Influence of Multi-Temporal High Resolution Remote Sensing Products on Simulated Hydrometeorological Variables in the south-west of France

Centre d'Etudes Spatiales de la BIOsphère Toulouse – France

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Introduction

- **Societal issues** : Temporal and spatial **heterogeneity of the vegetation**, especially in agricultural landscapes → **impact on hydrometeorological fluxes** like evapotranspiration or drainage → difficulties for water management agencies to assess available water at the basin scale in a context of drought and irrigation supply.

Introduction

- **Technical solution** : **Sentinel-2 space mission** → images of the land surface with **high spatial resolution and revisit frequency** (20m, 5 days) → monitoring of the land cover and vegetation dynamic.

- **Variable of interest** : **Leaf Area Index** (LAI) : most used index to represent the vegetation dynamic and its effect on the evapotranspiration fluxes.

  LAI is not accurately taken into account in **Land Surface Models** : often climatologic LAI with low spatial resolution → do not allow representing the actual temporal and spatial variability of the vegetation cover

Aim of the study: Demonstrate the contribution of Sentinel-2 like remote sensing products as Land Surface Model inputs.

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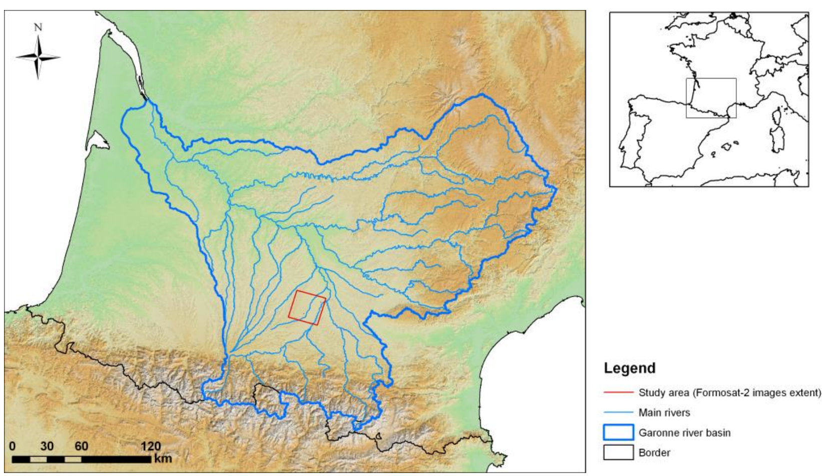
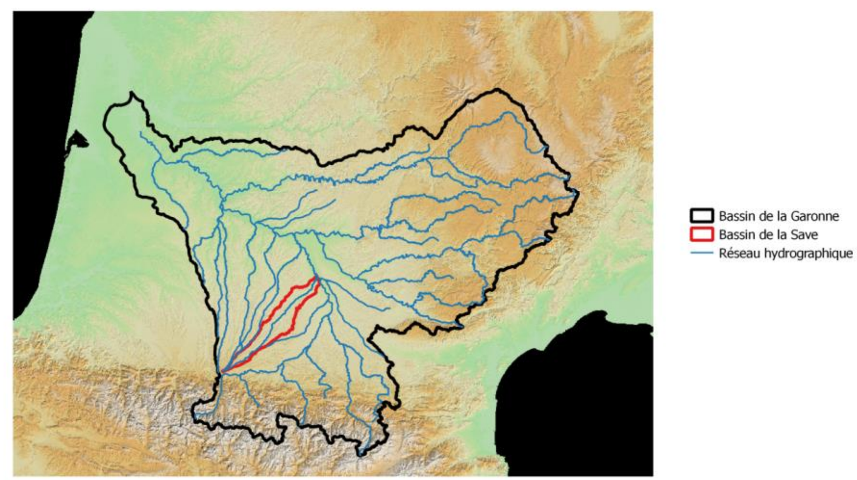
Study area

- **Agricultural area** in the South-West of France within the footprint of a **Formosat-2 image** (24x24km).
- **2 sites of in-situ measurements** with different crop rotations as part of the Observatoire Spatial Régional (***Dejoux & al. 2012***): Auradé and Lamasquère.
- Simulation from **2006 to 2010**



- **Save basin**(20x105km)
- Simulation of the year **2009**



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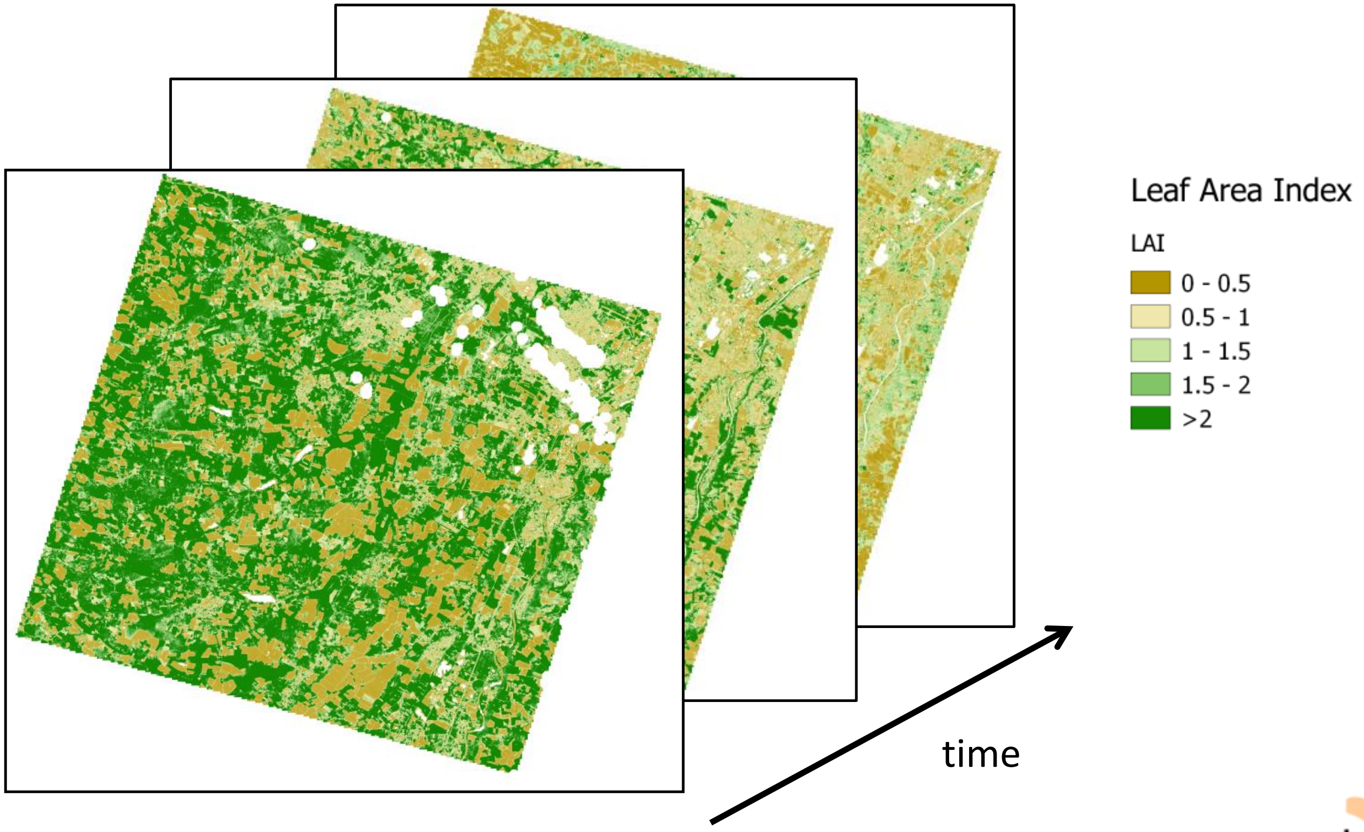
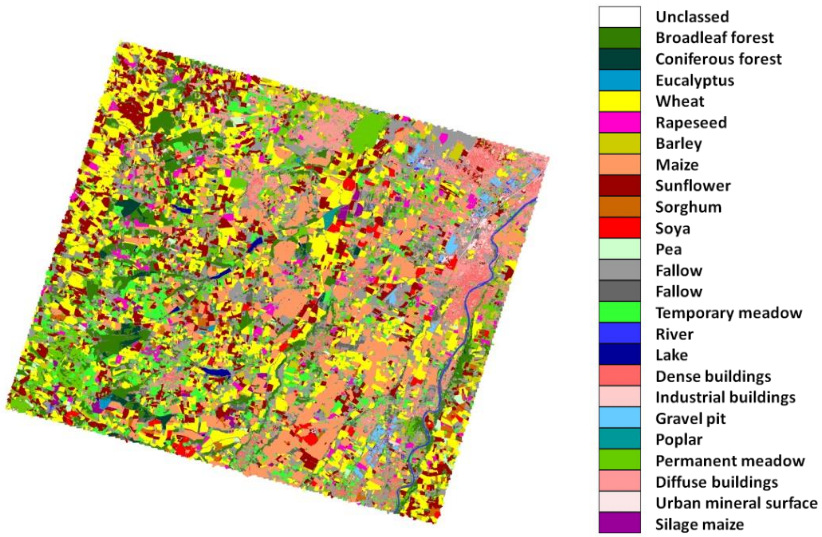
I. Data

- **Multi-temporal LAI maps** derived from **Formosat-2** images (8m, 105 images over the period, ***Claverie 2012***) and **Landsat-5** (30m, 40 images over the period) for the Save basin.

