

Annual Progress Report

Long-Term Monitoring of Gangotri Glacier, Garhwal Himalaya

(April 2022–March 2023)

By

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Submitted to



उत्तराखण्ड शासन

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Background

The Himalayan Mountain Range contains thousands of glaciers of varying properties, which are spread over 37000 km² and a stretch of 2400 km from East to West. The glacier inventory by the Geological Survey of India indicates there are 9575 glaciers in the Indian Himalayan Region (IHR). It is a well-established fact that changes in the glaciers are a key indicator of climate change; recent observation shows that snow accumulation is reducing while the ablation is increasing in the Himalaya. However, there are only a handful of ground-based studies on Himalayan glaciers. Therefore, the Department of Science and Technology (DST) has given the Wadia Institute of Himalayan Geology (WIHG), Dehra Dun the mandate to monitor Himalayan Glaciers. Presently, Uttarakhand State Disaster Management Authority (USDMA) has sponsored a project entitled “Long-term monitoring of Gangotri Glacier, Garhwal Himalaya” to WIHG (Letter no. 1765/XVIII-B-1/21-12(5)/2021 dated 21.12.2021) for which the funds were allocated 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.

Based on the work plan submitted to USDMA, WIHG has carried out the following tasks from April 2022 to March 2023:

1. Permission for the establishment of meteorological, hydrological and seismological observatories within the Gangotri National Park from the district administration and forest department has been requested.
2. Permission for watch and wards to be stationed at Bhojwasa throughout the has been granted by the forest department (Gangotri National Park) for the year 2022-2023.
3. Appointment of two (02) watch and wards has been done and stationed at Bhojwasa.
4. Recruitment of project staff (Project Scientist and Project Assistant) has been done successfully.
5. Tenders for the purchase of one (01) manual meteorological observatory, two (02) Automatic Weather Stations (AWS), one (01) Automatic Water Level and Velocity Recorder (AWLR), and two (02) broadband seismometers (BBS) have been done.

During the project, several visits by project staff were carried out for the monitoring of the snout and nearby regions. Based on the field observations, it has been indicated that the meltwater stream from Gangotri Glacier originates near the left lateral moraine, flowing across the snout of the glacier (Gaumukh) before moving downward (**Figure 1a**). This flow across the snout of the glacier accelerates the melting of the frontal region of the Gangotri Glacier. Also, a fresh snowfall event (7 cm) was witnessed on 24th May 2022 at Bhojwasa.

Further from April to June 2022, the pro-glacial stream emerging from Raktvarn is exposed from the right bank of Gaumukh, i.e. the ice wall retaining the debris material has been evacuated and the stream is now joining the main Bhagirathi River on the surface, which was earlier discharging into the sub-glacial channel of Gangotri Glacier (**Figure. 1b**). The ice from the Gaumukh (snout) breaks and falls into the Bhagirathi stream during the melting season (May to October 2022) which is a natural process (Figure 1c) and is transported downstream up to 3 km at Bhojwasa (**Figure 1d**). A manual water level recorder at the Bhagirathi River (**Figure 1e**) and an ordinary rain gauge (**Figure 1f**) were installed near the base camp at Bhojwasa for the monitoring of extreme events. The depletion of snow cover during the melting season over the Gangotri glacier basin is depicted using satellite images acquired during the same period. The upper region of the basin is covered with permanent snow. Also, a fresh snowfall event (7.62 cm) was witnessed on 11 October 2022 at Bhojwasa, which is confirmed by the satellite image (**Figure 2**). During this period, no development of any major lake was reported in the Meru Bamak, Raktvarn Glacier, and Gaumukh region

(Figure 3). The Bhagirathi River was flowing uninterrupted without any natural or artificial damming from the debris in the proglacial region of Gangotri Glacier.



Figure 1. Path of Bhagirathi River flowing across the snout of Gangotri Glacier in September 2022 (a); frontal part of the Gangotri glacier (left to right view) covered with ice and debris and exposure of pro-glacial stream emerging from Raktvarn Glacier during September 2022 (b); the opening of Gaumukh (snout) and broken ice blocks scattered in the river during the peak melting season (c); and transported ~3 km downstream at Bhojwasa (d); location of manual river gauge installed for the recording of water level during the melting season (e); and location of ordinary rain gauge installed near the base camp at Bhojwasa (f).

