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IIT-I maps Gangotri glacier flow over 4 decades; says July, not Aug, now peak discharge month

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A study by IIT-Indore has reconstructed Gangotri glacier system's streamflow over the past four decades and found that snowmelt has declined while rainfall and underground water contributions have increased, shifting peak discharge from Aug to July. The study, based on historical data and computer modelling, reflects how climate variability is gradually altering the hydrological balance in the upper Bhagirathi basin.

Gangotri glacier, one of the largest in the Himalayas, is the main source of the Bhagirathi—a major tributary of the Ganga. While the Ganga receives a relatively smaller share of its flow from glacier melt compared to the Indus, meltwater dominates in high-altitude areas like Gangotri. In recent decades, shrinking glaciers and shifts in melt timing have raised concerns for downstream communities that rely on the Ganga basin water for irrigation, hydropower, and drinking.

The research team — Parul Vinze, Mohd Farooq Azam, Ghulam Hussain, Smriti Srivastava, Md Arif Hussain, and Umesh Haritashya — published their findings in the 'Journal of the Indian Society of Remote Sensing'. Vinze, a PhD scholar at IIT-Indore's Glaci-Hydro-Climate Lab, said the long-term reconstruction offered a clear picture of how Himalayan headwaters are responding to climate shifts. "After 1990, the discharge peak shifted from Aug to July, linked to reduced winter precipitation and earlier summer melting," she said.

File pic

The team used a high-resolution glacio-hydrological model — a simulation tool to estimate water release from snow, glacier ice, rainfall, and underground sources — to reconstruct streamflow from 1980 to 2020. The model was calibrated using field discharge records (2000–03), satellite-derived glacier mass balance data (2000–19), and snow cover maps from MODIS (Moderate Resolution Imaging Spectroradiometer), a Nasa satellite system tracking snow and ice.

Their findings showed that snowmelt accounted for 64% of annual streamflow, glacier melt 21%, rainfall-runoff 11%, and baseflow — water from underground sources like springs — 4%. Rainfall-runoff refers to water that flows over the surface into rivers after rain, while baseflow comes from underground seepage. The average yearly discharge was 28 ± 1.9 cubic metres per second, peaking at about 129 m^3/s in July. Despite a rise in average annual temperatures, the study did not find a significant long-term increase in glacier melt or rainfall. Instead, it found a decline in snowmelt contribution due to reduced snow cover, while runoff from rainfall and underground sources increased. "This subtle but steady reshaping of the basin's water balance signals that climate variability is already altering runoff seasonality," said Azam, who supervised the study and also serves as senior intervention manager (cryosphere) at the International Centre for Integrated Mountain Development in Kathmandu.

The study identified summer rainfall and winter temperatures as key drivers of annual streamflow. Summer rainfall had a strong correlation ($r = 0.62$), followed by winter temperatures ($r = 0.52$), highlighting the influence of seasonal climate patterns on water availability.

Researchers warned that changes in meltwater timing and volume will directly impact hydropower, irrigation, and livelihoods in upper Himalayan regions. "Any change in the timing and volume of meltwater directly affects irrigation, hydropower, and livelihoods in upper reaches," Azam said. He added that Uttarakhand's increasing vulnerability to floods, cloudbursts, and glacial lake outburst floods underlines the need to monitor glacier-fed rivers more closely.

The team stressed the importance of long-term field monitoring, high-resolution climate projections, and updated glacio-hydrological models. "Accurate modelling, backed by field data, is key for anticipating shifts in water availability," Azam added. "These changes in meltwater seasonality and runoff volume will severely affect hydropower generation and irrigation at higher elevations."

The IIT-Indore study — conducted at an institute established only in 2009 — confirms that beyond physical retreat, the glacier's internal water dynamics are also changing. These shifts could significantly affect the lives of millions living in the Ganga.