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Extreme value analysis of precipitation and temperature over Jammu & Kashmir and Ladakh in western Himalaya, India

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सार – जलवायु परिवर्तन आज दुनिया के लिए एक बड़ा मुद्दा बन गया है। हिमालय क्षेत्र में जलवायु में छोटे परिवर्तन नाजुक पारिस्थितिकी तंत्र पर महत्वपूर्ण प्रभाव डाल सकते हैं, जो ऐसे परिवर्तनों के प्रति बहुत संवेदनशील है। पश्चिमी हिमालय में जलवायु परिवर्तन की हालिया जाँच से इस बात के पुख्ता सबूत मिले हैं कि ये क्षेत्र विशेष रूप से विभिन्न प्रकार की विनाशकारी घटनाओं के प्रति संवेदनशील हैं। वर्तमान परिदृश्य में, जम्मू और कश्मीर (इसके बाद इसे जम्मू-कश्मीर के रूप में जाना जाएगा) तथा लद्दाख क्षेत्र में मानव अस्तित्व के लिए जलवायु परिवर्तन से उत्पन्न खतरा अधिक ठोस और स्पष्ट हो गया है। इस क्षेत्रीय जलवायु परिवर्तन का पता लगाने के लिए तापमान और वर्षा के आँकड़ों का उपयोग किया जा सकता है। इस शोध पत्र में जम्मू-कश्मीर और लद्दाख के चौदह जिलों में 1901 **से** 2002 **तक एक शताब्दी के लंबे डेटासेट का उपयोग करके वर्षा और तापमान में दीर्घावधि स्थानिक-अस्थायी भिन्नताओं का विश्लेषण और पूर्वानुमान किया गया है। ऑगमेंटेड डिकी-फुलर (एडीएफ) परीक्षण और क्वियाटकोव्स्की-फिलिप्स-श्मिट-शिन (केपीएसएस) परीक्षण डेटा में स्थिरता से पता चलता है कि समय श्रृंखला स्थिर है। चरम मान सिद्धांत (ईवीटी), जो भविष्य में चरम घटनाओं की संभावना के अनुमान के लिए रिकॉर्ड की व्याख्या करने के लिए एक उत्कृष्ट सांख्यिकीय पद्धति है, का उपयोग इस अध्ययन में किया गया है। इसके अलावा, क्रमशः** 50, 80, 100, 120, 200, 250, 300, **और** 500 **वर्ष की प्रत्यंतर अवधि के लिए वर्षा और चरम तापमान का पूर्वानुमान किया गया है और परिणाम बताते हैं कि जम्मू, राजौरी, लेह, श्रीनगर, बारामूला और पुंछ जिले में अधिक प्रचंड मौसमी घटनाओं की संभावना है।**

ABSTRACT. Climate change has become a major issue for the world today. Small changes in the climate in the Himalayan region can have a significant impact on the delicate ecosystem, which is very sensitive to such changes. Recent investigations into climate change in the Western Himalayas have provided compelling evidence that these regions are especially susceptible to a wide variety of catastrophic occurrences. In the current scenario, the threat posed by climate change to human existence in Jammu and Kashmir (hereafter referred to as J&K), as well as the region of Ladakh, has grown more tangible and evident. Temperature and precipitation statistics could be used to observe this regional climatic shift. This study analyses and forecasts long-term spatio-temporal variations in precipitation and temperature using a century-long dataset from 1901 to 2002 over fourteen districts of J&K and Ladakh. The Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test of stationarity on the data show that the time series is stationary. Extreme Value Theory (EVT), which is an outstanding statistical method to interpret the records for the estimation of the future probability of the occurrence of extremes, is utilised in this study. Further, precipitation and temperature extremes are forecasted for 50, 80, 100, 120, 200, 250, 300 and 500 year return periods respectively and results reveal that the districts- Jammu, Rajouri, Leh, Srinagar, Baramulla and Poonch will be more prone to extreme weather events phenomenon.

Key words – Extreme weather, Extreme value theory, Jammu & Kashmir, Ladakh, Himalaya.

1. Introduction

The entire world is more or less susceptible to natural calamities. In terms of climate change, the Himalayan mountain range plays a key role as it influences the climate over a vast region (Archer & Fowler 2004; Bhutiyani *et al.*, 2007). Complex geology, dynamic geomorphology and seasonal hydro-meteorological variables make the Himalayas more vulnerable to catastrophic calamities. (Rawat *et al*., 2012). Climate change is undeniably the biggest environmental challenge that our planet is facing today (Singh *et al*., 2016). Climate change causes rising temperatures (Ahsan *et al*., 2021, Wani & Bhatt 2017), shifting species distribution (Parmesan & Yohe 2003), glacier retreat (Ding *et al.*, 2006; Rashid *et al.*, 2020) and changing precipitation patterns (Chen *et al.*, 2011; Gautam *et al.*, 2009). Temperature and precipitation are key markers of climate change and variability (Rana *et al.*, 2017). Extreme weather events like droughts and floods can cause havoc, affecting various strata of society, particularly in coastal and mountainous regions. Jammu and Kashmir, the Himalayan area of north-western India, is one such cataclysmically produced mountainous terrain. In the past few decades, the local weather in this area has observed the following significant influences : (*i*) diminishing glaciers, (*ii*) destructive floods, (*iii*) decreasing winter duration and rainfall, and (*iv*) increasing summer duration and temperature (Kohler *et al*., 2010; Romshoo *et al*., 2018; Solomon *et al.*, 2009). (Bhutiyani *et al*., 2007; Kumar *et al*., 2010) in their findings, depicted an increase in temperature in the North-Western Himalayas with significant variations in precipitation patterns. A number of studies have found that winter temperatures are increasing and winter precipitation is increasing, while the monsoon season is decreasing in the Himalayan region (Ahsan *et al*., 2021, Pandey *et al*., 2023). (Lobell & Field 2007; Lobell *et al*., 2011) found that crop yields are declining as a result of shifting environmental variables such as precipitation and temperature. Fruits like apple, saffron, and walnut are the main source of revenue for the Kashmiri people. The temperature rise has caused apple farmers to move to higher altitudes to get three to four months of winter chilling period required for high-quality apples (Kumar *et al*., 2012; J&K ENVIS Centre 2015; Parvaze *et al*., 2017; Wani & Bhatt 2017). As a result, lower altitude farms are producing different crops to offset rising temperatures. (Mall *et al*., 2006) analyzed the work of several authors regarding the impact of climate change on Indian agriculture and concluded that by the year 2080 when the rate of increase in temperature will be larger, Indian agriculture will suffer the most.

Developing strategies for predicting meteorological phenomena is always of interest to both meteorologists and statisticians. Extreme value theory is an alternate and improved method for quantifying a process's stochastic behavior at extremely large or small levels. Extreme value theory offers a statistical framework for estimating the probability of rare and extreme occurrences. It is based on the study of the highest (or lowest) value for a certain time interval. Recently, there has been a spike in interest in modeling extreme occurrences, notably in instances in which scientists overestimated the possibility of severe events that caused devastating damage. Numerous studies in India focus on climate variability including variations in precipitation and temperature (Dash *et al*., 2009). Work has been done in this field by various researchers that shows how crucial it is to simulate temperature and precipitation datasets from various parts of the world: (Solomon *et al*., 2009) observation shows that daily minimum temperatures rise more significantly than daily maximum temperatures. Generalised extreme-value (GEV) distribution has several applications in hydrology (Martins & Stedinger 2000); (Koutsoyiannis. 2004) applied extreme value theory to model rainfall data from Europe and the United States. (Nadarajah & Choi 2007) applied extreme value theory to model rainfall data from South Korea. (Koutsoyiannis & Baloutsos 2000) applied extreme value theory to Greece's rainfall data. The use of extreme value distributions is not only restricted to meteorological events such as to extreme floods, extreme winds, extreme precipitation and extreme temperature but also applicable to other fields including: economy (Gilli & Këllezi, 2006), telecommunications as well as the hydrology and climatology (Diebolt *et al*., 2008; Rahayu, 2013). Also, in most of the countries, this theory is used to calculate countries GDP, national income, birth and death rates, population growth rates, *etc*. To the best of our knowledge, this is the first study of its kind in J&K and Ladakh. In particular, the aim was to model the extreme precipitation and temperature data using the generalised extreme value distribution (GEVD) by using the maximum likelihood estimation method, the generalised maximum likelihood estimation method, Bayesian statistics, and the L-moments statistics approach (Gilleland & Katz 2016). The average number of years before another precipitation or temperature extreme of equal or greater intensity may occur is also computed.

The present study is thus an attempt to provide an updated and detailed description of future climatic variations based on statistical modeling. The entire analysis was done on a seasonal basis. Section 2 provides an overview of the region's geomorphology and climate. Section 3 outlines the EVT approach involved, followed by findings and debates, and the final section contains the concluding remarks on the statistical modelling of meteorological characteristics.

2. Physiographic and climatologic description of the region

The union territoriesin the northernmost part of India namely J&K and Ladakh, are situated nearly between 32°17′ to 37°5′ N latitudes and 72° 40′ to 80° 30′ E

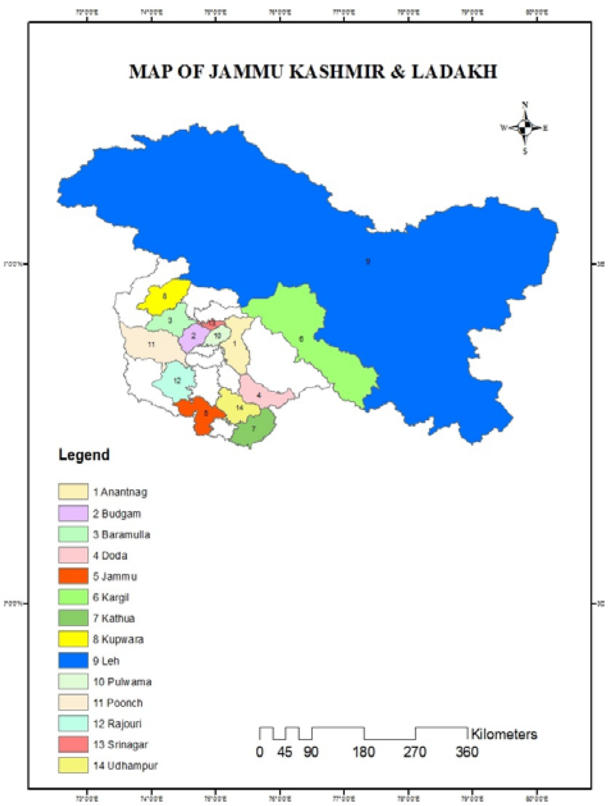

Fig. 1. Map of the study area

longitudes (Fig. 1) covering the geographical area of about 2,22,236 km^2.Thisentire region comprises complexly folded young mountain systems with elevations ranging from 290 m to above 7000m. Mountainous landscapes are extremely unstable and vulnerable to climate change. Because of its position and topography, the state's climate varies dramatically. Additionally, altitude and prevailing winds lead to significant climatic variances. The state's climate ranges from tropical in the Jammu plains to semi-arctic cold in Ladakh, with temperate climatic conditions in Kashmir and the Jammu hilly tracts. There is a significant amount of rainfall variation while considering districts of J&K and Ladakh, with Jammu district receiving upto 1200 mm of average annual rainfall as compared to Ladakh district, which receives about 45 mm of annual rainfall (http://www.imd.gov.in/section/hydro/distrainfall/jk.html. The Jammu region has lowlands, foothills, and forested mountains. The Jammu lowlands span from Punjab to the Shivalik mountains. Shivalik hill is a Himalayan range that merges into Pir Panjal. Jammu region and Kashmir valley are separated by the Pir Panjal range. The Kashmir valley is surrounded by forested mountains, lakes, rivers and sand terraced fields. It is situated between the Pir Panjal and Zanskar ranges. The valley region is normally flanked on all sides by mountains with an average height of 1615 m, while the surrounding mountains range in height from 3000 to 4900 m. The valley is predominantly flat and replete with springs and lakes while Ladakh, having an average elevation of 3650 metres, accounts for two - thirds of the area under examination, which is mostly snow - covered deserted region with elevations up to 7672 metres.

For extreme value analysis, annual data is split into four distinct seasons, covering the winter months from December to February and the warmer pre-monsoon months from March to May. The southwest monsoon season lasts from June to September, followed by the post-monsoon season in October and November.

3. Materials and methods

3.1. *Data source*

The database that is used for this work, is publicly available in (https://crudata.uea.ac.uk/cru/data/hrg/timm/grid/CRUTS20text.html). Central Water Commission and ISRO launched Water Resources Information System (WRIS), a comprehensive solution for accessing data on water in India**.** This published dataset consists of interpolated (on a 0.5-degree latitude-longitude grid) global monthly rainfall, temperature, humidity and cloud cover data, *etc*. from the year 1901 to 2002 and generate reports in the form of annual mean, monthly mean and annual totals.

3.2. *Extreme value theory and generalized extreme value distribution model*

Extreme weather and climate statistics have been investigated increasingly due to anticipated regional consequences of global warming (Gilleland & Katz, 2016). Infrequent weather extremes necessitate the estimation of the probability of events that have not yet occurred. EVT aims to assess the probability and severity of events more severe than any in a given data set. Based on Fisher and Tippett's (1928) theorem, EVT provides a method for modelling the asymptotic distribution of the maximum of a sequence and the sample size.

We have applied GEV distribution model to our dataset and used R Package for extremes that can perform parametric inferential analysis of the GEV distribution.

Generalized extreme value distribution (GEV)

In this work, we employ the GEV distribution, which combines the flexibility of the Gumbel, Frechet and Weibull distributions (Smith, 2002).

$$GEV(\chi,\xi,\sigma,\mu)=\exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\},\xi\neq 0 \quad (1)$$

$$\mathrm{GEV}(\chi,\xi,\sigma,\mu)=\exp\left\{-\exp\left[-\left(\frac{x-\mu}{\sigma}\right)\right]\right\},\xi=0 \quad (2)$$

Where x is the extreme values from the blocks, μ is the location parameter; σ is the scale parameter, and ξ is the shape parameter. The Shape Parameter 'ξ' of the GEV specifies the tail behavior of the GEV distribution. When ξ = 0, the GEV takes on a lightly tailed Gumbel distribution. For ξ> 0, the GEV takes on a heavy-tailed Fréchet distribution whereas for ξ< 0, the GEV takes on a bounded Weibull distribution.

3.3. *Stationarity of time series data*

A stationary series is one whose statistical features like mean, variance, covariance, and autocorrelation do not change with time, or time does not affect a variable's value. Many analytical methods, statistical tests and models rely on stationarity. Statistics make significant data assumptions. They assess whether a null hypothesis can be rejected or not. They do, however, provide a rapid check and confirmation that the time series is stationary or non-stationary.

To check the stationarity of time series data, the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski - Phillips - Schmidt – Shin (KPSS) test are used and both the tests are performed using R software. A key difference between KPSS test and ADF test is that the null hypothesis of the KPSS test is stationary whereas the null hypothesis for ADF test is that there is a unit root**.** Practically, the interpretation of *p*-value is just the opposite of each other. That is, in the case of KPSS test, if the *p*-value is less than the significance level (*i.e.*, 0.05), then the series is non-stationary whereas, in ADF test, it would mean the tested series is stationary.

3.3.1. *ADF test is performed with the following assumptions*

Null Hypothesis (H_0) : Either the series does not remain stationary over time or the series contains a unit root.

Alternate Hypothesis (H_A) : Either the series is stationary or the series does not have a unit root.

This test may show that the series is non-stationary if the null hypothesis is not rejected.

Conditions to Reject Null Hypothesis (H_0) : If Test statistic < Critical Value and *p*-value < 0.05, we can reject the null hypothesis and conclude that the time series is stationary.

3.3.2. *KPSS test is conducted with the following assumptions*

Null Hypothesis (H_0) : Series is trend stationary or series has no unit root.

Alternate Hypothesis (H_A) : Series is non-stationary or series has a unit root.

If the null hypothesis is failed to be rejected, this test may provide evidence that the series is trend stationary.

Conditions to Fail to Reject Null Hypothesis (H_0) : If Test statistic < Critical Value and *p*-value < 0.05, then we fail to reject null hypothesis (H_0) and conclude that the time series is trend stationary.

If any of the tests indicate non-stationarity, the trend must be removed to make the series stationary. The detrended series is then stationary.

3.4. *Parameters estimation*

Maximum Likelihood Estimation (MLE), Generalised Maximum Likelihood Estimation (GMLE), Bayesian method and L-moments are all statistical methods used for parameters estimation in probability distributions. (also known as model parameters, *i.e*., location, scale and shape parameters). The key differences between these methods are as follows:

(*i*) Maximum Likelihood Estimation (MLE) is a frequentist method that calculates the likelihood function- or the likelihood of witnessing the data, given the parameters-in order to estimate the parameters of a probability distribution. The probability distribution is known and MLE assumes that the data are independent and identically distributed.

(*ii*) The Generalised Maximum Likelihood estimate (GMLE) method is a variant of the Maximum Likelihood Estimation (MLE) method that enables the estimate of parameters in non-standard distributions or when the distribution's details are unknown. To estimate the parameters, it combines MLE with a probability distribution transformation.