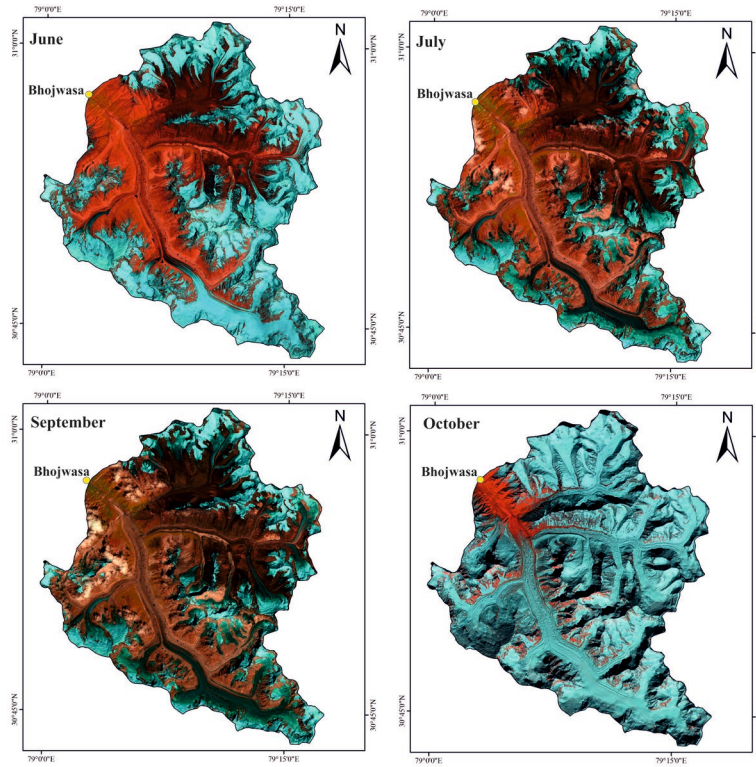


Figure 2. Overview of the snow cover pattern in the Gangotri glacier basin during the summer season of 2022

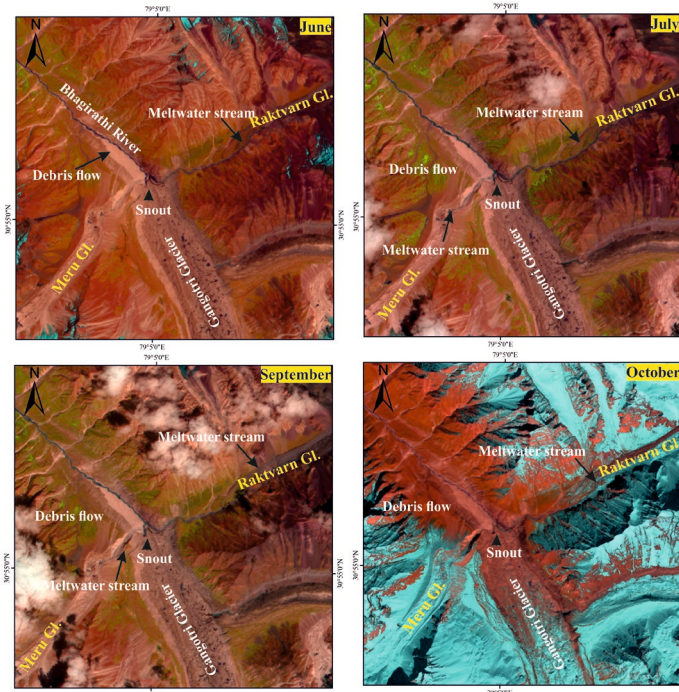


Figure 3. Satellite images indicating the presence of debris, no damming or lake, and uninterrupted natural flow of Bhagirathi River in the frontal region of Gangotri Glacier during the melting season (June to October) 2022.

Similarly, the fieldwork was conducted by the project staff from October to December 2022, and observed that, at the end of December 2022, the surface water of the Bhagirathi River near the snout was frozen, while the meltwater stream was flowing below the frozen layer (**Figure 4**). It has also been observed that there has been no major change in the path of the river Bhagirathi and the snout of Gangotri Glacier from July to September 2022. The Bhagirathi River was flowing uninterrupted during the observation period (**Figure 5**).

