Representation of soil water stress in GCM simulations of vegetation physiology

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JULES meeting, 2016

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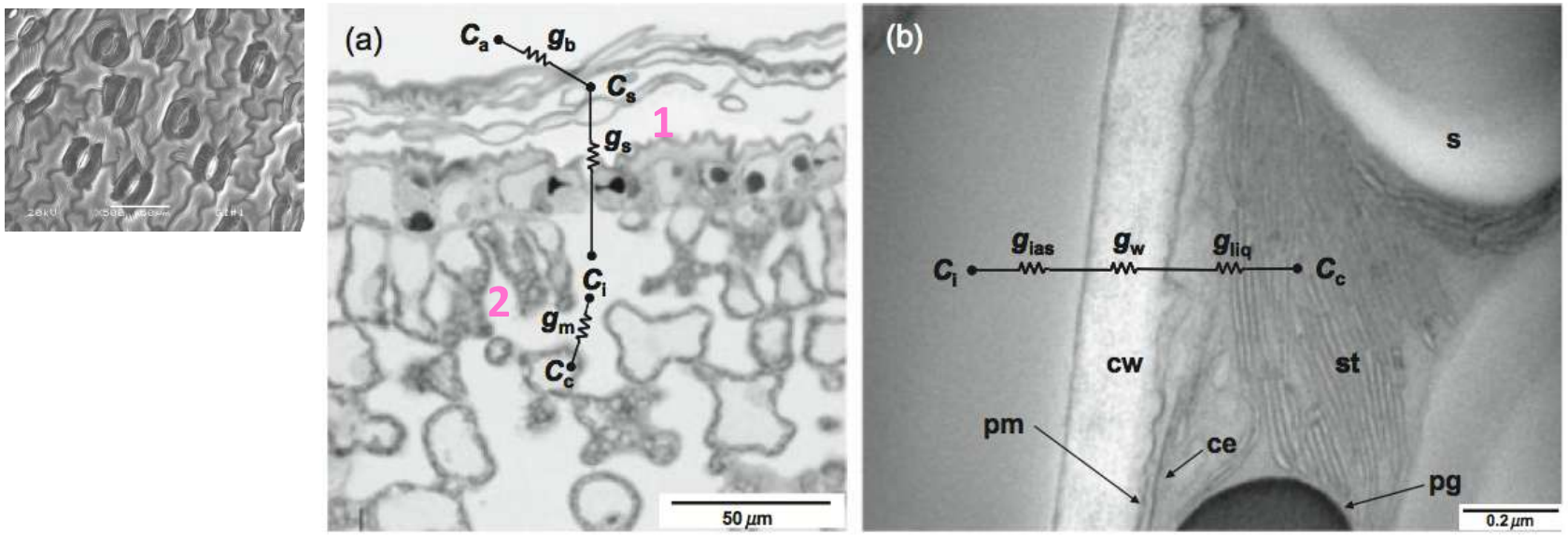
Do we include the right processes in simulating the EFFECTS OF SOIL WATER STRESS ON PLANT FUNCTION?

Water stress affects the **CO_2 concentration at chloroplast level**, **C_c** by:

1. Stomatal Conductance Limitation **(SCL)**, reducing stomatal conductance g_s (diffusion of CO_2 and H_2O)
2. Mesophyll Conductance Limitation **(MCL),** reducing mesophyll conductance to CO_2 diffusion (g_m)

Water stress affects the **biochemical capacity** (**BL**) by:

3. Reducing V_{cmax} (carboxylation rate)
4. Reducing J_{max} (electron transport rate)



Flexas et al. 2008

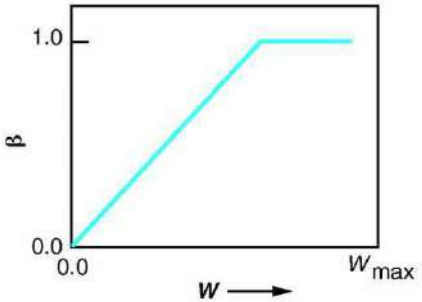
Figure 1. (a) Micrograph of the abaxial surface of an olive leaf (bottom side up), where the stomata can be seen, as well as the pathway of CO_2 from ambient (C_a) through leaf surface (C_s) and intercellular air spaces (C_i) to the chloroplast (C_c). Boundary layer conductance (g_b), stomatal conductance (g_s) and mesophyll conductance (g_m) are indicated. (b) Electron micrograph of a grapevine leaf where cell wall (cw), plasma membrane (pm), the chloroplast envelope (ce) and stroma thylakoid (st) can be observed. The pathway of CO_2 from C_i to chloroplastic CO_2 (C_c) is characterized by intercellular air space conductance to CO_2 (g_{ias}), through cell wall (g_w) and through the liquid phase inside the cell (g_{liq}). A grain of starch (s) and a plastoglobule (pg) can be also observed in the picture (photos by A. Diaz-Espejo).

GENERALISED, NEW APPROACH TO MODEL WATER STRESS

MODELS SUCH AS JULES NEGLECT DIFFUSIONAL LIMITATIONS (I.E. STOMATAL AND/OR MESOPHYLL CONDUCTANCE LIMITATIONS)

Egea et al. (2011) generalize the β relationship by introducing an **exponential dependence**, which allows for non-linear $\beta = \beta(\theta)$ functional dependencies through the exponent q_i:

$$\beta_i^l = \begin{cases} 1 & \theta^l \geq \theta_c^l \\ \left[\dfrac{\theta^l - \theta_w^l}{\theta_c^l - \theta_w^l}\right]^{q_i} & \theta_c^l > \theta^l > \theta_w^l \\ 0 & \theta^l \leq \theta_w^l \end{cases}$$



Furthermore, the indices (i=S,B,M) **enable three pathways** (**S**tomatal, **B**iochemical, **M**esophyll) for soil water stress β to affect plant function individually, or in any combination.

The generalised model limitations are thus applied to:

$A = A_p \beta_B$ **photosynthesis**

$g_m = g_m \beta_M$ **mesophyll conductance**

$g_s = g_s \beta_S$ **stomatal conductance**

A. Verhoef, from Egea et al. 2011, AFM; Vidale et al. 2013, in prep.

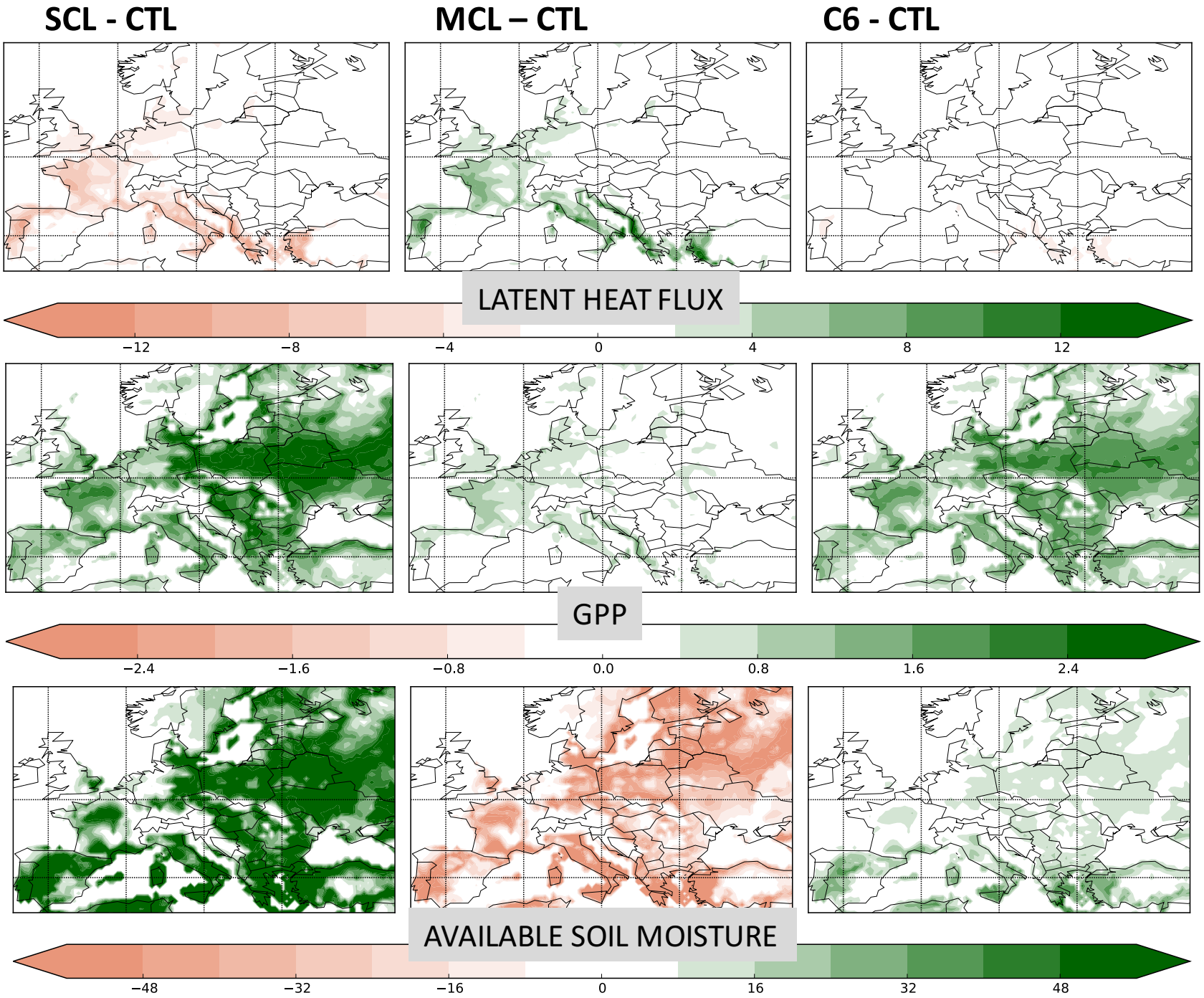
Experiments with recent version of JULES

