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Analysis of trends in extreme precipitation events over Western Himalaya Region: intensity and duration wise study

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ABSTRACT

The impact of climate change on precipitation has received a great deal of attention by scholars worldwide. Efforts have been made in this study to find out trends in terms of intensity and duration of precipitation for different altitudes and ranges in Western Himalaya region representing Jammu & Kashmir and Himachal Pradesh. In terms of intensity, precipitation has been classified as Low, Medium and Heavy. Durations of precipitation are classified as prolonged dry days (PDD), short dry days (SDD), prolonged wet days (PWD) and short wet days (SWD). Analysis indicates significant positive trends for low and heavy precipitation events and negative for medium precipitation events in Pir-Panjal range. For Shamshawari and Great Himalaya ranges, there is no significant trend for low, medium and heavy precipitation events. In terms of altitude, significant positive trends in low precipitation events have been observed for lower and middle altitudes and no significant trend has been found for medium and heavy precipitation events for other altitudes. In terms of duration, PDD/SDD shows significant increasing/decreasing trends for all ranges and altitudes. PWD and SWD show decreasing and increasing trends alternatively but not significant for all ranges and altitudes. For this study, the widely accepted Mann-Kendall test was run at 0.1, 0.05, 0.01 and 0.001 significance levels on time series data for the time period, 1991 to 2016.

Key words: Precipitation events, Dry and Wet days, Mann-Kendall test, Tele-connections, Western Himalaya.

INTRODUCTION

Report in Intergovernmental Panel on Climate Change (IPCC): "Changes in Climate Extremes and their Impact on the Natural Physical Environment" indicates that the changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of weather and climate extremes, and can result in the unprecedented extremes (Field et al., 2012). The report also describes that in the 21st century the frequency of heavy precipitations from total rainfall will increase over many areas of the globe. This is particularly the case in high latitudes and tropical regions and in winter in the northern mid-latitudes. The Himalaya region contains the most extensive and rugged high altitude areas on the earth. In the Indian subcontinent context, Himalayas govern the climate and weather system. Northwest India receives enormous amount of snow during winter due to a synoptic weather system called Western Disturbance (WD) and monsoon phenomenon during summer time. Some WDs produce well-distributed and large amounts of precipitation over the Himalayan region, while others pass across this area without causing precipitation (Malurkar, 1947). Several studies have been undertaken by researchers to see the trends of extreme events all over India. Significant trends in the occurrences of heavy rainfall events during the summer monsoon season have been studied by Rakhecha and Soman, 1994. Das (2002) studied the frequency of WDs in the pre-monsoon season, as well as its relation with monsoon rainfall and its advancement over Northwest India. Their study found a significant decreasing trend in the frequency of WDs during May. Using observations and reconstructions from tree rings, pre-monsoon and summer cooling have been reported in some portions of the Western Himalaya (Yadav et al., 2004). And overall annual temperatures in the Himalayas have recorded significant increase in the last century (Pant and Borgaonkar, 1984; Sharma and Ganju, 2000; Bhutiyani et al., 2007).

Bhutiyani et al., (2008) conducted trend analyses on discharge data from rivers in the Northwest Himalaya and found that a number of high magnitude flood events had increased in this region in the last three decades. Dash et al., (2009) studied the changes in the characteristics of rainfall events in India. Their results show that the frequencies of moderate and low rainy days considered over the entire country had significantly decreased in the last half century. Due to extremely intricate topography and altitude-dependent climate, mountain region is highly vulnerable to extreme rainfall events and cloudbursts. These sharp weather fluctuations cause sudden short term as well as long term flood / outbursts in this orographic region (Nandargi and Dhar, 2011). Cloudbursts and associated flash floods are the regular and frequent disasters in Himalaya region (Thayyen et al., 2013). Kedarnath

