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Winter precipitation climatology over Western Himalaya: Altitude and Range wise study

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ABSTRACT

An Attempt has been made in this study to find the Climatology of winter precipitation over western Himalaya region (WH). Characteristics of Precipitation Variation Trends (PVT) with different altitude regions and Himalayan ranges have been analysed by using monthly cumulative precipitation data from 81 surface observatories of western Himalaya from 1971-2013. With respect to elevation, western Himalaya is divided into three altitude regions and four Himalayan ranges. The altitude regions considered for study are below 1500m, 1500-3500m and above 3500m respectively. Results show that more than 80 % of the stations under study indicates strong negative precipitation tendency rate over western Himalaya. Simple linear regressions have been used for trend analysis. The statistical significance of winter precipitation trends has also been studied by using Mann-Kendall method. The results confirm the decreasing trends in winter precipitation there by indicating the impact of climate change and precipitation variability in western Himalayan region.

Key words: Precipitation Variation Trend, Western Himalaya, Climatology, Mann-Kendall test, Range and altitude.

INTRODUCTION

The Himalayan Mountains play an important role in shaping the weather and climate system of Indian subcontinent. The main weather systems which bring precipitation in western Himalayan region are Western Disturbances (WDs) during wintertime and monsoon phenomenon during summer time. The summer monsoon dominates the climate from June to September and WDs dominate the climate form November to April. During winter i.e. December, January, February (DJF), WDs yield enormous amount of precipitation over northern India (Lang and Barros, 2004 and Dimri and Mohanty, 2009), which is important for overall ecology and socioeconomic requirements of the region. Himalayan climatology with special reference to extreme rainfall events in the context of global climate change has been studied by Joshi and Rajeevan (2006). Bhutiyani et al., (2007) and Shekhar et al., (2010) attempted studies to understand the impact of climate variability and precipitation and temperature trends in Himalayan region. Many studies have brought out the topographic effects on precipitation (Barros and Lettenmaier, 1994 and Liao et al., 2007), whereas a limited few have analysed the relationship between precipitation variation trends (PVT) and topography (Ma and Fu, 2007). Altitude is generally accepted as the most common topographic variable used to explain spatial variations in precipitation such as precipitation enhancement through orographic uplift. It may be noted that in Switzerland, depending on the region, altitude explains 0–90% of the variance of mean annual precipitation (Sevruk, 1997). The effect of altitude, however, is not always positive. Lu et al., (2008) discussed the negative correlation between summer precipitation and altitude in China and found that the correlation is becoming stronger with increased global warming.

PRESENT STUDY:

A primary objective of the present study is to preliminarily understand the relationship between Precipitation Variation Trend (PVT) and altitude of Himalayan Ranges over Western Himalaya; and thereby opening a direction to further understand the trends in precipitation patterns with larger number of topographic variables, such as orientation, slope, and exposure etc. especially in Western Himalayan region.

DATA AND METHODOLOGY

Data

In the present study 81 observation stations of Snow and Avalanche Study Establishment (DRDO) and India Meteorological Department (IMD), which are well distributed over WH are chosen for analysing data of winter season. The stations under study have been categorised into three altitude regions and four ranges as given in Table 1.

Table 1. Categories of Altitude and Himalayan ranges.

Altitude Regions	Western Himalayan ranges
1. altitude < 1500 m (28)	1. Pir Panjal (PP) (50)
2. altitude between 1500 m to 3500 m (44)	2. Shamshawari (SH) (8)
3. altitude > 3500 m (9)	3. Great Himalaya (GH) (16)
	4. Karakoram (KK) (7)

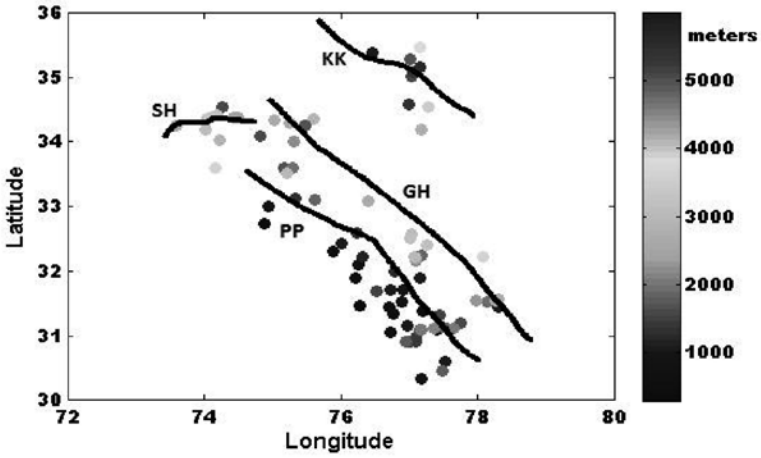

Figure 1. Indian Western Himalaya and data observation stations showing the altitude in meters above mean sea level; KK-Karakoram Range, SH-Shamshawari Range, GH- Great Himalaya Range, PP- Pir Panjal Range; Latitude and Longitude in Degrees).

