Annual Progress Report of the Project

'Long-Term Monitoring of Gangotri Glacier, Garhwal Himalaya'

(April 2025 – March 2026)

Submitted

by

Dr. Amit Kumar (Scientist C, WIHG)

Wadia Institute of Himalayan Geology,33, General Mahadeo Singh Road, Dehradun, Uttarakhand

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Background

The Himalayan Mountain Range hosts one of the largest concentrations of glaciers outside the Polar Regions, comprising several thousand glaciers that vary widely in size, morphology, and dynamic behavior. These glaciers play a crucial role in regional hydrology and serve as sensitive indicators of climate variability and change. Recent glaciological observations across the Himalaya reveal a pronounced reduction in snow accumulation rates accompanied by enhanced ablation, reflecting a sustained negative mass balance and accelerated glacier retreat. Despite their scientific and societal importance, systematic ground-based glaciological investigations in the Himalaya remain sparse due to the region's challenging terrain, harsh climatic conditions, and logistical constraints. Recognizing the need to strengthen long-term glacier monitoring, the Department of Science and Technology (DST), Government of India, has mandated the Wadia Institute of Himalayan Geology (WIHG), Dehra Dun, to undertake comprehensive monitoring of selected Himalayan glaciers. In this context, the Uttarakhand State Disaster Management Authority (USDMA) has sponsored a research project entitled ***"Long-term Monitoring of Gangotri Glacier, Garhwal Himalaya,"*** which was awarded to WIHG in December 2021, with financial support formally released in March 2022.

The approved objectives of the project are the following:

- Mapping and monitoring of the Gangotri group of glaciers.
- Mapping and monitoring of glacial lakes in the Gangotri group of glaciers.
- Monitoring of meteorological (temperature, rainfall and snowfall) and hydrological (water level/discharge and sediment transfer) parameters throughout the year and identification of extreme events.
- Risk assessment of glacial hazards (GLOF, debris flow, flash floods, etc.) using an integrated approach i.e. meteorological, hydrological, seismological and satellite data.
- Dissemination of information to the local administration with regard to any emanating threat from the glacial hazards.

WIHG has carried out the following tasks during the April 2025 to March 2026.

- All necessary permissions to visit the Gangotri Glacier region were obtained from the forest authorities. However, since March 2025, the project has largely remained without technical staff, as both the Project Scientist and Project Assistant positions became vacant. Although recruitment was initiated, only one Project Assistant joined for a short time, and the Project Scientist position remains vacant.
- Following the project extension, all monitoring activities resumed in the Gangotri Glacier region from April 2025. Significant snowfall during January to mid-March 2025 had restricted access to Gaumukh, and the project team was able to visit the snout only in late May 2025.
- To ensure continuity and monitoring, two (02) watch and wards were engaged in the project from April 2025. They monitored day-to-day activities at the base camp, ensured the safety of instruments, and regularly checked their proper functioning at Bhojwasa, Chirbasa, and Maneri sites.
- During field visits from **April to June 2025**, it was confirmed that the Bhagirathi River continued to flow along its original course, with no unusual activity observed near the Gangotri Glacier snout **(Figure 1)**. Both the Gaumukh region and Bhojwasa base camp were largely free of seasonal snow by late April and May **(Figure 1)**. Field observations also identified several small supraglacial lakes over the ablation zone of the Gangotri Glacier **(Figure 1)**, which were further corroborated by a LISS IV false-color image dated May 1st 2025 **(Figure 2)**. The formation of these lakes reflects ongoing melting processes on the glacier's debris-covered surface. As previously noted, the meltwater stream from the Raktavan Glacier, which was connected to the main trunk of the

Gangotri Glacier when the project was formulated, was flowing freely and merging with the main Bhagirathi stream, contributing directly to the river system. In an earlier visit in December 2024, the team also confirmed normal river flow and the absence of abnormal activity near the snout **(Figure 1)**.

Figure 1. Illustrating the (Gaumukh) snout, the base camp at Bhojwasa with field instruments, thick supraglacial debris cover over the ablation zone, and the meltwater stream emerging from the Raktavan Glacier.

