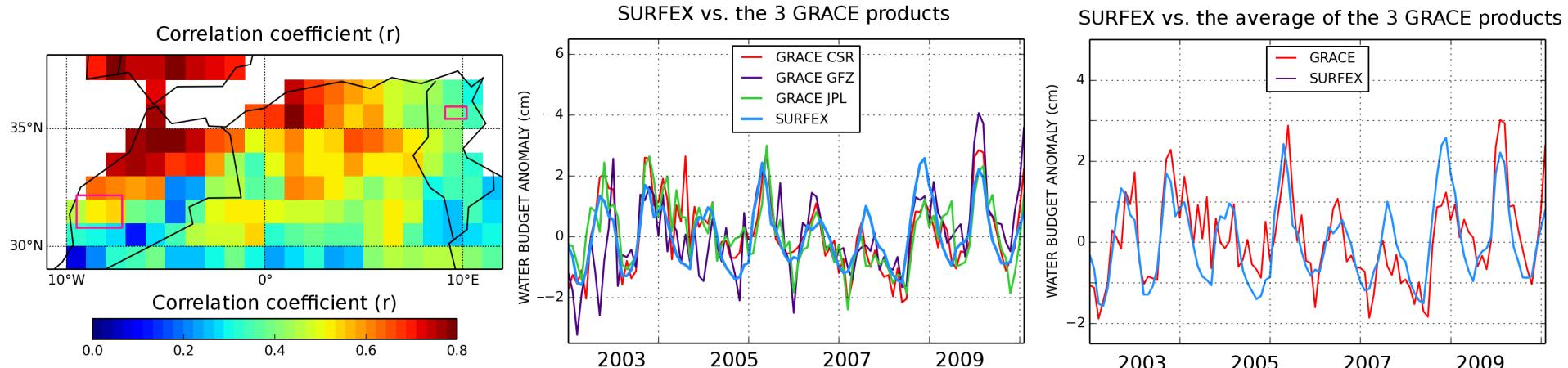
$\text{T}(\text{Mergueilil}) : +1.6^{\circ}\text{C}$

Evolution of the precipitation (1901-2010)



- Winter : basin water cycle driven by snow processes
- Spring : crops

Evaluation of the total water storage SURFEX vs. GRACE (2002-2010)



3 GRACE solutions

CSR (Center for Space Research at University of Texas, Austin)

GFZ (GeoforschungsZentrum Potsdam)

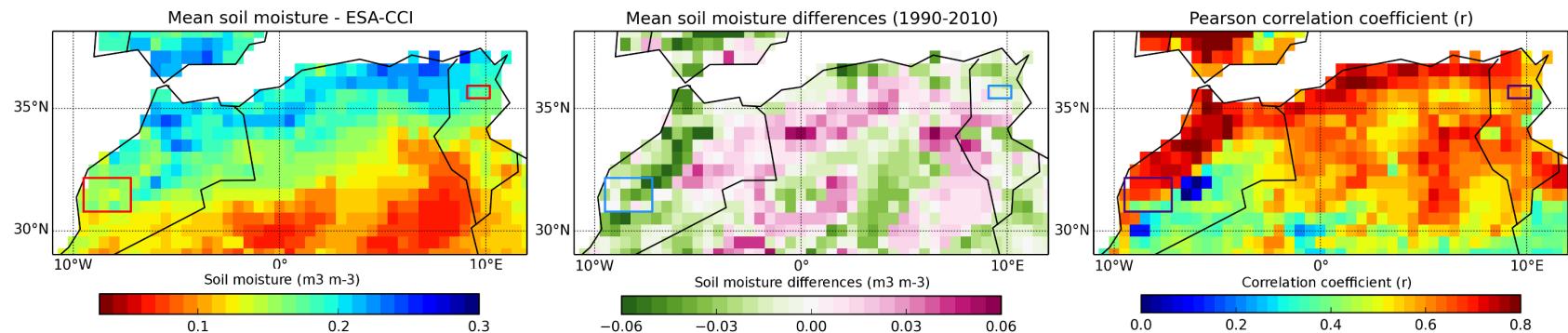
JPL (Jet Propulsion Laboratory)

The Gravity Recovery and Climate Experiment (GRACE) - changes in Earth's gravity field --> directly related to changes in surface mass.

