Response to RC1: Review of "Using observed river flow data to improve the hydrological functioning of the JULES land surface model (vn4.3) used for regional coupled modelling in Great Britain (UKC2)" by Martínez-de la Torre et al. (2018)

Summary

This manuscript presents simulation results from the Joint UK Land Environment Simulator (JULES) applied to 13 selected catchments in Great Britain. The authors compared observed and simulated streamflow discharge in these catchments. The objective is to analyse the differences between observed and simulated discharge and improve the prediction skill of JULES. A new topographic parameterisation has been proposed that can improve JULES' capability of reproducing daily observed discharge. Overall, the manuscript presents useful research that is of interest to the readers of GMD. However, there are some issues, which deserve attention before publication.

Major issues

1) The major weakness of this manuscript is its introduction. There are several issues related to the presentation style of the research in the introduction section.

- The last sentence of the first paragraph reads "In this paper we present the methods of evaluation for the runoff generation and how we have improved the selection of hydrological parameters for Great Britain in order to allow use of JULES within the coupled system." Without mentioning the related works and convincing the readers about the usefulness of the study (in relation to the knowledge gap in previous research efforts), this first paragraph already summarises the research. This structure of the introduction is not particularly interesting. Also note that there are two textual errors in this sentence (i.e., missing comma after paper and missing definite article before use). This manuscript requires proof-reading to improve grammar.

Authors:

We have modified the first paragraph of the introduction, adding a narrative of previous studies and noting the usefulness of the work to be presented in rest of the paper:

" The land surface provides a two-way link between terrestrial hydrology and meteorology. Improving the representation of runoff generation in models of the land surface which are coupled to the atmosphere and oceans, could potentially improve meteorological forecasts as well as hydrological predictions. For the UK, a fully coupled (land, atmosphere, ocean) environmental prediction system is being built at 1.5 km^2 spatial resolution (UKC2; Lewis et al., 2018). The land surface component of this coupled system is the Joint UK Land Environment Simulator (JULES) model. In this paper, we focus on the runoff generation process. Conceivably improved runoff to the sea surrounding the UK influencing sea surface salinity could influence meteorological forecasts in the UK.

Different stages of the development of the JULES capability for this process have been published (Best et al., 2011; Blyth, 2002; Clark and Gedney, 2008), and analysis of runoff outputs has been carried out at the site level (Blyth, 2002; Blyth et al., 2011; Weedon et al., 2015), for a set of Rhône subcatchments treated as single grid cells (Clark and Gedney, 2008) and at the global scale with JULES simulations at 0.5° or 1° (Blyth et al., 2011; Gudmundsson et al., 2012; Papadimitriou et al., 2016; 2017). However, a regional scale analysis of the process at ~1 km2 spatial resolution was needed in order to implement an appropriate JULES hydrological parameterization for the coupled system within UKC2. "

- The second paragraph summarises the runoff generation mechanisms in JULES. The third paragraph starts like this "The island of Great Britain represents an ideal platform to tackle the runoff generation in LSMs as it presents diverse climatic …". This sentence gives the reader an impression that JULES has some issues in generating runoff, which is tackled in this research. What are these issues? I did not find them in the previous paragraph. The authors should make these issues clear before this sentence.

Authors:
We agree that the implications of the word "tackle" are not explained before this point. We have changed the word to "study", which we feel is valid and brings across the point we are trying to make in this instance. The details/issues/shortcomings of the runoff generation in the model are explained on the rest of the paper.

- The introduction is also confusing because the usefulness of the study is not apparent from it. One sentence like "However, a LSM widely used in the research community like JULES needs physically-based parameters that produce sensible results at the regional and global scale, independently of the region studied (i.e. avoiding local calibration)." does not suffice. The authors should make the innovation and usefulness of the study very clear in relation to previous studies. Again, note an incorrect article before LSM.

Authors:
With the modification of the first paragraph the issue of regional application at km-scale resolution was introduced to indicate its requirement for the study. The narrative in this third paragraph (now fourth in the revised text) seeks to present the regional climate and physical characteristics of Great Britain, how hydrological models typically use catchment parameters calibration and why, in terms of methodology, an LSM like JULES needs physically-based parameterizations that are valid for different regions and scales.
We corrected the "a LSM widely used" instance to: "a widely used LSM". Thanks

- The last paragraph states the workflow of the manuscript. "Then, based on those catchment results, we present a simple model development that introduces a topography dependency in a parameter, reaching the best results for the region and avoiding catchment calibration." Which parameter? Best results of what? "Finally the implications of the new approach are investigated further using a cross-spectral analysis of performance against observations at time scales exceeding a day." How does the cross-spectral analysis fit to the objective of the study? (Note a missing comma after finally).

Authors:
Yes, this paragraph was a bit vague. We have clarified the points made by the reviewer with some additions as follows:
"In this work we perform, firstly, a sensitivity study of alternative runoff production schemes and parameters to identify the best representation of observed daily river flow at a range of selected catchments in Great Britain. Then, based on those catchment results, we present a novel model development that introduces a topography dependency in the parameters that determines the soil wetness at which a gridcell starts generating saturation excess runoff in relation to the subgrid saturation fraction. The development optimizes the generation of daily river flow compared to observations and avoids catchment calibration. Finally, as the ambition of UKC2 is to work towards a coupled prediction system for longer timescales (Lewis et al., 2018), the implications of the new

approach are investigated further using a cross-spectral analysis of performance against observations over scales ranging from days to multiple years."

The authors should re-think about the introduction to make the objective and usefulness of the study clear to the readers.

