Influence Of Vegetation Cover And Phenology On Water Resources : A Regional Climate Modelling Approach For The Year 2003

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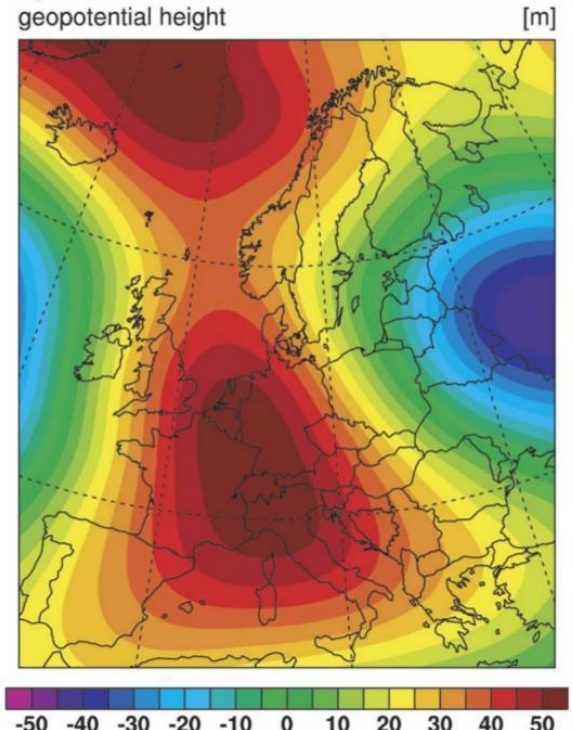
Summary

Summer 2003 and heat waves in Europe : Key drivers

① Synoptic circulation

- Heat waves over southern Europe associated with a zone of strong high pressure pushing Atlantic perturbations northward (Fischer et al.,2007a,b; Cassou et al., 2005).



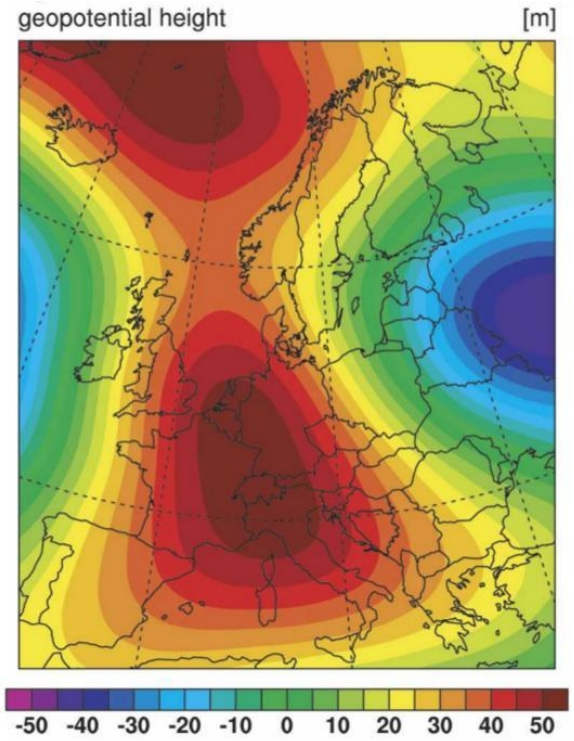
Summer 2003 geopotential height anomalies (m)

Summer 2003 and heat waves in Europe : Key drivers

② Soil moisture and atmospheric feedbacks

- Drier soil initiate larger positive temperature feedbacks (Fischer et al.,2007a,b; Seneviratne et al., 2010).

60%



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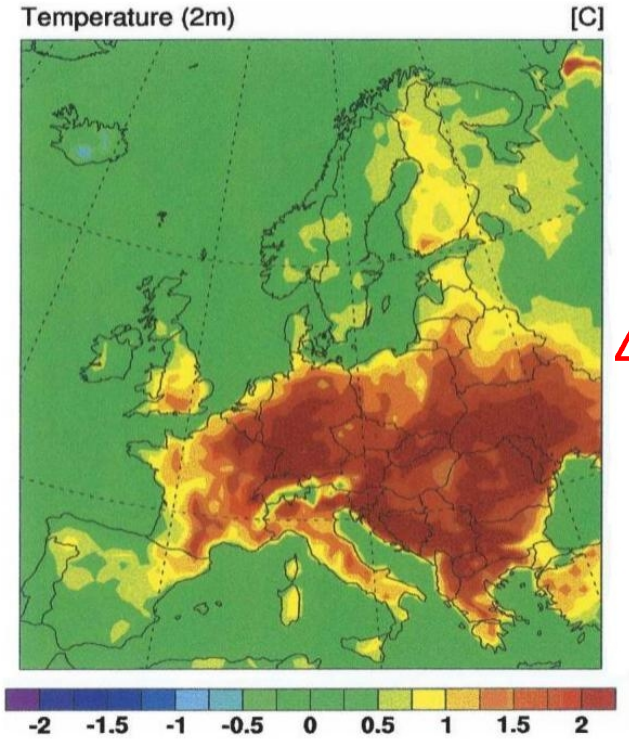
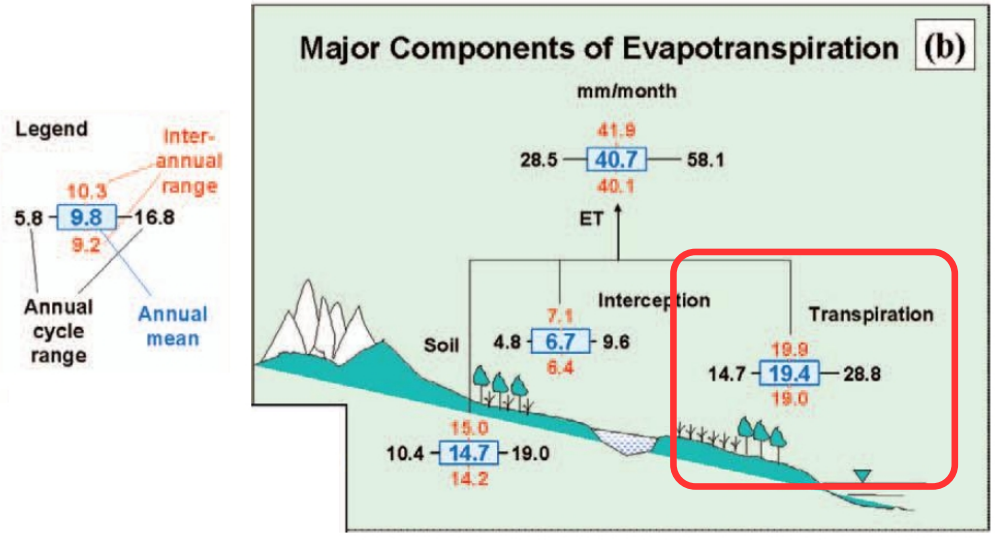


40%

Summer 2003 temperature anomaly due to spring soil moisture perturbation (°C)

Role of vegetation on climate variability



Transpiration 50%

Dirmeyer et al., 2006

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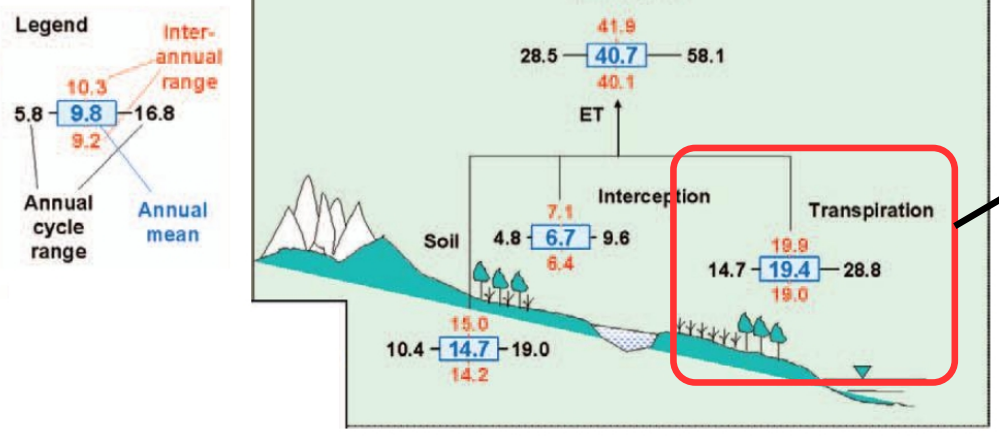

Influence of Phenology on Seasonnal Variability

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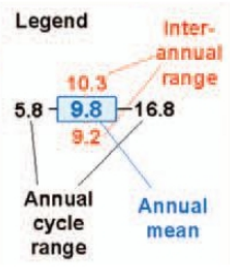

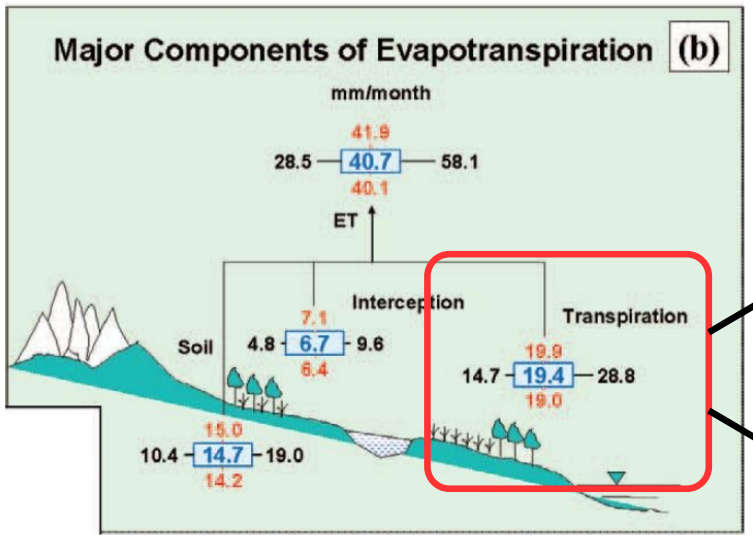

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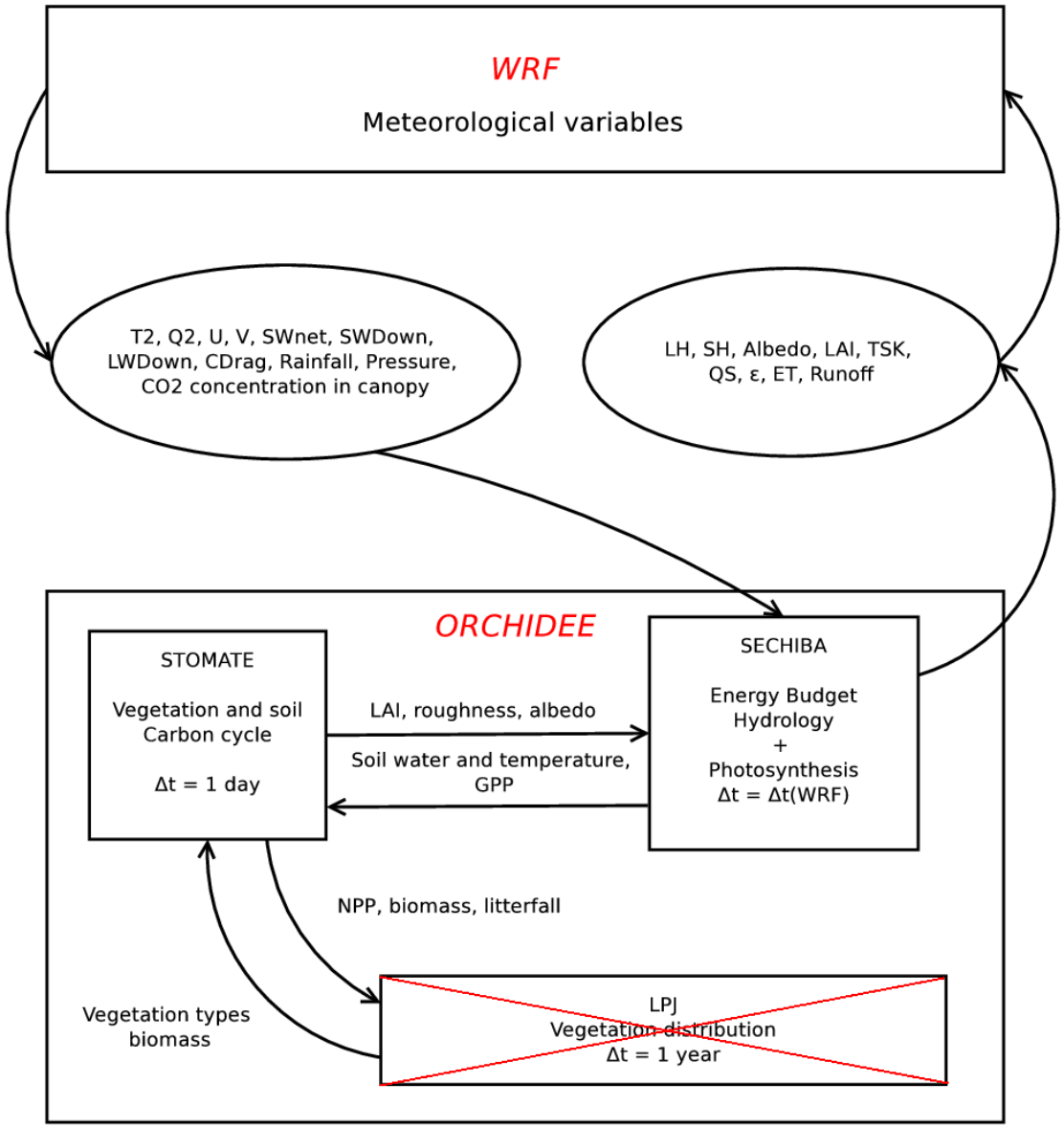
Influence of Phenology on Seasonnal Variability