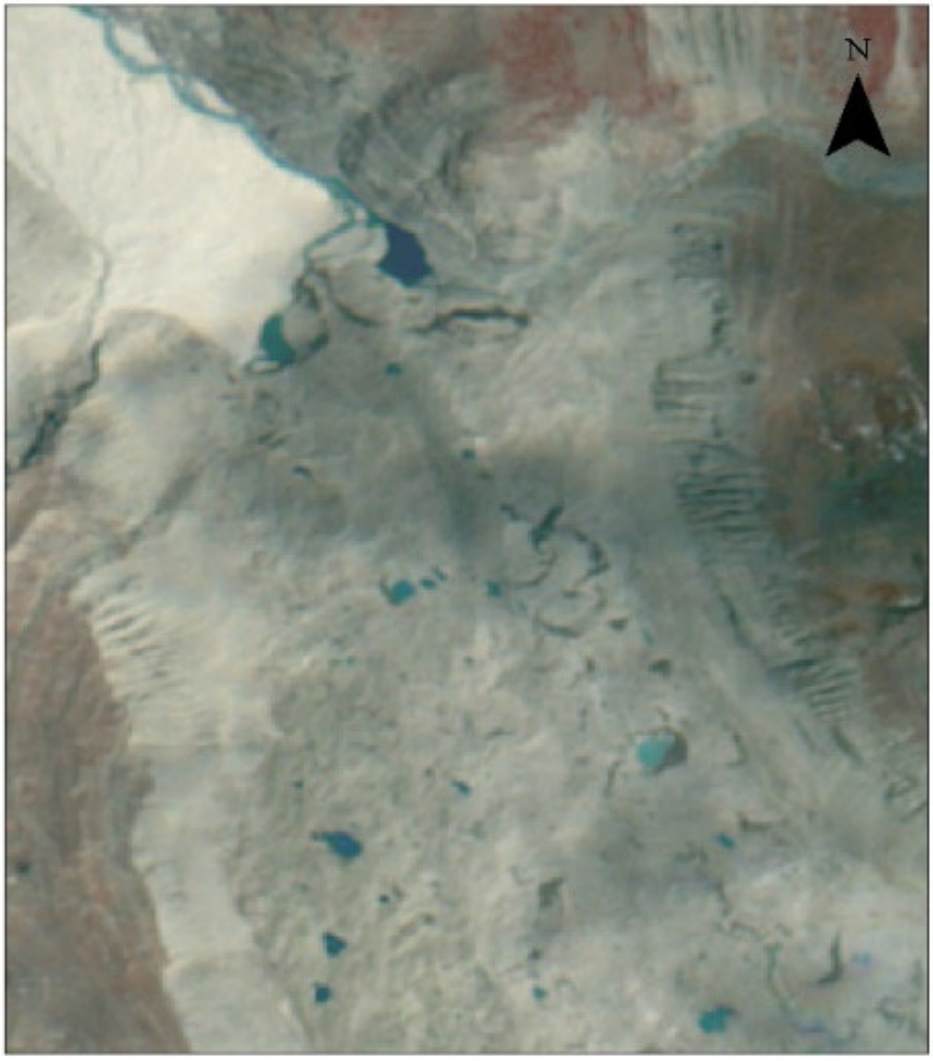

Figure 2. Supraglacial lakes over debris-covered ablation zone visible on LISS-IV False Colour Composite (01st May 2025).

- The Gaumukh (snout) and the emerging Bhagirathi River were distinctly observed, with sediment-laden meltwater actively flowing downstream during July 2025. To investigate the sediment source, two cloud-free Sentinel-2 images dated **19th and 27th July** were examined. The analysis indicated deposition of sediments in the proglacial zone near Gaumukh. The most likely origin of this material is the meltwater channel draining from the Meru Glacier, where a debris-flow event had occurred and continues to contribute sediment to the main channel, although no direct or significant alteration at the snout itself was evident **(Figure 3)**. Comparison of the two image dates highlighted short-term surface reconfiguration driven by meltwater dynamics. However, the absence of any major anomalies at the snout suggests that this zone remained largely stable during the observation period **(Figure 3)**.
- In early August 2025, the watch and wards inspected the broadband seismic station at Maneri Dam site. During their return toward Gangotri, intense rainfall affected the valley. By the following morning, the Dharali event had triggered landslides and flooding, disrupting the Bhatwari–Harsil–Gangotri road at several locations **(Figure 4)**. With damaged bridges and debris obstructing access, the team was stranded at Bhatwari and maintained coordination with local authorities while providing limited updates. Once conditions improved and partial access was restored, they reached Gangotri and

confirmed that the glacier region remained largely unaffected. All installed instruments were functioning, except for manual thermometers, which showed erroneous readings due to damaged mercury columns.

