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

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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 7th 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, ele

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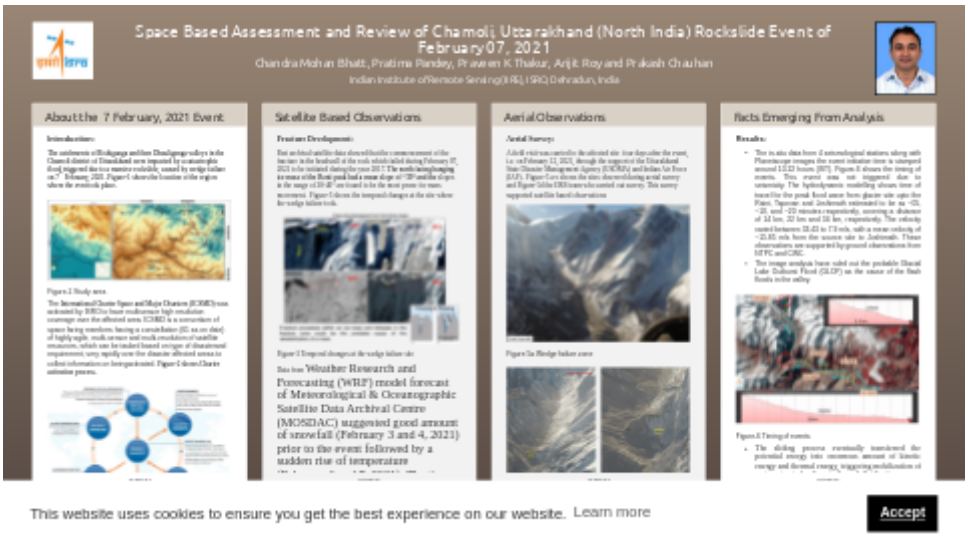

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PRESENTED AT:

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 7th February, 2021. Figure-1 shows the location of the region where the evnt took place.

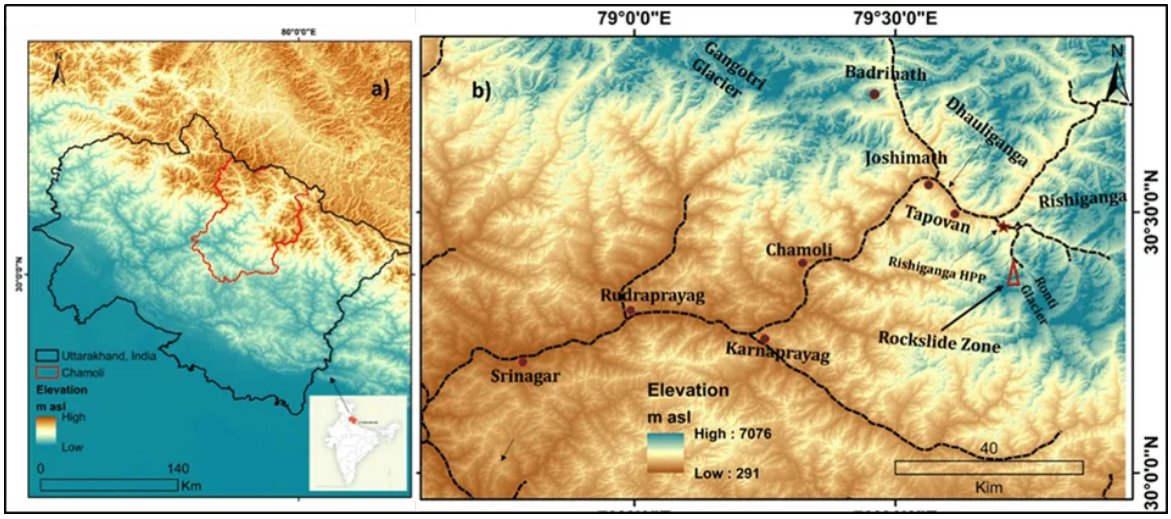

Figure-1 Study area

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 disasterand requirement, very rapidly over the disaster affected areas to collect information on beingactivated. Figure-2 shows Charter activation process.