Influence of Land Cover on Spatial Variability

Dirmeyer et al., 2006

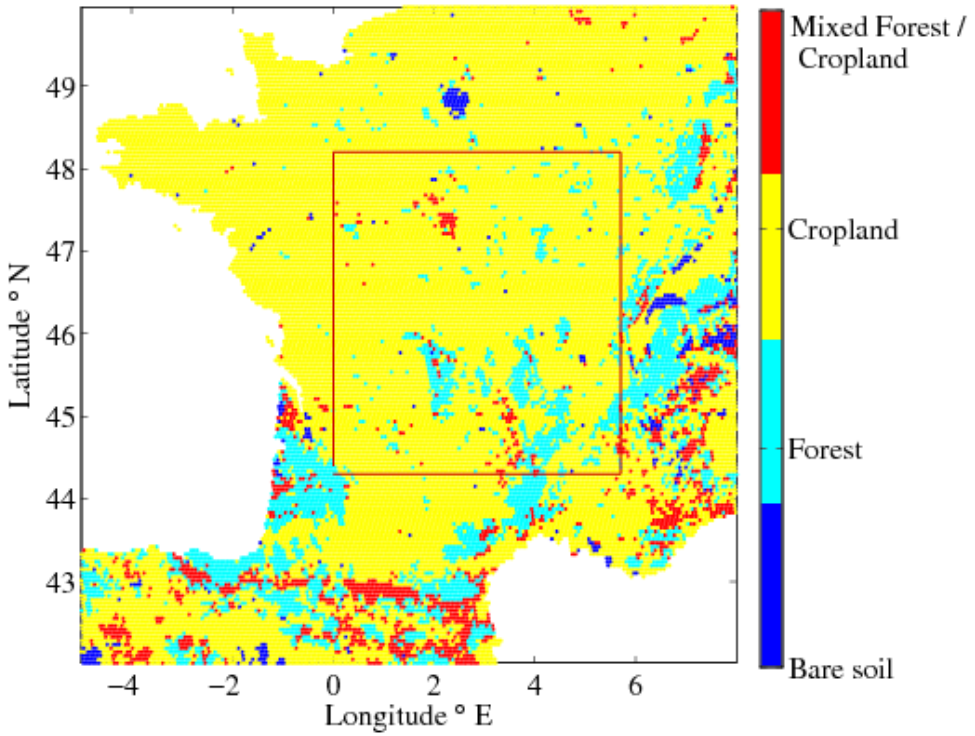
Modelling Tool



Summary

Choice of models and experiment

- MORCE* platform configuration : the Weather and Forecast Research (WRF) model coupled with the ORCHIDEE IPSL land surface model.
- Two integrations:
  (1) with prescribed LAI (UCL)
  (2) including the vegetation dynamics (MORCE)
- Numerical integration : 15km resolution and 2002-2003 ERA-Interim boundary conditions.



➢ * **Model of the Regional Coupled Earth system (MORCE): Application to process and climate studies in vulnerable regions. Drobinski, Anav, Lebeaupin-Brossier, Samson, Stéfanon *et al.*, (*Environ. Model. & Soft*),35,1-18,2012**

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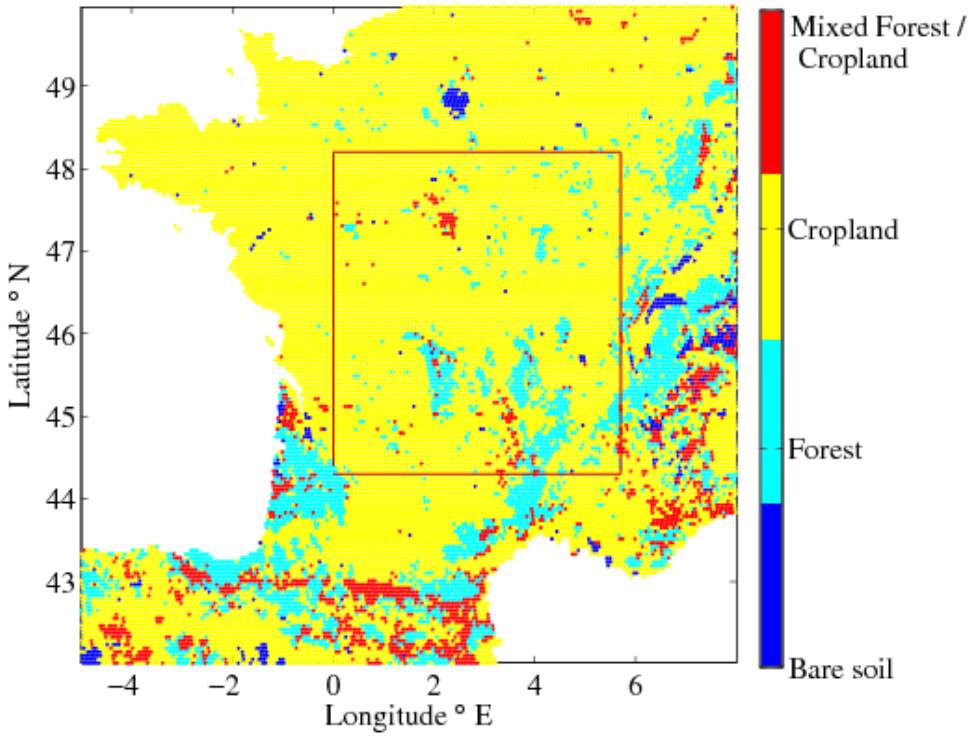

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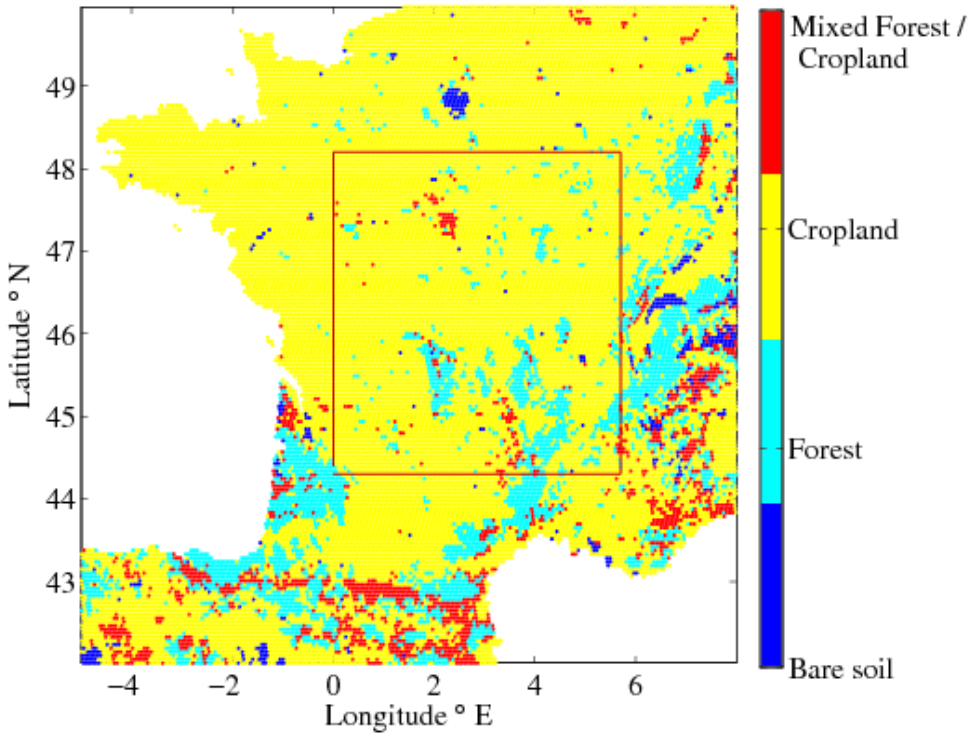

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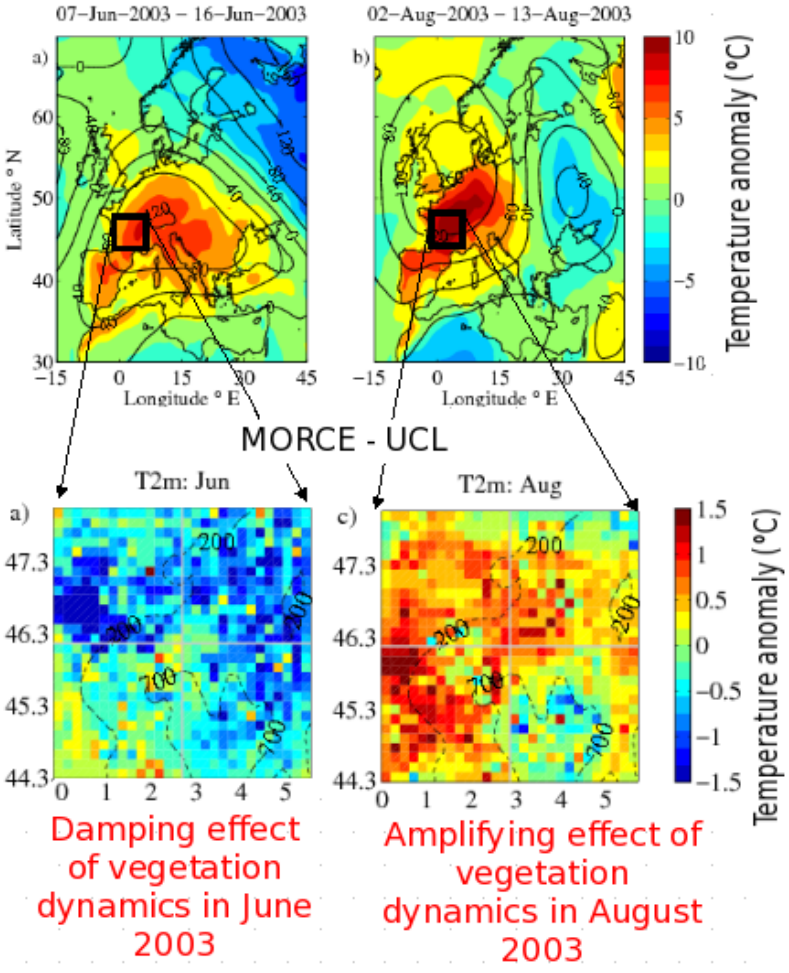
Modification of water cycle and temperature anomaly



