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Research Article

ENVIRONMENTAL HAZARD –LANDSLIDES AND AVALANCHES (KASHMIR REGION)

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ABSTRACT
The Himalayan region, especially over Kashmir area (32 N to 35 N & 70 E 80 E) enjoys the extra tropical type of climate and most of the precipitation during monsoon season (June to September) occurs during the withdrawal phase of monsoon. The heavy precipitation (Rain /Snow) sometimes cause catastrophic situations over the area. The precipitation in other seasons except monsoon is mainly governed by the westward moving systems, known as Western Disturbance (WD). The monsoon season precipitation involves the association of various features like Sea Surface Temperature (SST) anomaly, Southern Oscillation Index (SOI) and Outgoing Long wave radiation over the area. The unbalanced precipitation leads to natural disasters over the region. Hence, natural disasters are unbalanced events that occur as results of natural processes like landslides, avalanches, cyclones, earthquakes, droughts, floods heat waves, lightening; tsunamis etc. Other possible sources are cold weather and related phenomena such as blizzards, freezing rain, and ice storms will produce catastrophic situation some times. Due the variation in geo-climatic conditions and increase in development pressures around the western and central Himalayas, these areas and likelihood of the buildings are very susceptible to landslides and avalanches. The present study is based on landslides and avalanches occurrences over Kashmir region. To mitigate and evaluate the natural disasters various types of strategies have also been discussed.

Keywords: *Landslide, Avalanches, and Disasters*

INTRODUCTION
Natural occurrences of disastrous events landslide or avalanche are mainly associated with heavy precipitation.

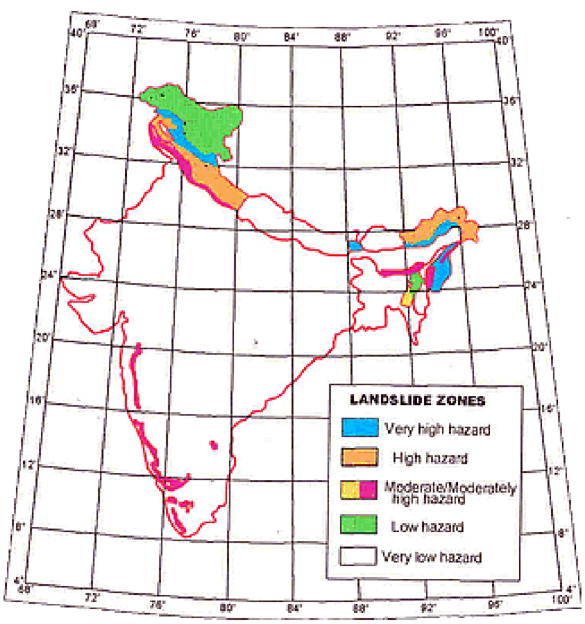

Figure 1: Land slide Zone Map
Source:http://www.portal.gsi.gov.in/portal/page?_pageid=127,671641&_dad=portal&_schema=PORTAL

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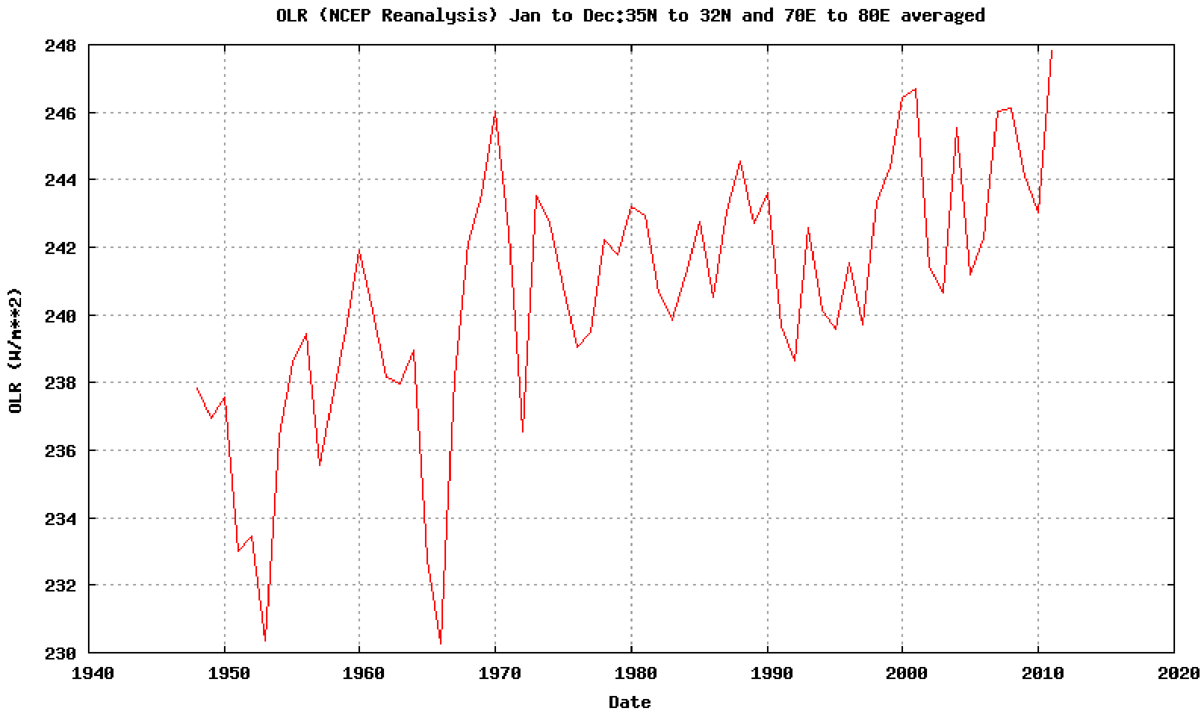