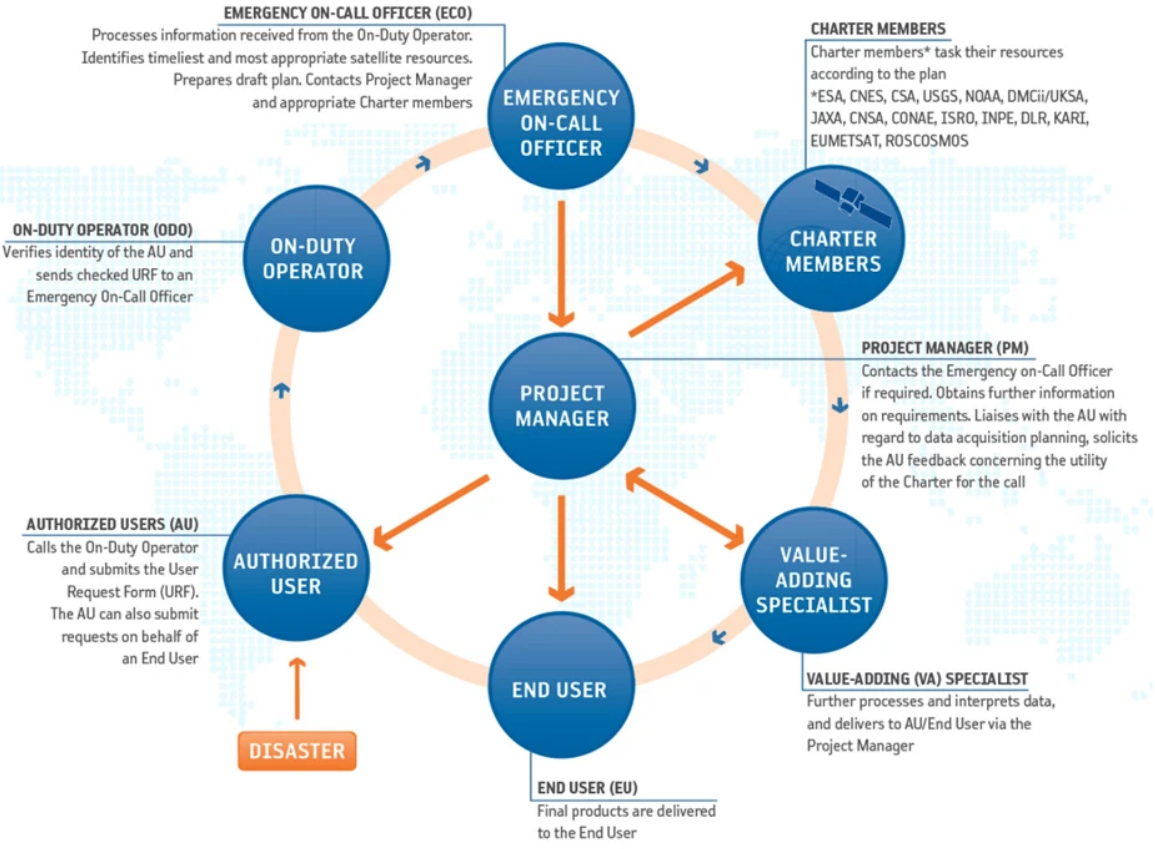

Figure-2 Charter working process

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 Pleaides, 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 integarted 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 ~39° and the slopes in the range of 30-40° are found to be the most prone for mass movement. Figure-3 shows the temporal changes at the site where the wedge failure took.