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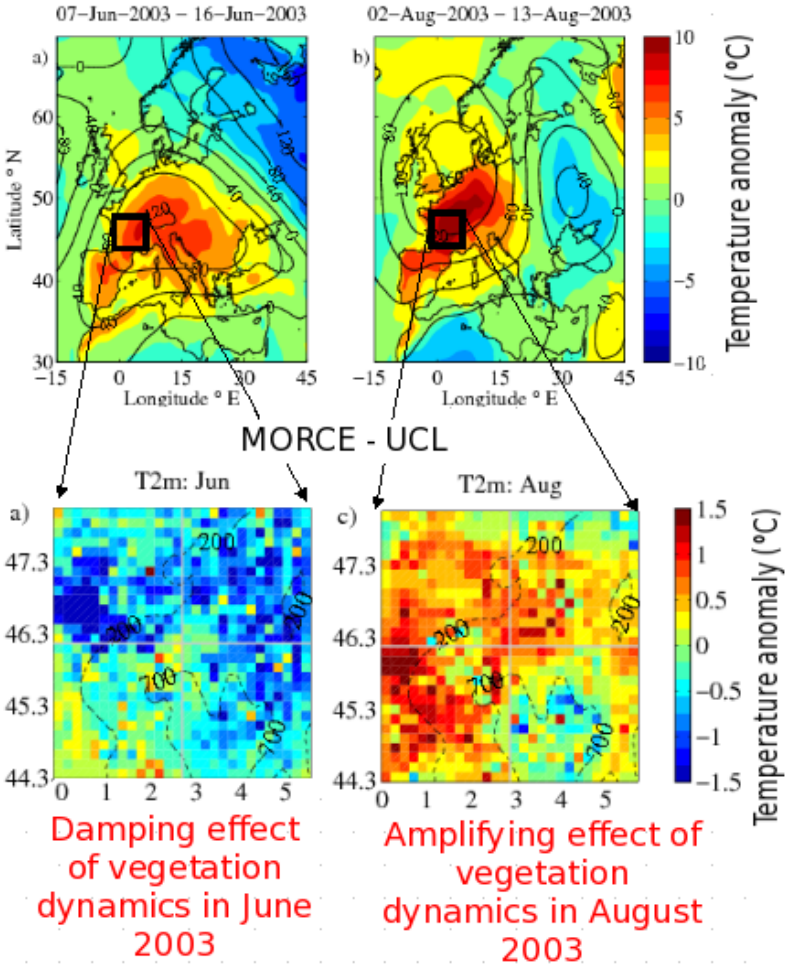
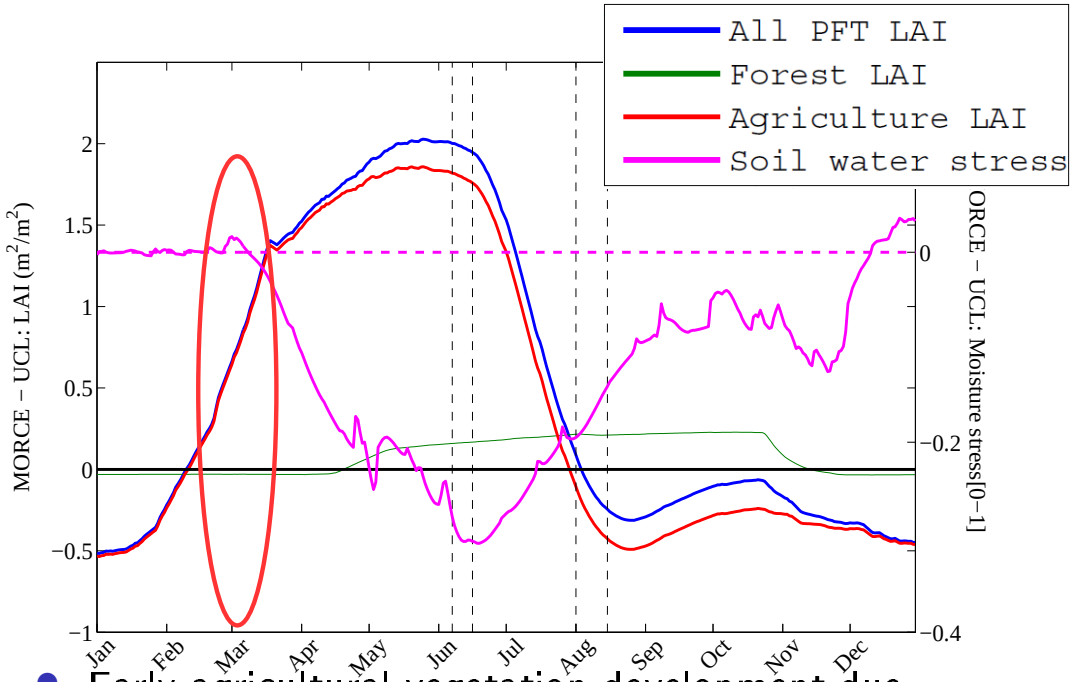
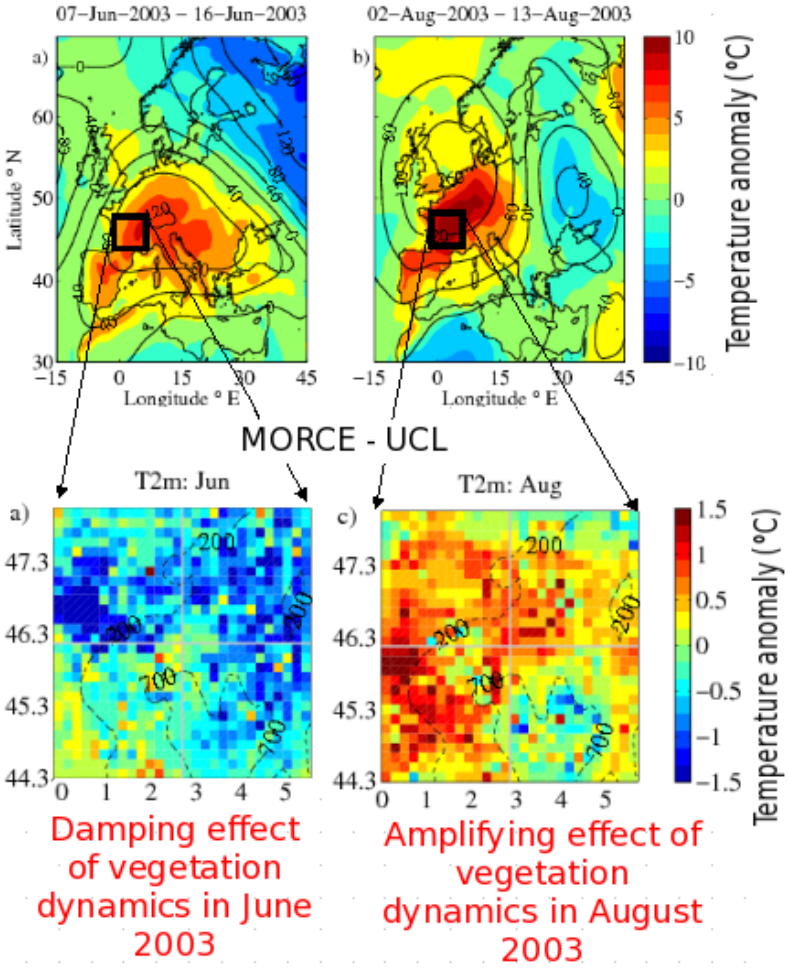
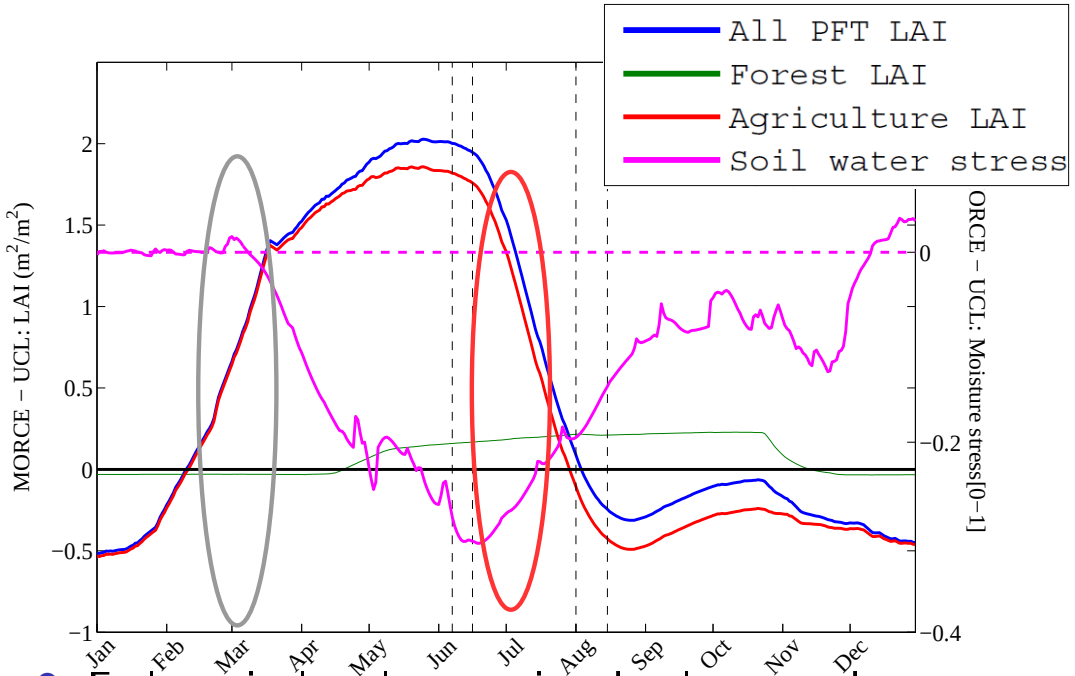




- Early agricultural vegetation development due to springtime meteorological drought → higher evaporation and lower temperature anomaly.

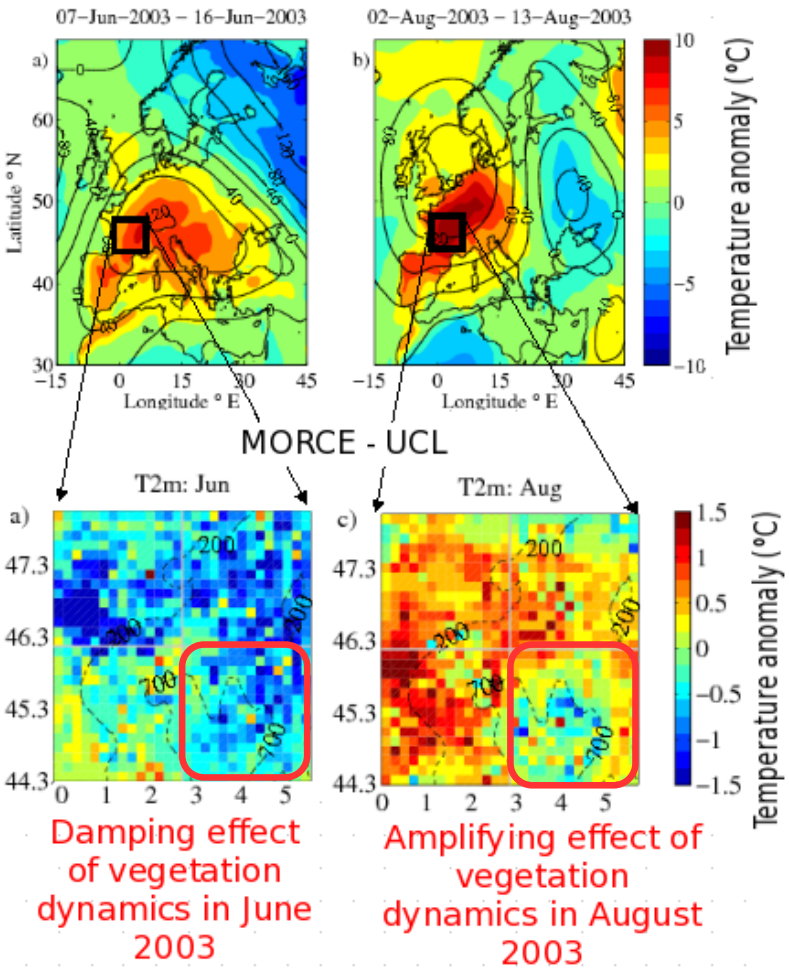
Modification of water cycle and temperature anomaly