Figure 2: Interpolated OLR values (Surface) over Himalaya region (32 N to 35 N & 70 E to 80 E)
Source: http://www.esrl.noaa.gov/psd/data/timeseries

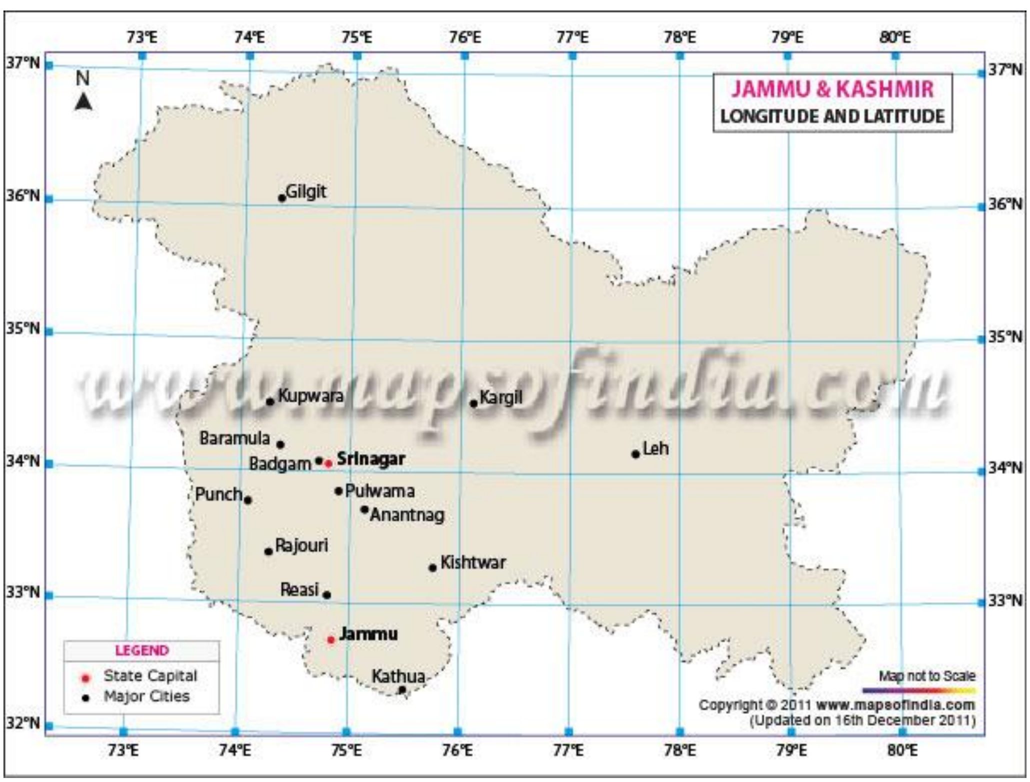


Figure 2: Enlarged view of Jammu & Kashmir area [Study of area interest lies between 32.00 N -35 N and 70.00 E to 80.00 E]
Source: http:// www.mapsof india.com

The heavy precipitation varies season to season and in each season the cause of precipitation is different. During retreat phase of monsoon when the monsoon trough is on the foot hills of Himalaya, most of the precipitation occurs over the area. The monsoon rain is associated globally by teleconnection of various parameters like SST anomaly, SOI index, El Nino or La Nina situations, OLR etc. During other seasons the WD and its quasi permanent nature over the region which embedded normally into westerly trough are responsible for heavy precipitation or avalanche activities. The landslide zone map (Figure 1) below shows the above said area lies between very high to high hazard zones. The interpolate OLR values from NCEP reanalysis data sets are shown in figure (2). Figure (3) shows the Jammu and Kashmir region zone map which marked over area of interest (AOI).

It is known when natural hazards turn into disasters they cause significant disruption of socio-economic life with loss of property and life of the people. The destruction of forests and disruption of communication brings out various techniques of forecasting and suitable control measures to mitigate these hazards. Himalaya, have young and complex geology and climate which is responsible for large scale tectonic activities and poses a unique challenge to the road construction and maintenance agencies in mitigation of problems of landslides and avalanches.

Landslides its downward movement of rock, soil or debris flows under the influence of gravity or in other words, under its own weight. Hence, landslides can occur on any terrain given the right conditions of soil, moisture and the angle of slope. Landslide generates enough force and momentum to wipe out anything in its path. In the era of information technology and use of Radar and Satellites in meteorological services {like digital data dissemination system (DMDD)} can disseminate the real time half hourly satellite images along with precautionary warnings for abnormal weather situation in an effective and timely manner.

Earlier studies (Sharma and Snehmani, 2003) have shown that GIS and remotely sensed data are critical components in regional, state and local disaster services detection, response and preparedness plans. In the similar way avalanches are very common and frequent phenomena during December to April. Table (4) shows some of the avalanched during the year 2005-March 2006, which cause damage and disrupt the normal life of the public.