- Control and *Improved Simulations of JULES 4.4

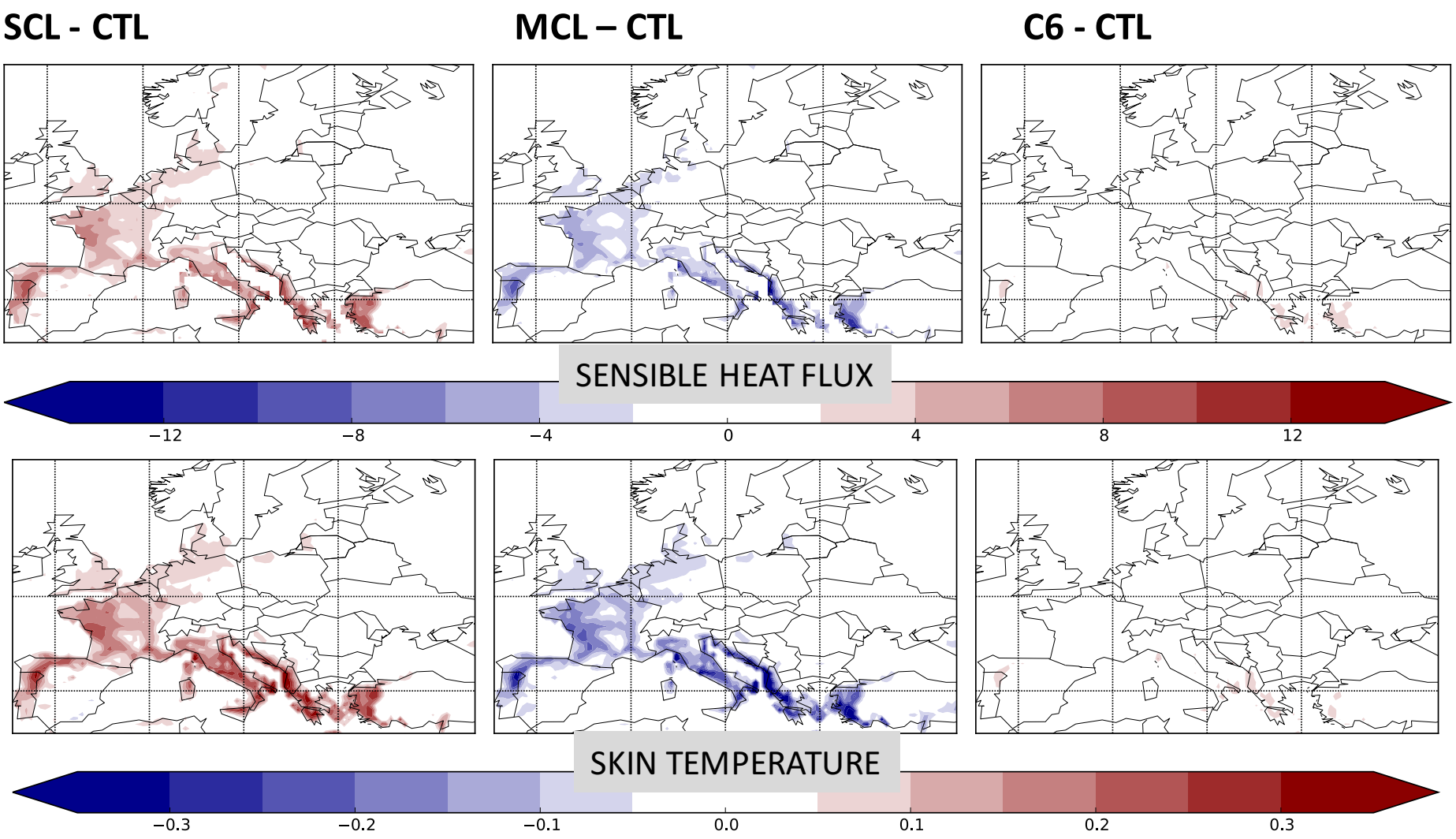
- Study domain -- Europe including the UK (10°W -40°E, 35°N -65°N)
- Resolution – 0.5° X 0.5° , Time step – 30 mins
- Forcing Dataset – WFDEI (Weedon et al. 2014), 3 hourly, 0.5 x 0.5 resolution, 8 atmospheric variables – SWdown, LWdown, Psurf, Qair, Tair, Windspeed, Rainfall, Snowfall
- Simulation period – 1979-2012
- Spin up cycles – 30 each

* Improved soil water stress factor (beta) representations using Stomatal (SCL), Biochemical (BL) and Mesophyll (MCL) limitations and their combinations (C6)

