EGU21-3565
https://doi.org/10.5194/egusphere-egu21-3565
EGU General Assembly 2021

Exploring the future hydrology of a Canadian Rockies glacierized catchment and its sensitivity to meteorological forcings

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Glacierized mountain areas are witnessing strong changes in their streamflow generation processes, influencing their capacity to provide crucial water resources to downstream environments. Shifting precipitation patterns, a warming climate, changing snow dynamics and retreating glaciers are occurring simultaneously, driven by complex physical feedbacks. To predict and diagnose future hydrological behaviour in these glacierized catchments, a semi-distributed, physically-based hydrological model including both on and off-glacier process representation was applied to Peyto basin, a 21 km2 glacierized alpine catchment in the Canadian Rockies. The model was forced with bias-corrected outputs from a dynamically downscaled, 4-km resolution Weather and Research Forecasting (WRF) simulation, for the 2000-2015 and 2085-2100 period. The future WRF runs had boundary conditions perturbed using RCP8.5 late century climate. The simulations show by the end-of-century, the catchment shifts from a glacial to a nival regime. The increase in precipitation nearly compensates for the decreased ice melt associated with glacier retreat, with a decrease in annual streamflow of only 7%. Peak flow shifts from July to June and August streamflow is reduced by 68%. Changes in blowing snow transport and sublimation, avalanching, evaporation and subsurface water storage also contribute to the strong hydrological shift in the Peyto catchment. A sensitivity analysis to uncertainty in forcing meteorology reveals that streamflow volume is more sensitive to variations in precipitation whereas streamflow timing and variability are more sensitive to variations in temperature. The combination of the temperature and precipitation variations caused substantial changes both in the future snowpack and in the streamflow pattern. By including high-resolution atmospheric modelling and unprecedented both on and off-glacier process-representation in a physically-based hydrological model, the results provide a particularly comprehensive evaluation of the hydrological changes occurring in high-mountain environments in response to climate change.