Earlier studies by Sharma and Ganju (2000) and Ganju *et al.*, (2002), shows that avalanche mitigation can be done by active and passive methods. The high resolution data available in the Visible, IR and WV spectral regions of satellite sensors can be helpful in deciding the terrain conditions, avalanche sites, and selection of landslide site, surface temperature, forest cover and type of soils. This type of information is further useful in making hazard maps for the region concerned.

A user interactive space based system prototype is already proposed by Indian Space Research Organization (ISRO) which can synthesize high resolution remote sensing imaging, GIS database, modeling framework and multi agency framework (Kasturirangan *et al.*, 2002). This in turn will save the natural lives and economy of the country. In this way the future of climate change depends on the predictability (with greater or lesser degree of certainty) of meteorological factors like temperature, relative humidity, rainfall and wind speeds (Palmer *et al.*, 2002).

The various factors which affect the vulnerability are mainly associated with individual community and geographical factors of the country (McCarthy *et al.*, 2001). After the any disastrous event the people will suffer various types of communicable diseases. A Theoretical investigation of impact assessment on humans is given in table (5) (Noji, 1997).

Data and Analysis

Data on Land-slides used in the study has been taken from Border Road Task Force (BRTF) centre Srinagar. Avalanche data used has been taken from mountain met center Srinagar. The Heavy rainfall and extreme cases of rainfall data has been taken from weekly Weather Reports Issued by India Meteorological Department (IMD) and Annual Disastrous Weather Events issued By IMD (2005).

The data is statistically analyzed and information is put in the form of table (1 to 5). Some cases of land slides occurring in remote interior areas or cases of less intensity may not have been reported and as such left out. In the similar manner the rainfall and avalanche cases not all are reported.

RESULTS AND DISCUSSION

Landslide details over Kashmir area are given in Table (1) and Table (2). This information is very important to make the efficient planning of hazard zonation and construction of road and houses. Table (2) shows some of the cases during 15 years in Bandipur, Sonamrg and Machal sector area. The weather severity of in case of monsoon can monitor globally by seeing the changes Nino, SOI indices (Figures 4-7). The global pressure difference of Tahiti and Darwin known as SOI modulates the monsoon flow. Similarly, Nino SST index is also teleconnected by the monsoon flow (Figures 4-7). The OLR values are the proxy indicator of convection. Its low values are responsible for cloudiness and high values shows drier region over the area. Precipitation in association with WD is normally associated with the low values of OLR and lies quasi permanently for few days over the area. These quasi permanent natures are generally responsible for heavy precipitation and can cause avalanche.

Because the landside and avalanche type of natural events took place mostly due to heavy rainfall/snowfall or certain translocations in earth material. So the size of the phenomena, the large variety of the triggering factors (slops, surface geology, land use, rainfalls,) limits considerably the traditional approach mainly based on interpretation of aerial photographs. The use of digital elevation terrain model (DTM), jointly with high resolution satellite images, opens new possibilities in quantitative geomorphology. Raster based GIS such as synergis, make it possible to determine from a supervised image classification which criteria is crucial for the slope instabilities. To enhance this type of modern techniques the present study is very useful to decide the frequency of events and such type of events prone area.

It has been found in the present study that 24 % landslide events occurred in March months and 16 % landslide events in July months during this 15 years study {table (2)}. It has been observed from this 15 years study that in Kashmir Bandipur –Gurej sector contains mainly Delhi Nallah, Z-Khushi, Badwan, Chandgi Nallah, Matrigam and Tragal produces 15 % occurrences of landslide and Srinagar-Sonamarg Gumri sector which include mainly Ganiwan, Gangagir , baltal, and Haripura produces 45 % occurrences.

Table 1: Season-wise details of landslides over Bandipur Gurez, Sonamarg, Z-Gali and Macchal sector during the year 1992 to Feb 2006:

Year	No. of occurrences (Total)	Winter season (Dec-Feb)	Pre-Mon season (Mar- May)	Monsoon season (June-Sept)	Post-Mon season (Oct-Nov)
1992	10	-	-	-	10
1993	05	-	-	04	01
1994	01	-	01	-	-
1995	36	01	15	08	12
1996	21	-	10	11	-
1997	21	-	12	09	-
1998	17	-	01	01	14
1999	02	-	-	-	02
2000	07	-	-	06	01
2001	30	03	07	17	03
2002	07	-	07	-	-
2003	29	11	16	-	-
2004	12	-	-	12	-
2005	11	03	07	01	-
2006	02	02	-	-	-
% wise distribution	100	10	36	33	21

Table 2: Month-wise landslide occurances over Bandipur –Gurej axis, Srinagar-Sonamarg Gumri axis, Hazzibal Z-Gali axis and Machhal sector:

Year	Jan	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1992	-	-	-	-	-	-	-	-	09	-	-	-
1993	-	-	-	-	-	-	02		02	01	-	-
1994	-	-	-	01	-	-	-	-	-	-	-	-
1995	-	01	08	-	07		08	-	-	11	07	-
1996	-	-	07	02	01	06	01	02	02	-	-	-
1997	-	-	05	-	04	01	01	07	-	-	-	-
1998	-	-	-	01	-	-	-	02	-	14	-	-
1999	-	-	-	-	-	-	-	-	-	02	-	-
2000	-	-	-	-	-	-	-	06	-	01	-	-
2001	-	03	-	-	02	03	05	04	05	-	03	-
2002	-	-	07	-	-	-	-	-	-	-	-	-
2003	-	11	20	-	-	-	-	-	-	-	-	-
2004	-	-	-	-	-	-	01	11	-	-	-	-
2005	-	03	03	07	-	-	-	-	-	-	-	-
2006	02	--	-	-	-	-	-	-	--	-	-	-
Total	02	18	50	11	14	10	18	33	18	29	10	-
% wise distribution	01	08	24	05	07	04	09	16	08	13	04	00

