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CLIMATIC EXTREMES AND CHANGING CLIMATE IN WESTERN HIMALAYAS: A STUDY OF CLOUDBURST INCIDENCES IN HIMACHAL PRADESH

Vishwa B.S. Chandel
Karanjot Kaur Brar

Abstract

Our climate is changing faster than ever before and this has been causing various types of natural disasters such as droughts, floods and cloudbursts. Cloudburst is a weather anomaly representing highly concentrated rainfall both in time and space. Himachal Pradesh is a part of a dynamic and complex Himalayan region where climate is very variable. Cloudburst results excess and intense rainfall that can lead to flash floods in the state. Cloudburst related disasters have an established history of causing catastrophes, therefore, these are of grave concern for this mountainous state whose economy is directly linked to prevailing climatic conditions. This work, therefore, is an effort to understand cloudburst occurrences as an indicator and expression of changing climatic conditions in the state of Himachal Pradesh. The spatio-temporal analysis reveals the fact that such events have not only increased over time but their area of influence has also expanded over a larger space. In addition there is seasonal spread which indicates changing rainfall regime over the area.

Introduction

Changing climate is one of the most debatable issues of today. Climatic changes are very slow and episodic; the extreme patterns of today are attributed to the human induced impact on natural systems (Walker and Walter, 2000; Intergovernmental Panel on Climate Change (IPCC), 2001; Center for Research on the Epidemiology of Disasters (CRED), 2004; World Disaster Report, 2009). Climatic change is leading to accelerating rates of various types of natural disasters such as floods and drought (International Centre for Integrated Mountain Development (ICIMOD), 2007) that may have striking impacts on society and on the process of development. Regional studies pertaining to northwestern India also suggest that the drier parts are getting greater rainfall and the wetter parts becoming drier (Brar, 2000). These have implications for the occurrence of extreme events such as cloudburst and flash floods. The recent Leh cloudburst on August 6, 2010 which killed over 200 people clearly exhibits such changes. Visualized as a local phenomenon, this incident reveals a graver situation. The intense rainfall over 200 mm in just one hour was not just a local phenomenon; the cold desert areas of Himachal Pradesh also witnessed high rainfall during the same period causing numerous landslides and flash flood incidents. It is an indication that the cold desert areas are also becoming more vulnerable to

such disasters.

Cloudburst is an extreme form of rainfall, sometimes mixed with hail and thunder. It is a weather anomaly representing highly concentrated rainfall both in time and space and is the result of intense vortices on a small scale wherein moisture laden air rapidly rises to form cumulonimbus clouds which cause highly intense downpour (Das, 1988). The precipitation from cumulonimbus clouds is caused by Langmuir precipitation process in which large sized droplets grow rapidly by coupling with smaller droplets. The occurrence of cloudburst requires fulfillment of certain climatic conditions such as presence of highly moist air and a mechanism that causes sudden rise of air and it's cooling at a fast rate thus leading to highly intense rainfall. The rainfall amounts to over 100 mm per hour accompanied by strong winds and lightening and concentrated over an area not exceeding 20-30 km^2 (Das et al. 2006). The conditions leading to cloudburst in western Himalayas are only possible during the monsoons when air possesses very high degree of moisture. The presence of high mountain ranges ensures the sudden rise of moisture laden air which gets rapidly cooled. An intense system could lead to cloudbrust resulting enormous quantities of rainfall concentrated to just a few hours.

Objectives, Data Source & Methodology

This work is an endeavor to understand cloudburst as an indicator and expression of climatic changes. It is expected that such incidents have increased spatially as well as temporally and there is a marked variation in cloudburst occurrence among different physiographic divisions in the study area. The aim of this study is to understand how cloudburst occurrence has manifested through time and space. The time-period under study is 1971-2009. The database has been extracted from a daily regional newspaper 'The Tribune' for the said period. The extracted information was tabulated and the database thus created has been analysed for historical reconstruction, spatio-temporal and seasonal manifestations, impact on humans and demarcation of major cloudburst prone areas. The location of cloudburst events has been mapped on topographical sheets of 1:250,000 scale. The interpretation of locational distribution takes into consideration the character of different physiographic and climatic zones.