Model	r	RMSE
JPL	0.64	0.88
CSR	0.74	0.82
GFZ	0.64	1.03
AVG	0.76	0.73

Evaluation of the superficial soil moisture SURFEX vs. ESA-CCI (1991-2010)

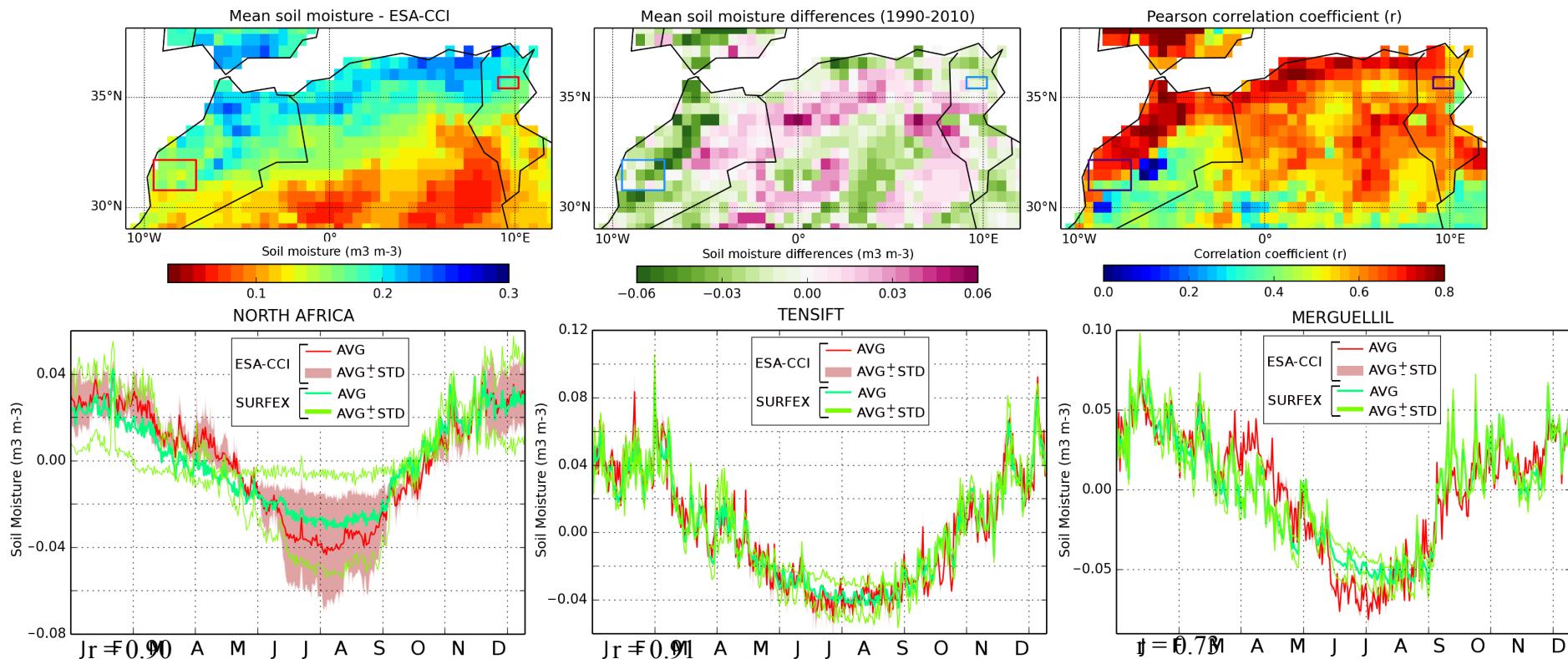
→ Period : 1991 – 2010 ; correlation : daily timestep