Table 3: Period of heavy precipitation, their duration and cumulative rainfall distribution for the period 1990-Feb'2005 along with Loss of life and extent of damage are also indicated

S.No	Year/Period	Cumulative pptn (mms)	Highest pptn. (mms)/ Station	Loss of life/ Damage
	1990			
	i) Mar,17-23	271.2	364.0/Gulmarg	1. 30 persons washed away by flash floods
1				2. Houses collapsed in which 2 students died
	ii) Dec,28-30	185.1	277.2Gulmarg	----
	1991			
	i) Feb'10-12	94.1	233.1/Gulmarg	1. 19 persons died and 17persons unfound
2				due to avanalches.
	ii) April,13-15	75	97.2/Gulmarg	2. Hundreds of huts destroyed.
				3. 21 persons died due to landslides.
	1992			
	i) Jan,01-04	166.1	267.4/Gulmarg	1. 350 persons died.
3	ii) Mar,22-24	103.7	222.5/Gulmarg	2. 11,185 cattle head perihed.
				3. Peripherils with Rs. 164 crores damaged.
				4. 3600 houses totally or partially damaged.
	1993			
	i) Jan,01-04	66.9	142.7/Gulmarg	
4	ii) Mar,11-13	173.5	194.4/Gulmarg	
	iii) Mar,23-25	178.5	263.8/Gulmarg	1. 20 persons died.
	1994			
	i) Apr,04-06	112.3	172.3/Kupwara	
5	ii) Sept,05-07	53.8	99.0/Pahalgam	1. 5 persons died.
	iii) Dec,07-09	92.7	117.4/Kupwara	

	iv) Dec, 25-29	184.5	345.0/Gulmarg	
	1995			
6	i) Mar, 23-26	79.5	125.6/Kupwara	1. 104 persons died.
	ii) Jul,25-28	180.6	271.9/Gulmarg	2. 500 houses partially damaged.
	1996			
	i) Mar,15-19	153.3	262.2/Kupwara	1. 33 persons died due avalanches.
	ii) Apr, 5-8	100.5	157.0/Kupwara	19 persons died due floods.
7				241 persons died.
	iii) June,19-21	118.0	183.4/Qazigund	2. 26 houses collapsed.
	1997			
8				
	1998			
	i) Feb,17-19	134.6	310.9/Gulmarg	----
9	ii) Mar,03-05	119.3	356.0/Gulmarg	----
	1999			
10	i) Mar,06-09	83.9	124.4/Kupwara	----
	2000			
11	Jan,12-14	84.3	133.0/Gulmarg	----

Table 3 Continued----

	2001			
12	2-Nov-04	64.3	91.9/Kupwara	----
	2002			
13	Jan,13-15	44.9	106.2/Kupwara	----
	2003			
	i) Feb,16-19	171.2	308.9/Qazigund	----
14	ii) Mar, 1-3	128.1	205.7/Pahalgam	----
	iii) May, 1-3	84	98.5/Kupwara	----
	iv) Dec,14-16	75.5	117.3/Qazigund	----
	2004			
15				
	2005			
16	i) Feb, 7-9	93.8	170.7/Gulmarg	----
	ii) Feb,18-20	118.3	180.0/Qazigund	----

While Hazibal –Z-Gali Machal sector, Mohra Baaz route sector produces 10 % occurrences and Chowkibal Tangdhar sector prone to 20 occurrences. This highlight us the area and months, which are very susceptible to Landslides. Further by seeing the characteristics of rock, soil type, elevation etc. we can mark it as critical, highly unstable, moderately unstable or stable in hazard zonation map. Similar finding from Table (1) is observed. It is clear from the table (1) the pre-monsoon season (March to May) and Monsoon seasons (July to September) are very prone to Landslide occurrences. In pre-monsoon season 36 % occurrences and in monsoon season 33 % occurrences of landslides during 15 years. The damage and loss of life due to heavy rain (from year's 1990-2005) and avalanches (year's 2004- March 2006) are given in the table (3) and (4) respectively. Some gaps in the table (3) show no availability of the data. Table (5) indicates an idea of theoretical assessment of communicable diseases after the natural disaster. This will be very useful in planning and coordinating the various relief and social activities.

Table 4: Extent of damage and loss of life due to avalanche 2004 to March 2006

Date	Area affected	Type of avalanche	Extent of losses and damage
30-11-2004	GR 967588 (Map Sheet J &K 43 N/3)	Not clear	2 persons died and tree line up to 3.0 Km damaged.
23-11-2004	Between (GR 007514 & GR 999518)	Wet loose avalanche	1 person along with avalanche dog died.
08-01-2005	Drass sector	Soft, loose avalanche	2 persons died and bunch of cable damaged.
25-01-2005	Karen sector	Loose avalanche	Bunch of cable along with radio set damaged.
07-02-2005 (morning) 07-02-2005 (afternoon)	BQ axis (Near D-10) (b) BQ axis (D-10)	Major avalanche Major avalanche	(a) 06 persons of ITBP died and damage of bunkers. (b) 07 persons and around 550 vehicles trapped and later 04 persons rescued.
09-02-2005	BG axis	Loose avalanche	02 empty houses buried in Nayala bridge and avalanche debris reached up to the road.
10-02-2005	C.T. axis	Soft slab avalanche (Heavy snowfall)	20 people trapped in complete swept due to snow out of which 14 rescued alive.
11-02-2005	(a)Karen sector (Near Bela) (b) Near Kanjalwan (c) B.G. axis (2 Km away from Niru)	(a) Loose avalanche (b) Loose avalanche (c) Loose avalanche	(a) All stores and bunkers damaged. (b) 04 Empty houses damaged. (c) 02 sheep died and 04 empty houses buried.
12-02-2005	B.G. Axis (Near Niru)	Major soft slab avalanche	01 bridge and 09 empty houses damaged. 01 lady died.

