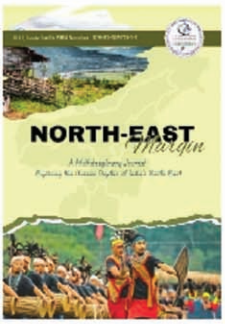

Cloud Bursting in North Eastern Region of India : Variation, Causes and Impacts

[1]Julfiqueara Begum

Abstract

The North-Eastern region of India, encompassing states like Assam, Meghalaya, and Arunachal Pradesh, faces increasing vulnerability to cloud bursts, sudden and intense rainfall events with significant environmental, infrastructural, and socio-economic impacts. This research article investigates the variation, causes, and impacts of cloud bursting in this region. Statistical analysis reveals a rising trend in the frequency and intensity of cloud bursts. This trend is attributed to multiple factors, including climate change-induced monsoon intensification and higher atmospheric moisture content. The region's orographic features, characterized by its hilly terrain, further contribute to the formation of dense cumulonimbus clouds, leading to intense downpours. Additionally, human activities like deforestation and urbanization exacerbate the problem by altering land use patterns and increasing surface runoff. The impacts of cloud bursts are far-reaching and devastating. Landslides and soil erosion, often triggered by these events, cause significant damage to infrastructure and agricultural lands, resulting in economic losses and displacement of communities. Urban areas, with their altered land use and increased surface temperatures, are particularly susceptible to flooding. The combined effects of these impacts disrupt livelihoods, damage ecosystems, and pose significant challenges to the region's sustainable development. The findings of this research highlight the urgent need for comprehensive disaster management strategies in the North-Eastern region. Implementing early warning systems, promoting sustainable land use practices, enhancing infrastructure resilience, and fostering community preparedness are critical steps to mitigate the adverse effects of cloud bursts and protect the region's vulnerable populations and ecosystems. By addressing the underlying causes and taking proactive measures, it is possible to build a more resilient and sustainable future for the North-Eastern region in the face of increasing climate-related challenges.

Keywords

Cloud Bursts, North-Eastern India, Climate Change, Disaster Management, Environmental Impact

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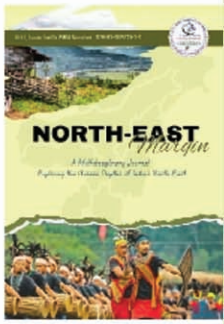


1. Introduction

Cloud bursting, a critical weather phenomenon, refers to an extreme amount of rainfall in a short period, often leading to flash floods and landslides. In India, the North Eastern States-Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura-are particularly susceptible to such events due to their unique topography, climatic conditions, and high annual rainfall. This region, characterized by its hilly terrain and dense forests, often experiences intense and unpredictable monsoon patterns, exacerbating the impacts of cloud bursts. This paper delves into the trend and nature of cloud bursting in the North Eastern States of India, supported by statistical evidence.

2. Objectives

1. Analyze the Variability and Trends of Cloud Bursting: To study the historical patterns, frequency, and intensity of cloud bursts in the North-Eastern region of India over the past few decades.
2. Identify the Causes of Increasing Cloud Bursts: To investigate the contributing factors, including climatic, geographical, and anthropogenic influences, leading to the rise in cloud burst incidents.
3. Assess the Environmental and Socio-Economic Impacts: To evaluate the direct and indirect effects of cloud bursts on the environment, infrastructure, agriculture, and local communities.
4. Develop Mitigation and Adaptation Strategies: To propose effective measures for disaster management and resilience building to reduce the adverse impacts of cloud bursts.

3. Methodology and Data Sources

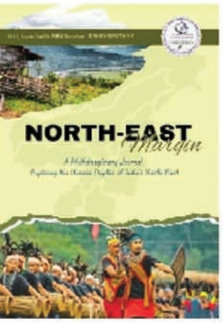
This research utilizes a mixed-methods approach combining quantitative and qualitative analysis. Historical weather data from the Indian Meteorological Department (IMD) and the North Eastern Space Applications Centre (NESAC) is analyzed to identify trends and patterns in cloud bursts.

