Referee 2 (Stefan Hagemann)

'The authors analysed the effect of using a climate dependent root zone storage capacity Sr instead of a vegetation type dependent Sr on simulated runoff and evaporation fluxes in Australia. They estimated this 'climate controlled' Sr with the "memory method" (MM) in which Sr is derived from the vegetation's memory of past root zone water storage deficits and introduced this into the HTESSEL land surface scheme. By using forcing from the GSWP-3 dataset, the new Sr led to improved seasonal climatologies (1975–2010) and inter-annual anomalies of river discharge over 15 selected small catchments while only a negligible impact on evaporation fluxes and long-term mean model biases was found. As the climate control on root development is not regarded by most of the existing land surface models (LSMs), this study is a valuable contribution on climate – hydrology interactions within the topic of Earth System Modelling. The paper is generally written well so that I suggest accepting the paper for publication after minor revisions have been conducted.'

We would like thank dr. Hagemann for the comments. We appreciate the time and effort taken to read our manuscript in detail and to provide us the very useful and interesting thoughts on our research. We will take the comments into account in revising the manuscript.

We have separated the different comments (shown in *italic*) and have written our replies below. Text in the original manuscript is shown in *'italic'* and revised text in '***bold***'. Wherever line numbers are mentioned in our reply they refer to the original manuscript version.

Comment 2.1

'My only major remark is that I miss a more thorough analysis on why the HTESSEL evaporation is rather insensitive to the changes in Sr. Opposite to the present study, the evaporation of other LSMs reacts usually more sensitive to water holding capacity changes. However, many climate models tend/tended to have LSMs with more shallow soils, and, hence lower Sr, so that in related studies, Sr was often increased. In the present study, CTR seem to have a rather large Sr, and there is a general reduction of Sr using the MM method. Does this has something to do with this insensitivity?'

Indeed, the limited sensitivity of evaporation to changes in soil depth can be partly explained by $S_{\mathrm{r,CTR}}$ being larger than $S_{\mathrm{r,MD}}$. We further elaborate on this in comment 2.2.

Comment 2.2

'In addition, the authors state that E is rather insensitive to changes in Sr because E depends on the relative soil moisture. It is well known that E is sensitive to soil moisture when soil moisture in the transitional regime between the wilting point soil moisture (dry regime if moisture is below) and a critical soil moisture above which evapotranspiration is occurring at its potential rate Epot (wet regime). In order to investigate this further I suggest considering in which catchments, the soil moisture is in the transitional regime, and whether the relative soil moisture changes due to the introduction of the new Sr. If, for example, a catchment is in the wet or dry regime for most of months, then E will not react to changes in Sr.'

Figure C3 shows modelled transpiration and soil moisture in the four separate soil layers in a tropical (a), temperate (b) and Mediterranean (c) catchment. In order to further explain the evaporation (in)sensitivity we will consider a wet period (mid 1990) and a dry period (start 1991) in the temperate catchment (Fig. C3b).

During the wet periods soil moisture in the upper three layers is above or close to θ_{cap} and little differences are observed between CTR and MD. However, in layer 4, MD soil moisture is larger than CTR soil moisture. In this case evaporation is not moisture limited and is controlled by the top three layers because of the larger root distribution in these layers (eq. 14 and 15). Therefore, the modelled transpiration is not sensitive to the increase in layer 4 soil moisture in MD.

During the transition from a wet to a dry period, the upper three layers dry out first, as there is a reduction in precipitation input. As these layers are dry, evaporation is controlled by the fourth layer. Layer 4 soil moisture in MD also reduces to values close to θ_{pwp}, while in CTR layer 4 remains wet. This difference causes the sensitivity of transpiration in MD during this wet to dry transition.

Most of the time the modelled soil moisture is in the wet and insensitive regime, and, therefore, the overall effects of MD on modelled evaporation are small.

We will add this explanation and Figure C3 to the revised manuscript in the discussion 4.1.

