EO for SM and ET retrieving- impact of CC on wheat yield and water requirement in Morocco

Jamal Ezzahar
ENSA(UCAM, Safi)/CRSA (UM6P, Ben Geurir)

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I. **Surface soil moisture (SSM) retreiving over wheat crops using the backscattering coefficient and the interferometric coherence (**Ouaadi, Jarlan, Ezzahar et al. 2019, RSE (in revision)

II. **Using the photochemical reflectance index (PRI) to detect the water stress of winter wheat in semi-arid regions (**Rafi et al. in preparation **)**

III. **Assessing evapotranspiration of mountain foothills agriculture in the south Mediterranean region using scintillometry and thermal infrared satellite data: Case of the Rheraya catchment, Morocco.** (El Farkh, Ezzahar et al. RS (submitted))

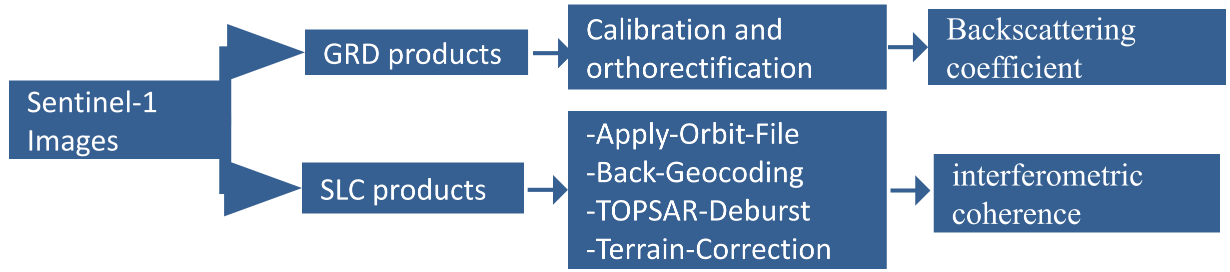
IV. **Assessing the impact of global climate changes on irrigated wheat yields and water requirements in a semi-arid environment of Morocco** (Bourass et al. 2019, Scientific reports/Nature research , minor revision)

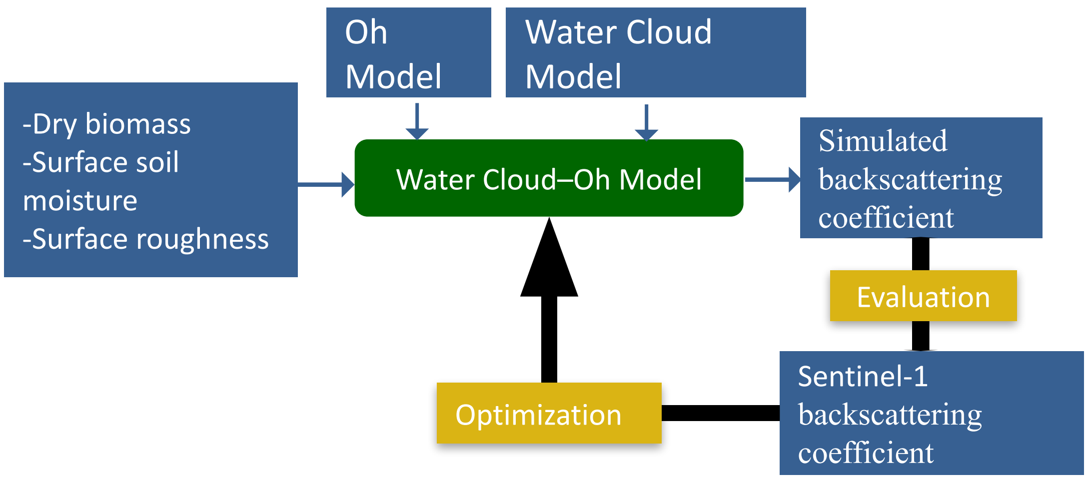
I. SSM retreiving over wheat crops using the backscattering coefficient and the interferometric coherence

Methodology

Part 1:

- Processing the C band Sentinel-1 products.
- Analysis of the processed radar data basing on the measurements and the field knowledge.



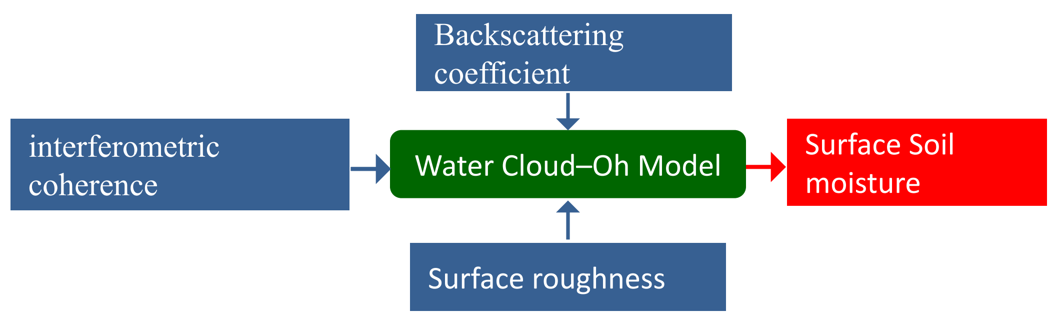


Part 2:

- Modeling the backscattering coefficient of wheat by coupling two models : soil (Oh Model) and wheat (Water Cloud Model)
- Calibration of the coupled model.

Part 3:

Developing a new approach for the surface soil moisture retrieval under vegetated area (example of wheat) using radar data only



I. SSM retreiving over wheat crops using the backscattering coefficient and the interferometric coherence

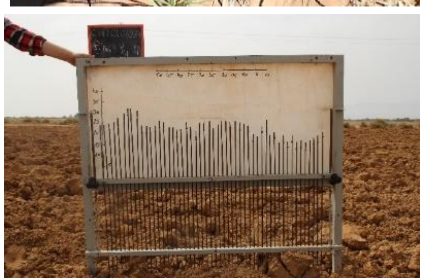
Study area: Chichaoua : (2016-2017 and 2017-2018)

Wheat measurement

- Biomass
- LAI
- Height
- Canopy cover

Soil Measurement

- Surface soil moisture
- Surface roughness (needle-profilometer)



Meteorological data

- Rainfall
- Temperture

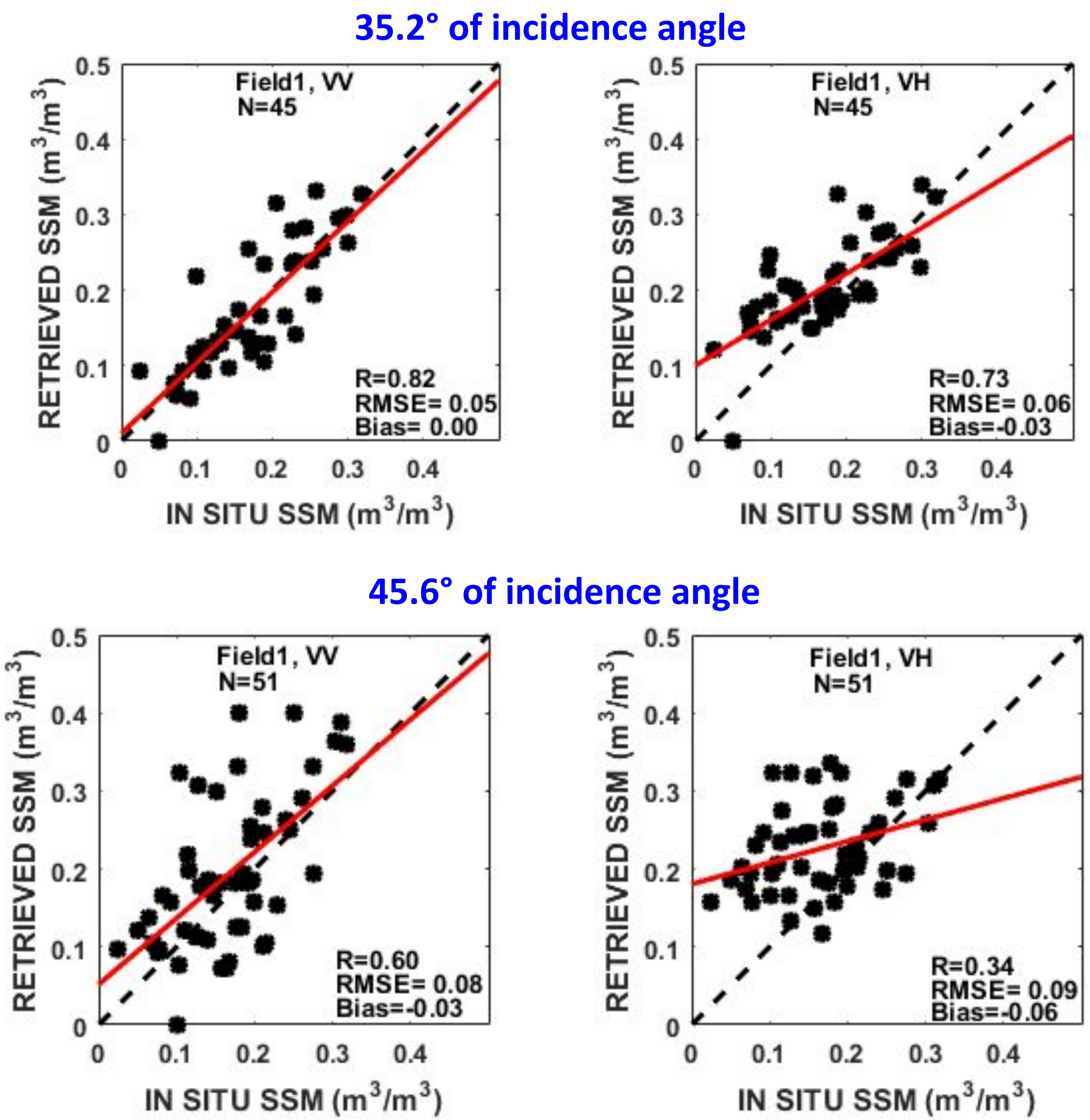
I. SSM retreiving over wheat crops using the backscattering coefficient and the interferometric coherence