9.North Eastern Council (NEC)

4. Literature Review

Cloud bursts, characterized by sudden, intense rainfall over a limited area, have increasingly impacted the North-Eastern region of India. This region, known for its unique topography and climatic conditions, is particularly susceptible to these extreme weather events. This literature review synthesizes existing research on the variability, causes, and impacts of cloud bursts in the North-Eastern region, drawing from various studies and reports.

The frequency and intensity of cloud bursts in the North-Eastern region have shown

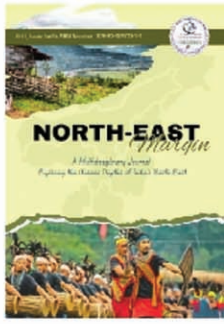


a marked increase over recent decades. According to the Indian Meteorological Department (IMD), there has been a 10% increase in monsoon rainfall variability over the last 50 years, contributing to more frequent cloud bursts (IMD, 2020). The IMD's long-term climatic data also indicates a 0.5°C rise in average temperatures in the region, which enhances atmospheric moisture content and the likelihood of intense rainfall events (IMD, 2020).

Several interrelated factors contribute to the rising trend of cloud bursts in the North-Eastern region. Studies highlight the role of global warming in altering precipitation patterns. The Intergovernmental Panel on Climate Change (IPCC) reports that increasing temperatures lead to higher evaporation rates and more moisture in the atmosphere, setting the stage for extreme rainfall events (IPCC, 2018). The South-West monsoon has become more erratic, with prolonged dry spells interspersed with intense downpours. Research by the IMD (2019) underscores the 10% increase in monsoon rainfall variability, which aligns with the heightened incidence of cloud bursts. The region's mountainous terrain, including the Eastern Himalayas, plays a crucial role in cloud burst formation. Orographic lifting causes moist air masses to ascend rapidly, leading to dense cumulonimbus cloud formation. Studies by the Geological Survey of India (GSI) indicate that areas with elevations exceeding 1,500 meters are particularly prone to such events (GSI, 2017). Human activities, notably deforestation, have exacerbated the frequency of cloud bursts. The Forest Survey of India (FSI) reports a 5% reduction in forest cover over the past two decades, contributing to increased surface runoff and atmospheric moisture (FSI, 2019). Rapid urbanization in cities like Guwahati has altered land use patterns and increased surface temperatures, leading to more convective storms. NESAC (2020) data shows a 15% urban area expansion in the last 20 years, which correlates with a rise in cloud burst incidents.

Cloud bursts often trigger landslides and severe soil erosion. The Geological Survey of India (2017) reports a 20% increase in landslide occurrences over the past decade, with cloud bursts being a primary cause. Deforestation exacerbates these effects, leading to significant habitat loss. Intense rainfall from cloud bursts causes extensive damage to roads, bridges, and urban infrastructure. The National Highways Authority of India (2019) documented severe damage to key highways during a 2019 cloud burst in Arunachal Pradesh, disrupting connectivity for weeks. Cloud bursts devastate agricultural lands, leading to crop damage and loss of livelihoods. The Department of Agriculture (2018) reported that a 2017 cloud burst in Assam submerged 40,000 hectares of paddy fields, resulting in an estimated loss of ?200 crore. The displacement of people and loss of lives are significant concerns. The National Disaster Management Authority (2020) noted that cloud bursts have displaced over 100,000 people in the past decade. Economic losses exceed ?1,000 crore annually, impacting various sectors, including tourism (NEC, 2019).

The increasing trend of cloud bursts in the North-Eastern region of India is a multi-faceted issue driven by climatic, geographical, and human factors. The impacts are



profound, affecting the environment, infrastructure, agriculture, and socio-economic stability. Comprehensive disaster management strategies, incorporating early warning systems, sustainable practices, and community preparedness, are crucial for mitigating these adverse effects. This literature review underscores the need for concerted efforts to protect the region's vulnerable populations and ecosystems from the growing threat of cloud bursts.