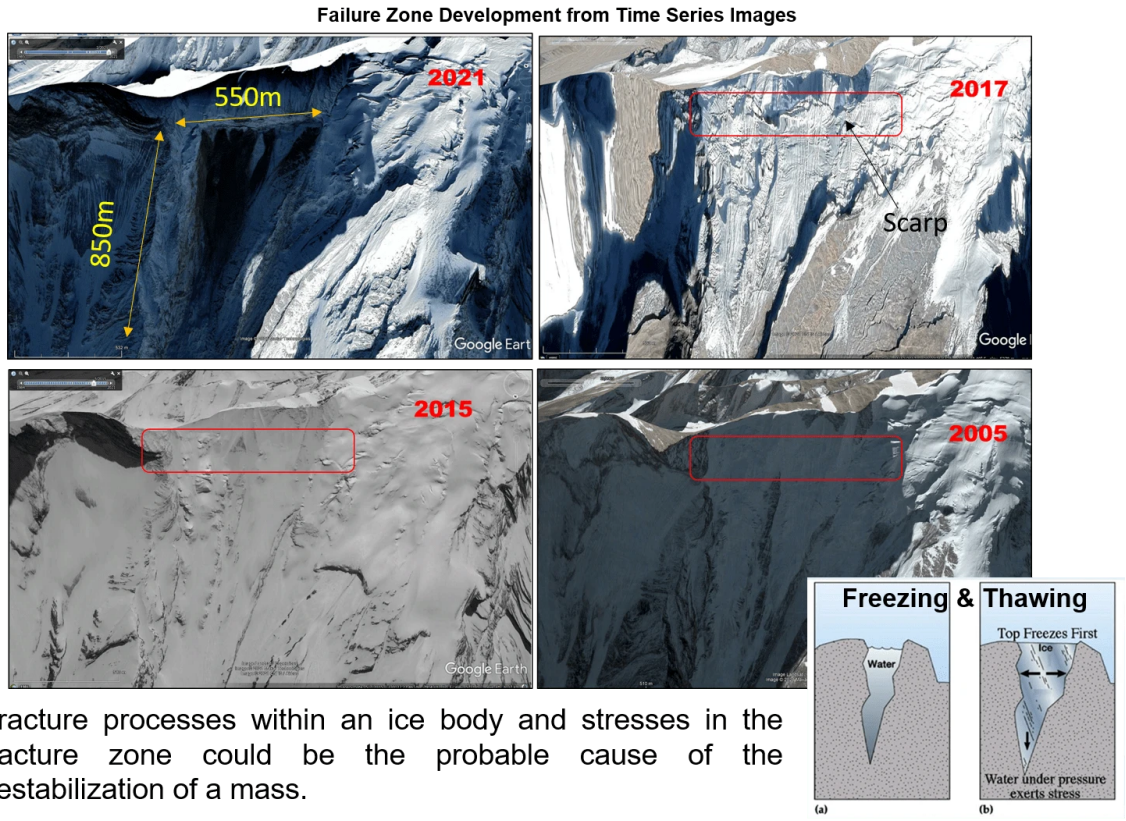

Figure-3 Temporal changes at the wedge failure site

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.

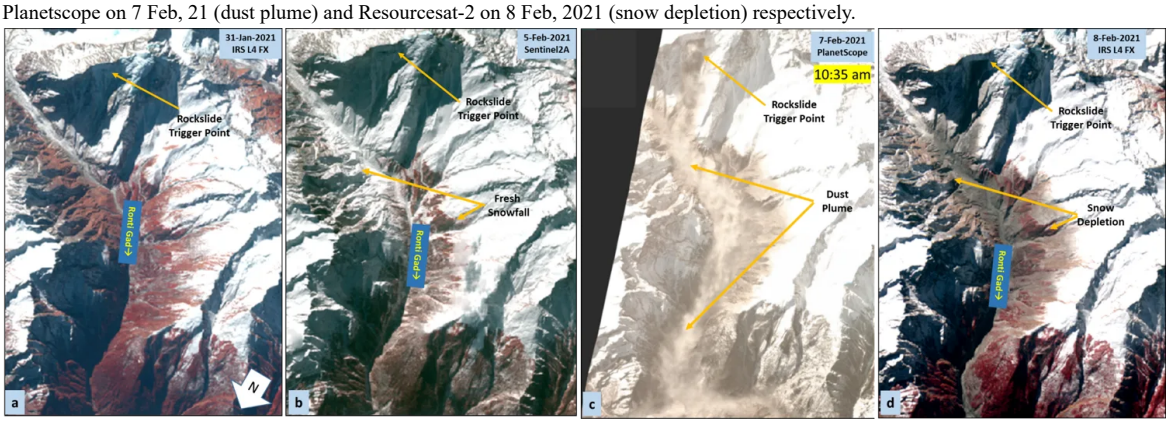

Figure-4 Temporal changes pre and post event in Ronti Gad valley

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.