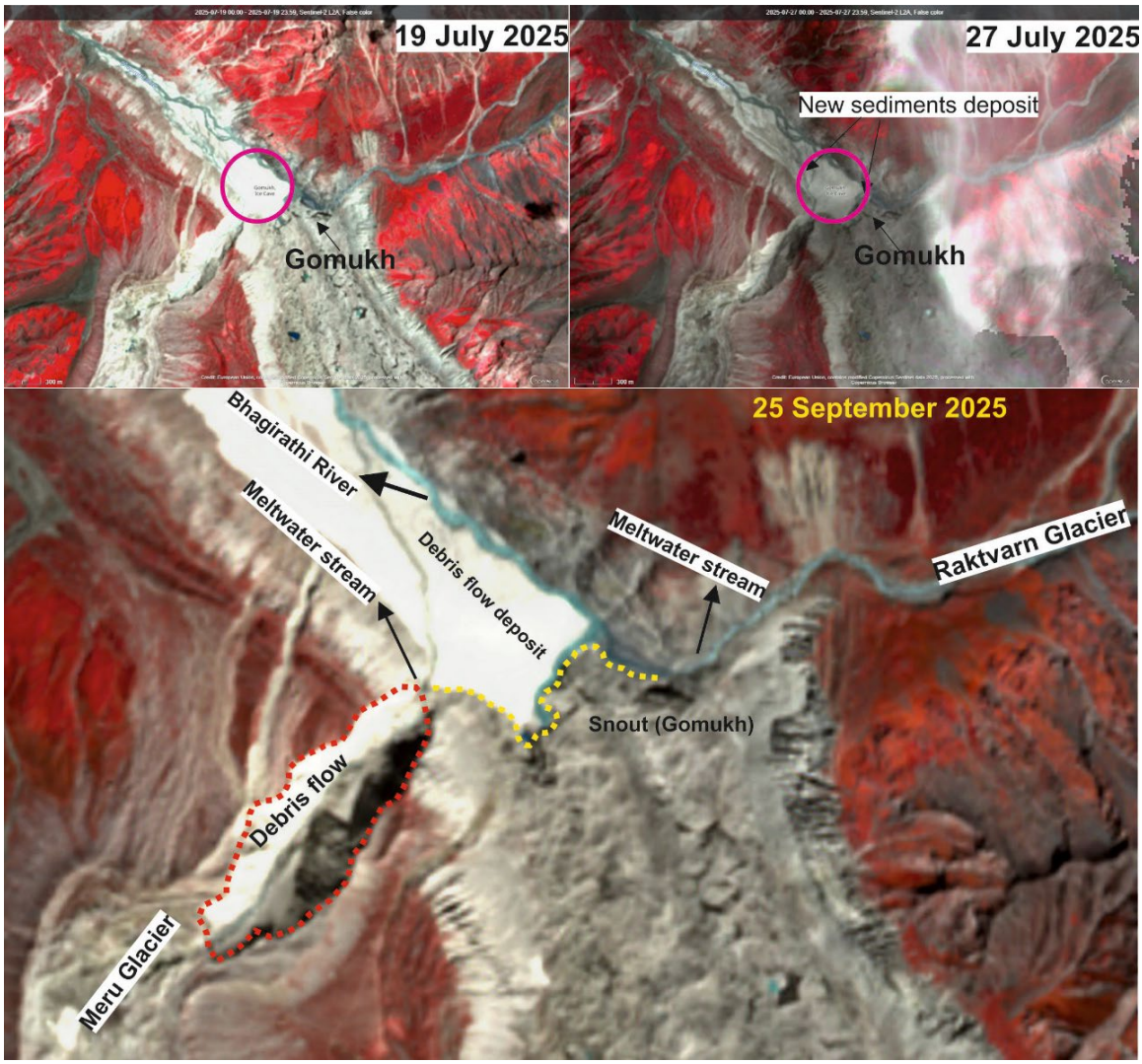

Figure 3. Showing the Gaumukh (snout) and the meltwater stream emerging from the Raktavan–Meru (tributary) glaciers, which subsequently joins the main Bhagirathi River.

- A WIHG team from had planned a field visit during this period to initiate project-related activities; however, the Dharali event (5th August 2025) prevented this visit. Consequently, critical tasks such as fencing and securing the observatory could not be completed. In addition, the installation of the WIHG-procured Automatic Water Level Recorder (AWLR) was postponed.
- Between July and September 2025, the watch and ward staff stationed at Bhojwasa carried out routine monitoring of instrumentation, and ensured their safety from any unusual activities. They conducted regular checks at Maneri, Chirwasa, and Bhojwasa to confirm proper functioning of the instruments. The team also provided continuous updates on road conditions and accessibility following the Dharali event, reporting severe disruption of key routes and restricted access to the valley **(Figure 4)**.
- Field observations in September 2025 indicated enhanced meltwater activity near the glacier snout. The Meru Glacier contributed a consistent meltwater that incised further along the left lateral moraine, while the Raktavan Glacier supplied continuous flow eroding the right lateral moraine. Meltwater discharge from the main glacier trunk was

also significantly elevated, likely due to sustained ablation and limited fresh snowfall across the basin **(Figure 4)**.

Figure 4. Showing the road condition along the Gangotri Highway, where debris flows have washed away sections of the road, caused cracks, and rendered the flood-affected Bhagirathi valley without any motorable route.

- A subsequent visit up to Dharali confirmed that travel beyond Harsil toward Gangotri remained highly difficult. Even the Uttarkashi–Harsil route was disrupted, making field movement unsafe. Updates from the watch and ward staff proved crucial in informing the project team about ongoing conditions and the persistent challenges in accessing the glacier region.
- The progress of the project for the period April to September 2025 (six months) was presented at USDMA in October 2025. During the presentation, it was conveyed that several planned activities could not be executed due to the Dharali event, particularly the fencing of the observatory. Furthermore, the installation of the Automatic Water Level Recorder (AWLR) procured by WIHG could not be carried out in the region. Therefore,

an extension of at least two summer seasons was requested to complete the remaining tasks, and the project has accordingly been extended up to December 2027. Approval from the competent authority at WIHG was also obtained for the engagement of watch and wards valid until March 2026.