Extreme values : $\pm 15\%$

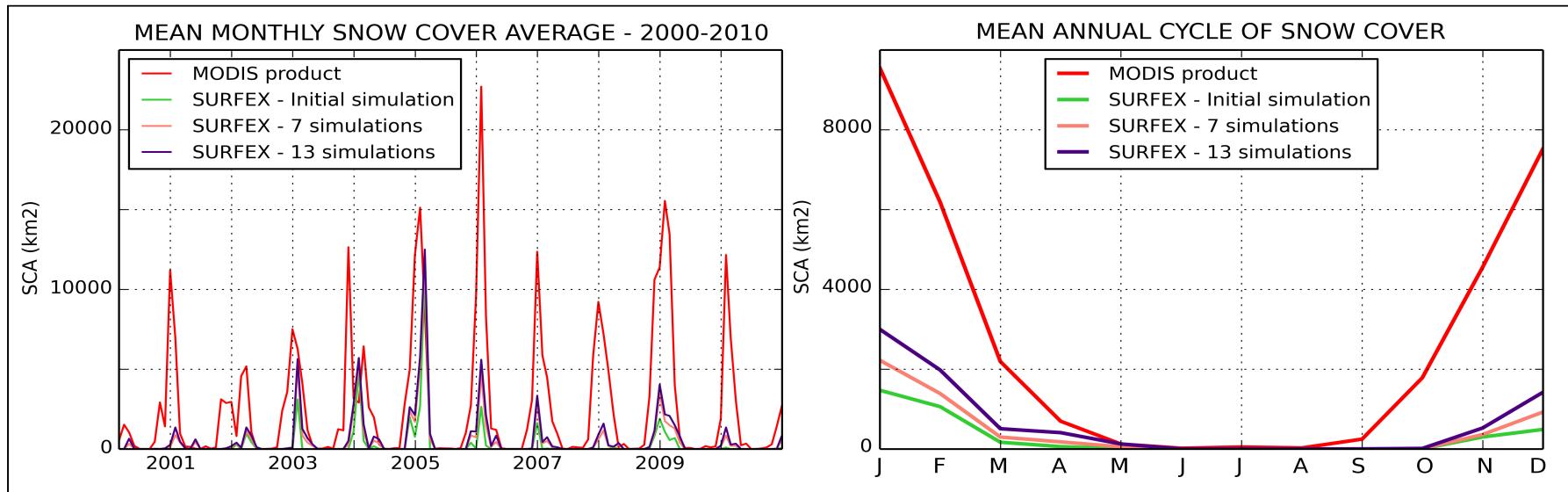
Evaluation of the superficial soil moisture SURFEX vs. ESA-CCI (1991-2010)