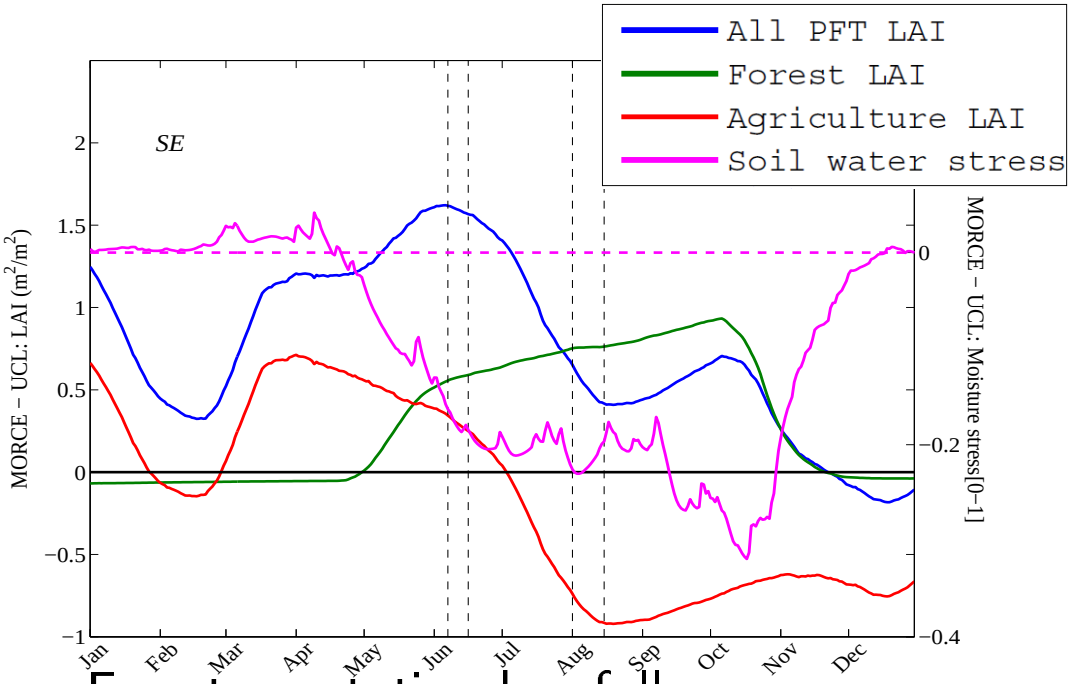




- Early agricultural vegetation development due to springtime meteorological drought ➙ higher evaporation and lower temperature anomaly.
- Death of agricultural vegetation due to hydrological drought ➙ lower evaporation and higher temperature anomaly.

Modification of water cycle and temperature anomaly

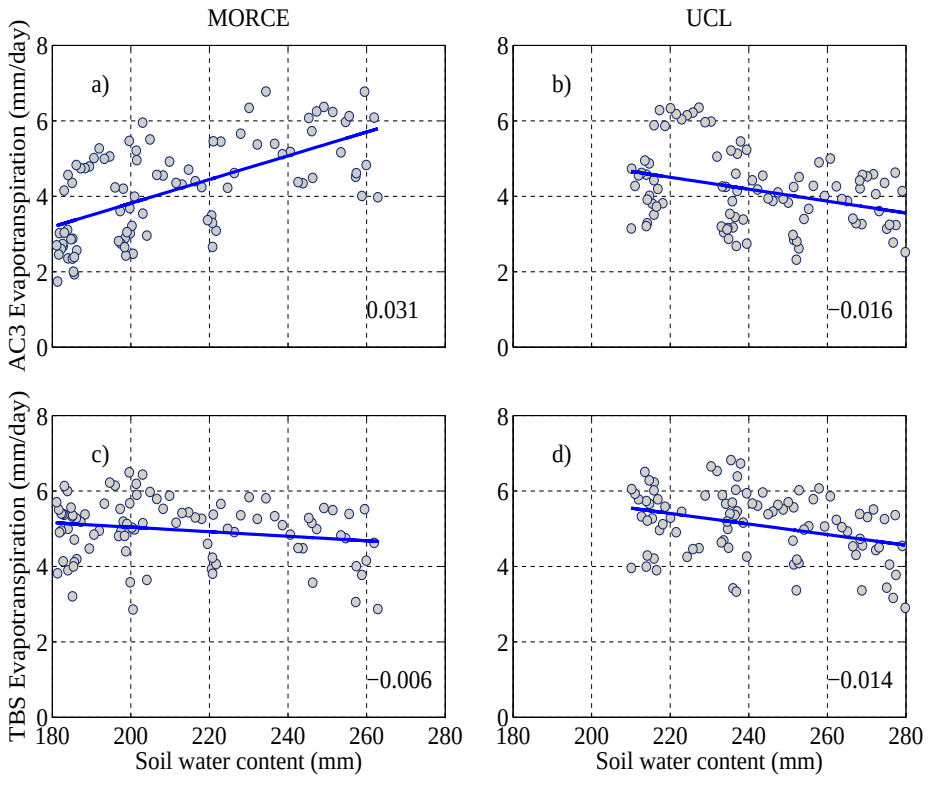




- Forest vegetation has fully compensated the early loss of crops in MORCE. ➙ higher evaporation and lower temperature anomaly.

Comparison of ecosystem tranpiration

- Drought mitigation by conservative water use of trees



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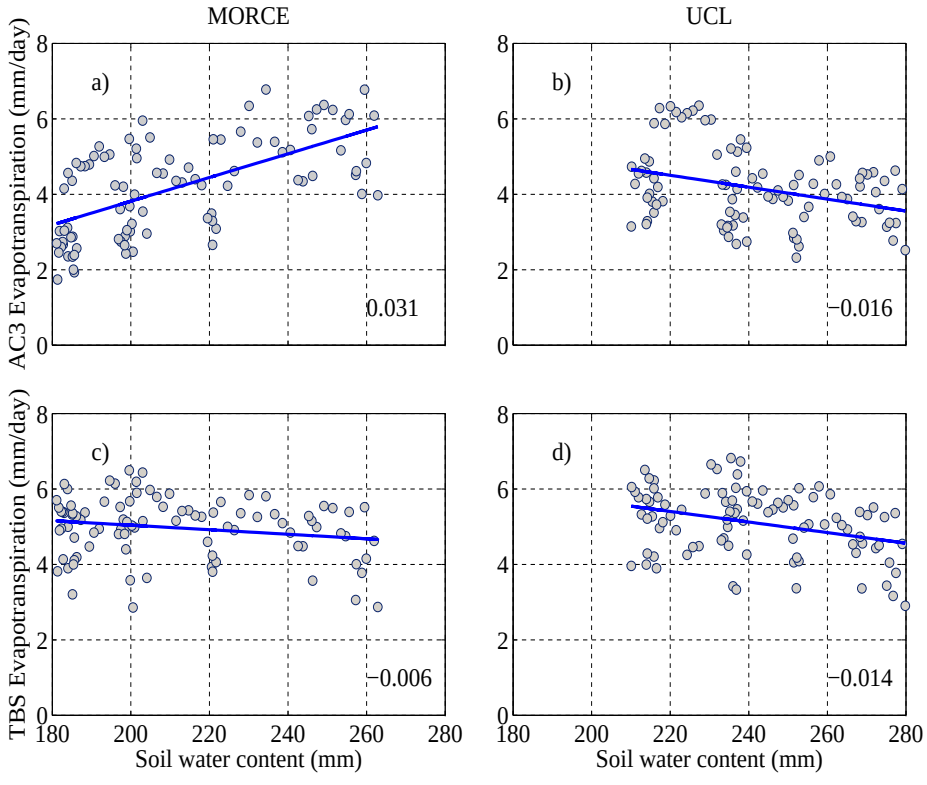

➥ In the MORCE simulation, cropland areas switch from an energy limited evapotranspiration regime to a soil moisture limited during June.

Summary

Choice of models and experiment

- Two integrations:
  (1) with current vegetation (CUR)
  (2) with potential vegetation (POT)
- The MORCE platform : The Weather and Forecast Research (WRF) model coupled with ORCHIDEE IPSL land surface model.
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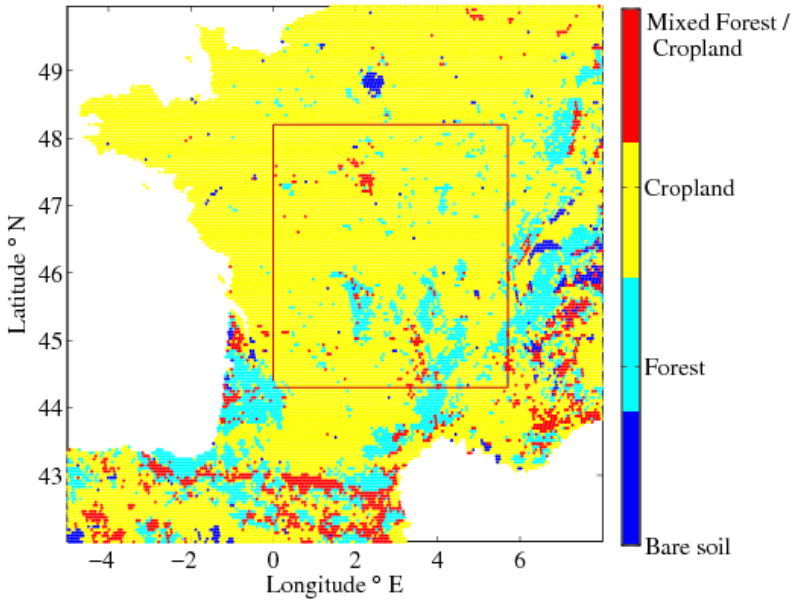
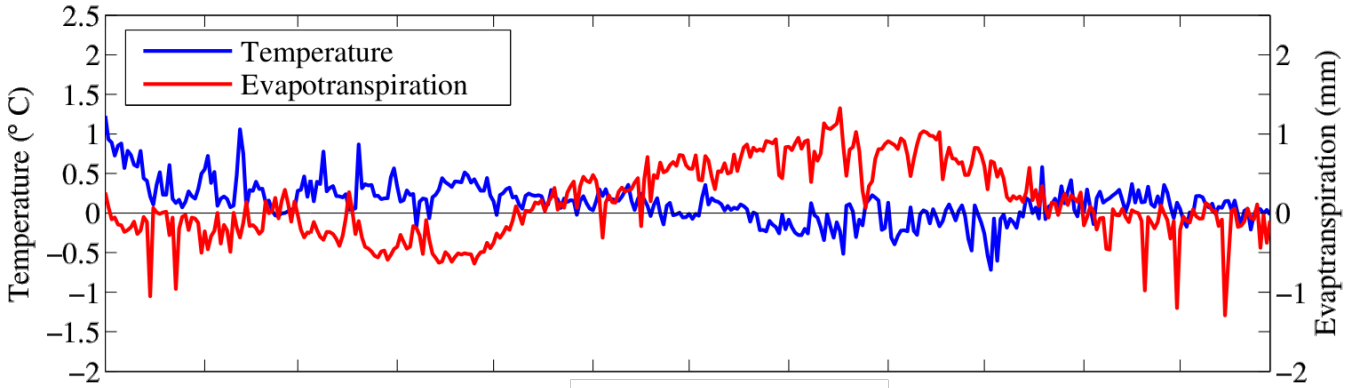


Vegetation	Bare soil	Forest	Herbaceous	Cropland	Root Coef (m)	Z_0 (m)
CUR (%)	15	13	3	69	0.28	0.08
POT (%)	10	57	33	0	0.5	0.39

➢ **Simulating the effect of anthropogenic vegetation land cover on heatwave temperatures over central France.**