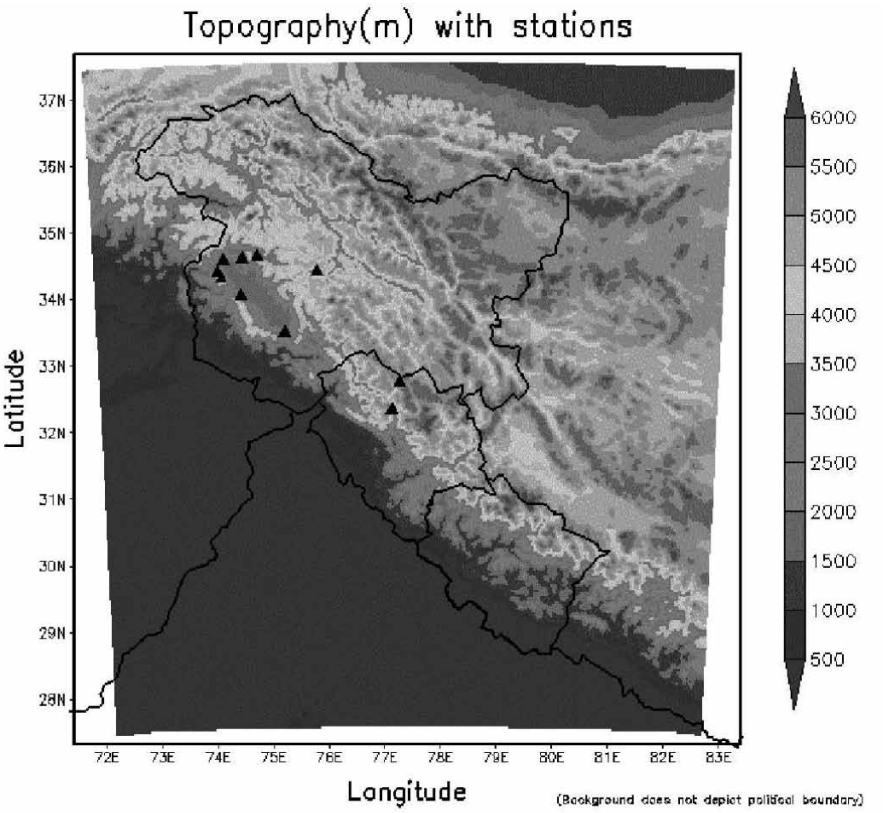

Figure 1. Location of the 10 meteorological stations considered for the present study.

disaster (June 2013), Rudraprayag cloudburst (September 2012), Manali cloudburst (July 2011) are a few of the major cloudburst events notable for causing great damages to human lives and infrastructure. Therefore study of changes in the spatial and temporal distributions of extreme precipitation events over Western Himalaya has great relevance in the context of planning, policy formulation and global warming.

Though several studies were carried out by earlier researchers to find out significant trends in precipitation over the Western Himalaya, this is the first attempt to analyze trends in intensity of precipitation depending upon number of occurrences and durations, altitude and range wise in Western Himalayan region representing Jammu & Kashmir and Himachal Pradesh. An attempt is also made in this study to link/relate the influences of global features via El Niño and North Atlantic Oscillation (NAO) Index with precipitation events in the area selected for the study.

DATA AND METHODOLOGY

Data

Daily precipitation data for winter season (Nov–April) for the period (1992–2016) of 10 stations over Western Himalaya region (Figure 1) maintained by Snow and Avalanche Study Establishment (SASE), Defence Research and Development Organization (DRDO) has been taken up for the present study. In order to study the intensity and duration of extreme precipitation events in terms of ranges and altitudes, Western Himalaya has been divided into 3 ranges i.e. Pir-Panjal, Shamshawari and Great Himalaya as was already done in Shekhar et al.,(2014) and 3 altitudes as Lower (2400- 2800 meter), Middle (2800-3200 meter) and Higher altitudes (3200-3800 meter). There is no basis for division of altitudes except to include at least 3-4 stations per every altitude range.

Methodology

The present study deals with examination of trends in the frequency of extreme precipitation events over Western Himalaya region in terms of their intensity and duration. In terms of intensity, the maximum number of the occurrence of the precipitation events is considered. Similarly in terms of duration, continuous precipitation with intensity ≥2.5 mm/day for < (less than) or ≥ (more and equal) 4 consecutive days are defined as Short Wet Days (SWD) or Prolonged Wet Days (PWD). Similarly, continuous precipitation with intensity <2.5 mm/day for < (less than) or ≥ (more and equal) 4 consecutive days are considered as Short Dry Days (SDD) or Prolonged Dry Days (PDD)