Calibration site: Morrocco

The SSM is successfully retrieved using data of two agricultural seasons.

Results at VV are better than VH because of the important effect of the vegetation at VH.

Likewise, the high contribution of vegetation at higher incidence angle explains the observed difference between the results at 35.2° and 45.6°



Ouaadi, Jarlan, Ezzahar et al. 2019, Remote sensing of environement (in revision)

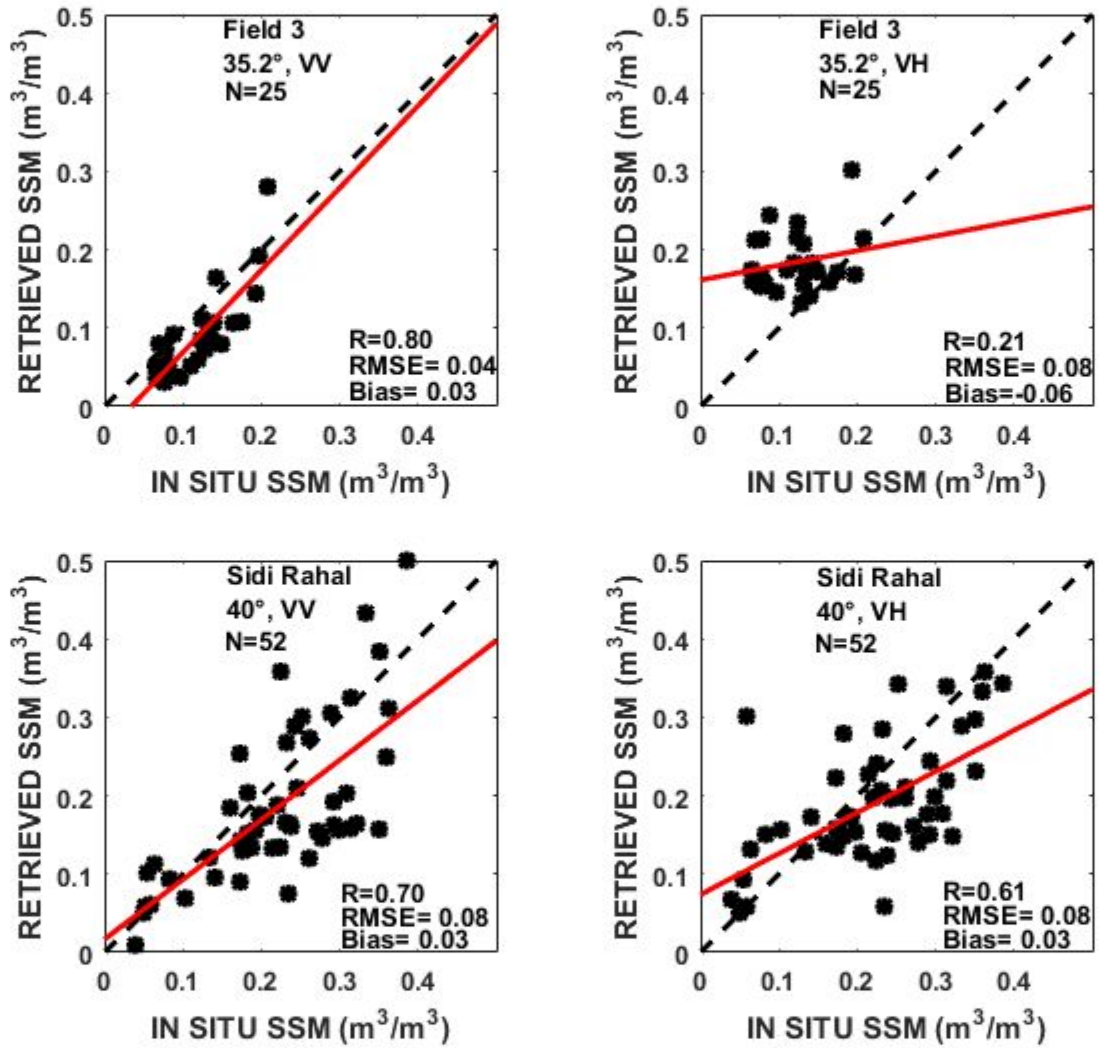
I. SSM retreiving over wheat crops using the backscattering coefficient and the interferometric coherence

Validation site: Morocco

The Field 3 is an irrigated wheat field while Sidi Rahal is a rainfed field.

The statistical metrics are closed to those obtained over the study site.

A higher value of the correlation coefficient is obtained over Field 3 comparing to Sidi Rahal. This is mainly related to the higher incidence angle at the second site.



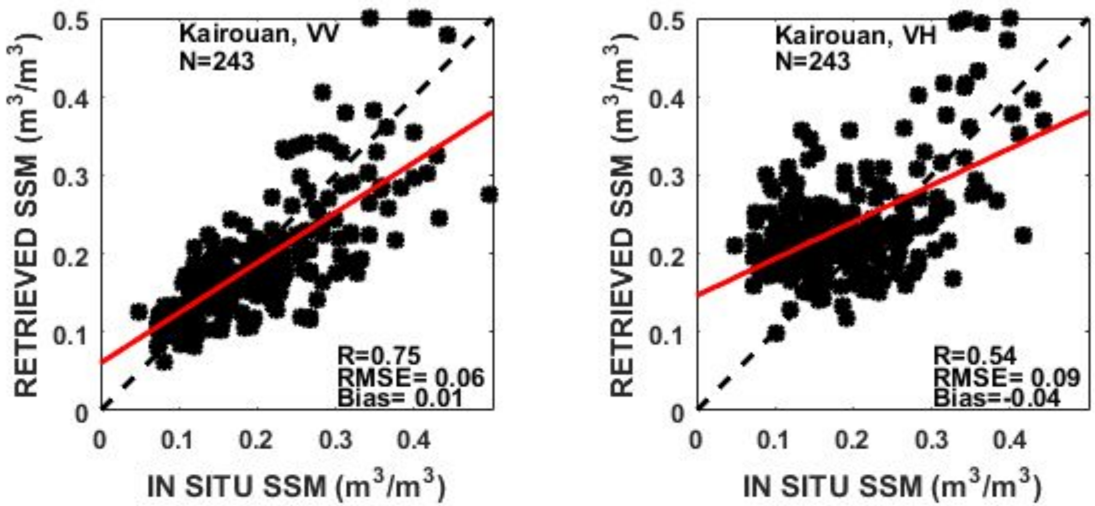
Ouaadi, Jarlan, Ezzahar et al. 2019, Remote sensing of environement (in revision)

I. SSM retreiving over wheat crops using the backscattering coefficient and the interferometric coherence

The validation over 18 irrigated and rainfed plots in Tunisia yield higher correlation coefficient and lower RMSE and bias.

The limited performance loss on all validation sites demonstrates the robustness of the developed approach.

