We thank Professor Döll for her time spent in reviewing our manuscript and appreciate the positive and constructive criticism. Hopefully we have answered the questions satisfyingly, otherwise we are available for further clarifications.

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- 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.

Answer:

We agree with Prof. Döll that showing the changes for the uncorrected climate model outputs relative to the observations is not appropriate. As climate model outputs without downscaling do not account for biases between observations and model outputs it is not an appropriate way to compare them with observations as reference. We will do the necessary recalculations and change the according sections in the manuscript.

However, we do think that showing bias corrected model outputs relative to observations is appropriate. Statistical downscaling is defined as a method to scale down climate model outputs to smaller application scales by reducing the biases between climate model output and observations at the study scale. Therefore as we have stated in our manuscript (page 7533 l. 10) we share the opinion of Goderniaux et al. 2009, that future changes could be expressed relative to hydrological control simulations driven by the observed climate data, as through the downscaling process biases should be accounted for. Consequently, we think it is a fair test for

the downscaling approaches to use observation data as a reference. If the downscaling is effective (depending on the goals), no biases should be visible and average values of observations and downscaled climate model outputs should be identical. This is the case for two (Factor + monthly CDF correction) of our approaches. The annual CDF Correction is not designed to optimize monthly values and accordingly the monthly change signal is superposed by the biases and not trustworthy (as we have stated at page 7537 l.10; page 7537 l.20 etc.). These are exactly the things we want to reveal by showing both the change signals relative to the observations and the evaluations of the downscaling approaches. If we would show the changes relative to the specific climate model data and not to observations we could skip the downscaling and just apply a site-independent delta change approach.
Prof. Döll supposes that our conclusion concerning the expected winter-time precipitation increase and therefore increase of groundwater recharge/levels may change if we would define change relative to the specific climate model outputs (1961-2000).
As stated above, two downscaling methods (Factor + monthly CDF correction) already show the relative climatic changes (as downscaled values and observations are identical for the period 1961-2000) and they do support our conclusion of no future groundwater stress. Additionally, also Fig. 9 (where absolute values and no changes are shown) supports this finding by showing increasing groundwater levels which are consistent with the reported changes. Below Figure 1 shows changes in CDF corrected precipitation relative to observations (left) and also the newly calculated changes relative to the specific climate model output (right). Although the signal is damped with the new reference, the general pattern of increased winter precipitation is still clearly visible.

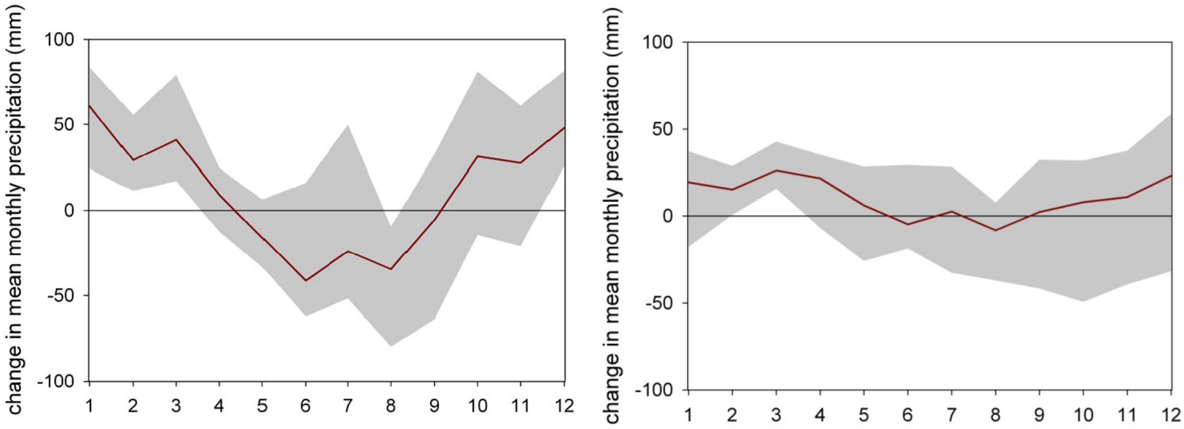

Figure 1: Monthly changes of CDF corrected precipitation (mm) relative to observations (left) and relative to climate model outputs (right).

Additionally, Table 1 shows the annual changes in precipitation for both references. Not surprisingly (as the CDF Correction, is designed to optimize mean annual values) hardly any difference between the two references is visible. Given that and knowing the strong relation between precipitation and recharge and the results of the other two downscaling methods we can exclude, that the increase of groundwater levels is dominated by the choice of the reference.

Table 1: Annual changes of CDF corrected precipitation (mm) relative to observations and relative to climate model outputs.

Reference	DMI	MPI	KNMI	SMHI ECHAM	SMHI BCM	HC	ETH	C4I	average
Climate model output	196	81	216	173	216	99	-86	80	122
Observations	197	81	217	176	226	101	-84	82	125

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 (precipitation) 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 and1961-2000 (or 1981-2000).

Answer:
As mentioned above we will calculate the changes driven by the uncorrected climate model data relative to values as computed by the climate models in the reference period. Although this not exactly the delta change approach, as we do not integrate the changes over 30 years, it is very similar and should provide results which should be comparable to the changes expected with the delta change approach.

Specific remarks
P. 7523, l. 25: Please explain in some more detail why water suppliers could not to 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.

Answer:
In order to handle the questions of the reviewer we will deliver more information and extend 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?

Answer:
We agree that this section is rather sketchy. The section will be rewritten, more information delivered and the nomenclature clarified

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).

Answer:
We appreciate the indication and will add the requested data.

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.

Answer:
We appreciate the indication. The text will be modified in order to handle this comment.

P. 7541, l. 22: I do not understand how you could exclude a possible shift in the intraannual 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

Answer:
This is a misunderstanding, as we placed the brackets at the wrong position. We suggest analyzing historic data to identify processes that caused significant groundwater drawdowns in the past. For example, historical data indicate that especially limited winter precipitation causes large groundwater level declines. Groundwater levels react less sensitive to reduced summer precipitation. Thus we want to identify those climate settings which could be a threat for groundwater resources in the future. We agree with the reviewer that for those analyses it is essential to have climatic and land use data. The text will be modified in order to clarify this.

References:

Goderniaux, P., Brouyère, S., Fowler, H. J., Blenkinsop, S., Therrien, R., Orban, P., and Dassargues, A.: Large scale surface-subsurface hydrological model to assess climate change impacts on groundwater reserves, J. Hydrol., 373, 122–138, 2009.