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Climate change and hydrological response in a glaciated catchment in the Himalayas

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Hydrological effects of climate change on glaciated catchments are difficult to assess due to a poor representation of future glacial evolution in most models and the large heterogeneity of climate in areas with steep topography. We develop a spatial-dynamic hydrological model of the Langtang catchment (Nepal) at a spatial resolution of 90 meter that relates river runoff to precipitation and glacial melt processes. The model is forced by high resolution temperature and precipitation fields and at each daily time step precipitation is partitioned in either snow or rain. Part of the rain is routed along the digital elevation model (DEM) and leaves the catchment as rain runoff, while snow accumulates in the upstream parts of the basin and feeds the glaciers. Whereas previous hydrological studies adopt a simple degree day approach in combination with lumped glacier areas to quantify glacial melt, in this study the dynamic sliding of glaciers in the downstream direction is explicitly modeled. Glacier sliding is based on the shear stress with the bedrock and is evaluated on a pixel basis according to Weertman's sliding law. Glaciers only slide when the shear stress exceeds a threshold value that is derived using the slope of the terrain, local glacier thickness and assuming perfect plasticity of the ice. Each time step the sliding ice is transported down the digital elevation model and as temperature increases a degree day factor method is used to model ablation. The melt water is subsequently routed along the DEM. A two step calibration approach was used. Firstly, a 40 year period from 1960-2000 was simulated to calibrate the threshold shear stress, the degree day factor and the resistance of the bedrock using the observed glacier extent in 2000. Secondly, the rain runoff coefficient and base flow parameters were calibrated using observed daily discharges at the outlet of the catchment from 2000 to 2007. Results show that model is able to accurately simulate both the glacier extent using the 40 year time series and the discharge from 2000 to 2007. Based on precipitation and temperature change fields of the IPCC AR4 A1B scenario the effects of climate change on the hydrology are simulated. Preliminary results show that the glaciers withdraw significantly in the future, but that the reduction in melt water is compensated for by an increase in rain runoff. Given the fact that monsoon season coincides with the melt season no significant temporal shifts in the hydrograph occur and effects for downstream areas are likely to be limited. The innovative approach used to model the glaciers is highly suitable for climate change studies as it allows quantifying the future evolution of the glacier tongues dynamically without making assumptions on future glacier extent.