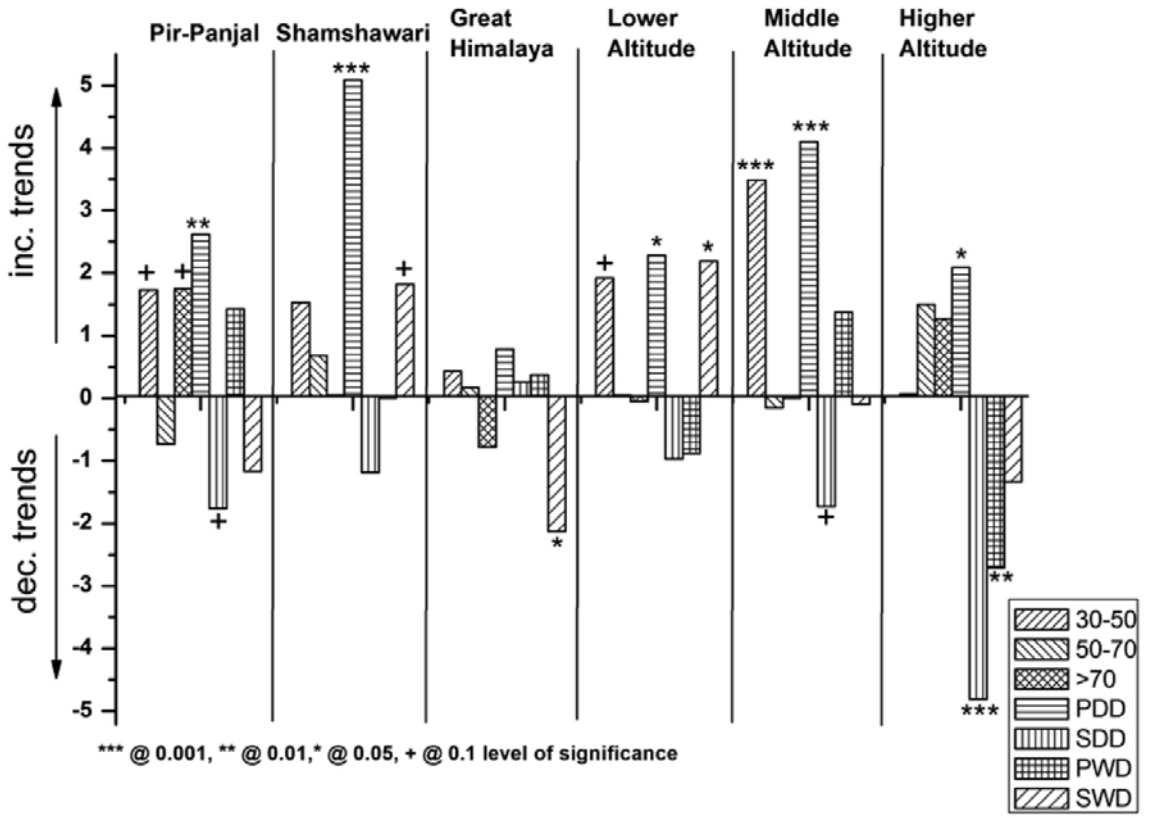

Figure 2. Mann-Kendall trends of ranges and altitudes in terms of intensity and duration for all extreme precipitation events 30-50 mm, 50-70 mm, >70 mm, PDD, SDD, PWD and SWD.

(Dash et al., 2009). This study pertains to winter season only as maximum precipitation observed only in this season in Western Himalaya region. Prevalent practice in IMD is to use rainfall data of 5 consecutive days for the average of precipitation. In this study we have used 4 consecutive days as the minimum duration of long precipitation events.

The intensity of precipitation between 30-50(mm), 50-70(mm) and >70(mm) are considered as low, medium and heavy precipitation events respectively. In this study the calculations of trend statistics were carried out by using Mann-Kendall schemes and tested at 0.1, 0.05, 0.01 and 0.001 levels of significance as can be seen in Figure 2. The Mann-Kendall (MK) is a nonparametric technique for detecting trends in meteorological time series (Gemmer et al., 2011).