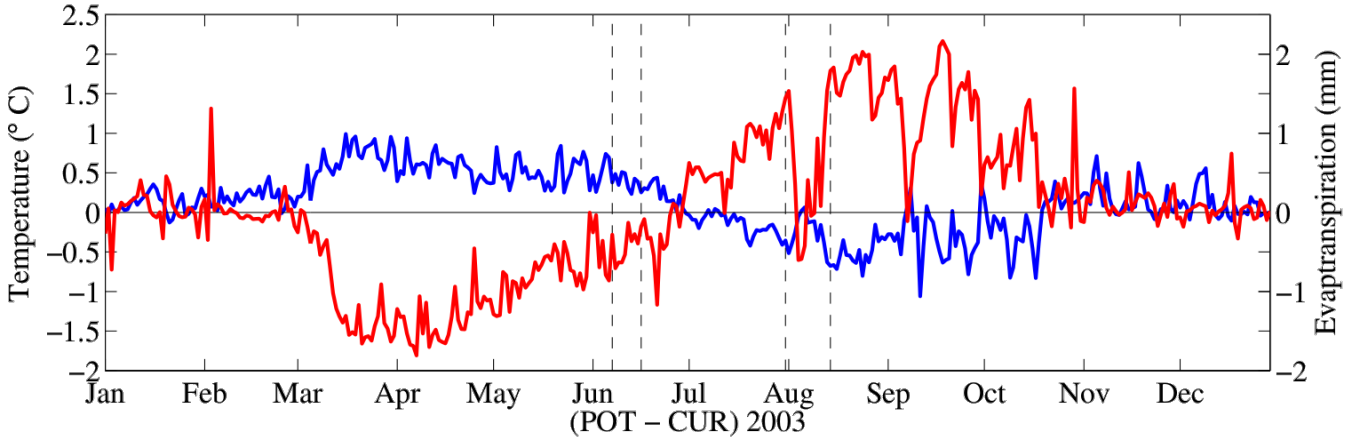
Stéfanon, *et al.* 2014. *Climate Research*

Surface changes



2002

POT - CUR



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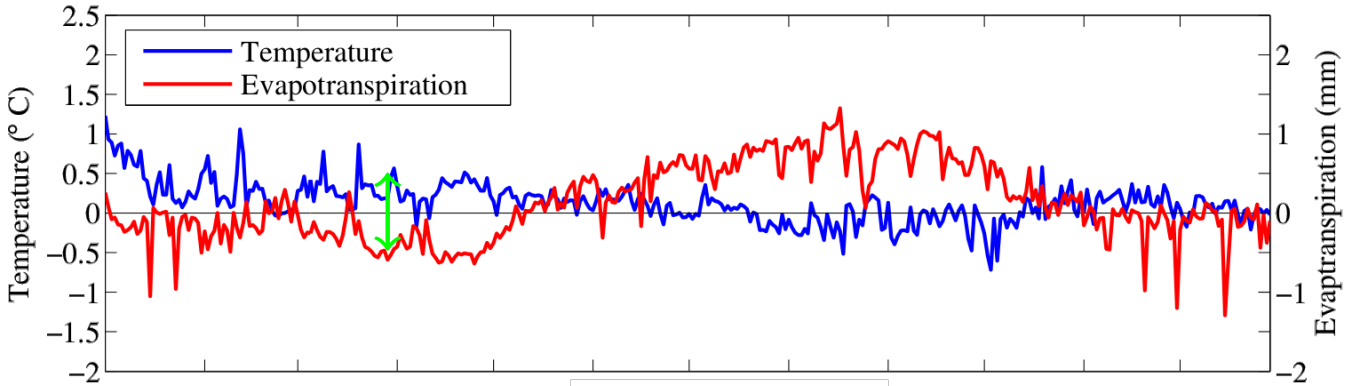

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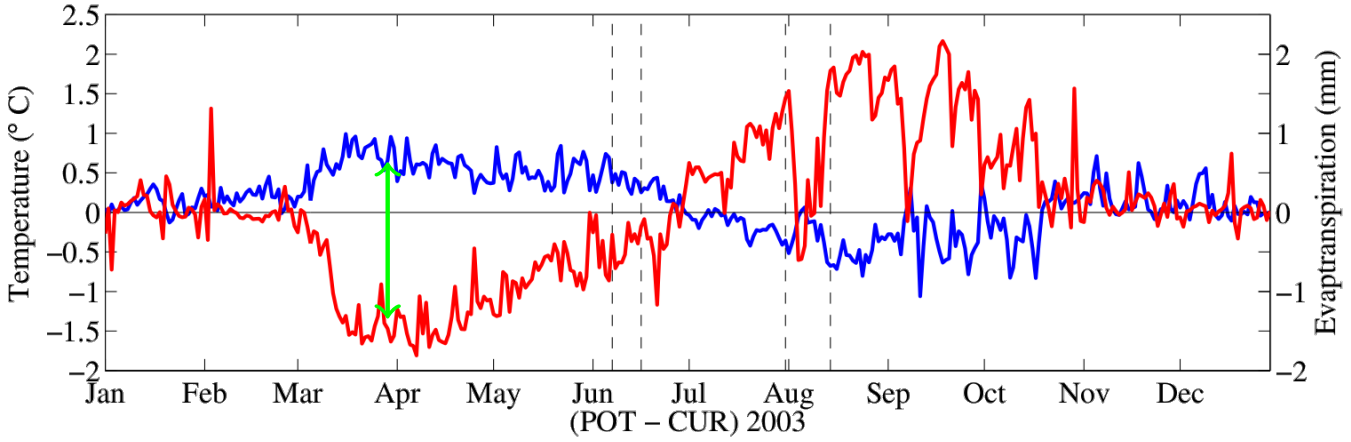
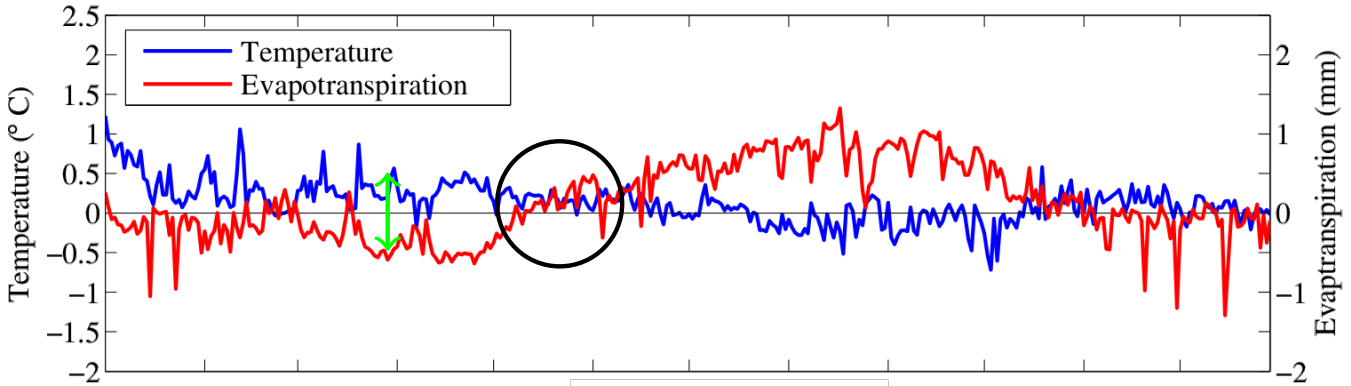


2003

- Larger differences in 2003 between POT and CUR.

Surface changes



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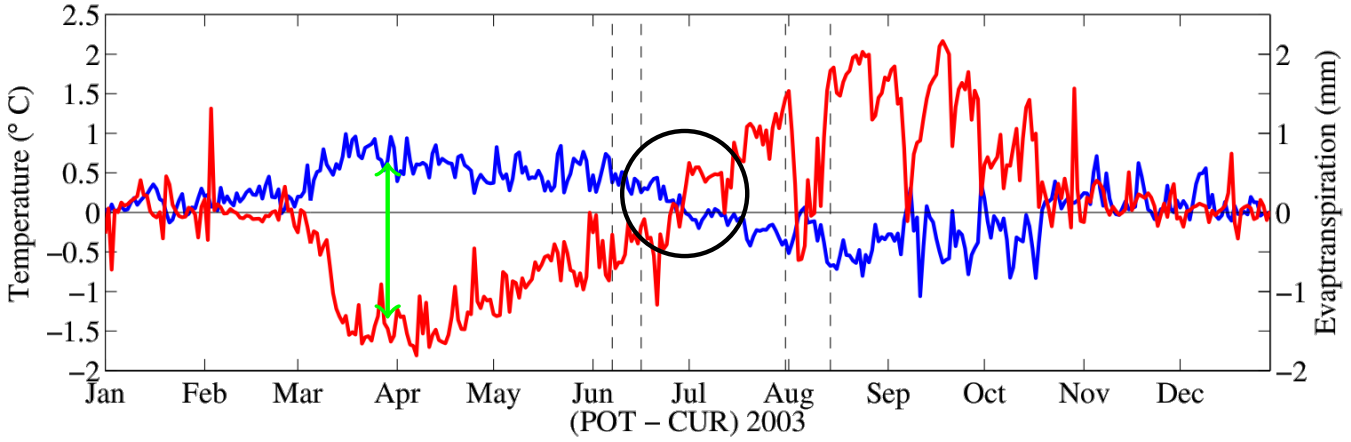

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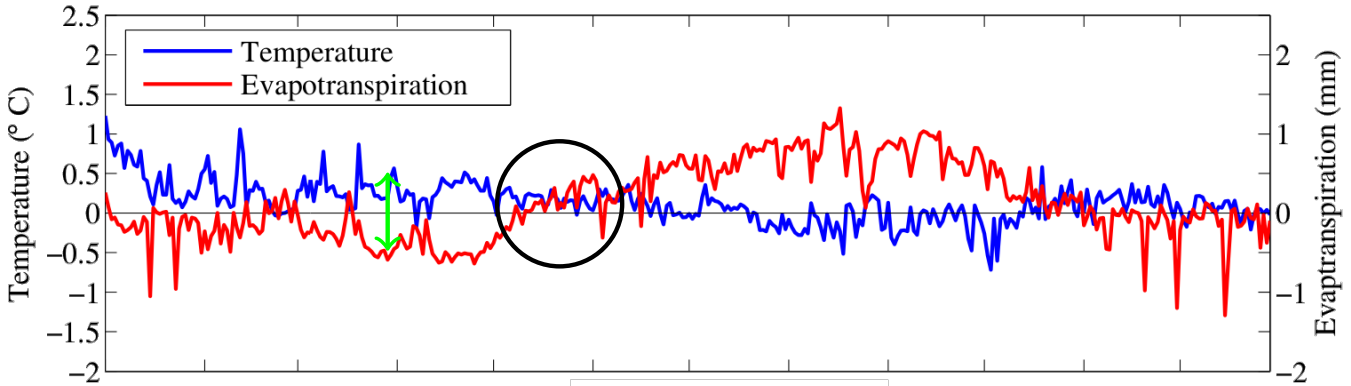
- Larger differences in 2003 between POT and CUR.
- Temperature difference sign switch is earlier in 2002.