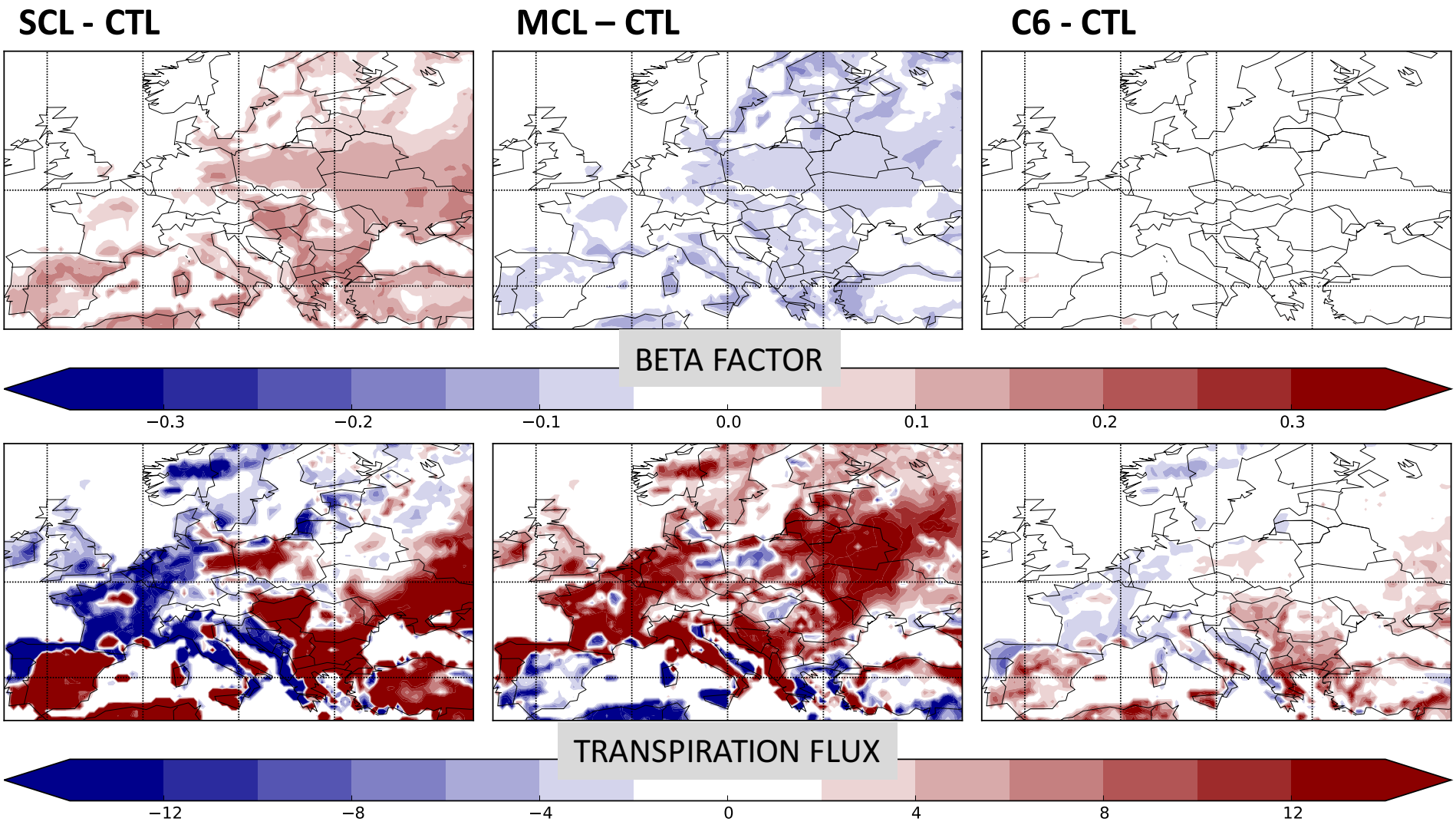
CLIMATOLOGY



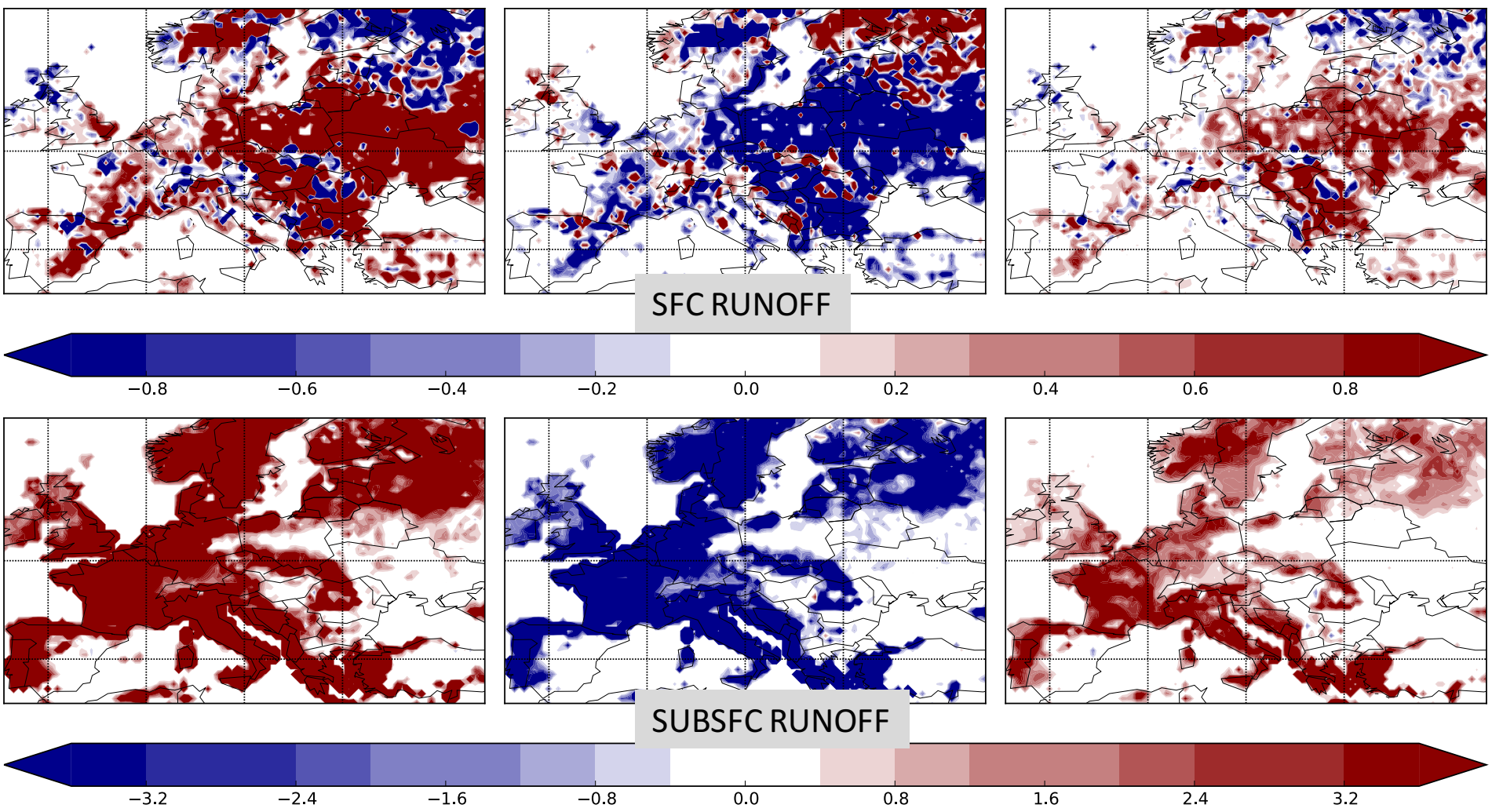
Difference in climatologies w.r.t BL (CTL): LH (W/m^2) (top), GPP (1E-8 kg/m^2/s) (middle), Available SM (mm) (bottom)



Difference in JJA climatologies w.r.t BL (CTL): SH (W/m^2) (top), Tstar (K) (bottom)