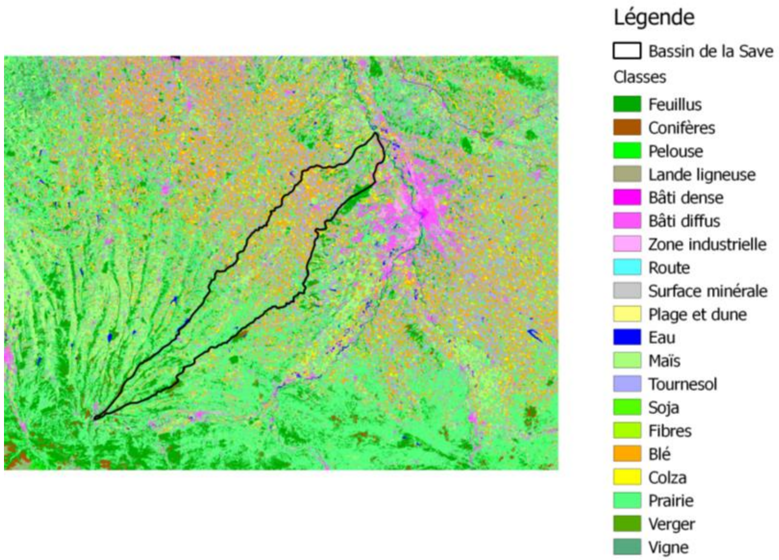


I. Data

- **CESBIO's land cover maps** determined from the **Formosat-2** images (***Ducrot & al. 2005, 2007 and 2009***) and **Landsat-5** for the Save basin (IOTA-2, ***Inglada & al. 2015***).



➔ 34 different classes



➔ 20 different classes

I. Data

- **In-situ measurements** : **Radiative components** (eddy covariance tower), **LAI** (destructive method), meteorological variables, Soil Water Content

II. Experiments

Physiographic parameters

Topography
NTM : altitude

Soil texture
HWSD map : %sand, %clay

Occupation des sols
ECOCLIMAP –II : 12 plant functional types (pft) and associated parameters
LAI, VEG, Z0, α, ε, Rs_{min}

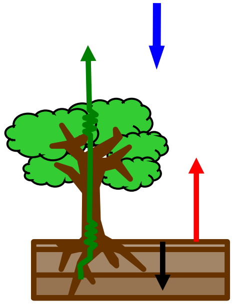
Meteorological Forcing

Reanalysis
SAFRAN : Rain, Snow, T2m, Ps, Wind, q2m, Rg, LWD

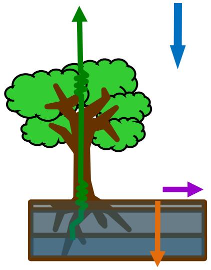
ISBA

Budgets

Energy budget
$Rn + H + LE + G = 0$



Water budget
$\Delta SWC = P - ETR - R - D$



ECOCLIM experiment

Physiographic parameters

Topography
NTM : altitude

Soil texture
HWSD map : %sand, %clay

Occupation des sols
ECOCLIMAP –II : 12 plant functional types (ft) and associated parameters
LAI, VEG, Z0, α, ε, Rs_{min}

Meteorological Forcing

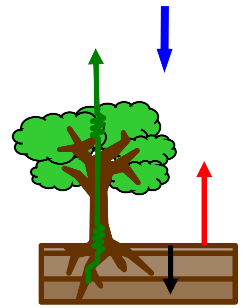
Reanalysis
SAFRAN : Rain, Snow, T2m, Ps, Wind, q2m, Rg, LWD

ISBA

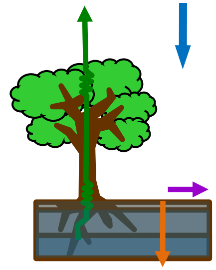
New grid:
1 grid cell = 1 field

Budgets

Energy budget
Rn + H + LE + G = 0



Water budget
ΔSWC=P – ETR – R – D



- ECOCLIMAP : regular grid **1km resolution** → inaccurate spatial and temporal variability
- **Climatologic LAI** derived from MODIS 2000-2005

FORMOSAT/SAVE experiment

Physiographic parameters

Topography

NTM : altitude

Soil texture

HWSD map : %sand, %clay

Occupation des sols

~~ECOCLIMAP –II~~ : 12 plant functional types (pft) and associated parameters

~~LAI~~, VEG, Z0, α, ε, Rs_{min}

Monthly Formosat-2 LAI

Meteorological Forcing

Reanalysis

SAFRAN : Rain, Snow, T2m, Ps, Wind, q2m, Rg, LWD

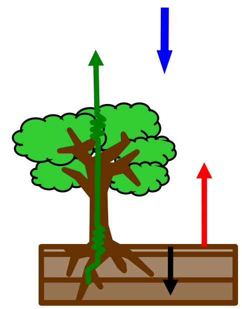
ISBA

New grid:
1 grid cell = 1 field
PFT forced by CESBIO's land cover map

Budgets

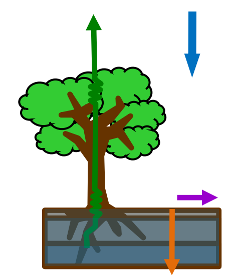
Energy budget

Rn + H + LE + G = 0



Water budget

ΔSWC=P – ETR – R – D



~13 000 plots on Formosat area
~ 5500 on Save basin
(~85-90% of the total image surface)

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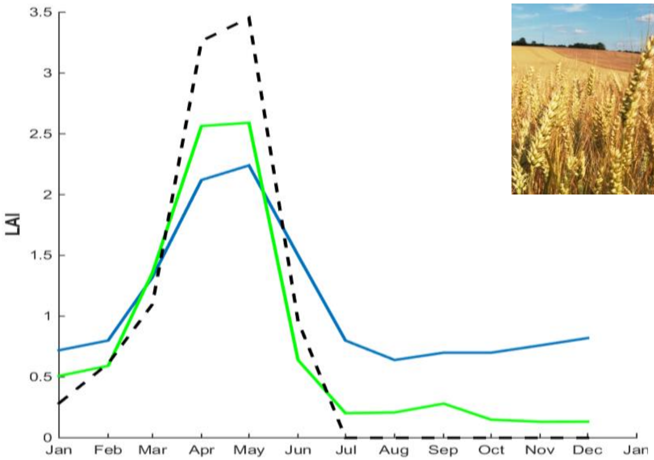
III. Results

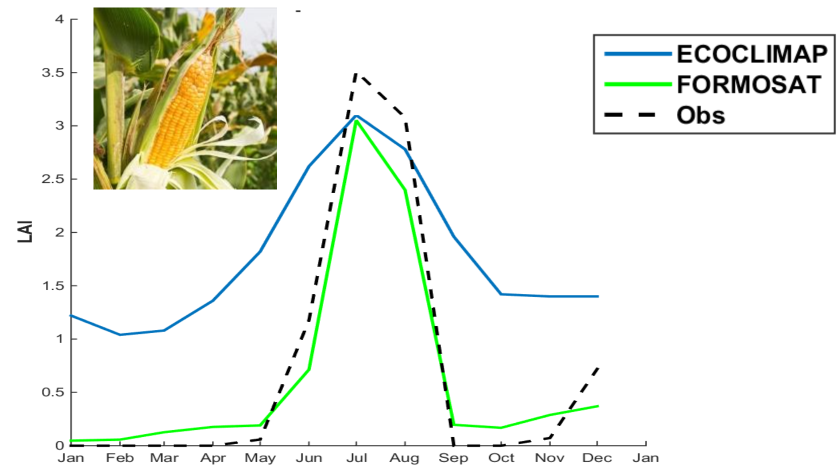
1. Local comparison:

Auradé : Wheat (C3)

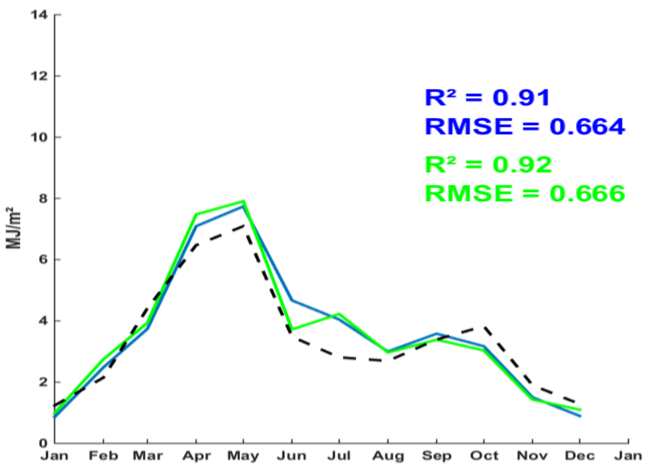
Lamasquère : Maize (C4)

