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Hydrology and Earth System Sciences Discussions

Interactive comment on "Use of regional climate model simulations as input for hydrological models for the Hindukush–Karakorum–Himalaya region" *by* M. Akhtar et al.

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Response to anonymous Referee #1 The authors of this paper gratefully acknowledge the invaluable comments of Referee #1 on this manuscript. We have attempted to revise the manuscript accordingly. We have added additional analysis and further information, clarified the text where necessary and made changes in figures and tables as requested. We feel the paper has benefited substantially from these changes. The sequence of our response follows the points made in the review comments.

1. Meteorological fluctuations and hydrology of HKH-region Section 3 Methodology of manuscript gives some details of the climatological inputs. We agree with the referee

that this section does not distinguish the general differences of different type of forcing data. However, we feel detailed description of different forcing data sets is not necessary here as it is described elsewhere. We also agree with the referee that the daily meteorological fluctuations are not very important for the hydrology of pluvial runoff regime of HKH-region. To clarify this fact additional analysis and discussion is added in section 4.3 of revised manuscript.

2. BIAS in precipitation data CRU data is derived from meteorological stations observations. The uncertainties in CRU climatology averaged for multi-decadal periods are of the order of 0.5–1.3 ˚C for temperature and 10–25% for precipitation, and are largest over regions having sparse station network and high spatial variability, such as for example in many mountainous areas (New et al., 1999, 2000). In case of HKH region the valley-based meteorological stations are not representative of elevated zones (see section 2 of manuscript). This may result huge precipitation biases in data derived with PRECIS ERA and PRECIS Had. However, the precipitation bias of PRECIS ERA is somewhat higher compared to PRECIS Had. A detailed regional analysis of South Asian domain shows that this fact is observed only in HKH region (Akhtar, 2008) which is may be due to deficiencies in global forcing data. Another reason for large biases may be due to the fact that HKH region receives small amount of precipitation and a small absolute increase/decrease in precipitation data derived from PRECIS simulations gives a larger percentual precipitation bias. To test the feasibility of runoff modeling in HKH region there are two possibilities to use RCM data as input to hydrological models. One approach is to calibrate a hydrological model using bias corrected RCM data. In another approach a hydrological model can be calibrated using RCM data without applying any bias correction. However, in second approach there is a risk that potential biases in RCM simulations may lead to over parameterization (Akhtar et al., 2008). In data sparse regions like HKH region CRU data can be used as reference data for bias correction. A correction factor is derived to level out the modeled monthly average with CRU monthly average. Daily temperature and precipitation data series are bias corrected with this monthly correction factors. This approach provides

a correction of monthly mean climate only and does not consider day to day variability. Therefore the relatively good performance of the GCM downscaled data is not because of the bias correction procedure. However, biased data may influence parameters of hydrological model in a way leading to erroneous results. After bias correction the seasonality of PRECIS ERA and PRECIS Had is similar. To show this bias corrected data in figures will not add any additional information. We will add some of these comments in section 3.1.1 of revised manuscript. We have also added data from Gilgit, Skardu and Astore meteorological stations in Fig. 6 and 7.

3. Variations of T and P with altitudes Catchments in HKH-region have extreme altitude difference and elevation affects the meteorological input variables strongly. For each global forcing the meteorological input variables are averaged over the river basins. For HBV-ERA and HBV-Had (i.e. downscaled reanalysis and downscaled GCM forcing data) average altitude applied was 4472 m for Hunza river basin, 3740 m for Gilgit river basin and 3921 m for Astore river basin (see table 1). These altitudes are derived from the topography used by the PRECIS RCM. For HBV-Met (meteorological station measurements) average altitude applied was 2210 m for Hunza river basin, 1460 m for Gilgit river basin and 2394 m for Astore river basin. We have applied default values of elevation correction factor for precipitation i.e. pcalt=0.1 and for temperature lapse tcalt=0.6 ˚C/100 m. Precipitation values will be multiplied by 1 + h . pcalt, where h is altitude difference (hundreds of meters) between current zone elevation and precipitation station elevation (or weighted mean of several stations).

