CLOUDBURST: A FREQUENT NATURAL DISASTER IN INDIA

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Abstract:

National Disaster Management Group has identified cloudburst as one of the frequent natural disasters in India. According to Indian Meteorological Department (IMD), Western Himalaya is suitable place for recurrent cloudburst in association with rainstorm. Common mechanism responsible for cloudburst process is known as Langmuir Precipitation. Colder clouds are more likely to precipitate than warm clouds because cold (deep) clouds have higher cloud tops than warm clouds.High concentration of aerosol trapped in the atmosphere and glaciers initiated the nucleation process in the concentrated water vapour responsible for the formation of cloudburst.Global Warming causes glacial melting which helps to increase the volume of cloud which ultimately accelerate the process of Langmuir Precipitation. This article deals with different mechanisms related to frequent cloudburst in India in recent times in relation to recent climate change phenomenon.

Keywords: Cloudburst, Cumulonimbus convection, Langmuir Precipitation, Thunderstorm, Aerosol

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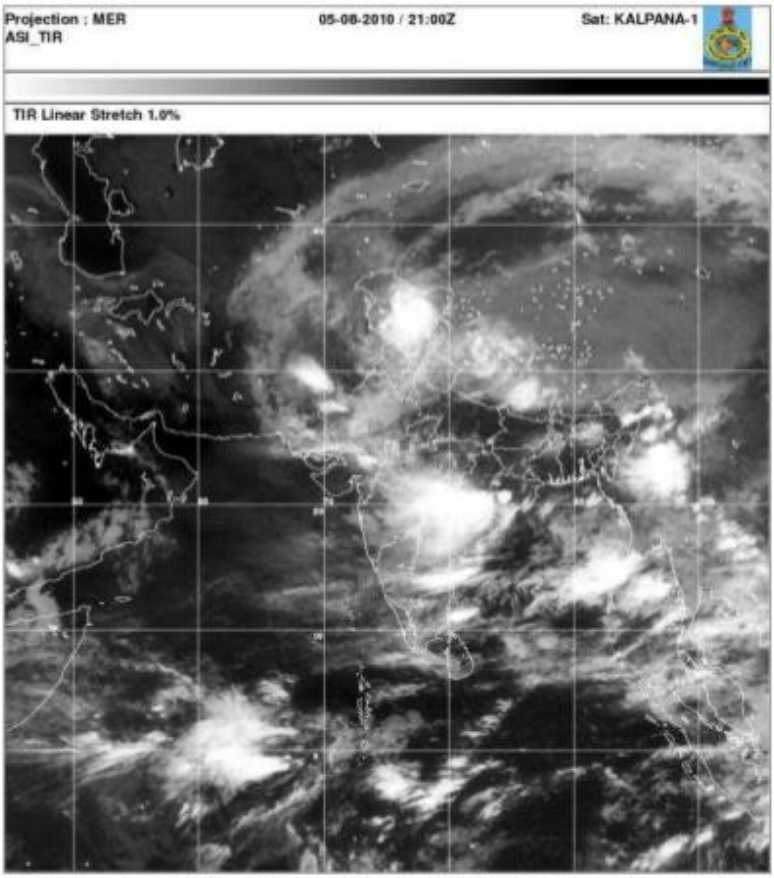
Introduction

According to the India Meteorological Department (IMD) a cloudburst features very heavy rainfall over a localized area at a very high rate of the order of 100 to 1000mm per hour featuring strong wind and lightning. Various researches suggest that they are manifestations of intense vortices on small scale that generate strong convection currents, which lift the moisture laden air with sufficient rapidity to form cumulonimbus clouds. The copious rainfall characteristic is caused by a phenomenon known as Langmuir Precipitation process, in which drops of rain coalesce together at almost lightning speed to create larger and larger sized drops. As they grow more and more in size, they fall quicker and quicker.(Bandhyopadhyay,2011)In India cloudbursts usually occur during the monsoon season over orographically dominant regions like the Himalayas and the Western Ghats. These can also occur over the plains, but such occurrences are rare.