(*iii*) Bayesian estimation is a technique that requires creating a prior distribution for the parameters of the probability distribution and then using Bayes' theorem to

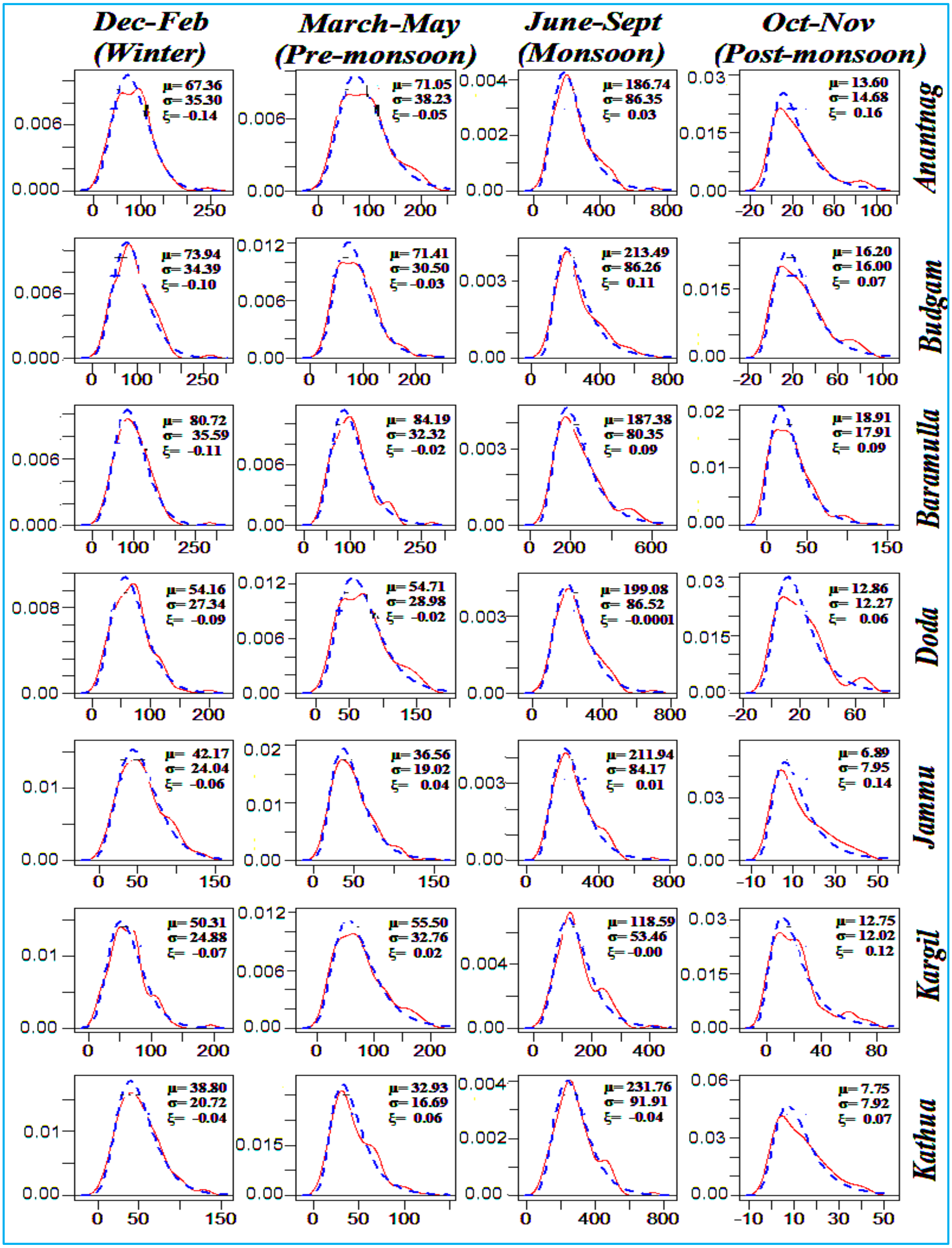

Fig. 2. Probability density plots for seven districts of J&K corresponding to Precipitation. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon, and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts. Corresponding location scale and shape parameters are embedded over each plot

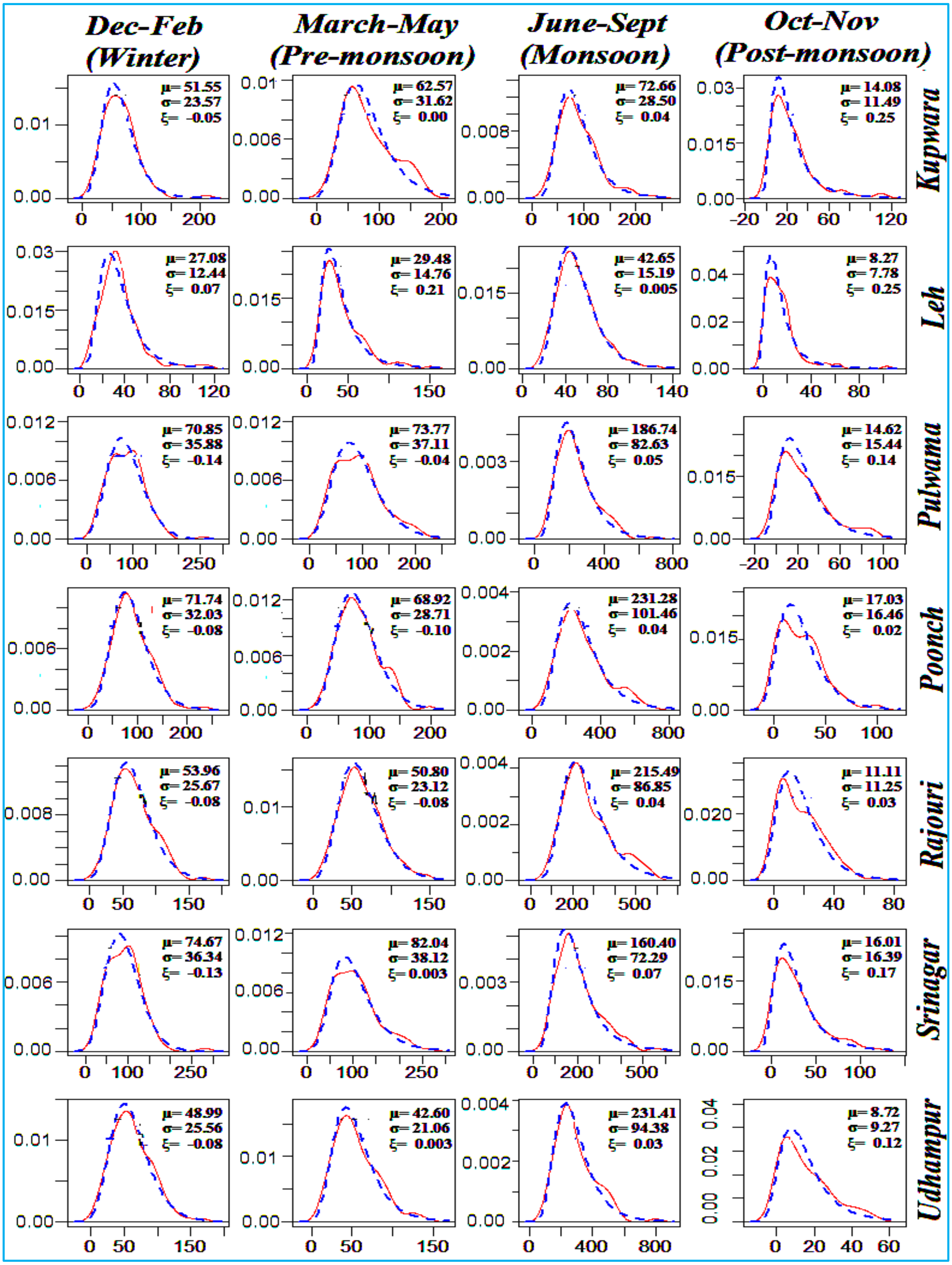

Fig. 3. Corresponding to Precipitation, probability density plots for six districts of J&K and P for the Leh district which is in the union territory of Ladakh are represented. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts

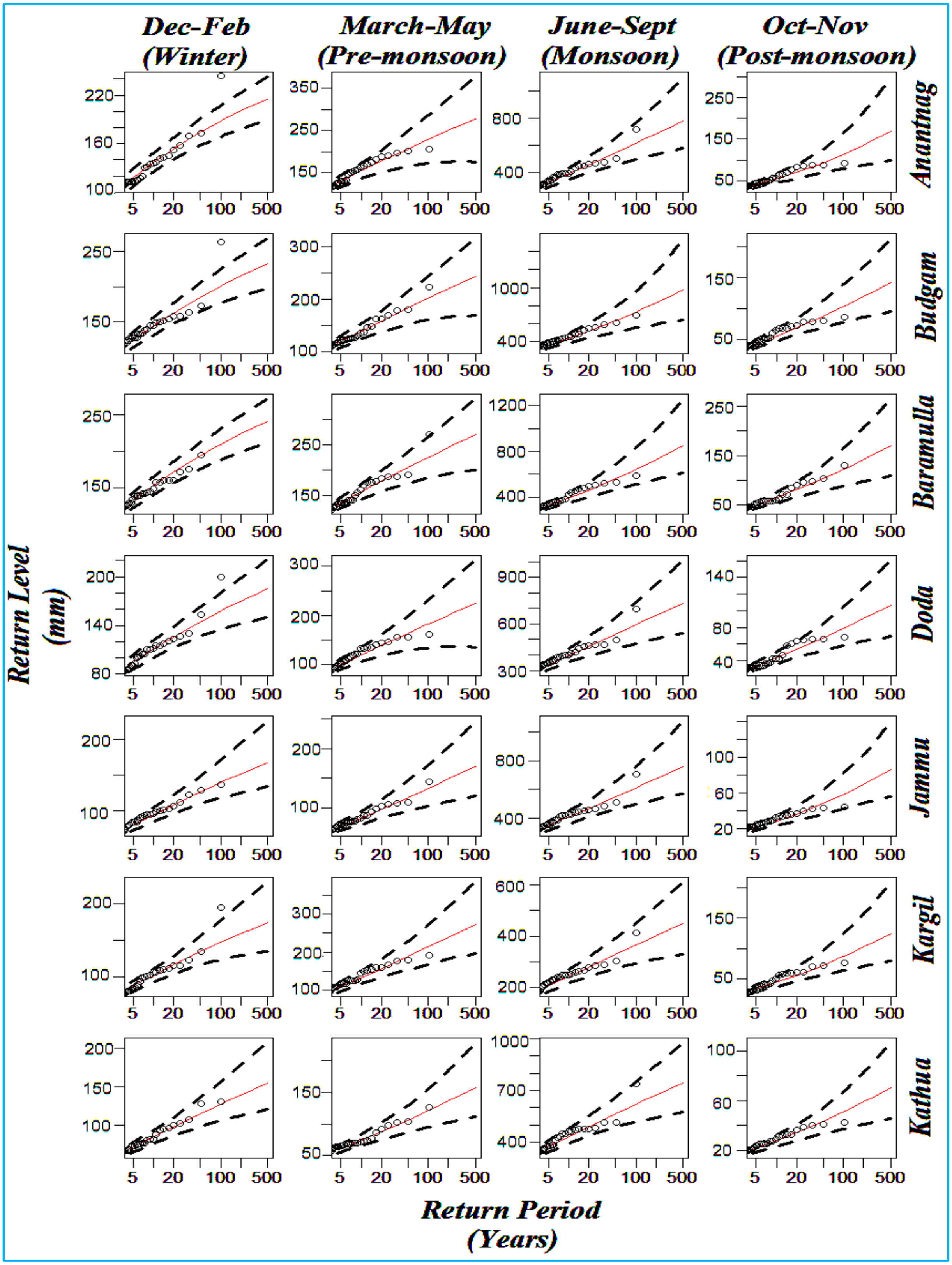

Fig. 4. Return value estimation plots for seven districts of J&K corresponding to maximum precipitation. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts (indicated right side of each row)

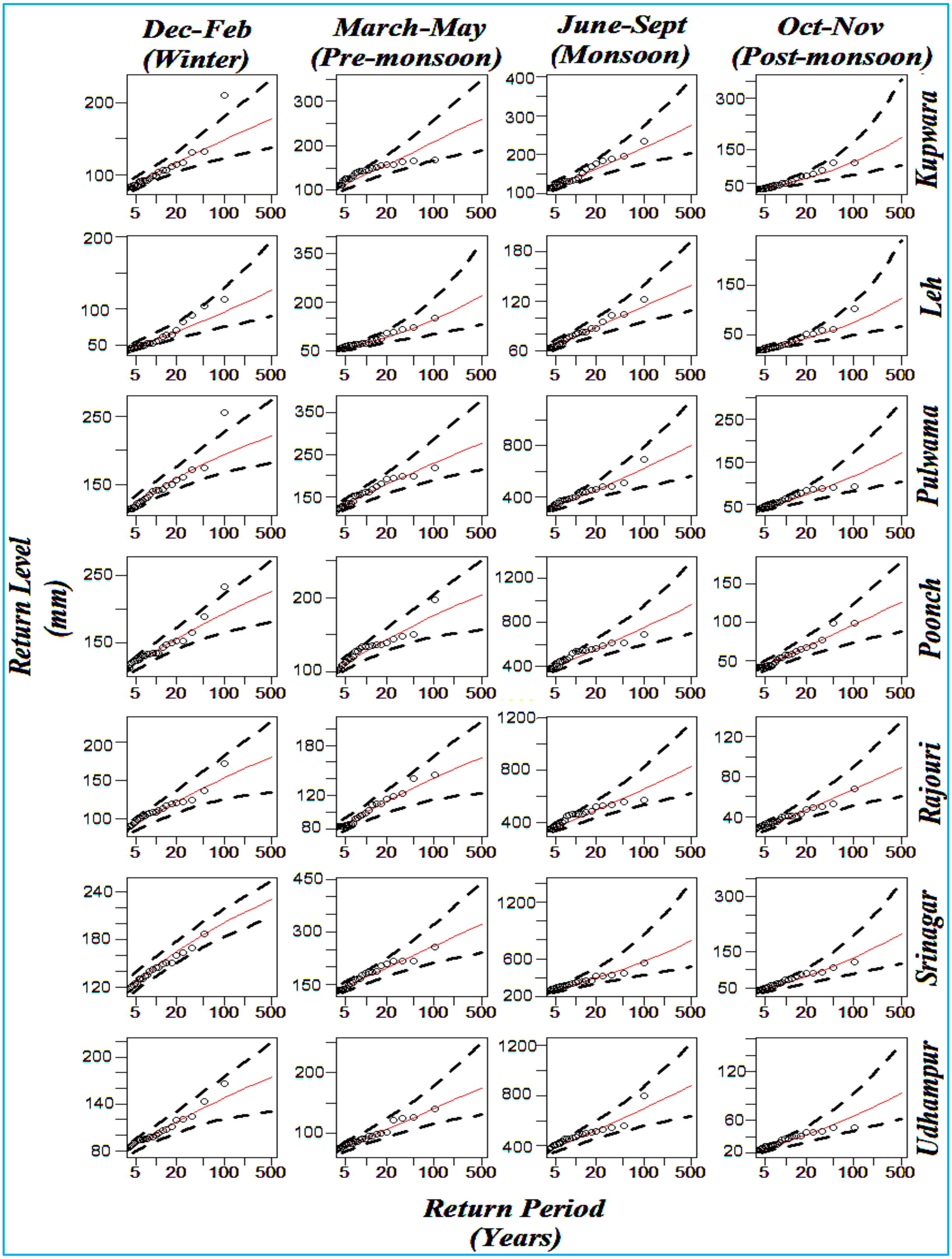

Fig. 5. Return value estimation plots for six districts of J&K and the Leh district corresponding to maximum precipitation are represented. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts (indicated right side of each row)

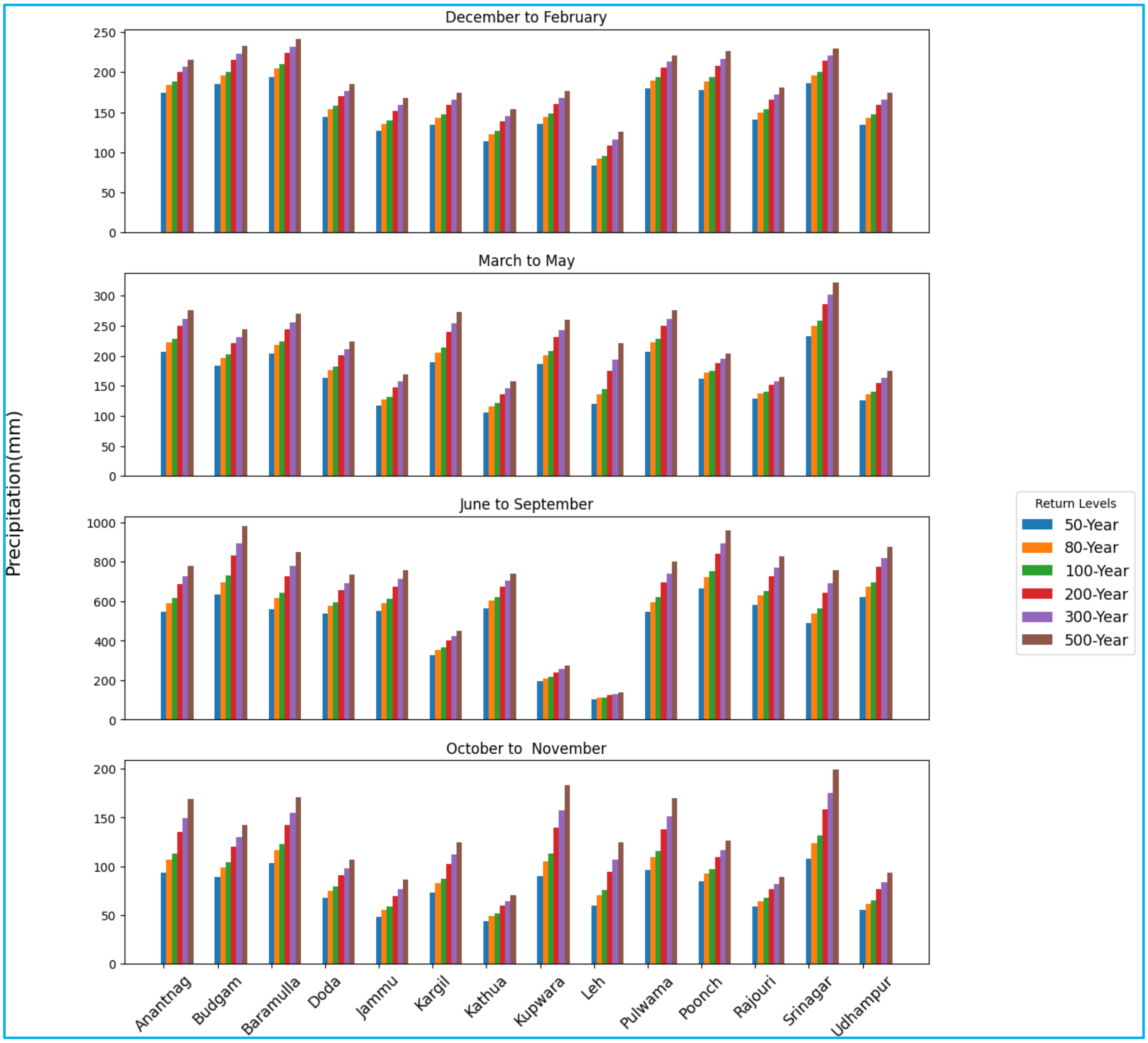

Fig. 6. Bar plot for maximum precipitation corresponding to different seasons with 50, 80, 100, 200, 300 and 500 years return levels respectively, where, each return level is represented by a particular colour

update the prior distribution in light of the observed data. The posterior distribution of the parameters is estimated using Bayesian estimation, which also allows for the incorporation of previous knowledge about the parameters.