Validation site : Tunisia



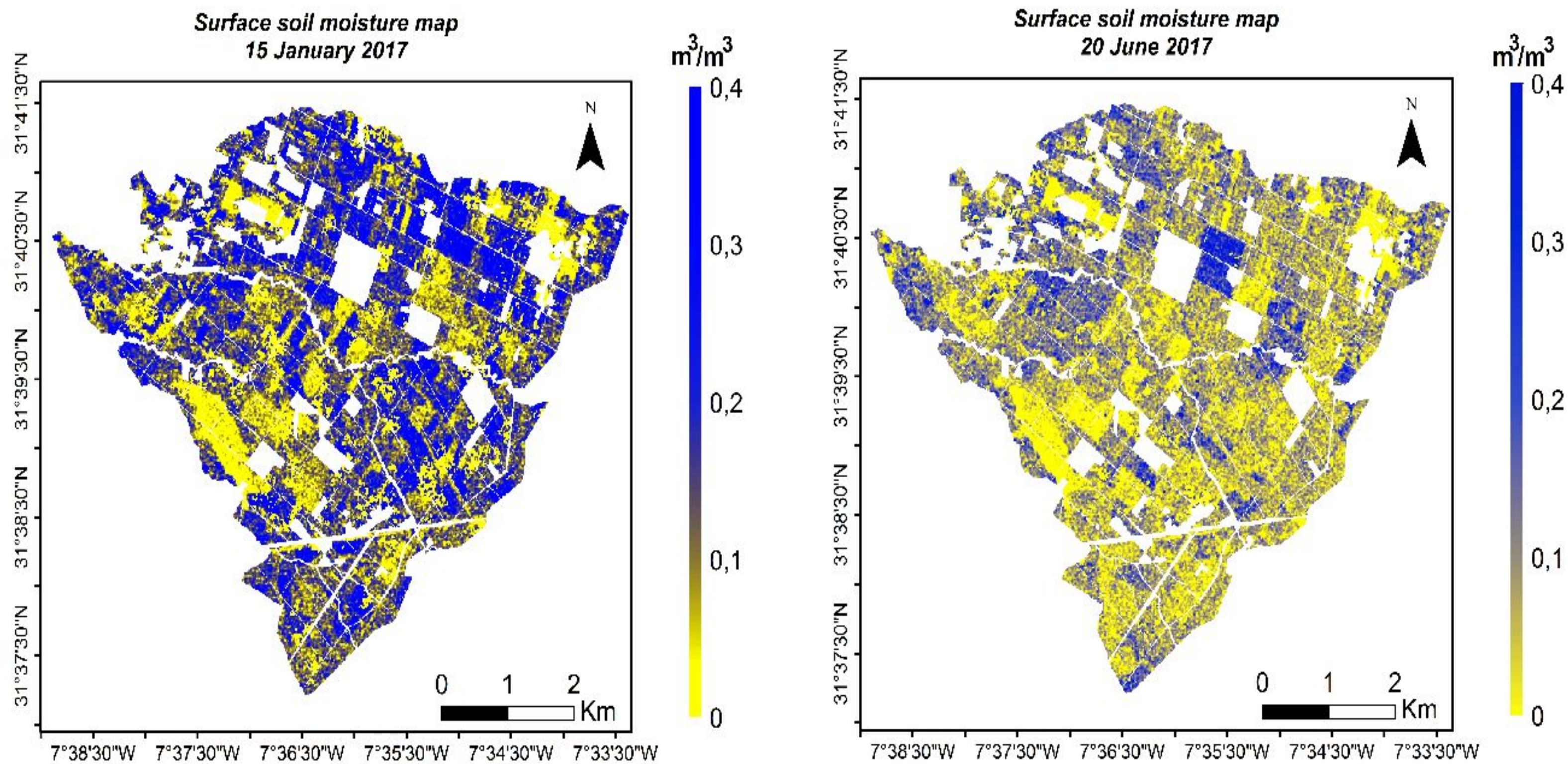
Ouaadi, Jarlan, Ezzahar et al. 2019, Remote sensing of environement (in revision)

I. SSM retreiving over wheat crops using the backscattering coefficient and the interferometric coherence

Surface Soil moisture maping using the new developped approach

The approach is used for SSM maping over an irrigated perimeter in Morocco dominated by wheat crops. During January the fields are irrigated while after 15th June most of the fields are harvested.

As the SSM is retrieved at the Sentinel-1 pixel scale, the approach allows the monitoring of the hydric variability as it is cleary observed in the maps.

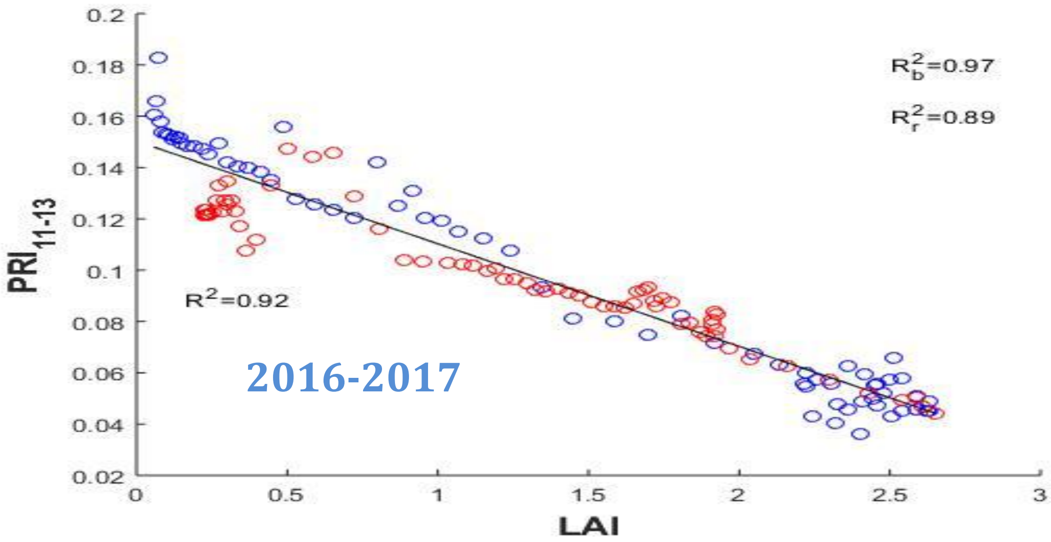


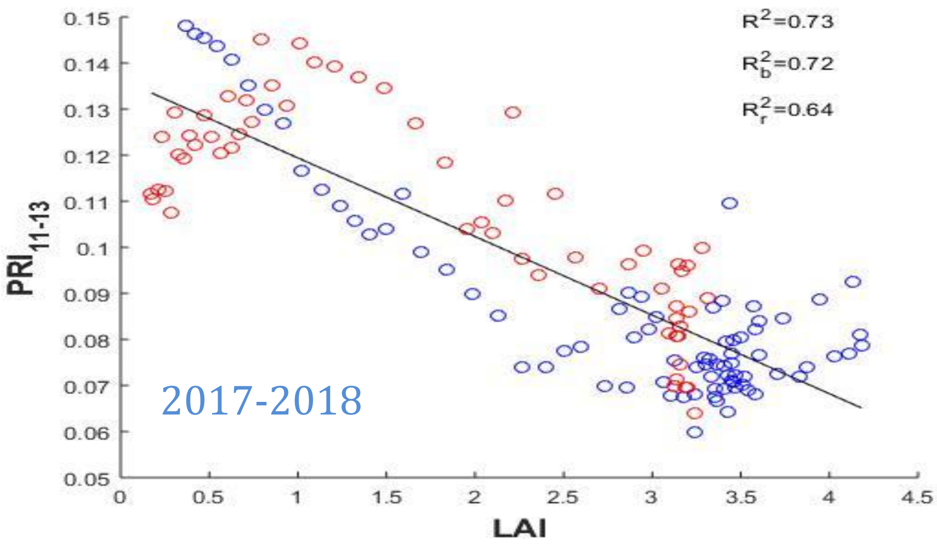
Ouaadi, Jarlan, Ezzahar et al. 2019, Remote sensing of environement (in revision)

II. Using the photochemical reflectance index (PRI) to detect the water stress of winter wheat in semi-arid regions

Relation between PRI and LAI

The impact of LAI on the seasonal evolution of the PRI signal is clear and very significant. The decrease in the PRI(11-13) signal is clearly correlated with the increase in LAI, this strong correlation provides us with information on the impact of LAI on the PRI signal.