Surface changes



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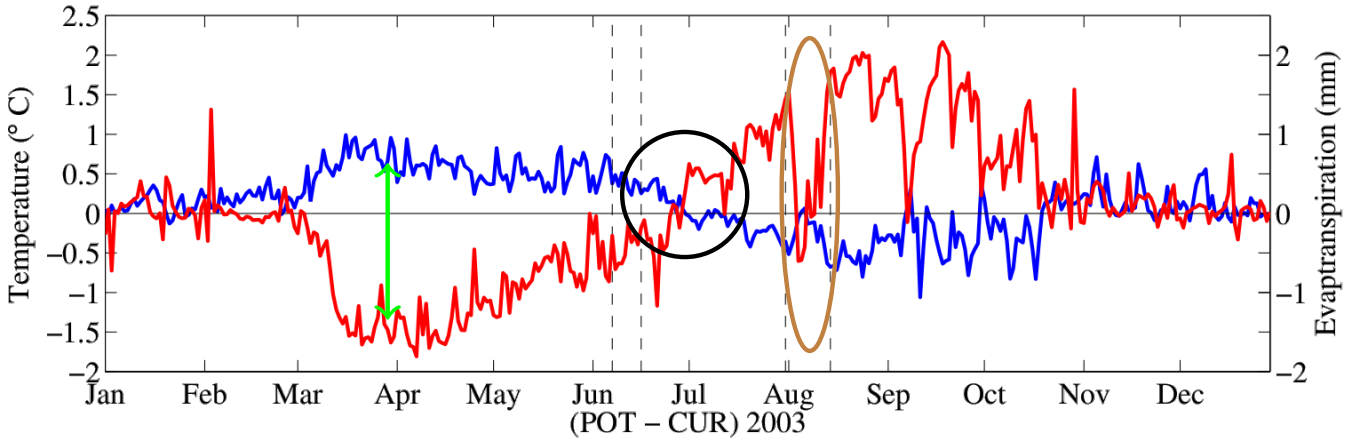
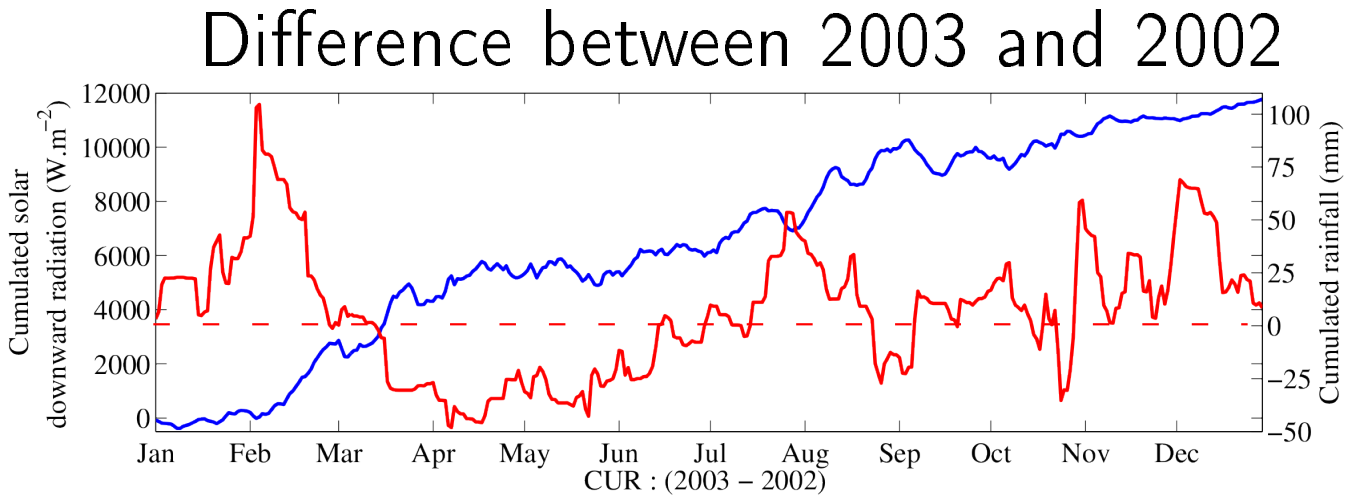


2003

- Larger differences in 2003 between POT and CUR.
- Temperature difference sign switch is earlier in 2002.
- No difference during the August heat wave.

How to explain the interannual variability ?



Cumulated Solar Radiation

Cumulated Rainfall

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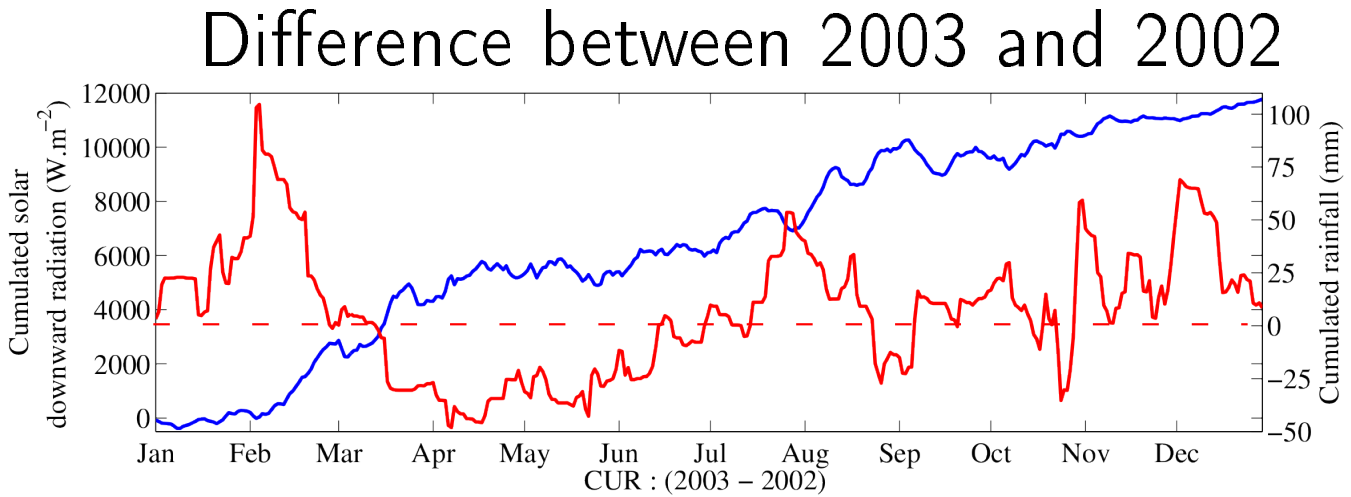

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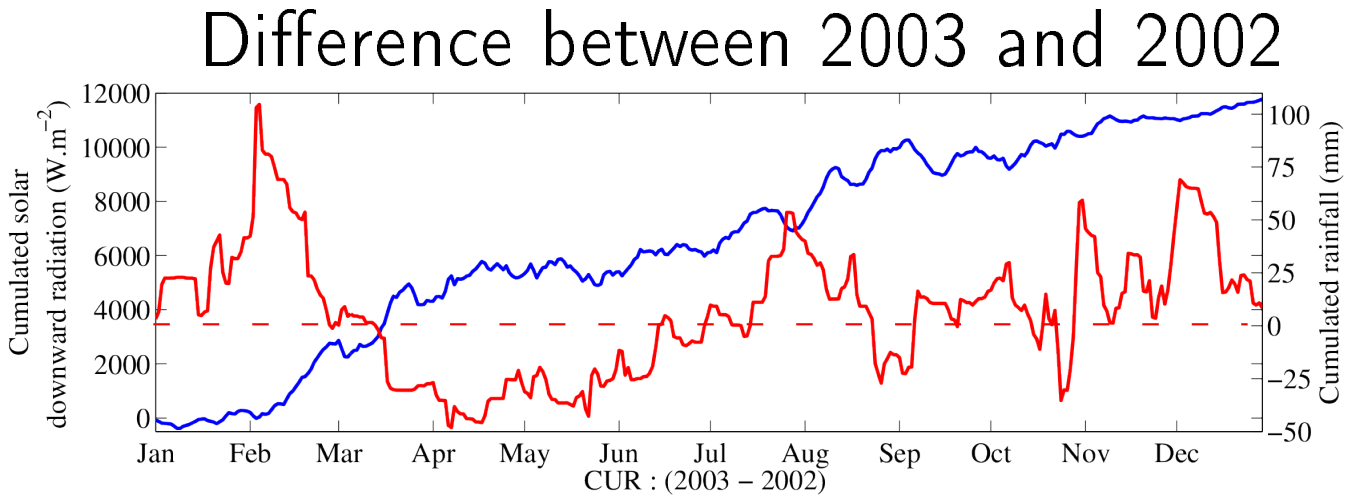

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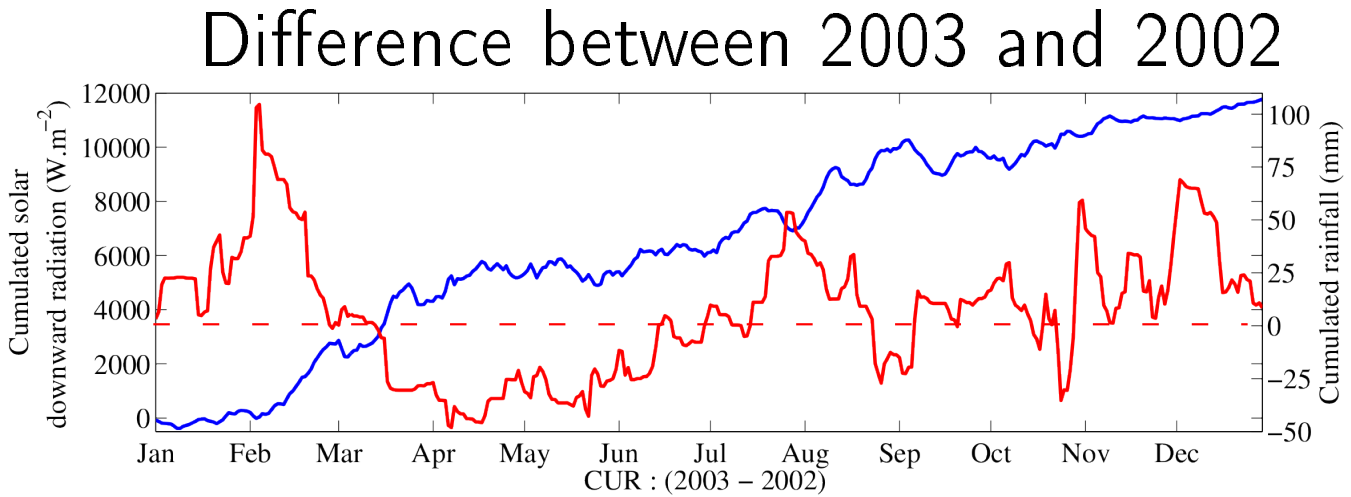

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- ✚ LAI difference = ✚ "climate" difference

August 2003 heat waves

- No difference in evapotranspiration between POT and CUR

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Stomatal conductance G_s

$$G_s = G_{s,slope} \frac{h_r}{C_a} A(\epsilon_{temp}, \epsilon_{water}) + G_{s,offset}$$

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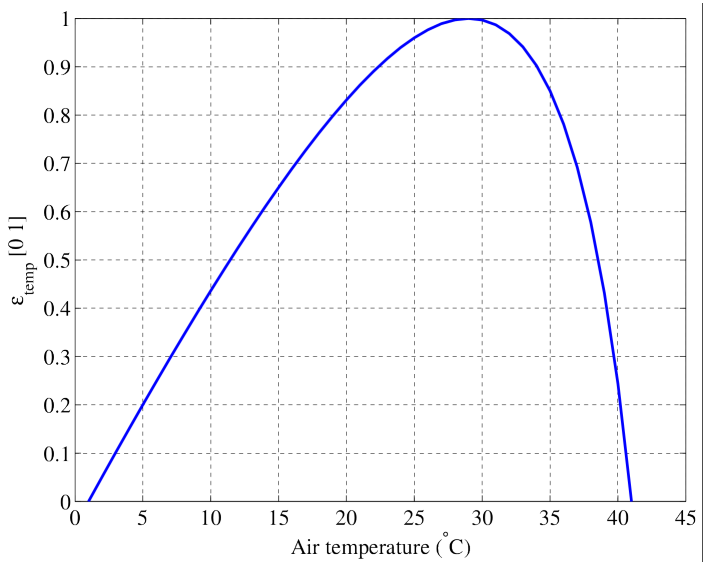