→ Period : 1991 – 2010 ; correlation : daily timestep



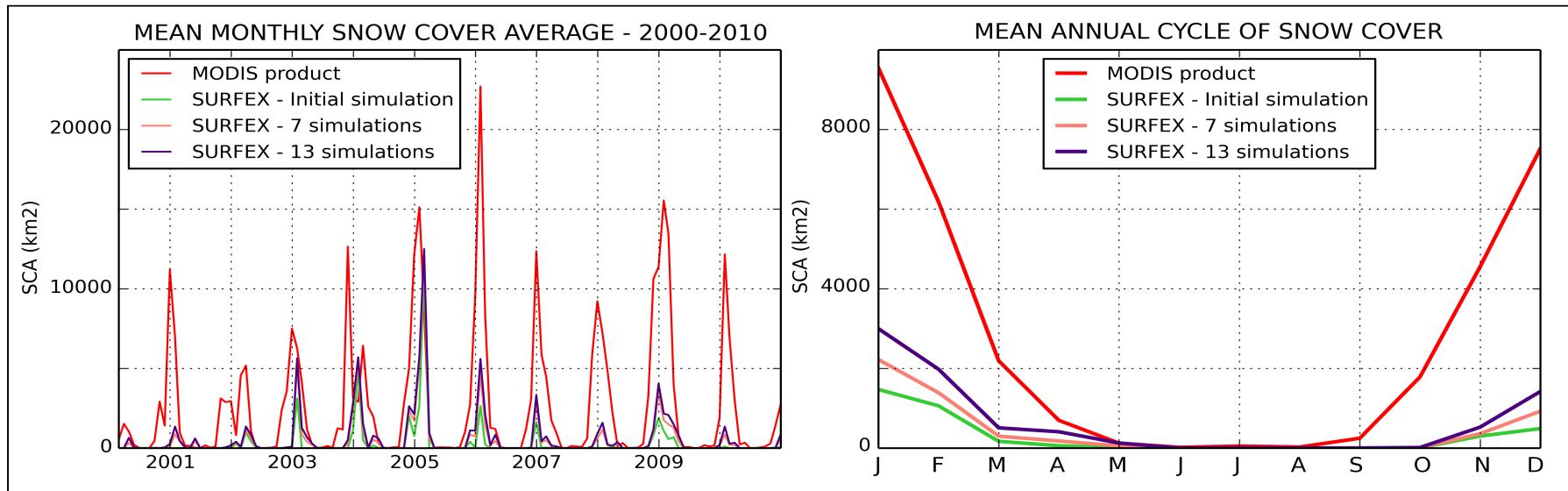
ESA CCI SM - based on a series of active and passive microwave satellite sensors. It provides daily surface Soil Moisture with a spatial resolution of 0.25°

Evaluation of snow snow cover fraction area (SFCFA) SURFEX vs. MODIS (2000-2010)



- Altitude bands: improves the results
- Underestimation of SCFA & snow depth (Oukaimeden)
- Problem : over-estimation of melt
- bands help- another possible cause exposition
- Relatively little consequences on the (larger scale) water budget, but important for basins with snow-process dominated hydrological functioning (Tensift)

Evaluation of snow snow cover fraction area (SFCFA) SURFEX vs. MODIS (2000-2010)



Exposition
(Tensift)



Evaluation de l'évapotranspiration totale SURFEX vs. GLEAM (2003-2010)

