Vulnerability to climate change in glacierized headwater mountain basins in the Canadian Rockies and the Austrian Alps is controlled by summer snow dynamics

Caroline Aubry-Wake[1], Lindsey Nicholson[2], Rainier Prinz[2], John W Pomeroy[1]

1 Centre for Hydrology, University of Saskatchewan, Canmore, Canada

2 Department of Atmospheric and Cryospheric Sciences, University of Innsbruck, Innsbruck, Austria

Mountain glaciers worldwide are retreating, with varied consequences for downstream water supply. With a warming climate and shifting precipitation phase, timing and volume, the hydrological processes occurring in headwater mountain catchments are changing. These changes were investigated in two well-studied INARCH basins, Peyto Glacier Research Basin, Canadian Rockies, and the Rofental Basin, Austrian Alps, using a semi-distributed glacio-hydrological model in the Cold Region Hydrological Modelling platform (CRHM) which includes process representation for energy-balance snow and ice melt, ice melt under debris, blowing snow sublimation and redistribution, avalanches, evapotranspiration, and subsurface water storage and flow. The CRHM models were forced with bias-corrected, high-resolution, dynamically downscaled and bias-corrected atmospheric modelling outputs, available at 4km resolution from the WRF model for Peyto, and at 2km resolution from the COSMO for the Rofental. Current climate conditions (the early 2000s) and pseudo-global-warming conditions, which represent simulated weather perturbed by an end-of-century RCP 8.5 scenario, were compared for both basins. The CRHM models were evaluated in each basin with available field data from glacier mass balance, snow accumulation and streamflow observations. Both basins are composed of similar mountain landforms and are predicted to be almost glacier-free by 2100. They have different areas, current glacier coverages, and elevation ranges. Currently, both Peyto and Rofental basins have basin-averaged annual air temperature near -3.8°C and this warms by 5°C in both PGW simulations. The precipitation regime in both basins is currently dominated by snowfall, but Peyto basin receives 15% more precipitation and has a larger proportion of precipitation falling as snow than Rofental. Under PGW, precipitation in Peyto Basin increases by 16%, largely as greater summer rainfall. In contrast, precipitation in Rofental Basin decreases due to a substantial decline in snowfall and increase in rainfall. These contrasting shifts in precipitation cause differing hydrological responses and therefore contrasting climate change impact on streamflow. Peyto Basin end-of-century streamflow will decrease by 7%, mainly due to a substantive decline in late summer flow and a 30% decrease in peak flow, whose timing will advance by one month. In contrast, Rofental Basin streamflow will decrease by 33%, primarily in mid to late summer, and spring streamflow will change very little. Process diagnosis with CRHM suggests the different responses stem from differences in the frequency of future summer snowfall and snowmelt dynamics. The substantial decrease in snowfall and snowmelt in the Alps leads to substantially greater vulnerability to climate change than in the relatively snowier Canadian Rockies.