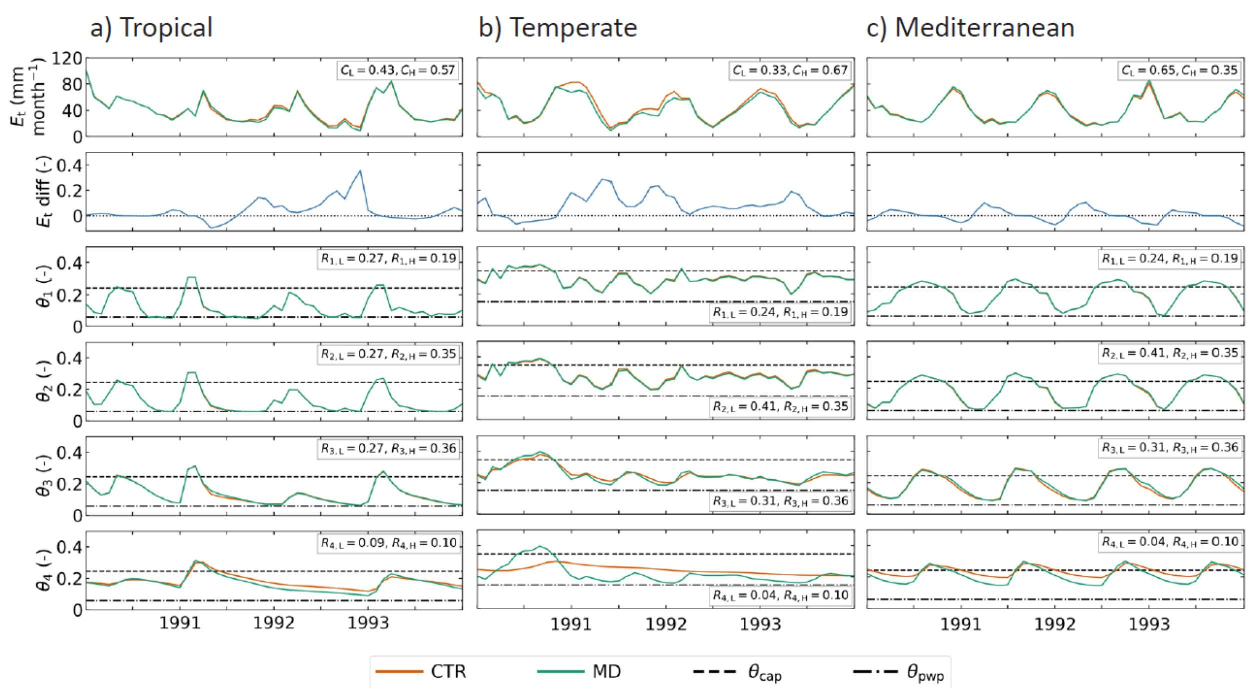

Figure C3 (new Figure 8). *Modelled transpiration and soil moisture with CTR and MD models in a (a) tropical (Mi), (b) temperate (Na) and (c) Mediterranean (K) catchment. From top to bottom: transpiration, relative difference between CTR and MD transpiration* $\left(\frac{E_{t,CTR}-E_{t,MD}}{E_{t,CTR}}\right)$*, soil moisture layer 1, soil moisture layer 2, soil moisture layer 3, soil moisture layer 4. Additionally, the vegetation coverage (*C_L *and* C_H*) and the relative rooting distribution (*R_k*) for the dominant high and low vegetation types are presented.*

Minor remark

Comment 2.3

'p. 1 - line 17

… long-term annual mean river discharge are …'

Ok, we will change this line.

Comment 2.4

'p. 7 - line 146 It is written:

… long-term mean transpiration derived from the water balance (E_t = P_e −Q) …

The evapotranspiration at the land surface (without the canopy, such as in your balance equation) comprises also evaporation of snow and evaporation over bare soil. While the first may not play a role over Australia, the latter certainly does as I do not expect that all catchments are completely covered by vegetation so that bare soil fraction equals Zero. Please elaborate on this issue in more detail.'

The transpiration flux (E_t) considered here includes both transpiration and soil evaporation. We can defend this linguistic inexactness since E_soil << E_t, especially during dry periods where the soil deficits are largest and determinant thus of S_r. To illustrate this: soil evaporation only occurs over the top few cm of the soil (in HTESSEL only top layer of 7 cm and ranging from top 4 cm – top 15 cm soil depending on soil characteristics as found in Wythers et al. (1999)). Considering top 7 cm of soil active for soil evaporation, this translates into an S_r of 70 mm * 0.2 (approximation of plant available water) → 14 mm. This is an order of magnitude smaller than the S_r estimates from the memory method which are on average 333 mm.

