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Interactive comment on "Trends in evapotranspiration and its drivers in Great Britain: 1961 to 2015" *by* Eleanor M. Blyth et al.

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Overview. The authors were happy to receive these well considered reviews. Many of the issues can be easily addressed, while others are require more research. I am very much looking forward to working on the issues raised by this paper. We intend this paper to set a benchmark against which such research could be judged. The model (JULES) is used by a wide community of researchers and is the model used in the UK Met Office Unified Model. The configuration of the model used is the standard configurations used by the community for work in the UK. Both reviewers mentioned the issue of the word 'evaporation' verses 'evapotranspiration'. There has been a long debate among micro-meteorologists on the correct term to be used. I was trained to use 'evaporation' for all forms of evaporation (transpiration, interception and soil surface),

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Discussion paper

but whenever I use that collective term, I find the new generation of environmental scientists object to it. So I have recently started using the term ‘evapotranspiration’. For the sake of the majority of readers therefore, I will stick to ‘evapotranspiration’. Both reviewers also suggest that the method of how the trend was calculated needs more information. I have included in Section 2.4 a description of this (see A). The textural changes requested by the two reviewers are noted and changes highlighted below. But the more fundamental points are addressed here. Reviewer 2 notes 4 main criticisms. 1. That the paper does not address the land-cover change. This is quite true, although the issue is somewhat exaggerated by the reviewer. The paper by Rounsevell and Reay (2009) is for the whole of the UK (United Kingdom – includes Northern Ireland), not just GB (Great Britain). So the area is not as big as suggested here. The crop model in the current version of JULES is very simple (Osborne et al, 2015, Williams et al, 2017). In terms of evaporation, the crops will be similar to grass. Only half the change from agriculture has been to forest. The total change in forest (also quoted in Rounsevell and Reay 2009) is 1.3m hectares which is less than 5% of the area. This doesn’t mean we should study the effect of land cover on the water budget of GB. The issue when we setup the modelling experiment was to see how the climate drivers had altered the water budget. Adding in a land-cover change was likely to complicate the analysis. It would be very interesting to move onto that subject and use this bench-mark paper to quantify the difference. Some text explaining the strategy has been included in the introduction. See B 2. I was particularly excited to read this part of the review. The reviewer is right that the model is indeed sensitive to the assumptions made about rainfall distributions. It is possible that these are changing (with more intense rainfall) and it is important to start to work on this issue. However, what the reviewer is suggesting is a major piece of work in its own right. I hope that this paper demonstrates the importance of such a piece of research. By identifying the role of interception in the evaporation budget and trend, the authors have motivated the kind of study mentioned here. In the discussion section, we have included a discussion of this issue. See C 3. The main drivers were chosen as they were highlighted in the Robinson et al