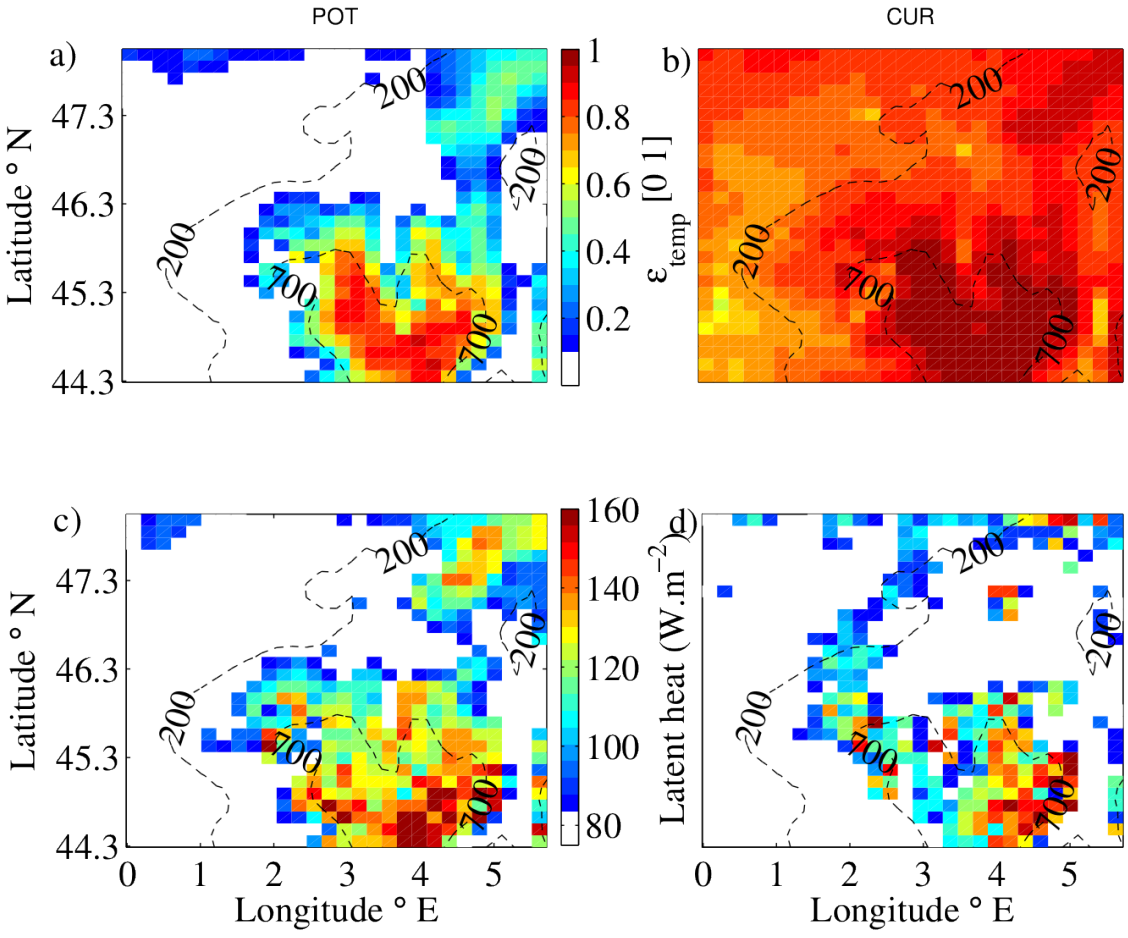

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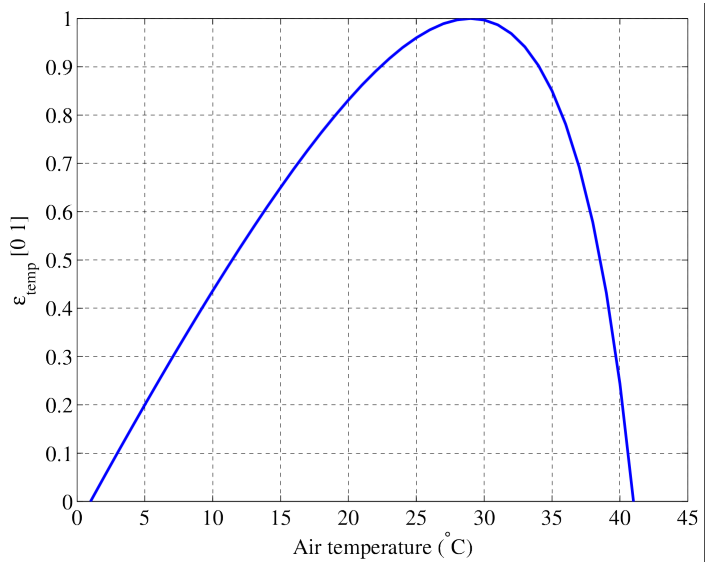

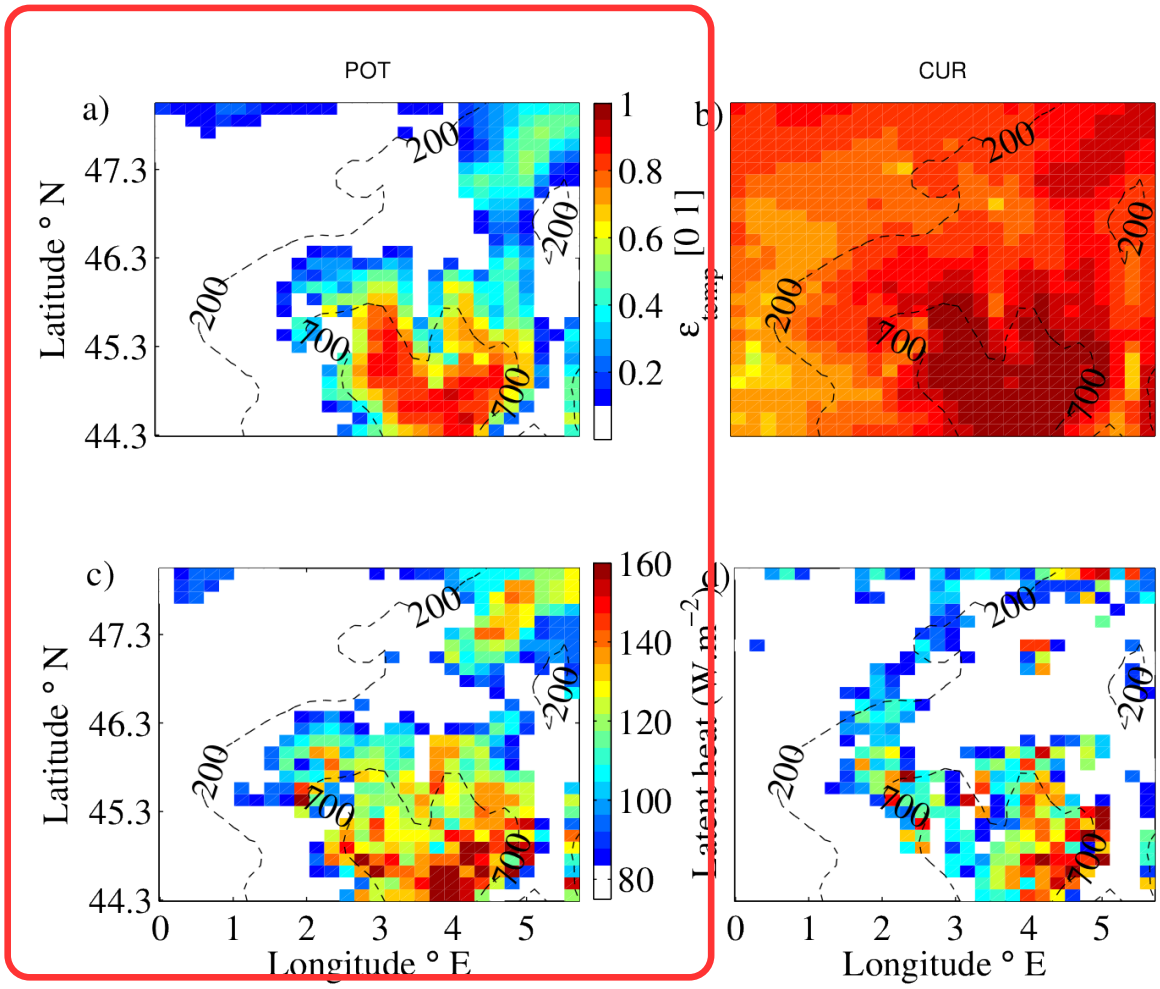

➢ Assimilation is limited by temperature for POT, which causes stomata closure and decreasing transpiration.

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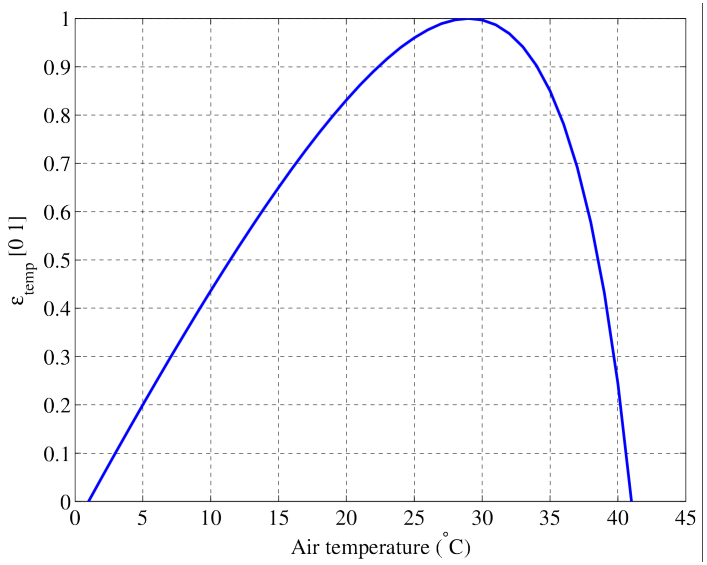

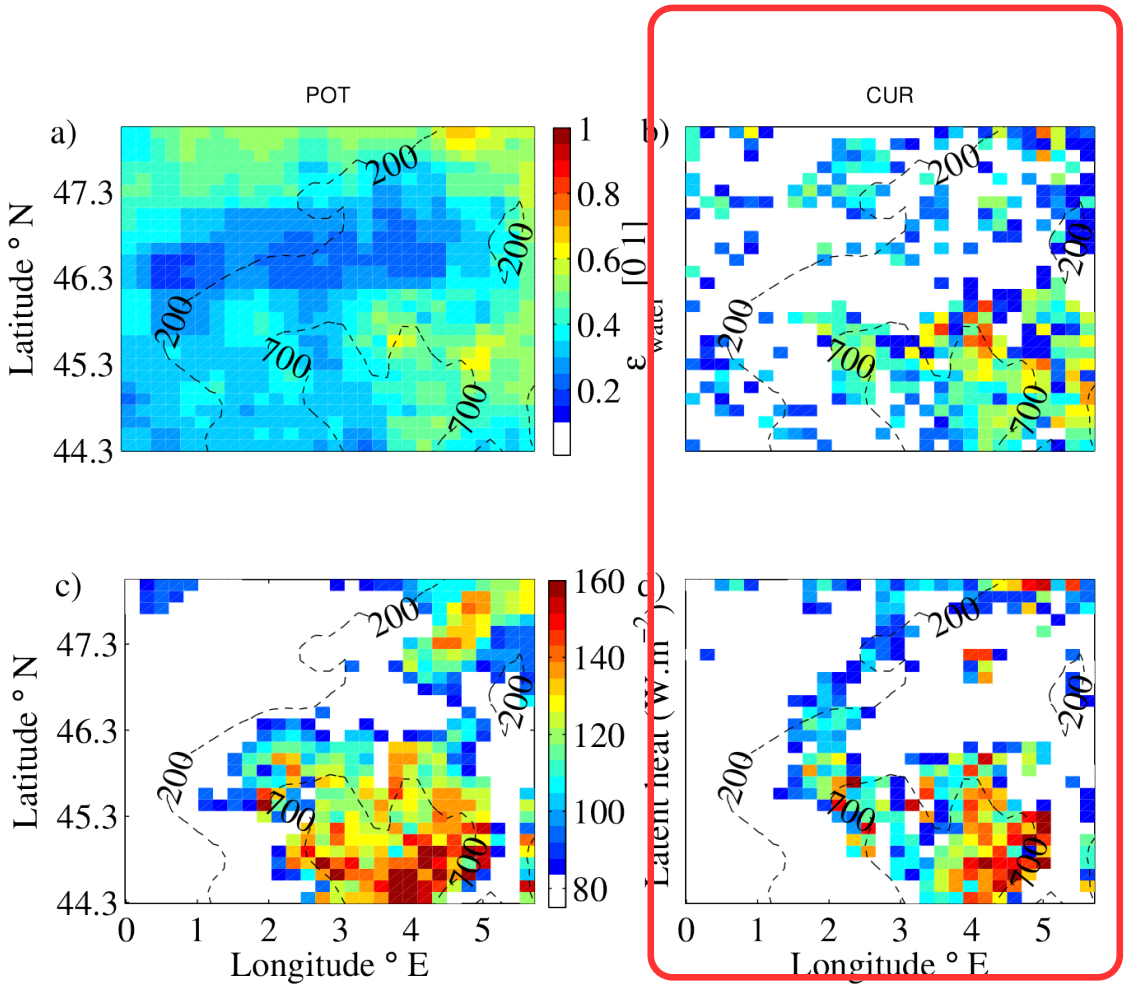

➢ Assimilation is limited by soil moisture for CUR, which causes stomata closure and decreasing transpiration.