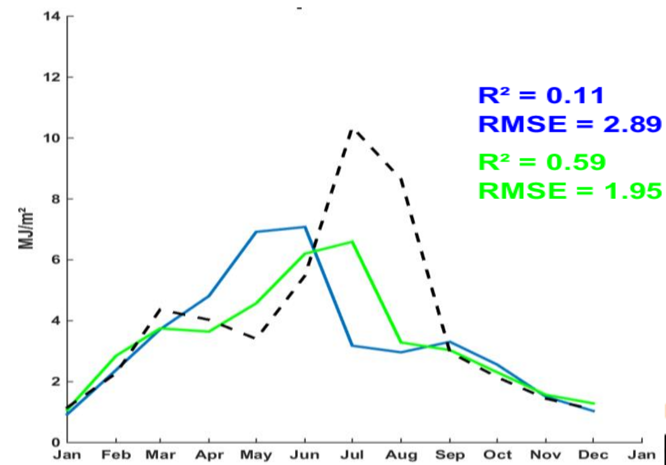
LAI →





LE →



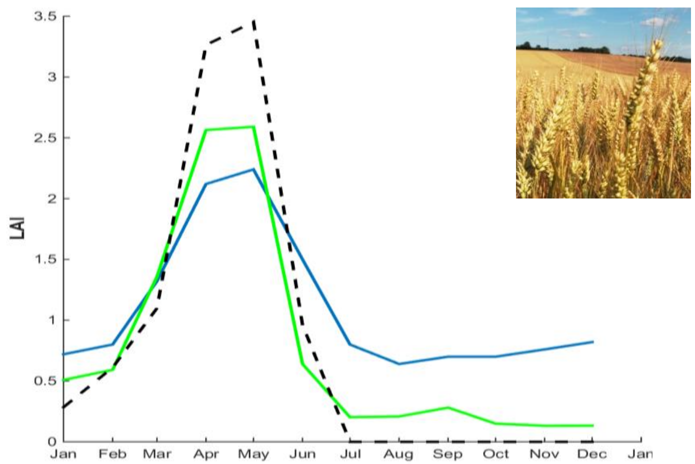


III. Results

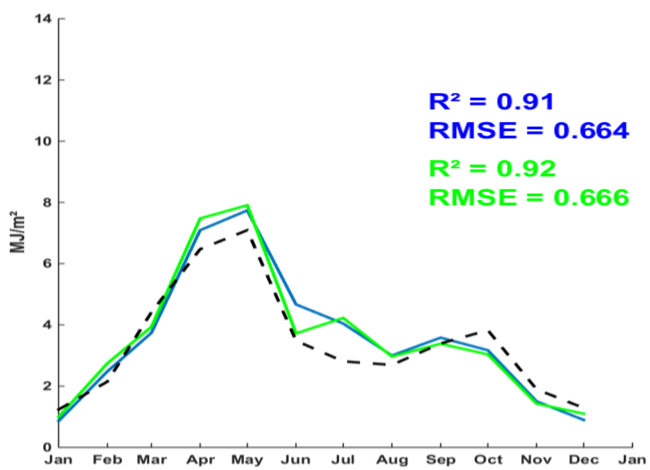
1. Local comparison:

Auradé : Wheat (C3)

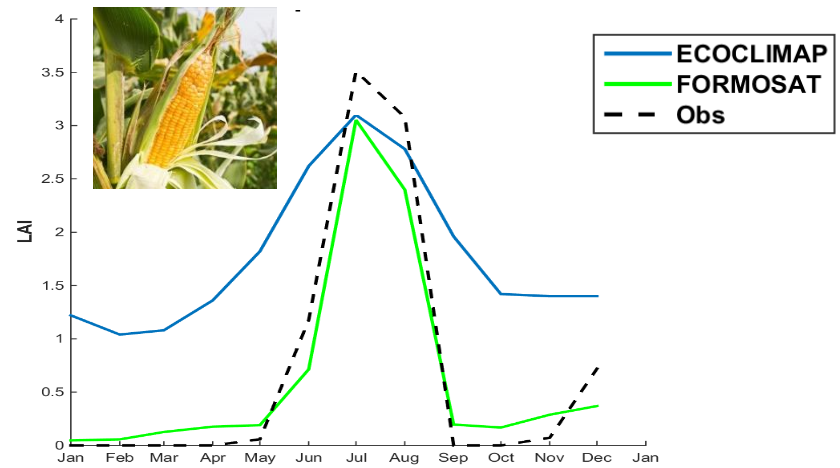
LAI →

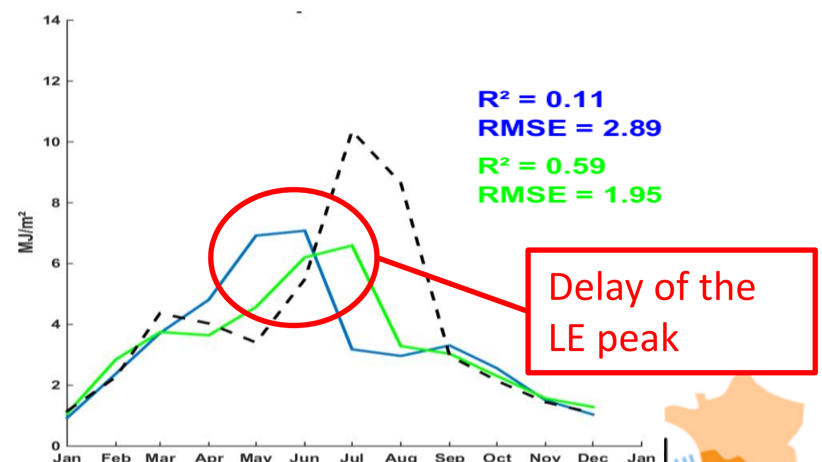


LE →



Lamasquère : Maize (C4)



