Modification of land-atmosphere interactions by CO2 effects: implications for summer dryness and heatwave amplitude

Léo Lemordant[1], Pierre Gentine[1,2], Marc Stéfanon[3], Philippe Drobinski[4,5], Simone Fatichi[6]

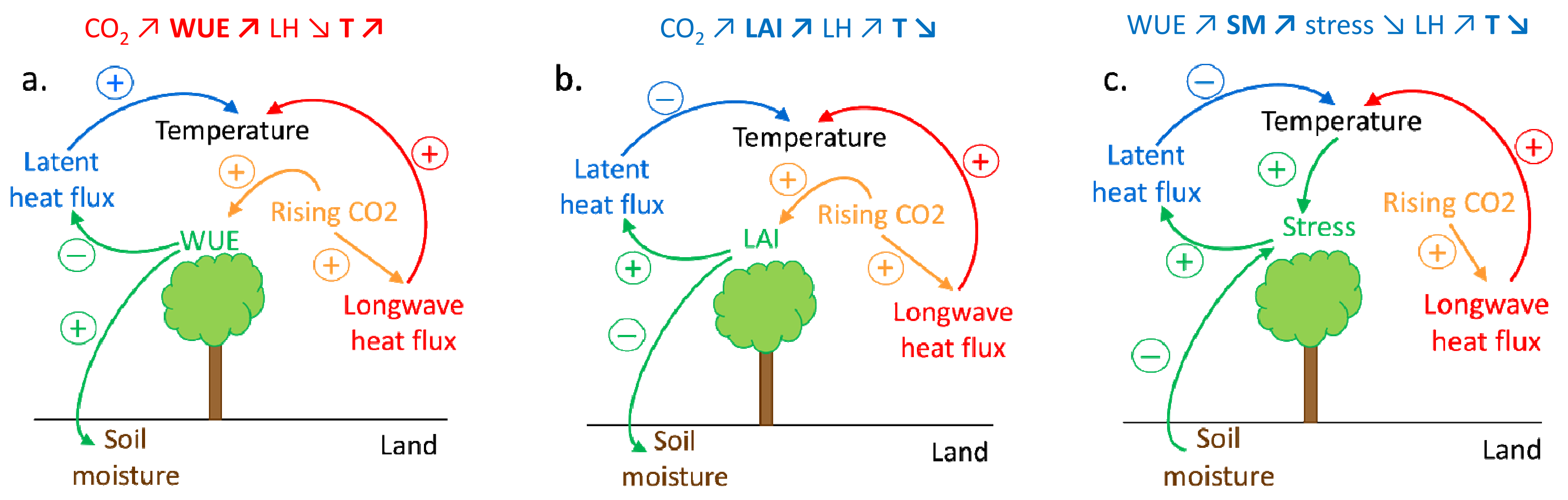
[1]Earth and Environmental Engineering Department, Columbia University [2]Earth Institute, Columbia University [3]Laboratoire des Sciences du Climat et de l'Environnement, France [4]Laboratoire de Météorologie Dynamique, CNRS / Institut Pierre Simon Laplace, Gif sur Yvette, France [5]Ecole Polytechnique, Pälaiseau, France [6]Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland

Columbia Water Center
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Abstract

Plant stomata couple the energy, water and carbon cycles. We use the framework of Regional Climate Modeling to simulate the 2003 European heat wave and assess how higher levels of surface CO_2 may affect such an extreme event through land-atmosphere interactions. Increased CO_2 modifies the seasonality of the water cycle through stomatal regulation and increased leaf area. As a result, the water saved during the growing season through higher water use efficiency mitigates summer dryness and the heat wave impact. Land-atmosphere interactions and CO_2 fertilization together synergistically contribute to increased summer transpiration. This, in turn, alters the surface energy budget and decreases sensible heat flux, mitigating air temperature rise. Accurate representation of the response to higher CO_2 levels, and of the coupling between the carbon and water cycles are therefore critical to forecasting seasonal climate, water cycle dynamics and to enhance the accuracy of extreme event prediction under future climate.