II. Using the photochemical reflectance index (PRI) to detect the water stress of winter wheat in semi-arid regions

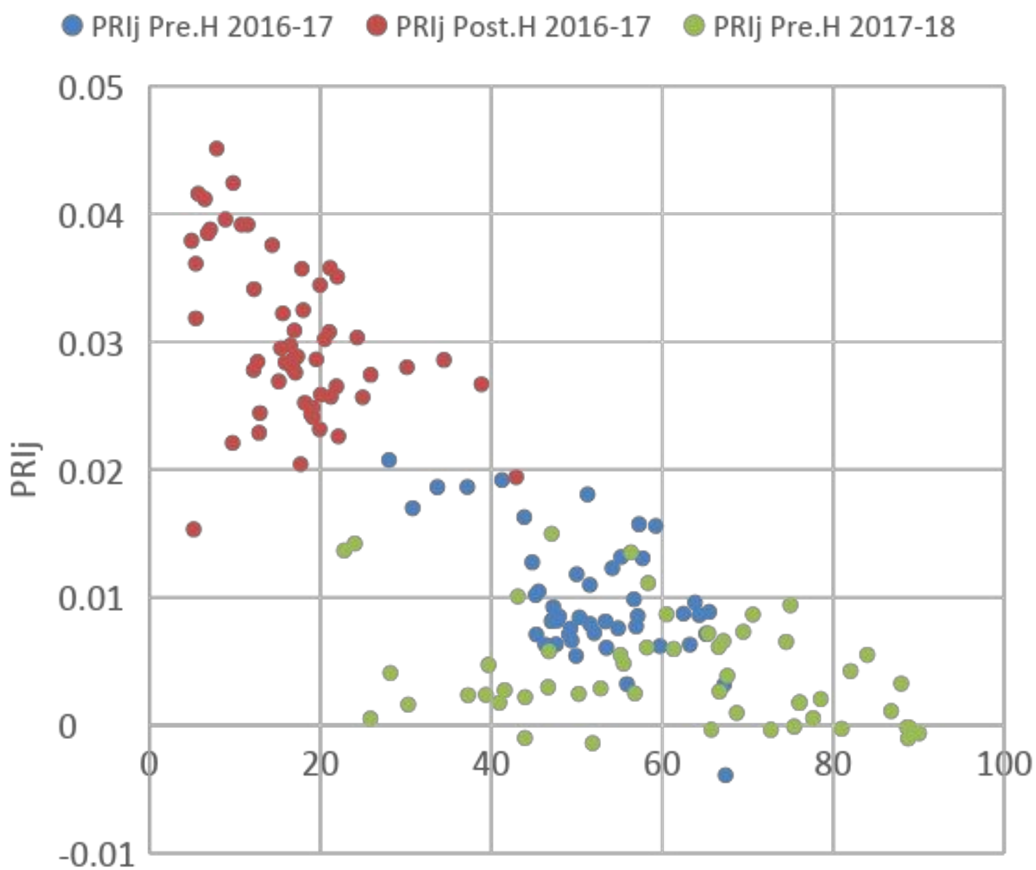
Response of the PRIj water stress index to useful reserve

The PRIj water stress index is calculated as follows:

$$PRI_j = PRI_{(11-13)} - PRI_0$$

Where PRI_0 is the PRI signal measured in the morning.

The PRIj index was correlated against the useful reserve (RU) calculated on the basis of moisture measurements. We notice in this figure a decrease in the index according to the increase in the useful reserve, this trend stabilizes beyond 40% of the useful reserve. PRIj can provide us with information on the water status of wheat and in this figure can be divided into two parts.

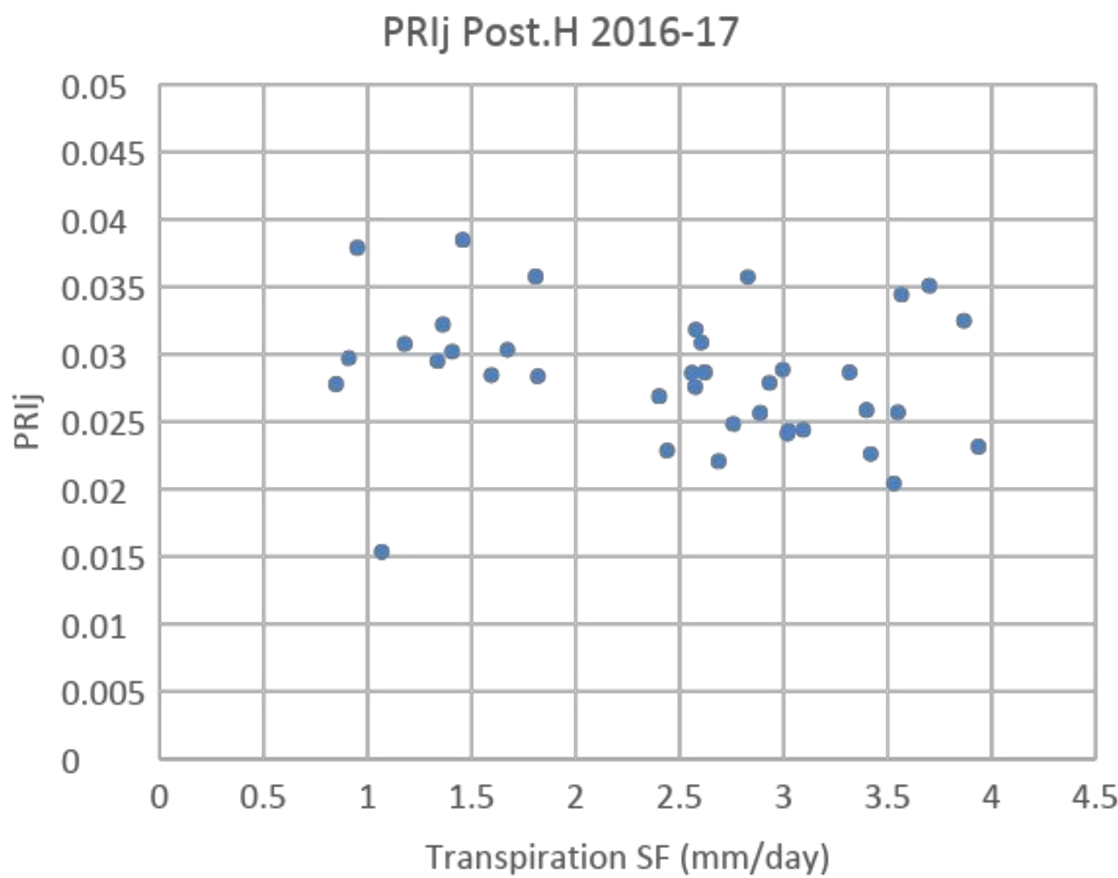


II. Using the photochemical reflectance index (PRI) to detect the water stress of winter wheat in semi-arid regions

Response of the PRIj water stress index to Transpiration

- ✔ We notice that there is a certain decrease in the PRIj as a function of the increase in daily transpiration of sap flows.

- ✔ This variation may show a good response of the PRIj water stress index to the restriction of wheat transpiration may be due to lack of water in the root zone.



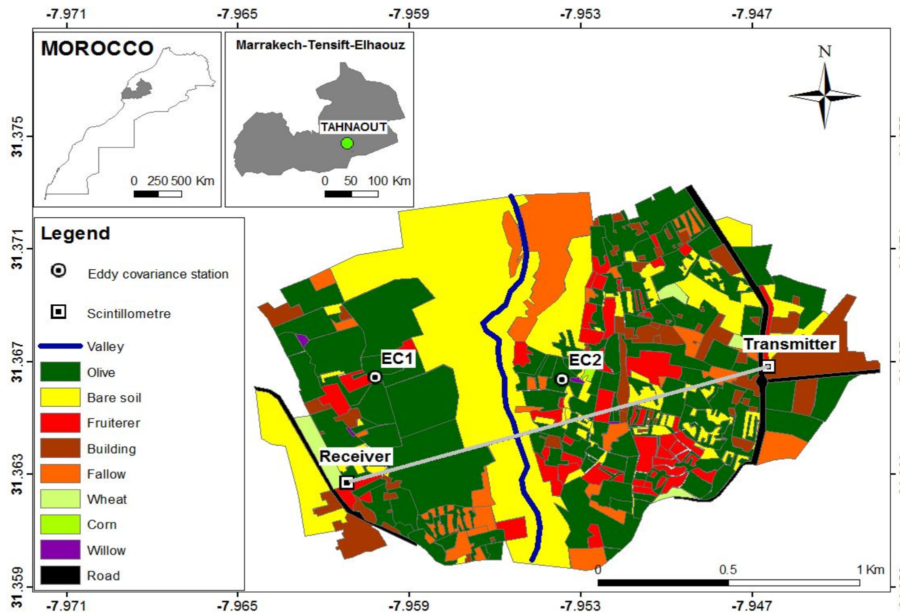
Correlation between the PRIj water stress index and daily transpiration of sap flows during the post-season heading of the 2016-17 season.

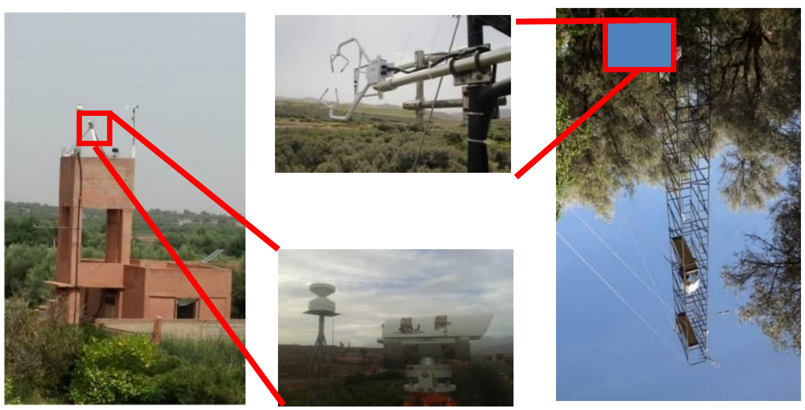
III. Assessing ET of mountain foothills using scintillometry and thermal infrared satellite data: Case of the Rheraya catchment, Morocco

The study area :

- Is located in the piedmont of the High Atlas specifically in Tahanaout, about 35 km from Marrakech, Morocco.
- is characterized by a semi-arid Mediterranean climate with a very low rainfall rate of around 230 mm per year
- is consisted of a mixed of arboriculture mainly olive trees, wheat, corn, alfalfa, follow and bare sol.
- Flood irrigation is particularly used using runoff water that occurs as a result of melting fallen snow.

