The reduction of systematic summertime warm biases in the soil-moisture limited regions of Southern Europe by stochastic root depth variation

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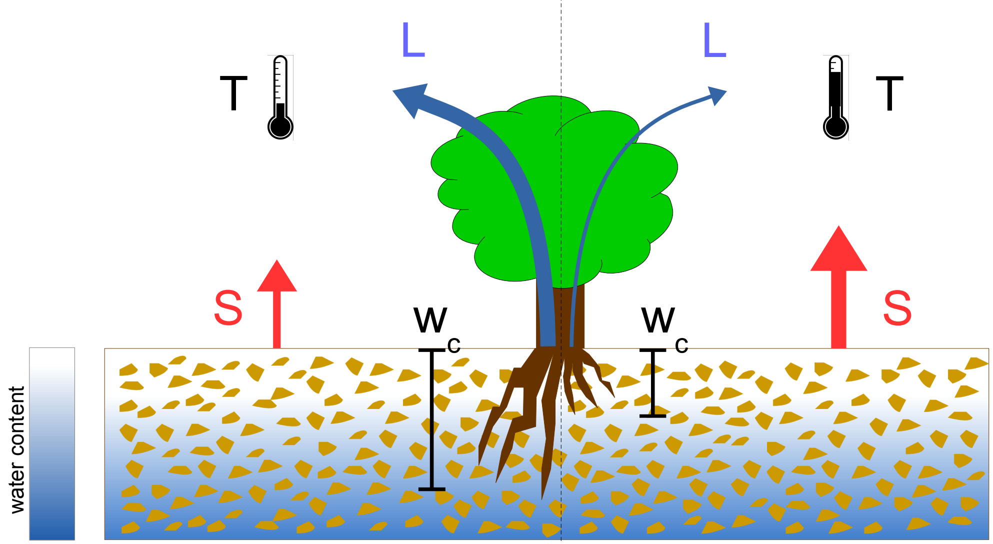
Motivation

- near-surface temperatures (T) depend on latent (L) and sensible (S) heat fluxes
- their intensity and ratio depends on the available soil water amount within the rooted soil depth (w_c)
- if w_c is large → L is large → S is small → T is low (left hand side of the figure)
- if w_c is small → L is small → S is large → T is high (right hand side of the figure)
- but w_c is associated to uncertainties
- e.g. root depths are unknown and vary on the sub-grid scale
  → turbulent heat fluxes are consequently spuriously simulated, resulting in systematic model biases (e.g. consistently simulated warm bias in South-Eastern Europe (JJA) in model intercomparison studies)

  → **stochastic root depth variation** is applied to break the deterministic model behavior and to account for these uncertainties



Stochastic root depth variation

- Stochastic variation of the root density profile in the Land Surface Model VEG3D, coupled to the Regional Climate Model COSMO-CLM in climate simulations for Europe (driven by ERA-Interim)
- The root density profile is perturbed by using uniformly distributed random numbers between -1 and 1
- For positive random numbers, the depth of the maximum root density is shifted downward, for negative numbers upward (see table below; the vegetation specific shape of the density distribution is preserved) → this root profile variation is within the observed root depth variability
- The root depth variation is performed each month (on midnight of the first day of the month to avoid sudden latent heat flux jumps and associated numerical problems)

