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Assessment of water resources of Himalayan headwaters – a combined modeling and remote sensing approach

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The Himalayan headwaters are significant source areas for many important rivers in Central and Southern Asia during the dry season. Thus, detailed knowledge of the water resources in those areas is a prerequisite for sustainable development of the entire region (incl. downstream regions) and especially of the touristic attractive headwater catchments. This study presents a combined modeling and remote sensing approach based on distributed hydrological modeling and image analysis of repeated terrestrial photographs. The distributed catchment model TAC_D was developed further and applied to a highly glacierized Himalayan catchment in the Sargamatha National Park (near Mt. Everest). The model runs on a daily time step with daily mean air temperature and daily sums of precipitation as input data. The spatial delineation of hydrological response units was achieved by taking topographic and physiographic information from maps and satellite images into account, which enabled the incorporation of process knowledge into the model. The simple but robust data pre-processing and modeling approach allowed the determination of all components of the water balance of a remote, data scarce headwater catchment with a minimum of input data. A series of repeated photographs taken over a period of 50 years in the Sargamatha National Park was analyzed to assess changes in glacier extent. The qualitative results show that the main valley glaciers did not change much in length due to a substantial coverage of debris. In elevations around 5500 m asl., however, a considerable thinning could be observed at glaciers without debris cover. Several small glaciers without mass gained from higher elevations have already disappeared. However, some high altitude debris-free glaciers exhibited only a small change or even an increase in size. These glaciers are located at elevations up to 7000 m asl. and experienced increasing solid precipitation inputs during the monsoon season as reported for the Gokyo area and Kathmandu airport. These findings in combination with the simulations of the TAC_D model enabled a reliable assessment of the water resources available in the Himalayan headwaters. Glaciermelt (330 to 700 mm/a) is the largest source of water in most of the simulated hydrological years, whereas precipitation (200 to 1000 mm/a) dominates the years 1987/88 and 1988/89. Discharge (420 to 850 mm/a) is the largest component of the water balance. Actual evapotranspiration ranges from 80 to 120 mm/a. Storage change varies between 40 and 570 mm/a. The combined modeling and terrestrial photography approach improves the model evaluation and delivers more reliable simulation results in data scarce catchments.