Study area: Tahanouate :





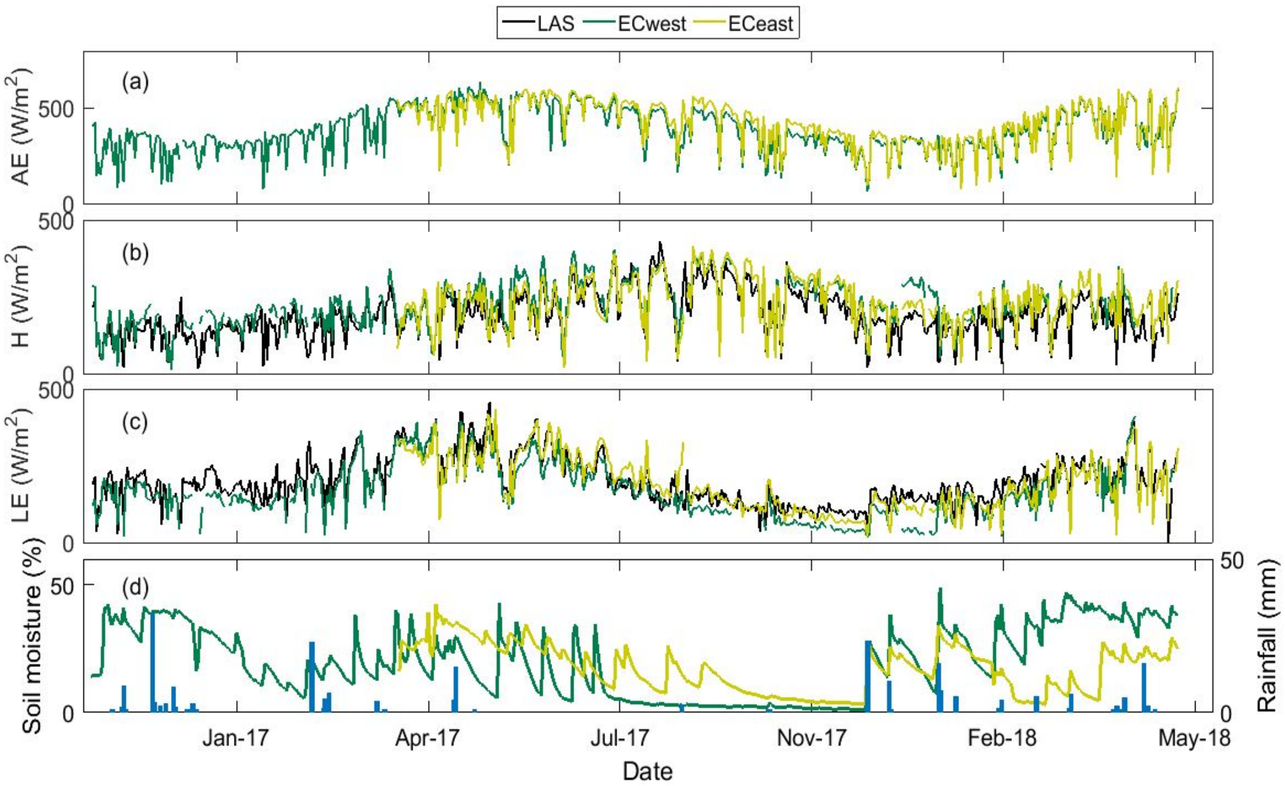
Receiver scintillometer

Eddy covariance station

III. Assessing ET of mountain foothills using scintillometry and thermal infrared satellite data: Case of the Rheraya catchment, Morocco

The figure displays the time series of daily average of convective fluxes (*LE* and *H*, derived from LAS and EC systems), available energy (*AE=Rn-G*), soil moisture and rainfall, collected from November 2016 to April 2018 over both sites.

At the seasonal scale, we note an acceptable agreement between LAS and Eddy covariance daily turbulent fluxes (H and LE) values, especially for dry conditions which lead to homogeneous surface soil moisture.



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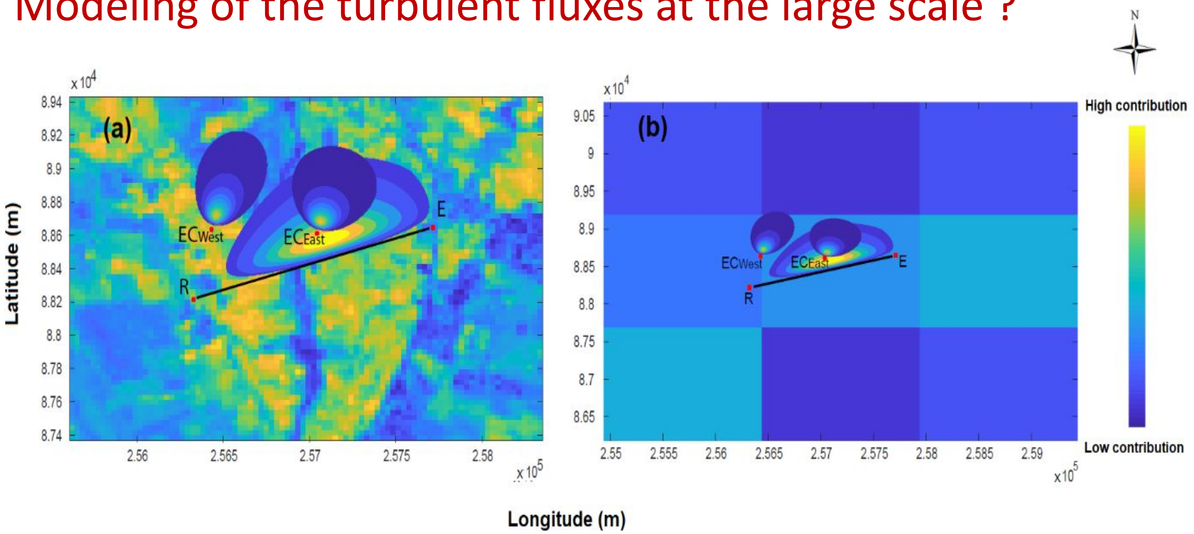
Modeling of the turbulent fluxes at the large scale ?