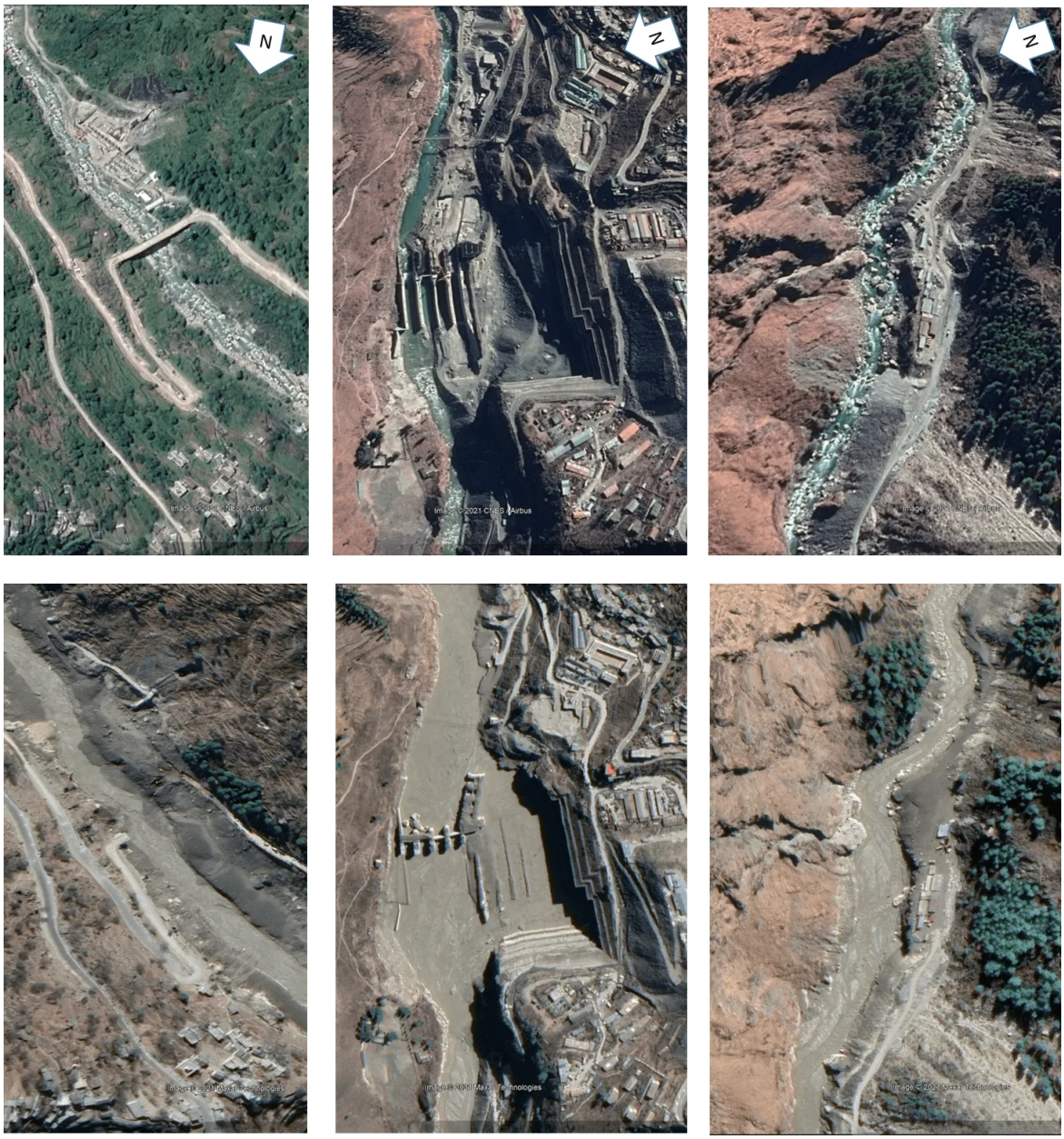

Figure-5 Pre (top image) and post (bottom image) damages observed at three sites i.e. Rishi Ganga HP, Tapovan HP and further downstream.