- Both the Project Assistant and Project Scientist positions remained vacant during the extended period (till September 2025). Following a further extension (up to December 2027) and to maintain project continuity, the recruitment process for both roles will be initiated. In the meantime, a request to relax the qualification criteria and fellowship emoluments for the Project Scientist position was made and subsequently approved by USDMA and the Director, WIHG.

Figure 5. The base camp at Bhojwasa and field instruments remained under snow during October and November, while the snout (Gaumukh) was clearly visible with snow cover across the region and a snow-free landscape during December.

- Between October and December 2025, the watch and ward staff stationed at Bhojwasa carried out regular monitoring of daily base camp activities and routine inspections were conducted to verify proper functioning of instruments at Maneri, Chirbasa, and Bhojwasa.
- The installation of the Automatic Water Level Recorder (procured from WIHG), along with fencing of observatories and maintenance of hydrological sites using gabion mesh, is planned after the winter season, likely from May 2026. Multiple snowfall events during October–December 2025, coupled with logistical challenges, prevented field operations and delayed AWLR installation. Additionally, the production of a documentary film is planned once all instruments are integrated with real-time monitoring systems.

Figure 6. The base camp at Bhojwasa and Chirbasa remained under snow during October and November, while the observatories were clearly visible and snow-free during December.

- Observations from multiple visits conducted between October and December 2025 indicated that the Bhagirathi River continued to follow its natural course, with no abnormal activity reported near the Gangotri Glacier region. The Gaumukh area and

Bhojwasa base camp remained largely free of persistent snow cover, except during episodic fresh snowfall events **(Figure 5)**.

- During October and November, rainfall followed by snowfall events blanketed the Gangotri region, resulting in complete snow cover at the Bhojwasa and Chirwasa **(Figure 6)**. These conditions significantly restricted access and hindered routine field visits.

Figure 7. The base camp at Bhojwasa and field instruments remained under partial snow during March 2026, followed by a transition to largely snow-free conditions.

- Observations from multiple field visits conducted between January and March 2026 indicate that the Gangotri Glacier region, including the Gaumukh snout area and Bhojwasa base camp, remained completely snow-covered, with intermittent episodes of fresh snowfall **(Figure 7)**. Despite the harsh winter conditions, all installed instruments were found to be functioning properly, and no unusual geomorphic, hydrological, or glacial activity was observed during the visits. These observations suggest relative stability in the region during the winter monitoring period, while also highlighting the persistence of seasonal snow cover.
- The temporal monitoring of snowfall and snowmelt dynamics within the basin was carried out over an annual cycle using multispectral satellite data, primarily derived from Landsat 7/8, Sentinel-2, and LISS-4 sensors and field observations were complemented by satellite-based analysis.

- The analysis of Sentinel-2 satellite data over the Gangotri Glacier during April 2025 onwards reveals significant variability in snow cover, influenced by both seasonal patterns and regional meteorological conditions typical of the central Himalayan basin.
- Satellite-based analysis revealed significant variability in snow cover during **April 2025 to June 2025**. Snow cover decreased from ~74% (5th April) to ~68% (10th April), followed by a temporary increase to ~80% (25th April) due to fresh snowfall at higher elevations. Thereafter, a consistent decline was observed, with snow cover reducing to ~58% (15th May), ~55% (20th May), and further to ~33% by 23th June **(Figure 8)**, reflecting dominant ablation processes.