Motivation: the CO_2 direct and indirect feedbacks



$g_{canopy} = g_{stomax}(CO_2) * LAI * f(stress)$ $g_{canopy} = g_{stomax}(CO_2) * LAI * f(stress)$ $g_{canopy} = g_{stomax}(CO_2) * LAI * f(stress)$

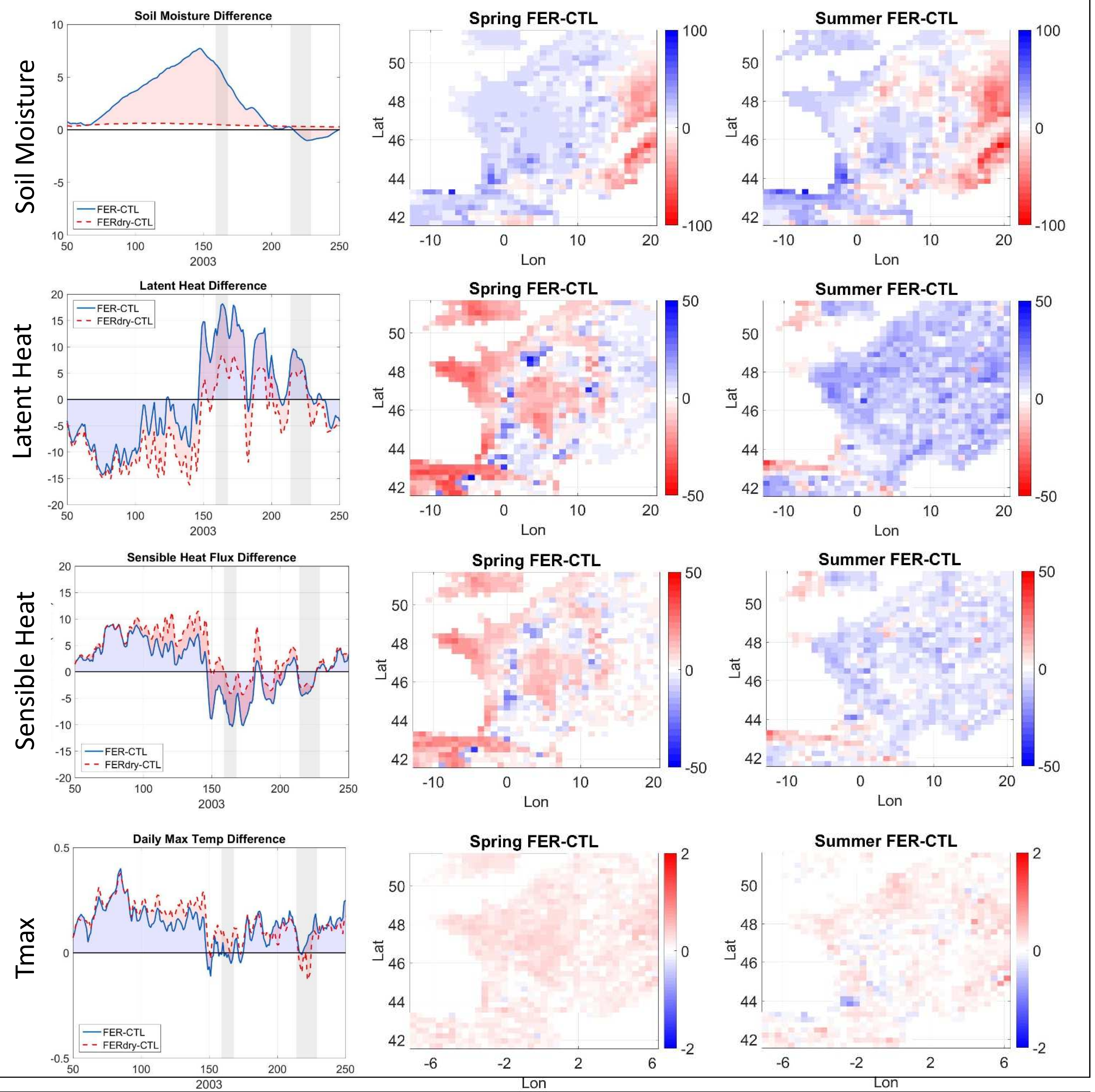
Growing season — Early Summer — Heat-wave

Methods

- Reproduction of the **2003 heatwaves** that hit France: 2nd week of June and the 2 first week of August
- **Coupling** of atmospheric model (WRF) with a surface model (ORCHIDEE)
- **Regional scale** domain : 10x15 deg centered on France

	[CO2]atm in the surface model	Other parameter tweaked in the surface model
CTL	376 ppm (Base case)	N/A
FER	936 ppm	N/A
FER_{dry}	936 ppm	Soil moisture = soil moisture in CTL

Results



Conclusion

The present study illustrates the role of plant physiology in altering land-atmosphere interactions under higher CO_2 concentration. CO_2 indirect effects can mitigate heat-wave impacts and the severity of summer dryness in the Western Europe mid-latitude climate. Spring water savings enabled by increased ecosystem water use efficiency modifies the surface energy partitioning, allowing increased latent heat flux later in the summer that more than compensates the reduced stomatal opening induced by increased CO_2.