Relationship between Indian summer monsoon and melting Himalayan glaciers

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Melting glaciers and rainfall from the Indian summer monsoon (ISM) are the two major sources of potable water in the Indian subcontinent. However, how ISM influences the Himalayan glaciers is still uncertain, despite the fact that ISM is responsible for 80% of annual rainfall (300-400 cm yr^{-1}) over the south-facing slopes of the Himalaya. Here we have used stable-isotope ($\delta^{18}O$, δD) compositions of stream water to quantify the relative contributions from glacial melt, precipitation (snowmelt and rainfall), and groundwater over various stages of the monsoon's annual cycle. Stream water samples were collected during pre-monsoon (April-June), monsoon (July-September) and post-monsoon (October-November) periods of 2014, 2015, and 2016 in the headwaters of the Ganges River. Moreover, groundwater samples were collected from all over the basin. The $\delta^{18}O$ and δD compositions of river water show large seasonal variations. A site- and season-specific three-component isotope-mixing model was constructed using a Monte Carlo framework and matrix inversion technique. Results show that the post-monsoon season (October-November) has the highest glacier melt proportions (83±11%), as compared to pre-monsoon (53±7%), and monsoon (40±6%) periods. This is contrary to conventional wisdom that proportions of glacial runoff are highest during summer, i.e. the pre-monsoon season (April-June) when temperatures are high. This observation cannot be readily explained by temperature variability or other factors. We hypothesize that latent and sensible heat released from rainfall will act as drivers that enhance glacial melting. Energy balance calculations support this hypothesis, and our calculation reveals that rain-induced glacial melting could contribute ~8% to 30% of the total glacial runoff. It appears that Monsoon rainfall is a significant driver of Himalayan glacier melt.