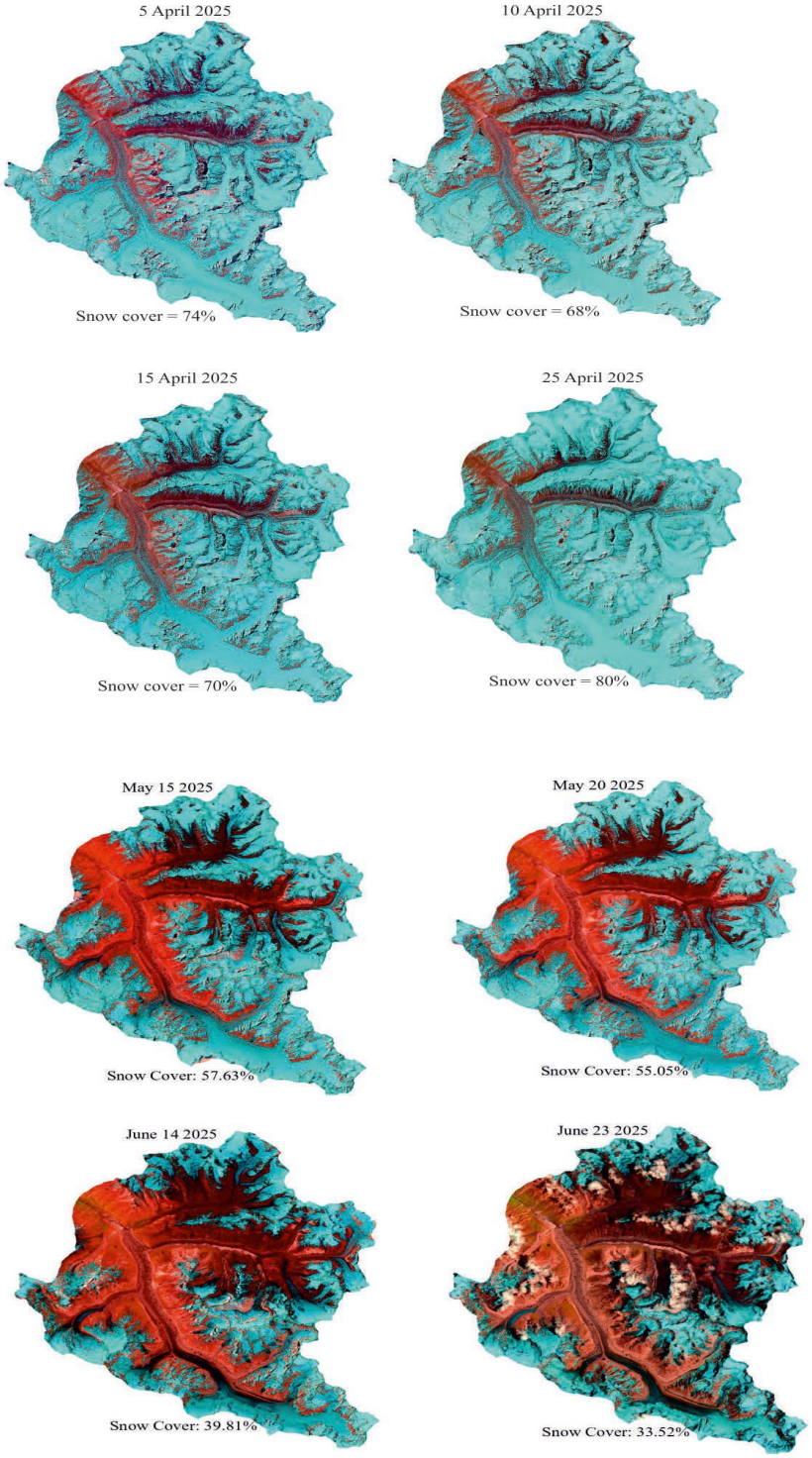

Figure 8. Snow cover distribution in the Gangotri Glacier basin during April to June 2025, mapped up to Bhojwasa.

