

We would like to thank H.M. Jones for his interest in this topic and for the comments to improve our manuscript. Based on the comments some calculations have been performed. Our point-by-point response to the comments is given in the following (**Comments in black, Answers in blue** and **the content related to the changes in the revised manuscript are marked in orange.**):

**1. After reading the manuscript, I do not think the results can support the research objective. First, the WAYS is calibrated and the runoff simulation is compared with others after that. Therefore, the better performance of WAYS (let's assume it is better first, and actually I do not think so) could be due to the calibration, not because of the consideration of root zone water storage changes. Second, the NDII data were used as a surrogate of root zone water storage changes. The NDII is just suggested in a river basin in Thailand. However, it is still not clear if it is appropriate to do so on large scales with different climate and hydrological regimes. Therefore, the simulated root zone water storage is not actually verified.**

Thank you. In fact, the simulated runoff of WAYS is first compared to the reference data ERA-Interim/Land runoff. The performance of WAYS in runoff simulation is evaluated based on the comparison between ERA-Interim/Land data and WAYS simulation. Since WAYS uses the same driving data as the ISIMIP2a models and the ISIMIP2a simulations are widely discussed in many studies, an additional comparison between WAYS and the ISIMIP2a models can provide added-value for evaluating our model. Therefore, the ISIMIP2a simulations are also shown in the results section together with the ERA-Interim/Land data.

Moreover, to investigate the impacts of RZSC on model simulation, we have additionally conducted the simulation of WAYS with the root zone storage capacity derived from uncertain root depth and soil data. The simulated results are then compared with the two runs, i.e., one with RZSC from Wang-Erlandsson (2016) and the other with uncertain RZSC. The uncertain RZSC ( $S_{R,UNCERTAIN}$ ) is derived based on the literature values of root depth and soil texture data (Müller Schmied et al. 2014; Wang-Erlandsson et al. 2016). For details of related changes, we refer to the response to the comments of Referee #2 (comment 5) to avoid repetition, as the response is long. The corresponding revision in the manuscript can also be found there.

We agree with the reviewer that the NDII is just investigated in a river basin in Thailand, thus the evaluation could weaken the conclusions. Thus, additional evaluations covering large areas have been conducted to further strengthen conclusions. Since this comment shares the similar opinion with Referee #3 (comment 5), we would like to refer to the responses to the comments of referee #3 to avoid repetition, as the response is long. The corresponding revision to the manuscript can also be found there.

**2. I also feel it is not rigorous that without in situ hydrological gauge and flux tower data to verify simulations of ET, runoff, soil moisture etc. Comparison with ISIMIP model runoff simulation is not convincing. The spatial distribution of simulation is also important. Please show the spatial distribution.**

Thank you. In the revised manuscript, we have substantially improved the model evaluation by conducting additional simulations, validations and comparisons, following the comments by reviewers and the short comments. In brief, we have compared the discharge with GRDC observations and evaluated evaporation simulation against FLUXNET2015 and LandFluxEVAL data. Please refer to our responses to comments 2 and 5 of Reviewer 3 for details.

Regarding the comment on comparing our model simulation with soil moisture, we have stated in the manuscript (page 2, line 16: However, all these studies estimated the root zone soil moisture up to a certain depth, e.g., 100 cm, thus still retaining drawbacks to the accurate calculation of the water stored in the entire root zone layer. Since the root depth is location-dependent and could reach a depth of more than 30 meters (Fan et al. 2017).). The soil moisture in the top 100 cm cannot reflect the water content in the entire root zone layer. Evaluating the model performance against soil moisture would not necessarily contribute to improving the model robustness. Therefore, we did not verify the model with the soil moisture.

**3. As shown in Figure 1 and the manuscript descriptions, the soil layer is separated into vadose zone (includes the root zone) and saturated zone, which is similar to many existing models. In addition, in this manuscript, the NDII is not justified to represent root zone water storage changes on large scales with different climate and hydrological regimes. Therefore, the novelty of this manuscript is not enough.**

Thank you. We agree with the reviewer that NDII is not justified to represent root zone water storage changes on large scales, which could weaken the conclusions. Referee #3 shares a similar opinion in his comments. We have addressed this issue in detail in the response to the comments of Referee #3 (comment 5). The corresponding revision in the manuscript can also be found there.

