

Interactive comment on “Analysis of the impact of climate change on groundwater related hydrological fluxes: a multi-model approach including different downscaling methods” by S. Stoll et al.

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General remarks

The manuscript has the potential to contribute relevant new knowledge regarding the assessment of the impact of climate change on groundwater (and freshwater in general) in small aquifers/basins. The investigation is state-of-the-art as the authors use the output of eight regional climate models to drive an integrated unsaturated zone-

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groundwater model, and the investigation of downscaling effects is of broad interest to the many researchers involved in climate change impact studies.

However, the analysis is flawed with respect to how changes of climatic and groundwater variables as driven by climate change are defined. The authors compare future climate variables like precipitation as computed by climate models (bias-corrected) for 2071-2100 to observed values for the reference period (1961-2000). This is not an appropriate way for defining changes to future climate change. This approach results, for example, in the effect that uncorrected climate model output (as compared observations) shows a decrease over approx. 100 years, while the bias-corrected values show a significant increase (see DMI model in Table 6). Comparing Figs. 6 and 7, it is obvious that Fig. 7 does not really show climate change but in addition the maybe dominant existing biases of the models as compared to observations: the overestimation of winter precipitation in Fig. 6 is similar to the “increase” of precipitation due to climate change in Fig. 7.

Therefore, any changes due to climate change should be defined by comparing the (2071-2100) values as computed by climate models (and bias-corrected) to the (1961-2000) values as computed in the same way. In their discussion (p. 7537, l. 24), the authors even state that “a comparison with observed values as a reference is problematic for assessing future changes”. However, it is necessary that the authors actually provide their results regarding climate change impacts using as a reference for changes not the observed climate data but the respective downscaled model computations. Their conclusion about the expected increase of precipitation in winter and therefore no future decrease in groundwater recharge/levels may change if they define “change” correctly. It may then be interesting to compare this to the results obtained using observations as reference.

Secondly, I suggest applying an additional method for downscaling, the traditional delta-method, and then compare the results to the other three downscaling methods. In the delta-method, the future climate variables are computed by multiplying (precipi-

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tation) or adding mean monthly changes of climate variables as computed by climate models to values observed during the reference period. Then the impact model is run with these future climate variables, and the impact model result is compared to the result obtained using observations during the reference period. To compute changes of monthly means, the authors could use the time periods 2071-2100 and 1961-2000 (or 1981-2000).

Specific remarks

P. 7523, l. 25: Please explain in some more detail why water suppliers could not meet water demand in the dry summer of 2003 from groundwater. Could some of them not continue pumping? How frequent was that? And how often did that just lead to increased drawdowns? Also, in your research area, what happened at that time? In Fig. 3, I cannot recognize anything special in the summer of 2003. Please discuss this at the appropriate location in the manuscript.

P. 7529/30: Please explain the three downscaling methods more clearly. Regarding the factor correction method, explain that monthly factors are added to/multiplied with the daily values computed by the climate models. Indicate the strength of this approach. Regarding the CDF correction method, say “to downscale a specific daily climate model value” (P. 7530, l. 1). Regarding the monthly CDF correction, say something like “for each of the 12 months individually (if this is correct). Later, you call the “CDF correction method” “inter-annual” correction method, why? Would it not be better to call it “annual” as compared to the “monthly” approach?

P. 7532: Please provide the value of observed precipitation in mm/d and of the observed standard deviation as a reference for the biases listed in Table 4 (also put these values in the table caption).

P. 7353, l. 24: You do not show that variability is not characterized adequately. You could refer to Fig. 9 if you would also show the time period 1981-2000.

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P. 7541, I. 22: I do not understand how you could exclude a possible shift in the intra-annual distribution of precipitation from historic analyses, as future climate changes are unprecedented at least during the last 1000 years. Besides, historic analyses require that not only groundwater data but also land cover data and climate data are available for the historic period.

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