Hydrol. Earth Syst. Sci. Discuss., 7, C3326–C3333, 2010
www.hydrol-earth-syst-sci-discuss.net/7/C3326/2010/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Assessment of climate change impact on hydrological extremes in two source regions of the Nile River Basin" *by* M. T. Taye et al.

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Received and published: 4 November 2010

The Authors wish to express their gratitude to the reviewer for the well-thought-out review. The following are the responses to the comments.

General comments

–The reviewer's suggestions are valuable to this study and will help in restructuring the paper.

–The description of the construction of the climate change scenario will be included

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in the revised manuscript. The GCM quality section will explain how the models were evaluated. To explain briefly, the GCM grid point data was compared with the station data closest to the grid point. Here, the stations with the longest data periods were selected from the available stations in the two catchments (Kisumu station for Nyando and Bahar dar for Lake Tana). Using areal reduction factors, it was possible to ascertain whether the GCM output, which is presumably an areal output, was closer to the areal rainfall. For most models it was not the case. It was clear that for the daily statistics, the GCM performance was poor. However, with the monthly data, the GCMs appeared to perform well. This was expected given the high temporal scale.

–The frequency perturbation method will now be included (see response to reviewer 1 comment 5). Regarding the ETo perturbation, it was estimated from the changes in the maximum and minimum temperature. First, the changes were used to calculate the future maximum and minimum temperature. This was followed by the estimation of ETo from the Penman-Monteith equation given the new temperatures (see response to short comment to Axel Thomas). For the catchment, it was assumed that the perturbations (change factors) at one grid point in the catchment were similar to other points in the catchments due to the low spatial variability of temperature.

–The frequency perturbation of the intensity is the probabilistic element in the perturbation. The rainfall intensity is altered based on the changes in the frequency distribution of the rainfall; each intensity (or quantile) has a unique change factor.

–The random removal is addressed in the response to reviewer 1 comment 5.

Specific comments

Abstract

p5442, l14-17: The description of the results is somewhat brief. Please try to be more complete and include the most important conclusions.

o Response –The abstract will be edited to include the most important conclusions.

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Introduction

p5442, l20: Provide some examples of relevant impact studies worldwide.

o Response – Examples of impact studies worldwide will be included. Examples of such studies are Jiang et al. (2007), Xu et al. (2005) and Andersson et al. (2006) among others.

p5443, l10-11: Which results have been obtained for Lake Tana and Nyando catchments in these studies?

o Response – The papers mentioned in p5443, l10-11 examined and reported results based on a larger catchment, either for the entire Nile basin or the Blue Nile and Lake Victoria region. Thus it is not possible to specifically report their results for smaller catchments like Lake Tana and Nyando. However, efforts will be made to identify any other climate change studies that have been performed in these catchments.

p5443, l11-13: How were the changes in climatic inputs translated to changes in hydrological regimes in these studies/ which methods have been used?

o Response – These studies used different methods for translating the changes into hydrological regimes. Bias correction, monthly changes and disaggregation are some of the methods that were used to generate the climate series after which they are used as inputs to hydrological models to generate the hydrological regimes. More details on the specific methodologies will be included in the updated introduction section.

p5443, l15-16: Although not widely investigated, could you give some examples of hydrological climate impact studies where different hydrological models, resolutions or parameterizations have been used?

o Response – Most studies in the Nile basin used a single model to assess impact of climate change. However, outside the Nile, Jiang et al. (2007) used six hydrological models to assess the impact of climate change in a large catchment in China.

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p5443, l20-29: Please clearly indicate in the objective of the paper that besides 17 GCMs and two SRES scenarios, also two different hydrological models for two catchments are applied.

o Response – The objective of the paper will be clarified to include the use of two different hydrological models for the two catchments.

p5444, l14-21: What is the relation between the monsoon-type climate of Lake Tana catchment and the ITCZ?

o Response – In the Lake Tana catchment, the monsoon-type rain refers to the fact that rainfall occurs in high-sun season, which coincides with the northwards shift of the ITCZ.

p5444, l25-26: Please include the surface areas of the two catchments and some geographical information (e.g. elevation and land use distribution).

o Response – The surface areas will be included in the revised manuscript (Nyando $\sim$ 3600 km^2 and Tana $\sim$ 15000 km^2) including the geographical information of the catchments.