**4. Because the soil is separated into different zones, at every grid, each zone must have a certain depth (or a percentage value) at a moment and the depth or percentage will change with rainfall-runoff processes. The manuscript failed to report the changes of the depth of each zone or what percentage of soil is saturated/unsaturated at different time. Please also show the spatial distribution. This is important to see if the simulation is reasonable.**

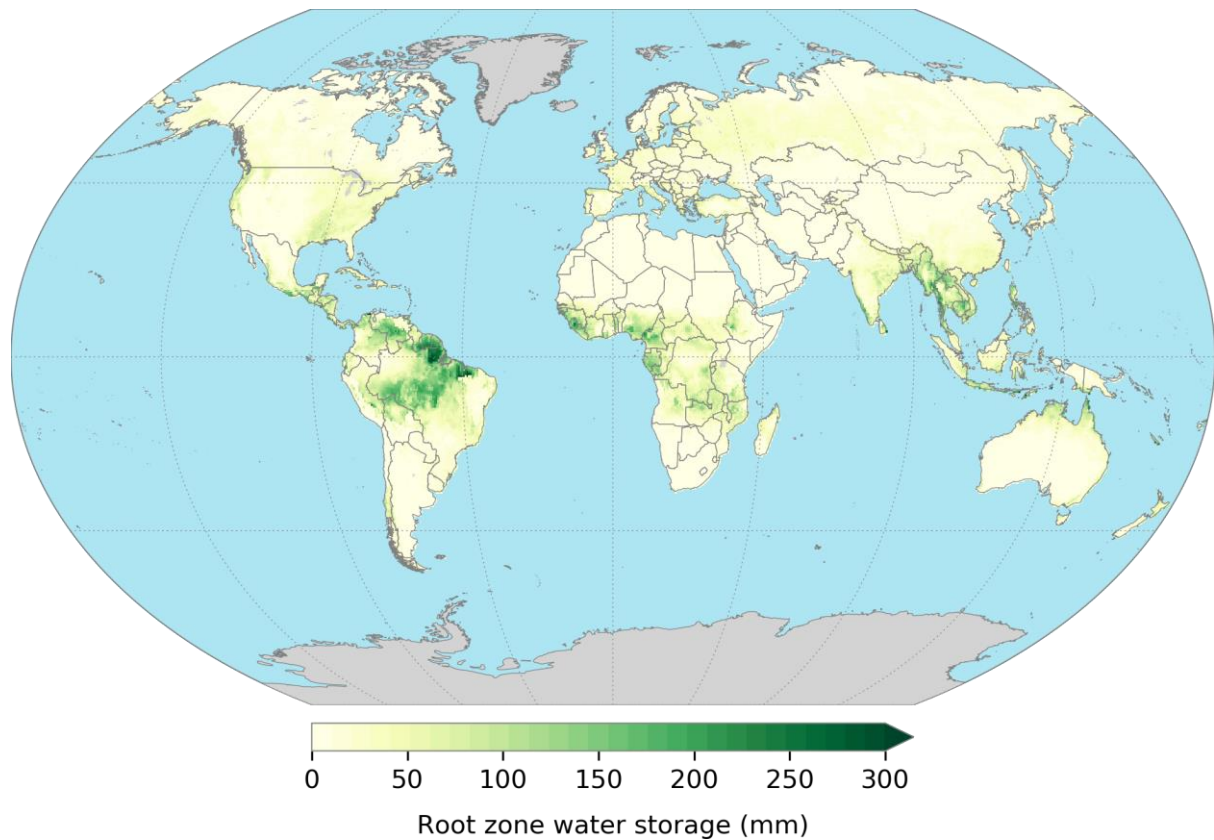
Thank you. One of the motivations of our work is to simulate root zone water storage on a global scale, without constraining the quantification to a certain depth. In fact, RZWS is simulated in terms of the water equivalent depth. Based on the comment, we have analyzed the spatial pattern of the simulated RZWS as well as the dynamics of RZWS in different latitudes in different months. Due to the length of the manuscript, this information has been included in Supplementary Information (SI).