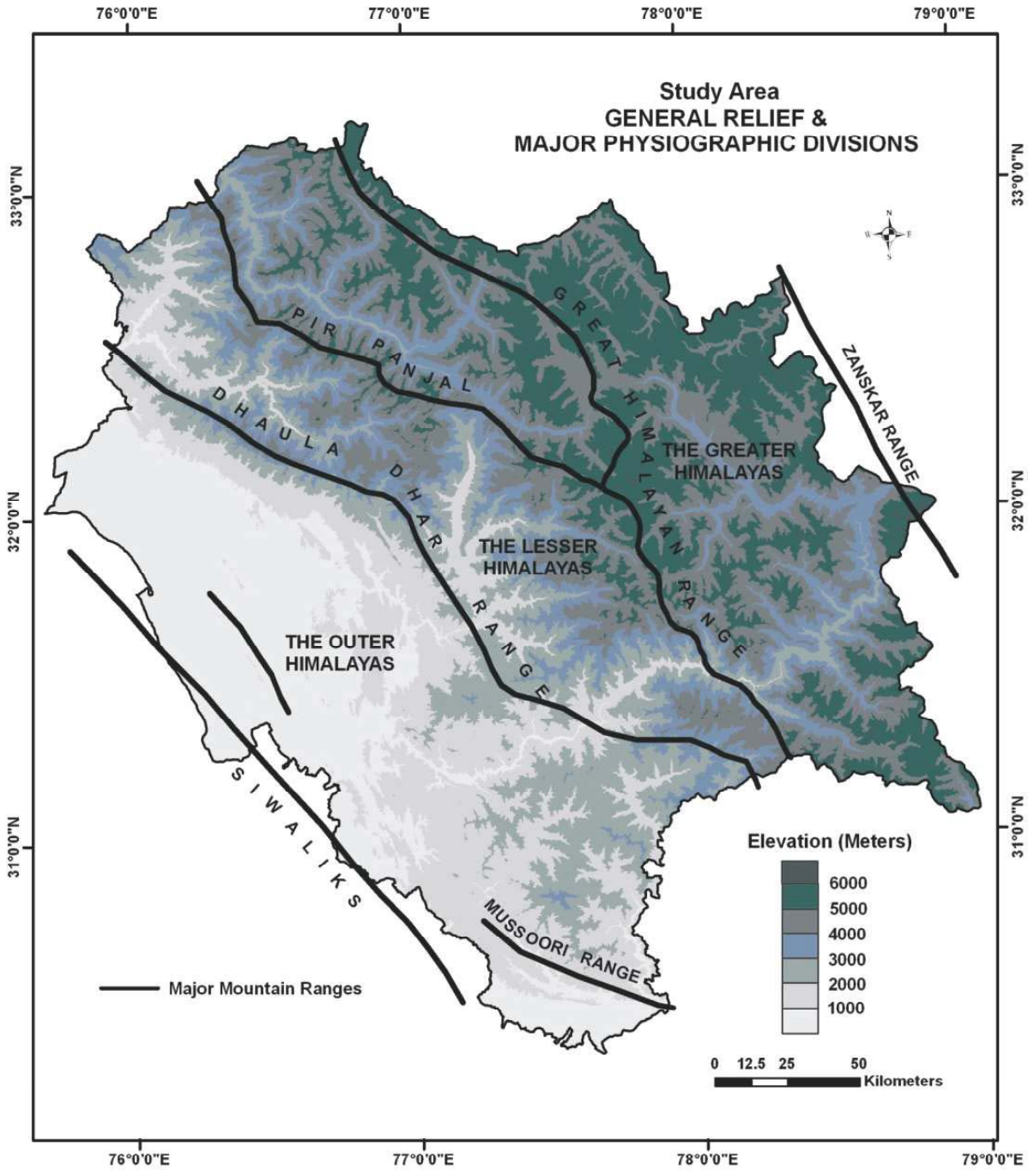
Study Area

Himachal Pradesh forms a part of the dynamic and complex Himalayan region, where altitude varies from 450 meters to about 7000 meters above mean sea level. The altitude increases from west to east and south to north. The general landscape presents an intricate mosaic of mountain ranges, hills and valleys. Important ranges include the Siwaliks, Dhauladhar, Pir Panjal, Great Himalaya and the Zanskar separated by valleys, glens and hills. The topography of the state is a part of the Himalayan System and is usually divided into three physiographic zones: Siwaliks, Lesser Himalayas and Greater Himalayas running almost parallel to each other throughout the length of the state from northwest to southeast (Map 1). The climate here is highly variable. The monsoon rainfall that is concentrated for two to three months in the western Himalayas (Chalise and Khanal 2001) governs the climate. Excessive rainfall leads to incidents of cloudburst and flash floods. These disasters have an established history of causing catastrophes and more so it is matter of grave concern in this hilly state which has its economic development dependent on hydro-power, tourism and horticulture which are directly influenced by climatic variations. Therefore such extreme events need to be

understood in time and space for the preparedness to face such disastrous events.

