

# Space Based Assessment and Review of Chamoli, Uttarakhand (North India) Rockslide Event of February 07, 2021

**About the 7 February, 2021 Event:**

**Introduction:**

The unfortunate Chalkpaga and Chalkpaga valleys in the Chamoli district of Uttarakhand were impacted by a massive landslide event triggered by a massive earthquake, caused by a major rupture on 7 February 2021. Figure 1 shows the location of the region where the landslide took place.

**Figure 1 Study area:**

The International Space Station (ISS) and the Indian Space Research Organisation (ISRO) have been monitoring the region since the landslide event. The ISS has been providing high-resolution satellite imagery of the region, which can be used to monitor the landslide event and its impact on the surrounding area. The ISRO has been providing high-resolution satellite imagery of the region, which can be used to monitor the landslide event and its impact on the surrounding area.

**Satellite Based Observations:**

**Post-event Developments:**

The satellite-based data showed that the landslide event was triggered by a massive earthquake on 7 February 2021. The satellite-based data showed that the landslide event was triggered by a massive earthquake on 7 February 2021. The satellite-based data showed that the landslide event was triggered by a massive earthquake on 7 February 2021.

**Aerial Observations:**

**Aerial Images:**

Aerial images were collected from the region after the landslide event. The aerial images showed that the landslide event was triggered by a massive earthquake on 7 February 2021. The aerial images showed that the landslide event was triggered by a massive earthquake on 7 February 2021.

**Facts Emerging From Analysis:**

**Results:**

- The satellite data from the International Space Station (ISS) and the Indian Space Research Organisation (ISRO) have been monitoring the region since the landslide event. The ISS has been providing high-resolution satellite imagery of the region, which can be used to monitor the landslide event and its impact on the surrounding area. The ISRO has been providing high-resolution satellite imagery of the region, which can be used to monitor the landslide event and its impact on the surrounding area.
- The satellite-based data showed that the landslide event was triggered by a massive earthquake on 7 February 2021. The satellite-based data showed that the landslide event was triggered by a massive earthquake on 7 February 2021.
- The aerial images showed that the landslide event was triggered by a massive earthquake on 7 February 2021. The aerial images showed that the landslide event was triggered by a massive earthquake on 7 February 2021.

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## ABOUT THE 7 FEBRUARY, 2021 EVENT

### Introduction:

The catchments of Rishiganga and then Dhauliganga valleys in the Chamoli district of Uttarakhand were impacted by a catastrophic flood triggered due to a massive rockslide, caused by wedge failure on 7<sup>th</sup> February, 2021. Figure-1 shows the location of the region where the event took place.

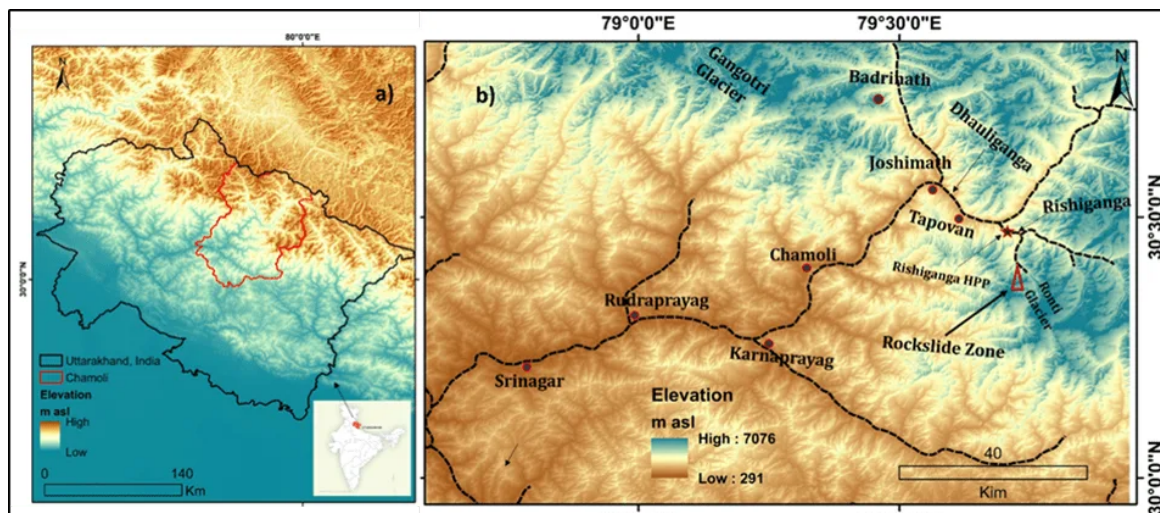


Figure-1 Study area

The International Charter Space and Major Disasters (ICSMD) was activated by ISRO to have multisensor high resolution coverage over the affected area. ICSMD is a consortium of space faring members having a constellation (61 as on date) of highly agile, multi-sensor and multi-resolution of satellite resources, which can be tasked based on type of disaster and requirement, very rapidly over the disaster affected areas to collect information on being activated. Figure-2 shows Charter activation process.