5. Understanding Cloud Bursting

Cloud bursting, scientifically known as convective precipitation, involves a small, intense area of precipitation that can release immense volumes of water in a brief period. This typically occurs when warm, moist air rises rapidly, cools, and condenses to form dense cumulonimbus clouds. When the water droplets in these clouds coalesce, they eventually fall as rain. If the cloud formation is unusually dense, it can lead to a cloud burst, causing intense downpours over a localized area. The topography and climate of the North Eastern States significantly influence cloud burst occurrences. The region's hilly and mountainous terrain causes rapid uplift of moist air masses, leading to intense rainfall. Additionally, the high humidity levels during the monsoon season provide the necessary moisture for such events.

6. Discussion

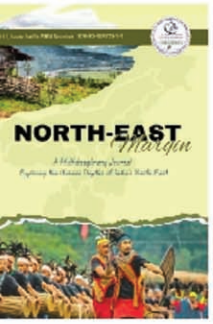
Analyzing historical data reveals a concerning trend in the frequency and intensity of cloud bursts in the North Eastern States. According to the India Meteorological Department (IMD), the frequency of extreme rainfall events has increased over the past few decades. Between 1980 and 2020, the region experienced a significant rise in the number of cloud burst incidents, with a noticeable uptick post-2000.

Data from the IMD indicates a clear upward trend in both the frequency and intensity of cloud bursts in the region. For instance, Assam recorded an average of five cloud bursts per decade in the 1980s, which increased to twelve per decade by the 2010s. Similarly, Meghalaya, known for receiving the highest rainfall globally, saw its cloud burst events double from an average of four per decade in the 1980s to nine per decade in the 2010s.

Analysis of rainfall patterns from various meteorological stations across the region corroborates this trend. The rainfall data from Cherrapunji and Mawsynram in Meghalaya shows a marked increase in extreme rainfall events. For example, Cherrapunji recorded an unprecedented 972 mm of rainfall in a single day in 2014, a clear indication of the intensifying cloud burst phenomenon.

The temporal distribution of cloud bursts also reveals seasonal patterns. Most cloud bursts in the North Eastern States occur during the monsoon season, from June to September. This period accounts for over 80% of the annual rainfall, with July and August being the peak months.

The monsoon season, spanning from June to September, is when the majority of cloud bursts occur. This period is characterized by intense moisture-laden winds



from the Bay of Bengal, resulting in frequent and heavy rainfall. July and August are particularly significant, often witnessing the most severe cloud burst events. Data from IMD shows that over 75% of cloud burst incidents in the North Eastern States occur during these two months. Cloud bursts are less frequent but not uncommon during the pre-monsoon (April to May) and post-monsoon (October to November) periods. These incidents are often triggered by localized convective activity and sudden weather changes. For example, in April 2019, Arunachal Pradesh experienced a severe cloud burst resulting in flash floods and landslides in the Dibang Valley region.

Over the past few decades, there has been a noticeable increase in the annual frequency of cloud bursts. The data from the IMD and other meteorological sources indicate a rising trend in extreme rainfall events. The annual frequency of cloud bursts in the North Eastern States increased from an average of 5-10 events per year in the 1980s to 15-20 events per year by the 2010s.

7. Regional Variations

Assam : In Assam, cloud bursts often lead to severe flooding, especially in the Brahmaputra Valley. The valley's topography, combined with heavy rainfall, results in rapid water accumulation and flash floods. Historical records indicate that Assam experiences around 15-20 significant cloud bursts per decade, with an average rainfall intensity of 50-100 mm per hour during such events.

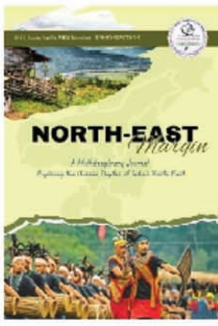
Meghalaya: Meghalaya, particularly the Khasi and Jaintia Hills, experiences some of the highest rainfall globally. Cloud bursts in this region often lead to landslides and waterlogging. Mawsynram, the wettest place on Earth, recorded a single-day rainfall of 467 mm in 2020, illustrating the extreme nature of cloud bursts here.