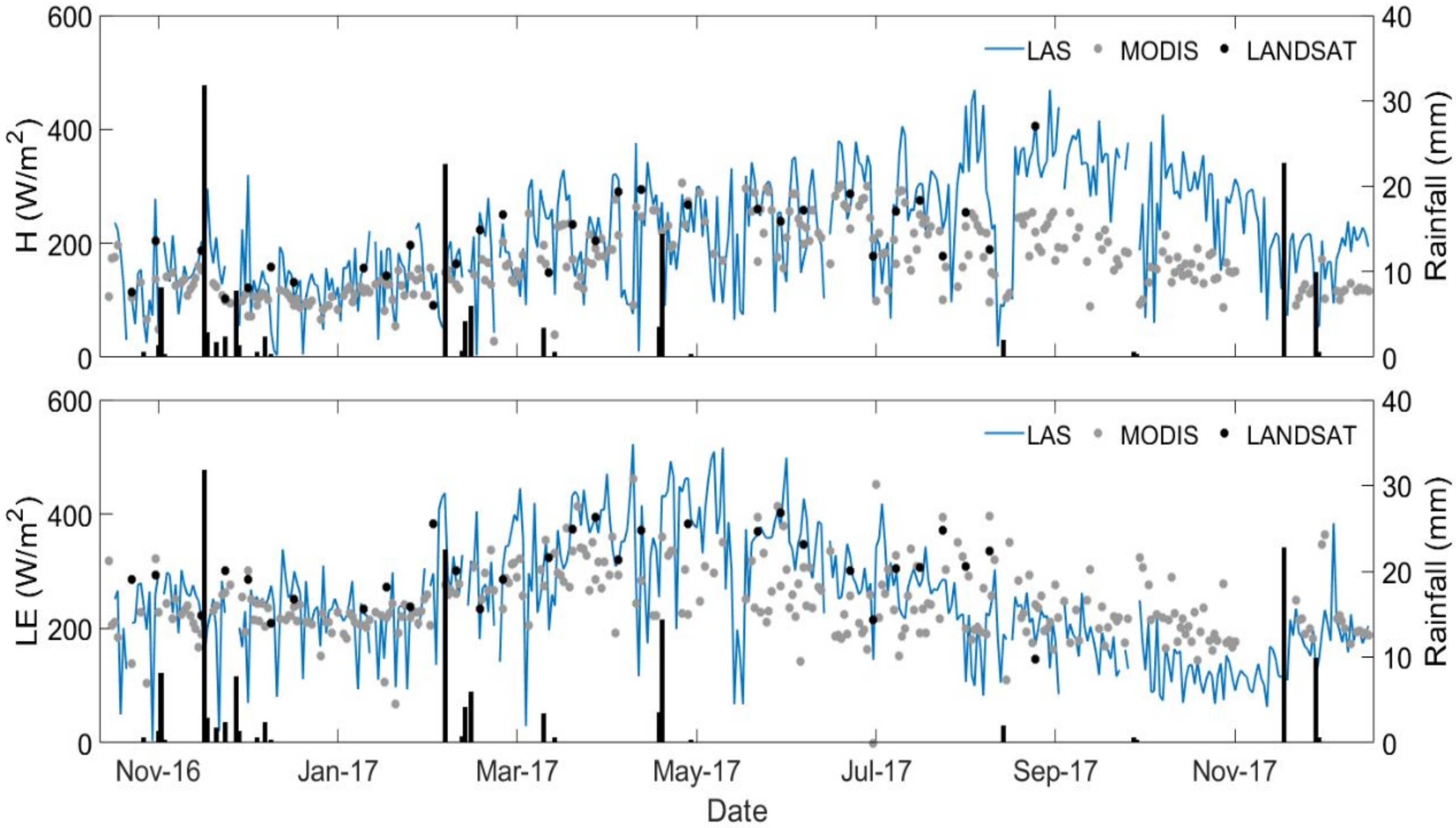


Inputs Ts and albedo

TSEB model

III. Assessing ET of mountain foothills using scintillometry and thermal infrared satellite data: Case of the Rheraya catchment, Morocco

Comparison between LAS and TSEB turbulent fluxes estimates



IV. Assessing the impact of global climate changes on irrigated wheat yields and water requirements in a semi-arid environment of Morocco

- Two scenarios (RCP4.5 and RCP8.5) and two horizons (2041-2060 and 2081-2100) was considered.

- Projected Temperature and precipitation was provided form MEDCORDEX ensemble

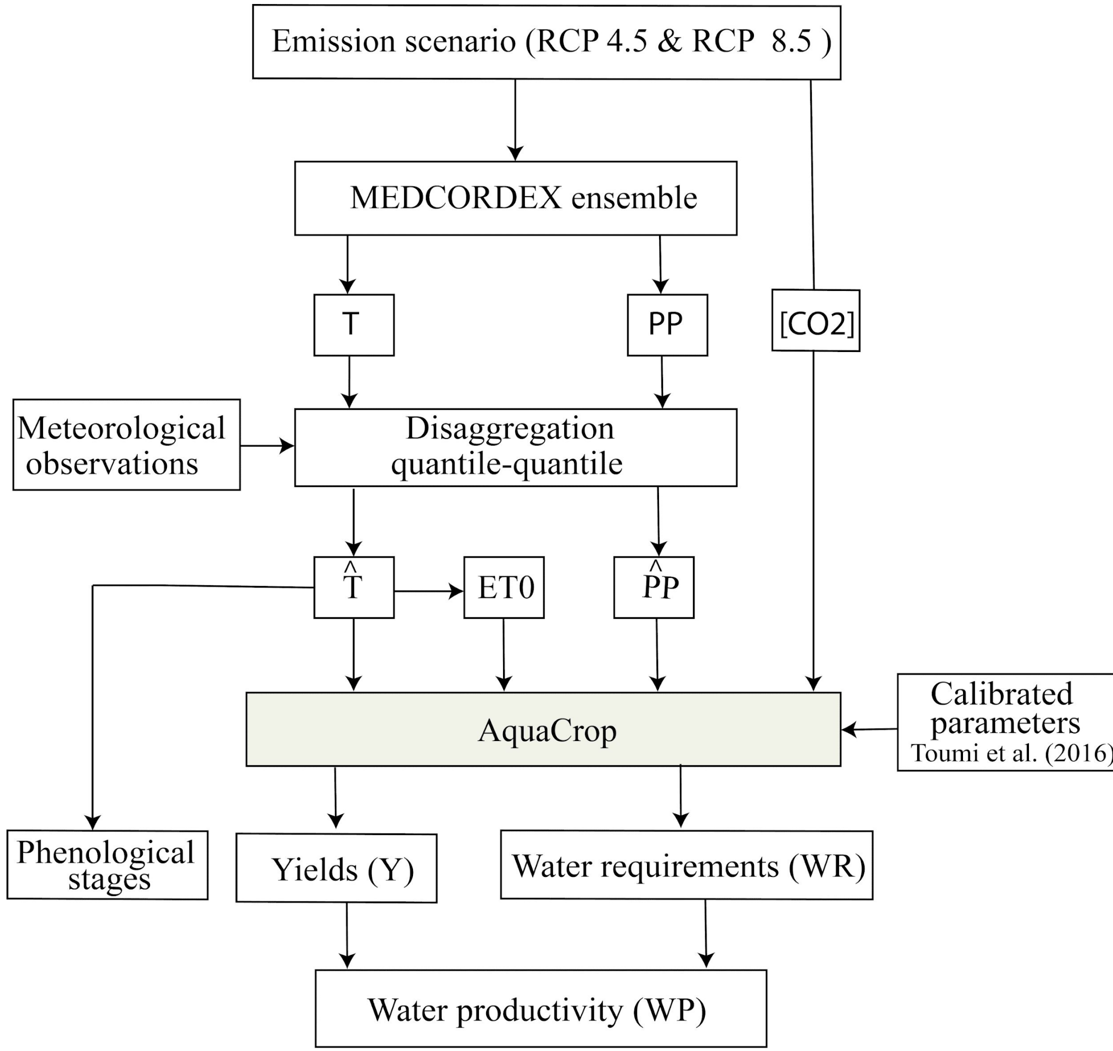
- Aqua Crop model was used to asses the impact of climate change in Yield, water requirement and water productivity

- **Three typical sowing dates were evaluated:**

✔ Early sowing around November 15th

✔ Intermediate sowing around December 15th

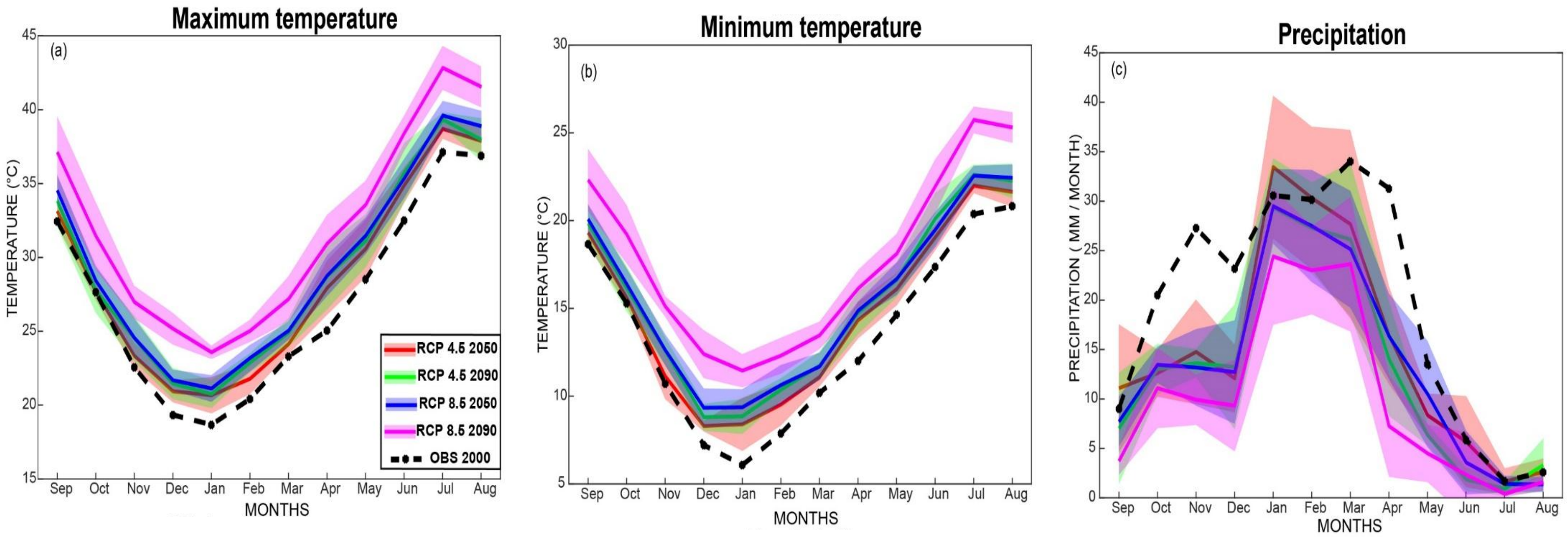
✔ Late sowing around January 15th



T̂, P̂P :Disaggregated daily temperature and precipitation

IV. Assessing the impact of global climate changes on irrigated wheat yields and water requirements in a semi-arid environment of Morocco

❑ Temperature and precipitation trends



- ✔ A systematic increase in maximum and minimum temperature for all scenarios and horizons is observed. This temperature rise ranges from 1°C (RCP4.5 by 2050) to 6°C (RCP8.5 by 2090) for yearly averages.
- ✔ The decrease in precipitation is particularly prominent in spring (March and April) during the grain filling stage and autumn (October to December) around emergence.