RESULTS AND DISCUSSION

Trend analysis, as shown in Figure 3, indicates that the frequency of precipitation events over Western Himalaya region in terms of their intensity in Pir-Panjal range has increasing trend in case of low and heavy precipitation events at 0.1 level of significance. There is however, no significant trend in Shamshawari and Great Himalaya ranges. In medium precipitation events decreasing trends are observed in Pir-Panjal range and increasing trends in Shamshawari and Great Himalaya but these are not significant. In case of lower and middle altitudes, the low precipitation events show increasing trends at 0.1 and 0.001 levels of significance respectively. No trends have been observed for medium and heavy precipitation events. In terms of intensity, no significant trends have been observed in higher altitude.

Study of precipitation events in terms of duration show that there is increasing trend in case of PDD in Pir-Panjal and Shamshawari range at 0.05 and 0.001 significance levels respectively but no significant increasing trend for PDD in case of Great Himalaya. All the three altitudes have positive trends for PDD. SDD indicates decreasing trends for all altitudes and ranges except Great Himalaya as shown in Figure 4. PWD shows positive trends for all ranges but not significant and mixed trends have been observed for all altitudes (Figure 4). SWD has alternately decreasing and increasing trends for all ranges and altitudes.

Teleconnection studies

Walker circulation is the vast loop of winds that influence the precipitation in Himalayan region which varies during El-Nino and La-Nina oscillations. As per ncdc.

