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## Accuracy assessment of ISI-MIP modelled flows in the Hindukush-Karakoram-Himalayan basins

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Large Asian rivers heading in the Hindukush-Karakoram-Himalayan mountains, and whose streamflow includes significant snow-melt and glacier-melt components, may be highly susceptible to climate warming and pattern changes. Millions of people depend on these streamflows for agriculture and power generation. Reliable predictions of future water availability are therefore needed for planning under a changing climate, and depend on the quality of hydro-climatic modelling. ISI-MIP provides global hydrological modelling results, and need validation at regional scale. This study evaluates the accuracy of modelled flows from the hydrological models used in ISI-MIP, in various sub-basins of the Upper Indus Basin (UIB) and for the reference period 1985-1998. The modelled flows are based on six hydrological models, which are: i) H08, ii) VIC, iii) WaterGAP, iv) WBM, v) MPI-HM, vi) PCR-GLOBWB. Of these models, H08 and VIC are energy-based hydrological models, while the others are temperature-based hydrological models. WBM and MPI are not suitable for the UIB, due to significant under-estimation (by 70-90%) of measured flows by their modelled flows. The remaining four models provide consistent, but still significantly under-estimated flows (up to 60% of measured flows) in all sub-basins, except the Kharmonig basin. Monthly differences between modelled and measured flows vary between sub-basins, but with noticeable over-estimation in winter-spring months and under-estimation during summer months. Accuracy of the bias-corrected precipitation data sets (based on five GCMs) used in the ISI-MIP hydrological models has been assessed, using a basin-wide water balance assessment method. This method shows that all precipitation data sets significantly under-estimate precipitation in the UIB, particularly in the Karakoram sub-basins. The selected ISI-MIP hydrological models have used precipitation data which are under-estimates, which may be a main reason for under-estimated flows. ISI-MIP hydrological modelling needs to use the best available precipitation data for the UIB, but other input data and calibration parameters also need revision. An important message from this study is that caution must be exercised in selecting precipitation data sets and hydrological models in alpine regions such as the Hindukush-Karakoram-Himalayas.