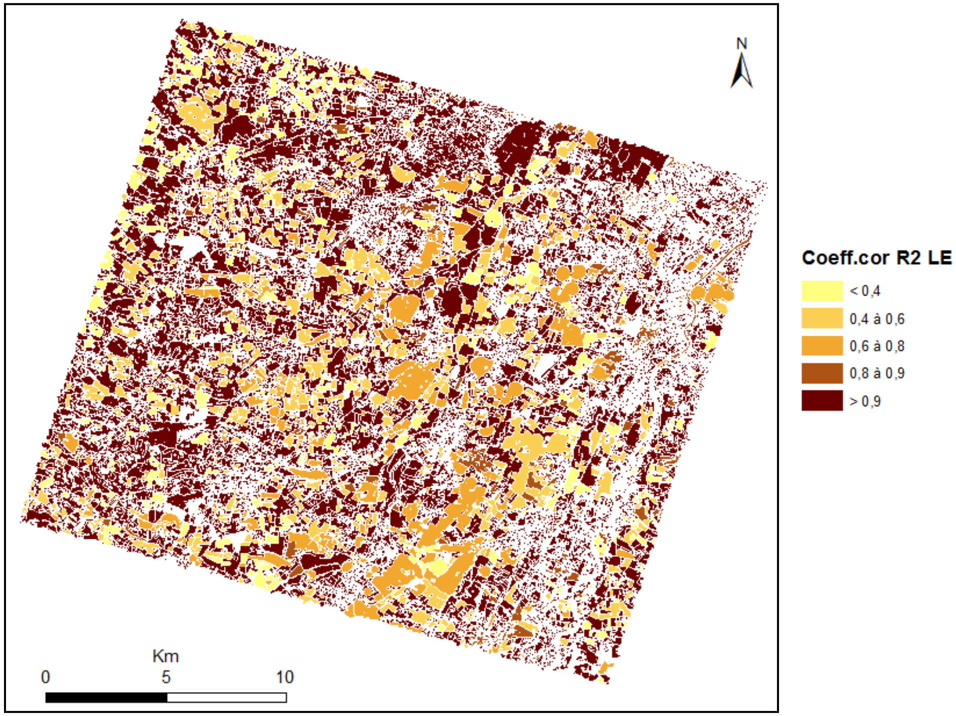


III. Results

2. Spatialized comparison:

Correlation $LE_{ECOCLIM}$ vs $LE_{FORMOSAT}$

All the plots



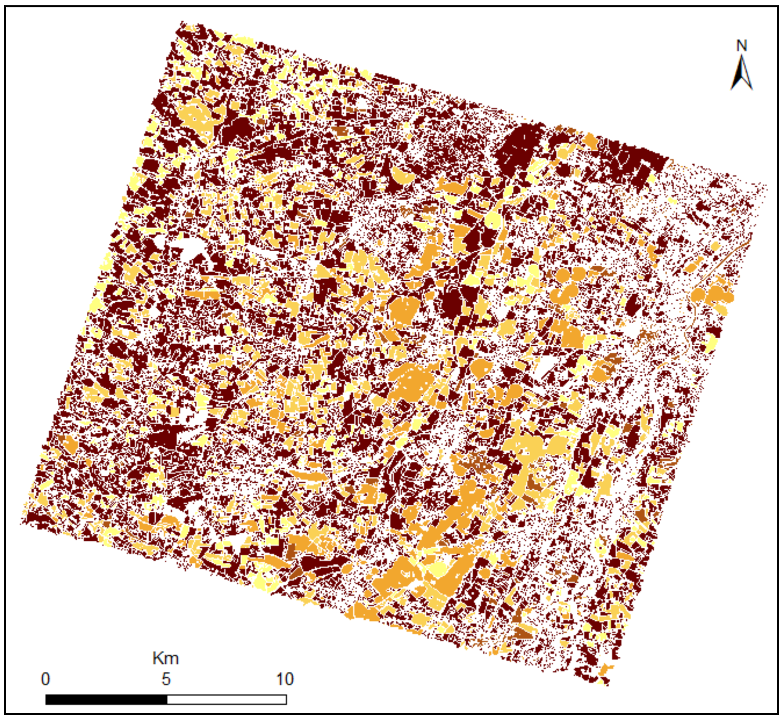
2006

III. Résults

2. Spatialized comparison:

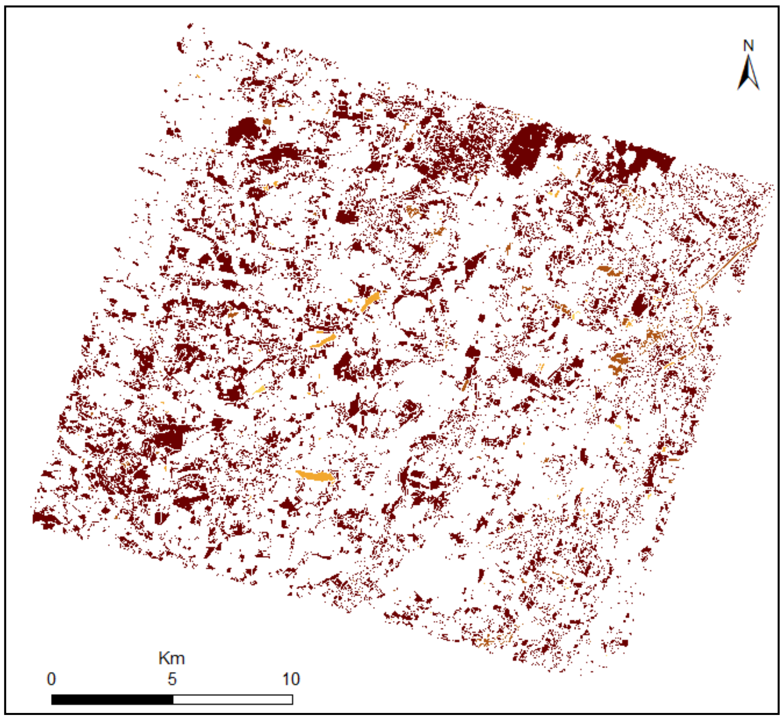
Correlation $LE_{ECOCLIM}$ vs $LE_{FORMOSAT}$

All the plots



Coeff.cor R2 LE
< 0,4
0,4 à 0,6
0,6 à 0,8
0,8 à 0,9
> 0,9

Outside the crops

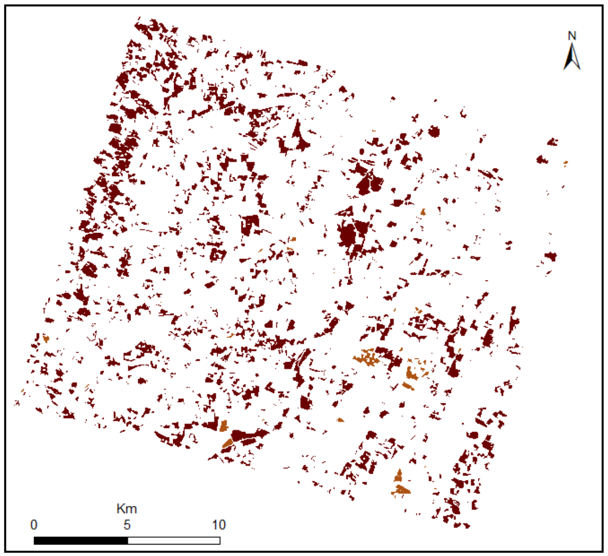


2006

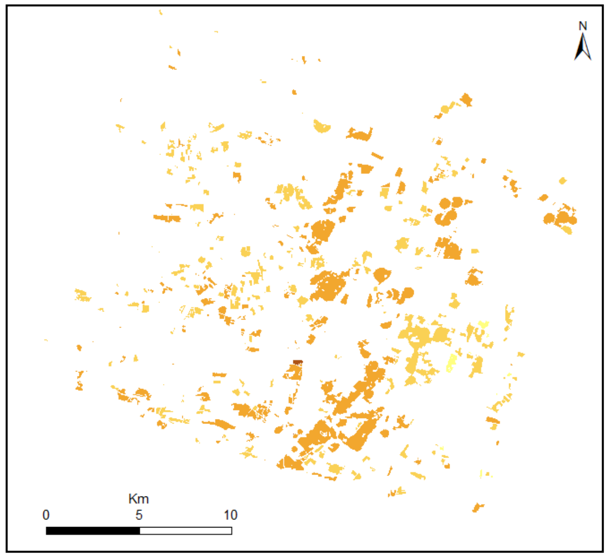
Coeff.cor R2 LE

- < 0,4
- 0,4 à 0,6
- 0,6 à 0,8
- 0,8 à 0,9
- > 0,9

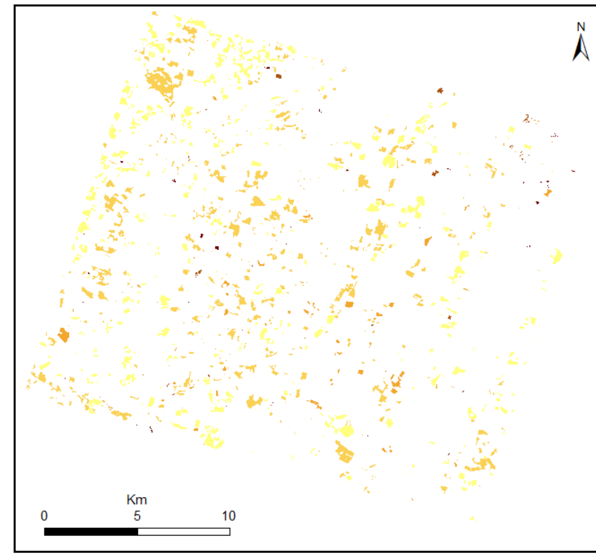
Wheat (C3)

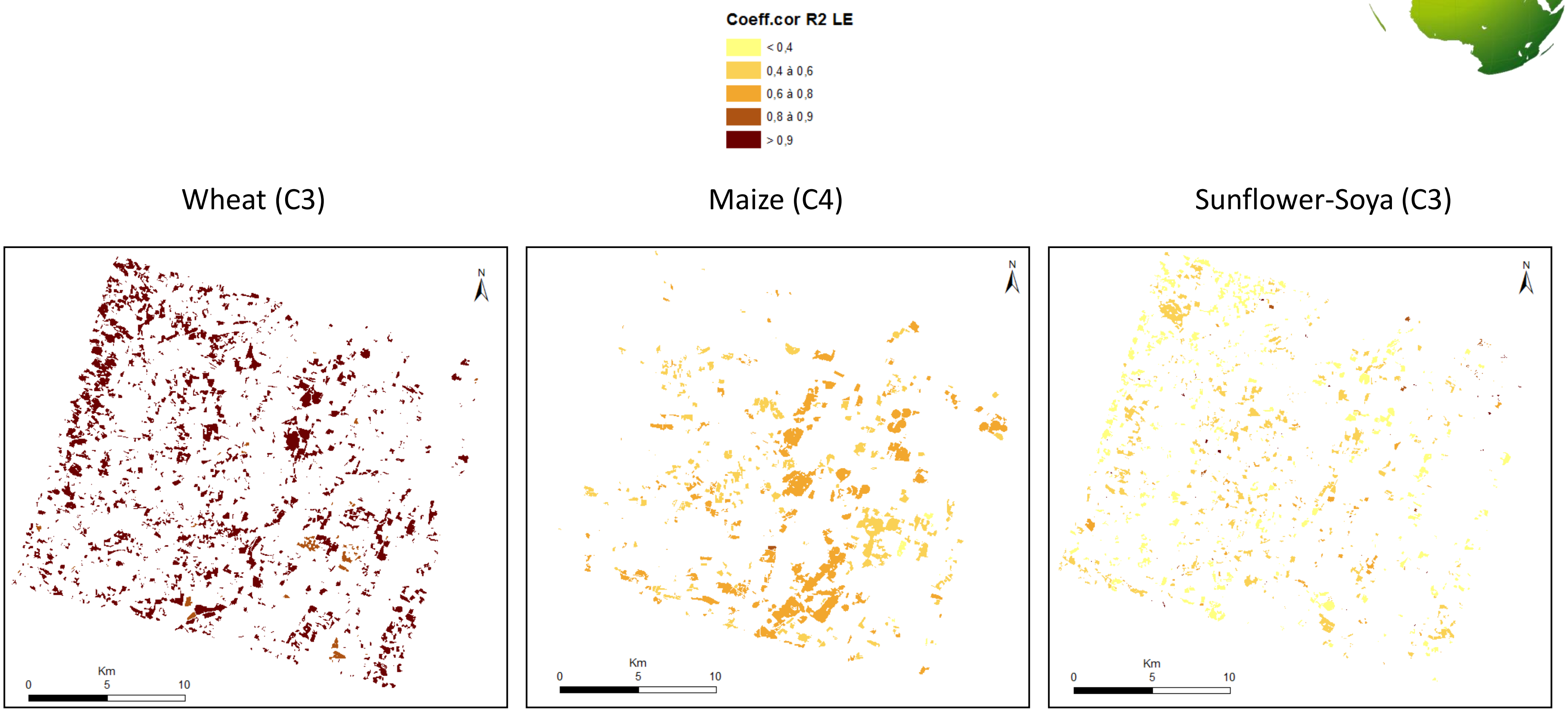


Maize (C4)



Sunflower-Soya (C3)