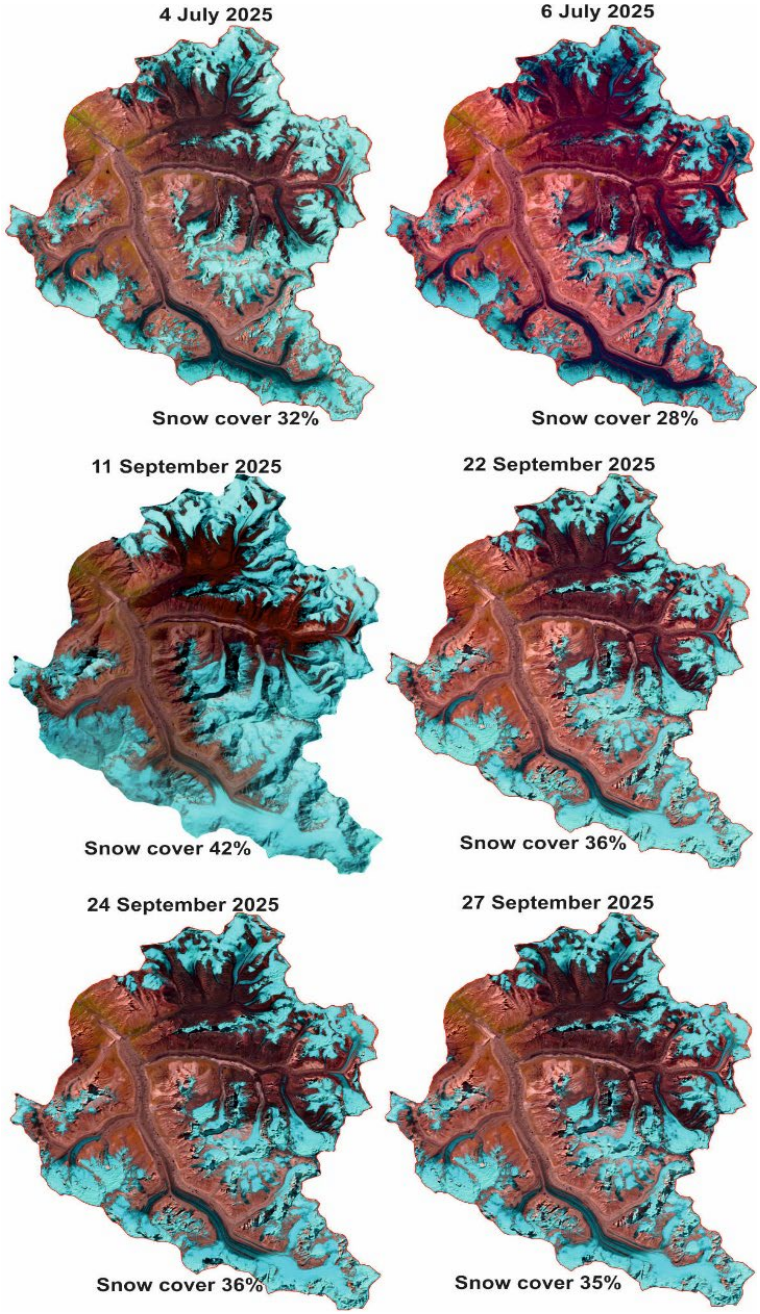

Figure 9. Snow cover distribution in the Gangotri Glacier basin during July to September 2025, mapped up to Bhojwasa.

- Overall, the pattern indicates that while late-season snowfall events in April briefly increased snow cover, the dominant process through May and June was ablation, leading to rapid depletion of the seasonal snowpack. This progressive melting is likely to have contributed significantly to river discharge in the Bhagirathi Basin during the pre-monsoon period.
- Seasonal snow cover analysis revealed a clear decline during the peak melt season from July to September 2025 was observed. Snow-covered area reduced from 32% on 4th July to 28% by 6th July, indicating rapid ablation under warmer conditions. In September, snow cover decreased from 42% on 11th September to 36% on 22th September, remained stable around 36% on 24th September, and further stabilized near 35% by 27th September, suggesting either short-term fresh accumulation or a temporary slowdown in melt toward the end of the month **(Figure 9)**.