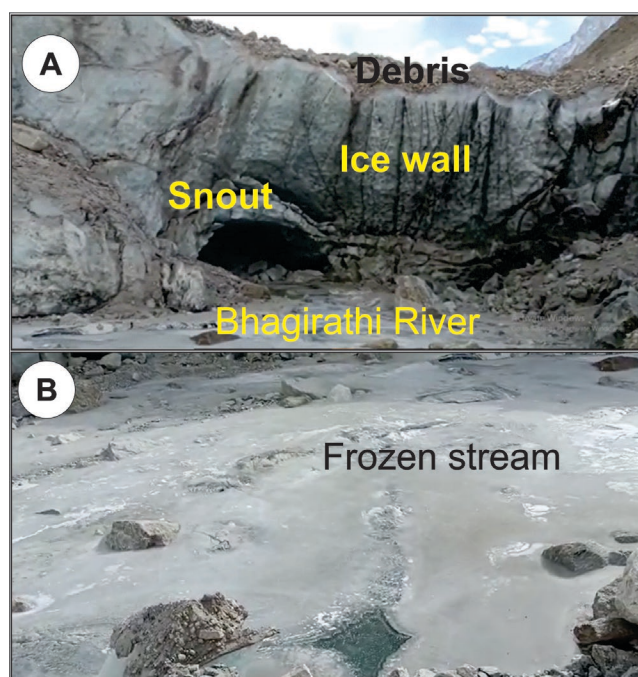


Figure 4. Field photographs showing the snout and meltwater stream of Gangotri Glacier (A) and the frozen surface of the stream (B).

Further, the changes in the snow-covered area (SCA) in the basin up to Bhojwasa during the period from October to December 2022, indicate that the higher reaches of the basin witnessed snowfall during early October 2022 while the November and December months were dry. This has also been confirmed by field observations. The basin was covered by ~81% snow on 13th October 2020 which significantly reduced to 35% on 16th December 2022 reflecting a consistent reduction in SCA between October and December 2022 (**Figure 6**). A meeting was called by the Secretary, of USDMA with other officials of USDMA on 17.11.2022 to discuss the updates of the project. The difficulties faced by WIHG in the implementation of the project were also discussed and the minutes for the same were communicated to the concerned departments.