(*iv*) The L-Moments approach, which is based on linear combinations of order statistics, is a technique for estimating the parameters of probability distributions. It offers estimates of the L-moments, which are linear combinations of the distribution's moments and can be used to infer the distribution's parameters.

Finally, the best-fitted model is accepted for the parameter estimation and return value estimation after applying all the different methods. The return level is defined as a value that is expected to be equalled or exceeded on an average once every interval of time (T) (with a probability of 1/T). Therefore, CDF of the GEV distribution is obtained by the equation $\left(X_T\right)=1-\frac{1}{T}$ (where X_T is the level exceeded on an average only once in T years).

4. Results and discussion

To check the stationarity of time series data, the ADF and KPSS tests are applied on temperature and precipitation datasets for the districts of J&K, and Ladakh and corresponding *p*-values are estimated at a 5%

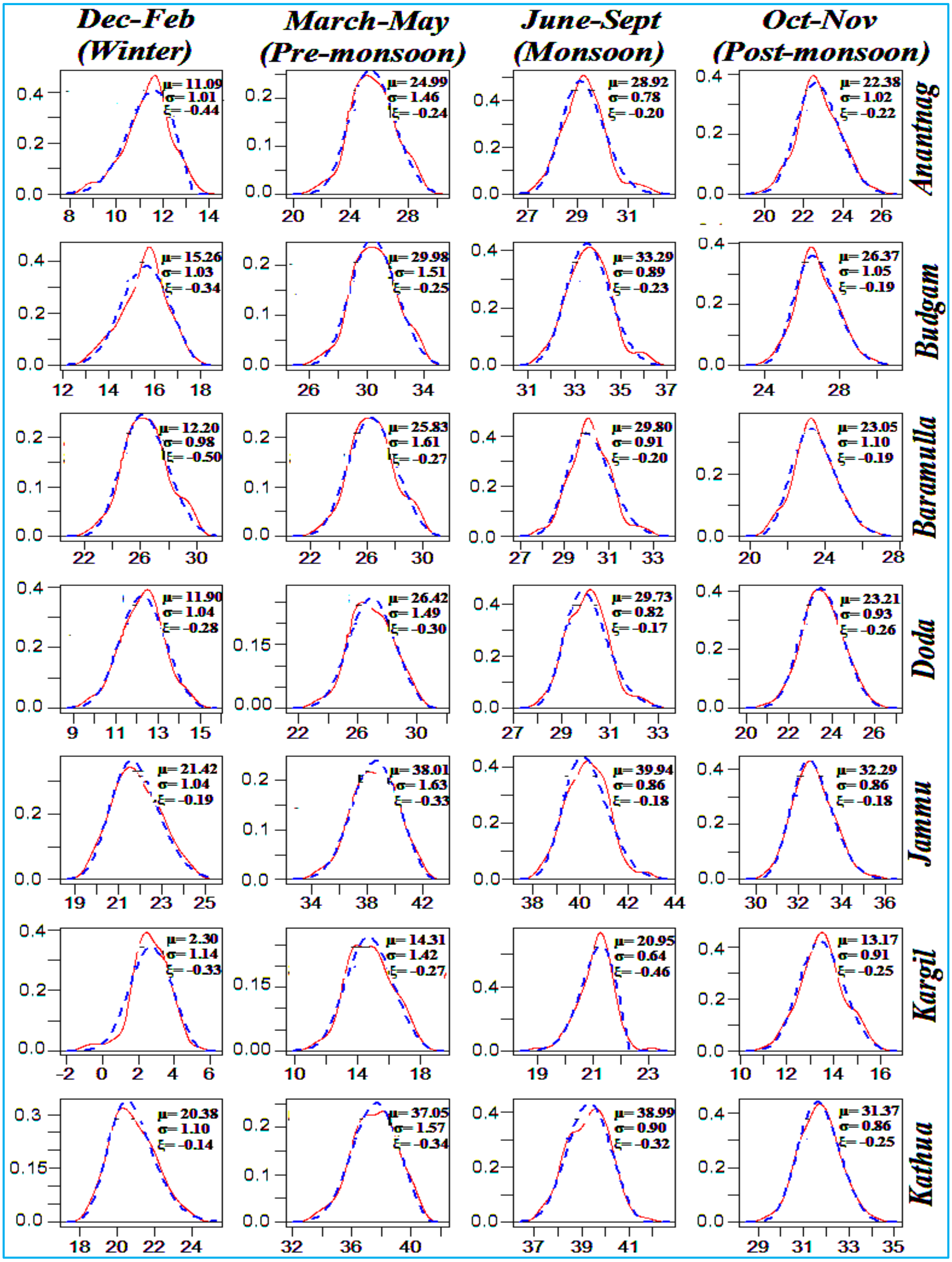

Fig. 7. Probability density plots for seven districts of J&K corresponding to maximum temperature. Seasonal analysis, *viz*., winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts

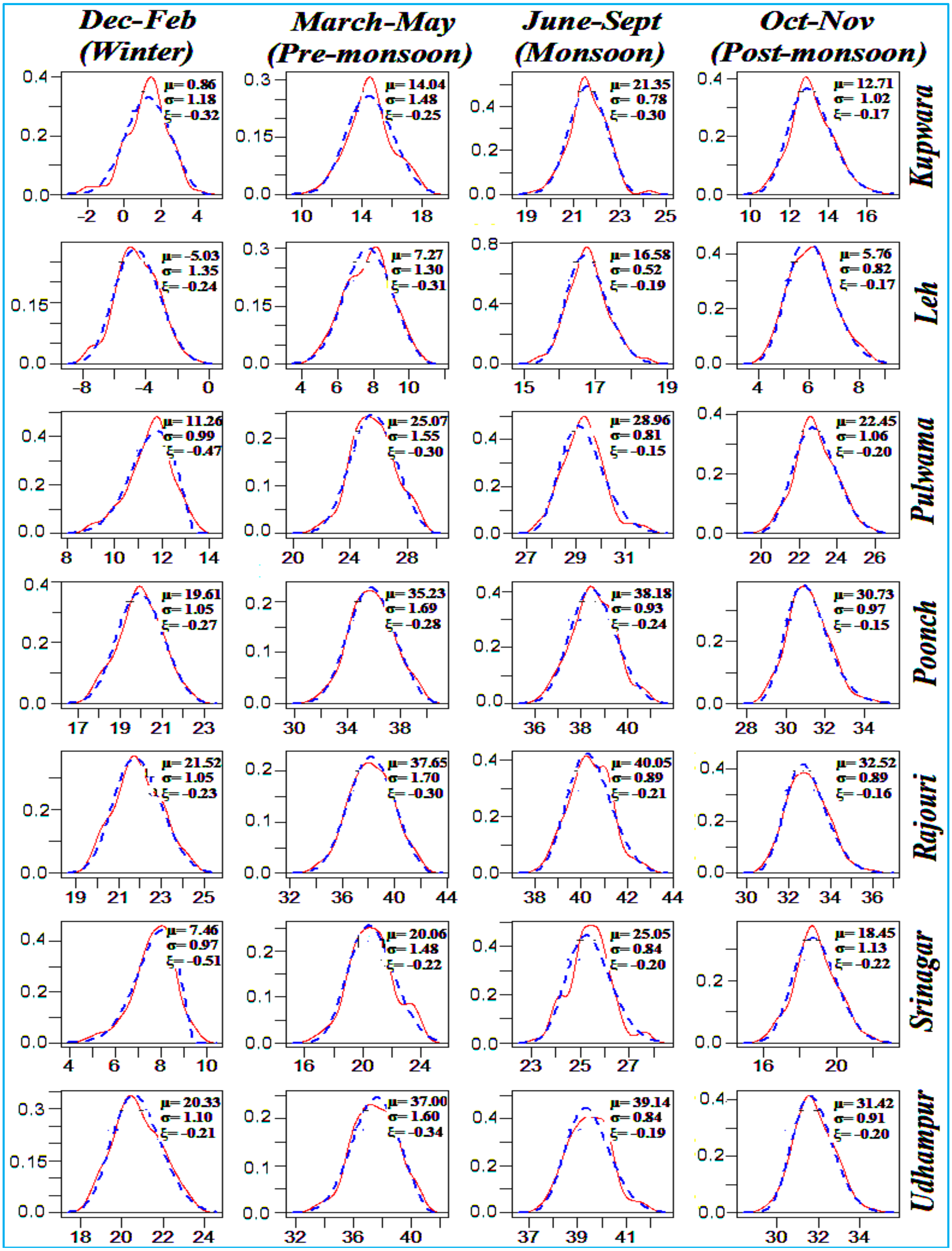

Fig. 8. Corresponding to the maximum temperature, probability density plots for six districts of J&K and for the Leh district which is in the union territory of Ladakh are represented. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts

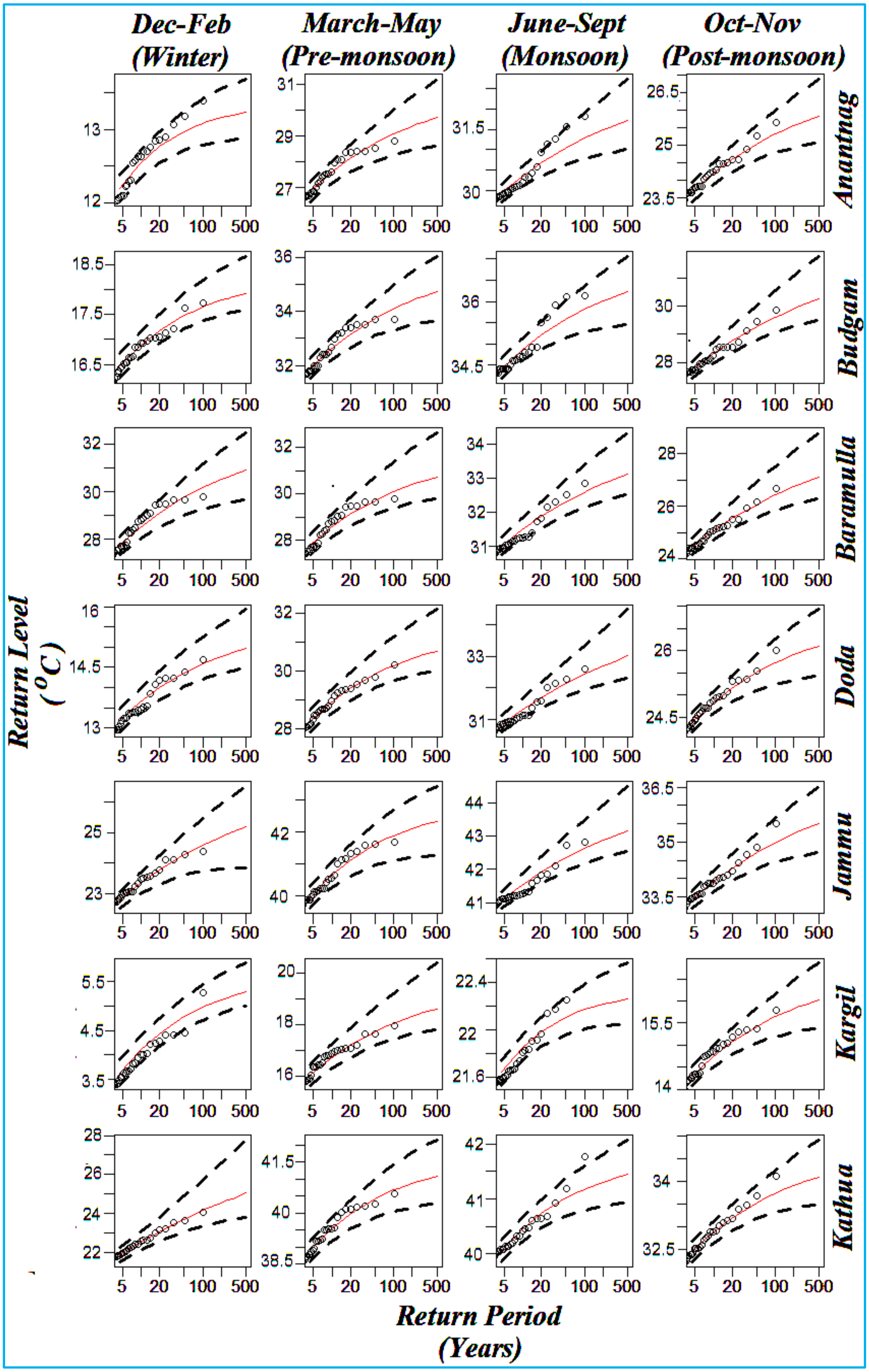

Fig. 9. Return value estimation plots for seven districts of J&K corresponding to maximum temperature. Seasonal analysis, *viz*., winter, pre-monsoon, monsoon, and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts (indicated right side of each row)

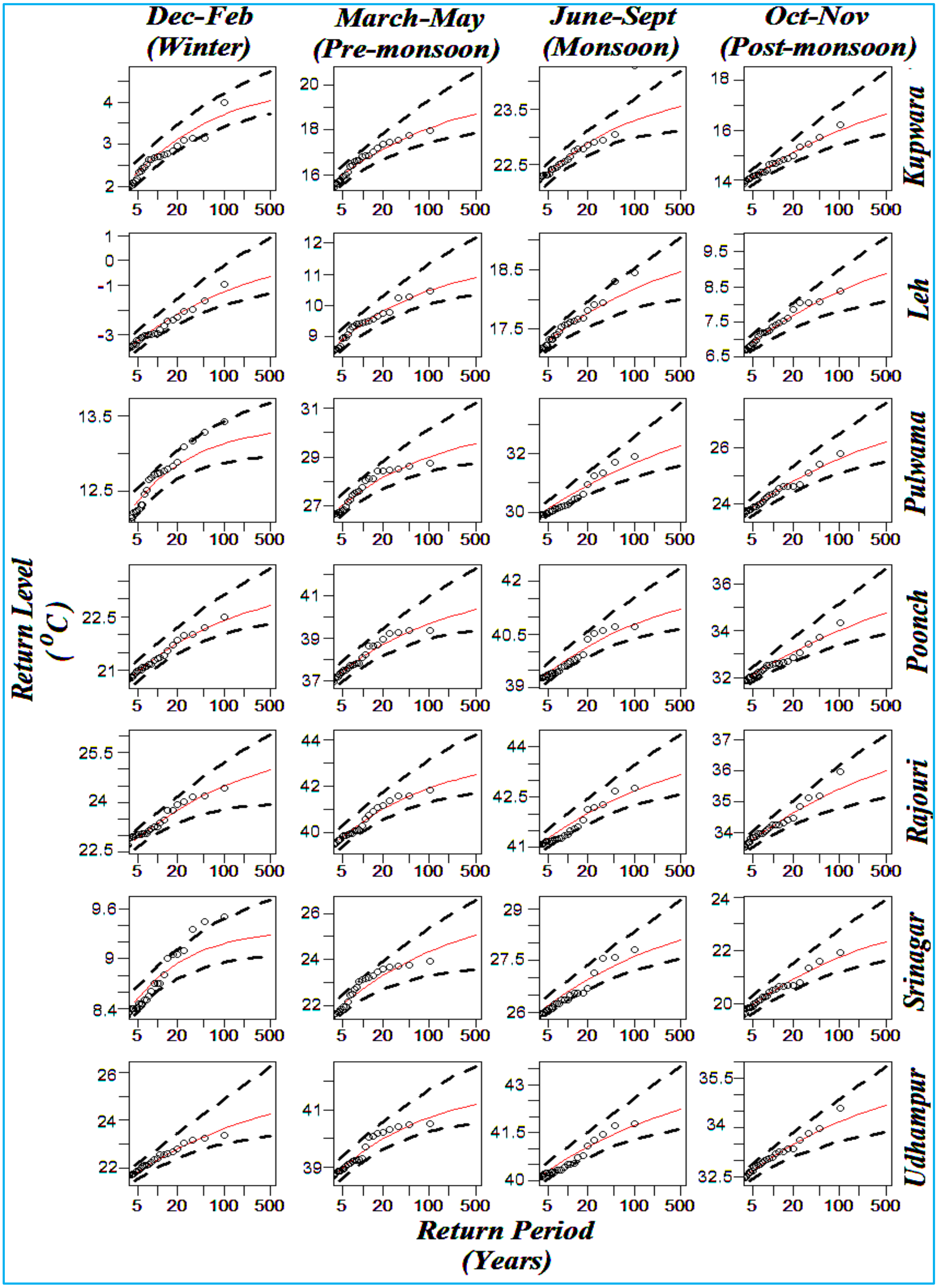

Fig. 10. Return value estimation plots for six districts of J&K and the Leh district corresponding to maximum temperature are represented. Seasonal analysis, *viz*., winter, pre-monsoon, monsoon, and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts (indicated right side of each row)