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

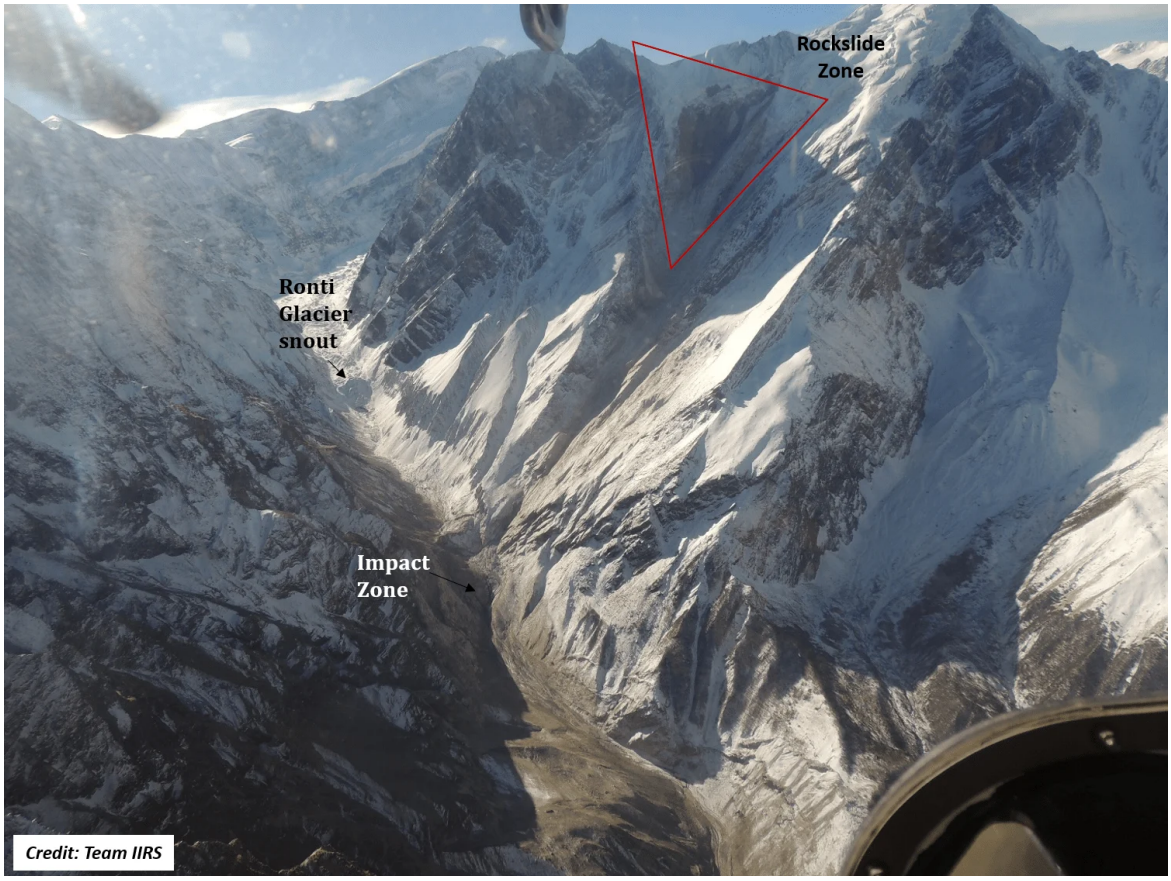

Figure 5a Wedge failure zone

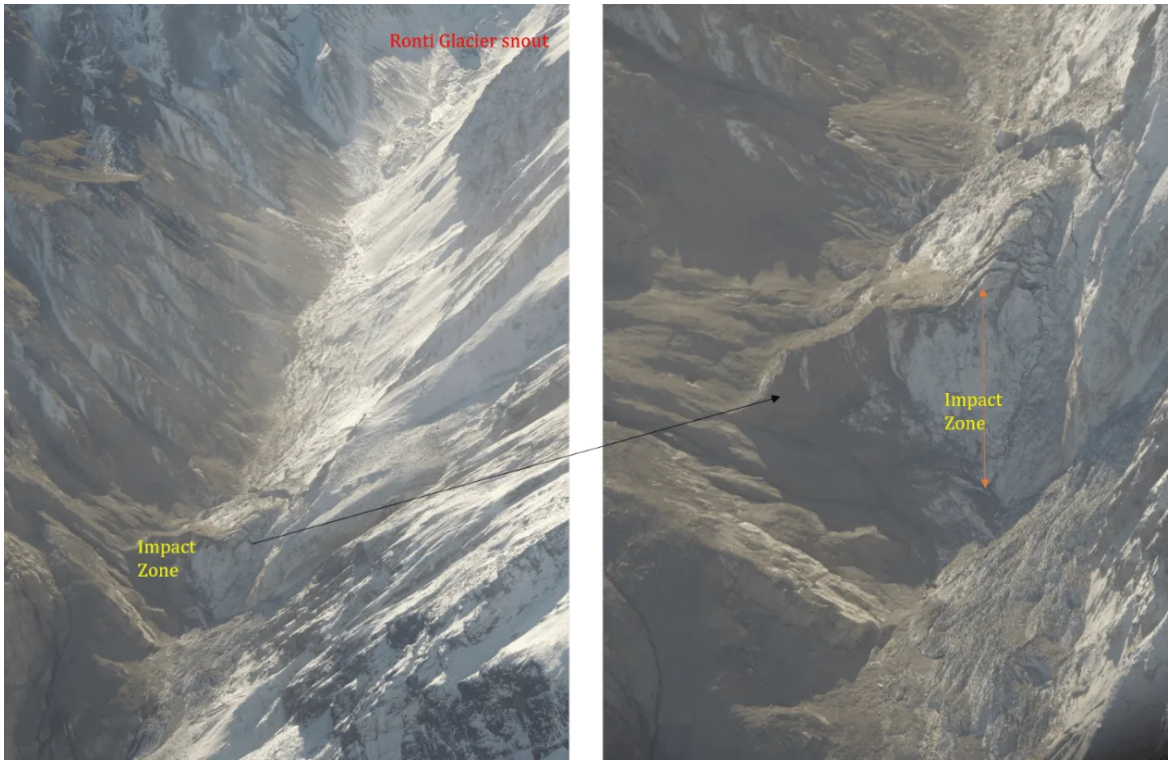

Figure 5b Impact zone

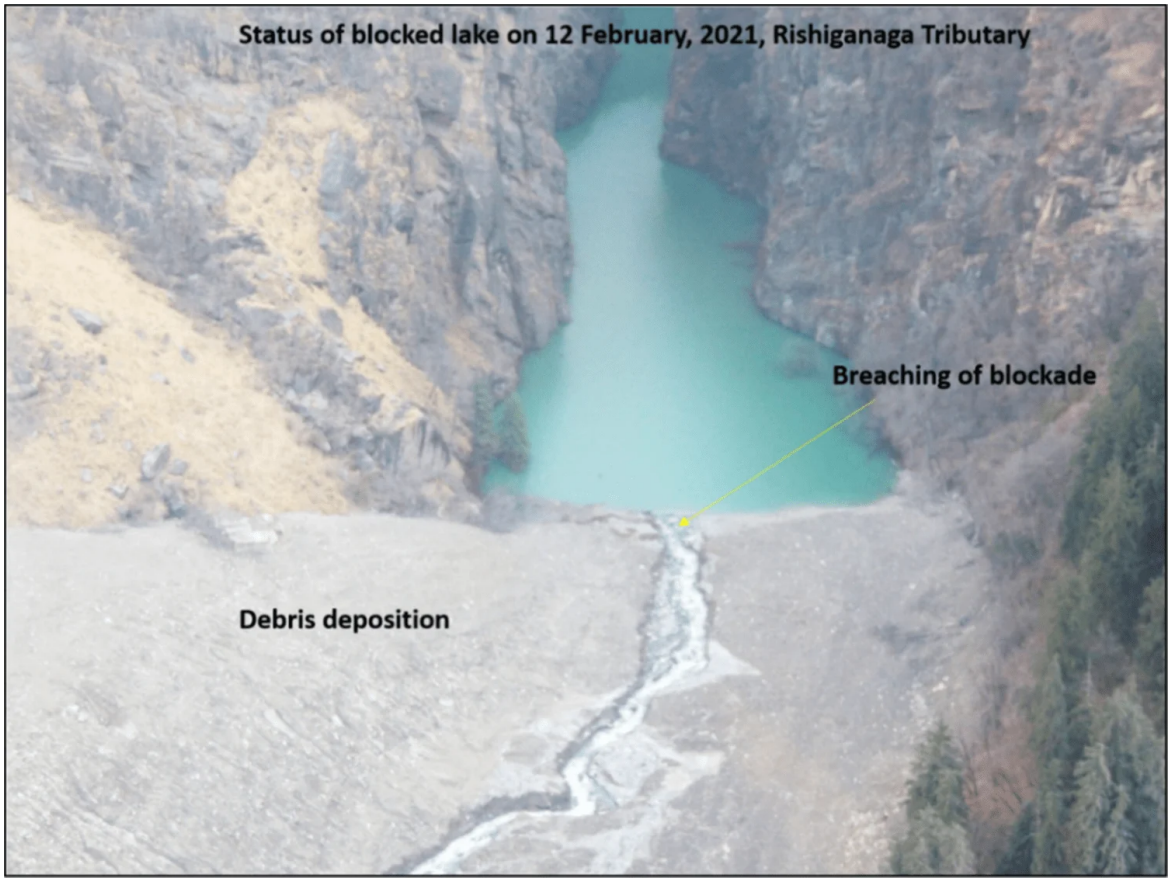

Figure 5c Channel impoundment

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.

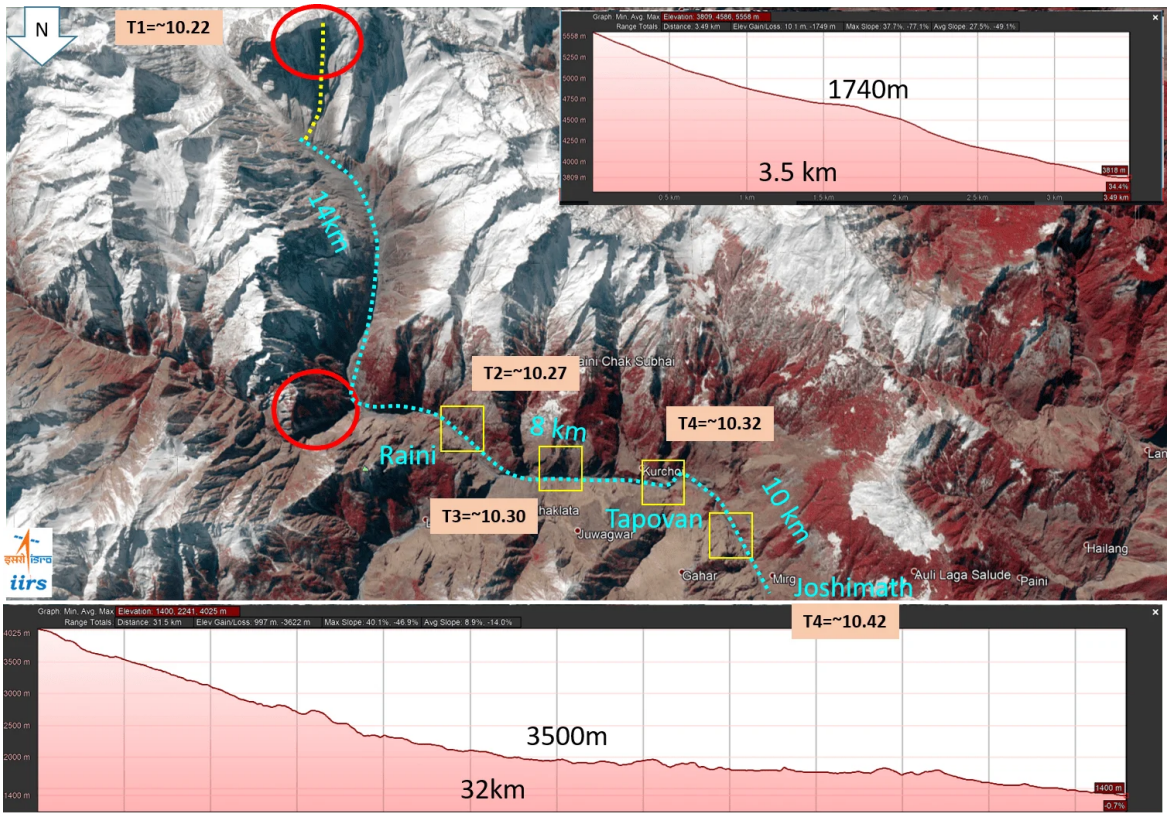

Figure-6 Timing of events

- 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 thetectonically 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-termthermal disturbances in permafrost bedrock etc. could have facilitated the triggering of the rockslide.
- The detailed geomorphological, structural and glaciological investigation, supportedwith continuous long-term monitoring of glaciated regions, focussing on developing of earlywarning systems and involvement of community is suggested as long term strategy.
- Application of satellite based technologies has unequivocally supported by all studies.

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 7th 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.

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