Specific comments:

4. Resolution of RCM: In introduction we have made the statement that the high resolution of RCM (about 10 – 50 km) is more appropriate for resolving the small scale features of topography and land use, that have a major influence on climatological variables such as precipitation in the climate models. We do agree with the referee that a 10 – 50 km resolution is still far from “ideal” for capturing the spatial variability of rainfall and hydrological processes. However climate simulations

up to 10 km resolution is currently only possible with RCMs such as PRECIS.

5. Downscaled RCM data: to clarify the sentence we will change Kay et al. (2006) demonstrated the feasibility of the direct use of RCM data for flood frequency estimation with Kay et al. (2006) demonstrated the feasibility of dynamically downscaled data for flood frequency estimation.

6. Length and periods of available data series: We will add the following sentences in section 2 in the revised manuscript: “Daily observed discharge data for three river basins are available at the outlets of the basins. These data cover the periods, 1975-1996 for the Hunza basin, 1962-1996 for the Gilgit basin and 1975-1996 for the Astore basin.

7. Source and credibility of CRU data: We will add following sentence in section 3.1.1 “The uncertainties in CRU climatology averaged for multi-decadal periods are of the order of 0.5–1.3 ˚C for temperature and 10–25% for precipitation, and are largest over regions having sparse station network and high spatial variability, such as for example in many mountainous areas (New et al. 1999, 2000)”.

8. Role of bias correction procedure: Please see answer of second comment

9. Revision of section 3.2: We will revise this section in revised manuscript

10. Maps of differences in P and T: This work will affect the length of paper and add little additional information.

11. Conclusions: we will add following sentence to improve this section. Under present climate conditions glacial component is well handled by HBV model and daily meteorological fluctuations are not very important for the hydrology of the region which resulted good performance of hydrological model.

12. Calibration of alpha and beta value: For each river basin, a univariate sensitivity analysis was performed to assess the influence of individual parameters on the output

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of the model. This was done by varying the value of one parameter while keeping other parameters constant (default value). This univariate sensitivity analysis has shown little sensitivity for parameters alpha and beta. Hence multivariate sensitivity analysis was not performed to optimize these parameters and default values were used.

13. Figures: We will improve Figure 1 and Figure 5. We will add observed meteorological observations in Figure 6 and Figure 7. HKH-region is highly elevated zone of the globe and snow is important factor which controls the energy balance of the region. The huge difference in simulated temperature during winter may be due to the deficiencies of energy balance of the driving GCM and re-analysis. However a detailed investigation is needed to address the problem of energy balance of the driving GCM and re-analysis. There are some common biases in both PRECIS Had and PRECIS ERA experiments which indicate that these errors are due to deficiencies in the internal model physics (Akhtar, 2008). However, some of the biases may be related to the inadequate representation of land surface in PRECIS because seasonal variations in surface albedo, roughness and leaf area index could have a significant effect on the climate (Hudson and Jones, 2002). The model currently uses vegetation distribution and soil properties based on the climatology of Wilson and Henderson-Sellers (1985) which does not account for these factors. We think Figure 9 add some additional information on the robustness of hydrological model. This will help in deciding which model is more feasibility for hydrological impact studies.

14. Hydrographs are hardly detectable: Yes an addition of flood and low flows will gives more details however here an addition of double mass curve analysis relating observed and simulated discharges are more informative.

15. References: Following new references are added in the revised manuscript

Akhtar, M.: The climate change impact on water resources of Upper Indus Basin-Pakistan, PhD thesis, University of the Punjab, Pakistan, 132pp, 2008. Akhtar, M., Ahmad, N., and Booij, M.J.: The impact of climate change on the water resources of

Hindukush-Karakorum-Himalaya region under different glacier coverage scenarios. J. Hydrol., 355, 148-163, 2008.

New, M.G., Hulme, M., and Jones, P.D.: Representing twentieth century space time climate variability. Part I. Development of a 1961–1990 mean monthly terrestrial climatology, J. Climate, 12, 829-856, 1999.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 5, 865, 2008.