It is believed that cloudburst occur because of rapid lifting of clouds by the steep orography of the region.This process is called the "Cumulonimbus Convection condition".This lifting is usually dynamic causes thermodynamic instability resulting in rapid condensation.In Himalayan region the soil moistened by earlier precipitation perhaps acts as an additional source of moisture might also have a role in the frequent cloudbursts in the region **(**Jain,et al.,2013). According to IMD scientists the cloudburst in Leh occurred due to an unusual movement of monsoon cloud.Analysis of satellite imageries indicate that the intense convective system developed in the easterly current associated with monsoon conditions over the region. The convective cloud band extending from southwest to northeast developed over Nepal and adjoining India.(IMD 2010)



Source :Investigating the Leh 'Cloudburst'. Raghavendra Ashrit , *National Centre for Medium Range Weather Forecasting ,Ministry of Earth Sciences*

Fig: 1 Concentration of Cloud over Ladakh

In UttarakhandExtraTerrestrial influence leads to rise in temperature to release the aerosol trapped in the glaciers and atmosphere in Indo China border to initiate the cloudburst in 2013**.(**Mukherjee,2014).Himalayan Glaciers have been in a general state of recessionsince a long time. As per the report "Snow and Glaciers of the Himalayas: Inventory and Monitoring" released by the Ministry of Environment and Forests(MOEF)in 2011,out of 2700 glaciers which are monitored 2184 are retreating ,435 are advancing and 148 glaciers show no change. Existing studies of Himalayan glaciers indicate that many have exhibited an increased receding trend over the past few decades.(Jain,et al.,2013)

Materials and Methods

Relevant research concerning mechanism of cloud burst was identified by searching the literature or article reviews published in different peer review journals during a period of last two decades

for primary research material. Finally, a comprehensive search was made of Internet resources in India and internationally.

A total of 12 research databases were identified with key articles obtained primarily fromJournal Of The Centre For Creative Learning And Research,Vol.1,2011, Science Reporter August 2013, IMD 2010,Geophysics and Remote Sensing 2014,Volume 3,Issue 3,IOSR Journal Of Environmental Science, Toxicology And Food Technology, Volume 7, Issue 2 (Nov. - Dec. 2013),Critchfield,Howard j, 2003, General Climatology(4th ed.), National Disaster Management Guidelines, The Tribune News Service,Siddhartha,k,2004,Atmosphere,Weather and Climate**.**The next step was a detailed examination of articles, and at this point studies were excluded if phenomena were insufficiently described. For the studies investigating direct associations between cloud formation and burst, the review includes all peer reviewed longitudinal studies investigating mechanism behind it. Longitudinal studies were seen as a particularly valuable resource as they facilitate the testing of relationships between early events or characteristics and later outcomes, and enable the identification of developmental sequences and pathways, as well as the construction of theoretical models which can then be validated in future research.

But, due to the limited volume of published studies, quantitative and qualitative studies and their comparisons werenot done satisfactorily, but attempts were made to elucidate direct possible mechanism behind their formation wherever possible.

Results and Discussion

A) Cloudburst and Thunderstorm

Cloudburst is formed from mature stage of thunderstorm.Precipitation from the mature storm is intense and composed of large raindrops,literally known as cloudburst**(Fig.2)**.