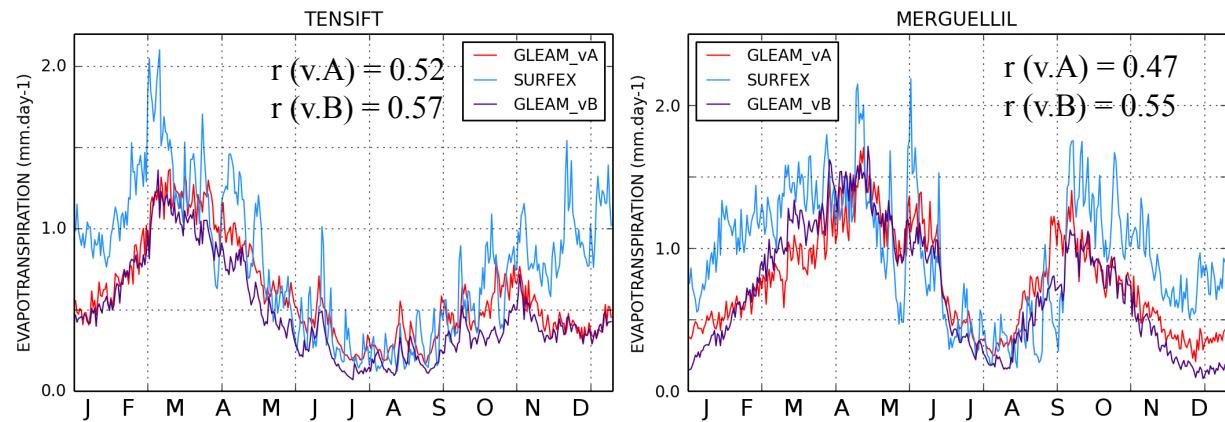
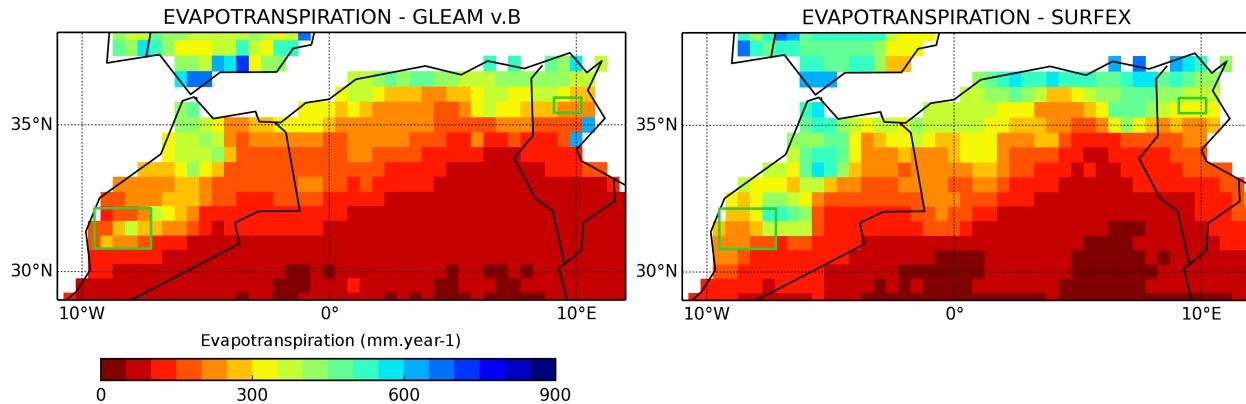
GLEAM : 2 versions :

- v.B : seulement satellite (2003-2010)
- v.A : sat + model + obs (1980-2010)

- Datasets quite similar
(v.B slightly lower)

- For AVG annual cycles :
SURFEX evaporates more mainly in DJF (winter), slightly more in autumn

- What are errors in GLEAM ?
(station data)



GLEAM (Global Land-surface Evaporation (Amsterdam, using MERRA analysis))

Evolution of components of the water budget (1910-1940) vs. (1980-2010)

- Precipitation
- Evapotranspiration
- Drainage
- Sfc Runoff
- Soil Moisture Change

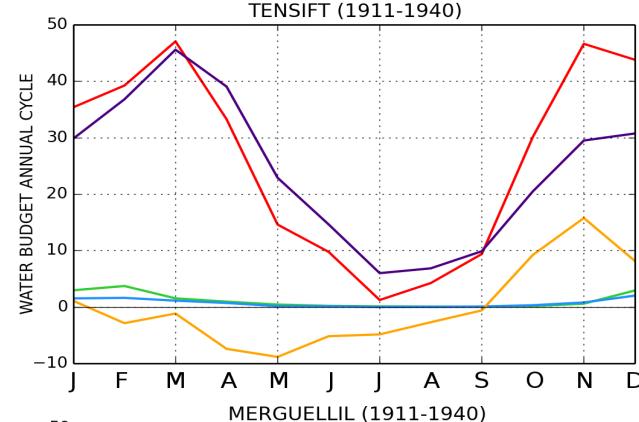
April-August (1981-2010)