Historicalical Overview

The state has been devastated by several major damaging cloudbursts during the period 1971-2009 (Table 1). During the 1970s cloudburst was a rare phenomena and only five incidents were reported claiming 71 human lives. These include two cloudbursts in Rohru area of Shimla and Churdhar area of Sirmaur districts in 1975 and three cloudbursts during monsoons of 1978, one each in Chamba, Kinnaur and Solan districts. There were seven



Map 1

Table 1
Himachal Pradesh Major Cloudbursts (1971-2009)

	Date	Place of occurrence	Damages
1	12.07.1975	Lena Cheta Village, Nohradhar, Sirmaur	13 persons killed, 8 water mills damaged along with heavy loss of property
2	01.07.1978	Gohra, Tarodu & Kirti villages, Chamba	21 persons killed including 7 in Gohra, 13 in Tarodu and 1 in Kirti village.
3	18.08.1978	Dayari Village, Dharampur, Solan	24 persons washed away in flash flood
4	12.06.1980	Daigaon and Karasa villages, Rohru, Shimla	5 persons, 20 sheep and 10 cattle were killed. One house washed away while 3 bridges and one *Jhula* were damaged.
5	13.08.1987	Sarahan, Rampur, Shimla	15 persons killed in Badhal, Gharat and Darali villages near Sarahan. An entire locality of 15 houses at Gharat Nullah washed away. Loss estimated over Rs.5 crore.
6	06.07.1990	Dharamsala, Kangra	2 people killed. 3 houses collapsed and about 25 were damaged. Some buildings were rendered unsafe due to landslides.. The bridges on Khaniara-Dharamsala road and Dharamsala-Palampur were damaged.
7	15.09.1991	Jangli Village, Rohru, Shimla	The entire Jangli village of 25 houses washed away due to a cloudburst in Rohru area; 1 female and 90 cattle were killed along with the damage to 175 *bighas* of cultivated land.
8	08.07.1993	Chuhar valley, Swar & Devgarh villages, Mandi	28 people killed, 62 cattle perished, 11 buildings and 125 hectare of agricultural land washed away.
9	11.07.1994	Shaat Village, Manikaran, Kullu	70 people killed and 11 houses, 15 kiosks, 9 water mills, 10 bighas of agricultural land, 4 vehicles, 1 bridge over and a long stretch on Bhuntar- Manikaran road washed.
10	11.08.1994	Fojal, Katrain, Manali	11 people died. 3 houses, 1 health centre, 1 dispensary, 5 water mills, 16 kiosks, 2 cowsheds, 3 shops, 2 scooters and 1 truck washed away.
11	23.08.1994	Paladi village, Bhuntar, Kullu	15 persons died. 10 houses, 1 watermill, 1 bridge and few other structures washed away.
12	22.08.2001	Sarali & Badali village, Ani, Kullu	10 persons were killed, 10 cattle perished and the Khanag road leading to Kulu via the Jalori pass damaged.
13	16.07.2003	Pulia *Naullah*, Gadsa, Kullu	35 persons died extensive damage to the Parbati Project of the National Hydroelectric Power Corporation (NHPC).
14	07.08.2003	Kangni *Naullah*, Manali, Kullu	60 labourers were washed away
15	14.08.2007	Ghanvi Village, Rampur, Shimla	65 persons washed away; 14 houses were swept and 13 partially damaged; A primary health centre building and a residence of a doctor were also washed away.

Source: The Tribune, 1971-2009

cloudbursts during the decade 1980-89 in which 24 people lost their lives. The damaging events include a cloudburst on 12 June 1980 in the villages of Daigaon and Karasa in Rohru tehsil of Shimla district that washed away 5 people, 20 sheep, 10 cattle and damaged one house and three bridges and one ropeway (Table 1). Another damaging cloudburst occurred during monsoons of 1987 in Shimla district which claimed 15 lives and damaged property worth Rs. 5 crore. The other areas hit by cloudbursts include Chamba, Kullu and

Lahaul & Spiti districts.

1990s was the decade of heavy rainfall and cloudburst incidences occurred with more ferocity. There was noticeable rise and spread of such events. A total of 28 incidents occurred, most of which were reported in the years 1994 and 1999. These incidents claimed more than 170 human lives. Some of the major incidents in early 1990s include cloudburst at Dharamsala on 6 July 1990; Jangli village of Rohru tehsil of Shimla district on 15 September 1991 and Chuhar valley of Jogindernagar area in Mandi district on 8 July 1993. During the year 1994, a total of 12 cloudbursts occurred in the state including 4 in Kullu, 3 in Kangra, 2 in Lahul & Spiti, and 1 each in Hamirpur, Mandi and Kinnaur districts. In 1995, three cloudbursts hit the state, two in Solan and one in Shimla district. In the next two years no incident was reported in the state. There were six incidents in 1999, two each in Kullu and Chamba districts, one each in Kangra and Mandi districts which killed eleven persons in Kullu, two in Kangra and one in Chamba district of the state.

Himachal Pradesh was hit by 67 cloudbursts during 2000-2009. There were six cloudbursts in 2000, six in 2001, two in 2002, five in 2003, three in 2004 and five in 2005. There were 13 cloudbursts in the state during 2006. These mainly occurred in Chamba, Kinnaur and Lahul & Spiti districts. In 2007, 15 incidents of cloudbursts were reported, five in Chamba, three in Kangra, two each in Solan and Shimla, one each in Mandi, Kinnaur and Sirmaur districts respectively. During 2008, 10 cloudbursts occurred in the state, five in Chamba, two in Sirmaur and one each in Kullu, Kinnaur and Solan districts. There were three incidents of cloudburst in 2009. The first occurred near Nagar in Kullu district, second in the Salooni tehsil of Chamba district while third occurred in Mandi district.