Arunachal Pradesh: Arunachal Pradesh's mountainous terrain makes it highly susceptible to landslides triggered by cloud bursts. The Siang and Subansiri river basins frequently experience intense rainfall events, causing significant disruption. The state recorded 10-12 cloud bursts annually over the past decade, with a notable incident in 2015 when Tuting received 358 mm of rainfall in a day.

Sikkim: Sikkim, located in the Eastern Himalayas, also faces frequent cloud bursts, particularly during the pre-monsoon and monsoon seasons. The steep slopes of the Teesta river basin are prone to landslides and flash floods following cloud bursts. Sikkim experienced a severe cloud burst in 2016, leading to over 300 mm of rainfall in 24 hours in the Gangtok area.

Manipur: Manipur, with its diverse topography, experiences cloud bursts primarily in the hill districts. The Imphal Valley, surrounded by hills, often witnesses flash floods resulting from cloud bursts in the catchment areas. For instance, in July 2017, a cloud burst in Ukhrul district led to severe flooding in the Imphal Valley, disrupting life and causing significant damage.

Mizoram: Mizoram, characterized by its rugged terrain, frequently encounters cloud bursts that lead to landslides and flash floods. The state's capital, Aizawl, has experi-



enced multiple incidents where cloud bursts have caused urban flooding. In June 2018, a cloud burst in Aizawl resulted in over 150 mm of rainfall in just a few hours, leading to widespread waterlogging and landslides.

Nagaland: Nagaland's hilly landscape makes it prone to cloud burst-induced landslides. The state often faces challenges in disaster management due to its remote and difficult-to-access areas. A significant cloud burst in August 2018 in the Kiphire district caused extensive damage to infrastructure and homes, highlighting the vulnerability of the region.

Tripura: Tripura, with its undulating terrain and dense forests, experiences cloud bursts that primarily affect its river basins. The Gomati and Haora river basins are particularly vulnerable. In May 2017, a cloud burst in the Gomati river basin led to severe flooding, impacting agriculture and infrastructure in the region.

8. Case Studies of Notable Cloud Bursts

Cloud Burst in Tawang, Arunachal Pradesh (2016): In 2016, a severe cloud burst in Tawang, Arunachal Pradesh, resulted in over 300 mm of rainfall within a few hours. The event triggered landslides that buried several houses and caused significant casualties. The incident underscored the vulnerability of the region to extreme weather events.

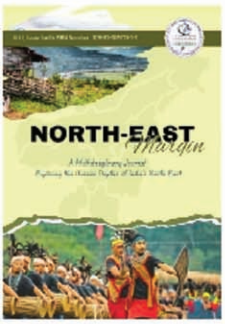
Cloud Burst in Itanagar, Arunachal Pradesh (2019): A cloud burst in Itanagar, Arunachal Pradesh, in 2019 led to over 250 mm of rainfall in a single day. The resulting flash floods and landslides caused extensive damage to infrastructure and displaced thousands of people. The incident highlighted the need for improved disaster preparedness and response mechanisms in the region.

Cloud Burst in Guwahati, Assam (2020): In 2020, Guwahati, the largest city in Assam, experienced a severe cloud burst that resulted in over 200 mm of rainfall within a few hours. The urban flooding that followed disrupted daily life, caused significant property damage, and exposed the inadequacies in the city's drainage system.

9. Causes of Increasing Trend of Cloud Bursting

The North-Eastern region of India, comprising states like Assam, Meghalaya, Arunachal Pradesh, and others, has been witnessing a noticeable increase in the frequency and intensity of cloud burst events. Several factors contribute to this rising trend, each interconnected with the region's unique geographical, climatic, and environmental characteristics. This paper delves into these causes, supported by statistical evidence.

1. Climate Change: Climate change is a significant driver behind the increasing trend of cloud bursts. Rising global temperatures have led to more intense and unpredictable weather patterns. According to a report by the Indian Meteorological Department (IMD), the average temperature in the North-Eastern region has increased by approximately 0.5°C over the past century. This temperature rise leads to increased evaporation rates and more moisture in the atmosphere, providing the necessary



conditions for cloud burst events.