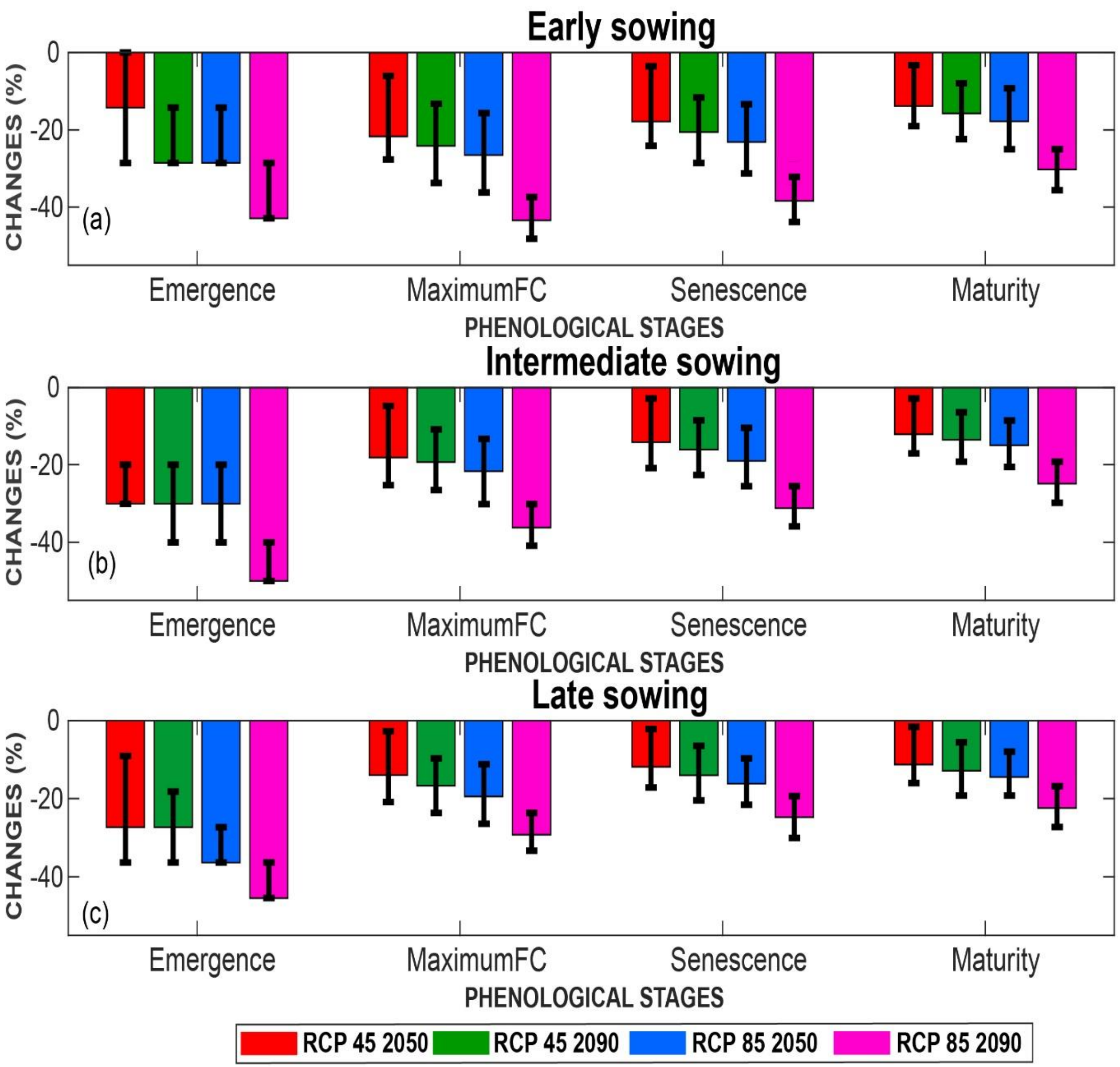
IV. Assessing the impact of global climate changes on irrigated wheat yields and water requirements in a semi-arid environment of Morocco

❑ Impact of climate change on the duration of phenological stages

- ✔ The impact of CC on the duration of the phenological stages is quantified by the variation of the cumulative degree days (CDD)

- ✔ The results show a systematic reduction of the LCS (Length of crop season) from **10 to 32%**

- ✔ Small differences are observed between the sowing dates, the early-season LCS could be decreased by **11%** (about **17 days**) for RCP4.5 at 2050 and a **10%** reduction is expected under the same conditions for late sowing (about **13 days**).



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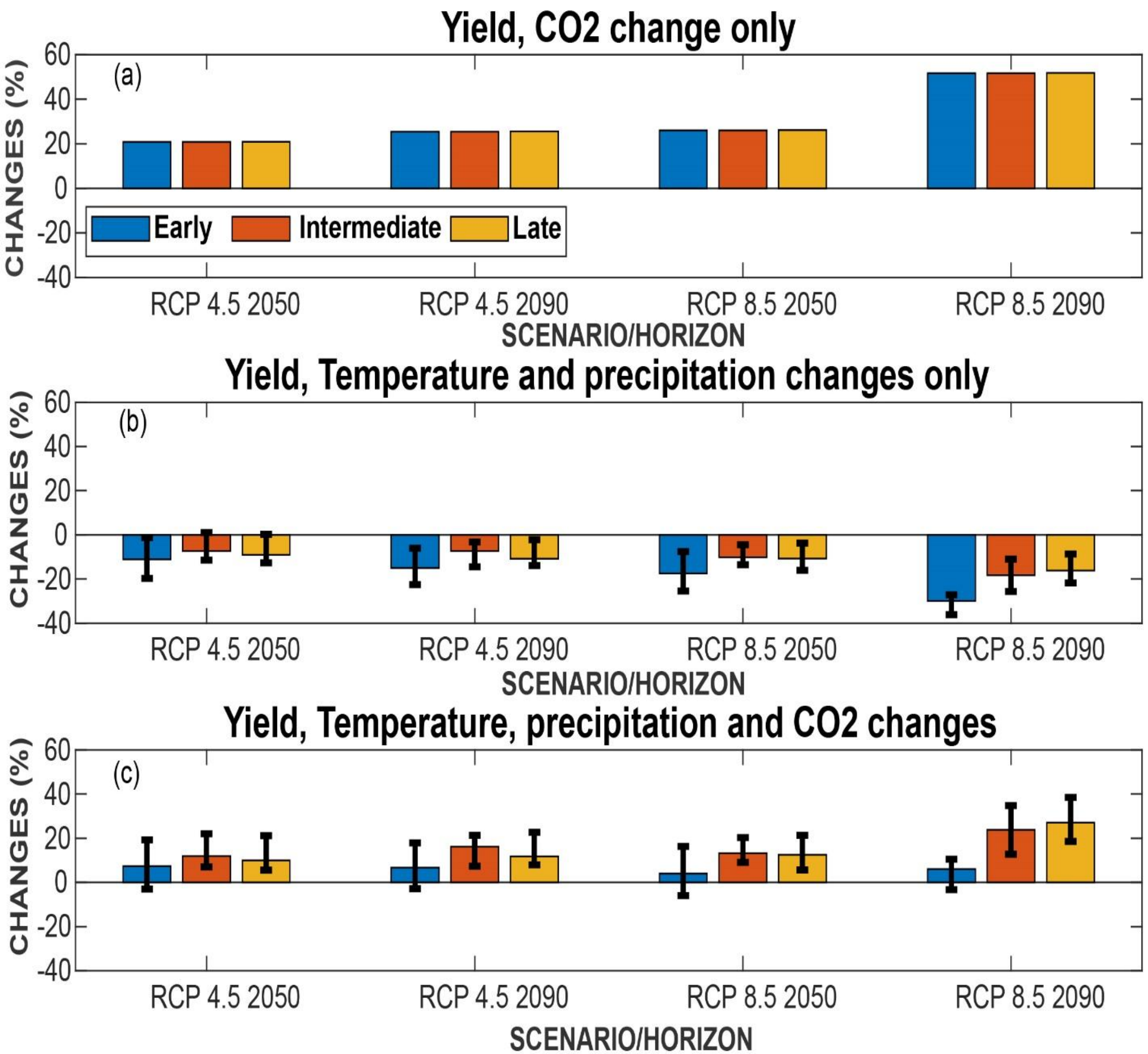
❑ Impact of climate change on grain yield

- ✔ Higher atmospheric CO_2 concentrations increased yield in 2090 for RCP 85 yields are expected to increase by as much as **52%**

- ✔ Temperature rise at constant atmospheric CO_2 concentration result in lower yields. In 2090 for the RCP8.5 a **30%** loss of yield due to an increase in temperature of **4.9°C** (associated with a **30 %** decrease in LCS).