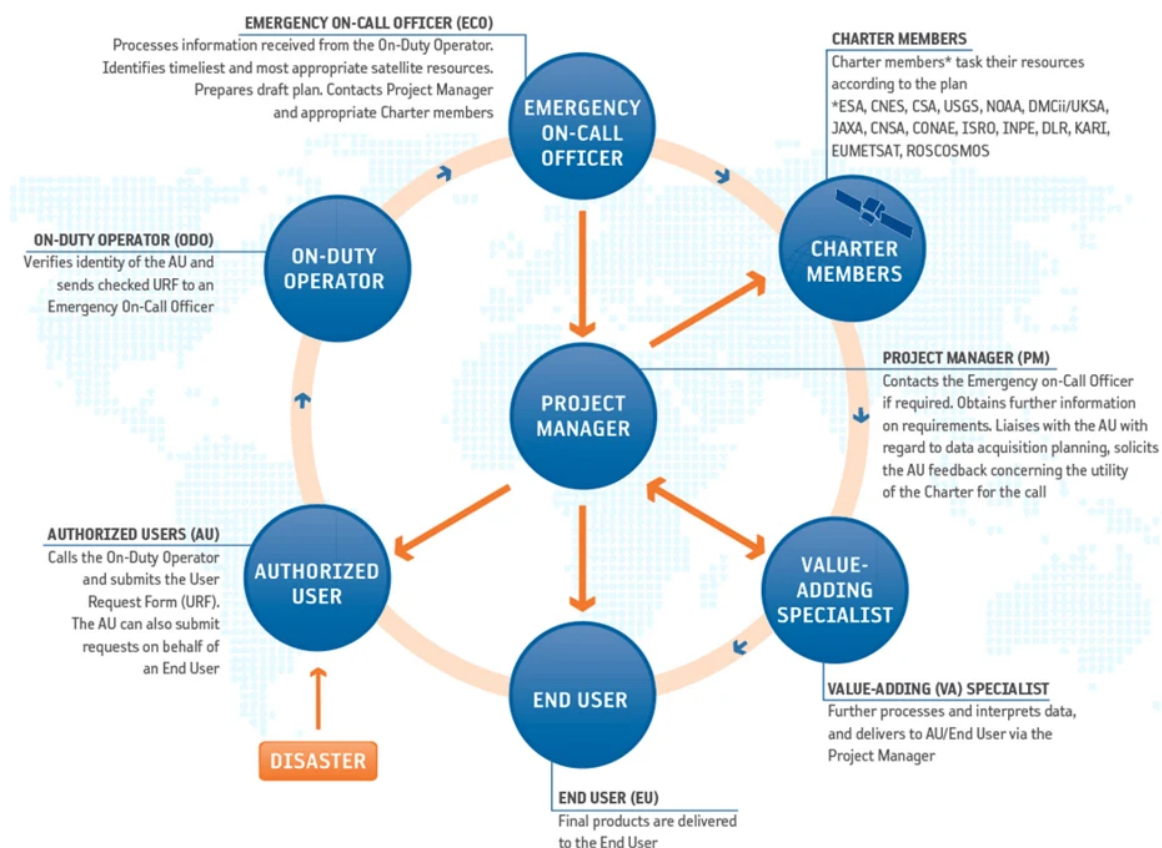


Figure-2 Charter working process

### **Datasets Used and Methodology**

The present study assess the high resolution satellite datasets from Indian Remote Sensing satellites (Resourcesat-2 & Cartosat-2A) alongwith data from Pleiades, PlanetScope, Sentinel-2 & Google Earth data. The Pleiades panchromatic (PAN) and multispectral (MS) stereo satellite datasets were used to generate DEMs for post event and Cartosat-1 DEM was used for pre-event information. Apart from this seismological data, hydrological data was also used. The data from various sources was processed and analysed to have and integrated understanding of the event.



