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Regional climate modelling of European summer climate variability over the period 1970-2003

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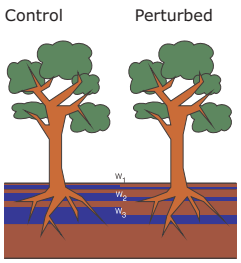
Introduction

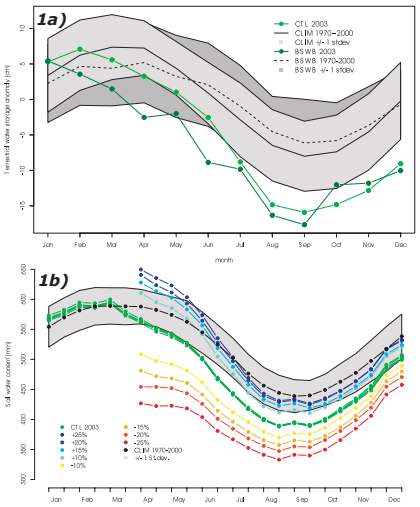
Recent extreme events such as the devastating 2003 European summer heatwave highlight the importance of a better understanding of the key processes and feedbacks relevant for the continental-scale summer climate. We analyse simulated soil moisture-atmosphere interactions during the 2003 European summer heatwave *(1,2,3)* in comparison to 31 years of European summer climate variability.

Data and Methods

- We simulate the European summer 2003 using the regional climate model CHRM (Climate High-Resolution Model) *(4)* driven by lateral boundary conditions and SSTs from the ECMWF operational analysis.
- We perform sensitivity experiments including 15 simulations for 2003: a control ensemble of 5 members to determine the model's internal variability, and 10 sensitivity runs with perturbed soil moisture.
- The simulated feedbacks are analysed in relation to a 31-year CHRM run (1970-2000) driven by ECMWF re-analysis (ERA-40) lateral boundary conditions.

Sensitivity experiment





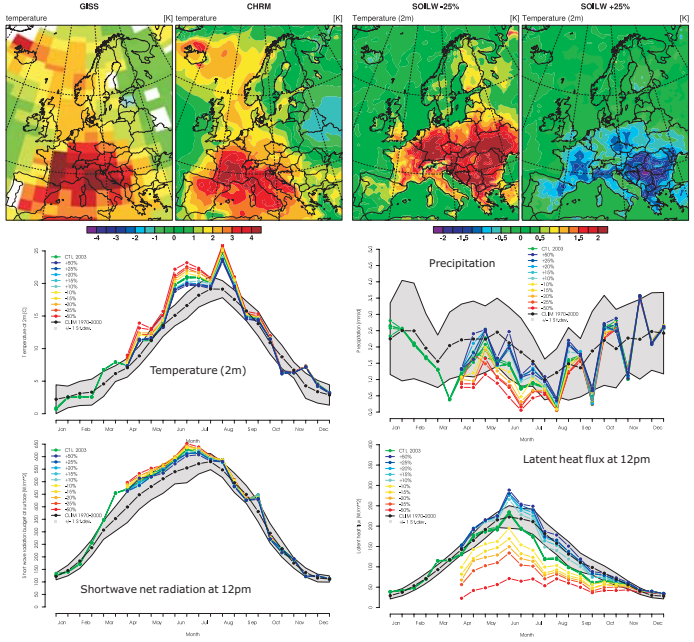
	Perturbation	JJA Anom
CTL ENS	unchanged	3.50°C
WET50	+50% Apr 03	2.39°C
WET25	+25% Apr 03	2.66°C
WET20	+20% Apr 03	2.60°C
WET15	+15% Apr 03	2.76°C
WET10	+10% Apr 03	3.02°C
DRY10	- 10% Apr 03	3.83°C
DRY15	- 15% Apr 03	4.18°C
DRY20	- 20% Apr 03	4.32°C
DRY25	- 25% Apr 03	4.60°C
DRY50	- 50% Apr 03	4.96°C

Figure 1a *(upper right): Terrestrial water storage (Rhine catchment) derived from runoff measurements and analysed moisture flux convergence (BSWB, 5) and simulated by CHRM.*
Figure 1b *(lower right): Simulated soil moisture content in perturbed and unperturbed runs averaged over France.*