Figure 1 shows the locations of 81 surface observatories in the Indian Western Himalaya. To maximize data quality, the annual stations, ordinary climatological stations, and observation stations with any missing data (a month without measured precipitation data) were removed. Ultimately, data collected from 1971 to 2013 from these 81 stations were considered for analysis. The present study is restricted to the winter season, where precipitation is measured only from November to April.

Methodology

Simple linear regression has been used to calculate the precipitation tendency rate as $X_t = a_0 + a_1 t$; Here, t is time from 1971 to 2013, and X_t is the estimated monthly mean precipitation by simple linear regression. The regression coefficient is $a_1 = dX_t/dt$, and the precipitation tendency rate is $b = a_1 x10$, with units of mm/10 a. A positive value indicates an increasing trend, and a negative value indicates decreasing trend. The regression coefficient indicates quantitatively the relationship between t and X_t. The Mann–Kendall (MK) test being a widely used nonparametric technique for detecting monotonic trends in hydrological and meteorological time series (e.g., Gemmer et al., 2011), the same MK test for trend analysis to test the statistical significance (passing the 95% significance level) is used in the present study.

RESULTS AND ANALYSIS:

In Figure 2 are shown scatter plots between the winter PVT and altitudes and ranges in the Western Himalaya region. In addition to these the spatial distribution of winter PVT and winter precipitation patterns (shown in Figures 3 and 4) were also analysed.

The relationship between winter PVT, altitude regions and Himalayan Ranges

Figure 2 indicates overall negative winter precipitation variation trends for all altitudes and ranges in western Himalayan region. The decreasing tendency rate has been observed within (±10mm/10a) in lower altitudes and within ±50 mm /10a in middle and upper altitude regions. The findings clearly indicate that decreasing trends are more in middle and higher altitudes compared to lower altitudes. The overall negative tendency rate has been observed in all the Western Himalayan ranges except for Shamshawari Range, wherein positive tendency rate has been observed. A Complete negative tendency rate has been observed in Karakoram Range. The Spatial distribution of the winter precipitation tendency rate is shown here in Figure 3 Spatially positive tendency rate is dominant in the western part, whereas the tendency rate is negative in Eastern, Middle and Southern parts of Western Himalaya respectively.

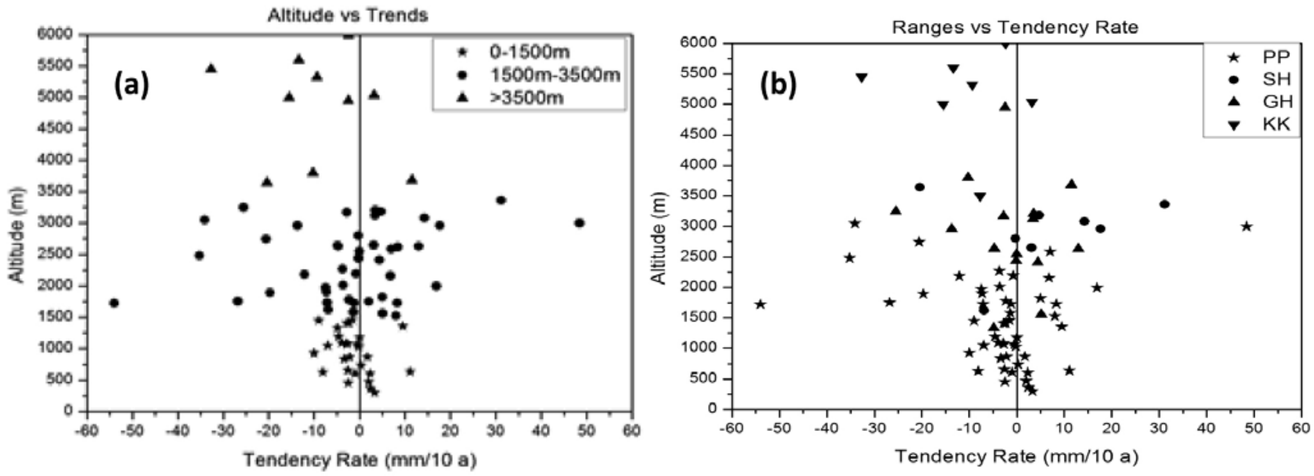

Figure 2. Scatter plots of the winter precipitation tendency rate versus (a) altitude regions and (b) Himalayan Ranges.