Authors:
Already addressed above. We have now a better introduction stating the aims and usefulness of the study more clearly. Thanks to the reviewer for his/her comments

2) It seems that the major contribution of this study is the proposed spatial dependence of S0/Smax. However, it is described in Section 3.4. I understand that the authors developed this parameterisation based on the comparison between observed and simulated runoff, which has been discussed in the previous sections. However, such an important contribution should not be introduced so late in the manuscript. The spatial dependence of b can be described in a separate section after the introduction (or even in the methods section). Later, it can be substantiated in the results section using the modelled and observed runoff data.

Authors:
We have now briefly introduced the development in the last paragraph of the introduction. Other than that, we stress that the spatial dependency of S0/Smax on terrain slope is a result in our study. Hence, we would like to maintain the structure where we discover and develop the issue in Sections 3.3 and 3.4.

3) The conclusion section just summarises the study. What is the take-home message? What are the useful findings that can benefit the scientific community? The authors should make these clear in the conclusion

Authors:
Thanks. We have deleted a few unnecessary details in the first paragraph of the conclusion, divided it in two, and added a new third paragraph about the "take-home message" and usefulness of our study. The conclusion section reads now like this:

"Motivated by the search of the best representation of hydrological processes over the land in the context of a coupled UK land-ocean-atmosphere model (UKC2; Lewis et al., 2018), we find that the JULES LSM has the potential to simulate daily river flow accurately over selected catchments in Great Britain when driven by the 1 km^2 resolution CHESS-met database, obtaining results comparable to those of a Great Britain rainfall-runoff model (CLASSIC-GB, Crooks et al., 2014). Previous studies using JULES (e.g. Best et al., 2015; Schellekens et al., 2017; Ukkola et al., 2016) use a fixed S_0 parameter within the PDM scheme. In this study we vary the values of S_0 and are able to improve performance (% *bias* and *NS*) as a result. The parameter S_0 controls the soil water content necessary to start producing surface runoff. The parameterization that produces the best results for each catchment uses the mean catchment slope. When applied on a gridded model, a new linear function of slope at the model resolution scale can produce performance metrics comparable to those using the mean catchment slope. The new parameterization constrains surface runoff production to wet soil conditions over flatter regions, whereas over steeper regions the model produces surface runoff for every rainfall event, regardless of the soil wetness conditions.

Hence, a simple terrain slope dependency has improved greatly the JULES river flow results for different catchments in Great Britain. We stress that this finding should be tested for other regions/scales on JULES and other LSMs, as topography datasets are available at very fine resolution (e.g. https://www.hydrosheds.org/). The capability of an LSM to reproduce the water balance at regional scales with performance (in terms of river flow generation) comparable to hydrological models can potentially impact weather forecast and climate predictions using regional coupled modelling systems such as UKC2.

We have also shown that cross spectral analysis for evaluating model performance against observations quantifies the mismatches in variability, and separately mismatches in phase, at different time scales that are not otherwise apparent from metrics such as NS and RMSE. Potentially the recognition of a specific time scale where a model is performing poorly could help identification of the incorrect behaviour in terms of water transport and/or sub-surface storage. The cross-spectral analysis comparing the modelled river flow with observations has reinforced the choice of the new parameterization for surface runoff production."

Minor comments

1) The spectral analysis (Figure 10) compares the performance of JULES-PDM with slope dependent S0/Smax. How does the spectral power of the observation compare with JULES-PDM with default parameters? Does the inclusion of slope dependent S0/Smax improve JULES' performance in reproducing runoff at timescales longer than a day? I would assume it does (looking at Figure 9). The authors may consider including this comparison in the spectral analysis.

Authors: The comparison in amplitude and phase of the spectral power of observations with other parameterizations (*no hyd*, TOPMODEL, other parameter choices for PDM) are shown in the next figure (Fig. 11) and discussed in Section 3.6 (third and fourth paragraphs).

2) As I have mentioned earlier, this manuscript needs a proof-reading to improve the language.

Authors: Thanks, we have done so and improved the language in the updated new submission.

3) What are the Great Britain catchments (Section 2.2 and other places in the manuscript)? Can this be replaced by Selected catchments in Great Britain or something like that?

Authors: Yes, thanks for the suggestion. We have modified the Section 2.2 title and other instances in the text as suggested by the reviewer.

4) Similarly, what is a Great Britain hydrological model?

Authors: With "Great Britain hydrological model" we mean a national scale hydrological model developed for the domain of Great Britain (Crooks et al, 2014). We would like to keep the Section 3.5 as it is, but we agree with the reviewer that it needs clarification and we modified slightly the explanation in the first paragraph: "CLASSIC-GB is a ~~Great Britain~~ grid-based rainfall-runoff model developed for the domain of Great Britain that uses the same 1 km^2 resolution CEH-GEAR precipitation input used here and higher resolution parameters derived from the Hydrology of Soil Types (Boorman et al., 1995)."

5) Caption of Figure 1: Generally, an abbreviation goes inside the parentheses (NRFA).
Authors: Yes, we have corrected Table 1 and Figure 1 captions with NRFA inside the parentheses.
"Note that the catchments Ure, Severn1 and Ock are contained within the larger catchments Ouse, Severn2 and Thames, respectively." May be you could call them sub-catchments?
Authors: Yes, corrected.

6) Caption of Figure 2: Variability of the soil moisture …
Authors: Thanks. Corrected.

7) Caption of Figure 10: In each case, the variability and relative timing of daily …
Authors: Thanks. Corrected.

REFERENCES

Crooks, S., Kay, A., Davies, H. and Bell, V.: From Catchment to National Scale Rainfall-Runoff Modelling: Demonstration of a Hydrological Modelling Framework. Hydrology 1(1), 63. 2014