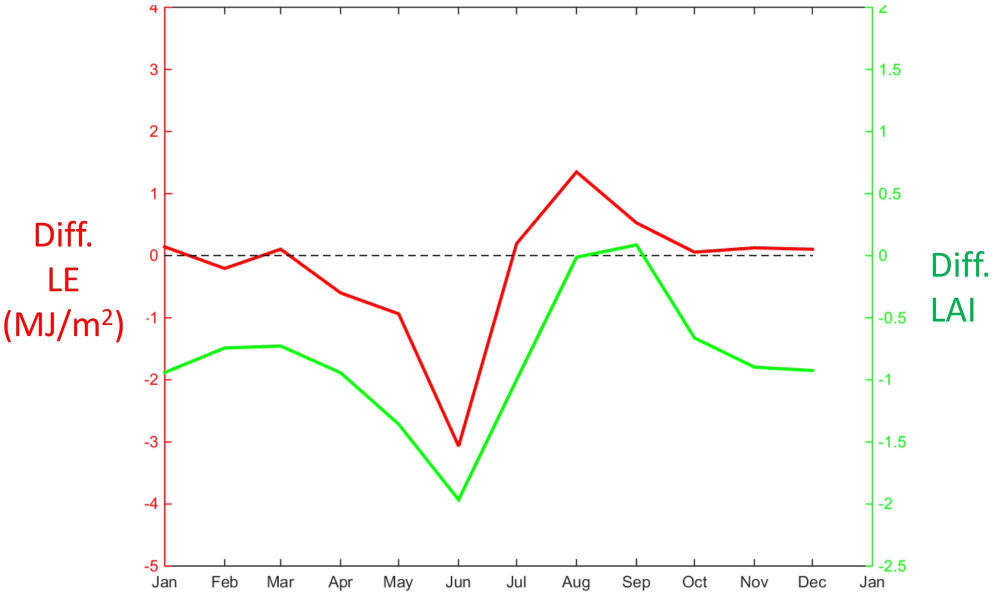


Impact on evapotranspiration seasonality:

→ Lower impact on winter crops (wheat) and outside the crops

→ Significant impact on summer crops (sunflower, maize …)

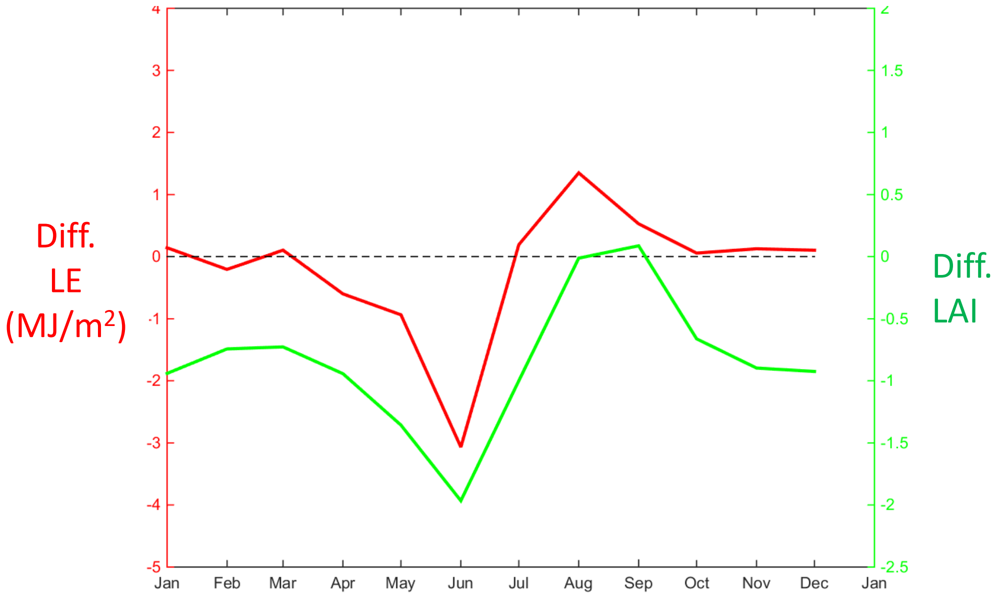
3. Link between the different hydrometeorological fluxes



LE_{FMST} - LE_{ECO} and LAI_{FMST} - LAI_{ECO} over maize plots in 2008

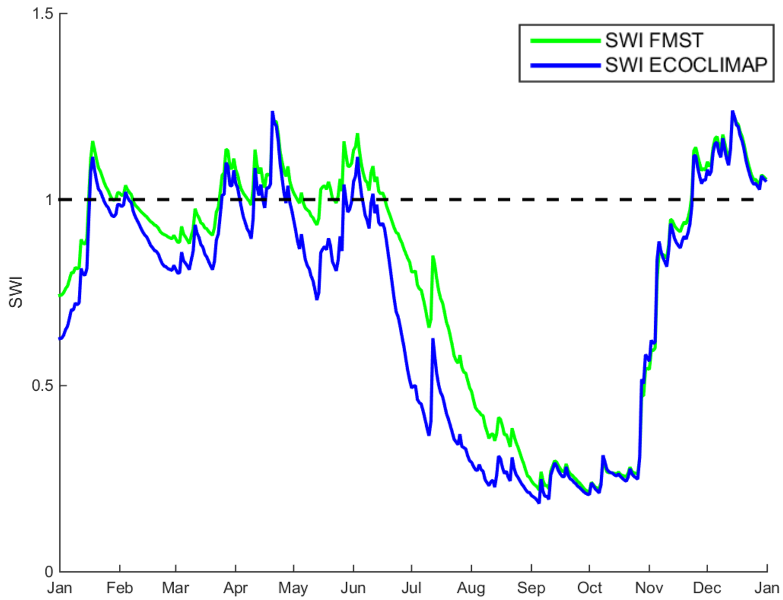
3. Link between the different hydrometeorological fluxes

- → **LE difference highly correlated to LAI difference** : modification of the transpiration process but also of the evaporation from the soil.
- → **LE_{FMST}<LE_{ECO}**: a smaller LAI implies a lower transpiration during spring.

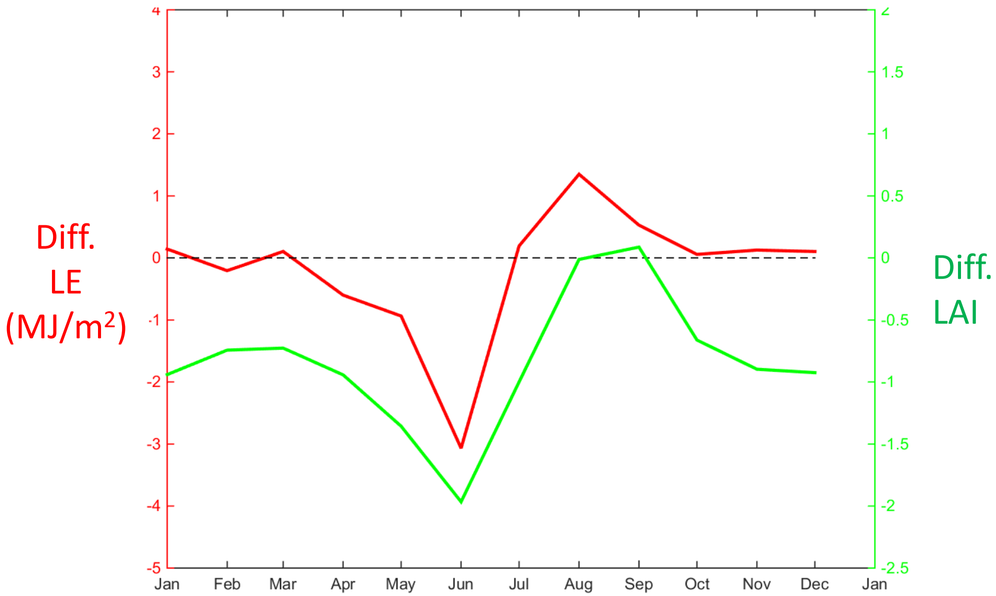


LE_{FMST} - LE_{ECO} and LAI_{FMST} - LAI_{ECO} over maize plots in 2008

3. Link between the different hydrometeorological fluxes



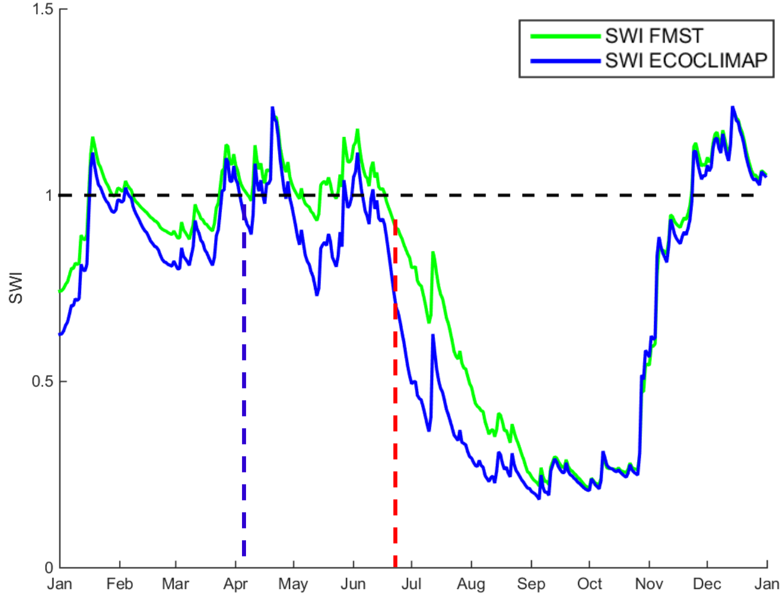
SWI $_{FMST}$ and SWI $_{ECO}$ over maize plots in 2008



