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Large-scale glacio-hydrological modelling and its usefulness to correcting high-mountain precipitation in Central Asia

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Mountain precipitation is often strongly underestimated as observations are scarce, biased towards lower-laying locations and prone to wind-induced undercatch, while topographical heterogeneity is large. This presents serious challenges to hydrological modelling for water resource management and climate change impact assessments in mountainous regions of the world, where a large population depends on water supply from the mountains. Assessments of future changes to the Asian water towers have been hampered due to the large precipitation uncertainties.

The quality of six existing precipitation datasets (observation-based reanalysis datasets, satellite observation datasets and the output of high-resolution regional climate models) were compared over five headwaters of the Tarim River (Cenral Tian Shan, East Pamir and Karakoram). The dataset incorporating the highest observation density (APHRODITE) is corrected by calibrating a newly-developed glacio-hydrological (SWIM-G) that simulates all important mass balance and ice dynamics terms. Fitness to observed discharge, glacier hypsometry and mass balance are used as objective functions.

The application of the large-scale glacier-dynamics model demonstrates the utility of using this form of inverse modelling to inform the precipitation correction in such data-scarce conditions and reduce the uncertainty of climate change impact assessments in high-mountain and glacierised catchments. Substantial disagreement of annual mean precipitation between the analysed datasets, with coefficients of variation in catchment mean precipitation of 68% on average was found. The model-based precipitation estimates are on average 1.5 to 4.3 times higher than the APHRODITE data, but fall between satellite-based and regional climate model results.