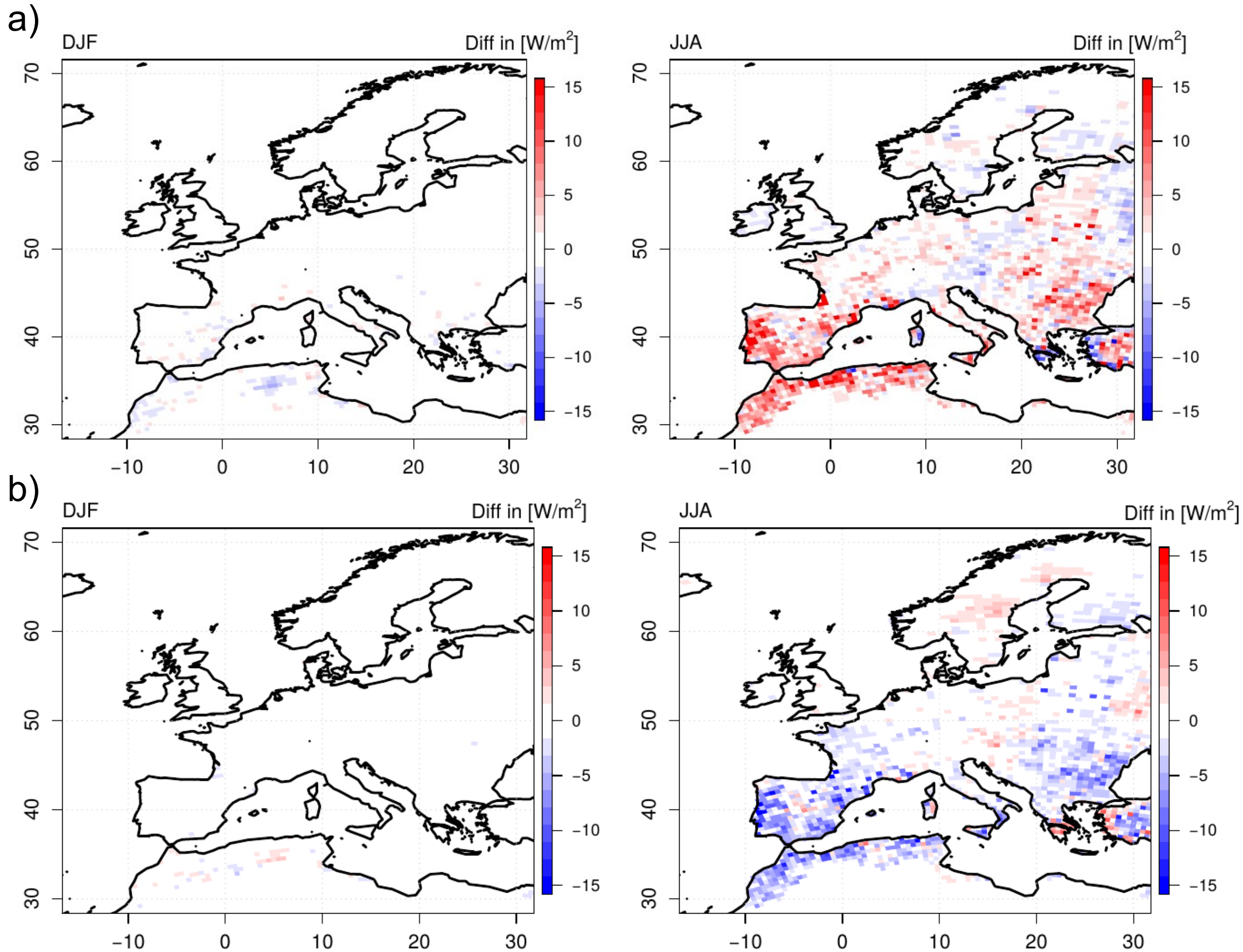
→ **in this way, the available soil water amount is increased for one half of the grid boxes and reduced for the other half**

→ the total evapotranspirative potential is preserved

Layer No.	Layer depth [m]	Root density [%] (ref)	Root density [%] (stoch-1.0)	Root density [%] (stoch1.0)
1	0.02	5.0	17.0	0.0
2	0.05	12.0	19.0	5.0
3	0.1	19.0	26.0	12.0
4	0.2	26.0	27.0	19.0
5	0.5	27.0	8.0	26.0
6	1.0	8.0	2.0	27.0
7	2.0	2.0	1.0	8.0
8	5.0	1.0	0.0	2.0
9	10.0	0.0	0.0	1.0
10	15.0	0.0	0.0	0.0

Results

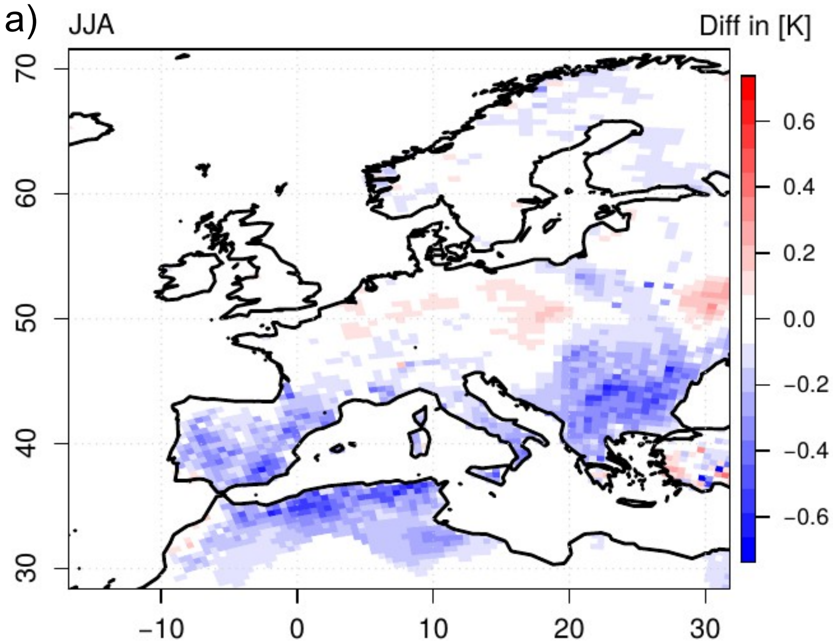
- In **winter**, almost **no differences** in latent and sensible heat fluxes occur between the the reference run and the stochastic simulation
- In **summer, latent heat fluxes are increased** and sensible heat fluxes are reduced in the whole **Mediterranean region** with stochastic modelling
- Random changes in turbulent heat fluxes occur in Central Europe