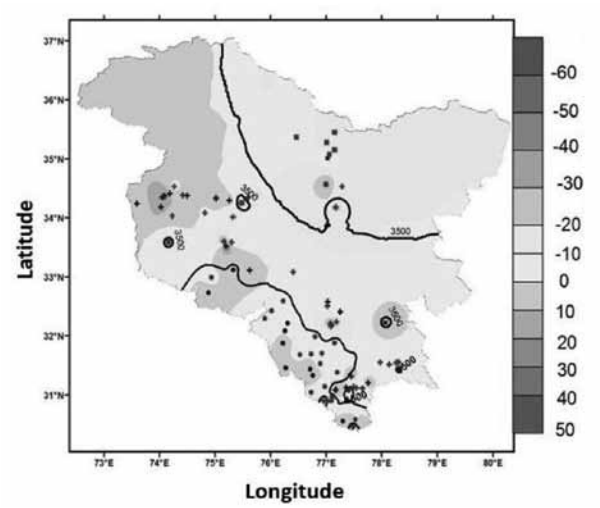

Figure 3. Spatial distribution of the winter precipitation tendency rate b (mm/10a). Black solid lines are 1500m and 3500m contour lines ;(•, +,) represent the points 0- 1500m, 1500-3500m and above 3500m, respectively. Blue (•, +,) represents positive, and red (•, +,) negative.

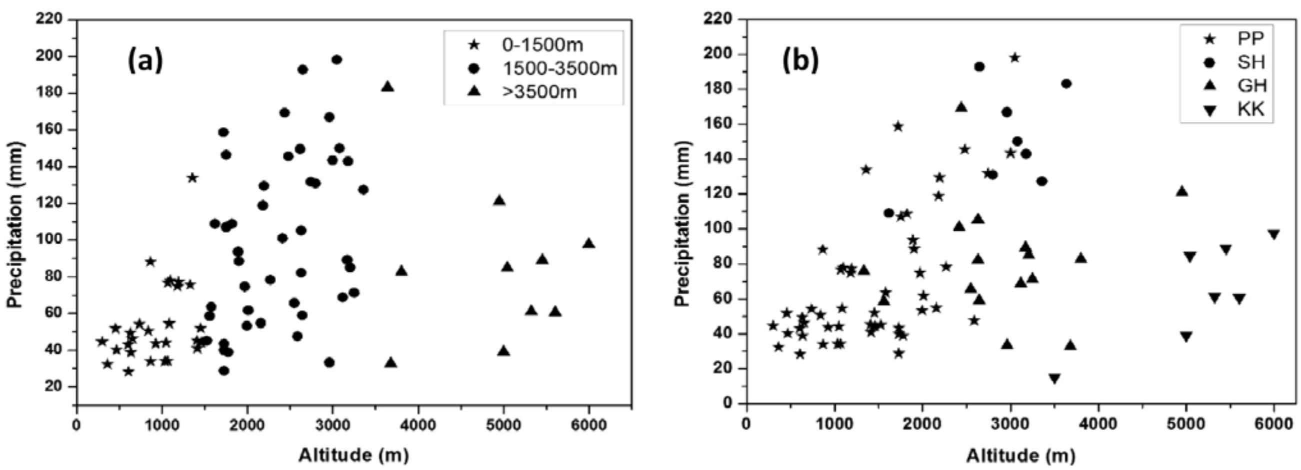

Figure 4. Scatter plots of the regional winter precipitation versus (a) altitude regions and (b) Himalayan Ranges.

