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Reply on RC1

Jolanda J. E. Theeuwen et al.

Author comment on "Local moisture recycling across the globe" by Jolanda J. E. Theeuwen et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-612-AC3, 2022

Dear reviewer,

Thank you for your time and for reviewing our manuscript: 'Local moisture recycling across the globe'. We appreciate your feedback, which is very helpful to improve our manuscript. Below we respond to each major point of feedback separately to discuss how we will implement them. The minor comments will be addressed when we get the opportunity to revise our manuscript.

- **Novelty**

The manuscript repeatedly claims that local moisture recycling ratios are calculated "for the first time" (l. 9) and that "it is unknown which fraction of moisture recycles within its source location, and how this recycling varies across the globe" (l. 22-23). However, this is not the first study to do exactly this: Van der Ent et al. (2010) and Van der Ent & Savenjie (2011) already featured such local evaporation recycling ratios and calculated them globally. Furthermore, 'evaporationsheds' (see e.g. Van der Ent & Savenije, 2013) contain the exact same information and papers and data sets have been published on this, see e.g. Link et al. (2020).

Unfortunately, I also cannot consider the approach, or the objective referred to in the discussion novel: the perspective on understanding the potential influence of land cover, and land- and water management practices via moisture recycling is not new either. Keys et al. (2016), for example, describe this in the context of 'ecosystem services' or 'water security' (Keys et al. 2020) - to name just a few examples. And this is also the subject of all 'green water' studies (e.g., te Wierik et al., 2021; te Wierik et al. 2020).

We thank the reviewer for explaining why they believe our manuscript is not as novel as stated in the manuscript. Considering that the comment posted by Dr. Ruud van der Ent, the review posted by Dr. Patrick Keys and your review all include this point of feedback, we see the importance of improving on this point. Therefore, we will better acknowledge all relevant previous studies, for example the studies mentioned by the reviewer. Following this we will be better capable of highlighting the differences between our work and the previous work as we do believe there are important new steps being made in our paper. Namely, first, we study the effect of its spatial scale on local moisture recycling. of our definition of local, i.e., the area within which the moisture recycles, and second, we assess potential drivers of local moisture recycling. Besides, the datasets that were used to calculate local recycling in previous studies differ from the dataset used in our study. To obtain these datasets different models were used and the forcing data of these models has a different spatial resolution. We will mention this in our introduction and come back to it in our discussion in more detail by comparing it to the earlier work done by Van der Ent and Savenije (2011). Furthermore, we will highlight how our work compares but also deviates to the work done related to 'ecosystem services', 'water security' and 'green water' studies, to which the reviewer refers Those studies have a focus on source-sink relations in which the sink, apart from the source region, includes also remote locations. In contrast, our work aims to quantify and better understand local recycling. In contrast our work focusses on to quantify and better understand local recycling. The main reason is that previous research on atmospheric moisture connections mainly focusses on non-local water management even though research shows regreening can cause local drying. This suggests the relevance of studying the impact of land cover changes on the local water cycle. Local moisture recycling can help us here. Even though Van der Ent and Savenije (2011) calculated a similar type of recycling the link with preventing local drying has not been made yet, which we believe could be highly valuable. In addition, the spatial scale of 0.5 degrees allows better to study local impacts than the scale of 1.5 degrees. We are thankful for this comment as it helps us to specify the novelty of our manuscript better. We will do this by better acknowledging relevant previous studies.

- **Moisture recycling drivers**

I do, however, like the idea of looking at the drivers of moisture recycling; but the current analysis of the drivers is rather simple. In particular, I am a bit hesitant about the variables used to unravel the drivers of LMR, and the methodology used to do so. First of all, while I understand that there is a latitudinal dependence of moisture recycling, I wonder if 'latitude' is the real driver here. Shouldn't it rather be wind, incoming solar radiation and maybe even the underlying area of a grid cell (that differs with latitude)? Similarly, is it fair to use 'evaporation' and 'precipitation' as drivers of LMR? Isn't LMR defined based on these two fluxes? Of course, there is a dependency on both fluxes then... Second, calculating (globally averaged?) Spearman correlations to unravel drivers of LMR is a cheap way of doing this. LMR and any variable in Tab. 1 may be correlated through a third variable that represents the 'true' driver. Or in other words: a correlation does not imply causality.

