Cloudburst analysis in the Nainital district, Himalayan Region, 2021

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Case Report

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Abstract

Some areas of Uttarakhand faced heavy rainfall during 17-19th October 2021. Mainly on 18th October, rainfall hits its all-time high. Due to this, a sudden heavy rainfall occurred, which had affected daily life of humans. More than 50 casualties were recorded during this study period. The main focus of this study was to monitor the Uttarakhand flood event using satellite observations. The Nainital and Almora districts of the state were mainly affected by this sudden heavy rainfall. On 18th October Nainital has received the maximum rainfall of about 21.51 mm at 11:00 am (UTC). The Nainital district has recorded cumulative rainfall of more than 300 mm on 18th October 2021. From the observation, we find out that this heavy rainfall occurred due to the sudden cloud burst at the Ramgarh of Nainital district. This sudden extreme rainfall further caused a flash flood in the study area. The rainfall pattern has moved towards Assam after it caused a flash flood in Nainital district of Uttarakhand, India.

Introduction

In several recent studies, the increased risk of flash floods due to changing rainfall patterns over India has been reported (Goswami et al. 2006; Rajeevan et al. 2008; Mishra and Liu 2014; Mishra 2019; Ali et al. 2019). Ray et al. (2019) has given a brief statement on the recent flood events in India. Cloud burst is one of the major natural disasters in the Uttarakhand state of India; they cause flash floods, landslides and massive destruction of property.

Kumar et al. (2018) suggested that natural climate variability has played a much more significant role in driving these extreme events in the Himalayan. The major role of climate change, teleconnections, large atmospheric circulations, and land use/land cover change are major driving forces for these extreme events. Kumar et al. (2017) has assessed the cause of landslide hazards and concluded that the extreme rainfall event had influenced landslides in the Jammu and Kashmir Himalaya, northwest India

In the year 2013, Uttarakhand had faced a devastating flood and landslide due to the mid-day cloud burst, multiple rainfall spells, and Glacial Lake Outburst Flood (GLOF); this was the worst natural disaster in India since the 2004 tsunami. It caused a flash flood and landslide because of the major overflows of the river. Bhambri et al. (2016) investigated the massive devastation in the Kedarnath (Mandakini) Valley, Garhwal Himalaya, during 16–17 June 2013 using satellite remote sensing and in-situ based assessment. Kumar et al. (2016) studied that hydroclimate influences the particle size distribution of suspended sediments evacuated from debris-covered Chorabari Glacier, upper Mandakini catchment, and central Himalaya. Shugar et al. (2021) find out that the rock and ice avalanche has caused the 2021 disaster at Chamoli, Indian Himalayas. The western Himalaya region are hotspots of several hazards like GLOF, forest fires, cloud bursts and convective storms (Das and Meher, 2019).

Recently in February 7th 2021 a sudden flood occurs in the middle of the day due to a portion of the Nanda Devi detachment of sizeable rock mass and overlying hanging glacier in the Chamoli district, Uttarakhand (Sain et al. 2021). There were 15 casualties and 150 missing recorded during this sudden

flood event. Again in May 2021 a series of cloud burst were recorded in the Uttarakhand, which had further triggered a severe flash flood. One cloud burst occurred in Chinyalisaur block of Uttarkashi and multiple cloud bursts were recorded in the Augustmuni in Rudraprayag.

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These flood events were some major events that occurred in the Uttarakhand state, India. Above mentioned flood events were recorded in the high altitude area due to heavy rainfall, cloud burst and GLOF. When we record extreme rainfall in a short time period that is called a cloud burst. Cloud burst is the main reason behind the flash flood.

The focus of the present work was is to monitor the flash flood event in Nainital district, Uttarakhand during the 17-18th Oct, 2021 with aid of satellite observations.

Study Area

The Nainital district of the Uttarakhand which is located in Himalayan region of India was selected as study area (Appendix I). The study area has been divided into the sub Himalayas, the Piedmont alluvial plains, and the Lesser Himalayas. Further, these divisions are characterised by different rock types of different geological age, tectonic setting and geomorphic units. Major geomorphic features are mountain peaks, hill slopes, topographic depressions and debris cone.