# SATELLITE BASED OBSERVATIONS

## Fracture Development:

Past archival satellite data showed that the commencement of the fracture in the headwall of the rock which failed during February 07, 2021 to be initiated during the year 2017. The north facing hanging ice mass of the Ronti peak had a mean slope of  $\sim 39^\circ$  and the slopes in the range of  $30\text{--}40^\circ$  are found to be the most prone for mass movement. Figure-3 shows the temporal changes at the site where the wedge failure took.

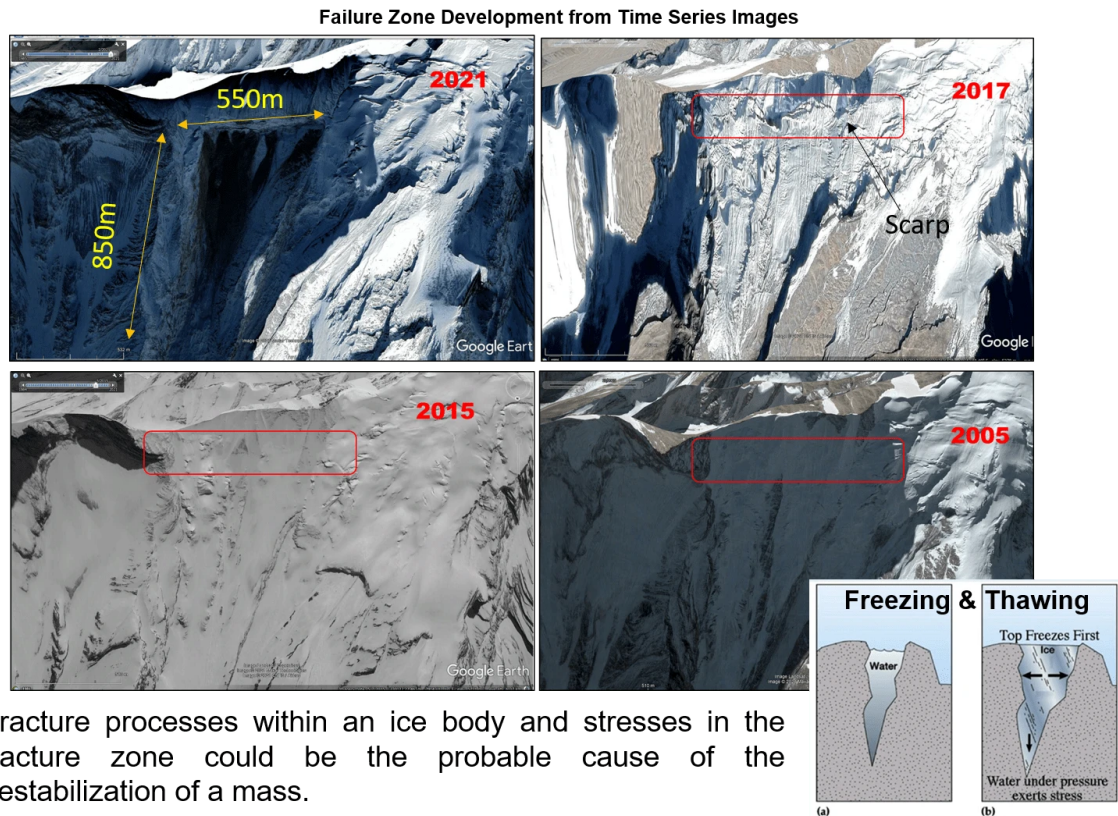


Figure-3 Temporal changes at the wedge failure site

Data from Weather Research and Forecasting (WRF) model forecast of Meteorological & Oceanographic Satellite Data Archival Centre (MOSDAC) suggested good amount of snowfall (February 3 and 4, 2021) prior to the event followed by a sudden rise of temperature (February 6 and 7, 2021). The time series GPM data showed high precipitation on February 3 and 4, 2021. Heavy snowfall on the steep slope/side increased the vulnerability through over-steepening and overloading.

## Wedge Failure

The Planet Labs satellite images were able to capture the event as it unfolded and the satellite image pass of February 07, 2021 at around 1035 h (IST) showed up an extensive plume of dust generated traveling downstream in the valley. Figure-4 shows temporal changes observed from pre and post event captured by IRS Resourcesat-2 on 31 Jan, 21, Sentinel-2 on 5 Feb, 21 (increase in snow cover), PlanetScope on 7 Feb, 21 (dust plume) and Resourcesat-2 on 8 Feb, 2021 (snow depletion) respectively.