Table 4 Continued----

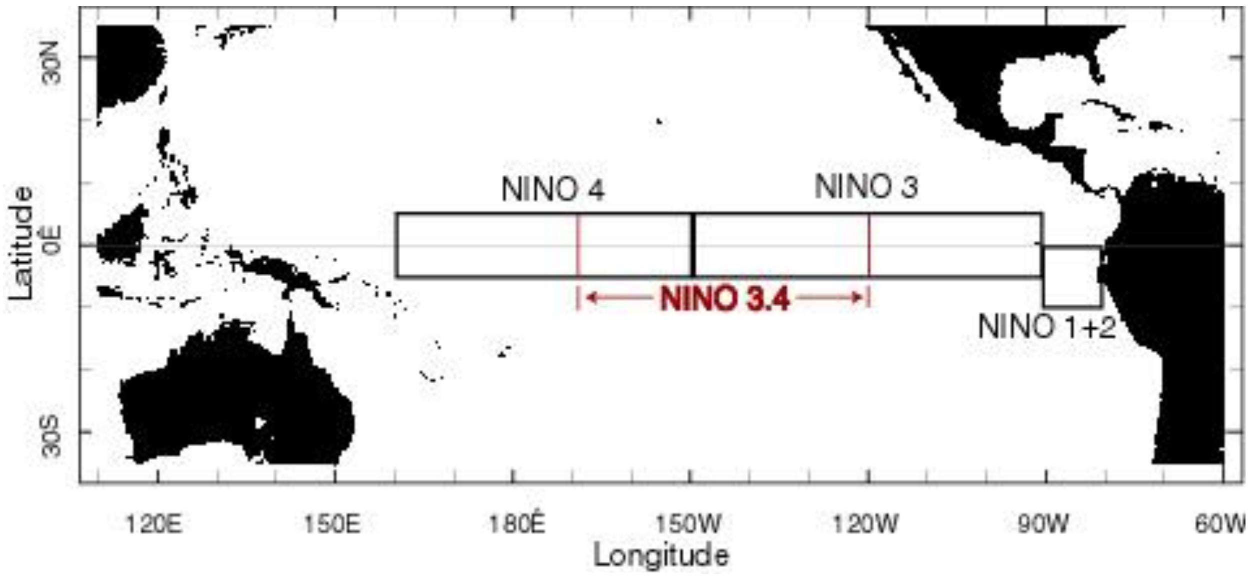
Date	Area affected	Type of avalanche	Extent of losses and damage
14-02-2005	G.G. axis (Near Niru)	Medium size avalanche	01 Post, 01 Bridge and 01 school building

			damaged.
18-02-2005	BQ axis (West of D10)	Major avalanche	09 Persons (06 GREF and 03 media persons). 03 media persons rescued alive but 06 GREF persons not found.
19-02-2005	(a) Karen sector near Nag village. (b) B.G. axis (Near Niru village)	(a) Soft + slab avalanche. (b) Major loose avalanche	(a) 05 persons trapped and 02 dead and 03 rescued safely. 06 houses damaged. (b) 02 shops, 01 medical dispensary and some people injured.
16-03-2005	C.T. axis	Wet avalanche	Road blocked
20 to 22-03-2005	CT axis	Wet avalanche	Road blocked
28-29 January 2006	Macchal sector	Loose avalanche	08 houses damaged. 02 civilian trapped. 03 sheep died.
27-02-2006	Ragini sector	Loose avalanche	Vehicle damaged
27-02-2006	Drass sector	Loose avalanche	Vehicle damaged
28-02-2006	Near Kharbu (Kargil – Drass road)	Loose avalanche	04 people died and vehicle damaged.
06-03-2006	Ku road Kaiyan	Loose avalanche	01 person died.
21-03-2006	N.K axis	Loose avalanche	Vehicle damaged
30-03-2006	Eagle complex (Towards Dhundi)	Loose avalanche	07 persons trapped and later rescued safely.