EVAP > PRECIP

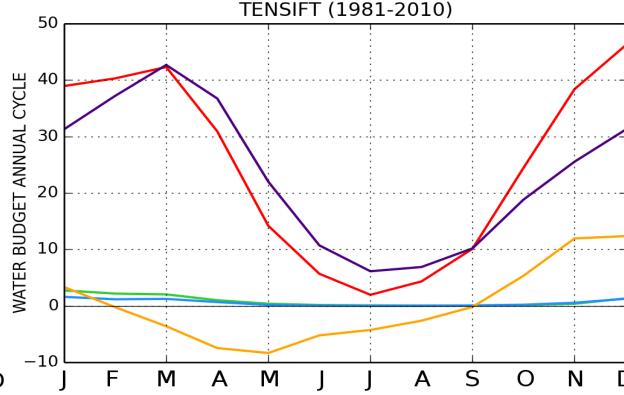
(deficit one month earlier in early 20th century)

→ Variation (SM)

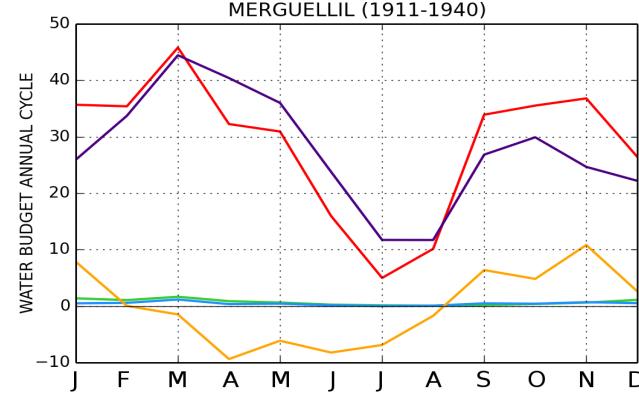
TENSIFT (1911-1940)



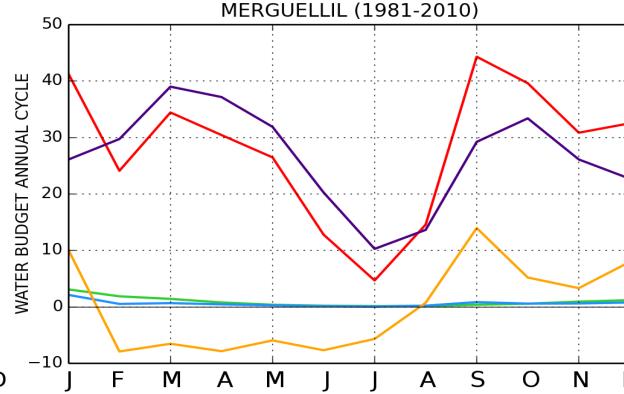
TENSIFT (1981-2010)



MERGUELLIL (1911-1940)



MERGUELLIL (1981-2010)



March-Sept. (1981-2010)

EVAP > PRECIP

Recharge in fall, autumn : little change

February-Aug. (1981-2010)

EVAP > PRECIP

(~2 months earlier than at beginning of century)

ANR



AMETHYST

METEO FRANCE

Conclusions

Evaluation of the GSWP3 forcing :

- Good representation of air Temperature, Relative Humidity, Precipitation compared to observations SYNOP (correlation, bias...) over North Africa

Evolution of Air Temperatures and Precipitation during the 20th Century :

- Augmentation des températures : + 0.8°C en moyenne sur la zone
- Precipitation reduction : -10 mm/yr on average over zone BUT more variable (x,t)

Evaluation of SURFEX simulations :

- Total water storage compares well with GRACE estimates (dynamic range)
- Superficial soil moisture (and daily var) well represented for 2 sites
- Underestimation of SCFA (MODIS) and depth (station data) – scale problem
- Order of magnitude and annual cycle of ET reasonable for the 2 sites, but winter months show an over-estimation (compared to GLEAM)...GLEAM applicable ? SFX problem for semi-arid locations ?