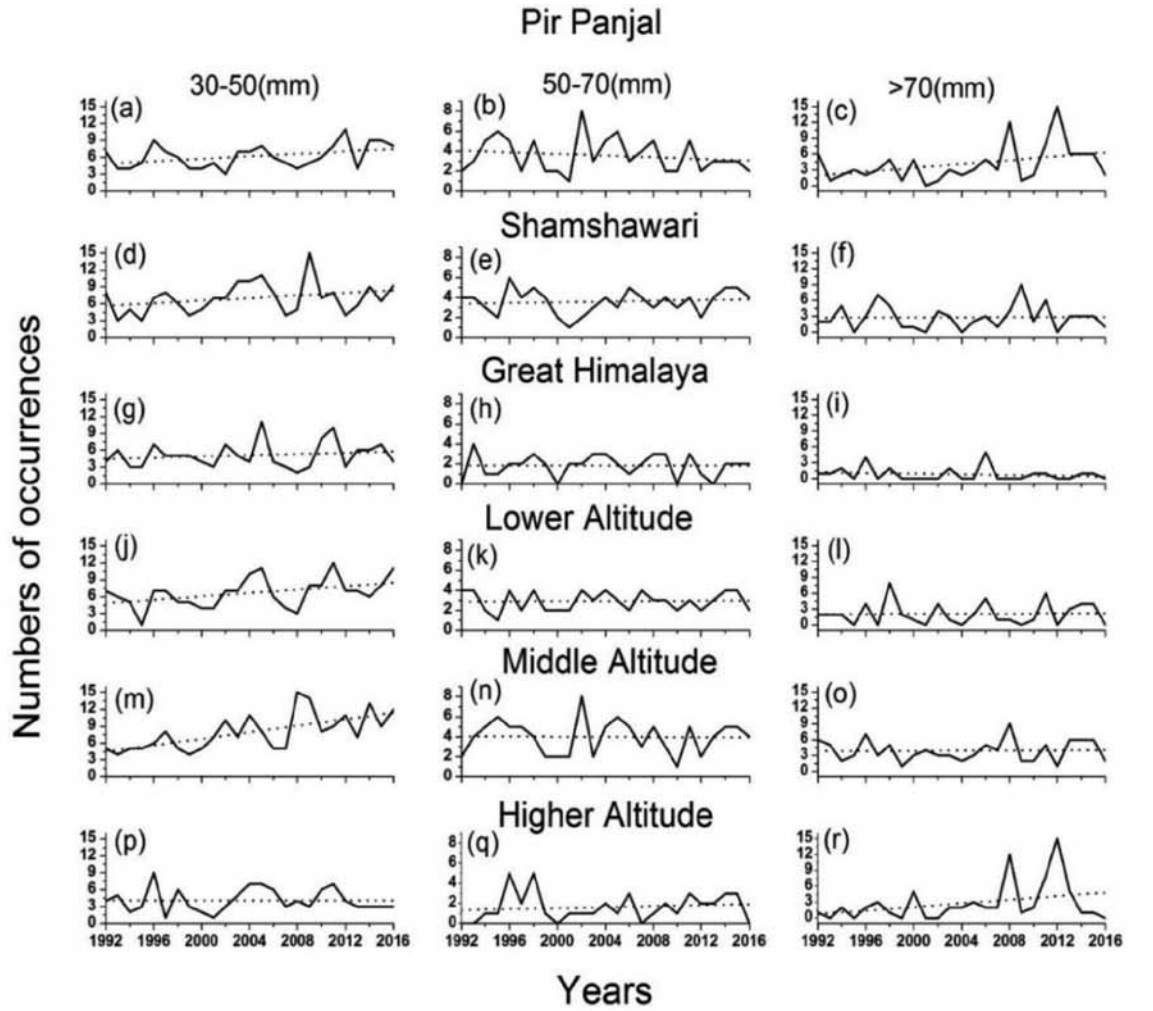

Figure 3. Time series of the numbers of occurrences for 30-50mm (1st column), 50-70mm (2nd column) and >70mm (3rd column) during winter season. Sets of plots (a), (b), (c) represents Pir-Panjal, (d), (e), (f) represents Shamshawari, (g), (h), (i) represents Great Himalaya, (j), (k), (l) represents Lower Altitude, (m), (n), (o) represents Middle Altitude and (p), (q), (r) represents High Altitude over Western Himalaya. In each subplot a linear trend line is represented by dashed line.

noaa.gov, ENSO is a periodic fluctuation in sea surface temperature (El-Nino) and the air pressure of the overlying atmospheric (Southern Oscillation) across the equatorial Pacific Ocean. A permanent low and high-pressure system over Iceland (Icelandic low) and the Azores (The Azores High) respectively controls the strength and direction of westerly winds which bring precipitation in Himalayan region. The relative strengths and the positions of these systems vary from year to year and the variation is known as North Atlantic Oscillation (NAO). Details can be found in www.plumbot.com. Relation of El-Nino and NAO with winter precipitation over Western Himalaya is shown in Figure 5.

Positive correlation of low and medium precipitation events and negative correlation for heavy precipitation events with El-Nino have been observed for all ranges except Great Himalaya which indicates positive correlation for low and heavy precipitation events and negative with medium precipitation events. In terms of duration, all precipitation events show positive correlation with El-Nino except PWD which indicates negative correlation for all ranges.

In terms of altitudes, lower altitude has a positive correlation with all duration and intensity precipitation events except PWD which shows negative correlation with El-Nino. In middle altitude, precipitation events show negative correlations in terms of intensity and positive in terms of duration except for PWD. No clear correlation for higher altitude precipitation events has been observed with El-Nino. NAO has positive correlation with low and medium precipitation events and negative correlation with heavy precipitation events for all ranges except Pir-Panjal which indicate negative correlation for medium precipitation events and positive for heavy precipitation