Data and Methodology

The Integrated Multi-satellite Retrievals for Global Precipitation Measurement (IMERG) a multi-satellite precipitation estimation algorithm of GPM, based on TMPA, CMORPH and PERSIANN. In this research we have estimated half-hourly (or 30 min) rainfall at a 10 km (or 0.1[°]) spatial resolution of GPM (<https://giovanni.gsfc.nasa.gov/giovanni>). Half-hourly precipitation data were collected during the flood period for study area. We have collected total cloud data for measuring rainfall of the study area. We have also used cloud cover data obtained from NOAA (https://psl.noaa.gov/cgi-bin/db_search/DBListFiles.pl?did=198&tid=95797&vid=4285). For detailed methodology the authors can consult the work of Mishra and Srinivasan (2013).

IMERG Overview

The IMERG is the quasi-global (between 60°N and 60° S) product of GPM (Huffman et al. 2015). IMERG has Level 3 precipitation with three runs, i.e., early run (latency of 6 h and can be used for warning a probable flood event or landslides), late run (latency of 18 h and suitable for drought monitoring and

agricultural forecasting), and final run (latency of three months and used for observation like precipitation observation). Latest version 06 of algorithm fuses the early precipitation estimates collected during the operation of the TRMM satellite (2000-2015) with more recent precipitation estimates of the GPM satellite (2014 - present).

The IMERG level 3 data was downloaded from NASA Earth Data Homepage. The accessible website is <https://disc.gsfc.nasa.gov/datasets?page=1&keywords=imerg>.

Precipitation is estimated from various satellites in the GPM constellation carrying associated passive satellite microwave sensors (PMW) computed using the 2017 version of Goddard Profiling Algorithm (NASA, 2017) then gridded, inter-calibrated to the GPM Combined Instrument product, and combined into 30 minutes and $0.1^\circ \times 0.1^\circ$ grids space.

Results And Discussions

From the study we have observed that cloud cover of the study area was increased on 17th Oct, 2021. In the morning time the cloud burst occurred in the study area which has caused a heavy rainfall. This heavy rainfall has mainly affected the Nainital district and some adjoining parts near to the Nainital. During 2 days study period we have found that on 17th Oct, 2021 the temperature of the study area was slightly increased which resulted into a low pressure belt in the study area. Further result to a large cloud cover over the area. On 18th Oct, 2021 it resulted into a cloud burst.

The Nainital had received its all time highest rainfall which has caused a flash flood. On 17th Oct the total cumulative rainfall of the area was 72.25 mm which was changed to 357.76 mm on 18th Oct. On 18th Oct morning at 4:00 am (UTC) the rainfall was recorded as 4.11 mm.h^{-1} and which increased to 20.54 mm.h^{-1} at 4:30 am (UTC).

Figure 1 (A) depict the total cloud cover (18th October), (B) half-hourly rainfall, and (C) half-hourly cumulative rainfall of the study area during 17 to 19th Oct 2021. From this we have observed that 18th Oct south part of the Uttarakhand have a major cloud cover than the other parts. The most affected area was Nainital located in the southern part of the state.

Figure 2 describes the rainfall of the study area during at 10:00 am (UTC) to 14:30 pm (UTC), 18th Oct, 2021.

From Fig. 3 we observed the daily accumulated rainfall of northern part of India during 16th-19th Oct, 2021.

Mostly cloud bruts are confined by a large number of geoenvironmental factors namely land use and lithology, high relief, and steep slopes.

Declarations

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Authors' contributions Kishan Singh Rawat led the development and design of the manuscript, Sudhir Kumar Singh and Smruti Ranjan Sahu analyzed the parameters. And writing under the supervision of Prof. Anil Kumar Mishra. All authors read and approved the final manuscript.

Data availability All data generated or analysed during this study are included in this article.

Competing interests The authors declare that there is no conflict of interest in this study.

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Figures

Figure 1

(A) describe the total cloud cover (18th October), (B) half-hourly rainfall and (C) half-hourly cumulative rainfall of the study area during 17 to 19th Oct 2021

Figure 2

10:00 am to 14:30 pm half-hourly rainfall of the study area during 18th October 2021

Figure 3

Daily accumulated rainfall of northern part of India during 16th-19th October

Supplementary Files

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- [AppendixI.docx](#)