**The following part is put in the SI.**

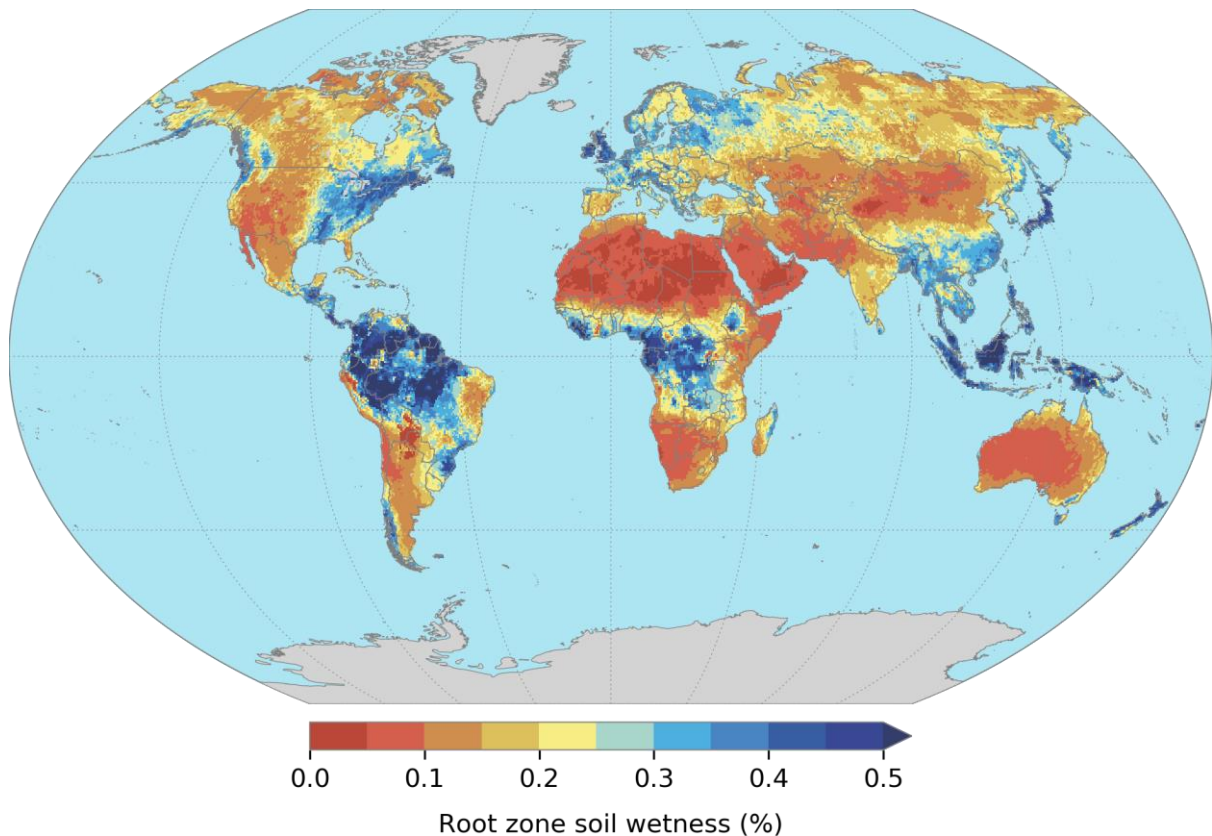
Figure S1 shows the spatial distribution of the annual averaged RZWS simulated by WAYS in the 1971-2010 period. It shows that RZWS is high in low-middle latitudes, while RZWS in

middle-high regions is relatively low. RZWS represents the water content that is stored in the root zone as well as the available water for plants. Therefore, for lower or middle latitudes, the available water for plants is relative higher than for high-latitude areas.

To further investigate the soil water condition, we have calculated the root zone soil wetness by dividing RZWS by RZSC, and the results are shown in Figure S2. The root zone soil wetness follows the spatial patterns of RZWS in general. However, differences can also be found in regions such as Europe, South America and the eastern part of North America.



*Figure S1. The spatial distribution of the annual averaged RZWS simulated by WAYS in the 1971-2010 period.*



*Figure S2. The spatial distribution of the annual averaged root zone soil wetness in the 1971-2010 period.*

The simulated RZWS is shown in Figure S3 to reveal dynamics in different latitudes and in different months. The latitudinal averaged RZWS again confirms that the RZWS are relatively plentiful compared with the high latitudes. However, a decreasing trend can also be found by moving from a low latitude to the equator. Two simulations of the WAYS model show similar fluctuation along the latitudes, while the simulation with  $S_{R,CHIRPS}$  is slightly higher. Figure S3 shows that RZWS in low-middle latitudes has a larger monthly variation than in other regions, while the Northern Hemisphere and Southern Hemisphere show opposite changing trends. In the low latitudes in Northern Hemisphere, the RZWS peak occurs in May-June and the off-peak in October-November. In the Southern Hemisphere, the RZWS off-peak occurs in May-June and the peak in October-November.