Summary

Take away messages

- Interactive vegetation phenology improve the drought representation during 2003 summer heat waves and contributes to 20% of the temperature anomaly.
- Replacement of crops by forests amplifies the June temperature (up to $+2^{\circ}$) while it damps the temperature anomaly in August (down to -2°).
- Phenology, vegetation processes and vegetation cover matters and are essential to model the seasonal water cycle dynamics and land-atmosphere interactions at regional scale.
- But how far should we go on the representation of vegetation functioning and terrestrial biodiversity ?

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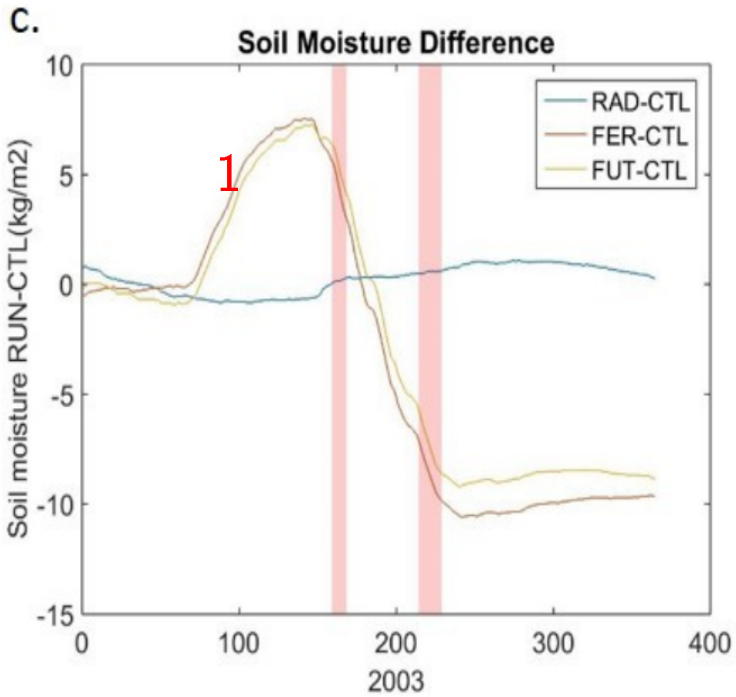
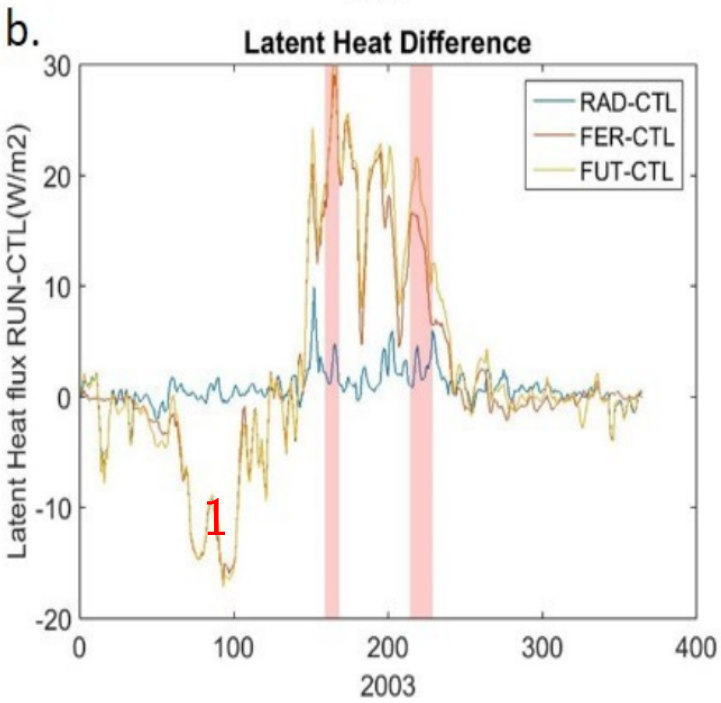
Perspective

- How the 2003 heatwave event would be different under 2100 [CO_2] ?
- How the vegetation respond to a CO_2 fertilization ?
- radiative forcing vs. fertilization ?

➢ Water saving induced by CO_2 increase can mitigate the severity of heat waves. Lemordant et al., *et al.* in prep.

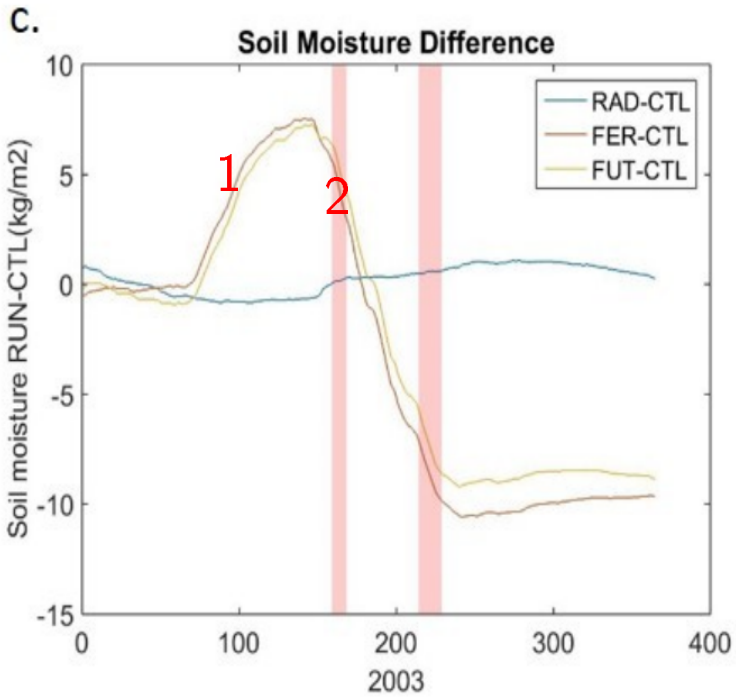
Water & energy cycles altered: the soil moisture acts as a buffer

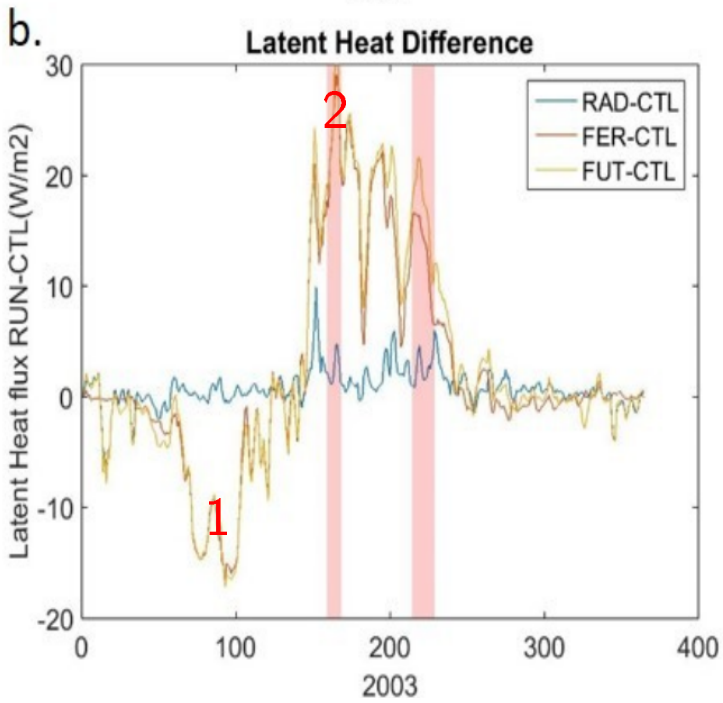




1. Lower transpiration leads to an increased water storage.

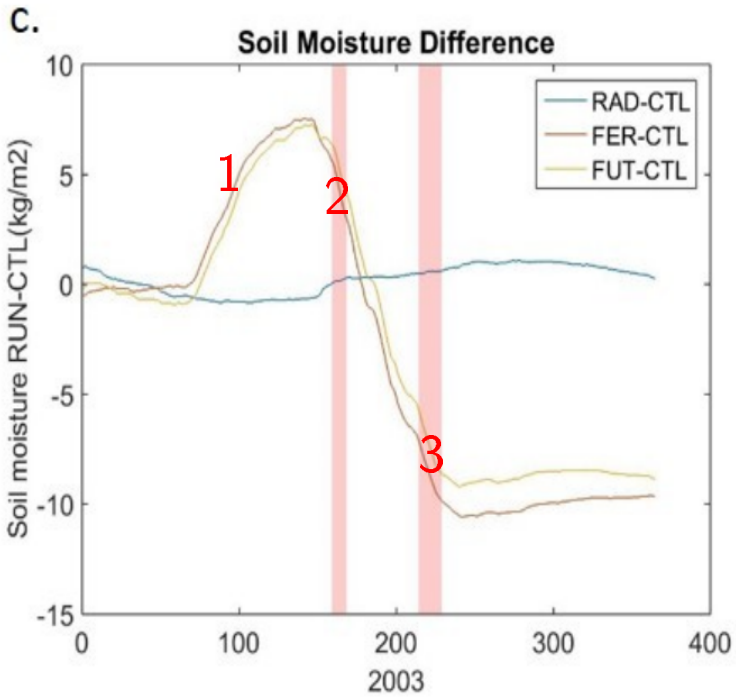
Water & energy cycles altered: the soil moisture acts as a buffer

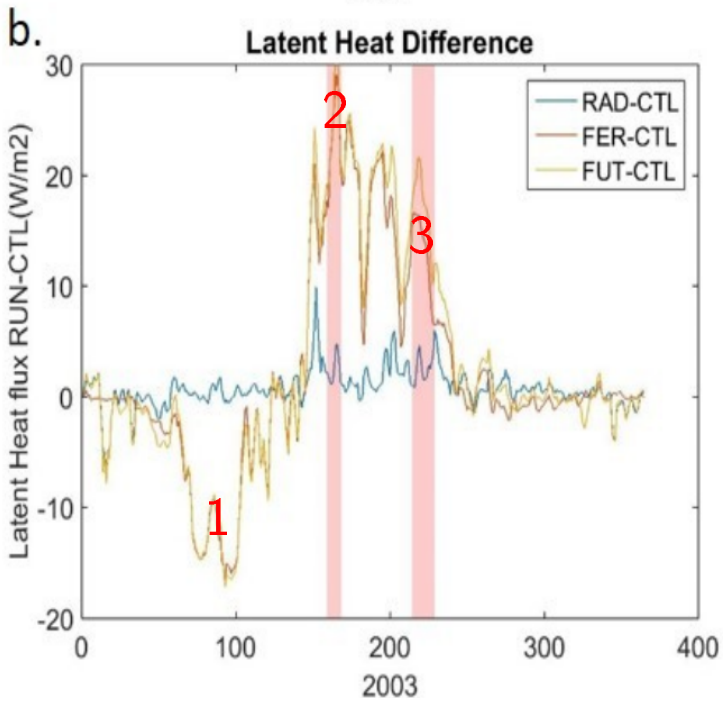




1. Lower transpiration leads to an increased water storage.
2. Transpiration increases and mitigates (better) the June heat wave.

Water & energy cycles altered: the soil moisture acts as a buffer





1. Lower transpiration leads to an increased water storage.
2. Transpiration increases and mitigates (better) the June heat wave.
3. Soil dryness at the end of the summer is exacerbated.

Thank you for your attention !