Water budget component Evolution :

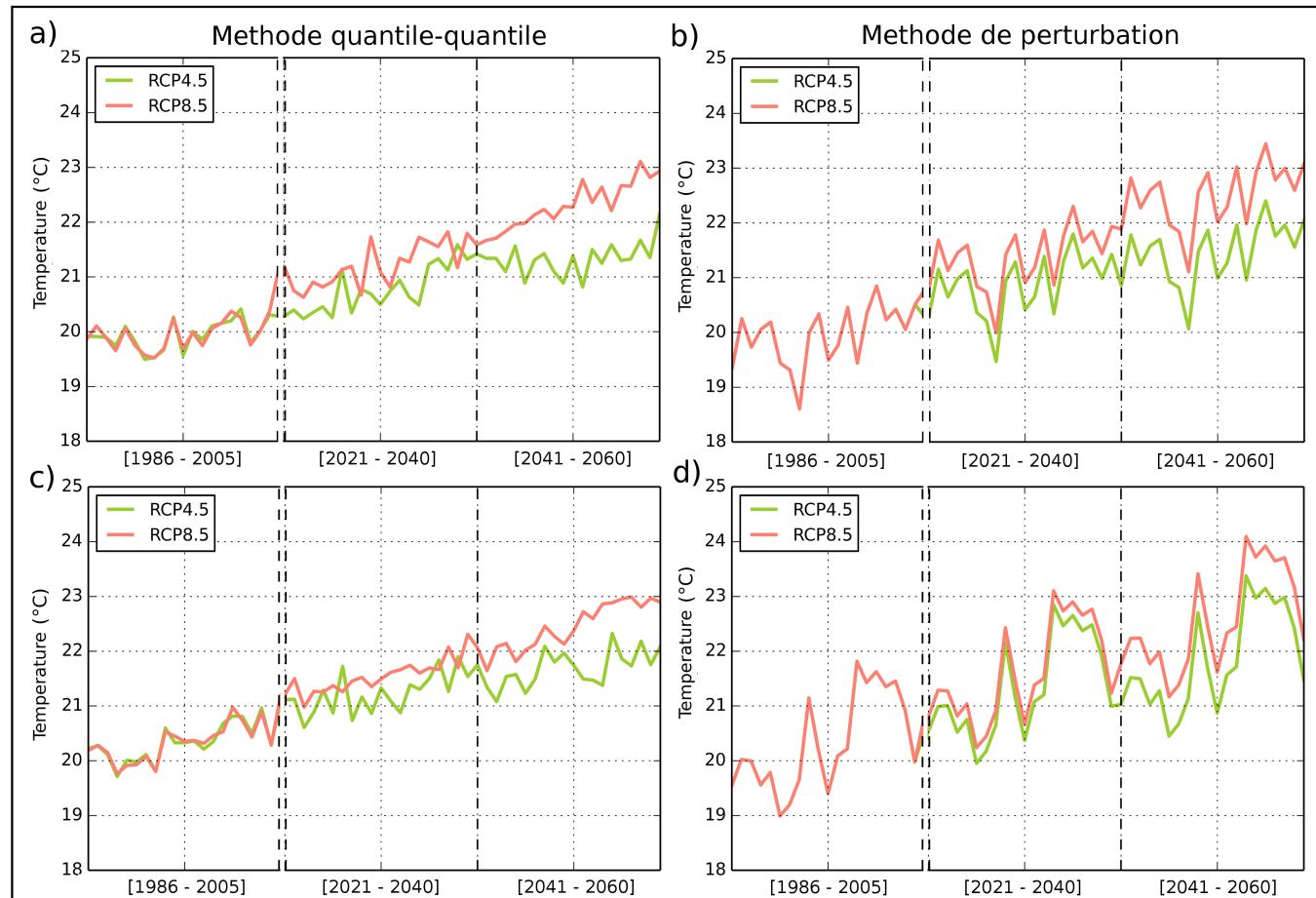
- EVAP > PRECIP : 1 month sooner since the turn of the century (> summer deficit)
- Greater pressure on the water resources (2 months earlier for Merguellil)
- Hydrology (river discharge)Anthropization !