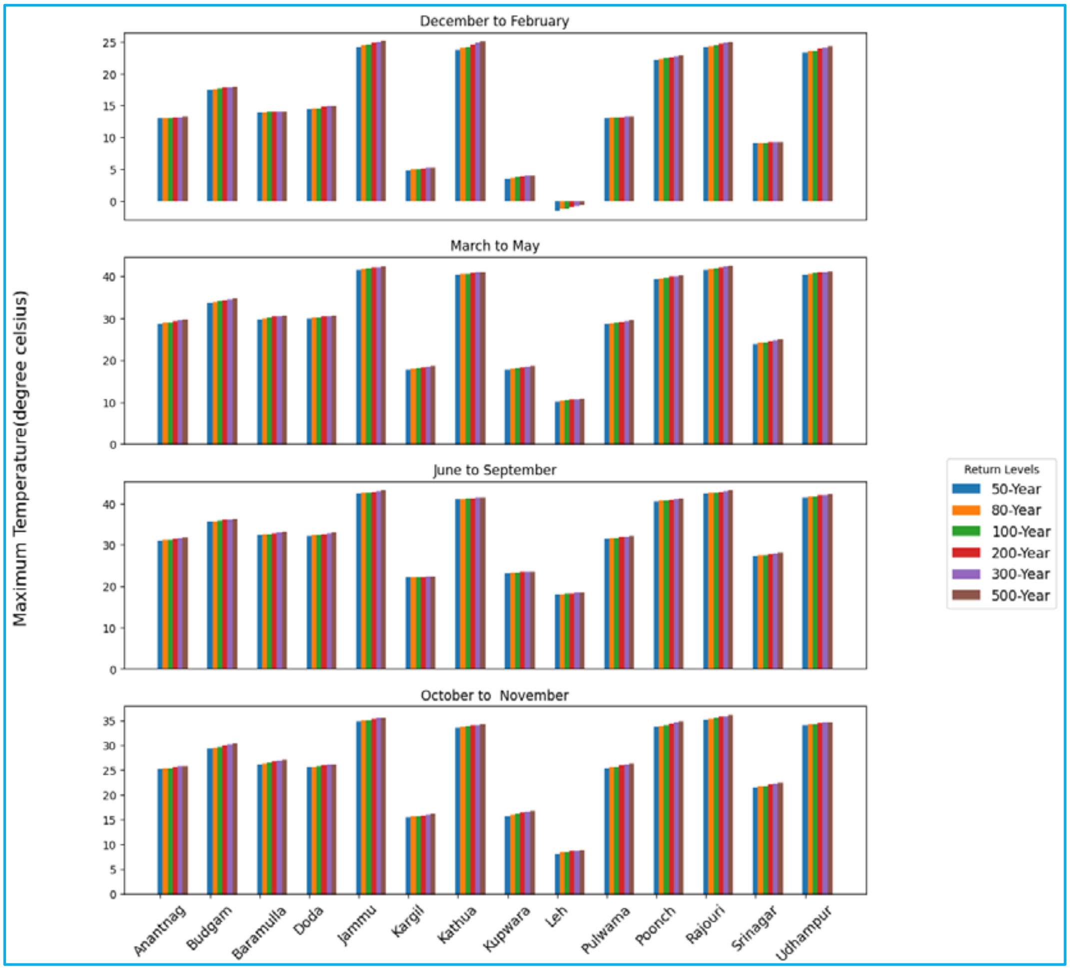

Fig. 11. Bar plot for maximum temperature corresponding to different seasons with 50, 80, 100, 200, 300 and 500 years return levels respectively, where, each return level is represented by a particular colour

significance level which revealed that datasets are stationary. Thus we can say that it has a time-independent structure and has constant variance over time.

In the present work, statistical modeling and forecasting studies are performed utilizing century-long datasets of meteorological parameters (*viz.*, Temperature, Precipitation) from fourteen districts of J&K and Ladakh, India. The analysis is based on seasonal (maxima) monthly mean precipitation and seasonal (maxima and minima) monthly mean temperature.

4.1. *Precipitation*

Precipitation falls in the form of rain and snow in J&K and Ladakh. Western disturbances cause snowfall from November through March. January and February are snowiest months. Because of its topography, the annual rainfall varies substantially from region to region. The annual rainfall in Jammu is more than in Ladakh. In the Ladakh region, Leh district receives the least amount of rainfall, 10 cm per year. Figs. 2&3 provide probability density graphs for the GEV fit for maximum precipitation of fourteen districts of the J&K and Ladakh regions. In each figure blue colour indicates empirical and the red colour depicts the best model fit using either MLE, GMLE, L-moments, or Bayesian methods. Corresponding location, scale and shape parameters are embedded over each plot.

Return period values for 50, 80, 100, 120, 200, 250, 300 and 500 years were investigated further and are shown in Fig. 4 and Fig. 5 respectively. The return periods indicate how long specific precipitation is predicted to be exceeded once for a given period (Fig. 6).

4.2. *Temperature*

The climate in the entire region varies greatly, from the scorching heat of the Jammu plains to the chill of the

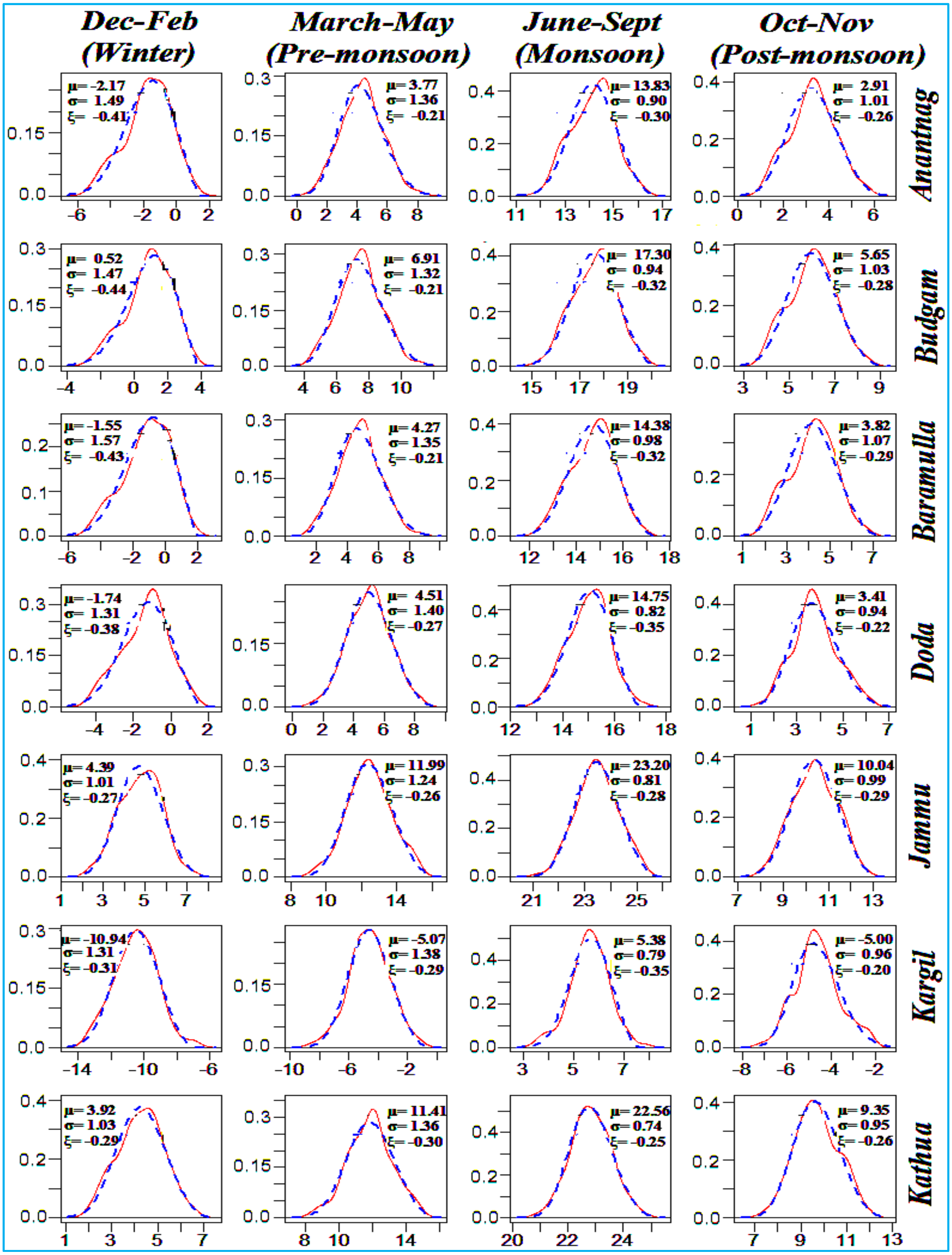

Fig. 12. Probability density plots for seven districts of J&K corresponding to minimum temperature. Seasonal analysis, *viz*., winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts

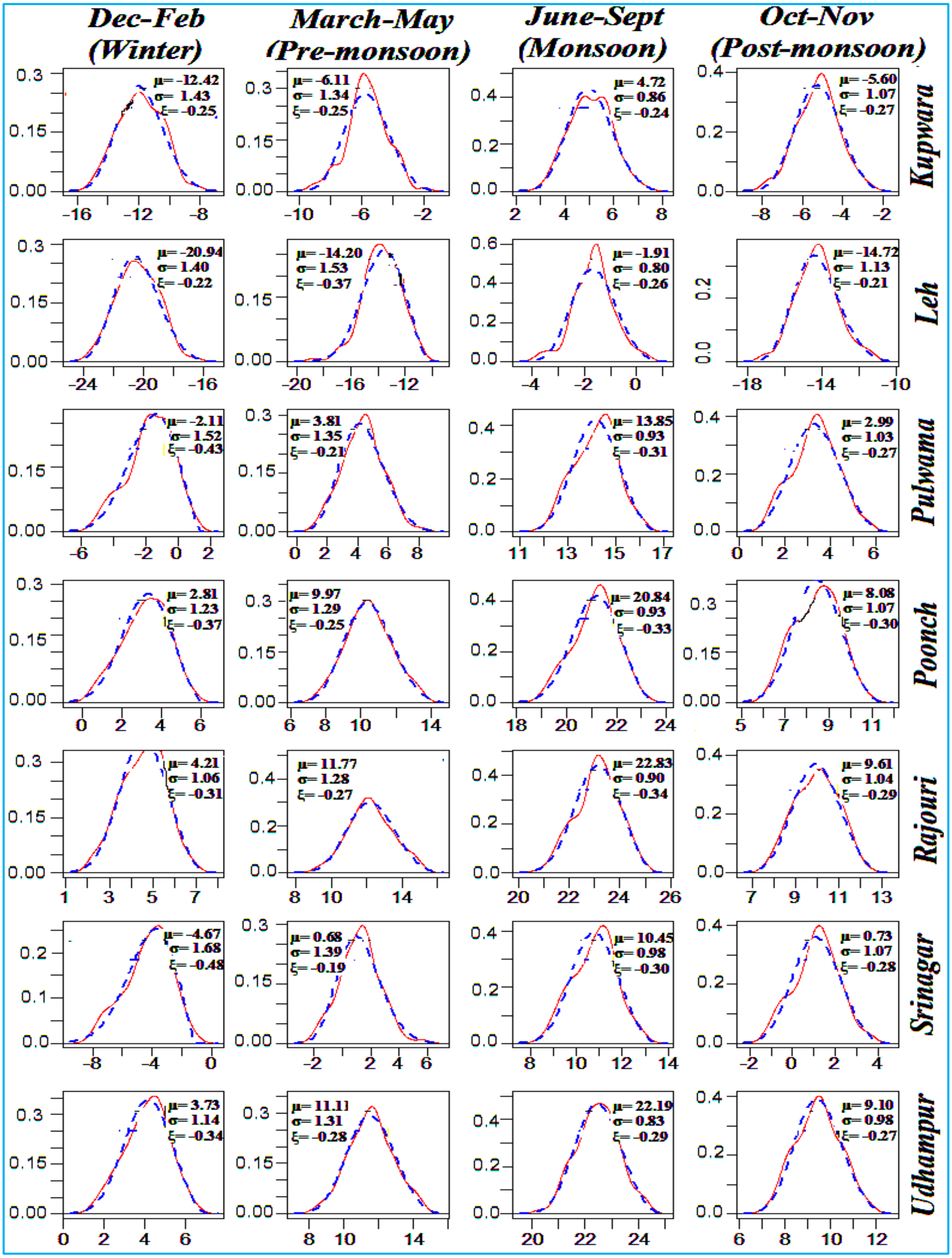

Fig. 13. Corresponding to minimum temperature, probability density plots for six districts of J&K and Leh district are represented. Seasonal analysis, *viz*., winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts

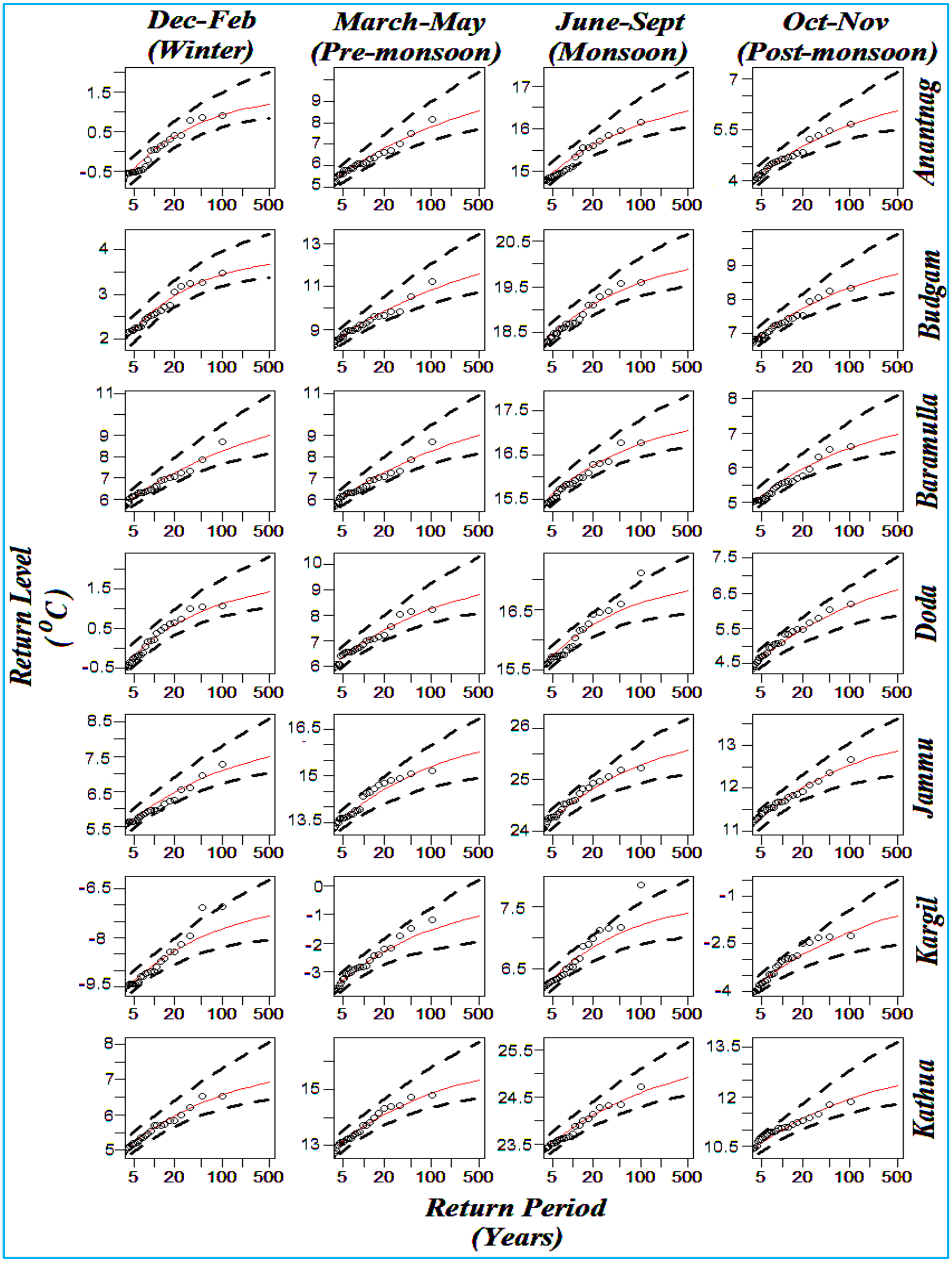

Fig. 14. Return value estimation plots for seven districts of J&K corresponding to minimum temperature. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon, and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts (indicated right side of each row)

