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Soil moisture - atmosphere interactions during the 2003 European summer heatwave

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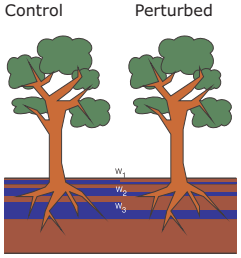
Introduction

A record-breaking heatwave affected Europe in summer 2003. With temperatures exceeding the 1961–90 mean over continental-scale Europe by over 3°C *(1)* it was very likely the hottest European summer over the past 500 years *(2)*. Estimates based on the statistical excess over mean mortality rates amount to between 22,000 and 35,000 heat-related deaths across Europe *(3)*.

We use the regional climate model CHRM (Climate High-Resolution Model, originating from the DWD) *(4)* to simulate the European summer 2003 in order to identify the influence of different processes on the evolving heatwave.

Data and Methods

- We perform sensitivity experiments driven by lateral boundary conditions and SSTs from the ECMWF operational analysis.
- 15 simulations are conducted for 2003: a control ensemble of 5 members to determine the model's internal variability, and 10 sensitivity runs with perturbed soil water.
- The simulated temperatures are expressed as departures from a 31-year CHRM run (1970-2000) driven by ERA40 boundary conditions.



	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

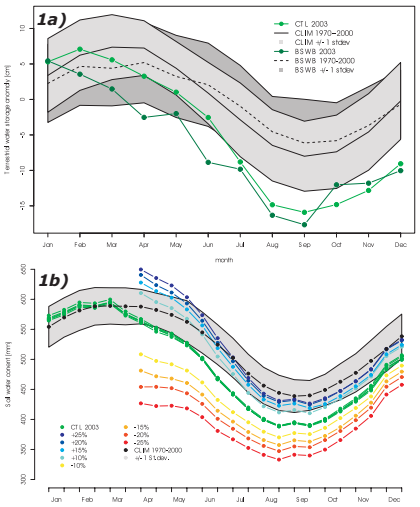
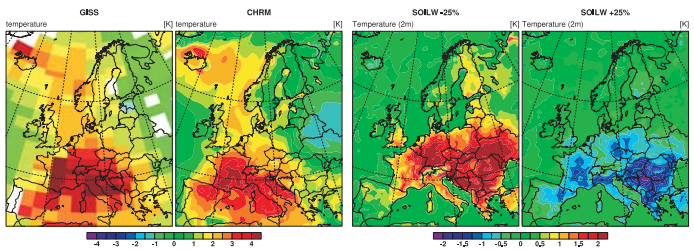


Figure 1a *(upper right): Terrestrial water storage (Rhine catchment) derived from runoff measurements and analysed moisture flux convergence (BSWB, 5) and simulated by CHRM.*

Figure 1b *(lower right): Simulated soil moisture content in perturbed and unperturbed runs averaged over France.*

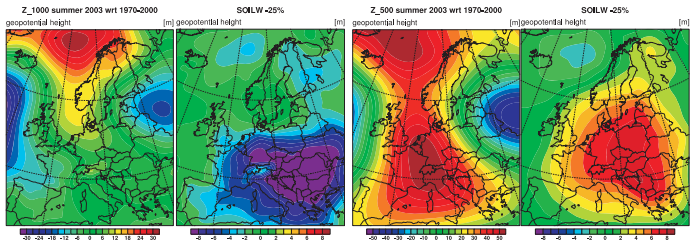
Figure 2a) Temperature (2m) in summer 2003 wrt 1970-2000
GISS Temp anom **CHRM CTL**

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



c) Geopotential height 1000hPa JJA 2003
CTL wrt CLIM **DRY25** wrt CTL

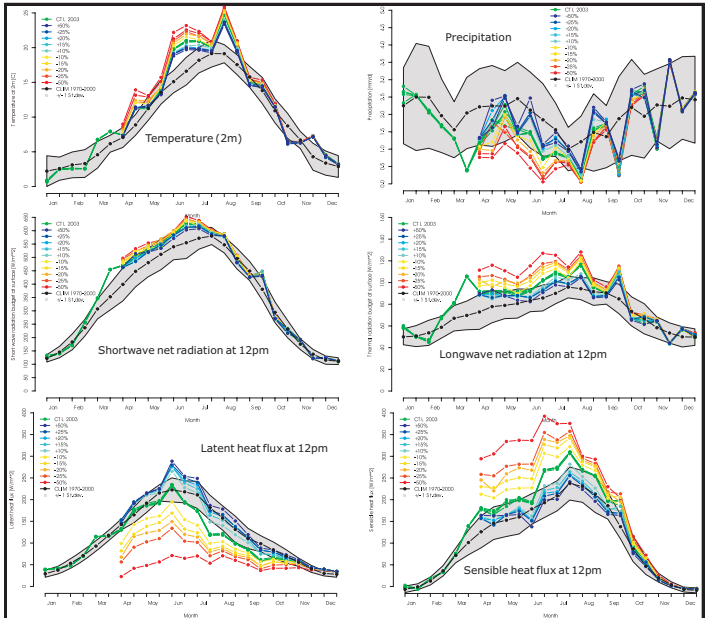
c) Geopotential height 500hPa JJA 2003
CTL wrt CLIM **DRY25** wrt CTL



- Good agreement between observed (GISS analysis; Fig 2a, left) and simulated (CHRM; Fig 2a, right) summer 2003 temperature anomalies.
- Reduction of spring soil moisture results in substantially enhanced and spatially expanded (>2°C) temperature anomalies (fig 2b, left).
- Lack of soil moisture results in a pronounced summer heat depression (1000hPa) over the heated surface (fig 2c, right).
- Simultaneously geopotential height (500hPa) anomalies are enhanced ⇒ positive feedback between surface drought conditions and anticyclonic forcing (fig 2d, right).

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) L. Ferranti and P. Viterbo *J. Clim.* (2006) accepted.
(7) Background picture by R. Stöckli et al. (2005), NASA Earth Observatory



- 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.
- Sensible heat flux and long wave net radiation were strongly enhanced during spring and summer.

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) in spring and early summer contributed to a rapid loss of **soil water** resulting in **reduced latent cooling.**
- Negative soil water anomalies result in the formation of a surface heat low and **strengthen** the positive **height anomaly** in the upper troposphere (**positive feedback**).