Physical processes during the 2003 European summer heatwave

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PRUDENCE

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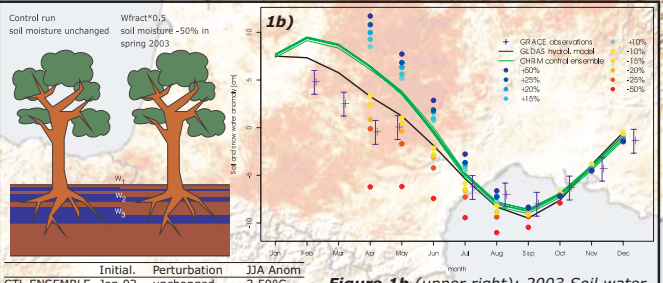
Introduction

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.



	Initial.	Perturbation	JJA Anom
CTL ENSEMBLE	Jan 02	unchanged	3.50°C
SOILW +50%	Jan 02	+50% Apr 03	2.39°C
SOILW +25%	Jan 02	+25% Apr 03	2.66°C
SOILW +20%	Jan 02	+20% Apr 03	2.60°C
SOILW +15%	Jan 02	+15% Apr 03	2.76°C
SOILW +10%	Jan 02	+10% Apr 03	3.02°C
SOILW - 10%	Jan 02	- 10% Apr 03	3.83°C
SOILW - 15%	Jan 02	- 15% Apr 03	4.18°C
SOILW - 20%	Jan 02	- 20% Apr 03	4.32°C
SOILW - 25%	Jan 02	- 25% Apr 03	4.60°C
SOILW - 50%	Jan 02	- 50% Apr 03	4.96°C

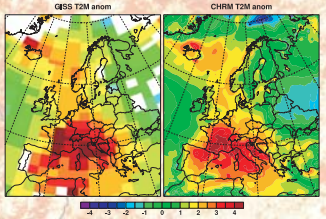
***Figure 1b** (upper right): 2003 Soil water anomaly over Europe measured by GRACE satellites (purple) (5), simulated by GLDAS (black curve) (5) and by CHRM (green curves).*

***Table 1:** 5 CHRM control sim. and 10 runs with perturbed soil water. Col. 4 shows the simulated JJA temp. anom. over France.*

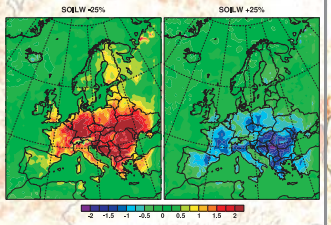
References

(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) O. B. Andersen et al. *Geophys. Res. Lett.* (2005) submitted.
(6) L. Ferranti and P. Viterbo (2005), to be submitted.
(7) Background picture by R. Stöckli et al. (2005), NASA Earth Observatory

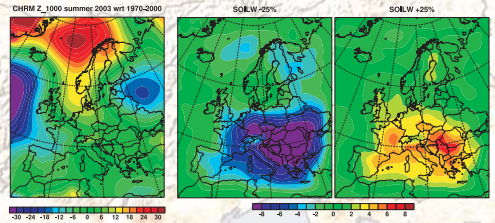
Figure 2a) Temperature (2m) in summer 2003 wrt 1970-2000
GISS Temp anom **CHRM** CTL



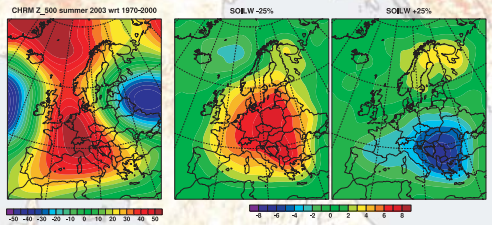
b) CHRM Temperature (2m) anomaly perturbed runs wrt CTL
Dry run wrt CTL **Wet run** wrt CTL



c) Geopotential height anomalies at 1000hPa in summer 2003
CTL wrt 1970-2000 **Dry run** wrt CTL **Wet run** wrt CTL



d) Geopotential height anomalies at 500hPa in summer 2003
CTL wrt 1970-2000 **Dry run** wrt CTL **Wet run** wrt CTL



- Good agreement between summer 2003 temperature anomalies from CHRM simulation (fig 2a, right) and GISS analysis (fig 2a, left).
- In dry runs temperature anomalies are substantially enhanced and cover an extended region (fig 2b, left panel).
- Lack of soil water results in the formation of a pronounced summer heat depression at the surface (fig 2c, central panel).
- Simultaneously geopotential height anomalies are even enhanced ⇒ positive feedback mechanism between surface drought conditions and anticyclonic forcing (fig 2d, central panel).

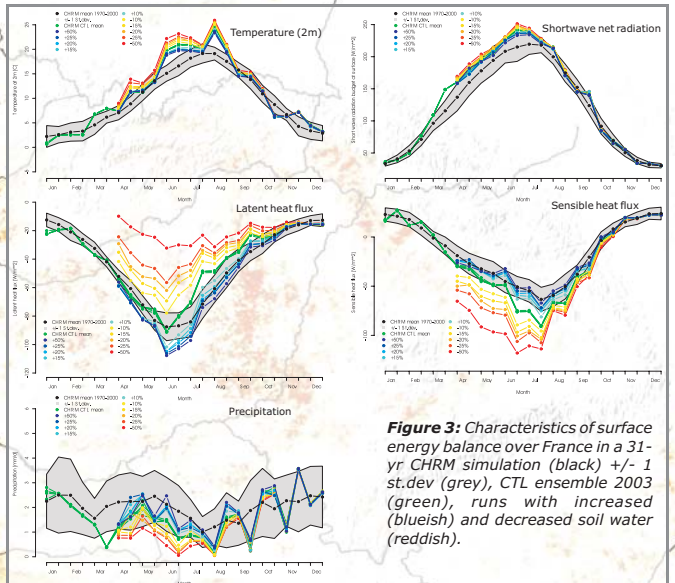


***Figure 3:** Characteristics of surface energy balance over France in a 31-yr CHRM simulation (black) +/- 1 st.dev (grey), CTL ensemble 2003 (green), runs with increased (blueish) and decreased soil water (reddish).*

- Surface temperature is highly sensitive to spring soil water perturbations (soil water memory up to 7 months).
- Precipitation was substantially below and shortwave net radiation above average in all months Feb-Aug 2003.
- Latent heat flux decreased in June and remained far below average due to drying of land surface.
- Sensible heat flux was enhanced in spring and early summer with a distinct drop in early August (maximum heat wave).

Conclusions

- Simulations show that **soil water** anomalies may account for 2-4°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.