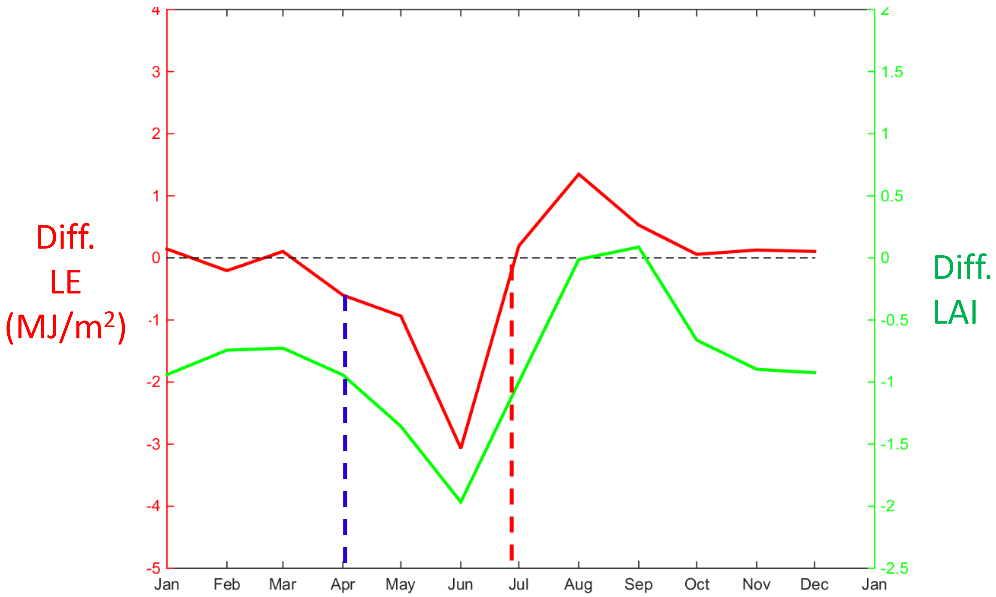
LE $_{FMST}$ - LE $_{ECO}$ and LAI $_{FMST}$ - LAI $_{ECO}$ over maize plots in 2008

$$SWI=(\Theta - \Theta_{\text{Wilting Point}})/(\Theta_{\text{Field Capacity}} - \Theta_{\text{Wilting Point}})$$

3. Link between the different hydrometeorological fluxes



SWI $_{FMST}$ and SWI $_{ECO}$ over maize plots in 2008

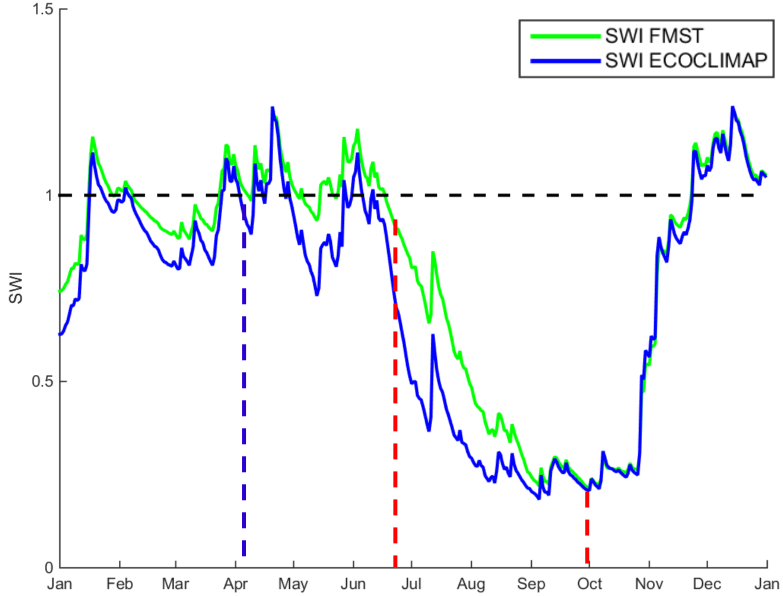


LE $_{FMST}$ - LE $_{ECO}$ and LAI $_{FMST}$ - LAI $_{ECO}$ over maize plots in 2008

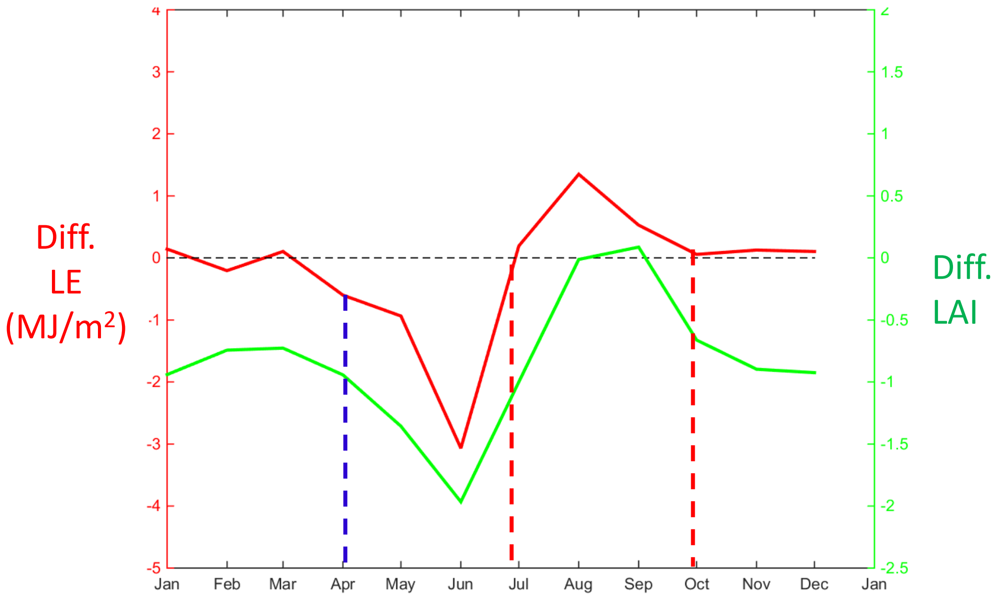
→ **Memory effect of the soil water content:**

Less transpiration during spring → higher SWI

3. Link between the different hydrometeorological fluxes



SWI $_{FMST}$ and SWI $_{ECO}$ over maize plots in 2008



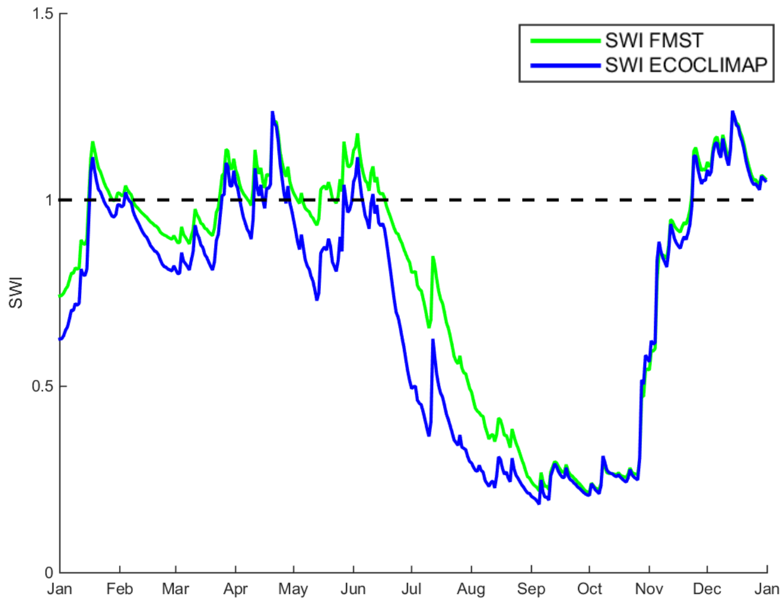
LE $_{FMST}$ - LE $_{ECO}$ and LAI $_{FMST}$ - LAI $_{ECO}$ over maize plots in 2008

→ **Memory effect of the soil water content:**

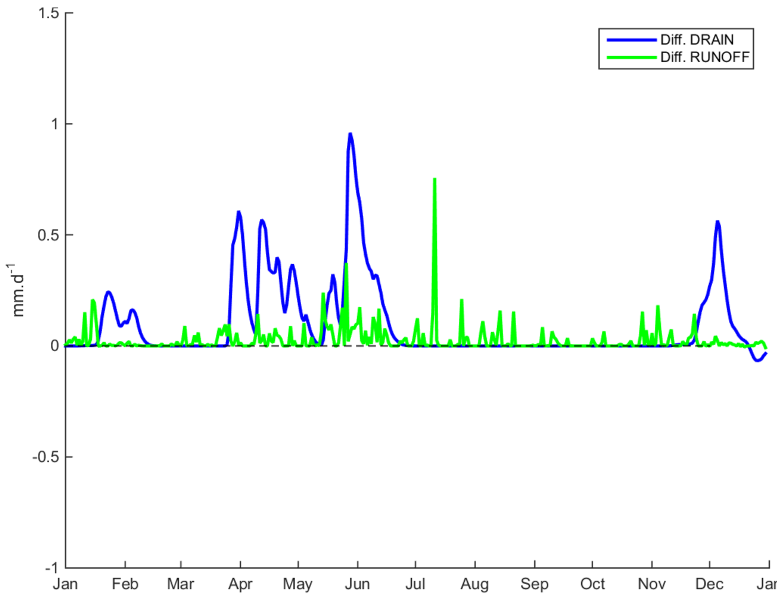
Less transpiration during spring → higher SWI

