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Future glaciation and river flow in the Vakhsh and Panj drainage basins, Central Asia

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Central Asia is well known as an area of substantial water problems mainly caused by climate change and careless consumption of water resources. As in other parts of the globe where high mountains are surrounded by arid and semi-arid zones, snow and glacier melt are major contributors to runoff and important resources for agriculture in the lowlands. The FAO-UNESCO has started a "Climate Impact Study on Streamflow" to estimate future discharge in the catchments of the rivers Vakhsh (39,100 km2) and Panj(114,000 km2), the two tributaries of Amu Darya river. According to the World Glacier Inventory (WGI) prepared in the mid 20th century, the Panj and Vakhsh catchments have glacier covers of 3,913 km2 and 3,675 km2, respectively. A new inventory was conducted in 2003 within the frame of the GLIMS project.

We used a simple parametrization scheme based on steady state conditions to infer the ice volumes for the two different time periods in the past and to extrapolate future changes. The resulting volumes for the WGI are 170-200 km3 for the Panj catchment and 200-240 km3 for the Vakhsh catchment. From the mid of the 20th century to 2003, an area (volume) decrease of 8.2% (10.5%) for the Panj and 7.5% (4.1%) for the Vakhsh catchment was determined.

A comparison of two digital elevation models (SRTM of 2001 and Aster 2008) show for the glacier areas a mean mass change of -0.61 m a-1 for the Vakhsh and -0.81 m a-1 for the Panj.

Regional climate simulations project a warming of 1.8°C-2.9°C until 2050, while it remains unclear if and in what direction precipitation will change. Assuming a temperature increase of 2°C until 2050 and no change in precipitation, the ice reserves in the two catchments will decline at an accelerated rate in comparison to the past with total volume reduction of 75.5% for the Panj basin and of 53% for the Vakhsh basin.

To simulate present-day and future runoff, the HBV-ETH hydrological model was set up in the two sub-basins of Abramov (56 km^2, 51% glaciated, Vakhsh catchment) and Kudara (1575 km^2, 21% glaciated, Panj catchment). The daily time step model needs semi-distributed topographic input (area by elevation and exposition classes for glaciated parts and the whole catchment) and is driven by temperature and precipitation. Calibration is performed on the basis of measured runoff and, if available, glacier mass balance. Results show that the model can reproduce observed runoff curves in the two basins quite well, which is expressed by mean model efficiencies of R^2=0.84 and R^2=0.91 for Abramov and Kudara, respectively.

Runoff scenarios for mid-century conditions were created by modifying glaciation and the meteorological input data. Glacier cover was changed according to the findings above and a temperature rise of 2°C was assumed. To test the sensitivity of precipitation changes, additional model runs with an increase and with a decrease of 20% were performed. While annual discharge remains stable or increases up to 30%, a common feature of all runoff scenarios is a seasonal shift of water resources from August towards early summer.