Spatio-Temporal Distribution and Concentration

Spatio-Temporal Patterns

The spatio-temporal analysis of cloudburst occurrences present a very interesting picture which indicates a changing climatic regime in the study area. During the period under study the first event of cloudburst was recorded in 1975 in Shimla district and by 2009, 108 such events were reported. The data for the period 1971-2009 reveals that there is consistent rise in cloudburst occurrences (Fig. 1 & Map 2) over time in Himachal Pradesh and this rise is more prominent after 1990s. About 96 out of 108 events, which account for about 90 per cent of the total events, occurred during past twenty years and about 63 per cent in just the last decade decade of 2000-09 (Fig.1,Table 2).

The cloudburst incidents during 1970s and 1980s were very few and their spread was restricted spatially. In 1970s only five events occurred, one each in the districts of Chamba, Kinnaur, Shimla, Solan and Sirmaur. The following decade recorded seven incidents; three in Shimla and one each in Kullu, Chamba, Lahaul & Spiti and Bilaspur districts. There was a four time increase during 1990s when a total of 28 cloudburst events were recorded (Table 2). The frequency was exceptionally high in the year 1994 when 12 incidents were recorded. The worst hit districts were Kullu, Kangra, Chamba and Mandi. The first decade of 21st century witnessed 68 incidents that account for two-thirds of the total cloudburst occurrences during the study period. There was not only marked rise in frequency as compared to the previous decades but occurrences also became more prominent in the later half of 2000s. The frequency was very high in 2006, 2007 and 2008 and these were mainly concentrated in Kullu, Chamba, Shimla and Kinnaur districts. The data establishes the clear

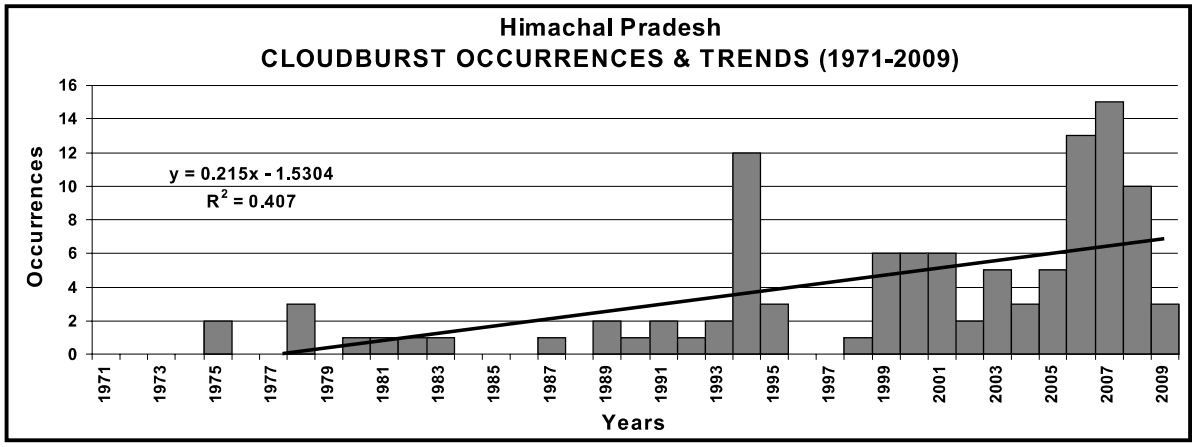


Fig. 1

Table 2
Himachal Pradesh: Cloudburst (1971-2009)

		1971-1979	1980-1989	1990-1999	2000-2009		
	District	Occurrences	Occurrences	Occurrences	Occurrences	Total	per cent
1	Kullu	0	1 (14.28)	9 (32.14)	14 (20.59)	24	22.22
2	Chamba	1 (20)	1 (14.28)	3 (10.72)	14 (20.59)	19	17.59
3	Shimla	1 (20)	3 (42.86)	2 (7.14)	9 (13.24)	15	13.89
4	Kinnaur	1 (20)	0	1 (3.57)	9 (13.24)	11	10.19
5	Kangra	0	0	5 (17.86)	4 (5.88)	9	8.33
6	Mandi	0	0	3 (10.72)	5 (7.35)	8	7.41
7	Lahaul & Spiti	0	1 (14.28)	2 (7.14)	4 (5.88)	7	6.48
8	Solan	1 (20)	0	2 (7.14)	3 (4.41)	6	5.56
9	Sirmaur	1 (20)	0	0	5 (7.35)	6	5.56
10	Bilaspur	0	1 (14.28)	0	1 (1.47)	2	1.85
11	Hamirpur	0	0	1 (3.57)	0	1	0.92
12	Una	0	0	0	0	0	0.00
	Total (percent)	**5 (100)**	**7 (100)**	**28 (100)**	**68 (100)**	**108**	**100**

Source: The Tribune, 1971-2009
Note: Figures in parentheses are percentages

cut rise in frequency and spatial spread of cloudburst during 1990s which was further amplified, during the first decade of 21st century (Table 2).