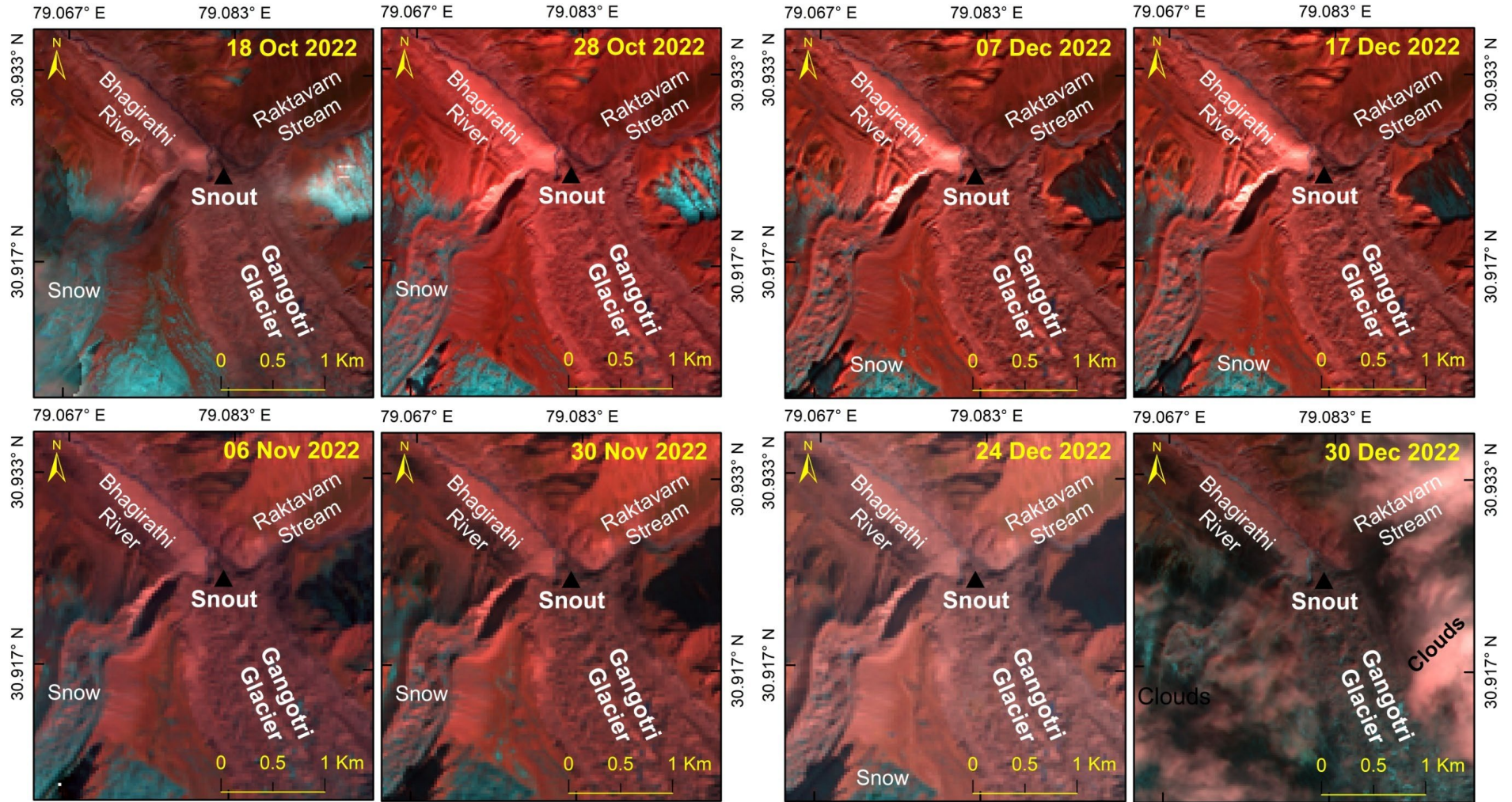


Figure 5. Satellite images indicating the presence of debris, no damming or lake, and uninterrupted natural flow of Bhagirathi River in the frontal region of Gangotri Glacier from October to December 2022.