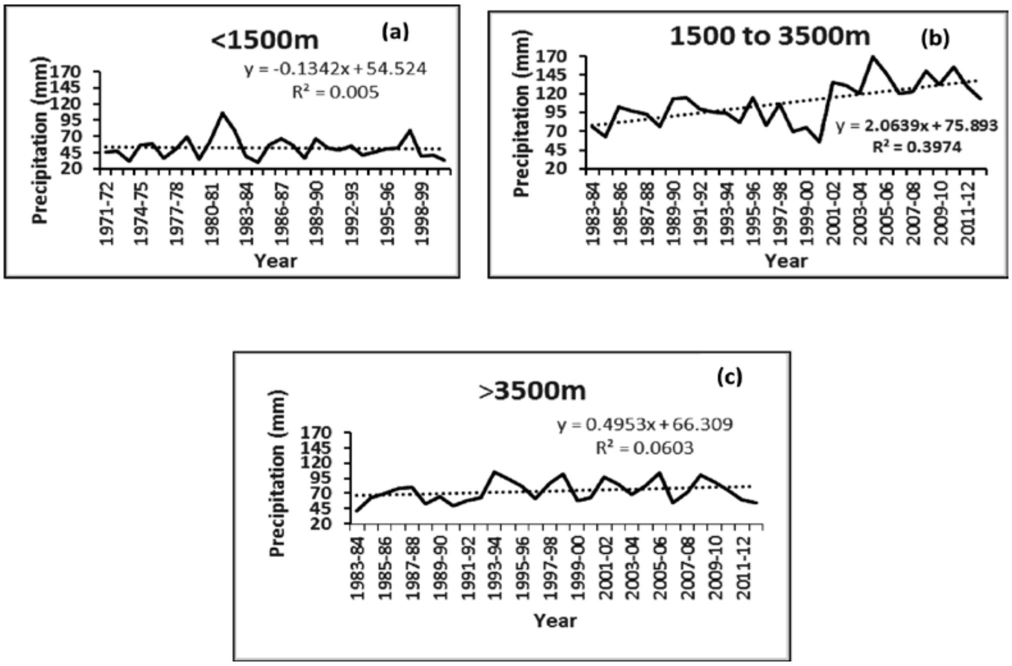

Figure 5. Trends in precipitation over different altitude zones of Himalaya.

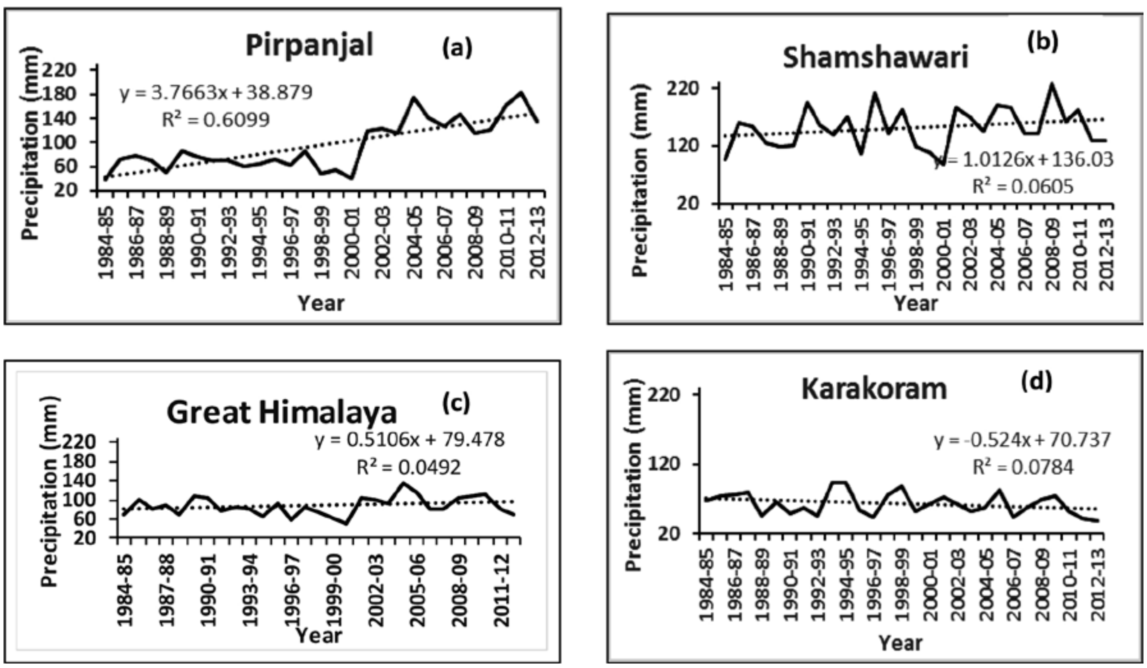

Figure 6. Trends in precipitation over different ranges of Himalaya.

Winter precipitation patterns for different altitude regions and Ranges in Western Himalaya.