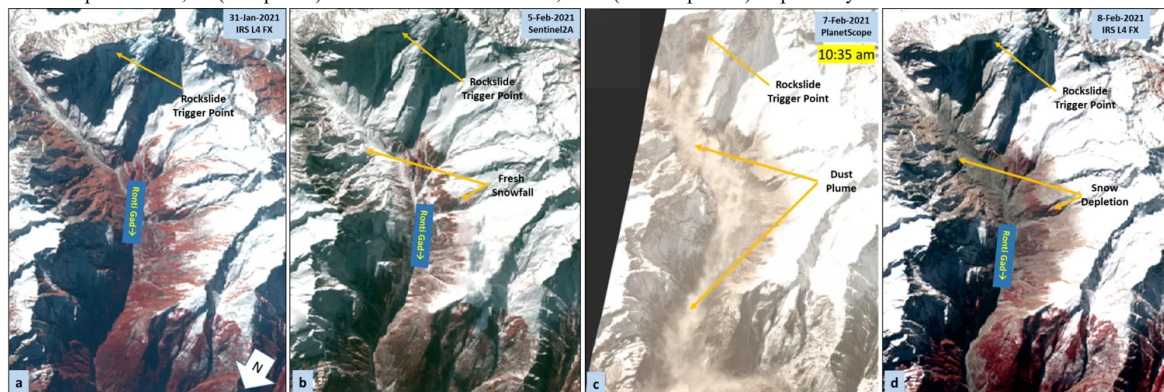




Figure-4 Temporal changes pre and post event in Ronti Gad valley

**Damage Downstream:**

The huge mass with estimated volume of ~23 million cubic meter from a fall height of ~1700 m, generating a potential energy of ~0.93 Peta Joules rolling down caused damages to the hydropower projects (HP) downstream and also causing loss of life of persons working in these projects. Figure-5 shows pre (top image) and post (bottom image) damages observed at three sites i.e. Rishi Ganga HP, Tapovan HP and further downstream available from Google Earth.



Figure-5 Pre (top image) and post (bottom image) damages observed at three sites i.e. Rishi Ganga HP, Tapovan HP and further downstream.



# AERIAL OBSERVATIONS

## Aerial Survey:

A field visit was carried to the affected site four days after the event, i.e. on February 12, 2021, through the support of the Uttarakhand State Disaster Management Agency (USDMA) and Indian Air Force (IAF). Figure-5 a-c shows the sites observed during aerial survey and Figure-5d the IIRS team who carried out survey. This survey supported satellite based observations



