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Hydrology and Earth System Sciences Discussions

Interactive comment on "Assessing the response of groundwater quantity and travel time distribution to 1.5, 2 and 3 degrees global warming in a mesoscale central German basin" *by* Miao Jing et al.

Anonymous Referee #1

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This manuscript analyzes the possible response of groundwater to climate change scenario obtained by combining a few Global and Regional Climate models under three warming levels (1.5, 2 and 3 oC). The analysis is conducted for the aquifer of a small catchment (850 kmˆ2) located in Germany with a total of 35 combinations of Global and Regional Climate Models. The resulting precipitation and temperature scenarios are used into a mesoscale hydrological model (mHM) to simulate vertical hydrological flow exchanges and the resulting infiltration is used as spatially variable recharge of a groundwater model (OpenGeoSys, OGS).

The manuscript is well written and technically sound (see below for a few comments) and the topic is of interest, given the relevance of groundwater.

General comments

From the description provided in the methodology and materials section I argue that mHM and OGS, the mesoscale hydrological model and the groundwater model are decoupled. In fact, at line 13 of page 5 I read "The projected recharge from mHM calculations are fed to the groundwater model OpenGeoSys (OGS) for the assessment of groundwater quantity and travel time distribution." From this short description I concluded that vertical fluxes, including those of the unsaturated zone are modeled with mHM and that the resulting "deep" infiltration is used as recharge (i.e., as boundary condition) for OGS. In doing that the processes of infiltration and flow inside the aquifer are decoupled. This may be reasonable when the water table is deep, but I am wondering what is the impact of this assumption on the simulations showing significant rises of the water table. In this situation decoupling leads to significant errors as the water table gets close to the ground surface. This is relevant both for water levels and the following travel time analysis. The authors provide only limited information on this important point and do not discuss its implications in term of representativity of the model. Decoupling these two processes is a great advantage from a modeling point of view, but I am not sure it can be actually introduced at least in the scenarios showing the largest increase of groundwater levels.

Another aspect that is not fully explained is the validation of the groundwater simulations. The authors touch very briefly this point by saying that mHM has been validated at the European scale in a previous paper, but what about this specific small catchment or the larger, but still small compared to the European scale, Thuringian catchment? And what about the groundwater model? At page 8, line 17 I read: "The post-calibrated values of the hydraulic conductivity in each geological unit obtained from a previous study are assigned to the corresponding geological layers of the mesh (Jing et al., 2018a). Meanwhile, a uniform porosity of 0.2 is assigned to each geological layers

(Table 2)". In a previous work (Jing et al., 2018a) the authors presented a comparison between observed and simulated heads at a number of observation wells (Figure 5 and related text on section 3.2.5) and for a number of recharge scenarios. The analysis is based on 400 calibrated Monte Carlo realizations and I am wondering if the authors used all the 400 realizations in the present work, or just one, in the latter case what was the criteria used to assign the hydraulic conductivity? Figure 5 of the previous paper shows apparently a good reproduction of the observed heads, but what puzzled me is that the standard deviation of the error is 4.6 m, a rather large portion of the variation presented in this manuscript as an effect of climate change.

The third issue I would like to comment is uncertainty. My impression is that combining a large number of GCM-RCM pairs introduced a large variability of the meteorological forcing and therefore to water levels and travel time distributions, which should be validated in some way. According to the presented analysis it is very difficult, if not impossible, to sort out unrealistic scenarios, or weight less them in the ensemble. On the other hand, uncertainty in the hydrological models is neglected, in particular that related to the groundwater model.

Overall I feel that the manuscript, although interesting and pleasant to read, cannot be accepted for publication in the present form. As it is the manuscript reads like an application of previously published modeling efforts, with little analysis of the results. However, I see value in what the author presented and I think that with some extra effort they may accommodate the above drawbacks, by explaining more the underlying hypotheses and limitations of the current analysis and improving and enriching the discussion of simulation results. With these changes I think this manuscript will be a valuable contribution to the community.

Minor comments Page 9 line 6: The recharge seems to increase almost linearly with the temperature, which is strange considering the many nonlinearities involved in the infiltration process;

Page 9, line 9: "The projected....." This seems to suggest that the number of combinations of GCM and RCM can be reduced, or even that similar results can be obtained by using only the GCM. Please elaborate a bit more.

Page 14, line 17 and following: this sentence is vague. Have these shallow local flow pathways actually been observed in the simulations and how realistic are they?

Page 15 line, 25: this disclaimer, saying that uncertainty may be even larger, since some uncertainty sources have not been considered is somewhat alarming because it casts doubts on the interpretation of the results.

Page 16, line 20: How can be that first-order effects of climate change are small and second-order effects are not negligible? If for not negligible you mean that they are however smaller than first-order effects, what is the reliability of their estimate considering the large uncertainty affecting these simulations? Please elaborate more

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