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Analysis of Climate Parameters Trend over Long Time Horizons and their Probable Impacts in the Beas Basin, H.P., India

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Abstract: The present study aims at investigating the climate parameters trends over long time horizons and their probable impacts in the ecology of Beas basin, Himachal Pradesh (H.P), India. In this study, large scale climate variables are downscaled to local scale meteorological variables. For large scale atmospheric modeling, HaDCM3 General Circulation Model (GCM) is used and downscaling is accomplished through SDSM (Statistical Downscaling Model). To detect monotonic trends and their magnitudes Mann-Kendall and Sen's slope test were employed. The study used a 100-years based period data (1901-2001) for A2 (medium to high emission) and B2 (medium to low emission) climate scenarios then an incremental scenarios over wide range climate variables for 2020s (2011- 2040), 2050s (2041-2070) and 2080s (2071-2100) were estimated. The important climate variables over the Beas basin considered for the assessment includes precipitations (PPT), maximum temperature (T-max) and minimum temperature (T-min) that covered four locales/districts -Hamirpur, Kullu, Kangra and Mandi of H.P, India. The paper ends with the concluding remarks with future impending trends and their probable impacts.

Keywords: Statistical downscaling, Large scale, SDSM, HaDCM3, Beas Basin

The changes in climate parameters trends can transform the current ecosystem. The disturbances and extreme events within the capacity of ecosystem of a region is a part of climate change impact. In general, climate is the proportion of variety of meteorological parameters such as - temperature, moisture, precipitation, winds and cloudiness in a given locale over significant stretch of time (Cohen et al 2000). Information on climate change is extremely important for every region, nationally and at global scale (Manohar et al 2005). Besides, environmental change can seed enormous consequences for water assets due to alternation in the water cycle. Key points to consider for contemporary examination for climate change may include- factual investigation of chronicled and upcoming atmosphere patterns (Anandhi et al 2008, Dharmaveer et al 2013); application of General Climate Models (GCMs) for reproducing the reaction of atmosphere factors comprehensively and expanding to centralizations of ozone harming substances in the environment (Arora 2001) and application of factual downscaling method (FDM) to demonstrate the hydrology factors (e.g., rainfall, temperature) (Schoof et al 2009). In particular, the changes in the course of two important factors of earth's atmosphere that is the temperature and precipitation greatly influence human wellbeing, financial development and improvement. Fluctuation in precipitation pattern can bring about the changes in the recurrence of inundation, occurrence of dry spells and effect on water standard (Duhan et al 2012). On the other hand, increment in temperature patterns of the earth brings about an expansion in dissipation and arrangement of cloud to happen that builds the rainfall, demonstrating that temperature and rainfall are correlated (Arora et al 2005). Therefore, it is very much important to investigate complete factual examination, especially the patterns of temperature and precipitation which are the two most significant climatic variables (Chakraborty at al 2013).

Climate has a huge tie-in to our livelihoods, health and future, and any change in climate patterns nearly affects every aspect of our lives such as food sources, transport, infrastructure, clothing, etc. It also contributes major influences on the available water resources system which in turn create pressure on agriculture due to variations in rainfall patterns and temperature. In a developing country like India, country's economy mainly depends on the agriculture besides service industry. Furthermore, the country suffers a fragile ecosystem due to increasing population pressure. IPCC (Intergovernmental Panel on Climate Change) reports indicate that India which is one of the most vulnerable countries of the world for global warming is going to face the devastating climate change for the coming years (Down To Earth 2018). The IPCC fourth appraisal report, in particular the SRES (Special Report on Emissions Scenarios) highlights different scenarios which are named as A1, A2, B1 and B2, narratives of subjective (e.g., political, conservative, social, natural and instructive turns of events) discharges drivers (IPCC 2007). These scenarios delineate the connection among the influences owning to ozone depleting substances and airborne discharges and progress during the latest century. For foreseeing the conceivable upcoming atmosphere, these SRES emissions situations are consider helpful. The A2 scenario depicts an extremely various different scenarios. This scenario portrays that there is a nonstop increment in population, financial improvements on territorial levels, monetary development and innovative changes are progressively lopsided and slower in contrast with other three scenarios. In the B2 scenario there is a persistent increment in worldwide population, yet at a decreasing pace than A2 emission scenario. The B2 scenario is additionally coordinated towards ecological security and social value, it focus around both nearby and provincial level (IPCC 2007).The main objectives in the present study is to assess the current and future trends of temperature and rainfall patterns over long time horizons and their probable impacts on Beas Basin, Himachal Pradesh (H.P), India.

Descriptions of Study Area

The Beas basin (Fig. 1) falls within the state of Himachal Pradesh (H.P), India which covers major part of Indus River Basin and is one of the major tributary of Sutlej River. It begins at an elevation of 3900m from Beas Kund on the eastern slopes of Rohtang Pass of the Himalayas and flows nearby Larji in the north–south direction where it takes a turn towards the west and flows in the same direction to Pandoh in H.P. The basin covers four districts of H.P. i.e. Kullu, Mandi, Kangra, and Hamirpur. It has a perpetual waterway, beginning from southern face of Rohtang pass in Kullu locale and streaming around 470 km to joins Satluj River in the Punjab province.