Table 5: Theoretical risk of acquiring communicable diseases, by type of disaster (Nogi, 1997)

Type	Person to person	Water borne	Food borne	Vector borne
Earthquake	M	M	M	L
Volcano	M	M	M	L
Hurricane	M	H	M	K
Tornado	L	L	L	L
Heat wave	L	L	L	L
Cold wave	L	L	L	L
Flood	M	H	M	H
Famine	H	H	M	M
Fire	L	L	L	L

Where, H=high, M=medium and L= Low



(The thin grey line in the center of the plot is the equator)

Figure 4: NINO regions (http://iri.columbia.edu/climate/ENSO/background/monitoring.html)

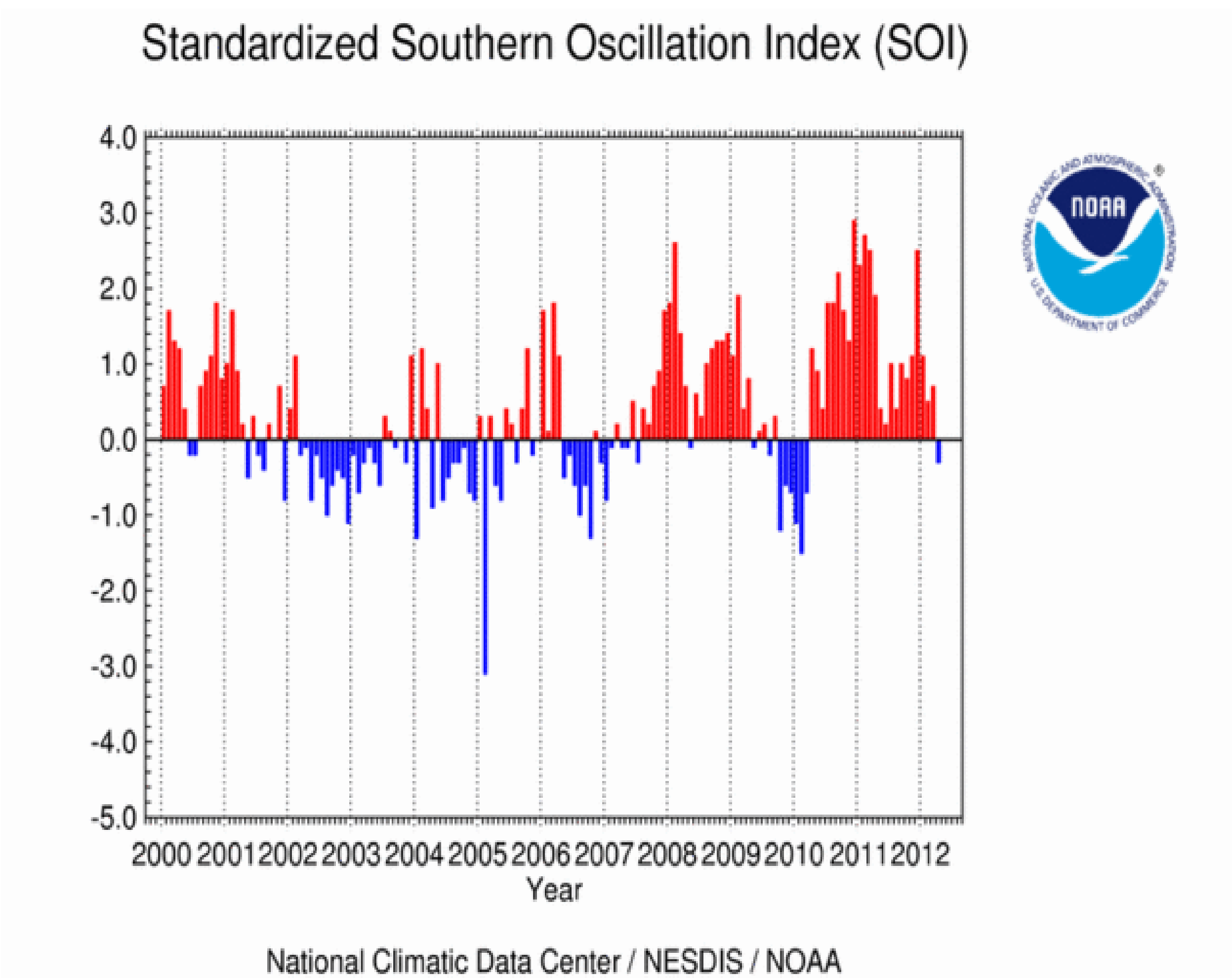


Figure 5: SOI values (NCDC NOAA): source: http://wattsupwiththat.com/reference-pages/enso/

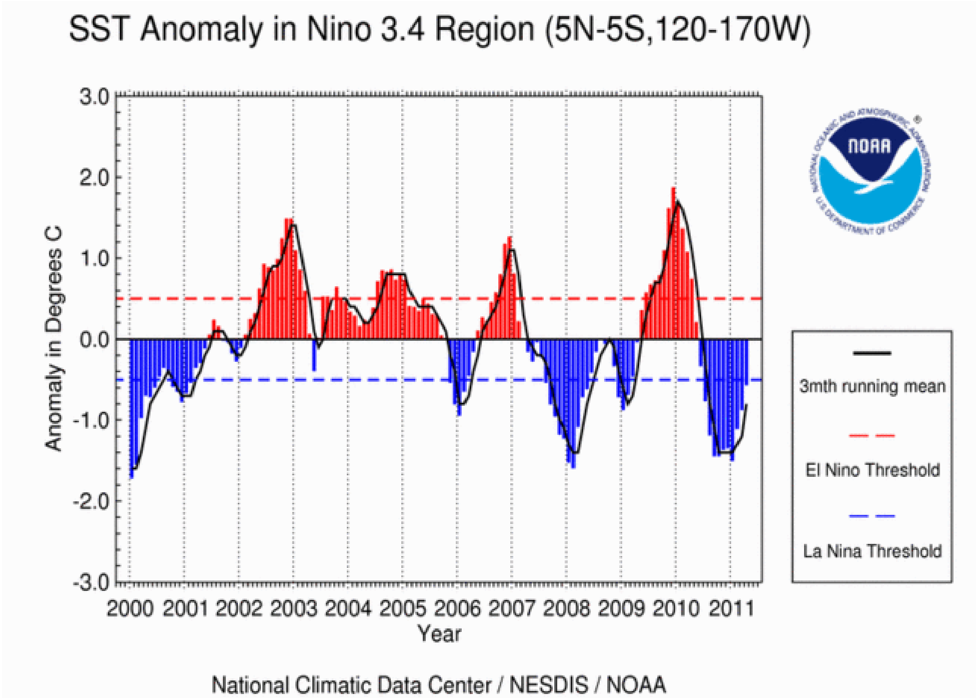


Figure 6: SST anomaly in El Nino and La Nina cases (NCDC NOAA): source: http://wattsupwiththat.com/reference-pages/enso/