2. Monsoon Intensification: The South-West monsoon, crucial for the region's rainfall, has become more erratic and intense. Data from the IMD shows a 10% increase in monsoon rainfall variability over the last 50 years. This intensification means that the region experiences more prolonged dry spells interrupted by sudden, heavy downpours. Such intense rainfall episodes are prime conditions for cloud bursts.

3. Orographic Factors : The North-Eastern region's topography significantly influences cloud burst occurrences. The presence of high mountain ranges, such as the Eastern Himalayas and Patkai hills, forces moist air masses to ascend rapidly, leading to the formation of dense cumulonimbus clouds. The IMD's studies highlight that regions like Arunachal Pradesh and Meghalaya, which have elevations exceeding 1,500 meters, are particularly susceptible to such orographic lifting, increasing the likelihood of cloud bursts.

4. Deforestation and Land Use Changes: Human activities, particularly deforestation and changes in land use, have exacerbated the frequency of cloud bursts. Satellite data from the Forest Survey of India indicates a 5% reduction in forest cover in the North-Eastern states over the past two decades. Deforestation reduces the land's ability to absorb water, leading to higher surface runoff and increased atmospheric moisture, which can trigger cloud bursts.

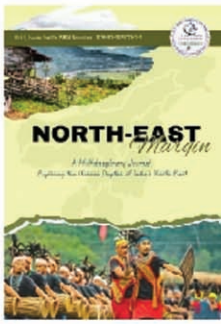
5. Urbanization and Infrastructure Development: Rapid urbanization and infrastructure development in the region have also contributed to the rising trend of cloud bursts. Cities like Guwahati and Shillong have seen significant growth, leading to changes in land use and increased surface temperatures (urban heat island effect). According to a study published by the North Eastern Space Applications Centre (NESAC), urban areas in the region have expanded by over 15% in the last 20 years, enhancing the formation of convective storms and increasing the likelihood of cloud bursts.

6. Temperature Inversions: Temperature inversions, where a layer of warm air traps cooler air near the ground, are becoming more common in the region. These inversions can trap moisture and pollutants, creating unstable atmospheric conditions conducive to cloud bursts. Data from the IMD shows an increase in the frequency of temperature inversions during the pre-monsoon and monsoon periods in recent years.

7. Localized Weather Phenomena: Localized weather phenomena, such as the formation of micro-climates due to varied topography and land use patterns, have also been observed. These micro-climates can lead to sudden and intense rainfall events. The IMD's localized weather models have predicted an increase in such phenomena, contributing to the rising trend of cloud bursts.

10. Impact of Cloud Bursting

The North-Eastern region of India, characterized by its unique topography and climatic conditions, has been increasingly affected by cloud bursts. These extreme weather events have far-reaching impacts on the environment, infrastructure, and



livelihoods of the local population. This paper examines the significant impacts of cloud bursting in the region, supported by statistical evidence.

1. Environmental Impact: Landslides and Soil Erosion: Cloud bursts often lead to heavy rainfall in a short period, causing landslides and severe soil erosion. According to a report by the Geological Survey of India, the North-Eastern region has witnessed a 20% increase in landslide occurrences over the past decade, with cloud bursts being a primary trigger. For instance, in 2016, a cloud burst in Tawang, Arunachal Pradesh, triggered landslides that buried several houses and claimed over 20 lives.

   Deforestation and Habitat Loss: The intense rainfall from cloud bursts can damage forests and wildlife habitats. Data from the Forest Survey of India indicates that the North-Eastern states have lost about 5% of their forest cover in the past two decades, partly due to extreme weather events like cloud bursts. This loss of forest cover exacerbates soil erosion and affects biodiversity, threatening the habitats of many endemic species.