- ✔ The fertilizing effect of atmospheric CO_2 concentration might offset the losses induced by rising temperatures. In 2050 yield could increase by **7** and **12 %** for early and intermediate sowing, depending on the RCP



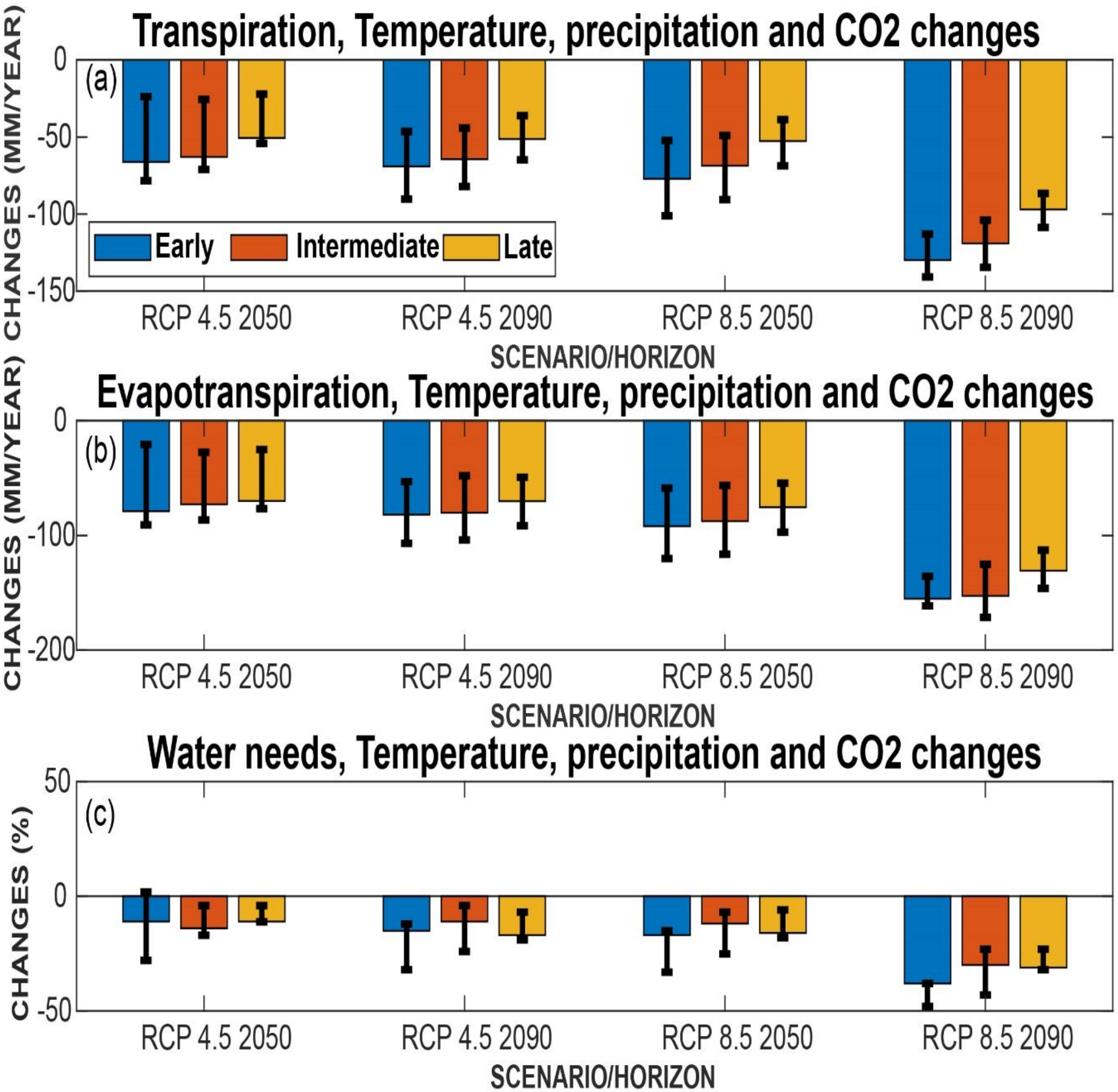
IV. Assessing the impact of global climate changes on irrigated wheat yields and water requirements in a semi-arid environment of Morocco

❑ Impact of climate change on Water needs

- ✔ Decrease in cumulative evaporative demand (computed from the Hargreaves formula) associated with a shorter growing season, leads to a decrease in transpiration and evaporation

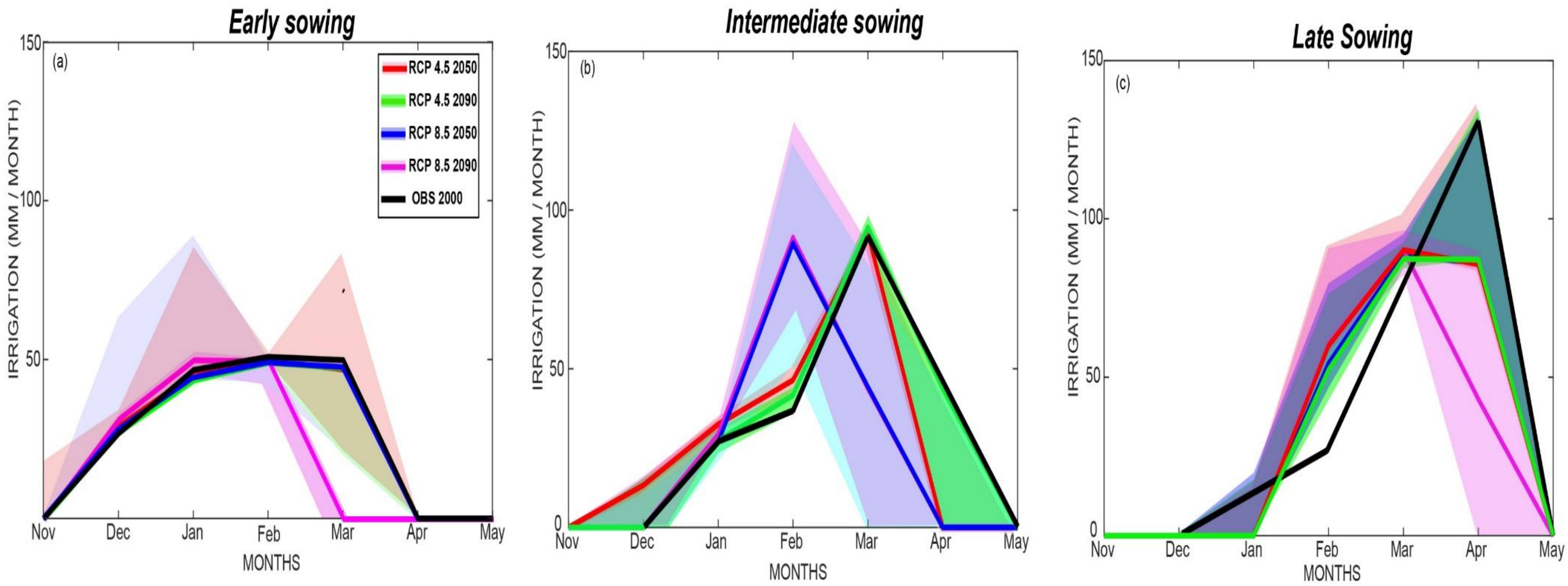
- ✔ In 2050, according to RCP4.5, transpiration is expected to decrease by **57, 48** and **38 mm** (**20, 16,** and **12%)**

- ✔ systematic decrease of WR indicating that the joint shortening of the LCS and the improved stomatal regulation associated with rising temperature and CO2 are able to counterbalance the increase in evaporative demand



IV. Assessing the impact of global climate changes on irrigated wheat yields and water requirements in a semi-arid environment of Morocco

❑ Impact of climate change on the irrigation demand



- ✔ In 2090, according to RCP8.5, irrigation demand should decrease of **33 mm** or **20 %** from December to February, with the maximum advanced by one month to January (**49 mm**).
- ✔ The seasonal pattern of irrigation demand could be significantly modified, with a peak requirement that might be advanced for wheat by about two months for late and intermediate sowing