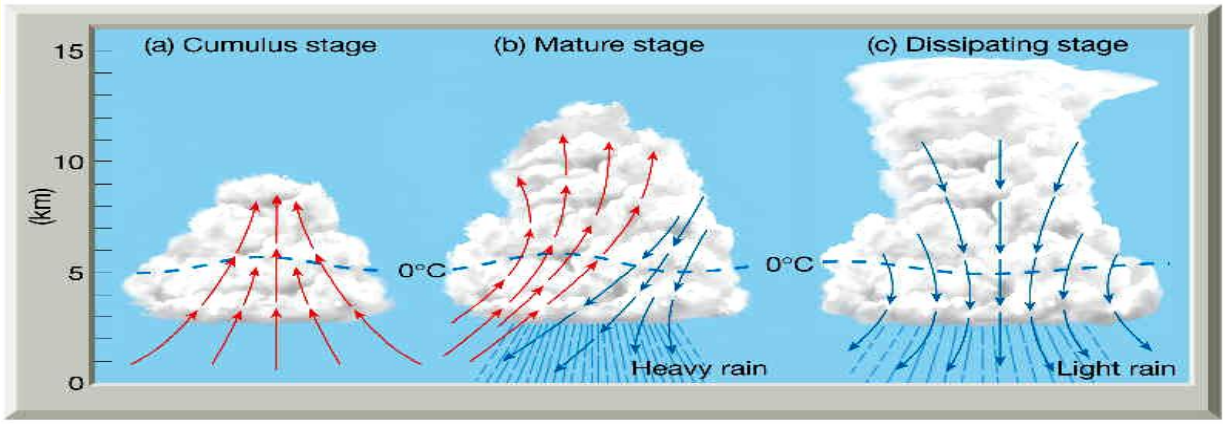


Fig 2:Stages of Thunderstorm Development

Source:http://www.geography.hunter.cuny.edu/~tbw/wc.notes/10.thunderstorms.tornadoes/thunderstorm_stages.htm

The common process that initiate thunderstorm development are-

- heating and convection in moist air over warm land surfaces;
- passage of cold,moist air over warm water;
- forced ascent of conditionally unstable air along zones of convergence or at mountain barriers;
- radiational cooling at upper levels;
- advection of cold air aloft.(Critchfield, 2003)

In case of tropical thunderstorm water droplets cannot reach the freezing level, hence they reach the surface as cloudburst formation.

Principal rain bearing meteorological systems that lead to short duration heavy rainfall and which may also cause floods are:

- ✓ monsoon depressions;
- ✓ fluctuations in the intensity and location of the monsoon trough over the plains of India;
- ✓ a mid-troposphere circulation or low pressure off the coasts of India particularly over Gujarat;
- ✓ off shore vortices;
- ✓ cumulonimbus convection in condition;
- ✓ moist thermodynamic instability.

Apart from these, land based lows or depressions during monsoon cyclones and persistence of low pressure areas over adjoining coastal areas may sometimes lead to floods. Hilly areas in Himachal Pradesh,Uttarakhand,the northern areas of West Bengal, Sikkim , Arunachal Pradesh , Manipur , Mizoram,Meghalaya,Nagaland and Tripura and the coastal areas in the states of West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Maharashtra and Gujarat and Union Territories (UTs) of Andaman and Nicobar Islands and Lakshadweep are more prone to such phenomena.Such events have also occurred in the states of Rajasthan, Chattisgarh, Madhya Pradesh and Uttar Pradesh.**(**National Disaster Management Guidelines, 2008)

B) Cloudburst and Langmuir precipitation:

Since the cloudbursts are associated with cumulonimbus clouds, where the upper part of the cloud exceeds freezing level and precipitation process remains under Bergeron-Fiendeisen's chain reaction domain,the lower part of the same cloud under favorable condition becomes a prey of Collision-Coalescence chain reaction domain.(Bandyopadhyay,K,K,2011)

Collision-Coalescence process is the process that explains the growth of raindrops or precipitation particles. Collision-Coalescence ideas were put forward by George Simpson and Mason. These ideas were modified by Langmuir. He pointed out that the terminal velocities of falling drops are directly related to their diameters. Drops that have grown on larger condensation nuclei become larger. The larger drops will have a higher terminal velocity than the smaller ones and so collide with them.When the collecting drop (the larger one)is 60 microns in diameter its collection efficiency is about 50 percent,but it is only about 10 percent at 40 microns and less than 5 percent at 30 microns.The collection efficiency is said to be 100 percent when the drop collects all the droplets in its direct path.Thus,when both the collection efficiency and the fall rate of the droplets and crystals are taken into consideration it is found that coalescence is almost nil until the droplets or crystals exceed 40 microns**(Fig.3)**.

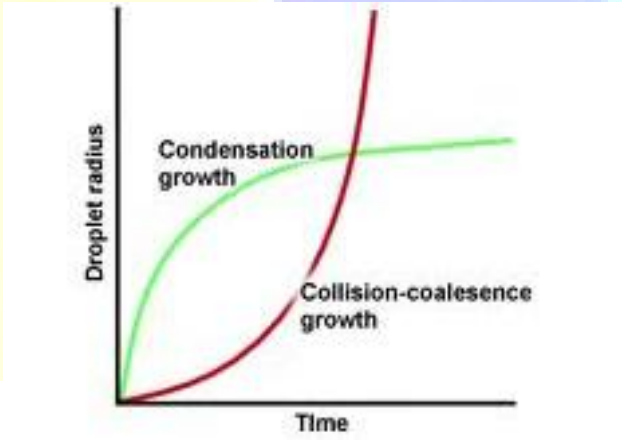


Fig: 3 Droplet Growth by Condensation andCoalescence

Source: http://www.meted.ucar.edu/norlat/orographic/media/graphics/rad_time_2/

Once the collecting particles are larger than this, coalescence proceeds so rapidly that raindrops would often be far larger if they didn't break apart once they exceeded a few millimeters in