Seasonality of Cloudburst Occurrence

Cloudburst occurrences are seasonally biased and mostly happen in monsoon season only. The most suitable period when cloudbursts frequently occur in Himachal Pradesh is late June to mid September. The study reveals that the occurrence of about ¾ cloudburst (77.78%) events is particularly limited to three monsoon months i.e. between July-September (Table 3).

The pre-monsoon months accounted for 21.29 per cent while post-monsoon season recorded less than 1 per cent occurrence of total

Table 3
Himachal Pradesh: Seasonal Distribution of Cloudburst (1971-2009)

Decade	Pre Monsoon		Monsoon			Post Monsoon	Total	Per cent	Annual Avg.
	MAY	JUNE	JULY	AUG	SEPT	OCT			
1971-1979	0	1	3	1	0	0	5	04.63	0.555
1980-1989	0	1	3	2	1	0	7	06.48	0.700
1990-1999	0	2	10	10	5	1	28	25.93	2.800
2000-2009	9	10	19	29	1	0	68	62.96	6.800
	9	**14**	**35**	**42**	**7**	**1**	**108**		
Per cent	**8.33**	**12.96**	**32.41**	**38.89**	**6.48**	**0.93**	**100**	**100**	**2.769**
Per cent	**21.29**		**77.78**			**0.93**			

Source: The Tribune, 1971-2009

cloudburst events. There has been a consistent annual as well as seasonal spread in the occurrences of cloudbursts. During 1970s, such events took place in just two years i.e. 1975 and 1978 and occurrences were confined to a three month period i.e. June-August. During 1980s, the duration of occurrence increased to four months i.e. June- September however, such events were recorded in six years (except the years 1984, 1985, 1986 and 1988). During 1990s the occurrence of these events in the state was recorded in eight years spreading over five months i.e. June-October (Table 3). For the first time in this decade cloudburst event was noted in the post-monsoon season.

The first decade of the 21st century witnessed an unusual seasonal change in the occurrences of cloudbursts. A large number of incidents accounting for about 20 per cent of the total incidents occurred in pre-monsoon period. As many as 19 events were noted in pre-monsoon season out of which 18 were prior to 15 June (Table 3). This is the sign of very erratic rainfall even prior to the early arrival of monsoon rains. Such change is found to be more prominent during the later half of the decade. These changes indicate towards shifting climatic regime during late 1990s and 2000s in the study area as a potential cause of increasing vulnerability to such disaster. It shows that even if there is no increase in the total amount of rainfall, its occurrence with more intensity in limited time is causing such disasters.

The seasonal occurrence of cloudbursts shows that such events in all districts are almost restricted to the monsoon period; however Chamba and Kullu districts are an exception in this context (Table 4). Kullu district accounts for 25 per cent of total cloudbursts in pre-monsoon period while about 4 per cent events occurred during post-monsoons. Chamba district recorded almost over half (52.63%) of the events in pre-monsoon period and most of which occurred in the month of May. As far as post- monsoon period occurrence is concerned, Kullu is the only district where this has happened once. Within the three monsoon months, i.e. July-September, all districts show maximum concentration of cloudbursts during the first two months when monsoons are in full swing. The retreat of monsoons in mid-September explains the fewer incidents of cloudbursts in this month.

Cloudburst Concentration Zones

The spatial distribution of cloudbursts during 1971-2009 exhibits that these have been occurring in and around certain specific areas and locations. These have concentrated mainly

