

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

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### **GENERAL COMMENTS:**

The manuscript addresses a topic of importance to HESS readers, and it represents a substantial contribution. The manuscript appears to be technically sound overall, and it is generally well organized, with some essential editorial revisions (see Technical Corrections below). The most significant, new contribution is the analysis of joint uncertainty propagation from GCM output, statistical climate downscaling, and extreme value analysis to the estimation of changes in groundwater head variations. Although, as the authors noted, it is a site-specific study in terms of hydrogeological and anthropological conditions, the case study is a good contribution in its approach

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and example of addressing changes in extreme values that are critical hydrological variables for decision making. Structural error of the hydrogeological model should also be discussed in terms of added bias and uncertainty.

As noted below, possible technical flaws include ignoring CO<sub>2</sub> effects on plant growth and transpiration, extrapolation to 100-year return intervals and use of two-tailed distributions for estimating bounded maxima. Assuming these can be addressed, along with various minor details of clarification, I recommend final publication.

#### SPECIFIC COMMENTS:

1. The term “evapotranspiration” is used loosely throughout the manuscript (first on line 7) without identifying how it is derived. Later “Ep” is used to denote potential evapotranspiration. I assume the authors mean “potential evapotranspiration” in all or most places as an input to the hydrological model. However, how were changes in actual evapotranspiration simulated in future projected climates where increased atmospheric CO<sub>2</sub> affects transpiration via stomatal control? It appears that CO<sub>2</sub> effects on plant transpiration were not considered. Models and studies that incorporate these effects should at least be cited to identify possible errors due to neglecting these effects on ET and recharge.
2. The main motivation of estimating extreme (maxima) head values is road construction, which leads me to think that the head distribution is bounded (limited to the land surface), such that an analytical distribution should be bounded or truncated (such as a beta distribution). The analyses also refer to 95% confidence intervals of assumed two-tailed distributions, but the minima are not of interest. These issues should be clarified and probably require additional, new EVA calculations.
3. These two issues point out a fourth and unaddressed source of uncertainty: hydrological model structural uncertainty (or model structural error), which causes

potential bias in all estimates. This may not be easy to assess, but it should be discussed.

4. Gumbel distributions are extrapolated to  $P = 0.01$  (return period = 100 years), and most of the cited metrics are based on this return period, but the simulation periods do not support these longer periods. Figs. 8 and 9 show that the fitted points go only to about 60 years (and one might question whether these points are estimated well). Instead, the simulations appear to support return periods of only 10 years with much confidence.

## TECHNICAL CORRECTIONS

(Page, Line: Comment)

7836, 2: insert “scenarios” after “Climate”

7836, 7: potential “evapotranspiration” (see comment 1 above)

7836, 11: insert “:” after “evaluated”

7836, 17: change “a more and more” to “an increasingly”

7836, 19-21: Move sentence from 7837, 21-23 here to help the reader see the relevance of groundwater to roads (as opposed to designing culverts for surface runoff).

7836, 12: change “Allen” to “Green”?? (J. Hydrology, “Beneath the surface of climate change ...”)

7838, 3: change “was” to “were”

7839, 12: should be “meters above mean sea level”

7839, 14 and 15: insert “the” after “Toward”

7839, 15: “topographical height” is unclear

7839, 19: insert “the land surface” before “topography”

7839, 23: insert “glacial” before “tills”

7840, 2: change “is properly” to “was”

7840, 4: change “evidencing” to “evincing”

7840, 20: change “in land” to “inland”; change “Highest” to “The highest”

7842, 6: change “See” to “Sea”

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7842, 8: “calibrated transient” is unclear and verbally awkward

7842, 11: change “was” to “were”

7843, 27: This approach neglects run-on within the area, which overestimates the total runoff.

7844, 17-23: define all parameters/variables, and make them consistent with abbreviations used in the figures. Also, specify the limits of the sums. Weights may be incorrectly defined,

$$i.e., w_i = w_j \text{ for } i = j.$$

7845, 4: How was  $K_h$  “tied to”  $K_v$ ? Explain the factor of 10.

7845, 20: insert “bias-” before “correct”

7845, 24: A1B is a moderate scenario. Emission scenarios comprise another source of uncertainty not captured in the current approach.

7846, 28: Cannot cite “Seaby et al. (2012)” as unpublished work.

7849, 2: change “north vest” to “northwest”

7849, 17: change “range” to “difference”?; “Pre-quaternary” is “Glacial” elsewhere

7849, 24: Could the K for clay till be affected by cracks/macropores?

7849, 27: potential “evapotranspiration”?

7850, 10-11: ARPEGE-CNRM produced an extreme Ep or outlier compared with other models (Fig 7). Why?

7851, 17: Isn’t the focus on extreme maximum h values?

7854, 9-12: Use past tense “investigated”, “had”, “reconstructed”

7855, 18: change “serie” to “series”

7855, 23: “critical to select too long periods” is unclear and grammatically incorrect.

7856, 713: use past tense “concluded” for previous work.

7856, 20: change “model-ability” to “model’s ability”

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## References:

Add Green et al. (2011, J. Hydrology 405:532-560)

Remove manuscripts “to be submitted” unless already submitted and accepted.

One example of incorporating CO<sub>2</sub> effects on plant growth and transpiration is:

Green, T.R., B.C. Bates, S.P. Charles and P.M. Fleming. Physically based simulation of potential effects of carbon dioxide altered climates on groundwater recharge, *Vadose Zone J.* 6:597-609. 2007.

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Interactive comment on *Hydrol. Earth Syst. Sci. Discuss.*, 9, 7835, 2012.

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9, C4170–C4174, 2012

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