diameter.Even with collision,growth will only occur if the two drops coalesce.This will occur most readily if-

a)the drops are of considerably different sizes, and

b)atmospheric electricity is present to hold the droplets together. If a droplet with a negative charge should collide with a positively charged droplet their electrical attraction will bind them together.

Continued collision, thus leads to coalescence resulting in many large unstable drops which on further disruption produce several large drops and its continued coalescence and further disruption leads to many larger drops**.(**Siddhartha,2004**)**

Case Studies:

There is no particular mechanism stating the formation of cloudburst.Hence mechanisms of recent cloudbursts in the areas of Leh,Uttarakhand from India are discussed here as case studies.

Case Study 1:Leh,August,2010

On August 6,2010 sudden overnight rains caused flash floods in the town of Leh.

Possible Mechanism: Usually,the western Himalayan region experiences the cloudburst events during the monsoon season in association with the strong monsoon circulation or the interaction of monsoon circulation with the mid-latitude westerly system.The orography of the region plays a dominant role by increasing the convection and hence the intensity of cloudburst.HoweverLadakh region is not known to be frequently affected by this type of phenomena.It is a cold desert and average rainfall for the month of August is 15.4mm only.The highest rainfall ever recorded over Leh during 24 hours period has been 51.3mm recorded on 22 August,1933.However in case of Lehcloudburst,the flow from the west or northwest seems to be sufficiently moisture rich following intense convection and flooding in August 2010.The instability trigger seem to have come from the cloud cluster that moved from Nepal region.The cloudburst was highly localised as the nearby meteorological observatory of Indian Air Force(IAF) reported. According to synoptic analysis,the monsoon trough at the mean sea level lay to the south of its normal position on 4^{th} and 5^{th} August.(**Fig:1**)There was a cyclonic circulation in lower levels over west Rajasthan and neighbourhood.Awell marked low pressure

area lay over northwest of Bay of Bengal on 5th and over north Orissa and neighbourhood on 6th August.**(**IMD2010**)**

Case Study 2:Kedarnath,Uttarakhand,June,2013

Between 16 and 17 June 2013,the hills of Uttarakhand were subjected to intense rainfall-370 millimetres of rainfall was recorded at Dehradun with a 24 hour period,which is exceptionally rare.

Possible Mechanism:The steep orography of Garhwal –Kumaun Himalaya and concentration of monsoon clouds create the situation of cloudburst. But there may be some other factors behind this catastrophic event.Climate change manifestation can be seen in the disaster of kedarnath,Himalaya of India.(Mukherjee ,2014) Himalaya is warming at least twice as fast as the globeThis glacier melt water come in direct contact with clouds due to higher altitude.The temperatures of the glacial lakes are normally below or near the freezing temperatureThe saturation vapour pressure over supercooled water remains high so the evaporated water of the lake immediately is being condensed over the cloud and volume of the cloud is increased with time.In 2013,monsoon arrived before the normal time due to extra tropical disturbances which causes high concentrations of clouds in and multiday cloudburst in Kedar Dome and surrounding areas**.(Fig:4)**Due to collusionbetween two airmasses the formation of cumulonimbus cloud generated rapidly.**(**Das,2013**)**

Fig:4NASASatellite Iimagery of Northern India on 17 June, Showing Rainclouds that led to the Disaster

Source:https://en.wikipedia.org/wiki/2013_North_India_floods

Case Study 3:Amarnath,Kashmir,July 2015

On July 2015 cloudburst are recurrent in and around Baltal,the base camp for the Amarnath shrine.