Mean winter precipitation patterns indicate more precipitation in middle altitudes as compared to other altitudes (Figure 4a). The maximum Mean winter precipitation has been observed in middle altitudes region (1500-3500 m) with value up to 200 mm. Mean precipitation for lower and upper altitudes is about 80 and 125mm respectively. Similarly, maximum winter precipitation pattern is observed in Shamshawari range followed by Great Himalaya, Pir Panjal and Karakoram ranges respectively (Figure 4b). In Shamshawari, the precipitation value ranges from 125 to 200 mm. In Pir Panjal the values are 80 mm for majority of stations except for a few stations where the values are up to 200mm. The

Precipitation values in Great Himalaya and Karakoram ranges are 125 and 100 mm respectively. The trends in winter precipitation (altitude wise) are depicted in Figure 5. Altitude wise decreasing precipitation trends has been observed in lower altitudes and increasing in middle and upper altitudes. Significant positive trend is observed in middle altitude region and no significant trends are present in lower and upper altitudes.

The range wise trends in winter precipitation are shown here in Figure 6. An overall increasing trend in precipitation has been seen in all ranges except the Karakoram. There are no significant trends in Great Himalaya, Shamshawari and Karakoram, whereas significant trend is found in Pir Panjal only. The study on climatology of fresh snowfall over Western Himalaya by Shekhar et al., (2010) indicates decreasing trends in snowfall in all the ranges of Western Himalaya. The decreasing trends in snowfall and increasing trends in total precipitation clearly indicate the increasing liquid precipitation i.e. rainfall in these ranges of Himalaya in the warming environment due to recent climate change and global warming. The trend in precipitation in Karakoram remains the same i.e. decreasing. This may be due to the fact that this range is situated in higher altitude which gets precipitation throughout the year in the form of snowfall only.

CONCLUSIONS

Range and altitude wise climatology of winter precipitation over western Himalaya region has been studied. Negative tendency rate of precipitation is observed in all the ranges of Western Himalaya except for Shamshawari where the rate is positive. Spatially positive tendency rate is dominated in western part and negative in Eastern, Middle and Southern parts of Western Himalaya respectively. Precipitation shows decreasing trends in lower altitudes and increasing trends in middle and upper altitude regions. However, the trends are not significant in lower and upper altitudes but show significant positive trends in middle altitude region. The increasing trend in total precipitation and decrease in snowfall confirms the increasing rainfall in almost all the ranges of Western Himalaya except the Karakoram range and thereby confirming the setting in of the climate change and global warming over the Himalayan region.

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Compliance with Ethical Standards

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

REFERENCES

Barros, A.P., and Lettenmaier, D.P., 1994. Dynamic modeling of orographically induced precipitation, Geophys Rev., v.32, no.3, pp: 265–284.

Bhutiyani, M.R., Kale, V.S., and Pawar, N.J., 2007. Long-term trends in maximum, minimum and mean annual air temperatures across the north-western Himalaya during the 20th Century. Climatic Change, v.85, pp: 159–177.

Dimri, A.P., and Mohanty, U.C., 2009. Simulation of mesoscale features associated with intensed western disturbances over western Himalayas. Meteorol Appl., v.16, pp: 289–308.

Gemmer, M., Fischer, T., Jiang, T., Su, B., and Liu, L.L., 2011. Trends in precipitation extremes in the Zhujiang River basin, South China. J. Clim. http://dx.doi.org/10.1175/2010JCLI3717.1., v.24, pp: 750–761.

Joshi, U.R., and Rajeevan, M., 2006. Trends in precipitation extremes over India, NCC Research Report No, 3/2006, National Climate Centre, Pune.

Lang, T.J., and Barros, A.P., 2004. Winter storms in central Himalayas. J Meteorol Soc Jpn., v.82, no.3, pp: 829–844.

Liao, F.Y., Hong, C., and Zheng, G.G., 2007. Review of orographic influences on surface precipitation, Meteor. Sci. Tech., v.35, no.3, pp: 309–316.

Lu, A.G., Kang, S.C., and Pang, D.Q., 2008. Altitude effect of precipitation and the influence of global warming on it in China, Ecol. Environ., v.17, no.5, pp: 1875–1878.

Ma, Z.G., and Fu, C.B., 2007. Global aridification in the second half of the 20th century and its relationship to large-scale climate background, Sci. China Ser D-Earth Sci., v.50, no.5, pp: 776–788.

Sevruk, B., 1997. Regional dependency of precipitation-altitude relationship in the Swiss Alps, Climatic Change., v.36, pp: 355–369.

Shekhar, M., Chand, H., Kumar, S., Srinivasan, K., and Ganju, A., 2010. Climate change studies over western Himalayan region., Ann. Glaciol., v.51, no.54, pp: 105-112.