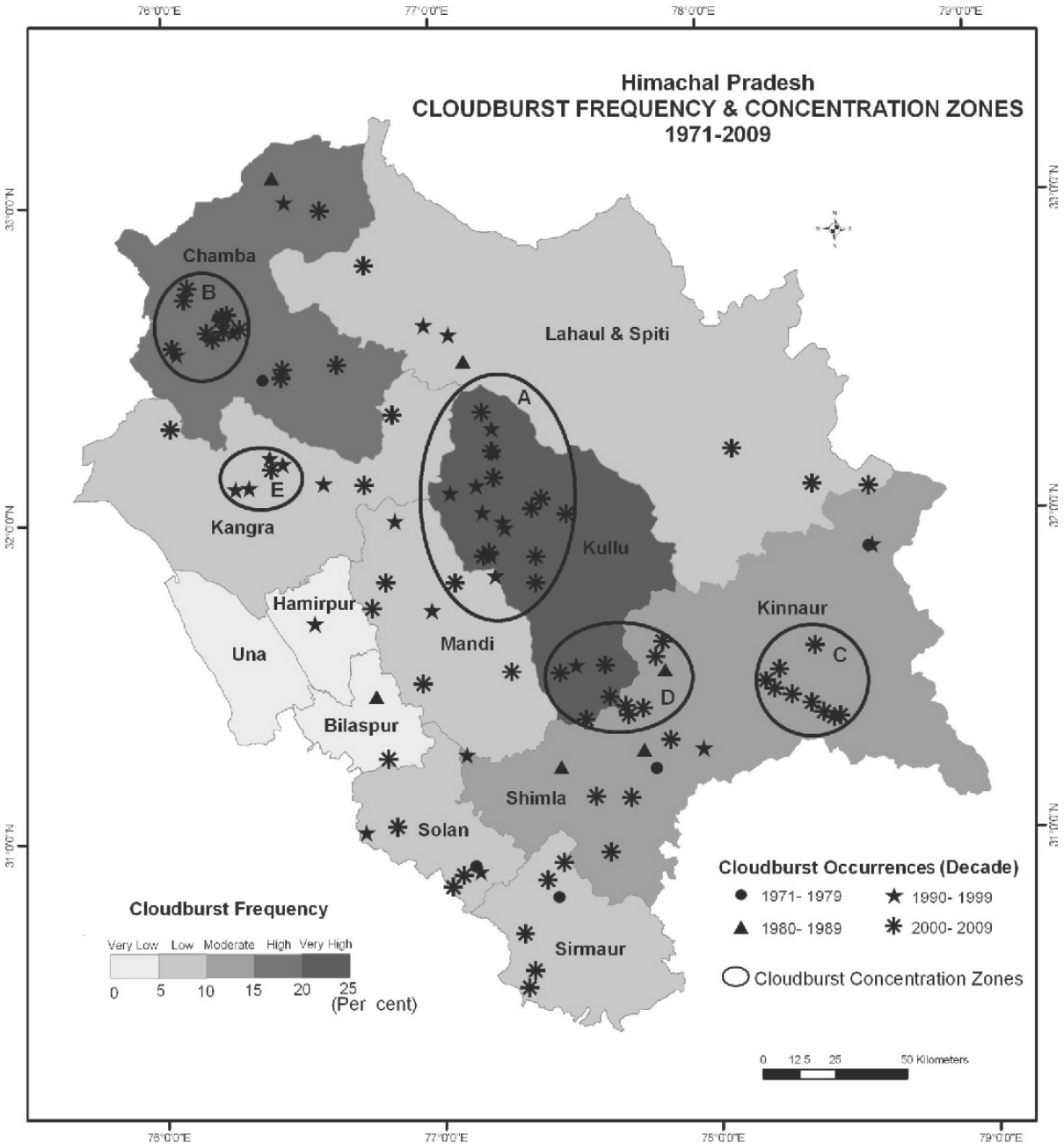
Table 4
Himachal Pradesh: Seasonal Frequency of Cloudburst (1971-2009)

		Cloudburst Events (per cent)						
		Pre Monsoon		Monsoon			Post Monsoon	
	District	MAY	JUN	JUL	AUG	SEPT	OCT	Total
1	Kullu	0	6 (25)	4 (16.67)	11(45.83)	2 (8.33)	1 (4.17)	24
2	Chamba	9 (47.37)	1 (5.26)	4 (21.05)	4 (21.05)	1 (5.26)	0	19
3	Shimla	0	2 (13.33)	6 (40)	6 (40)	1 (6.67)	0	15
4	Kinnaur	0	2 (18.18)	3 (27.27)	6 (54.55)	0	0	11
5	Kangra	0	0	6 (66.67)	3 (33.33)	0	0	9
6	Mandi	0	1 (12.5)	3 (37.5)	3 (37.5)	1 (12.5)	0	8
7	Lahaul & Spiti	0	0	5 (71.43)	2 (28.57)	0	0	7
8	Solan	0	1 (16.67)	1 (16.67)	4 (66.66)	0	0	6
9	Sirmaur	0	1 (16.67)	2 (33.33)	2 (33.33)	1 (16.67)	0	6
10	Bilaspur	0	0	1 (50)	1 (50)	0	0	2
11	Hamirpur	0	0	0	0	1 (100)	0	1
12	Una	0	0	0	0	0	0	0
	Total	**9**	**14**	**35**	**42**	**7**	**1**	**108**
	Per cent	**8.33**	**12.96**	**32.41**	**38.89**	**6.48**	**0.93**	**100**

Source: The Tribune, 1971-2009
Note: Figures in parentheses are percentages

in four districts accounting for about 64 per cent of total occurrences. Kullu district accounts for the maximum number of events (24, 22.22 %) followed by Chamba (17.59%), Shimla (13.89%) and Kinnaur (10.19%) districts respectively. Five districts, namely, Kangra, Mandi, Lahaul & Spiti, Solan and Sirmaur account for 5-10 per cent of total cloudburst occurrences. Two districts, Bilaspur (1.85%) and Hamirpur (0.92%) have witnessed very low occurrences while in Una district no such event has ever been recorded (Map 2, Table 2). The point pattern analysis of cloudburst occurrences in Himachal Pradesh clearly depicts that maximum concentration of these events is confined to few pockets which spread over north and western parts of Kullu; northern Shimla, southern Kinnaur and central parts of Chamba and Kangra districts (Map 2).