Figure 5a Wedge failure zone

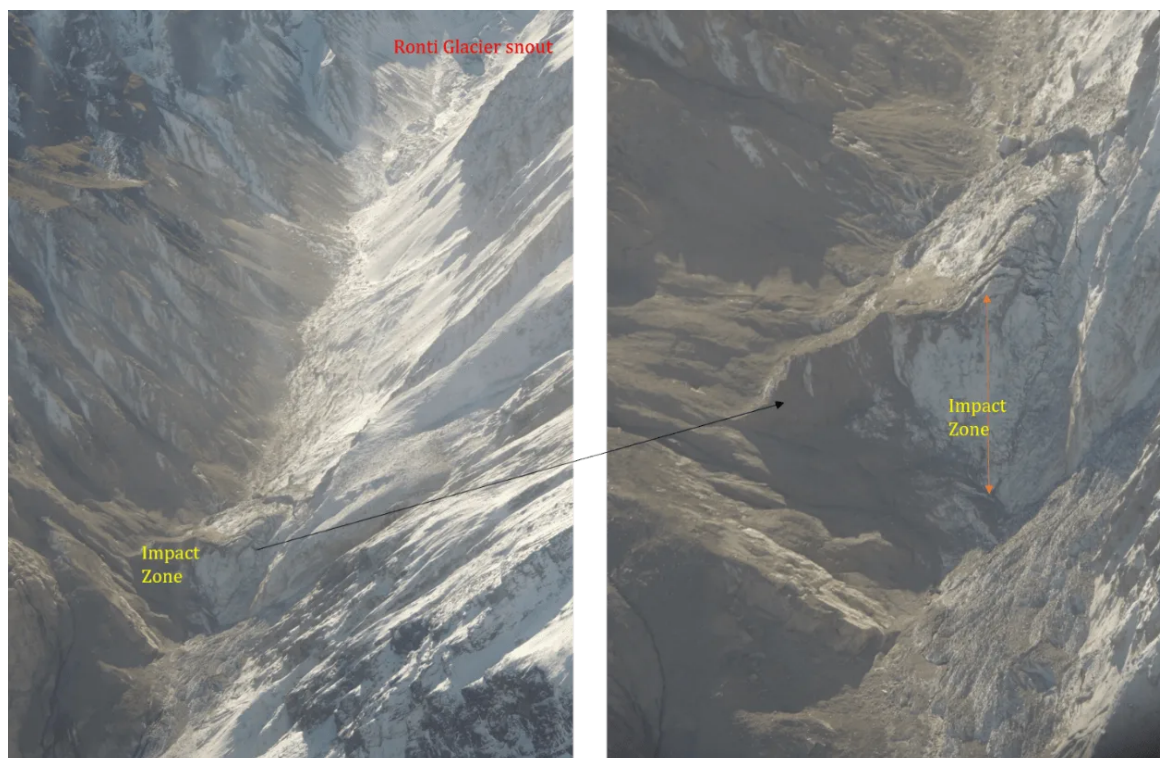


Figure 5b Impact zone





Figure 5c Channel impoundment



Figure 5d Team from IIRS





# FACTS EMERGING FROM ANALYSIS

## Results:

- The in-situ data from 4 seismological stations along with Planetscope images the event initiation time is stamped around 10.22 hours (IST). Figure-6 shows the timing of events. This event was not triggered due to seismicity. The hydrodynamic modelling shows time of travel for the peak flood wave from glacier site upto the Raini, Tapovan and Joshimath estimated to be as ~05, ~10, and ~20 minutes respectively, covering a distance of 14 km, 22 km and 34 km, respectively. The velocity varied between 33.43 to 7.9 m/s, with a mean velocity of ~15.85 m/s from the source site to Joshimath. These observations are supported by ground observations from NTPC and CWC.
- The image analysis have ruled out the probable Glacial Lake Outburst Flood (GLOF) as the cause of the flash floods in the valley.