2003 summer heatwave

Figure 2a) Temperature (2m) in summer 2003 wrt 1970-2000
GISS **CHRM CTL**

b) CHRM Temperature (2m) departure perturbed runs wrt CTL
DRY25 wrt CTL **WET25** wrt CTL

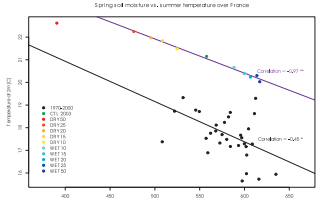


- Good agreement between observed (GISS analysis; Fig 2a, left) and simulated (CHRM; Fig 2a, right) 2003 summer temperature anomalies.
- Reduction of spring soil moisture results in substantially enhanced and spatially expanded (>2°C) temperature anomalies (fig 2b, left).
- Surface temperature is highly sensitive to spring soil water perturbations (soil water memory up to 7 months).
- Precipitation was substantially below and shortwave net as well as total net radiation above average in all months from Feb-Aug 2003.
- Latent heat flux decreased in June and remained far below average due to drying of land surface.

References

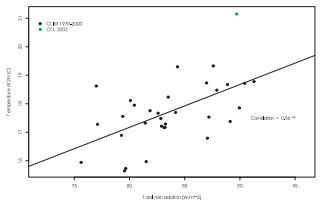
(1) C. Schär et al., *Nature,* **427** (2004).
(2) J. Luterbacher et al., *Science,* **303** (2004).
(3) C. Schär and G. Jendritzky, *Nature,* **432** (2004).
(4) P. L. Vidale et al. *J. Geophys. Res.* **108**(D18) (2003).
(5) M. Hirschi et al. *J. Hydrometerol.* (2006) in press.
(6) Background picture by R. Stöckli et al. (2005), NASA Earth Observatory

Summer temperature 1970-2000

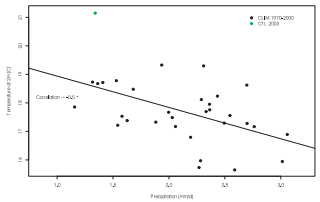


Soil moisture	Temperature Apr	May	Jun	Jul	Aug	Sep
Apr	-0.20	-0.61	-0.22	-0.24	-0.55	-0.15
May		-0.57	-0.31	-0.35	-0.58	-0.17
Jun			-0.55	-0.43	-0.64	-0.19
Jul				-0.65	-0.59	-0.26
Aug					-0.65	-0.27
Sep						-0.51

Significant at 95%
Significant at 99%



Net radiation	Temperature Apr	May	Jun	Jul	Aug	Sep
Apr	0.62	-0.21	-0.02	0.09	0.15	0.02
May		0.71	0.40	0.38	0.54	0.14
Jun			0.75	0.26	0.12	-0.04
Jul				0.72	0.01	0.02
Aug					0.36	0.34
Sep						0.60



Precipitation	Temperature Apr	May	Jun	Jul	Aug	Sep
Apr	-0.24	0.31	0.07	0.06	-0.08	-0.09
May		-0.45	-0.50	-0.37	-0.47	-0.18
Jun			-0.64	-0.43	-0.20	-0.15
Jul				-0.53	-0.29	-0.26
Aug					-0.30	-0.41
Sep						-0.29

- Spring soil water has a significant impact on surface temperature over France particularly in late summer (top).
- The temperature sensitivity to spring soil moisture in the 2003 sensitivity experiment equals the multi-year average sensitivity 1970-2000 (top).
- Spring precipitation (bottom) and total net radiation (middle) correlate with summer temperature over France.

Conclusions

- Simulations show that **soil moisture** anomalies may account for >2°C surface temperature difference during JJA 2003.
- **Anticyclonic forcing,** strong **radiative anomalies** and the **lack of precipitation** (Feb-Aug) contributed to a rapid loss of **soil water** resulting in **reduced latent cooling** and strong heat anomalies in summer 2003.
- **Late summer temperature** over France is significantly **influenced** by **spring soil moisture.**