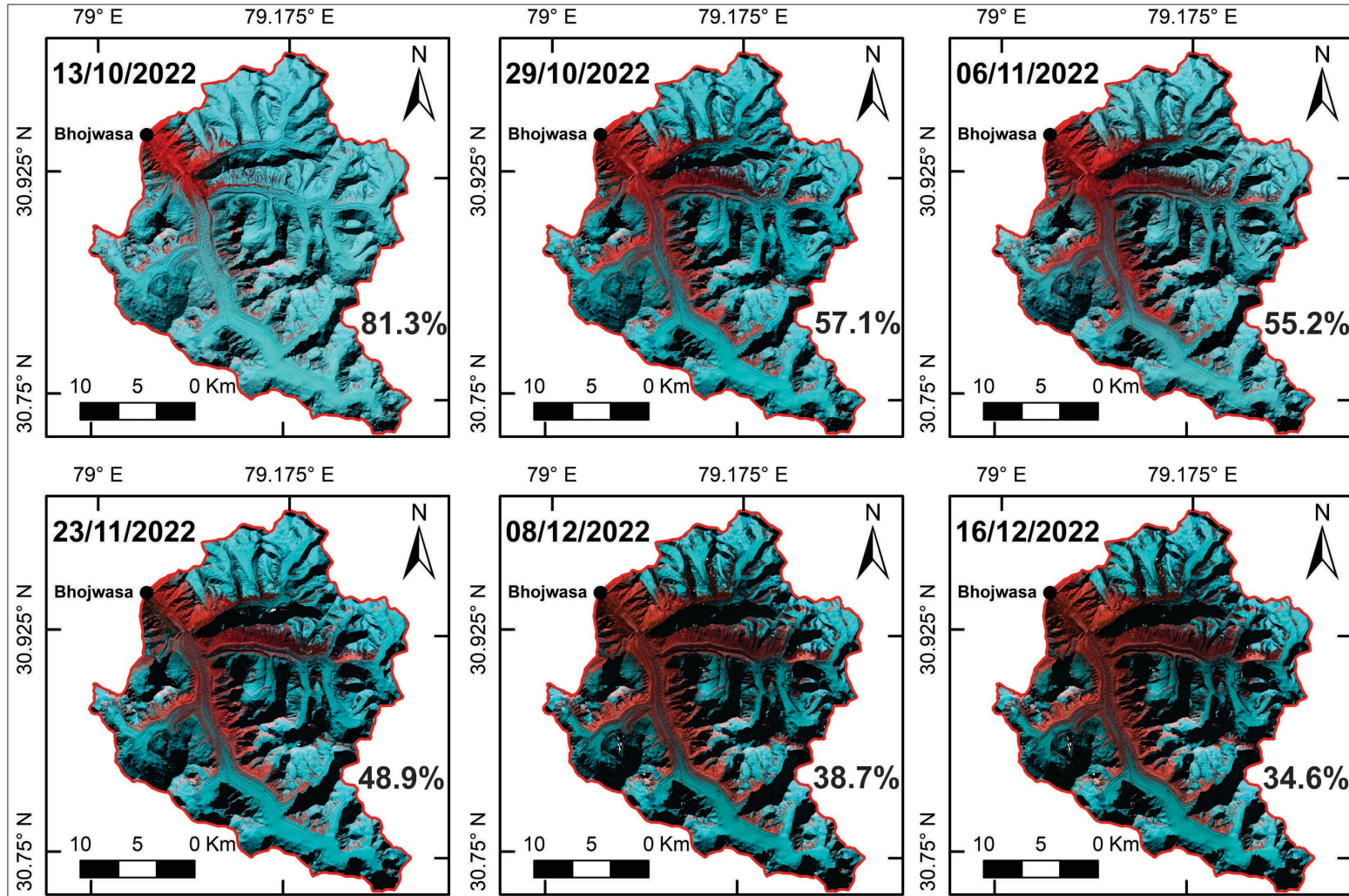


Figure 6. Distribution of Snow-covered area over the Gangotri Glacier basin from October to December, 2022.

After the meeting, permission for a satellite phone and to conduct a drone survey was granted and the letter for the same was sent to the state authorities for perusal. From October to December 2022, there is no emanating threat observed in the region. In continuation with this, the project staff was stationed at Bhojwasa during the winters. The physical observations and satellite-based information were collected to monitor the status of the snout and the river Bhagirathi from January to March 2023. The observations indicated that the stream from Gangotri Glacier still originates near the left lateral moraine, flowing across the snout of the glacier (Gaumukh) before moving downward (**Figure 7A**). During the end of January and February, surface water in the Bhagirathi River near the snout was found in a frozen state while some water was flowing below the frozen layer (**Figures 7B & 7C**). The base camp at Bhojwasa was fully covered under snow during winter (**Figures 7D**).