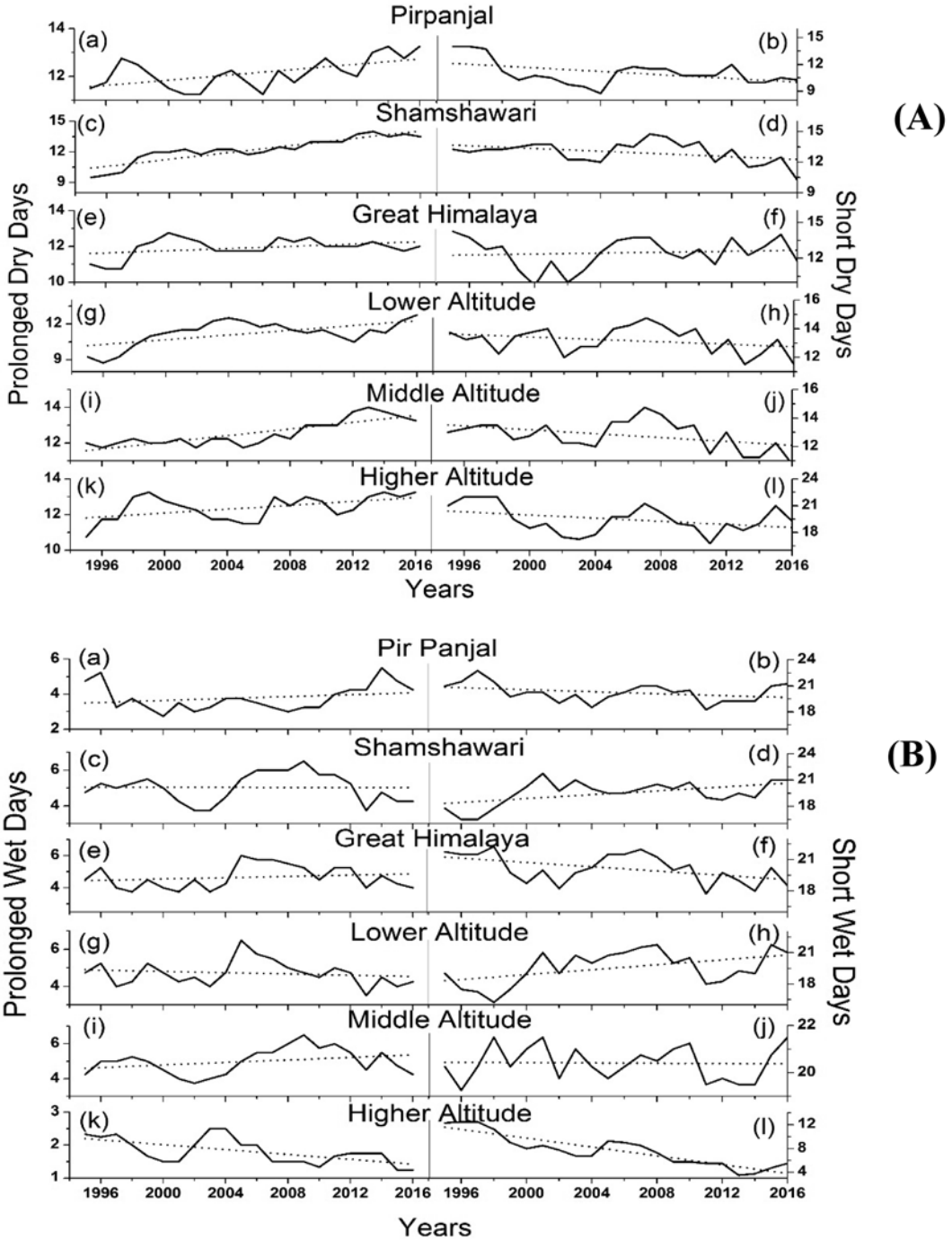

Figure 4. Time series of the numbers of (A) PDD/SDD and (B) PWD/SWD. Left/Right panels depict PDD/SDD and PWD/SWD respectively, in the winter season for (a and b) Pir-Panjal, (c and d) Shamshawari, (e and f) Great Himalaya, (g and h) Lower Altitude, (i and j) Middle Altitude and (k and l) High Altitude over Western Himalaya. In each subplot a linear trend line is represented by dashed line.

events. Positive correlation of ranges with NAO has been observed for all precipitation events in terms of duration except SDD. In terms of altitudes, positive correlation has been observed for lower altitude for all intensity and duration precipitation events except heavy and SDD. In middle altitude, positive correlation has been observed for all intensity and duration precipitation events except SDD and PWD. Similarly higher altitude shows positive relation for all intensity and duration precipitation events except low intensity events and SWD.