→ higher evaporation from the soil during summer

3. Link between the different hydrometeorological fluxes

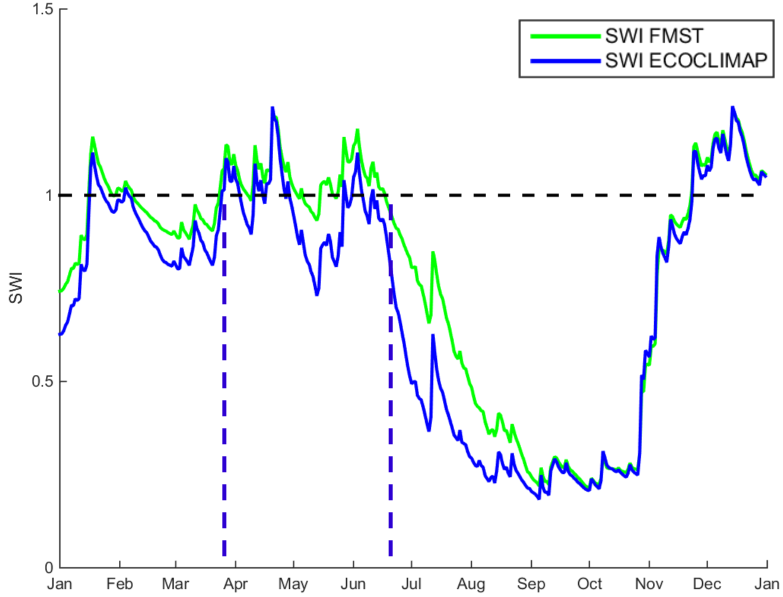


SWI $_{FMST}$ and SWI $_{ECO}$ over maize plots in 2008

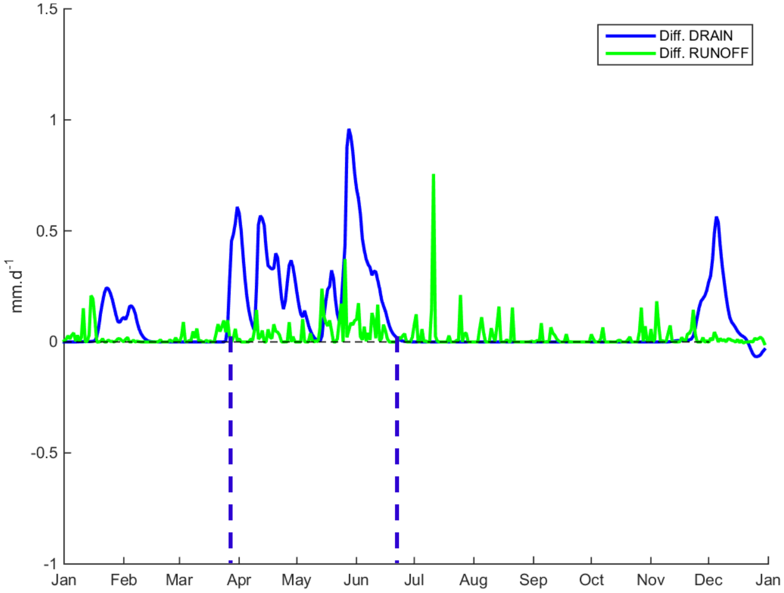


DRAIN $_{FMST}$ - DRAIN $_{ECO}$ and RUNOFF $_{FMST}$ - RUNOFF $_{ECO}$ over maize plots in 2008

3. Link between the different hydrometeorological fluxes



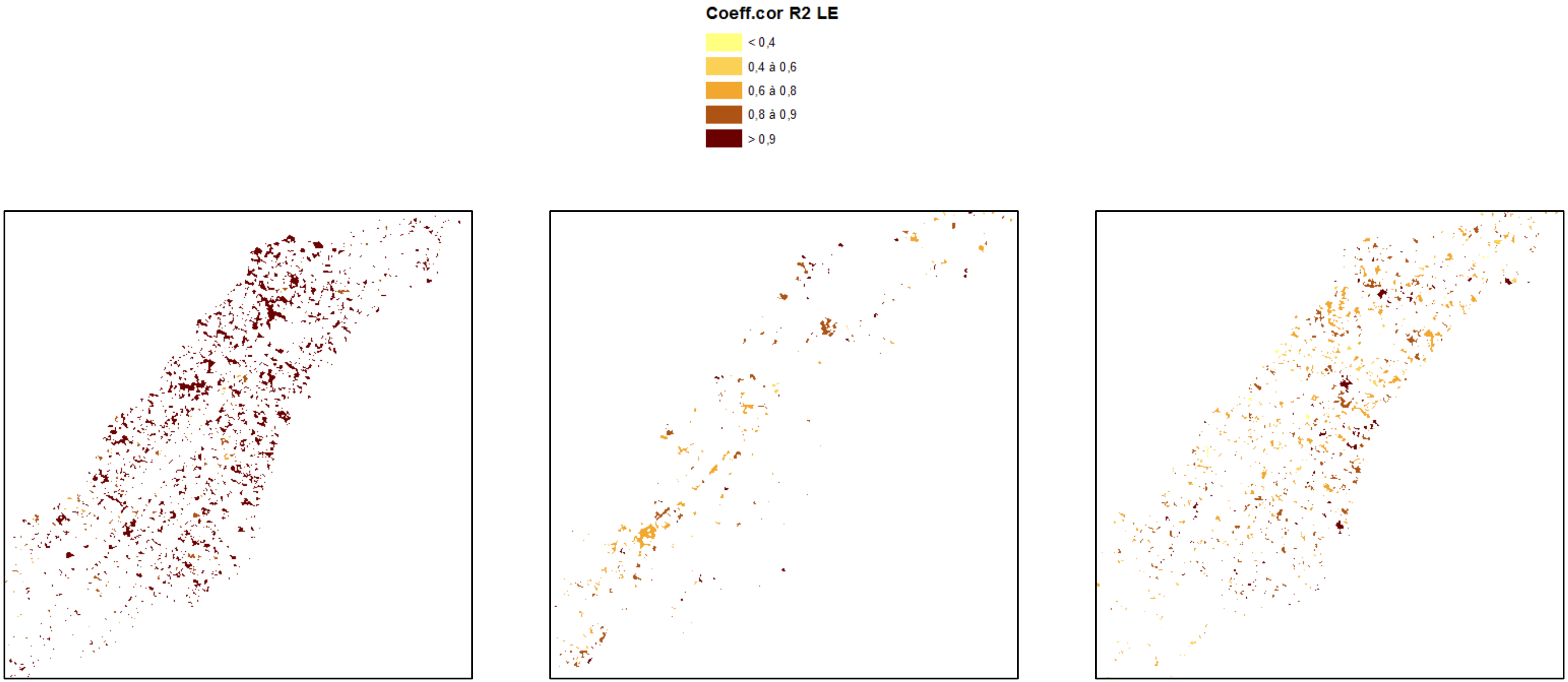
SWI $_{FMST}$ and SWI $_{ECO}$ over maize plots in 2008



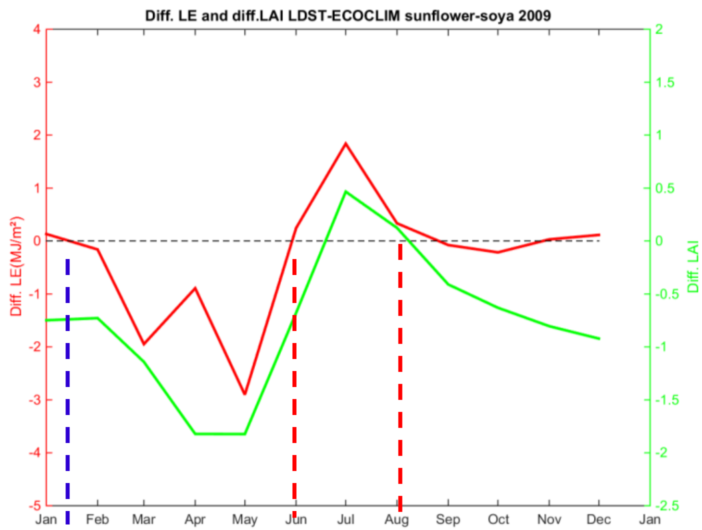
DRAIN $_{FMST}$ - DRAIN $_{ECO}$ and RUNOFF $_{FMST}$ - RUNOFF $_{ECO}$ over maize plots in 2008

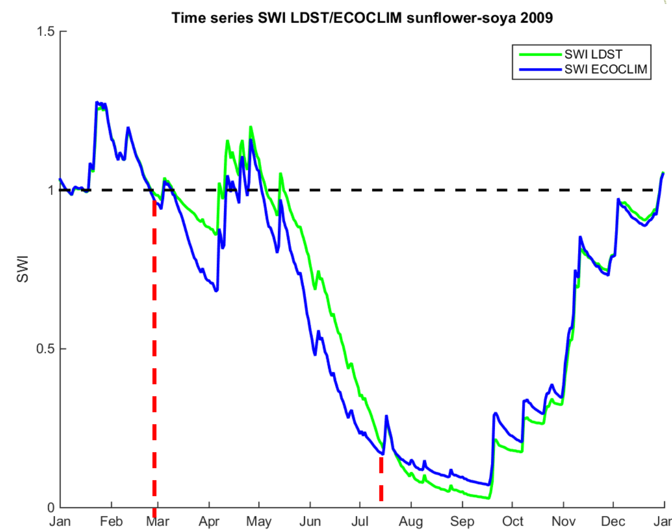
→ Higher SWI implies higher drainage and runoff