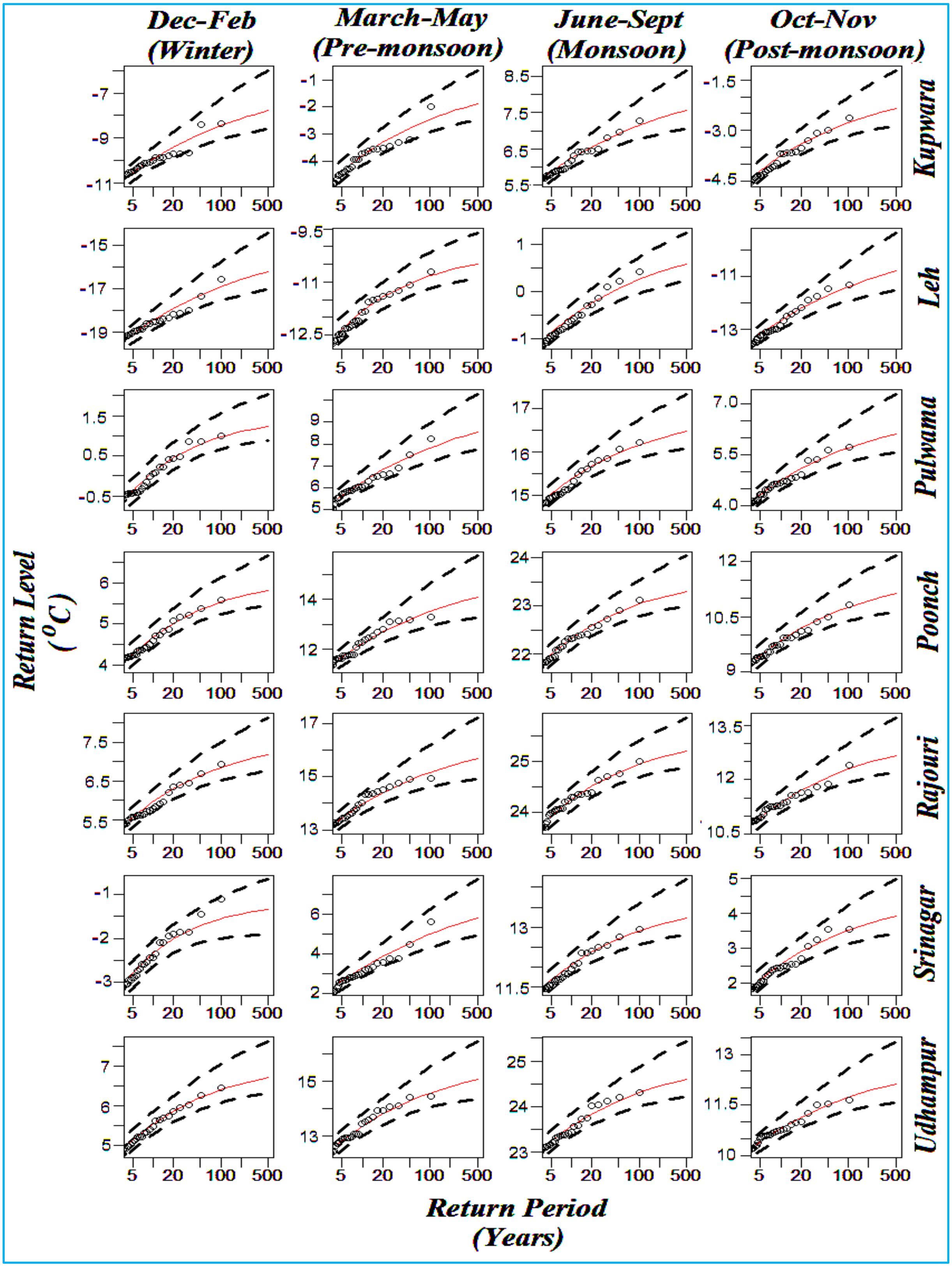

Fig. 15. Return value estimation plots for six districts of J&K and for Leh district corresponding to minimum temperature are represented. Seasonal analysis, *viz.*, winter, pre-monsoon, monsoon and post-monsoon presented in four different columns respectively and seven rows indicate seven different districts (indicated right side of each row)

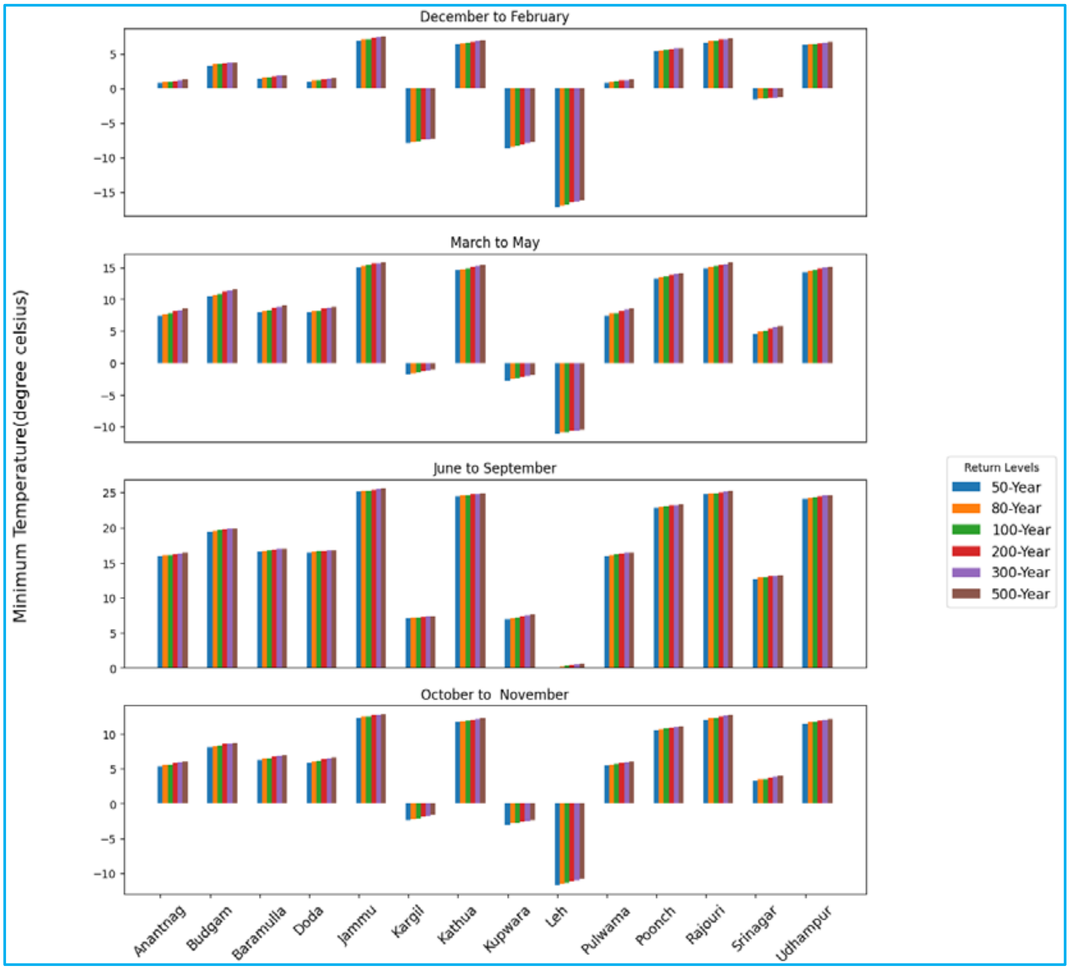

Fig. 16. Bar plot for minimum temperature corresponding to different seasons with 50, 80, 100, 200, 300 and 500 years respectively, where, each return level is represented by a particular colour

snow-capped mountains and mud peaks of Ladakh. The state's temperature changes are attributable to its topography and location. Temperature distribution in the study area can be separated into three regions based on topographic features: Jammu (southwestern windward part of the state), Kashmir valley, and Ladakh region (Northeastern leeward part of the state). Figs. 7&8 provide probability density graphs for the GEV fit for the maximum temperature of fourteen districts of the J&K and Ladakh regions in which blue colour indicates empirical and the red colour depicts the best model fit using either MLE, GMLE, L-moments, or Bayesian methods. Corresponding location, scale and shape parameters are embedded over each plot.

Return period values for 50, 80, 100, 120, 200, 250, 300, and 500 years were investigated further and are shown in Fig. 9 and Fig. 10 respectively. The return periods indicate how long a specific temperature is predicted to be exceeded once for a given period (Fig. 11).

Fig. 12 and Fig. 13 provide probability density graphs for the GEV fit for the minimum temperature of fourteen districts of J&K and Ladakh. The blue colour indicates empirical and the red colour depicts the best model fit using either MLE, GMLE, L-moments, or Bayesian methods. Corresponding location scale and shape parameters are embedded over each plot.

Return period values for 50, 80, 100, 120, 200, 250, 300 and 500 years were investigated further and are shown in Fig. 14 and Fig. 15 respectively. The return periods indicate how long a specific temperature is predicted to be exceeded once for a given period (Fig. 16).

To study the impact of climate change on a global scale, many studies have come forth showing an increasing trend of extreme events in the J&K and Ladak has it is vulnerable to climate variations owing to its fragile ecosystem. Impact of extreme climate events, such as increased glacial flow, cloud burst, and unexpected dry

TABLE 1

Precipitation Return Values

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Anantnag	Winter	174.19 (157.71, 190.68)	183.71 (165.44, 201.98)	188.01 (168.81, 207.21)	191.42 (171.44, 211.41)	200.53 (178.17, 222.89)	204.31 (180.85, 227.77)	207.31 (182.92, 231.71)	215.34 (188.22, 242.45)
	Pre-Monsoon	207.12 (165.60, 248.64)	221.98 (170.49, 273.46)	228.90 (172.27, 285.52)	234.49 (173.48, 295.50)	249.88 (175.72, 324.04)	256.48 (176.20, 336.77)	261.82 (176.37, 347.27)	276.52 (175.84, 377.21)
	Monsoon	545.71 (452.06, 663.37)	592.45 (474.54, 740.61)	614.83 (487.22, 779.95)	633.23 (495.95, 813.18)	685.26 (520.35, 906.94)	708.24 (529.45, 953.80)	727.13 (536.54, 995.95)	780.62 (557.76, 1111.56)
	Post-Monsoon	92.91 (66.68, 124.47)	106.32 (73.36, 150.91)	113.03 (76.48, 164.81)	118.69 (78.99, 176.82)	135.42 (85.94, 215.47)	143.16 (88.89, 233.52)	149.68 (91.30, 249.23)	169.00 (98.02, 298.65)
Budgam	Winter	185.02 (165.24, 204.79)	195.78 (173.15, 218.42)	200.71 (176.60, 224.81)	204.64 (179.28, 230.00)	215.28 (186.17, 244.39)	219.76 (188.91, 250.61)	223.34 (191.03, 255.65)	233.02 (196.42, 269.62)
	Pre-Monsoon	183.46 (152.74, 214.17)	196.16 (158.40, 233.92)	202.11 (160.69, 243.53)	206.94 (162.38, 251.49)	220.30 (166.28, 274.31)	226.06 (167.61, 284.51)	230.74 (168.52, 292.95)	243.69 (170.32, 317.06)
	Monsoon	632.99 (507.80, 789.98)	697.17 (541.91, 909.22)	728.74 (560.41, 968.89)	755.09 (574.01, 1016.32)	831.68 (609.57, 1170.23)	866.46 (625.90, 1248.27)	895.51 (639.21, 1317.04)	979.99 (674.73, 1513.44)
	Post-Monsoon	88.55 (70.50, 113.67)	98.83 (76.41, 132.25)	103.83 (79.09, 141.71)	107.97 (81.23, 149.28)	119.86 (86.92, 172.11)	125.19 (89.29, 184.28)	129.61 (91.51, 193.22)	142.31 (96.82, 222.27)
Baramulla	Winter	193.98 (175.79, 212.18)	204.76 (184.44, 225.07)	209.67 (188.26, 231.08)	213.59 (191.25, 235.93)	224.16 (199.04, 249.29)	228.59 (202.17, 255.02)	232.13 (204.62, 259.65)	241.69 (210.96, 272.41)
	Pre-Monsoon	204.26 (173.77, 234.76)	218.05 (180.96, 255.15)	224.53 (184.00, 265.05)	229.78 (186.32, 273.25)	244.36 (192.01, 296.72)	250.67 (194.13, 307.20)	255.79 (195.71, 315.86)	270.00 (199.40, 340.61)
	Monsoon	560.48 (465.30, 673.76)	614.99 (498.36, 766.40)	641.60 (513.20, 814.44)	663.71 (525.28, 855.91)	727.47 (557.87, 985.37)	756.20 (571.28, 1045.32)	780.07 (582.93, 1100.51)	848.99 (611.96, 1263.07)
	Post-Monsoon	103.55 (79.06, 135.61)	116.14 (86.70, 157.48)	122.30 (90.25, 169.71)	127.43 (92.85, 180.27)	142.26 (100.16, 212.63)	148.97 (103.73, 226.22)	154.55 (106.35, 237.62)	170.70 (113.27, 274.38)
Doda	Winter	144.57 (126.68, 162.46)	153.60 (132.67, 174.52)	157.74 (135.26, 180.23)	161.07 (137.25, 184.89)	170.10 (142.29, 197.90)	173.91 (144.25, 203.57)	176.97 (145.76, 208.18)	185.29 (149.52, 221.06
	Pre-Monsoon	163.61 (128.64, 198.59)	176.28 (132.49, 220.08)	182.24 (133.86, 230.63)	187.09 (134.76, 239.42)	200.56 (136.32, 264.80)	206.39 (136.55, 276.23)	211.14 (136.55, 285.73)	224.34 (135.60, 313.08)
	Monsoon	535.74 (447.85, 628.56)	576.50 (469.59, 696.24)	595.79 (481.00, 728.66)	611.53 (490.14, 756.12)	655.56 (518.35, 835.18)	674.76 (526.55, 873.99)	690.44 (532.99, 906.33)	734.33 (550.03, 998.21)
	Post-Monsoon	67.36 (53.24, 86.38)	74.98 (57.31, 99.94)	78.66 (59.13, 106.22)	81.71 (60.64, 112.27)	90.44 (64.91, 129.00)	94.35 (66.68, 136.81)	97.57 (68.11, 143.44)	106.82 (71.57, 164.63)