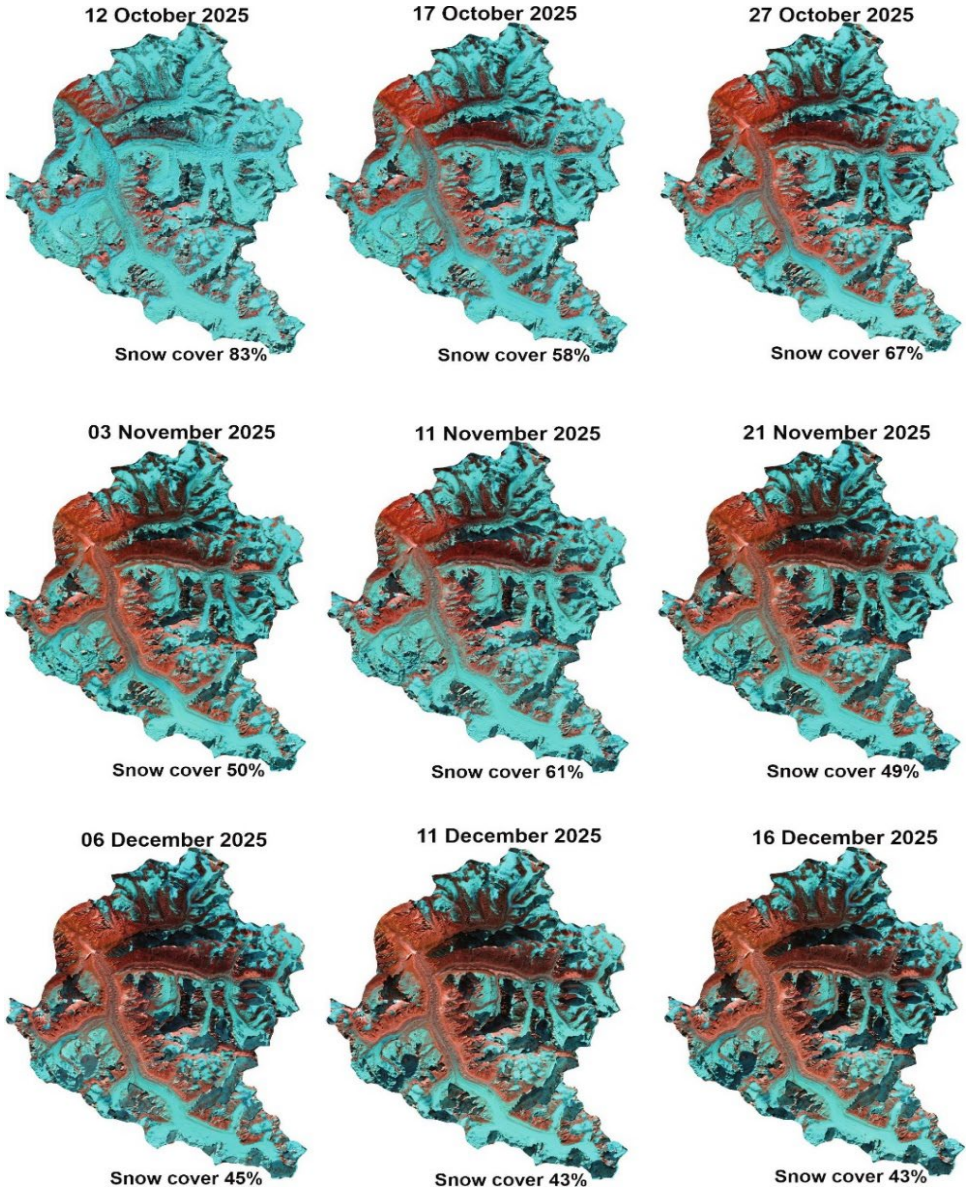

Figure 10. Snow cover distribution in the Gangotri Glacier basin during October to December 2025, mapped up to Bhojwasa.

- Further at the end of ablation season October 2025 onwards, Sentinel-2 and Landsat imagery from 12th, 17th, and 27th October were analyzed to validate field observations and assess the spatial extent of snowfall across the basin. Snow cover was highest (~83%) on 12th October, indicating extensive fresh snowfall. By 17th October, it declined to ~58% due to rapid melting and compaction at lower elevations following rainfall–snowfall transitions. By 27th October, snow cover increased again to ~67%, suggesting renewed snowfall at higher elevations under cooler conditions **(Figure 10)**. These results highlight the short-term variability of snow cover in response to changing meteorological conditions.
- Snow cover exhibited dynamic variation during November 2025. It was ~50% on 3rd November (pre-snowfall baseline), increased to ~61% by 11th November (peak extent), and declined to ~49% by 21st November, slightly below the initial level, indicating post-snowfall ablation through melting or sublimation. This pattern reflects rapid snow accumulation and decay linked to short-term weather fluctuations.
- Both field observations and satellite data indicated the absence of major snowfall events in December. Snow cover remained relatively stable, recorded at 45% on 6th December,

43% on 11th December 2025, and 43% on 16th December 2025. Minor decreases were attributed to compaction, sublimation, or localized melting. Field photographs from 29th December 2025 showed snow-free patches around Bhojwasa, while frozen water sources indicated low temperatures that preserved the November snowpack as the dominant snow cover throughout the month **(Figure 11)**.

