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Glaciers and small ice caps in the macro-scale hydrological cycle - an assessment of present conditions and future changes

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Glacier and small ice cap melt water contributions to the global hydrologic cycle are an important component of human water supply and for sea level rise. This melt water is used in many arid and semi-arid parts of the world for direct human consumption as well as indirect consumption by irrigation for crops, serving as frozen reservoirs of water that supplement runoff during warm and dry periods of summer when it is needed the most. Additionally, this melt water reaching the oceans represents a direct input to sea level rise and therefore accurate estimates of this contribution have profound economic and geopolitical implications.

It has been demonstrated that, on the scale of glacierized river catchments, land surface hydrological models can successfully simulate glacier contribution to streamflow. However, at global scales, the implementation of glacier melt in hydrological models has been rudimentary or non-existent. In this study, a global glacier mass balance model is coupled with the University of New Hampshire Water Balance/Transport Model (WBM) to assess recent and projected future glacier contributions to the hydrological cycle over the global land surface (excluding the ice sheets of Greenland and Antarctica). For instance, results of WBM simulations indicate that seasonal glacier melt water in many arid climate watersheds comprises 40 % or more of their discharge.

Implicitly coupled glacier and WBM models compute monthly glacier mass changes and resulting runoff at the glacier terminus for each individual glacier from the globally complete Randolph Glacier Inventory including over 200 000 glaciers. The time series of glacier runoff is aggregated over each hydrological modeling unit and delivered to the hydrological model for routing downstream and mixing with non-glacial contribution of runoff to each drainage basin outlet. WBM tracks and uses glacial and non-glacial components of the in-stream water for filling reservoirs, transfers of water between drainage basins (inter-basin hydrological transfers), and irrigation along the global system of rivers with net discharge to the ocean.

Climate scenarios from global climate models prepared for IPCC AR5 are used to explore an expected range of possible future glacier outflow variability to estimate the impacts on human use of these valuable waters and their poorly understood net contribution to sea level change.