Possible Mechanism: Weather scientists say the hilly terrain of the state favours formation of cumulonimbus clouds and the deadly interaction of two different wind patterns leads to shedding of larger droplets of water at a higher rate in a relatively short period. The topography of the state plays a role in making cloudbursts highly localised. Conditions across the Himalayas, including Jammu and Kashmir, are changing and witnessing extreme weather events due to climate change. For the last two years, there has been greater frequency of deadly interaction of moist warm monsoon winds and cool dry western winds called western disturbance, creating a low pressure area over the state and resulting in extremely heavy rain.According to Sonum Lotus, Director, Indian Meteorological Department, Srinagar,there is no accurate way to predict such an incident like cloudburst.(Hakhoo,2015**)**

Normal Precipitation and Cloudburst

Cloudburst is actually a situation when the inter-molecular forces between the water molecules get very high due to rapid decrease in temperature or excess of electrostatic induction in the clouds causing the lighting to remain inside the cloud only, which causes hyperactive energy inside the cloud. A chart is given below showing some differences between normal precipitation and cloudburst**(Table:1)**.

Table1: Table Showing Precipitation Size and Speed

Forms Of Precipitation	Intensity(cm/hour)	Median diameter(millimeters)	Velocity of fall(meters/second)	Drops per second per square meter
Drizzle	0.025	0.96	4.1	151
Light rain	1.02	1.24	4.8	280
Moderate rain	0.38	1.6	5.7	495

Heavy rain	1.52	2.05	6.7	495
Excessive rain	4.06	2.4	7.3	818
Cloudburst	10.2	2.85	7.9	1220

Source: Lull,H.W,1959,Soil Compaction On Forest And Range Lands,U.S.Department Of Agriculture,ForestryService,Misc,Publication No.768

From the above chart it is found out that median diameter of cloudburst is 2.85 millimeters which is equivalent to 2850 microns(as 1mm to 1000 microns).Therefore we can associate coalescence with droplet size in case of cloudburst.

Cloudburst in India

A chart is given below showing year wise occurrence of cloudburst in India**(Table:2)**.

Table2: Table Showing Year wise occurrence of Cloudburst in India

Date-Year	Location	Casualties
September 28 ,1908	Kurseong Municipality	15000 people were killed
July,1970	Uttarakhand	Badrinath to Haridwar was affected
August 15,1997	Chirgaon in Shimla district,Himachal Pradesh	115 people were killed
August 17,1998	Kumaondivision,Uttarakhand	250 people were killed
July 16,2003	Shilagarh in Gursa area of Kullu,Himachal Pradesh	40 people were killed
July 6,2004	Chamolidistrict,Uttarakhand	17 people were killed,28 were injured
July 26,2005	Munbai	Paralysed India's largest city and financial centre
August 16,2007	Bhavi village in Ghanvi,Himachal Pradesh	52 people were killed
August 7,2009	Munsiyari in Pithoragarh district of Uttarakhand	38 people were killed
August 6,2010	Leh town of Ladakh region in Jammu & Kashmir	179 persons were killed ,over 400 persons were injured
September 15,2010	Almora in Uttarakhand	Almora,Ranikhet has been worstly affected
June 9,2011	Near Jammu	4 persons were killed,over several injured
September 14,2012	Uttatakhand	39 persons were killed

June 15,2013	Kedarnath,Uttarakhand	5700 people were killed
July 31,2014	Tehri district of Uttrakhand	4 people were killed
September 6,2014	Kashmir Valley	200 people were killed
July 23,2015	Amarnath,Kashmir	3 people were killed and 11 were injured

Source: Compiled By Author

From the above table showing year wise occurrence of cloudburst in India, it is observed that before 2003,cloudburst was sudden in India.But after that it becomes a frequent phenomenon.

Conclusion:

The Cloudburst is one of the major natural hazards in the Himalayas,occurring amid extreme hydro-meteorological conditions.It is difficult to forecast a mesoscale weather phenomenon like cloudburst.It requires high-resolution numerical models,Doppler Weather Rader(DWR),Automatic Weather Station(AWS),Radiosonde/Rawinsond(RS/RW)etc.High intensity rainfall events in the Himalayan region are often localized which sometimes occur in remote areas as a result of topographic variations.Cloudburst sometimes even remain unreported due to inaccessibility of the region where they occur.(Kumar,2013)But the actual mechanism of cloudburst is still remain unknown to scientists.A possible cause of the copious rainfall could be the fusion of westerlies which triggered Flash Floods. Recent climate change can be predicted as one of the major causes of Cloudburst.

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