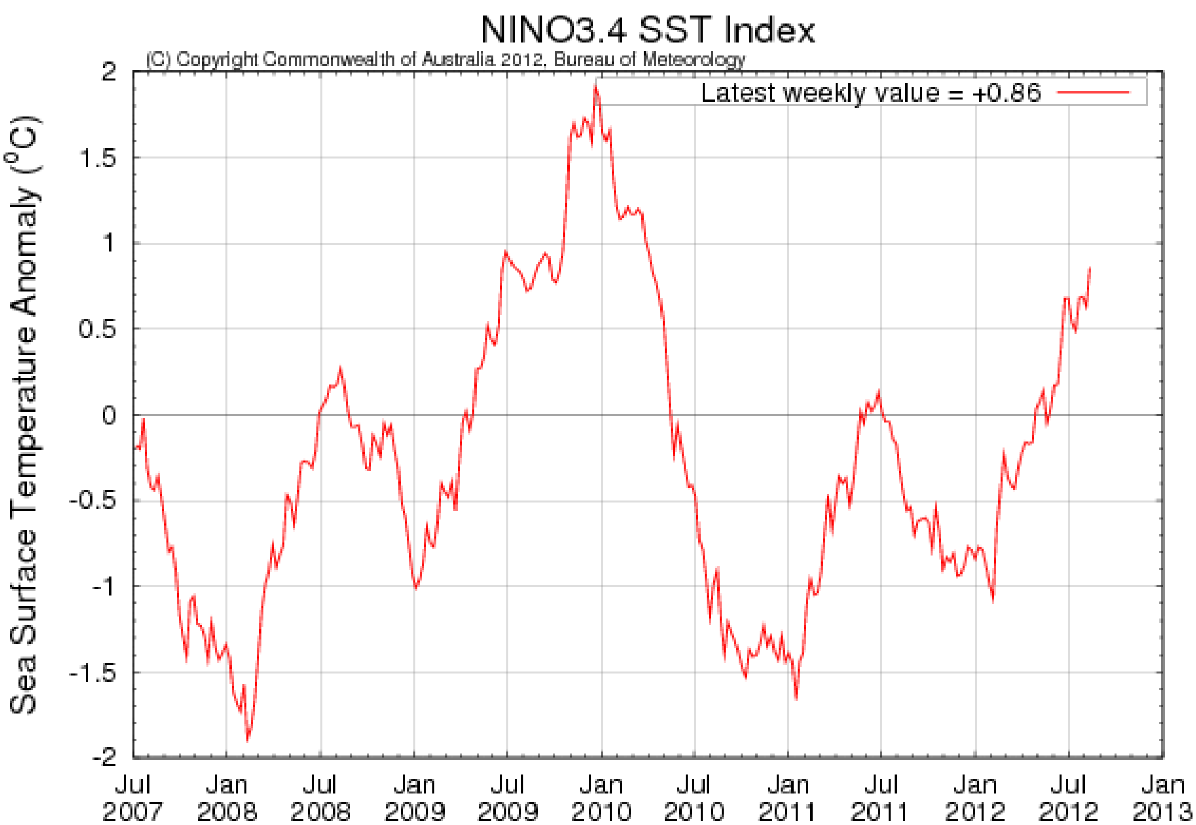


Figure 7: Nino 3.4 Index (NCDC NOAA): source: http://wattsupwiththat.com/reference-pages/enso/

Conclusion

Landslides, avalanches, heavy rain and floods etc. are most vulnerable potential natural disasters. The maximum occurrences of landslides are 24 % (March) 16 % (August) and 13 % (September). The weather system associated with are WD and monsoon and retreat phase of monsoon respectively. Year 2006 shows lesser avalanche and La Nina phase of monsoon (figure 6). This activity may weaken the intense precipitation episodes over the area if it is coherent with the monsoon activity over Indian regions. Sometimes it may remain in opposite phase also (Year 2000 & 2001, Figure 6) This may be due the weather activity either by monsoon or long wave tough involves complex interaction of land ocean and atmosphere.

The accurate assessment of meteorological conditions, hazard zone and its frequency of concrescences will provide better way of maintenance of natural drainage channels both micro and macro in vulnerable slopes. Over the area March and November months are most sensitive for landslide. For avalanches point of view winter and pre-monsoon seasons are most sensitive in western Himalayan region. The monsoon season is very sensitive for floods and landslides over the west Himalayan belt. Remote sensing studies in Near Infrared and Visible bands and GIS mapping were found to be very important to decide forest area or barren land. The interest of these indices lies in their usefulness in the interpretation of remote sensing images mainly for the evaluation of the vegetative cover density (Bannari *et al.*, 1995). This will be very useful to decide the soil characteristics by seeing their reflectance characteristics (especially in microwave region). And another most important application of satellite is to disseminate the information in vulnerable places in bad weather conditions like DMDD. The resources used by India meteorological Department, Lodi Road New Delhi NOAA and NCEP reanalysis data and various other global web links used to accomplish this task are duly acknowledged.