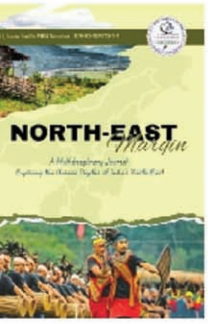
2. Impact on Infrastructure: Damage to Roads and Bridges:The sudden and heavy downpours associated with cloud bursts can cause significant damage to infrastructure, particularly roads and bridges. The National Highways Authority of India reported that during the 2019 cloud burst in Arunachal Pradesh, several key highways were severely damaged, disrupting connectivity and transportation for weeks.

   Urban Flooding: Urban areas in the North-Eastern region, such as Guwahati and Shillong, are increasingly experiencing urban flooding due to cloud bursts. According to the North Eastern Space Applications Centre (NESAC), urban flooding incidents have increased by 15% in the last decade. In July 2020, a cloud burst in Guwahati led to severe waterlogging, affecting over 50,000 residents and causing significant economic losses.

3. Impact on Agriculture: Crop Damage and Loss of Livelihoods: Cloud bursts can devastate agricultural lands, leading to crop damage and loss of livelihoods for farmers. The Department of Agriculture, Cooperation & Farmers Welfare reported that during the 2017 cloud burst in Assam, over 40,000 hectares of paddy fields were submerged, resulting in an estimated loss of ?200 crore. Such events severely affect the livelihoods of farmers, who depend on agriculture for their sustenance.

   Soil Fertility Degradation: The heavy runoff from cloud bursts can wash away the topsoil, reducing soil fertility and affecting future agricultural productivity. Studies by the Indian Council of Agricultural Research (ICAR) indicate that soil erosion rates in the North-Eastern region have increased by 10% over the past decade, largely due to extreme weather events like cloud bursts.

4. Social and Economic Impact: Displacement and Loss of Lives: Cloud bursts often lead to displacement of people and loss of lives. According to the National Disaster Management Authority (NDMA), cloud bursts in the North-Eastern region have caused the displacement of over 100,000 people in the past decade. For example, the 2019 cloud burst in Itanagar, Arunachal Pradesh, resulted in the displacement of



over 2,000 people and claimed 12 lives.

Economic Losses: The economic impact of cloud bursts is substantial, affecting various sectors including agriculture, infrastructure, and tourism. A study by the North Eastern Council (NEC) estimated that cloud burst-related damages have resulted in economic losses exceeding ?1,000 crore annually in the North-Eastern region. The tourism sector, a significant contributor to the region's economy, is particularly vulnerable, with decreased tourist inflow during and after such events.

11. Conclusion

The increasing trend of cloud bursts in the North-Eastern region of India poses significant challenges, including landslides, infrastructure damage, agricultural losses, and socio-economic disruptions. This study highlights the multifaceted causes, such as climate change, deforestation, urbanization, and orographic factors, that contribute to the rising frequency of these extreme weather events. Effective mitigation and adaptation strategies are essential to protect vulnerable populations and ecosystems. These include improving early warning systems, enhancing infrastructure resilience, promoting sustainable land use practices, and building community preparedness. By implementing these measures, the region can better manage the impacts of cloud bursts and enhance overall resilience.

Mitigating Measures

1. Early Warning Systems: Enhance meteorological monitoring and prediction capabilities to provide timely and accurate warnings of potential cloud bursts.
2. Community-Based Disaster Management: Train local communities in disaster preparedness, response, and recovery to improve resilience at the grassroots level.
3. Sustainable Urban Planning: Develop and implement urban planning guidelines that incorporate proper drainage systems, green infrastructure, and flood control measures.
4. Afforestation and Reforestation: Promote large-scale afforestation and reforestation projects to stabilize soil, reduce erosion, and enhance water retention capacity.
5. Watershed Management: Implement effective watershed management practices such as contour bunding and check dams to reduce runoff and improve groundwater recharge.
6. Infrastructure Resilience: Strengthen infrastructure, including roads and bridges, to withstand extreme weather events and reduce damage.
7. Policy and Governance: Formulate and enforce policies aimed at reducing deforestation, controlling urban sprawl, and managing land use changes sustainably.
8. Public Awareness Campaigns: Conduct awareness campaigns to educate the public about the risks associated with cloud bursts and the importance of disaster preparedness and environmental conservation.

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