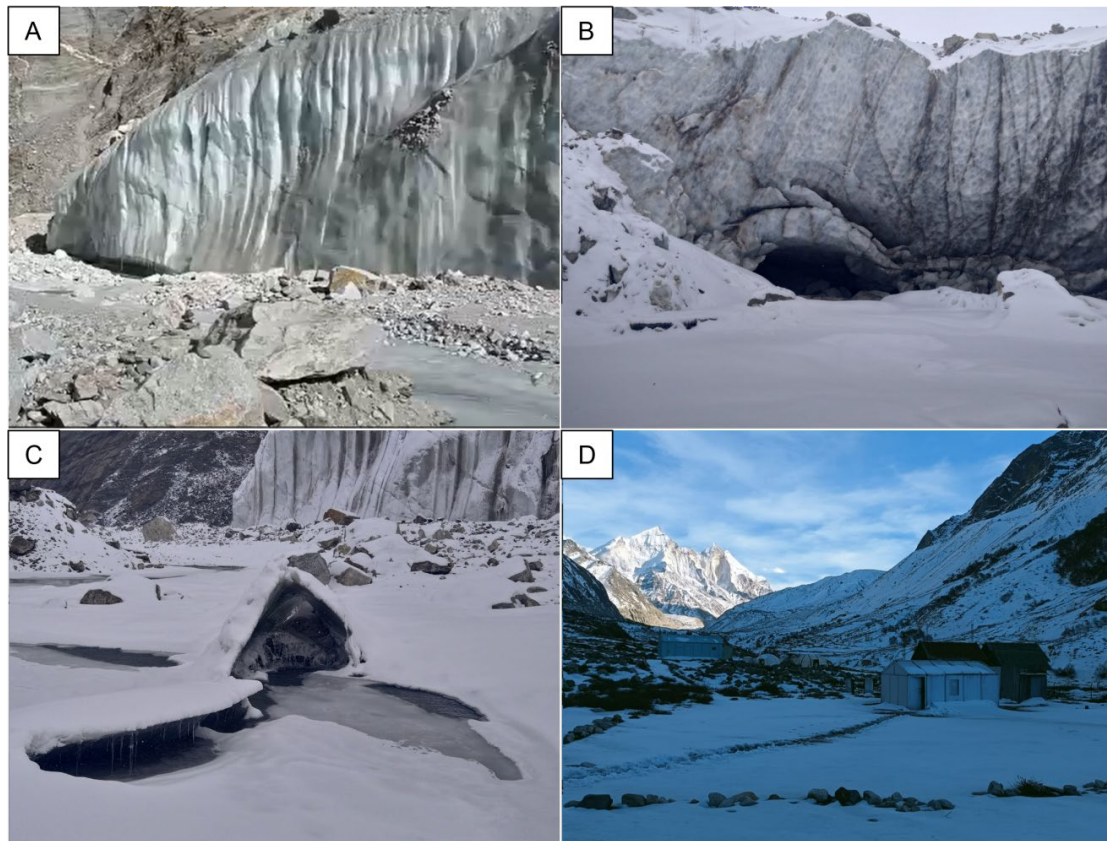


Figure 7. Field photographs showing the status of the snout of Gangotri Glacier, the stream emerging from it, and base camp at Bhojwasa during winters (January-March 2023).

The high temporal satellite images acquired from January to March 2023, there are no major changes observed in the snout and nearby region of the Gangotri Glacier. The

Bhagirathi River is found flowing uninterrupted during the observation period (**Figure 8**). Analysis also indicates that the Raktavarn stream was joining Bhagirathi below the Gangotri Glacier snout. Further, the ground-based information and satellite images indicates that Gangotri glacier witnessed snowfall between January and February 2023 while images of March 2023 indicate melting of snow exposing the glacier surface and ice (**Figure 8**).

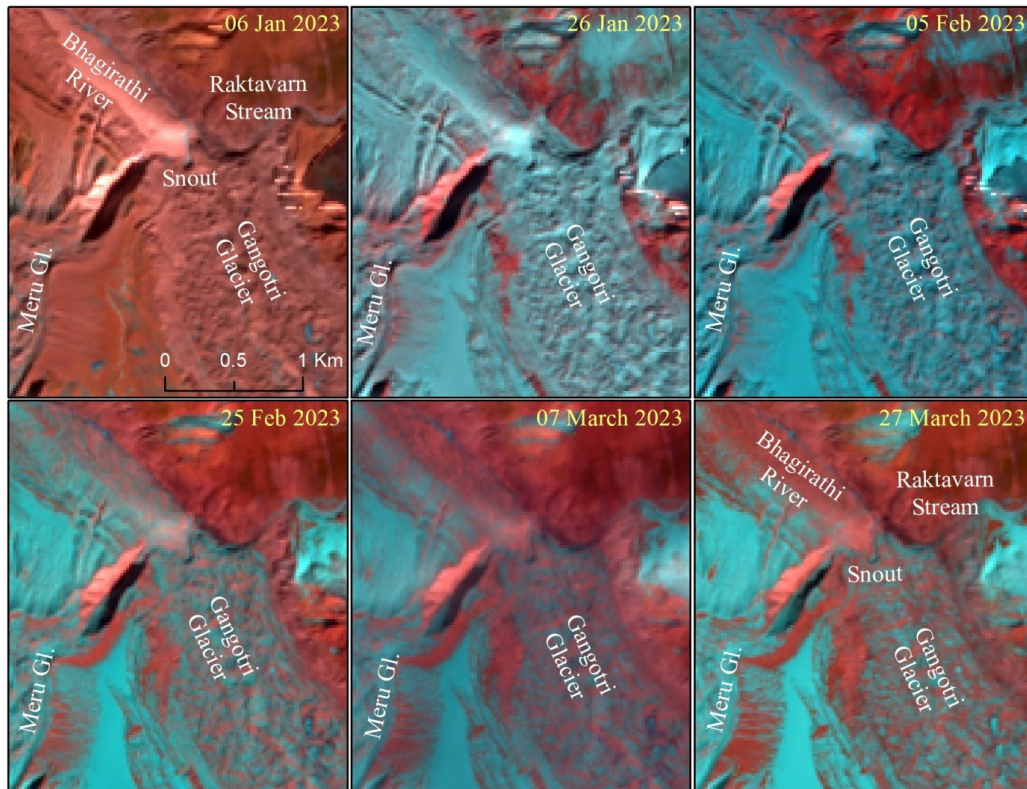


Figure 8. Satellite images indicating the presence of debris, no damming or lake, and uninterrupted natural flow of Bhagirathi River in the frontal region of Gangotri Glacier from January to March 2023. Moreover, images show the snowfall events around the Gangotri Glacier.

The inventory of glacier and glacial lakes will be prepared after the field visit of scientists and project staff from May to October 2023. The purchase and installation of the instruments requested in the project will also be completed by November 2023.

Based on field observations and satellite data, there is no emanating threat observed in the region from April 2022 to March 2023.