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Glacier regime and climate sensitivity of Chhota Shigri glacier in western Himalaya explored by energy-balance modelling

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The impact of climate change on Himalaya mountain glaciers is increasingly subject of public and scientific debate. However, observational data are sparse and important knowledge gaps remain in the understanding of what drives changes in these glaciers' mass balances. The aim of the present study was to investigate the glacier regime on Chhota Shigri, a benchmark glacier for the observation of climate change in the monsoon-arid transition zone of western Himalaya. To that effect, a glacier model based on the energy budget approach has been developed and tested against three years of observed mass balances. The model was driven by reanalysis data. Surface albedo is parametrized, subsurface heat fluxes and refreezing of meltwater are modelled explicitly. The correlation coefficient of modelled and observed mass balances on 50 m altitude intervals across the glacier for the three years is 0.974. The main source of uncertainty in model results are air temperatures across the glacier, which are calculated using a glacier wind parametrisation developed in the European Alps. Model results are robust to changes in other parameters such as surface roughness or boundary and initial conditions. Contrary to prior assumptions, monsoon precipitation accounts for a quarter to a third of total accumulation. It has an additional importance because it increases the surface albedo during the ablation season. When all accumulation is set to happen in winter, the glacier-wide specific mass balance is reduced by up to 1.000 mm w.e.. The ablation season begins in late April on the lower parts of the glacier and ends in August. Results confirm radiation as the main energy source for melt on Himalaya glaciers. During the monsoon season, shortwave radiation is strongly reduced by cloud cover. Latent heat flux acts as an important energy sink in the pre-monsoon season but is close to zero or even positive in the monsoon season. Mass balance is most sensitive to changes in atmospheric humidity, changing by 900 mm w.e. per 10 % change in humidity. Temperature sensitivity is 220 mm w.e. K^{-1}, which is relatively low on a global scale. For stronger (weaker) monsoon precipitation, temperature sensitivity in the model is reduced (increased). Climate change observed in the region has already reduced the annual mass balance by 1100 mm w.e. according to the model. Model results using 21st century anomalies of the PRECIS RCM based on the SRES A2 scenario suggest that a monsoon increase might offset the effect of warming.