Materials and methods

p5445, l9-25: The description of the VHM model is not very clear and needs some clarification. Although the structure will be identified based on time series analysis it would be helpful if some kind of flow diagram of the model is given (the same for the NAM model).

o Response – Flow diagram for VHM will be included.

p5446, l1: How subjective is the calibration of the NAM model? Would the calibrated parameter set be very different when another modeller had calibrated the NAM model? Shouldn't the same calibration method be used for both the VHM and NAM model?

o Response – The subjectivity of the NAM model is perhaps limited because of the

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few parameters it contains (9 to be precise). However, modeller-subjectivity is always involved in rainfall-runoff model calibration when not done in a fully automatic way. Regarding the calibration methods, it is not possible to use the same calibration method for NAM and VHM because of the differences in modelling philosophies for the two models. The VHM approach involves a step-wise model-structure identification process (making use of the sub-flow filter and POT results), while for NAM the more classical two step process (calibration and validation) is followed. Given that the NAM and VHM calibrations were done by the same person (the first author), and the model performance evaluated based on the same statistics (see also our reply to next comment), the authors are convinced that the influence of subjectivity was kept to a minimum.

p5446, l4-5: Which goodness-of-fit statistics have been used in the calibration of VHM and NAM? Also goodness-of-fit statistics related to extreme flows?

o Response – The goodness-of-fit statistics used for performance evaluation of the models are NSE and percentage difference of the total flow as mentioned in table 1 as well as using graphical plots. The NSE is useful as a goodness of fit statistic for the high extremes as they are implicitly assigned higher weights. These goodness-of-fit statistics were, however, not optimized by an automatic calibration method, but by manual calibration (because of the reasons outlined above).

p5446, l8-10: Which method has been used to calculate the weighted averaged time series for rainfall and potential evapotranspiration?

o Response – The method used to calculate the weighted average rainfall and ETo is the Thiessen polygon method; we shall include this information

p5446, l10: Is "Allen et al., 1998" the original reference for the Penman-Monteith method?

o Response – We used the FAO Penman-Monteith method that also explains the method of estimating ETo with limited data. Thus the appropriate reference is Allen

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et al. (1998). However, the original Penman-Monteith (without FAO) reference would perhaps be Monteith (1965).

p5446, l22-25: This data description does not seem to be consistent with the data description in lines 6-16 on this page.

o Response – The data description in the lines 6–16 is meant for describing the data available for calibrating the hydrological model while the data in line 22–25 explains the data used for calculating the change factors for the future climate. We now realize the confusion. The period should have been 1961–2000 and 2046-2065 for the climate model results. However, based on the available historical records (lines 6–16), we compared periods 1971–1990 (Nyando) and 1991–2000 for (Tana) to 2046–2065 to estimate the perturbations. These perturbations were then used to alter the historical periods. This will be clarified in the updated paper.

Results and discussion

p5450, l8: How is the water balance discrepancy (WBD) defined?

o Response – WBD is defined as the percentage difference between the modelled and the measured total flow with the equation. WBD = (modelled total flow- measured total flow)/ measured total flow

p5450, l15-17: In which way were the VHM model results given higher credibility; quantitatively or qualitatively?

o Response –The VHM model higher credibility was qualitatively determined based on the graphical plots shown in fig 3, as the observations' probability distribution is closer to the VHM model results than the NAM results.

p5452, l1-5: This study could be introduced already in the 'Introduction' section.

o Response –The study of Githui, et al (2009) will be moved to the introduction section. It was mentioned here for the purpose of comparison with our results.

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p5453, l1: Fig. 5 is not very clear. What is the change factor in Fig. 5?

o Response –The change factor in the fig 5 represents the perturbation factor that was computed as the ratio between the seasonal volumes from future scenario and the observations. Thus a factor >1 would mean an increase and a factor <1 would mean a decrease.

p5453, l9-12: Also Fig. 4 is not very clear and therefore it is very hard to derive the changes of high and low flows from this figure.

o Response –Fig. 4 compares the observed flows with the future projected flows. This way it is possible to visualize whether the future flows are above the observed flows (control). However, the changes are not easily deduced from this figure. This figure will be rethought.

Conclusions

p5454, l8-9: This conclusion seems to be doubtful. The performance of both models for Nyando catchment is much worse compared to the performance for Lake Tana catchment, at least in terms of NS efficiency. Please discuss the reasons for this large difference in performance. And what are the results for the validation period? Response

o When we compare the performance of both models for each catchment separately, both VHM and NAM show similar performance. However, when the two catchments are compared, the performance of the hydrological models is different. This could be explained by the characteristics of the catchments. Lake Tana catchment has a special feature which is the lake that attenuates the peak flows and the flow series is much smoother than the Nyando case. Since the NSE is highly affected by the peak flows, the model might not be able to simulate the peak flows in Nyando as they did in Lake Tana.

Technical corrections

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o All the technical corrections will be accounted for

References

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 5441, 2010.