TABLE 1 (*Contd*.)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Jammu	Winter	126.24 (105.63, 149.83)	135.24 (111.02, 163.99)	139.41 (113.12, 171.54)	142.78 (114.77, 177.47)	152.01 (119.69, 194.51)	155.96 (121.92, 202.53)	159.15 (123.69, 209.51)	167.90 (127.66, 229.95)
	Pre-Monsoon	116.49 (95.20, 142.26)	127.01 (100.62, 159.30)	132.06 (103.02, 168.23)	136.22 (104.93, 175.56)	147.99 (110.62, 198.63)	153.20 (113.13, 209.14)	157.49 (115.13, 217.89)	169.65 (120.58, 245.20)
	Monsoon	549.68 (469.78, 646.98)	591.99 (494.09, 717.41)	612.13 (504.49, 751.54)	628.61 (513.56, 780.03)	674.97 (536.76, 860.16)	695.30 (546.46, 900.10)	711.96 (554.20, 934.66)	758.83 (576.28, 1037.48)
	Post-Monsoon	48.25 (35.89, 62.06)	54.99 (39.38, 73.28)	58.36 (41.12, 78.99)	61.18 (42.30, 84.05)	69.47 (45.81, 98.89)	73.28 (47.46, 106.27)	76.48 (48.80, 112.61)	85.90 (52.38, 133.03)
Kargil	Winter	134.62 (116.29, 155.17)	143.30 (121.49, 168.52)	147.31 (123.87, 175.36)	150.53 (125.84, 181.26)	159.31 (130.50, 198.16)	163.04 (132.29, 205.72)	166.04 (133.68, 211.97)	174.23 (137.73, 229.37)
	Pre-Monsoon	188.73 (156.27, 228.71)	205.67 (165.76, 256.87)	213.75 (170.80, 271.19)	220.38 (174.05, 282.41)	239.05 (183.53, 317.52)	247.26 (187.62, 333.23)	253.99 (190.89, 346.23)	273.00 (199.58, 387.59)
	Monsoon	327.13 (275.00, 387.66)	352.45 (288.75, 425.37)	364.43 (295.10, 444.66)	374.22 (300.15, 460.96)	401.59 (313.69, 509.92)	413.54 (319.32, 532.72)	423.30 (323.19, 551.14)	450.61 (334.49, 605.67)
	Post-Monsoon	72.91 (55.63, 95.93)	82.37 (60.17, 113.25)	87.05 (62.17, 122.51)	90.97 (63.63, 130.16)	102.40 (68.20, 154.56)	107.63 (70.15, 167.26)	111.99 (71.83, 177.68)	124.77 (76.50, 209.48)
Kathua	Winter	114.18 (94.76, 135.69)	122.63 (100.15, 148.62)	126.58 (102.52, 154.48)	129.78 (104.59, 159.68)	138.63 (109.64, 175.93)	142.44 (111.37, 182.97)	145.53 (112.68, 188.77)	154.06 (117.18, 205.51)
	Pre-Monsoon	106.09 (86.38, 135.43)	116.17 (91.54, 153.77)	121.04 (93.84, 162.88)	125.07 (96.11, 170.52)	136.56 (101.27, 193.64)	141.68 (103.68, 204.86)	145.92 (105.62, 214.20)	158.02 (110.97, 241.75)
	Monsoon	565.19 (485.41, 651.88)	602.43 (510.24, 709.74)	619.84 (519.55, 736.90)	633.93 (526.45, 758.81)	672.87 (545.13, 826.25)	689.62 (553.79, 859.76)	703.20 (559.68, 885.61)	740.73 (576.61, 972.48)
	Post-Monsoon	43.54 (34.27, 55.78)	48.62 (37.31, 64.79)	51.09 (38.72, 69.28)	53.14 (39.75, 73.36)	59.02 (42.26, 86.06)	61.65 (43.31, 92.01)	63.84 (44.19, 97.06)	70.11 (46.73, 112.27)
Kupwara	Winter	134.86 (113.51, 155.59)	143.88 (118.98, 169.19)	148.07 (121.60, 176.65)	151.46 (123.54, 183.10)	160.77 (128.60, 201.64)	164.76 (130.73, 209.63)	167.98 (132.29, 216.05)	176.84 (135.88, 234.82)
	Pre-Monsoon	186.16 (154.88, 219.99)	201.19 (163.25, 244.07)	208.32 (167.29, 256.23)	214.14 (170.31, 267.06)	230.42 (177.19, 297.49)	237.52 (180.09, 311.10)	243.33 (182.61, 322.37)	259.59 (188.54, 355.32)
	Monsoon	193.12 (161.70, 232.75)	209.09 (170.67, 260.62)	216.76 (174.93, 275.39)	223.07 (178.32, 288.01)	240.98 (187.33, 323.45)	248.91 (190.79, 340.22)	255.44 (193.57, 354.28)	273.99 (201.87, 392.83)
	Post-Monsoon	89.55 (63.38, 121.54)	104.70 (71.04, 149.95)	112.53 (74.47, 165.09)	119.24 (76.87, 178.46)	139.72 (84.44, 221.71)	149.51 (88.03, 244.88)	157.91 (91.29, 265.13)	183.57 (100.51, 327.02)
Leh	Winter	83.49 (67.65, 103.19)	91.54 (71.80, 117.83)	95.45 (73.91, 124.99)	98.69 (75.50, 130.95)	108.01 (79.80, 148.77)	112.19 (81.65, 157.01)	115.65 (83.15, 164.01)	125.61 (87.18, 186.78)
	Pre-Monsoon	119.33 (89.57, 157.11)	136.24 (98.02, 190.09)	144.87 (101.97, 208.35)	152.22 (105.18, 223.64)	174.40 (114.35, 272.77)	184.86 (118.51 297.70)	193.78 (121.95, 319.46)	220.69 (131.76, 387.51)
	Monsoon	102.60 (87.40, 120.63)	109.98 (91.88, 132.47)	113.48 (93.75, 138.34)	116.34 (95.35, 143.91)	124.36 (100.36, 159.14)	127.86 (102.39, 166.71)	130.73 (103.90, 172.61)	138.78 (107.04, 190.23)
	Post-Monsoon	59.66 (41.96, 88.89)	70.02 (46.95, 111.27)	75.38 (49.32, 123.94)	79.97 (51.28, 135.86)	94.01 (57.13, 174.26)	100.73 (59.91, 193.08)	106.49 (62.30, 209.88)	124.12 (68.97, 265.91)

TABLE 1 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Pulwama	Winter	179.39 (155.50, 203.09)	189.05 (161.85, 217.84)	193.41 (164.58, 225.27)	196.88 (166.65, 231.59)	206.12 (171.80, 248.30)	209.95 (173.58, 255.09)	213.00 (174.92, 260.60)	221.14 (177.81, 276.37)
	Pre-Monsoon	207.15 (177.09, 239.60)	221.88 (186.74, 264.20)	228.76 (190.87, 275.08)	234.32 (194.02, 283.98)	249.66 (201.89, 310.96)	256.25 (205.03, 321.71)	261.59 (207.69, 330.60)	276.30 (214.45, 359.45)
	Monsoon	546.63 (458.98, 657.62)	595.86 (485.56, 745.28)	619.63 (498.27, 786.05)	639.25 (507.51, 821.98)	695.22 (531.68, 929.93)	720.15 (541.89, 974.16)	740.74 (550.43, 1013.93)	799.51 (574.71, 1135.68)
	Post-Monsoon	95.66 (69.89, 133.19)	108.99 (76.60, 160.19)	115.64 (79.72, 174.25)	121.22 (82.21, 186.46)	137.66 (89.14, 223.31)	145.23 (92.18, 240.99)	151.59 (94.71, 256.31)	170.34 (101.72, 305.47)
Poonch	Winter	178.09 (155.58, 200.60)	188.76 (162.20, 215.33)	193.67 (165.03, 222.31)	197.60 (167.20, 228.00)	208.29 (172.66, 243.93)	212.81 (174.77, 250.86)	216.44 (176.37, 256.52)	226.31 (180.32, 272.30)
	Pre-Monsoon	162.24 (140.33, 184.14)	171.35 (145.16, 197.55)	175.53 (147.15, 203.91)	178.87 (148.63, 209.10)	187.90 (152.20, 223.60)	191.71 (153.49, 229.92)	194.76 (154.44, 235.07)	203.01 (156.59, 249.42)
	Monsoon	664.85 (554.77, 819.77)	722.98 (589.45, 917.54)	750.96 (603.15, 968.17)	774.01 (614.43, 1014.82)	839.56 (651.26, 1141.80)	868.64 (663.77, 1201.63)	892.62 (673.08, 1254.20)	960.85 (698.61, 1410.90)
	Post-Monsoon	84.03 (67.56, 102.74)	92.56 (71.97, 116.68)	96.62 (73.96, 124.13)	99.96 (75.53, 130.12)	109.36 (80.08, 146.97)	113.49 (82.27, 155.25)	116.88 (83.86, 162.14)	126.45 (87.97, 182.38)
Rajouri	Winter	140.50 (119.05, 161.94)	149.35 (123.55, 175.14)	153.43 (125.41, 181.44)	156.70 (126.80, 186.61)	165.63 (130.14, 201.13)	169.42 (131.35, 207.50)	172.47 (132.23, 212.70)	180.77 (134.22, 227.33)
	Pre-Monsoon	128.86 (109.16, 148.56)	136.85 (113.07, 160.64)	140.54 (114.67, 166.41)	143.50 (115.86, 171.15)	151.58 (118.67, 184.49)	155.01 (119.67, 190.34)	157.76 (120.39, 195.14)	165.28 (121.95, 208.61)
	Monsoon	581.60 (493.51, 716.55)	629.98 (525.06, 803.07)	653.21 (538.87, 843.68)	672.32 (549.66, 876.50)	726.53 (580.79, 978.67)	750.53 (592.50, 1026.26)	770.29 (601.72, 1066.38)	826.37 (630.00, 1194.34)
	Post-Monsoon	58.12 (46.18, 70.91)	64.28 (49.67, 81.07)	67.23 (51.16, 86.41)	69.65 (52.32, 90.38)	76.52 (55.82, 102.19)	79.56 (57.18, 108.20)	82.05 (58.26, 113.32)	89.13 (60.80, 128.64)
Srinagar	Winter	186.06 (170.15, 201.97)	196.15 (179.13, 213.18)	200.72 (183.13, 218.31)	204.35 (186.29, 222.42)	214.07 (194.57, 233.57)	218.11 (197.95, 238.28)	221.33 (200.60, 242.06)	229.95 (207.53, 252.36)
	Pre-Monsoon	231.96 (197.64, 279.71)	250.32 (208.47, 310.39)	259.03 (213.44, 326.52)	266.15 (217.53, 339.95)	286.08 (227.87, 377.67)	294.79 (232.19, 395.29)	301.92 (235.40, 408.69)	321.88 (243.63, 452.09)
	Monsoon	489.55 (394.31, 667.82)	538.70 (420.42, 770.28)	562.88 (431.95, 821.80)	583.07 (441.66, 869.24)	641.89 (467.78, 1009.06)	668.69 (478.42, 1076.64)	691.12 (487.22, 1133.75)	756.72 (511.24, 1315.17)
	Post-Monsoon	107.40 (78.57, 142.90)	123.30 (86.57, 169.27)	131.31 (90.61, 183.51)	138.07 (93.62, 196.46)	158.18 (100.92, 235.94)	167.53 (104.26, 256.38)	175.44 (107.06, 274.17)	198.97 (114.88, 330.83)
Udhampur	Winter	134.75 (114.18, 155.32)	143.46 (118.75, 168.18)	147.48 (120.64, 174.32)	150.70 (122.05, 179.36)	159.48 (125.46, 193.50)	163.20 (126.70, 199.70)	166.19 (127.61, 204.77)	174.34 (129.67, 218.99)
	Pre-Monsoon	125.35 (105.64, 148.28)	135.47 (111.66, 163.98)	140.28 (114.31, 172.15)	144.20 (116.39, 179.43)	155.19 (121.75, 199.00)	159.99 (124.00, 208.32)	163.91 (125.77, 216.30)	174.92 (130.12, 239.76)
	Monsoon	621.95 (529.62, 754.20)	672.54 (558.09, 834.36)	696.75 (571.34, 875.43)	716.63 (583.69, 910.27)	772.85 (616.85, 1023.57)	797.65 (629.95, 1073.87)	818.03 (641.03, 1114.63)	875.69 (665.26, 1228.24)
	Post-Monsoon	54.54 (41.98, 74.33)	61.66 (46.27, 87.96)	65.17 (48.04, 95.61)	68.11 (49.39, 102.25)	76.67 (53.48, 122.94)	80.57 (55.16, 132.43)	83.83 (56.50, 140.63)	93.34 (60.08, 164.31)

TABLE 2

Maximum Temperature Return Values

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Anantnag	Winter	12.97 (12.72, 13.22)	13.05 (12.77, 13.33)	13.08 (12.79, 13.38)	13.10 (12.80, 13.42)	13.16 (12.84, 13.51)	13.18 (12.85, 13.55)	13.19 (12.85, 13.58)	13.23 (12.87, 13.65)
	Pre-Monsoon	28.69 (28.08, 29.37)	28.95 (28.27, 29.78)	29.06 (28.33, 29.94)	29.15 (28.39, 30.06)	29.37 (28.52, 30.44)	29.45 (28.56, 30.61)	29.52 (28.60, 30.74)	29.70 (28.70, 31.14)
	Monsoon	31.04 (30.66, 31.47)	31.20 (30.76, 31.70)	31.27 (30.80, 31.81)	31.33 (30.84, 31.90)	31.48 (30.91, 32.15)	31.54 (30.94, 32.26)	31.58 (30.96, 32.35)	31.71 (31.02, 32.56)
	Post-Monsoon	25.04 (24.55, 25.54)	25.24 (24.68, 25.82)	25.32 (24.72, 25.94)	25.39 (24.75, 26.05)	25.56 (24.82, 26.33)	25.63 (24.85, 26.45)	25.68 (24.88, 26.54)	25.82 (24.93, 26.81)
Budgam	Winter	17.47 (17.22, 17.89)	17.59 (17.32, 18.07)	17.65 (17.37, 18.14)	17.68 (17.40, 18.20)	17.78 (17.48, 18.36)	17.82 (17.51, 18.42)	17.85 (17.53, 18.48)	17.92 (17.59, 18.62)
	Pre-Monsoon	33.73 (33.12, 34.45)	33.98 (33.28, 34.84)	34.09 (33.35, 35.01)	34.17 (33.39, 35.16)	34.39 (33.53, 35.51)	34.48 (33.58, 35.69)	34.54 (33.61, 35.83)	34.71 (33.69, 36.19)
	Monsoon	35.58 (35.20, 35.98)	35.74 (35.31, 36.21)	35.81 (35.36, 36.32)	35.86 (35.39, 36.38)	36.01 (35.47, 36.64)	36.06 (35.51, 36.74)	36.11 (35.54, 36.81)	36.22 (35.60, 37.03)
	Post-Monsoon	29.27 (28.78, 30.05)	29.51 (28.97, 30.44)	29.61 (29.05, 30.62)	29.69 (29.11, 30.76)	29.91 (29.27, 31.13)	30.00 (29.33, 31.30)	30.07 (29.38, 31.43)	30.26 (29.49, 31.78)
Baramulla	Winter	13.89 (13.71, 14.13)	13.95 (13.75, 14.22)	13.98 (13.77, 14.25)	13.99 (13.78, 14.29)	14.04 (13.81, 14.37)	14.05 (13.82, 14.40)	14.06 (13.83, 14.42)	14.09 (13.84, 14.47)
	Pre-Monsoon	29.75 (29.13, 30.79)	30.01 (29.33, 31.24)	30.13 (29.40, 31.44)	30.22 (29.46, 31.60)	30.45 (29.60, 32.03)	30.54 (29.65, 32.21)	30.61 (29.69, 32.37)	30.80 (29.78, 32.79)
	Monsoon	32.29 (31.90, 32.91)	32.49 (32.06, 33.20)	32.57 (32.13, 33.34)	32.64 (32.18, 33.45)	32.82 (32.32, 33.77)	32.90 (32.37, 33.91)	32.95 (32.41, 34.01)	33.11 (32.52, 34.29)
	Post-Monsoon	26.06 (25.55, 26.88)	26.30 (25.74, 27.26)	26.41 (25.82, 27.45)	26.49 (25.88, 27.59)	26.72 (26.04, 27.99)	26.81 (26.10, 28.16)	26.88 (26.15, 28.30)	27.08 (26.27, 28.67)
Doda	Winter	14.36 (14.03, 14.92)	14.52 (14.16, 15.16)	14.59 (14.21, 15.28)	14.64 (14.25, 15.36)	14.77 (14.36, 15.60)	14.82 (14.39, 15.70)	14.87 (14.42, 15.78)	14.97 (14.50, 15.98)
	Pre-Monsoon	29.89 (29.42, 30.76)	30.11 (29.60, 31.13)	30.20 (29.67, 31.30)	30.28 (29.72, 31.43)	30.46 (29.85, 31.77)	30.53 (29.90, 31.91)	30.59 (29.93, 32.02)	30.74 (30.02, 32.33)
	Monsoon	32.10 (31.69, 32.79)	32.30 (31.84, 33.11)	32.39 (31.91, 33.26)	32.46 (31.96, 33.39)	32.65 (32.09, 33.74)	32.73 (32.14, 33.89)	32.79 (32.18, 34.01)	32.96 (32.28, 34.35)
	Post-Monsoon	25.51 (25.09, 25.97)	25.66 (25.19, 26.22)	25.73 (25.22, 26.32)	25.78 (25.25, 26.41)	25.91 (25.34, 26.62)	25.96 (25.37, 26.72)	26.00 (25.39, 26.79)	26.11 (25.45, 26.98)