The leading amongst such concentration zones is Kullu valley along the Beas river from Solang *naullah*, north of Manali town to Bajaura to Mandi area (Map 2: Zone A). The Manikaran valley along the river Parbati from east of Manikaran to Bhuntar; Gadsa and Sainj valley are the other sensitive parts within this zone. It is very interesting to note that within this part of the state, there was just one incident of cloudburst prior to 1990. Afterwards, a large number of events have occurred during 1990s which were further intensified during the decade 2000-2009. The second area of major concentration is Chamba-Bharmaur section along river Ravi, Saho valley, and Pangi area along Saichu *naullah*, a tributary of river Chandra Bhaga (Map 2: Zone B). This section has experienced a very high frequency of cloudbursts during the last decade i.e. 2000-09. The third area of major concentration is Sangla valley from Chitkul to Karcham along river Baspa and the stretch along Satluj river between Tapri and Morang in



Map 2

Kinnaur district (Map 2: Zone C). The Satluj valley from Jeori- Rampur-Luhri stretch and parts of Ani and Nirmand tehsils of Kullu district on the right bank of river Satluj and Kangra-Dharamsala region in Kangra district (Map 2: Zone D and E) are other specific zones of high concentration of cloudbursts in Himachal Pradesh.

Apart from these zones, Rohru-Kotkhai area of Shimla district; Rajgarh-Nohradhar and Nahan area in Sirmaur district, Parwanoo-Dharampur stretch and Nalagarh area of Solan district, Leo-Chango-Samdo-Tabo stretch in Kinnaur and Lahaul & Spiti districts are some other cloudburst sensitive areas in Himachal Pradesh.

Though cloudbursts occur in every type of climatic region of the state i.e. cold deserts of the Greater Himalayas, temperate climate of Middle Himalayas and the hot-humid climate of Lower Hills, yet the majority of cloudburst occurrences are concentrated in the Middle Himalayan zone i.e. in the proximity and between Dhauladhar and Pir-Panjal ranges in Kullu, Chamba, northern Kangra, Shimla and Kinnaur districts. In the first decade of 20th century cloudburst occurrence in the cold desert areas has put in an appearance. This point is pertinent in light of the fact that these areas were virtually devoid of rainfall and cloudburst activity was unheard of.

Human Casualty by Cloudburst

Cloudburst is a devastating weather event capable of causing flash flood and landslides that leads to disruption of communication networks, house collapse, land erosion and loss of human lives on a large scale. Cloudbursts have claimed a sizeable number of lives in Himachal Pradesh. In last 40 years a large numbers of people have been killed by several damaging cloudburst incidents (Table 1). Since 1971, 470 people were killed by cloudburst incidents (Table 5). Some of the deadliest events (Table 1) which claimed large number of human lives include the events that occurred at Shaat village in Manikaran valley of Kullu (1994); Ghanvi Village of Shimla (2007); Kangni *Naullah*, Kullu (2003); Pulia *Naullah*, Kullu (2003) and Chuhar valley in Mandi district (1993). There has been an increase in number of people killed by cloudbursts over time. Such casualties were limited during the 1970s. In this decade 71 people (15.11%) were killed mostly in 1975 and 1978 (Table 5, Fig. 2). The casualties were high in Solan (33.80%) and Chamba (29.58) districts although Sirmaur, Shimla and Kinnaur districts have also reported deaths due to cloudbursts (Table 5).

During 1980s, 24 (5.11%) such fatalities occurred and these happened in four years (1980, 1981, 1983 and 1987). These casualties were reported from Shimla, Kullu and Bilaspur districts. Shimla recorded maximum deaths (83.34%) in this period. A sharp increase was noted in 1990s which claimed 160 human lives (34.04%). The casualties occurred in all the years except for the period 1996-1998. The number of deaths was very high in 1994 when