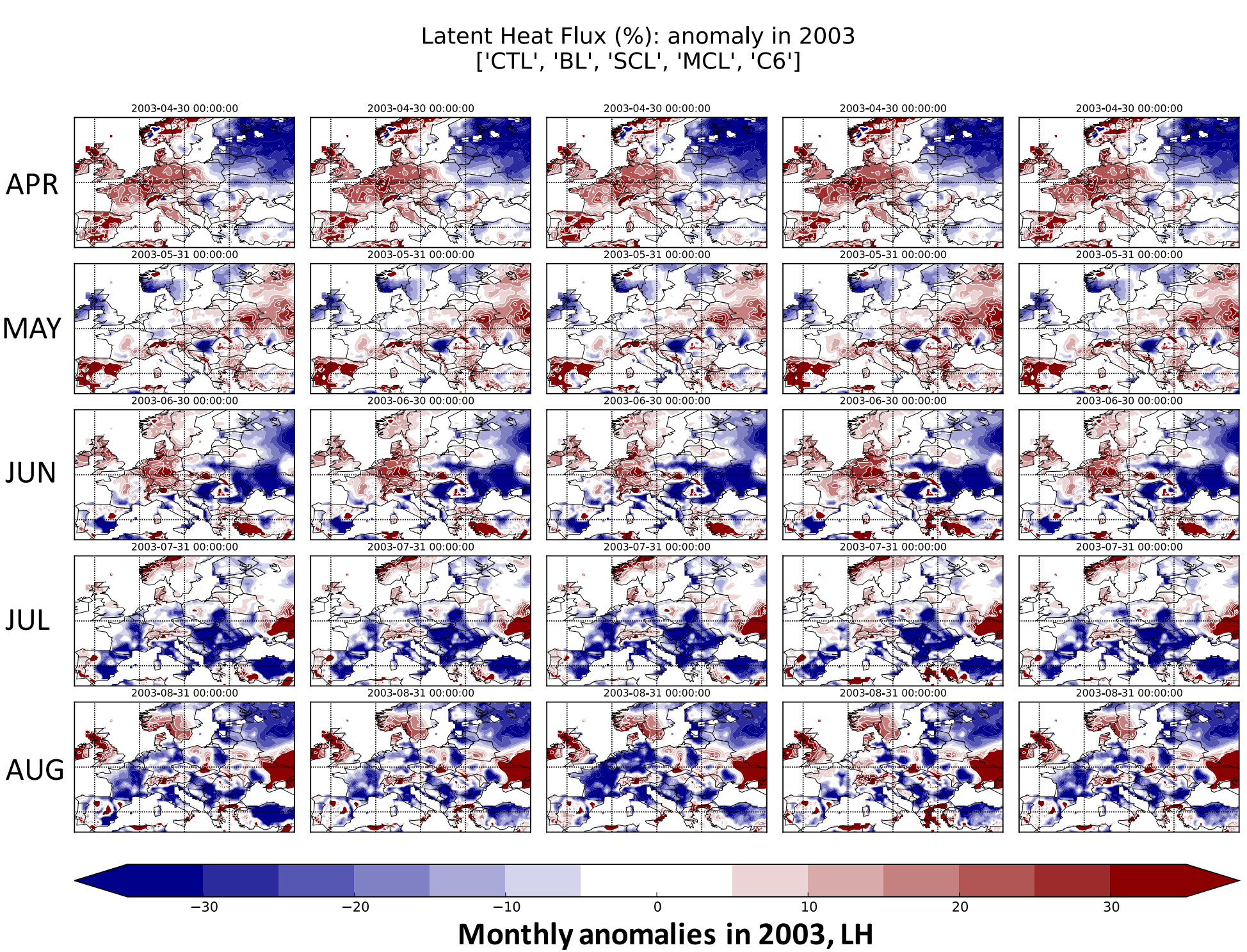


Difference in climatologies w.r.t BL (CTL): Beta (top), Transpiration Flux (bottom)



Difference in climatologies w.r.t BL (CTL): Surface Runoff (1E-8 kg/m^2/s) (top), Subsurface Runoff (1E-8 kg/m^2/s) (bottom)

RESPONSE TO THE 2003 HEAT WAVE


Latent Heat Flux (%): anomaly in 2003
['CTL', 'BL', 'SCL', 'MCL', 'C6']
2003-04-30 00:00:00
2003-05-31 00:00:00
2003-06-30 00:00:00
2003-07-31 00:00:00
2003-08-31 00:00:00
APR
MAY
JUN
JUL
AUG
−30
−20
−10
0
10
20
30
Monthly anomalies in 2003, LH