TABLE 2 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Jammu	Winter	24.27 (23.59, 24.95)	24.49 (23.69, 25.30)	24.59 (23.72, 25.46)	24.67 (23.75, 25.58)	24.87 (23.80, 25.93)	24.95 (23.82, 26.08)	25.01 (23.83, 26.20)	25.18 (23.85, 26.52)
	Pre-Monsoon	41.60 (40.95, 42.25)	41.80 (41.05, 42.54)	41.88 (41.09, 42.67)	41.94 (41.12, 42.77)	42.10 (41.18, 43.03)	42.16 (41.20, 43.13)	42.21 (41.21, 43.21)	42.33 (41.24, 43.42)
	Monsoon	42.34 (41.97, 42.96)	42.53 (42.12, 43.28)	42.62 (42.18, 43.42)	42.69 (42.23, 43.55)	42.87 (42.35, 43.88)	42.94 (42.40, 44.02)	42.99 (42.44, 44.13)	43.15 (42.53, 44.45)
	Post-Monsoon	34.70 (34.27, 35.24)	34.89 (34.39, 35.51)	34.98 (34.44, 35.65)	35.04 (34.48, 35.75)	35.22 (34.58, 36.03)	35.29 (34.63, 36.15)	35.35 (34.66, 36.25)	35.50 (34.73, 36.52)
Kargil	Winter	4.78 (4.52, 5.19)	4.92 (4.66, 5.38)	4.98 (4.71, 5.46)	5.02 (4.75, 5.53)	5.13 (4.86, 5.68)	5.18 (4.90, 5.74)	5.21 (4.93, 5.79)	5.29 (5.01, 5.91)
	Pre-Monsoon	17.74 (17.21, 18.70)	17.96 (17.38, 19.08)	18.06 (17.45, 19.26)	18.14 (17.50, 19.40)	18.33 (17.62, 19.76)	18.41 (17.67, 19.93)	18.47 (17.70, 20.06)	18.63 (17.79, 20.42)
	Monsoon	22.11 (21.95, 22.26)	22.15 (21.99, 22.33)	22.17 (22.00, 22.36)	22.18 (22.01, 22.38)	22.22 (22.03, 22.44)	22.23 (22.04, 22.46)	22.24 (22.04, 22.47)	22.26 (22.05, 22.51)
	Post-Monsoon	15.42 (15.02, 15.84)	15.57 (15.12, 16.06)	15.64 (15.16, 16.16)	15.69 (15.19, 16.24)	15.82 (15.27, 16.45)	15.87 (15.30, 16.53)	15.91 (15.32, 16.60)	16.01 (15.37, 16.83)
Kathua	Winter	23.73 (23.07, 24.97)	24.04 (23.28, 25.55)	24.18 (23.36, 25.83)	24.30 (23.43, 26.07)	24.60 (23.59, 26.75)	24.73 (23.65, 27.05)	24.83 (23.70, 27.29)	25.11 (23.83, 27.99)
	Pre-Monsoon	40.42 (39.88, 40.91)	40.60 (39.99, 41.15)	40.67 (40.04, 41.25)	40.73 (40.07, 41.34)	40.87 (40.16, 41.57)	40.92 (40.20, 41.66)	40.97 (40.23 , 41.73)	41.07 (40.28, 41.91)
	Monsoon	41.01 (40.70, 41.36)	41.13 (40.78, 41.53)	41.18 (40.81, 41.61)	41.22 (40.83, 41.67)	41.31 (40.88, 41.81)	41.34 (40.90, 41.88)	41.37 (40.91, 41.94)	41.44 (40.94, 42.08)
	Post-Monsoon	33.53 (33.16, 33.95)	33.67 (33.26, 34.18)	33.74 (33.30, 34.27)	33.79 (33.34, 34.35)	33.91 (33.41, 34.57)	33.96 (33.45, 34.67)	34.00 (33.47, 34.74)	34.10 (33.53, 34.93)
Kupwara	Winter	3.48 (3.19, 3.93)	3.63 (3.34, 4.13)	3.70 (3.39, 4.22)	3.75 (3.44, 4.30)	3.87 (3.55, 4.48)	3.91 (3.59, 4.55)	3.95 (3.62, 4.60)	4.04 (3.70, 4.75)
	Pre-Monsoon	17.71 (17.15, 18.66)	17.96 (17.34, 19.07)	18.07 (17.42, 19.26)	18.16 (17.48, 19.42)	18.38 (17.62, 19.83)	18.46 (17.68, 19.99)	18.53 (17.72, 20.12)	18.71 (17.82, 20.49)
	Monsoon	23.15 (22.85, 23.46)	23.25 (22.91, 23.62)	23.30 (22.94, 23.69)	23.33 (22.96, 23.74)	23.42 (23.01, 23.88)	23.45 (23.03, 23.94)	23.48 (23.04, 23.98)	23.54 (23.08, 24.10)
	Post-Monsoon	15.64 (15.14, 16.52)	15.89 (15.32, 16.92)	16.00 (15.41, 17.18)	16.09 (15.46, 17.27)	16.32 (15.62, 17.70)	16.42 (15.68, 17.89)	16.49 (15.73, 18.04)	16.70 (15.84, 18.46)

TABLE 2 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Leh	Winter	-1.60 (-2.11, -0.79)	-1.36 (-1.91, -0.42)	-1.26 (-1.83, -0.25)	-1.17 (-1.76, -0.11)	-0.96 (-1.60, 0.25)	-0.87 (-1.53, 0.41)	-0.80 (-1.49, 0.53)	-0.63 (-1.37, 0.89)
	Pre-Monsoon	10.24 (9.84, 10.93)	10.42 (9.98 , 11.22)	10.49 (10.05, 11.35)	10.55 (10.09, 11.45)	10.70 (10.20, 11.73)	10.76 (10.24, 11.84)	10.81 (10.27, 11.94)	10.92 (10.34, 12.18)
	Monsoon	18.01 (17.73, 18.34)	18.12 (17.79, 18.48)	18.17 (17.83, 18.59)	18.21 (17.85, 18.67)	18.31 (17.91, 18.85)	18.35 (17.93, 18.93)	18.39 (17.94, 18.99)	18.47 (17.97, 19.16)
	Post-Monsoon	8.09 (7.69, 8.54)	8.27 (7.81, 8.82)	8.36 (7.86, 8.95)	8.42 (7.91, 9.06)	8.60 (8.03, 9.37)	8.67 (8.07, 9.51)	8.73 (8.10, 9.63)	8.88 (8.16, 9.93)
Pulwama	Winter	13.04 (12.81, 13.27)	13.11 (12.85, 13.37)	13.14 (12.87, 13.42)	13.16 (12.88, 13.45)	13.20 (12.91, 13.53)	13.22 (12.92, 13.56)	13.24 (12.93, 13.59)	13.27 (12.94, 13.65)
	Pre-Monsoon	28.69 (28.17, 29.59)	28.91 (28.34, 29.98)	29.01 (28.41, 30.15)	29.08 (28.47, 30.30)	29.27 (28.58, 30.66)	29.35 (28.63, 30.81)	29.40 (28.66, 30.93)	29.55 (28.73, 31.27)
	Monsoon	31.35 (30.93, 32.05)	31.56 (31.09, 32.40)	31.66 (31.16, 32.56)	31.73 (31.22, 32.70)	31.93 (31.36, 33.09)	32.02 (31.41, 33.26)	32.08 (31.46, 33.39)	32.26 (31.57, 33.76)
	Post-Monsoon	25.30 (24.85, 26.05)	25.52 (25.02, 26.40)	25.61 (25.09, 26.57)	25.69 (25.15, 26.70)	25.88 (25.29, 27.07)	25.97 (25.34, 27.21)	26.03 (25.38, 27.34)	26.20 (25.48, 27.67)
Poonch	Winter	22.18 (21.81, 22.80)	22.35 (21.95, 23.09)	22.42 (22.01, 23.21)	22.48 (22.05, 23.32)	22.63 (22.16, 23.61)	22.69 (22.20, 23.72)	22.74 (22.23, 23.81)	22.86 (22.31, 24.06)
	Pre-Monsoon	39.29 (38.69, 40.33)	39.55 (38.90, 40.75)	39.66 (38.98, 40.94)	39.75 (39.04, 41.09)	39.98 (39.18, 41.52)	40.07 (39.23, 41.71)	40.14 (39.27, 41.85)	40.32 (39.37, 42.24)
	Monsoon	40.53 (40.18, 41.13)	40.69 (40.31, 41.40)	40.76 (40.37, 41.52)	40.82 (40.41, 41.63)	40.96 (40.50, 41.89)	41.02 (40.54, 42.01)	41.06 (40.57, 42.09)	41.18 (40.64, 42.34)
	Post-Monsoon	33.63 (33.09, 34.53)	33.89 (33.28, 34.99)	34.00 (33.37, 35.20)	34.09 (33.44, 35.38)	34.35 (33.61, 35.86)	34.46 (33.67, 36.05)	34.54 (33.73, 36.22)	34.76 (33.86, 36.70)
Rajouri	Winter	24.21 (23.65, 24.78)	24.40 (23.74, 25.07)	24.49 (23.78, 25.20)	24.55 (23.80, 25.30)	24.72 (23.86, 25.58)	24.79 (23.88, 25.70)	24.84 (23.89, 25.79)	24.98 (23.92, 26.03)
	Pre-Monsoon	41.59 (41.03, 42.59)	41.83 (41.22, 42.99)	41.94 (41.29, 43.17)	42.02 (41.35, 43.31)	42.22 (41.49, 43.70)	42.31 (41.54, 43.85)	42.37 (41.58, 43.97)	42.53 (41.67, 44.31)
	Monsoon	42.41 (42.04, 43.02)	42.59 (42.18, 43.31)	42.67 (42.24, 43.44)	42.73 (42.29, 43.55)	42.89 (42.40, 43.84)	42.96 (42.44, 43.96)	43.01 (42.48, 44.05)	43.14 (42.56, 44.33)
	Post-Monsoon	35.09 (34.59, 35.66)	35.30 (34.74, 35.99)	35.39 (34.80, 36.17)	35.47 (34.84, 36.33)	35.67 (34.99, 36.68)	35.75 (35.05, 36.84)	35.81 (35.08, 36.97)	35.99 (35.16, 37.35)

TABLE 2 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Srinagar	Winter	9.10 (8.90, 9.33)	9.16 (8.95, 9.43)	9.18 (8.97, 9.47)	9.20 (8.98, 9.51)	9.24 (8.99, 9.59)	9.25 (9.00, 9.62)	9.26 (9.00, 9.64)	9.29 (9.02, 9.70)
	Pre-Monsoon	23.92 (23.10, 24.74)	24.20 (23.24, 25.16)	24.32 (23.30, 25.35)	24.42 (23.34, 25.50)	24.67 (23.44, 25.90)	24.77 (23.47, 26.07)	24.84 (23.49, 26.20)	25.05 (23.54, 26.55)
	Monsoon	27.35 (26.99, 27.93)	27.53 (27.14, 28.22)	27.61 (27.20, 28.35)	27.67 (27.25, 28.45)	27.83 (27.38, 28.73)	27.90 (27.42, 28.86)	27.95 (27.46, 28.96)	28.09 (27.55, 29.25)
	Post-Monsoon	21.42 (20.95, 22.23)	21.64 (21.13, 22.58)	21.74 (21.20, 22.74)	21.82 (21.26, 22.87)	22.02 (21.40, 23.27)	22.11 (21.46, 23.42)	22.17 (21.50, 23.55)	22.34 (21.60, 23.90)
Udhampur	Winter	23.30 (22.78, 24.26)	23.53 (22.93, 24.69)	23.64 (22.99, 24.89)	23.72 (23.04, 25.06)	23.94 (23.16, 25.52)	24.03 (23.21, 25.72)	24.10 (23.24, 25.88)	24.28 (23.32, 26.32)
	Pre-Monsoon	40.45 (40.01, 41.22)	40.64 (40.16, 41.52)	40.73 (40.22, 41.66)	40.79 (40.27, 41.78)	40.94 (40.38, 42.08)	41.00 (40.41, 42.20)	41.05 (40.44, 42.29)	41.17 (40.50, 42.55)
	Monsoon	41.46 (41.08, 42.09)	41.65 (41.22, 42.40)	41.73 (41.28, 42.54)	41.80 (41.32, 42.66)	41.97 (41.44, 42.98)	42.04 (41.48, 43.12)	42.10 (41.52, 43.24)	42.25 (41.61, 43.55)
	Post-Monsoon	33.90 (33.44, 34.41)	34.09 (33.56, 34.67)	34.17 (33.62, 34.78)	34.24 (33.66, 34.88)	34.41 (33.75, 35.18)	34.48 (33.78, 35.31)	34.54 (33.81, 35.42)	34.68 (33.86, 35.70)

and rainy days, may result in the loss of life, livelihoods, assets, and infrastructure. If the occurrence of such extreme events can be forecasted based on return periods and their corresponding return level, then the loss of precious lives and property can be minimized. The present study is dedicated to the statistical modeling of monthly maximum precipitation and monthly minimum and maximum temperature for fourteen districts of J& K and Ladakh during the last century (1900-2002). The generalized extreme value (GEV) analysis approach is utilized for the probabilistic forecasting of the extremities. The seasonal analysis is performed for a detailed understanding of these parameters.

The analysis based on the extreme value theory has been carried out for various return levels and return periods and the resulting tables are appended for Precipitation (Table 1), Maximum temperature (Table 2) and Minimum temperature (Table 3) respectively. The results obtained are summarized as follows:

(*i*) As the data set considered for the study is the century-long dataset (1901-2002), so we have divided the same in two time periods, *i.e.*, from the year 1901-1950 and 1951-2002 to observe the changes in the last 50 years as compared to first 50 years. The analysis shows an average increase in maximum temperature of about 0.2 °C during the winter season and an average decrease in maximum temperature of about 0.1 °C is observed during the monsoon season.

(*ii*) A similar analysis shows an average decrease in minimum temperature of about 0.1°C during the winter season and an average increase in minimum temperature of about 0.4 °C is observed during the monsoon season.

(*iii*) For the 50-year return level, the maximum temperature of 24.3 °C is expected to exist for the Jammu district (alt ~327 m amsl) for the winter season, whereas the maximum temperature of 41.6 °C, 42.4 °C and 35.1 °C is expected to exist for Rajouridistrict (alt~915 m amsl) during pre-monsoon, monsoon, and post-monsoon seasons respectively. Similarly, the minimum temperature of -17.3 °C, -11 °C, 0.1 °C and -11.7 °C is expected to exist for Leh district (alt ~3500 m amsl) for winter, pre-monsoon, monsoon and post-monsoon seasons respectively.

(*iv*) For the 80-year return level, the maximum temperature of 24.5 °C is expected to exist for the Jammu

TABLE 3

Minimum Temperature Return Values

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Anantnag	Winter	0.74 (0.45, 1.23)	0.87 (0.57, 1.43)	0.92 (0.61, 1.51)	0.96 (0.65, 1.57)	1.06 (0.73, 1.74)	1.10 (0.76, 1.81)	1.12 (0.78, 1.86)	1.19 (0.83, 1.98)
	Pre-Monsoon	7.38 (6.83, 8.27)	7.65 (7.06, 8.69)	7.77 (7.15, 8.89)	7.87 (7.23, 9.04)	8.11 (7.42, 9.48)	8.21 (7.49, 9.66)	8.29 (7.54, 9.80)	8.49 (7.68, 10.19)
	Monsoon	15.92 (15.64, 16.39)	16.05 (15.75, 16.60)	16.10 (15.79, 16.69)	16.15 (15.83, 16.77)	16.26 (15.91, 16.96)	16.30 (15.94, 17.05)	16.33 (15.96, 17.11)	16.42 (16.02, 17.28)
	Post-Monsoon	5.41 (5.03, 6.07)	5.57 (5.16, 6.35)	5.65 (5.22, 6.48)	5.71 (5.27, 6.59)	5.85 (5.37, 6.87)	5.91 (5.41, 6.98)	5.96 (5.44, 7.07)	6.08 (5.51, 7.33)
Budgam	Winter	3.28 (3.00, 3.75)	3.40 (3.12, 3.94)	3.45 (3.16, 4.01)	3.48 (3.20, 4.07)	3.57 (3.28, 4.22)	3.60 (3.31, 4.28)	3.63 (3.33, 4.32)	3.69 (3.37, 4.44)
	Pre-Monsoon	10.45 (9.92, 11.33)	10.72 (10.14, 11.74)	10.83 (10.23, 11.92)	10.93 (10.30, 12.08)	11.17 (10.48, 12.51)	11.27 (10.55, 12.69)	11.34 (10.61, 12.84)	11.55 (10.74, 13.24)
	Monsoon	19.42 (19.15, 19.90)	19.55 (19.26, 20.11)	19.60 (19.30, 20.21)	19.64 (19.33, 20.28)	19.75 (19.41, 20.48)	19.79 (19.44, 20.56)	19.82 (19.46, 20.62)	19.90 (19.51, 20.80)
	Post-Monsoon	8.12 (7.77, 8.71)	8.28 (7.91, 8.97)	8.35 (7.96, 9.09)	8.40 (7.99, 9.19)	8.54 (8.09, 9.43)	8.59 (8.13, 9.54)	8.64 (8.15, 9.63)	8.75 (8.22, 9.86)
Baramulla	Winter	1.41 (1.13, 1.89)	1.54 (1.26, 2.07)	1.59 (1.30, 2.14)	1.63 (1.34, 2.20)	1.72 (1.42, 2.37)	1.76 (1.45, 2.43)	1.79 (1.47, 2.47)	1.85 (1.52, 2.59)
	Pre-Monsoon	7.87 (7.31, 8.77)	8.14 (7.53, 9.21)	8.27 (7.64, 9.41)	8.36 (7.71, 9.57)	8.61 (7.89, 10.00)	8.71 (7.96, 10.18)	8.79 (8.02, 10.33)	9.00 (8.16, 10.75)
	Monsoon	16.58 (16.29, 17.07)	16.71 (16.40, 17.28)	16.76 (16.45, 17.37)	16.80 (16.48, 17.45)	16.91 (16.57, 17.64)	16.95 (16.60, 17.72)	16.98 (16.62, 17.78)	17.06 (16.67, 17.94)
	Post-Monsoon	6.33 (5.99, 6.89)	6.49 (6.13, 7.14)	6.56 (6.18, 7.25)	6.61 (6.22, 7.35)	6.74 (6.32, 7.58)	6.79 (6.36, 7.69)	6.83 (6.39, 7.77)	6.94 (6.45, 7.99)
Doda	Winter	0.94 (0.64, 1.49)	1.07 (0.76, 1.69)	1.13 (0.80, 1.78)	1.17 (0.84, 1.85)	1.28 (0.92, 2.03)	1.32 (0.95, 2.11)	1.35 (0.97, 2.17)	1.43 (1.02, 2.32)
	Pre-Monsoon	7.90 (7.42, 8.71)	8.12 (7.60, 9.07)	8.22 (7.67, 9.23)	8.29 (7.72, 9.35)	8.48 (7.87, 9.69)	8.56 (7.92, 9.82)	8.61 (7.95, 9.94)	8.77 (8.05, 10.25)
	Monsoon	16.48 (16.23, 16.74)	16.57 (16.29, 16.87)	16.61 (16.3, 16.93)	16.64 (16.33, 16.98)	16.71 (16.37, 17.09)	16.74 (16.38, 17.14)	16.76 (16.39, 17.18)	16.81 (16.42, 17.28)
	Post-Monsoon	5.87 (5.40, 6.39)	6.05 (5.52, 6.68)	6.13 (5.58, 6.81)	6.19 (5.61, 6.90)	6.35 (5.69, 7.16)	6.42 (5.73, 7.28)	6.47 (5.76, 7.38)	6.60 (5.82, 7.65)