We are happy that the reviewer likes the aim to understand the drivers of local moisture recycling but also understand that the reviewer likes to see more regional (latitudinal) tests that can potentially provide more understanding. In our study we aimed to identify non-linear relations between two variables as most processes cannot be properly described using linear relations and therefore, we used Spearman rank correlations. However, of course we agree that correlation does not imply causality and we will clarify this in the discussion of our manuscript. Moreover, we will use literature to discuss our findings from a mechanistic point of view (see also reviewer Keys). Furthermore, we agree that latitude is not the actual driver of moisture recycling, but that other variables, that correlate with latitude, drive local recycling. As such, we included latitude as a proxy for a combination of processes that have a strong latitudinal pattern. This was not properly described in our manuscript and therefore, we will clarify this in our revision.

Further we will also add more drivers to study the correlation between local moisture recycling and other potential drivers of local moisture recycling, such as solar radiation as suggested by the reviewer. We will not move to multiple regression models, as also clearly indicated by the reviewer it is true that many drivers themselves are correlated to each other. Therefore, we will keep the Spearman rank correlation test per driver. In addition, we plan to split the data in classes based on latitude to account and can then better understand how drivers can change per latitude class which can help to understand the causality. We believe adding more variables to our analysis will improve the understanding of the drivers of local moisture recycling and we are thankful for this comment.

- **Issues of scale**

The definition of what is considered 'local' is rather random. The authors claim that the LMR is based on approx. 50km around the source; however, they also illustrate different definitions of this scale parameter, i.e. 1 grid cell, 9 grid cells and 25 grid cells. The argument for chosing 9 grid cells is rather vague: "To keep the spatial scale as small as possible but to still have a spatial pattern that we can explain physically" (l. 88-89). Could the authors explain why other patterns cannot be explained physically? Is there some lower limit to what the forcing and/or the model can represent? If so, could this limit be determined in a reasonable manner?

We thank the reviewer for pointing out the unclarity concerning the spatial scale of local moisture recycling. We agree that the definition is partly arbitrary. We will mention this in our manuscript. Concerning the decision to use recycling over 9 grid cells, local recycling within one grid cell results in exceptionally low values over mountain peaks, yet not over all elevated terrain and relatively high values over the ocean. This pattern is inconsistent with the result found for recycling within 9 and 25 grid cells. The patterns for recycling over 9 and 25 grid cells can be explained as high values over mountains can result from convection as a result of orographic lift and relatively low values over ocean can be explained by the large atmospheric moisture transport due to strong winds. Possibly a numerical process is in place for the recycling within one grid cell, causing the pattern to be different from recycling over 9 and 25 grid cells. As the pattern of the latter two definitions are similar and agree with our understanding we decided to define local moisture recycling as the recycling over evaporated moisture within its source grid cell and its 8 surrounding grid cells. We will clarify this part in our results section. Furthermore, we will rephrase the sentence in which we state we cannot "physically" explain the pattern of recycling within one grid cell. We will omit the word physically and state we cannot fully explain the pattern of recycling within one grid cell. We believe these adjustments will clarify our decision and we thank the reviewer for pointing this out.

Some suggestions

To make this a novel and interesting contribution in the field of moisture recycling, a bit more effort may be needed. The authors could, for example, compare their evaporation recycling ratios to the ones from Link et al. - I assume that much more could be learned from the difference of these data sets. Alternatively, the 'true' drivers of moisture recycling could be assessed, using a more sophisticated method to do so. Or the issue of scale and what can be considered local, given the spatio-temporal resolution of the forcing, could be put into focus... these are, however, just some suggestions that I could envision and that would make this paper novel and interesting to me. The authors do not need to follow those.

We agree with these suggestions. As described before we will conduct more analyses by studying the relation between local moisture recycling and more potential drivers (e.g., solar radiation and other aspects of the energy balance). In addition, we will classify our data based and for each latitudinal class and conduct a spearman rank correlation analysis separately. Furthermore, we will compare our results to the dataset by Link et al. (2020). This means we need to upscale our findings to the 1.5 degrees resolution to match the dataset from Link et al (2020) to the dataset by Tuinenburg et al. (2020). This will give some insight into potential differences due to different use of models and simulated time periods, independent to the resolution used.

We would like to thank the reviewer for their constructive feedback as it is valuable for improving our manuscript. As mentioned before, in a future response will address the minor points of the reviewer.

On behalf of all authors,

Jolanda Theeuwen

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