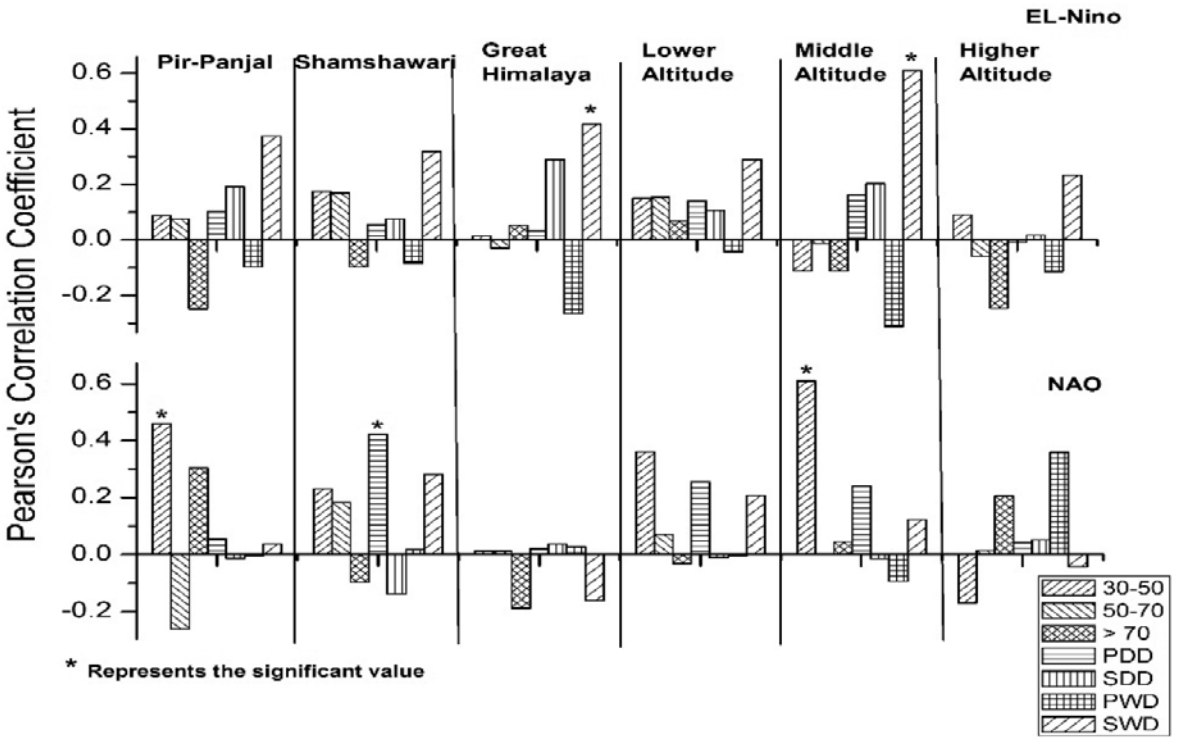

Figure 5. Pearson's correlation coefficient of El-nino and NAO with observed winter precipitation over Western Himalaya region.

CONCLUSIONS

Based on the study of intensity and duration for seasonal precipitation over the Western Himalaya region, following conclusions can be drawn. In terms of intensity, the low precipitation events indicate increasing trends for all ranges and altitudes over Western Himalaya. The medium precipitation events show over all negative trends for all ranges and altitudes except higher altitude where positive trend has been observed but not significant. Heavy precipitation events indicate significant increasing trend in Pir-Panjal range and no clear trend has been observed for other ranges and altitudes. PDD/SDD shows significantly increasing/decreasing trends for all ranges and altitudes in Western Himalaya region which indicate that rainy days have decreased and duration of dry spell has increased over the Western Himalaya region. PWD do not indicate any clear trend for all ranges and altitudes. SWD indicates alternately decreasing and increasing trend in all ranges and altitudes. No significant correlation has been observed of precipitation events in terms of intensity with El-Nino. SWD shows positive correlation with El-Nino for all ranges and altitudes but significant only for Great Himalaya and Middle altitude. NAO has positive correlation with low precipitation events for all ranges and altitudes except Great Himalaya and no clear correlation has been observed for other precipitation events.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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EARTH'S INNER CORE DOESN'T MELT

Scientists have found out why the inner core of our Globe remains solid, despite being hotter than the Sun. Researchers at KTH Royal Institute of Technology in Sweden, found to be reinserted due to that on the edge of the Inner Core; pieces of crystal structure continuously melt and diffuse, only to be re-inserted due to the superhigh overall pressure akin to "shuffling deck of cards".

This energy distribution cycle keeps the monocrystalline inner core stable and solid. Spinning within the Earth's molten core is a crystal ball, nearly the size of our Moon - composed actually of a mass formation of almost pure crystallized iron. Understanding this strange and unobservable feature of the planet we live on, depends on knowing the atomic structure of these crystals - something the scientists have been trying to do for years.

(**Source:** "Fact of the Matter": INNER MATTERS : Indian Express, Bhubaneswar Edition of Monday the 20th February 2017, Page14).