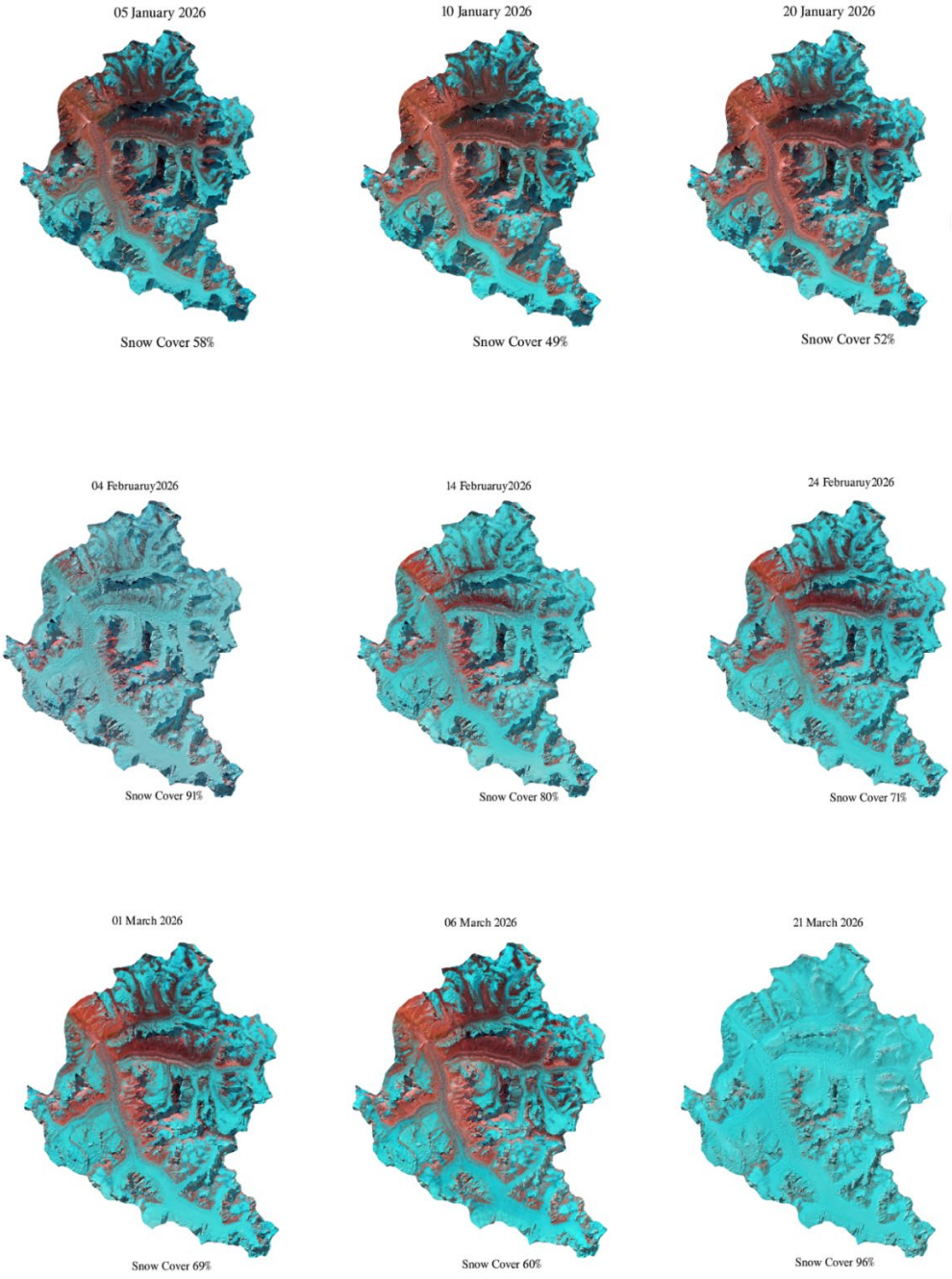

Figure 11. Snow cover distribution in the Gangotri Glacier basin during January to March 2026, mapped up to Bhojwasa.

- In January 2026, snow cover fluctuated between ~58%, 49%, and 52%, indicating a shift from the stable December regime to a more dynamic system influenced by intermittent snowfall and short-term ablation. In February, a marked increase in snow cover was observed, with peaking at ~91% (04th February 2026) and then gradually declining to ~80% (14th February) and ~71% (24th February 2026), reflecting strong initial accumulation followed by systematic melting. In March, the snow regime showed further

variability, with decreasing from ~69% (01st March) to ~60% (06th March 2026) due to early-month ablation, followed by a sharp increase to ~96% (21st March 2026), indicating a major late-season snowfall event.

- Across all months, spatial patterns remained consistent, with higher elevations and shaded slopes retaining snow for longer durations, while lower valley regions exhibited faster depletion. Overall, the observations highlight a transition from stable winter snow conditions to a highly dynamic and climate-sensitive snowpack system in the Gangotri Glacier basin.

During the entire period, the following major observations were made:

- *During April 2025 to March 2026, field observations confirmed stable geomorphic conditions, with the Bhagirathi River maintaining its natural course and no anomalous activity observed near the Gaumukh snout. Despite active sediment transport and short-term surface reorganization, no significant geomorphic alteration at the snout was detected, indicating localized impacts without major instability. As the basin falls within the Bhagirathi catchment, where the Dharali disaster occurred, it was observed that the heavy rainfall event of August 2025 had no significant impact on the Gangotri base camp and snout region.*
- *The region remained largely snow-free during late spring, summer, and winter, while significant snowfall events were observed from January to March 2026. However, supraglacial lakes were present over the ablation zone, as also confirmed through LISS-IV imagery, indicating active surface melting processes. Meltwater contributions from the Raktavan Glacier continued to feed into the Bhagirathi River system without disruption.*
- *Instrumentation, including broadband seismic stations and AWSs, remained fully operational during the reporting period. An integrated module for real-time data transmission from BBS installed at Maneri has been procured, and its installation is planned in May 2026.*
- *Tenders for satellite data procurement, procurement of a new AWLR, fencing works for observatories, and preparation of a documentary film are currently underway and will be floated upon receipt of the third installation.*
- *The unspent balance for the period April 2025 to March 2026, as reflected in the UC & SoE, has been committed towards the salary of watch and ward personnel (including ongoing and proposed engagements), salaries of newly recruited project staff, and fieldwork activities scheduled for April–May 2026. It will also support the procurement of consumables such as bottles and filter papers required for routine glacier monitoring.*
- *Following the project extension, monitoring activities resumed in the Gangotri Glacier region from April 2026. All necessary permissions is required and under processes from forest authorities, for the visit of watch and ward and WIHG team for the season 2026-2027.*
- *The Project Scientist selected following the extension of the project in June 2025 did not assume the position, and the Project Assistant who joined subsequently resigned within a short period. As a result, both positions remained vacant for a significant portion of the project duration, leading to a lack of dedicated technical personnel. This staffing gap adversely affected the continuity of field operations and may have influenced overall project progress. To address this gap, the recruitment process was initiated with approved relaxation in eligibility criteria for the Project Scientist position by USDMA. Subsequently, interviews for the positions of Project Associate-II and Project Assistant were successfully conducted on 23rd and 24th March 2026 to restore technical workforce capacity.*

Dr. Amit Kumar