We will change line 146 as follows:

'…long-term mean transpiration derived from the water balance ($E_t = P_e - Q$) and E_p (mm year^{-1}) the long-term mean potential evaporation. ***E_t considered here includes both transpiration and soil evaporation, but as E_{soil} << E_t, we use the term transpiration for simplicity.'***

Reference: *Wythers, K.R., Lauenroth, W.K. and Paruelo, J.M. (1999), Bare-Soil Evaporation Under Semiarid Field Conditions. Soil Sci. Soc. Am. J., 63: 1341-1349.* https://doi.org/10.2136/sssaj1999.6351341x

Comment 2.5

'p. 10 - line 198 It is written:

Total discharge (Q) is the sum of Q_s and Q_{sb} (Eq. 13).

Do you consider lateral flow within the catchment and the respective delay due to lateral transport? Or are the catchments small enough so that this delay is negligible. Please comment!'

We do not consider lateral flow within the catchment and the respective delay due to lateral transport. Our analysis is based on monthly fluxes, and routing at this timescale becomes negligible for the size of our catchments. To illustrate this: for a catchment size of 2500 km^2 (50 km x 50 km) and a 1 m/s (= 86.4 km/day) flow, the water will flow through the entire catchment within approximately 1 day, so we can neglect routing at monthly time scales.

We will change line 198 as follows:

'Total discharge (Q) is the sum of Qs and Qsb (Eq. 13) ***and typical travel times through the catchments are about 1 day at most, we did not consider routing to be important at the monthly time scale for which we analyze the results.'***

Comment 2.6

'p. 10 - line 217

… would cause the model …'

Ok, we will change this line.

Comment 2.7

'p. 11 - line 221 It is written:

It should be noted that the layer depths for thermal diffusion calculations are not modified in the MD model.

Do you assume bedrock (i.e. zero moisture) below the root zone for the thermal calculation if z4 is reduced for water? What do you do? How does this affect your simulation?'

HTESSEL defines depth parameters for moisture calculations and for thermal calculations separately. The layer depths for thermal diffusion calculations are kept constant in CTR and MD, but layer depths for moisture calculations are modified in MD. We assume zero moisture below the root zone for thermal calculations if z4 is reduced for water. The thermal calculations only interact with soil moisture calculations by the relative soil moisture content in a layer. Therefore, the depth change does not directly affect thermal calculations. We found insensitivity of the soil layer temperatures to depth changes in MD.

We will change line 221 as follows:

'… are not modified in the MD model **and that the soil layer temperatures are insensitive to depth changes in MD.**'

Comment 2.8

‘p. 13 - line 281

… affected as shown in …’

Ok, we will change this line.

Comment 2.9

‘p. 17 - line 324-325

… related to the applied methodology which will be further discussed in Section 4.2.

As Section 4.2 is about ‘Methodological uncertainty’, I assume you point to Sect. 4.2, and not 4.3 as written in the manuscript?!’

Yes, we will change this.

Comment 2.10

‘p. 19 - line 379-380

…is only a function …’

Ok, we will change this line.

Comment 2.11

‘p. 19 - line 385 It is written:

$S_{r,CTR}$ was found to be considerably larger than the climate controlled estimate S_r …

How do these values compare to those of other LSMs? This comment is also related to my major remark.’

It is expected that our $S_{\mathrm{r,MM}}$ estimates relate differently to S_{r} values in other LSMs. This paper focuses on the case of HTESSEL and analyzing other LSMs was out of scope. We will change line 385 as follows:

'… $S_{\mathrm{r,CTR}}$ was found to be considerably larger than the climate controlled estimate $S_{\mathrm{r,MM}}$ in 14 out of 15 catchments. ***These findings could be different for other LSMs when they have more shallow soil depths****.’*

Comment 2.12

‘p. 19 - line 403-404 It is written:

On the other hand, surface and subsurface runoff depend on the cumulative moisture content of the soil at any given time.

What do you mean with “cumulative” content? Looking at Figure 4, I assume that both depend on the moisture content above a certain threshold. Please clarify!’

With cumulative content, we mean the total, absolute moisture content of the soil, which is equal to the relative soil moisture multiplied with the soil depth. Changing the depth of the modelled soil therefore more strongly affects the quantity of surface and subsurface runoff fluxes.

We will change line 403-404 as follows:

*‘On the other hand, surface and subsurface runoff depend on the **total** moisture content of the soil at any given time.’*