(2017) paper as being important for evaporation. The wind speeds are indeed reducing (McVicar et al, 2012), but this would give a decrease in evaporation, not an increase. The soil moisture is also dropping globally (Jung et al, 2010) but not in GB, and would also give a decrease in evaporation. The land-use change was not studied here as we wanted to study the role of climate in the modelled evaporation. As discussed above, we are very much looking forward to going into that area. The CO2 fertilisation is a tricky subject mainly because the JULES model is very sensitive to CO2. We studied the outputs of the model, but felt that the uncertainty in the formulation introduced too many issues and that it would distract from the main message of the paper. Again, it is certainly something we would wish to follow up with soon. 4. I think the research approach suggested by the reviewer is a very good one. However, this paper does not describe an experiment. It describes a single configuration. It then asks an important question: for a given standard model in a given standard configuration, what can we learn? What we learn is that there are some aspects of the modelled water cycle (interception) that are more important to the trend than others. This is a unique result and motivates a new priority for hydrologists. We have added some text to the conclusions to highlight this. See D Specifics: Reviewer 1: Page 3, line 28-31. More discussion is given to the issue of limitations of processes assumptions. See E Page 5. I wanted a figure early on to give a flavour of the products being discussed. It is not strictly ‘method’ then ‘results’ but I find that approach to be unhelpful sometimes. I like to see the basic product so that I can visualise the rest of the paper. The authors prefer to have both figures (visual comparison for understanding) and a table (quantative, citable). The authors prefer to keep the results and discussions separate. The results are presented as straightforwardly as possible in relation to the original questions. The discussions explore some of the issues raised in more detail. We have added a table of the difference of trend between historic and current analysis. See F Typos all corrected. Reviewer 2: PET is used in the Robinson et al 2017 paper. We would prefer to keep it here for consistency. The biases reported in the results are now mentioned in the discussion of the trends. See G References Osborne, T., Gornall, J., Hooker, J., Williams, K., Wiltshire, A., Betts, R., and Wheeler, T.: JULES-crop: a parametrisation of crops in the Joint UK Land Environment Simulator, Geosci. Model Dev., 8, 1139-1155, https://doi.org/10.5194/gmd-8-1139-2015, 2015. Williams, K., Gornall, J., Harper, A., Wiltshire, A., Hemming, D., Quaife, T., Arkebauer, T., and Scoby, D.: Evaluation of JULES-crop performance against site observations of irrigated maize from Mead, Nebraska, Geosci. Model Dev., 10, 1291-1320, https://doi.org/10.5194/gmd-10-1291-2017, 2017. A Page 21. Line 12. We calculate the trends as the slope of the linear least squares fit of the annual time series for the different water budget variables. The reported trend errors are calculated as the difference between the trends and the 95 % confidence interval of the linear fit (Robinson et al., 2017). B. Page 4. Line 9. Although the model is complex, there are always simplifications and assumptions made. The model used here is the Joint UK Land Environment Simulator (JULES) which is used by the UK Met Office in the Unified Model. It is also used by a community of land surface and hydrology researchers. The version used in this paper is the new standard configuration used for the UK. The paper is intended to act as a benchmark against which model developments and new research can be compared. In order to interrogate the performance of the model and highlight new research agendas, the following will be addressed: Page 4, line 12. We have not included land-cover change in this analysis. There has been a 5% increase in forest cover over the GB (www.fao.org) which in practise would make a small difference to the water-budgets. But the model analysis for this benchmark paper would be made more complex by this addition variable. Future work would benefit from a comparison of the effect of climate verses land-cover change on the water budgets. C. Page 31. Line 19. The interception model has some uncertainties, and possibly underestimates the effect (see Section 2.2.3). Some of the uncertainty is due to the size of the interception store, some to do with the efficiency of evaporation (the aerodynamic resistance) and some to do with how the rainfall intensity distribution is represented (see Appendix A2) both in time and space. All of these aspects would benefit from further investigation. This paper is only able to highlight the importance of the role of interception in the modelled trend, thus motivating new research. However, the results of the current model configuration ...... D. Page 33. Line 2. This study set out to explore the long term evolution of the modelled water budget of Great Britain (GB), including how and why it is changing. The model used is the UK community model JULES, used by the Met Office in the Unified Model. The configuration described is the new standard configuration for the UK. E. Page 3. Line 31. For instance: using too shallow roots for the vegetation will result in premature reduction of evaporation in a dry spell (Teuling et al, 2010), ignoring interception and infiltration processes will mean that the surface runoff component will be insensitive to rainfall intensity (Dolman and Gregory, 1992), including water use efficiency processes can alter the long term response of the land to climate change (Prudhomme et al, 2014). F. Page 28. Line 14. Units mm yr-1 yr -1 Precipitation Runoff PET or Evapotranspiration Change in Storage Previous 2.96 1.6 0.7 or 0.77 0.5 New 2.96 2.16 0.87 0 Table 9. Overview of previous and new estimates of trends in the water budget for GB. G Page 28. Line 28. It should be noted that the trends calculated form these model results are subject to the model biases which are shown in Section 2. The overall evaporation is low compared to the observed and the interception is particularly low compared to the estimates from the Forestry Commission (Nisbet, 2005). If it is true that the trend in evapotranspiration is higher than the trend in PET due to the presence of interception, then it is possible that the true trend might be higher still if that is being under-estimated. References: Dolman, H. and Gregory, D., 1992. The parameterisation of rainfall interception in GCMs. Quarterly J. of Roy. Met. Soc., 118, 455-467 Teuling, A.J., Seneviratne, S.I., Stockli, R., Reichstein, M., Moors, E., Ciais, P., Luyssaert, S., van den Hurk, Amman, C., Bernhofer, C., Dellwik, E., Gianelle, D., Gielen, B., Grunwalkd, T., Klumpp, K., Montagnani, L., Moureaux, C., Sottocornala, M and Wohlfahrt, G. 2010. Contrasting response of European forest and grassland energy exchange to heatwaves. Nature Geoscience, 3, pages722–727

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