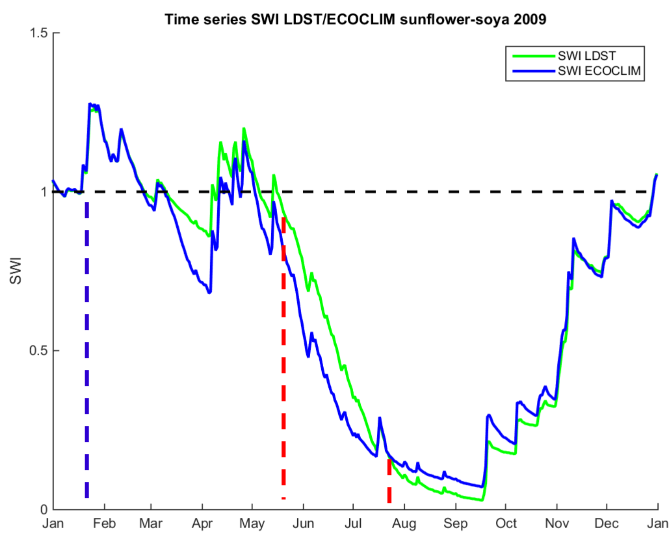
4. SAVE experiment: similar results

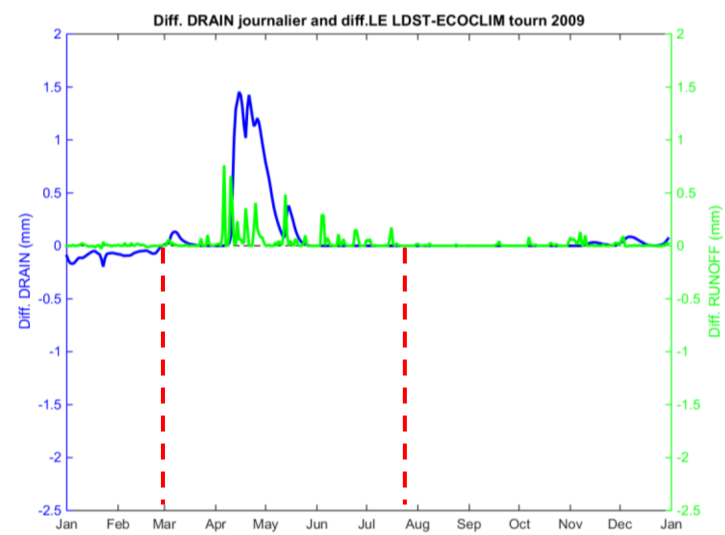


Wheat (C3) | Maize (C4) | Sunflower-Soya (C3)

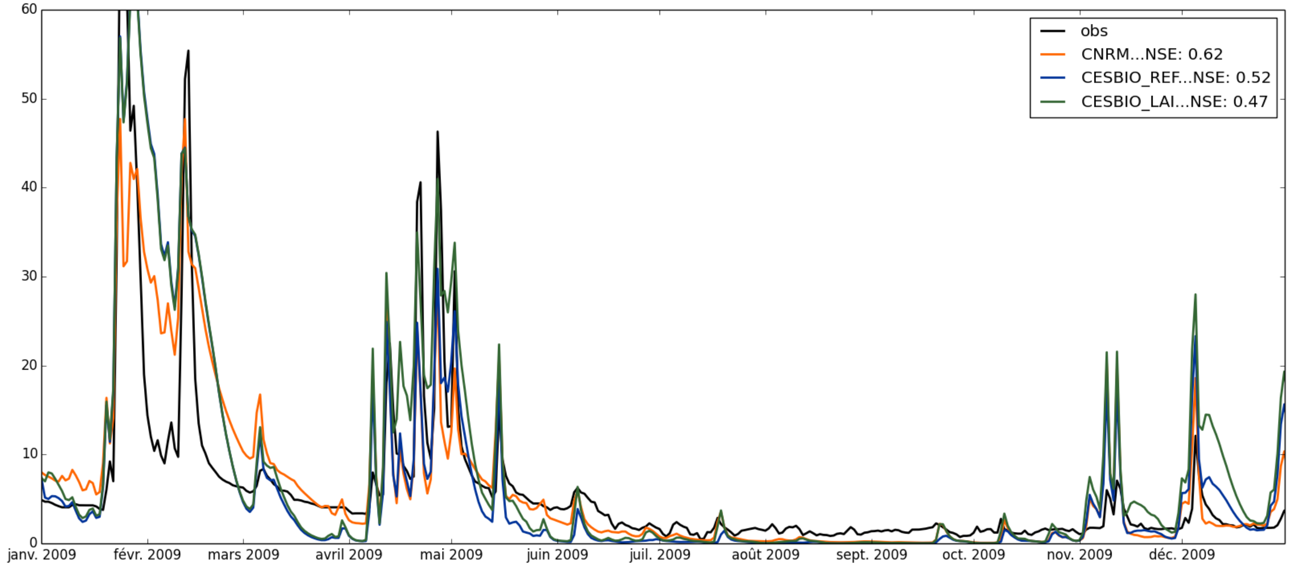

Diff. LE and diff.LAI LDST-ECOCLIM sunflower-soya 2009
Diff. LE(MJ/m²)
Diff. LAI
4
3
2
1
0
-1
-2
-3
-4
-5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Time series SWI LDST/ECOCLIM sunflower-soya 2009
SWI LDST
SWI ECOCLIM
SWI
1.5
1
0.5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Time series SWI LDST/ECOCLIM sunflower-soya 2009
SWI LDST
SWI ECOCLIM
SWI
1.5
1
0.5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan


Diff. DRAIN journalier and diff.LE LDST-ECOCLIM tourn 2009
Diff. DRAIN (mm)
Diff. RUNOFF (mm)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

Impact on river discharge?



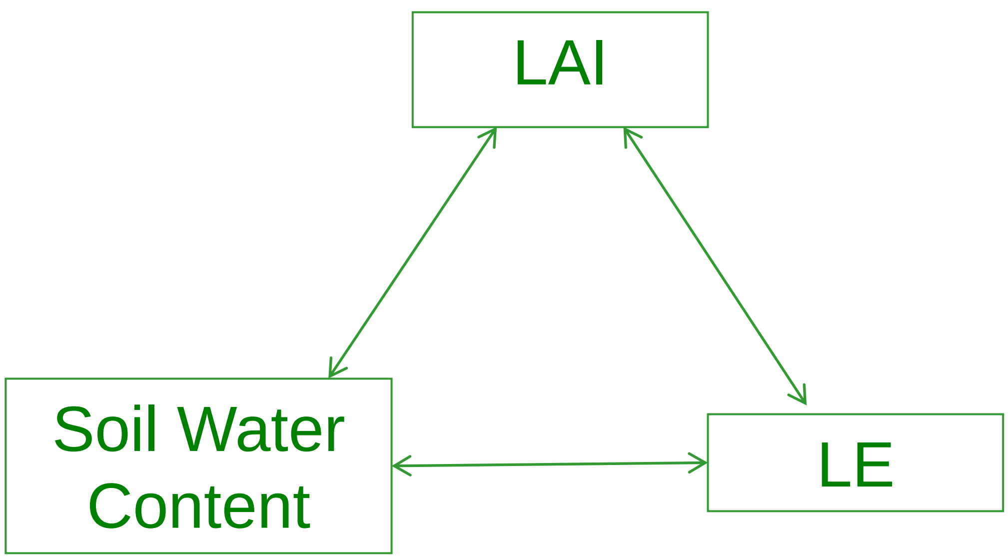
No visible improvements on **these particular year and basin** but coherent simulation
→ aggregation bias?
→ measurements fiability? (Save supplied by the Neste canal, cf. Banque Hydro)
→ improvements only on certain periods?

Conclusions and perspectives

Conclusions:

- **Significant difference in LAI dynamics especially on summer crops**, more realistic with remote sensing products → **impact on LE seasonality**
- Generally $LAI_{FMST} < LAI_{ECO}$ → **less transpiration during spring**
- **Memory effect of the soil water content**: less transpiration during spring

  → $SWI_{FMST} > SWI_{ECO}$ → **more evaporation from the soil** (more water available in the soil) and **more drainage and runoff.**



Conclusions and perspectives

- High spatial and temporal resolution remote sensing products allows **distinguishing more accurately the vegetation** and taking into account **his actual phenologic cycle** in the model. Consequently, it allows **capturing anthropogenic decisions** in the model, i.e seeding or harvest dates.
- Results also shows that the ECOCLIMAP crops classification (C3/C4) is not sufficient when finely simulating agricultural area. Maybe a separation of the different crops, especially the summer and winter crops, could help in this kind of context.

Perspectives :

- Taking **irrigation** into account → applying the A-gs irrigation module? Toward a new irrigation module?
- Exploit **other high resolution remote sensing products**: Surface temperature and humidity, irrigated area detection, albedo …
- Choice of **another basin and/or model for hydrological simulation**(RAPID, TOPMODEL …)
- Application of the method on **another region/climate**: Tunisia→ 6 months internship CESBIO/CNRM (V.Rivalland, G.Boulet, A.Boone)

Thanks for your attention

Paper under review in HESS:

Etchanchu, J., Rivalland, V., Gascoin, S., Cros, J., Brut, A., Boulet, G.: *Effects of multi-temporal high-resolution remote sensing products on simulated hydrometeorological variables in a cultivated area (southwestern France)*, Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-661, 2017