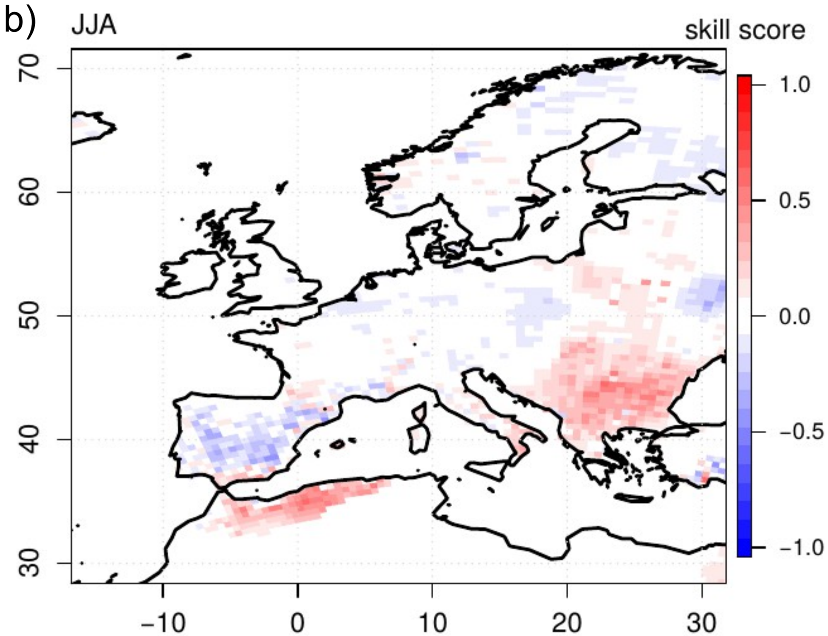


Differences in the simulated mean seasonal latent (a) and sensible (b) heat fluxes between the reference run and the stochastic run in winter and summer for the period 2001-2010

Results

- In **summer**, therefore, in the Mediterranean region the **2 m temperatures are reduced** in the stochastic simulation compared to the reference run (a)
- In **South-Eastern Europe**, these lower temperatures **reduce a systematic warm bias** in the reference run in this region, which is consistently simulated in several model intercomparison studies (added value in (b))
- But at the Iberian Peninsula, an additional cold bias is induced (no added value in (b))
- For the rest of Europe, stochastic modelling has no systematic effect on the near-surface temperatures





Differences in the simulated mean seasonal 2 m temperatures between the reference run and the stochastic run in summer for the period 2001-2010 (a). Added value of the stochastic run compared to the reference run in summer, calculated from a skill score which is based on the Mean Squared Error (b).

Discussion and Conclusions

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- A stochastic root depth variation is performed in regional climate simulations for Europe to account for the uncertainties in the available amount of soil water for evapotranspiration

- In winter, the stochastic perturbations do not affect the turbulent heat fluxes
- In summer, considerable difference occur between the stochastic simulation and the reference run in the whole Mediterranean region
  → latent heat fluxes are systematically increased

- In this region, evapotranspiration is soil-moisture limited in summer
  → a reduction of the evapotranspirative potential, as it takes place in one half of the grid boxes, does not further reduce the already limited evapotranspiration rates
  → but the increased evapotranspirative potential in the other half of the grid boxes leads to increased evapotranspiration rates
  → sensible heat fluxes and the near-surface temperatures are consequently reduced

- In regions in which the soil-moisture limitation is overestimated and a warm bias prevails, this **asymmetric effect of the stochastic root depth variation on evapotranspiration leads to a higher agreement with observations**.
  → added value in South-Eastern Europe
- In Central and Northern Europe, where evapotranspiration is not limited by the available soil water amount, a stochastic root depth variation has no systematic effects on the near-surface temperatures
  → **stochastic root depth modelling is therefore a tool to reduce systematic warm biases in soil-moisture limited regions without major negative side effects for the humid parts of Europe.**
  → But in regions in which the soil water supply is already realistically estimated, an increase in evapotranspiration introduces an additional cold biases (no added value for the Iberian Peninsula)