Diagnosing the Future Hydrology of a Central Asian Glacierized Basin using a Hydrological-Glaciological Land Surface Model

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ABSTRACT

Water resources in high mountain central Asia are strongly dependent on snow and glacier melt which are vulnerable to climate change. How climate change impacts hydrology has not previously been diagnosed in the region using physically-based glacio-hydrological models that can resolve mountain snow and glacier hydrology with confidence. This study assesses the impacts of projected climate change on the hydrology of the snow-covered Ala-Archa River Basin in the Tien Shan Mountains of Kyrgyzstan, a mountain headwater basin, 15% covered by glaciers. Current and future hydrological processes and streamflow were diagnosed using MESH, a Canadian physically-based hydrological land surface scheme with comprehensive representation of cold regions processes. The MESH Ala-Archa model was forced by the EM-Earth (0.1°) and ERA-5 (0.25°) datasets. Temperature and precipitation forcing data over 1991-2010 were seasonally perturbed using outcomes of CMIP5-AR5 subset for RCP 8.5 for the region over the 2081-2100 period. MESH streamflow prediction was good, with Kling-Gupta Efficiency (KGE) scores above 0.9 and percent bias below ±1% over both calibration and validation periods. Under the climate change scenarios examined, the snowfall ratio declined from 49% to 33%, snow-covered period decreased by two months, and peak SWE declined by 15%. Ice melt and snowmelt presently form 40% and 25% of the total runoff, respectively, but snowmelt became the largest source of runoff with warming and deglaciation. The timing of peak streamflow advanced from mid-July to early June, and both peak discharge and annual streamflow volume decreased by more than 50% for the 2081-2100 period compared to recent conditions. These results underline the need for renewed diagnostic assessments of water supply in high mountain headwaters of Central Asia to inform adaptation to climate change.

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