TABLE 3 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Jammu	Winter	6.86 (6.52, 7.41)	7.02 (6.66, 7.66)	7.09 (6.72, 7.78)	7.14 (6.77, 7.87)	7.28 (6.88, 8.12)	7.34 (6.92, 8.22)	7.38 (6.95, 8.30)	7.49 (7.03, 8.52)
	Pre-Monsoon	15.01 (14.52, 15.61)	15.21 (14.65, 15.94)	15.29 (14.71, 16.09)	15.36 (14.75, 16.20)	15.53 (14.84, 16.53)	15.59 (14.88, 16.65)	15.64 (14.91, 16.76)	15.77 (14.98, 17.01)
	Monsoon	25.11 (24.81, 25.44)	25.23 (24.88, 25.62)	25.28 (24.91, 25.69)	25.32 (24.93, 25.76)	25.42 (24.98, 25.94)	25.46 (24.99, 26.02)	25.49 (25.01, 26.08)	25.57 (25.03, 26.25)
	Post-Monsoon	12.34 (11.97, 12.78)	12.48 (12.07, 12.99)	12.54 (12.11, 13.11)	12.58 (12.15, 13.18)	12.70 (12.22, 13.35)	12.75 (12.25, 13.43)	12.78 (12.27, 13.50)	12.87 (12.32, 13.68)
Kargil	Winter	-7.98 (-8.50, -7.41)	-7.80 (-8.39, -7.15)	-7.73 (-8.34, -7.02)	-7.67 (-8.31, -6.92)	-7.53 (-8.24, -6.66)	-7.48 (-8.21, -6.56)	-7.43 (-8.19, -6.49)	-7.33 (-8.14, -6.25)
	Pre-Monsoon	-1.83 (-2.34, -1.29)	-1.63 (-2.18, -0.96)	-1.54 (-2.13, -0.82)	-1.48 (-2.09, -0.71)	-1.31 (-2.01, -0.45)	-1.24 (-1.98, -0.34)	-1.19 (-1.96, -0.24)	-1.06 (-1.90, 0.00)
	Monsoon	7.07 (6.82, 7.35)	7.16 (6.88, 7.49)	7.20 (6.90, 7.55)	7.23 (6.91, 7.60)	7.30 (6.96, 7.74)	7.32 (6.98, 7.80)	7.35 (6.99, 7.84)	7.40 (7.02, 7.93)
	Post-Monsoon	-2.41 (-2.91, -1.91)	-2.22 (-2.78, -1.62)	-2.13 (-2.73, -1.48)	-2.06 (-2.69, -1.37)	-1.88 (-2.59, -1.09)	-1.81 (-2.55, -0.98)	-1.76 (-2.53, -0.88)	-1.61 (-2.46, -0.61)
Kathua	Winter	6.33 (5.99, 6.93)	6.49 (6.12, 7.19)	6.55 (6.17, 7.32)	6.60 (6.20, 7.42)	6.73 (6.29, 7.68)	6.79 (6.33, 7.78)	6.83 (6.36, 7.86)	6.93 (6.42, 8.11)
	Pre-Monsoon	14.56 (14.13, 15.30)	14.76 (14.29, 15.62)	14.84 (14.36, 15.76)	14.91 (14.41, 15.88)	15.07 (14.53, 16.19)	15.14 (14.57, 16.32)	15.19 (14.60, 16.43)	15.31 (14.68, 16.68)
	Monsoon	24.41 (24.14, 24.86)	24.54 (24.25, 25.06)	24.60 (24.30, 25.16)	24.64 (24.33, 25.24)	24.76 (24.42, 25.46)	24.80 (24.45, 25.54)	24.84 (24.48, 25.62)	24.93 (24.54, 25.80)
	Post-Monsoon	11.69 (11.34, 12.33)	11.85 (11.46, 12.59)	11.92 (11.51, 12.72)	11.97 (11.55, 12.81)	12.11 (11.64, 13.07)	12.16 (11.67, 13.18)	12.21 (11.70, 13.28)	12.32 (11.76, 13.53)
Kupwara	Winter	-8.81 (-9.35, -7.89)	-8.55 (-9.14, -7.49)	-8.44 (-9.06, -7.31)	-8.36 (-8.99, -7.17)	-8.13 (-8.84, -6.76)	-8.04 (-8.78, -6.58)	-7.97 (-8.73, -6.44)	-7.79 (-8.62, -6.05)
	Pre-Monsoon	-2.78 (-3.23, -2.08)	-2.55 (-3.03, -1.76)	-2.45 (-2.94, -1.62)	-2.38 (-2.87, -1.50)	-2.18 (-2.71, -1.18)	-2.10 (-2.64, -1.05)	-2.04 (-2.59, -0.95)	-1.88 (-2.47, -0.67)
	Monsoon	6.93 (6.59, 7.53)	7.09 (6.71, 7.80)	7.16 (6.77, 7.92)	7.22 (6.81, 8.02)	7.36 (6.91, 8.29)	7.42 (6.95, 8.40)	7.47 (6.98, 8.49)	7.59 (7.05, 8.73)
	Post-Monsoon	-3.02 (-3.38, -2.47)	-2.86 (-3.24, -2.22)	-2.79 (-3.18, -2.09)	-2.73 (-3.13, -2.00)	-2.59 (-3.01, -1.75)	-2.53 (-2.97, -1.63)	-2.49 (-2.94, -1.56)	-2.37 (-2.86, -1.33)

TABLE 3 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Leh	Winter	-17.30 (-17.84, -16.43)	-17.03 (-17.63, -15.99)	-16.91 (-17.53, -15.77)	-16.82 (-17.46, -15.61)	-16.58 (-17.28, -15.17)	-16.48 (-17.21, -14.99)	-16.40 (-17.15, -14.84)	-16.20 (-17.02, -14.44)
	Pre-Monsoon	-11.05 (-11.39, -10.52)	-10.90 (-11.24, -10.31)	-10.83 (-11.18, -10.20)	-10.78 (-11.13, -10.13)	-10.66 (-11.03, -9.95)	-10.62 (-10.99, -9.88)	-10.58 (-10.96, -9.82)	-10.49 (-10.89, -9.67)
	Monsoon	0.06 (-0.20, 0.46)	0.19 (-0.08, 0.65)	0.25 (-0.04, 0.74)	0.29 (-0.00, 0.81)	0.41 (0.09, 0.98)	0.45 (0.13, 1.05)	0.49 (0.15, 1.11)	0.58 (0.22, 1.27)
	Post-Monsoon	-11.72 (-12.19, -10.93)	-11.50 (-12.01, -10.58)	-11.40 (-11.94, -10.43)	-11.32 (-11.88, -10.30)	-11.11 (-11.73, -9.96)	-11.03 (-11.68, -9.81)	-10.97 (-11.64, -9.66)	-10.80 (-11.54, -9.33)
Pulwama	Winter	0.80 (0.50, 1.29)	0.92 (0.62, 1.48)	0.97 (0.67, 1.56)	1.01 (0.71, 1.62)	1.11 (0.79, 1.78)	1.14 (0.82, 1.85)	1.17 (0.84, 1.89)	1.24 (0.89, 2.02)
	Pre-Monsoon	7.44 (6.89, 8.37)	7.72 (7.11, 8.82)	7.84 (7.21, 9.01)	7.94 (7.28, 9.17)	8.19 (7.46, 9.61)	8.29 (7.53, 9.80)	8.38 (7.59, 9.95)	8.59 (7.73, 10.39)
	Monsoon	15.98 (15.70, 16.46)	16.11 (15.80, 16.67)	16.16 (15.85, 16.77)	16.21 (15.88, 16.84)	16.31 (15.97, 17.05)	16.36 (15.99, 17.12)	16.39 (16.02, 17.18)	16.47 (16.08, 17.36)
	Post-Monsoon	5.46 (5.12, 6.06)	5.62 (5.25, 6.32)	5.69 (5.30, 6.45)	5.74 (5.34, 6.54)	5.88 (5.44, 6.80)	5.94 (5.48, 6.90)	5.98 (5.51, 6.99)	6.09 (5.57, 7.24)
Poonch	Winter	5.35 (5.07, 5.84)	5.48 (5.19, 6.05)	5.53 (5.24, 6.13)	5.58 (5.27, 6.21)	5.68 (5.35, 6.38)	5.72 (5.38, 6.45)	5.75 (5.41, 6.51)	5.82 (5.46, 6.64)
	Pre-Monsoon	13.19 (12.70, 14.05)	13.41 (12.86, 14.44)	13.51 (12.93, 14.62)	13.58 (12.98, 14.76)	13.78 (13.10, 15.15)	13.86 (13.15, 15.31)	13.92 (13.18, 15.43)	14.08 (13.26, 15.79)
	Monsoon	22.87 (22.63, 23.27)	22.99 (22.73, 23.44)	23.04 (22.77, 23.51)	23.08 (22.80, 23.58)	23.17 (22.88, 23.74)	23.21 (22.91, 23.80)	23.24 (22.93, 23.86)	23.31 (22.99, 23.99)
	Post-Monsoon	10.54 (10.21, 11.15)	10.69 (10.33, 11.41)	10.75 (10.38, 11.52)	10.80 (10.42, 11.61)	10.93 (10.51, 11.87)	10.98 (10.55, 11.96)	11.02 (10.57, 12.04)	11.11 (10.64, 12.28)
Rajouri	Winter	6.63 (6.33, 7.17)	6.78 (6.46, 7.41)	6.84 (6.50, 7.52)	6.89 (6.54, 7.61)	7.01 (6.63, 7.83)	7.05 (6.67, 7.92)	7.09 (6.70, 7.99)	7.18 (6.76, 8.17)
	Pre-Monsoon	14.86 (14.40, 15.72)	15.06 (14.55, 16.05)	15.15 (14.61, 16.21)	15.22 (14.66, 16.34)	15.39 (14.77, 16.64)	15.46 (14.81, 16.78)	15.51 (14.84, 16.90)	15.65 (14.91, 17.18)
	Monsoon	24.79 (24.56, 25.20)	24.90 (24.65, 25.37)	24.95 (24.69, 25.45)	24.99 (24.72, 25.51)	25.08 (24.79, 25.66)	25.11 (24.82, 25.73)	25.14 (24.84, 25.78)	25.20 (24.89, 25.92)
	Post-Monsoon	12.09 (11.73, 12.76)	12.25 (11.86, 13.05)	12.32 (11.91, 13.18)	12.37 (11.96, 13.28)	12.51 (12.06, 13.55)	12.57 (12.09, 13.67)	12.61 (12.12, 13.76)	12.72 (12.19, 14.05)

TABLE 3 (*Contd.*)

	Return Level	50 year	80 year	100 year	120 year	200 year	250 year	300 year	500 year
Srinagar	Winter	-1.70 (-2.11, -1.26)	-1.59 (-2.04, -1.08)	-1.55 (-2.01, -1.00)	-1.52 (-1.99, -0.95)	-1.44 (-1.96, -0.83)	-1.41 (-1.94, -0.78)	-1.39 (-1.93, -0.73)	-1.34 (-1.91, -0.63)
	Pre-Monsoon	4.53 (3.93, 5.52)	4.84 (4.18, 6.00)	4.98 (4.28, 6.22)	5.09 (4.36, 6.40)	5.38 (4.58, 6.87)	5.49 (4.67, 7.07)	5.59 (4.74, 7.25)	5.83 (4.91, 7.69)
	Monsoon	12.70 (12.40, 13.20)	12.84 (12.51, 13.42)	12.90 (12.56, 13.52)	12.94 (12.60, 13.60)	13.06 (12.69, 13.80)	13.10 (12.72, 13.88)	13.14 (12.74, 13.94)	13.23 (12.80, 14.12)
	Post-Monsoon	3.30 (2.95, 3.93)	3.47 (3.08, 4.23)	3.54 (3.14, 4.36)	3.60 (3.18, 4.47)	3.74 (3.29, 4.75)	3.80 (3.32, 4.87)	3.85 (3.35, 4.96)	3.96 (3.42, 5.19)
Udhampur	Winter	6.19 (5.89, 6.72)	6.32 (6.00, 6.94)	6.38 (6.05, 7.04)	6.42 (6.09, 7.12)	6.53 (6.18, 7.30)	6.58 (6.21, 7.38)	6.61 (6.23, 7.44)	6.69 (6.29, 7.61)
	Pre-Monsoon	14.26 (13.82, 15.03)	14.46 (13.98, 15.36)	14.55 (14.05, 15.50)	14.62 (14.09, 15.61)	14.79 (14.21, 15.92)	14.86 (14.25, 16.06)	14.91 (14.29, 16.16)	15.04 (14.36, 16.43)
	Monsoon	24.13 (23.87, 24.61)	24.26 (23.97, 24.81)	24.31 (24.01, 24.90)	24.35 (24.04, 24.96)	24.45 (24.12, 25.17)	24.50 (24.14, 25.26)	24.53 (24.16, 25.32)	24.61 (24.21, 25.50)
	Post-Monsoon	11.50 (11.14, 12.16)	11.66 (11.26, 12.45)	11.73 (11.31, 12.58)	11.78 (11.35, 12.69)	11.92 (11.44, 12.98)	11.98 (11.47, 13.09)	12.02 (11.50, 13.18)	12.14 (11.56, 13.45)

district (alt ~327 m amsl) for the winter season, whereas the maximum temperature of 41.8 °C, 42.6 °C and 35.3 °C is expected to exist for Rajouridistrict (alt ~915 mamsl) during pre-monsoon, monsoon, and post-monsoon seasons respectively. Similarly, the minimum temperature of -17 °C, -10.9 °C, 0.2 °C and -11.5 °C is expected to exist for Leh district (alt ~3500 m amsl) for winter, pre-monsoon, monsoon and post-monsoon seasons respectively.

(*v*) From the statistical analysis, for the 50 year return level, the maximum precipitation of 232 mm and 107.4 mm is expected to exist for the Srinagar district (alt ~1581 m amsl) for pre-monsoon and post-monsoon seasons respectively. For the winter season, the maximum precipitation of 194mm is expected to exist for the Baramulla district (alt ~1579 m amsl) whereas for the monsoon season, the maximum precipitation of 664.8 mm is expected to exist for the Poonch district (alt ~1006 m amsl).

The findings of the current study are consistent with the circumstances that are currently prevailing over the region. The result from our analysis also confirms an increment in temperatures during the winter months and a decrement in precipitation during both the monsoon season and the winter season respectively.

5. Conclusions

This research has been carried out in order to study the spatiotemporal variations of the extreme precipitation and temperature phenomenon over the Northwest Himalaya region for all of the seasons during the time period of 1901 to 2002. The primary motivation for this research was the recent occurrences of disastrous extreme weather events in the region of the Northwest Himalayas, as well as the growing concerns regarding the behaviour of such events in the future. Firstly, the seasonal analysis of precipitation and temperature data is taken into account and after that by applying Extreme Value Theorem, precipitation and temperature data was modelled to calculate return levels for the return period of 50, 80, 100, 120, 200, 250, 300 and 500 years respectively. Thus from the analysis we can conclude that-

(*i*) The Generalized Extreme value distribution showed a good fit for the data under consideration. From the analysis, the return levels increased with the increase in return periods for all the districts.

(*ii*) The overall analysis of the study reveals that the districts Jammu, Rajouri, Leh, Srinagar, Baramulla and Poonch are more prone to extreme weather related phenomenon.

(*iii*) The global surface temperature has risen considerably over the last century and is expected to rise further unless greenhouse gas emissions are drastically decreased. The shifting precipitation pattern may have severe environmental consequences, affecting both the region's ability to maintain ecological sustainability and its level of food security.

The estimated extreme values and their return levels may help the policymakers to take adaptive measures to protect the individual's life from future climate disasters.

This analysis is based on a dataset that spans 102 years, from 1901 to 2002. The limited availability of data is one of the study's limitations, as a result of which some districts were excluded from the analysis. EVT considers the data to be stationary during the research period. For analysis and comparison, it is necessary to consider the non-stationarity approach. Additionally, the block maxima technique uses the highest value in each block. As a result, some of the extreme values-those that are less extreme than the most extreme but still capable of posing risks-are overlooked. Therefore, generalised Pareto distribution technique analysis is also advised.

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The dataset is known as CRU TS 2.02 and is publicly available (https://crudata.uea.ac.uk/cru/data/hrg/timm/grid/CRUTS20text.html). The authors also acknowledge the availability of data from the India water portal. The authors are thankful to the Uttarakhand State Council for Science and Technology (UCOST) for financial assistance through the grant number UCS&T/R&D-11/20-21/19073. Anonymous reviewers are valued for their insightful comments and critical observations.

Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability Statement

Data analyzed in this study were a reanalysis of existing data, obtained from the Climate Research Unit (CRU) TS2.02, Tyndall Centre for Climate Change Research, School of Environmental Sciences, and the University of East Anglia in Norwich, UK (https://crudata.uea.ac.uk/cru/data/hrg/timm/grid/CRUTS20text.html).

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