Perspectives

« Futurize » GSWP3 using projections from MED-Cordex then use SURFEX to study future resource changes (RCP 4.5 & 8.5)

→ Future water budget for 2021-2040 and 2040-2060

Marrakech



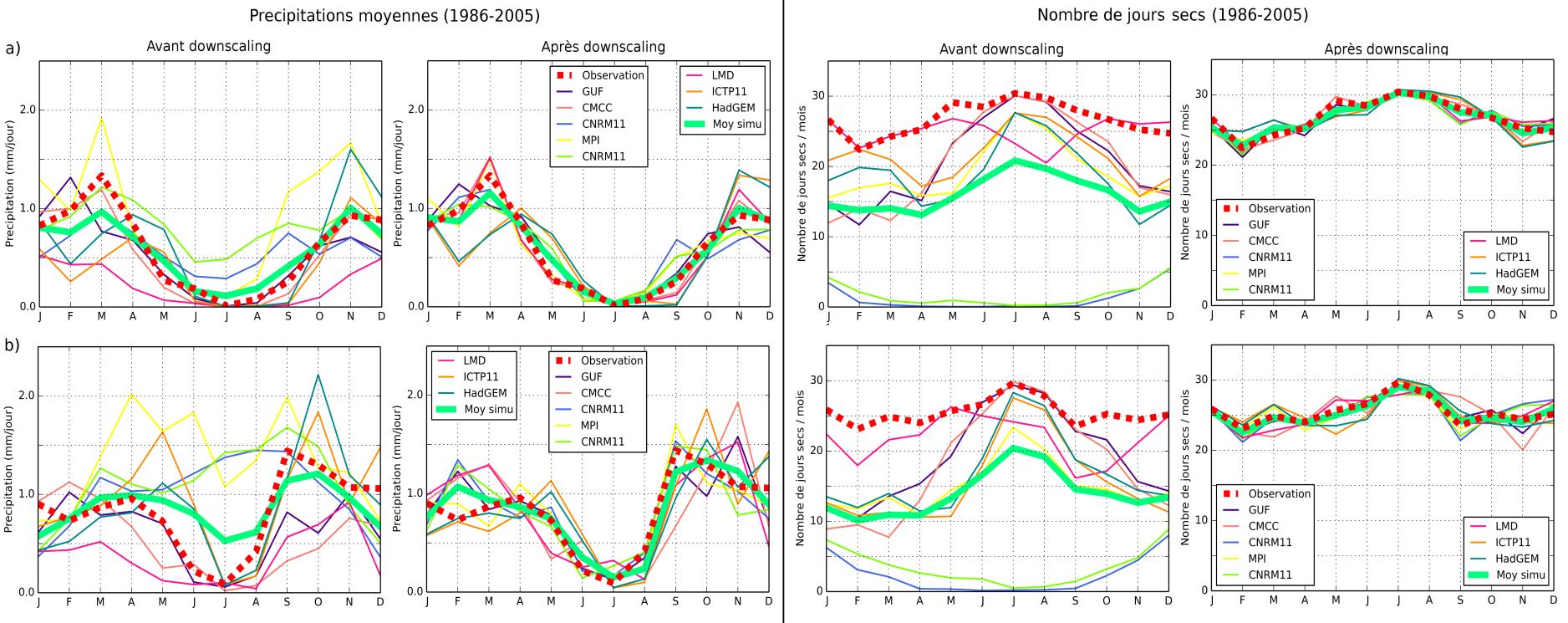
Kairouan

Perspectives

« Futurize » GSWP3 using projections from MED-Cordex then use SURFEX to study future resource changes (RCP 4.5 & 8.5)

Marrakech

→ Future water budget for 2021-2040 and 2040-2060 : QQ method



Kairouan

Merci pour votre attention !