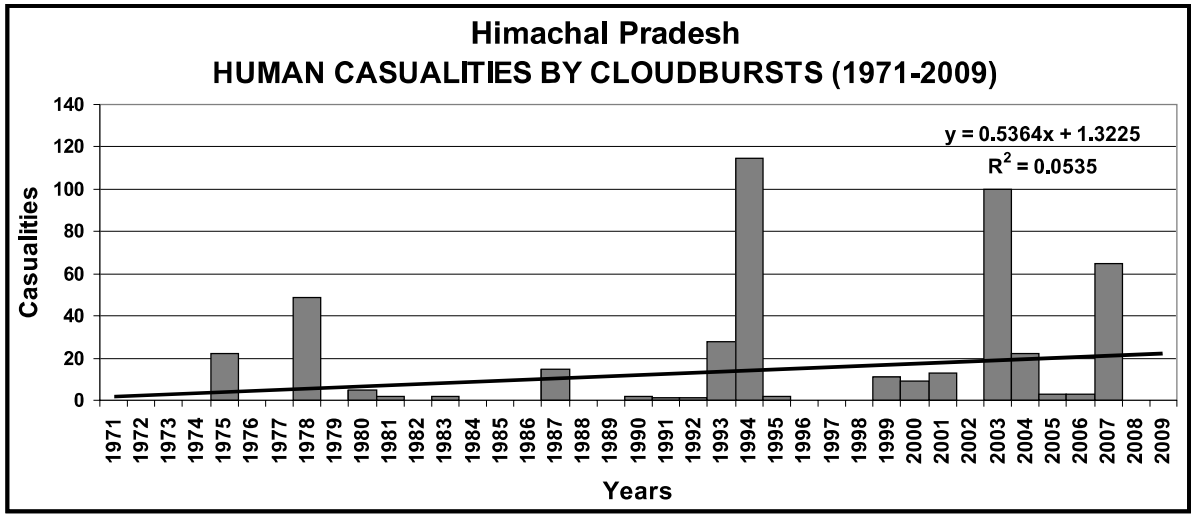


Fig. 2

Table 5
Himachal Pradesh: Human Casualties by Cloudbursts (1971-2009)

	District	1971-1979	1980-1989	1990-1999	2000-2009	Total	per cent
1	Kullu	0	2 (8.33)	104 (65)	130 (60.46)	**236**	**50.21**
2	Shimla	9 (12.68)	20 (83.34)	3 (1.88)	76 (35.34)	**108**	**22.98**
3	Mandi	0	0	30 (18.75)	1 (0.47)	**31**	**6.59**
4	Solan	24 (33.80)	0	0	0	**24**	**5.11**
5	Chamba	21 (29.58)	0	1 (0.63)	0	**22**	**4.68**
6	Sirmaur	13 (18.31)	0	0	0	**13**	**2.77**
7	Kangra	0	0	7 (4.38)	5 (2.33)	**12**	**2.55**
8	Lahaul & Spiti	0	0	7 (4.38)	0	**7**	**1.49**
9	Hamirpur	0	0	7 (4.38)	0	**7**	**1.49**
10	Bilaspur	0	2 (8.33)	1 (0.63)	3 (1.40)	**6**	**1.28**
11	Kinnaur	4 (5.63)	0	0	0	**4**	**0.85**
12	Una	0	0	0	0	**0**	**0**
		71 (100)	**24 (100)**	**160 (100)**	**215 (100)**	**470**	**100**

Source: The Tribune, 1971-2009
Note: Figures in parentheses are percentages

115 people were killed by cloudbursts. During 1990-99, Kullu was the worst affected district which accounted for 65 per cent of the total deaths by cloudbursts followed by Mandi (18.75%) district. In this decade, no death by cloudbursts was reported from Solan, Sirmaur, Kinnaur and Una districts. The increasing trends continued during 2000s as 215 people (45.74%) lost their lives to cloudburst events. Kullu (60.46%) and Mandi (35.34%) districts accounted for most of the deaths in this decade. Overall, Kullu district recorded maximum number of deaths (50.21%) by cloudbursts during 1971-2009 followed by Shimla (22.98%), Mandi (6.59%) and Solan (5.11%) districts respectively. The other districts reported less than 5 per cent of the total deaths while no casualty occurred in Una district.

Conclusions

The phenomenon of cloudburst in Himachal Pradesh has been increasing over time and space. These events have accelerated during 1990s and further amplified in 2000s. There is a consistent increase in the occurrence of cloudburst in terms of annual frequency as well as spatial and seasonal extent. Cloudbursts mostly occur in the period from the last week of June to October but the frequency is high during July and August. In all the districts most of the cloudbursts are restricted to monsoon period but Chamba and Kullu districts have experienced such events during pre and post-monsoon seasons also. The cloudburst incidents have spatially expanded overtime but these have highly concentrated patterns spatially and are mainly concentrated in the Lesser Himalayan districts of Kullu, Chamba, Shimla and Kinnaur. Within these four districts too, the events show high concentration in a few pockets. The seasonal and spatial spread in cloudburst events indicate changing rainfall regime particularly in post 1990 period. This explains the increasing vulnerability to such disasters. The vulnerability to cloudburst incidents in terms of human casualties, disruption of infrastructure and facilities has also increased over time.

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Dr.Vishwa B.S. Chandel
Map Curator

Dr. Karanjot Kaur Brar
Associate Professor
Centre of Advanced Study in Geography
Panjab University, Chandigarh