

Interactive comment on “Climate change impact on groundwater levels: ensemble modelling of extreme values” by J. Kidmose et al.

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Reply to comments from referee (#2) to Climate change impact on groundwater levels:
Ensemble modelling of extreme values

1 General comments

We thank the anonymous reviewer for a constructive review of the submitted manuscript. We acknowledge suggestions and follow recommendations in most cases. The reviewer emphasises some general shortcomings. Firstly, it is recommended that the manuscript also considers or discusses the potential for extreme value analysis for low groundwater levels, important for droughts or wetland conditions. We agree with

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the reviewer that application of extreme value analysis for estimation of low groundwater levels is also very relevant. The presented methodology could with minor changes be used to estimate return periods for extremely low groundwater levels instead. Because of the small changes needed to make the low extreme estimates we think it would be sufficient to bring the issue to the reader's attention via the discussion section. Secondly, the reviewer asks for a thorough going through the manuscript, both for the English but also for editing specific figures and improves explanations throughout the manuscript. In the below, described answers to detailed comments and editorial comments, we have addressed what we intent to do with the poor explanation and the specific figures. On top of this we have had a native English speaking person going over the manuscript and improve the manuscript in this respect.

2 Detailed comments

7837, 21-23: We agree with the reviewer that low GW levels might as well be of interest for an extreme value analysis. We have dedicated some words to this in the introduction.

7844, Eq. 1: The designed objective function has several terms regarding h because highest GW levels (T events) are both a result of mean GW level at a given site and seasonal fluctuations in GW level. Furthermore, time series should for example be used differently than single head measurements. The revised manuscript includes a recalibration also applying stream discharge data. The objective function does not contain a regularization term.

7846, 13-16 and 7846, 17-26: We acknowledge the recommendations given by Stoll et al. (2011) and in several ways our results support and follow their conclusions. Stoll et al. (2011) recommend using different downscaling methods in impact studies. This is why we apply both the traditional Delta Change downscaling method and the more advanced Distribution Based Scaling method. Because of the large downscaling uncertainty described in our manuscript, we have updated the study results with a

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more local downscaling methodology in order to reduce the difference between the two applied downscaling methods.

7847: Done

7848, 7-13: The EVA methodology section has been rewritten to describe the new methodology. The 9 series referred to the 9 climate model ensemble.

7849, 7-8: We think that an error on the annual GW fluctuation of 0.6 m is a bit too high considering observed annual fluctuations are between 0.1 – 0.4 m. The updated model error on annual amplitude is reduced and therefore our comments in the manuscript about this are omitted.

7850, 5: The climate models disagree by up to 2 mm/day of precipitation during summer and in September. This is now clarified in the text.

7850: In section 3.3.2 we mention that future and present simulated periods are run with a constant pumping value based on actual pumping from 2003-2010. We acknowledge that changed pumping activities can influence future GW levels but given the already strict regional regulation on agricultural pumping and a stagnant population development we think that the values from 2003-2010 are appropriate.

7851, 11-12: New sentence added.

7855, 2: We agree with the reviewer and updated the revised manuscript with the new and more local bias correction for the downscaling.

7855, 12-13: Done, new reference to results

3 Editorial comments

7836, 4: Done

7838, 3: Done

7839, 20-21: Rephrased

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7840, 7-8: Done

7840, 19-20: There is a variation of precipitation from coast to the central part of Jutland. "zones" is inserted.

7840, 21: Yes, "west" is correct.

7842, 1-2: The numerical layers of the groundwater model follow the hydrostratigraphic model. We think this is a normal approach for definition of numerical layering. For clarification the sentence is nevertheless changed to "Numerical layering follows a geological model with 11 layers."

7843, 1: Done

7844, 6: Section rewritten

7848, 18-19: Sentence is left out

7848, 22: The section is rewritten and a new Fig. 5 inserted as recommended.

7849, 10-12: The sentence is deleted because better fit of annual fluctuations is now obtained. The section is rewritten

7849, 28-: The sentence "Predictions of future precipitation are the most varying climate variable (Fig. 7)." Are omitted because we agree with the reviewer that our meaning is unclear and it do not make any sense to compare changes in for parameters in that context.

7850, 17-20: Section rewritten

7850, 23-24: Section rewritten

7850, 25: Done

7851, 8: Done

7851, 21-24: Reformulated

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7853, 4-5: Done

7854, 10: Changes to “had” (recommended by reviewer #1)

7855, 5-7: Rewritten

7855, 22: Done

7856, 10: Done

7856, 13: Changed to “concluded”

7856, 14-15: Reformulated

7856, 19: Done

7856, 25: Done

7857, 4: Done

7857, 7: Done

Fig. 1: The figure is not meant to show the modelled area but give an overview of the critical zones for the motorway (left) and to the right location of Silkeborg in Denmark. We agree that the right overview map is unclear. The rectangle showing the focus area is enlarged.

Fig. 2: The small illustration in the upper right corner of the figure is deleted and Fig. 1 is referenced instead.

Fig. 5: As recommended, a new figure only showing mean error of modelled head replaces the old figure.

Fig. 6: As recommended

Fig. 7: “shows” replaces “show”. Regarding the comment about too many lines in the figure we think this will be resolved if the figure when transferred to a whole page figure and thereby enlarging details.

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