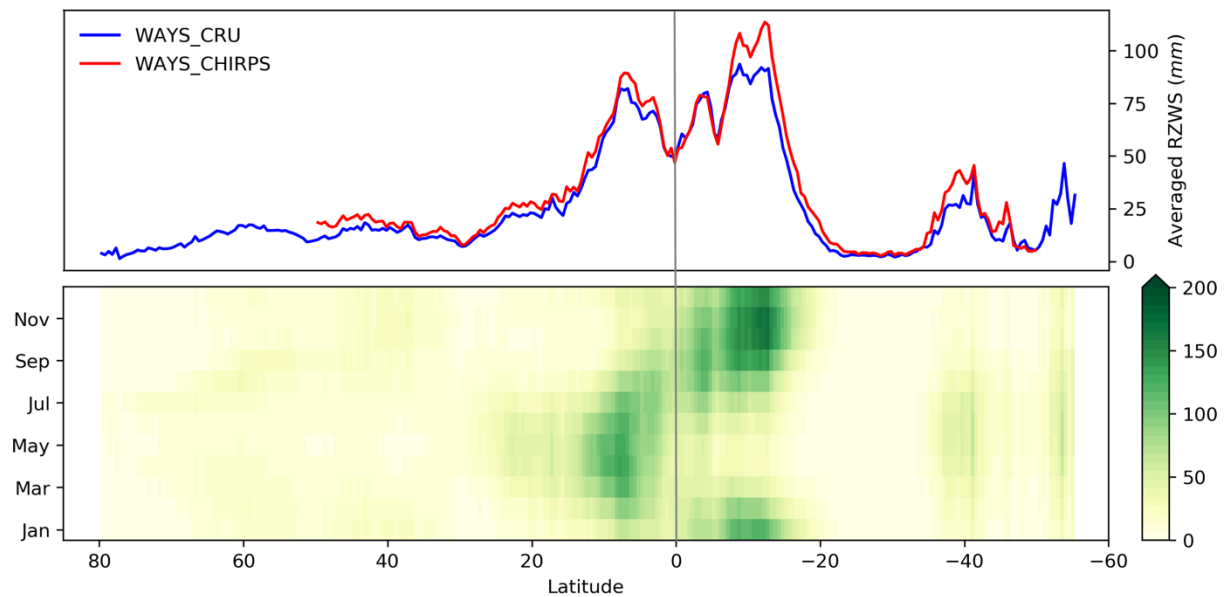


Figure S3. The dynamics of the simulated RZWS for different latitudes in different months.

**5. I don't think the WAYS is a new hydrological model because it only changed several equations and replaced a few parameters compared to the FLEX model. It is not an improvement of the FLEX model either, because it removed several important components of the original FLEX model and the manuscript failed to prove that the WAYS is better compared to FLEX after doing that.**

Thank you. In this work, we have extended a widely used lumped model, FLEX, into a distributed model that can be applied on a global scale. In addition, a climate-derived root zone storage capacity (RZSC) is integrated into WAYS to capture the spatial heterogeneity of the rooting systems. We have demonstrated the benefits of a climate-derived RZSC to the hydrological model for simulation, especially the capacity of root zone water storage (RZWS) simulation.

In fact, we did not remove any important components from the original FLEX model. Only the capillary module is disabled due to the lack of global information on the groundwater table. A detailed explanation can be found in the responses to the comments of Referee #1 (comment 6) and Referee #3 (comment 2). The corresponding revision in the manuscript can also be found there.

**6. When I saw the root zone water storage, I thought the manuscript would study vegetation. However, I did not find how they deal with vegetation transpiration. Because root zone water storage changes are largely controlled by vegetation transpiration, I don't believe the WAYS can simulate root zone water storage changes properly without considering vegetation transpiration. I share the similar concerns as other reviewers that WAYS has fatal flaws regarding this. In addition, WAYS means 'Water And ecosYstem Simulator' according to the manuscript. Without considering vegetation transpiration, WAYS cannot represent ecosystem and cannot simulate ecosystem influence on water**

**either. Thus, I believe that the manuscript title, the statement in the manuscript, and the model name are misleading and not suitable.**

Thank you. Like most of the conceptual models, WAYS considers the vegetation transpiration. It simulates the total evaporation, which consists of interception, soil evaporation and transpiration. A detailed list of all the model equations is shown in Table 1 in the manuscript. WAYS simulates the water stored in the root zone, which is a critical variable connecting the hydrology and ecology. Thus, the extension name of WAYS, i.e., 'Water And ecosYstem Simulator', will not mislead readers.

**7. The manuscript failed to report how many parameters the model has, which parameters need to be calibrated, what are the calibrated parameter values, which parameters use default values. The physical meanings of the parameters should be reported. Some parameters have their physical meanings and cannot be calibrated.**

Thank you for the comment. This comment shares the same opinion with comment 2 of Referee #1, to which a detailed interpretation and response to the comment can be found. The corresponding revision in the manuscript can also be found there.

**In sum, I am not convinced by the methodology and results, and several key issues of the study objective are not solved. I feel that this manuscript should be rejected.**

We have further improved our manuscript based on all the comments from referees and the short commenters. We believe that the manuscript has now been greatly improved.

**All the references are included in the manuscript.**