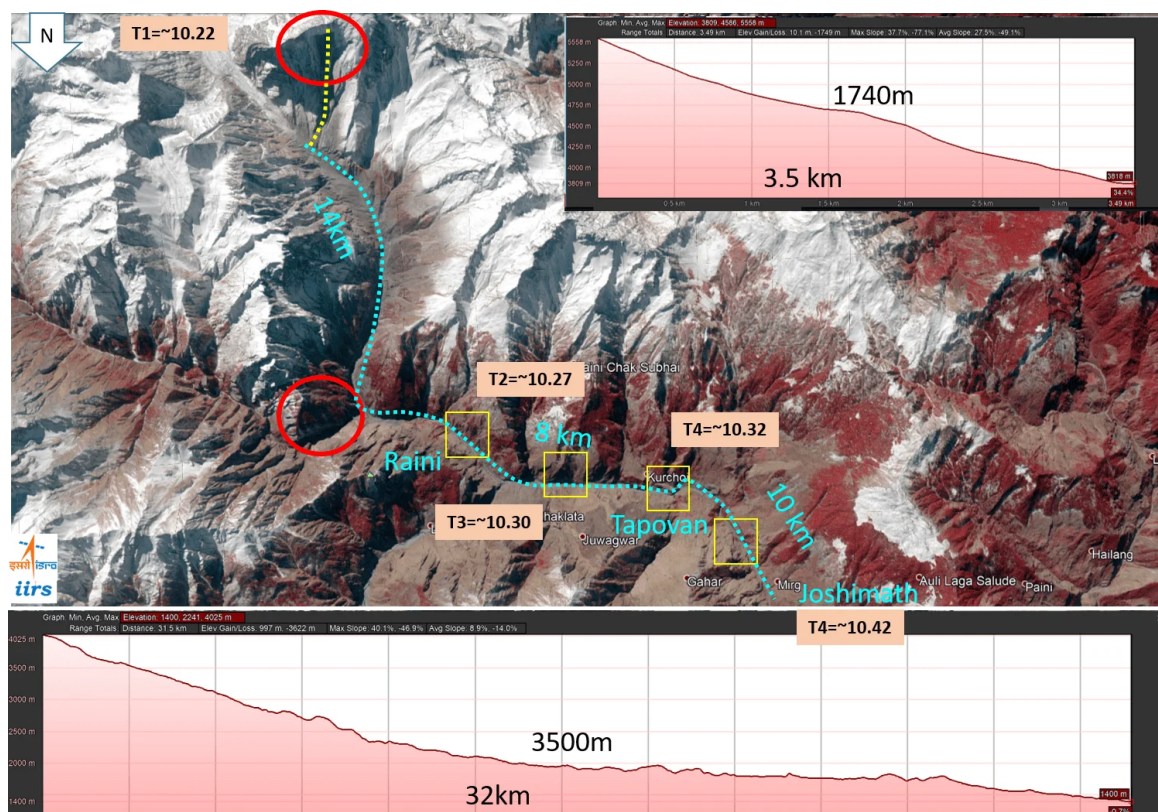


Figure-6 Timing of events

- The sliding process eventually transferred the potential energy into enormous amount of kinetic energy and thermal energy, triggering mobilization of water saturated sediments through fluidization.
- There have been almost 18 publications since the event published in peer-reviewed journals globally. From the various studies it is observed that there could be multiple factors like the tectonically active nature of the region, together with the heavy snowfall and abrupt rise in temperatures few days before event happened, steep topography of the terrain, long-term thermal disturbances in permafrost bedrock etc. could have facilitated the triggering of the rockslide.
- The detailed geomorphological, structural and glaciological investigation, supported with continuous long-term monitoring of glaciated regions, focussing on developing of early warning systems and involvement of community is suggested as long term strategy.
- Application of satellite based technologies has unequivocally supported by all studies.

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## ABSTRACT

Today with the advancement in remote sensing technology, very high resolution imaging together with the capability of stereo data acquisition has greatly enhanced the disaster management of high hazardous and inaccessible mountainous terrain. The Rishiganga valley in the Chamoli district of Uttarakhand (North India) was impacted by sudden flash floods triggered due to a massive rockslide, caused by wedge failure on 7<sup>th</sup> February, 2021. This event caused loss of more than 200 lives besides widespread damage to hydropower projects downstream. Due to the high altitude of the terrain, huge flow of mud and debris down the valley and disruption of road connectivity, made the disaster site inaccessible through conventional means. Therefore most of the preliminary and subsequent studies carried out to assess the impact and the causes of the rockslide have heavily relied on the space based observations.

The Indian Space Agency (ISRO) activated (Call Id-803) the International Charter "Space and Major Disasters" (ICSMD) to image the area of the disaster in Uttarakhand. The ICSMD is a consortium of space faring members having a constellation (61 as on date) of highly agile, multi-sensor and multi-resolution of satellite resources, which can be tasked based on type of disaster and requirement, very rapidly over the disaster affected areas to collect information on being activated. These satellite datasets are provided freely by the space agencies under ICSMD platform to serve humanitarian response for the disaster affected sites, keeping aside the commercial interests. The present study is carried out with two objectives first highlighting the role of space data in quick satellite based disaster response for this particular event which assisted the Uttarakhand State Disaster Management Agency (USDMA), Govt. of Uttarakhand to take immediate steps to mitigate the problem. The second objective tries to do an assessment and review of major studies published in peer reviewed journal between February and July, 2021 on this disaster globally to have a synthesised understanding of the event.

The pre and post multi-temporal and multi-sensor and multi-resolution satellite data from ICSMD over Rishiganga and Dhauliganga valleys provided first-hand information on the chronology of the events, causes and process mechanism of this unique event and identifying locations impacted downstream. The high resolution images were useful in providing in depth understanding of the damage to hydropower projects, changes in the river geomorphology and the river impoundment due to the obstruction in the flow of one of the tributaries of the Rishiganga joining from the northeast. The satellite based inputs proved to be valuable source of information during this event for the state machinery. From all the analysis it has emerged that the satellite images have unequivocally allowed researchers to determine and quantify various terrain parameters (volume, elevation differences and travel distances). These images have ruled out the probable Glacial Lake Outburst Flood (GLOF) as the cause of the flash floods in the valley which dominated the social media. The analysis of the seismological data from nearby observatories in these studies has also ruled out the occurrence of this event as an earthquake-triggered rockslide. The satellite analysis was able to pin point the rockslide zone where a large mass of ice and rock had dislodged and subsequently leading to generation of huge mud and debris flow. From the various studies it is observed that there could be multiple factors like the tectonically active nature of the region, together with the heavy snowfall and abrupt rise in temperatures few days before event happened, steep topography of the terrain, long-term thermal disturbances in permafrost bedrock etc. could have facilitated the triggering of the rockslide. The detailed geomorphological, structural and glaciological investigation, supported with continuous long-term monitoring of glaciated regions, focussing on developing of early warning systems and involvement of community is suggested as long term strategy.