REFERENCES

Annual Disastrous Weather Events (2005). Report compiled by IMD 1 25.

Bannari A, Morin D, Bonn F and Huete AR (1995). A review of Vegetation Indices. *Remote Sensing Reviews* **13** 95- 120.

Ganju A, Thakur NK and Rana V (2002). Characteristics of avalanche accidents in Western Himalayan Region, *Proceedings of International Snow Science Workshop* 200-207.

Kasturirangan K, Venkatachary KV, Rao M, Manikiam B, Navalgund RR and Jayaraman V (2002). EO based information system in support of disaster management, 53rd IAF Congress, Houston, U.S.A. **1** 378-382.

McCarthy JJ, CanzianiOF, Leavy NA, Dokker DJ and White KS (2001). *Climate Change 2001: Impacts, Adaptation and Vulnerability* (Cambridge university press) **1**(1) 1032.

Nogi EN (1997). *The Public Health Consequences of Disasters* (Oxford University Press) New York **15**(4) 147-158.

Palmer T and Ralsamen J (2002). Quantifying the risk of extreme seasonal precipitation events in a changing climate, *Nature* **415** 512-514.

Sharma SS and Ganju A (2000). Complexities of avalanche forecasting in Western Himalaya — An overview; *Cold Regions Science and Technology* **31**(1) 95–102.

Sharma SS and Snehmani (2003). Integrated Monitoring Systems for Snow and Ice with specific reference to Indian Himalayas, ISPRS WG VII/3 Workshop on "Integrated Monitoring Systems" **33**(3) 198-204.

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Appendices

(a) The Southern Oscillation Index

Source: http://iri.columbia.edu/climate/ENSO/background/monitoring.html

The Southern Oscillation Index (SOI), is a measure of the difference in surface air pressure between Darwin, Australia and Tahiti, and is the index of longest record. It dates back to the beginning of the 20th century when it was first realized by Sir Gilbert Walker that there was a large scale pattern in surface air pressure which extended over the entire tropical Pacific region. A drawback to this index is that it is based on the pressure at two points and therefore can easily be affected by local weather disturbances making it somewhat "noisy" when viewed on a month-to-month basis. In order for the index to be more representative of larger scale fluctuations in pressure, it is common to present the SOI averaged over a 5 month period. Generally, the SOI is negative during El Nino, and positive during La Nina.

How is the SOI Calculated?

Source: http://www.cpc.ncep.noaa.gov/data/indices/Readme.index.shtml

Note the anomalies are departures from the 1981-2010 base period.

Standard Deviation Tahiti = SQRT(SUMMATION(1) / N)
SUMMATION(1) - is the sum of all ((TA) ** 2)
TA - Tahiti anomaly = (actual(SLP) - mean(SLP))
N - number of months

$$\text{So, Standardized Tahiti} = \frac{\text{(Actual Tahiti (SLP) - Mean Tahiti (SLP))}}{\text{Standard Deviation Tahiti}}$$

Standard Deviation Darwin = SQRT(SUMMATION(1) / N)
SUMMATION(1) - is the sum of all ((DA) ** 2)
DA - Darwin anomaly = (actual(SLP) - mean(SLP))
N - number of months

$$\text{So, Standardized Darwin} = \frac{\text{(Actual Darwin (SLP) - Mean Darwin (SLP))}}{\text{Standard Deviation Darwin}}$$

To calculate the monthly standard deviation:
Monthly Standard Deviation (MSD) = SQRT(SUMMATION(3) / N)
SUMMATION(3) - is the sum of ((Standardized Tahiti - Standardized Darwin) ** 2)
N - total number of summed months

The SOI equation looks as follows: SOI = (Standardized Tahiti - Standardized Darwin) / MSD

(b) ***The NINO Regions***

Indices based on sea surface temperature (or, more often, its departure from the long-term average) are those obtained by simply taking the average value over some specified region of the ocean. There are several regions of the tropical Pacific Ocean that have been highlighted as being important for monitoring and identifying El Niño and La Niña.

- *NINO1+2* (0-10S, 80-90W). The region that typically warms first when an El Niño event develops.
- *NINO3* (5S-5N; 150W-90W). The region of the tropical Pacific that has the largest variability in sea-surface temperature on El Niño time scales.
- *NINO3.4* (5S-5N; 170W-120W). The region that has large variability on El Niño time scales, and that is closer (than NINO3) to the region where changes in local sea-surface temperature are important for shifting the large region of rainfall typically located in the far western Pacific.
- *NINO4* (5S-5N: 160E-150W). The region where changes of sea-surface temperature lead to total values around 27.5C, which is thought to be an important threshold in producing rainfall.

If the concern regarding El Niño and La Niña is the subsequent effect of that tropical Pacific variability on the climate in a particular region, then one index may be more useful than the others. For widespread global climate variability, NINO3.4 is generally preferred, because the sea surface temperature variability in this region has the strongest effect on shifting rainfall in the western Pacific. And in turn, shifting the location of rainfall from the western to central Pacific modifies greatly where the location of the heating that drives the majority of the global atmospheric circulation.