In this study the meteorological data was collected from CWC (Central Water Commission) and IMD (Indian Meteorological Department). The data considered for

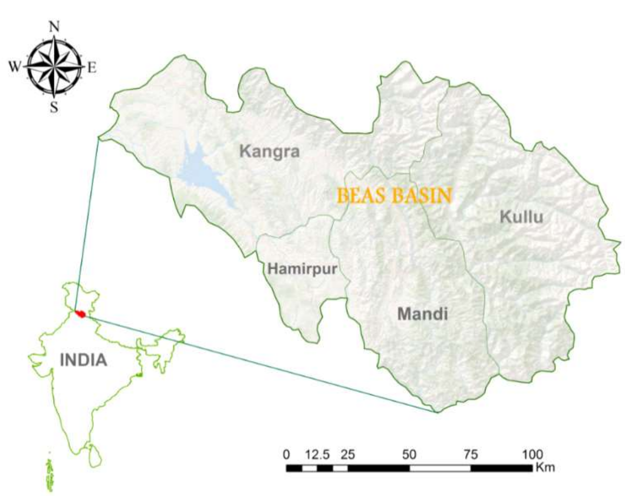

Fig. 1. Map of the study area

analysis includes - most extreme temperature, least temperature, mean temperature and precipitation data. The data collected from the above agencies covered the periods 1901-2001. Table 1 describes locations of 17 weather stations in different district of the Beas Basin. For downscaling, HadCM3 output and (NCEP/NCAR) data hasbeen successfully taken from CICS (Canadian climate Impact Scenarios). The NCEP/NCAR reanalysis data for SDSM model calibration and validation is from the periods 1961 to 2001acquainted with the HadCM3 having a resolution of 3.75^{o} x 2.7^{o}. The variables of HadCM3 are available in A2 and B2 scenarios for the period 1961-2100.

METHODOLOGY

General Circulation Model

In this study a GCM model Hadley Centre Coupled Model, version 3 (HadCM3) is considered. It is a coupled atmosphere-ocean general circulation model (AOGCM) developed at Hadley, U.K. It is one of the major models used in the IPCC Third Assessment Report in 2001 and Fourth Assessment Report in 2007. Simulations use a 360 day calendar, where each month is 30 days. HadCM3 is composed of two components: the atmospheric model HadAM3 and the ocean model HadOM3 (which includes a sea ice model). For more details on some GCMs variants, interested readers may find in the works of Houghton (2001), Carter (2007) and Kim et al (2008). Each GCM differ based on model resolution and discretization, domain areas spatial coverage, model parameterization and applied model algorithms.

Special Report on Emission Scenarios

The 4th assessment report of IPCC addressed to access the social, economic and technical information according to climate change. It published a report on SRES (Special Report on emission scenarios), which is utilize for prediction of environmental changes in light of ozone emission on the basis of four given scenarios. These are termed as A1, B1, A2 and B2. These four scenarios develop a relation between emissions and future development in upcoming features. Table 2 provides the descriptive SRES scenarios situations.

Statistical Downscaling Model

In order to overcome the limitations of GCMs at regional impact studies, downscaling techniques are used (Abdo et al 2009). Although, different downscaling techniques are available, however selection of appropriate downscaling techniques is also a thought-provoking (Dibike and Coulibaly, 2004) and usually depends on the study and availability of data. Statistical Downscaling Model (SDSM) is a decision support tool for assessing local climate change impacts using a robust statistical downscaling technique. SDSM facilitates the rapid development of multiple, low-cost, single-site scenarios of daily surface weather variables under current and future regional climate model. Additionally, the software performs ancillary tasks of predictor variable pre-screening, model statistical analyses and graphing of climate data.

In down scaling, both the predictors and a predict and variables quantitative relationship were established. The difference is such that daily information of state of atmosphere at large scale represents the predictor variables (PEV) while regional scale variables such as rainfall and temperature which are usually observed at weather and/or meteorological stations represent the predict and variables (PV). In other words, the model output of HadCM3 represents the predictor variables that can be avail from CICS on grid basis. The modified SDSM modelling procedure from Wilby and Dawson (2007) (Fig. 2).

Mann-Kendall Test

Mann-Kendall test (first proposed by Mann 1945)is a nonparametric test used to identify a trend in a series of values. It was further studied by Kendall (1975) and improved by Hirsch et al (1982, 1984) taking into account seasonality. The purpose of the Mann-Kendall (M-K) test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time (Mann 1945, Kendall 1975, Gilbert 1987). A monotonic upward and/or downward trend means that the variable consistently increases and/or decreases through time, but the trend may or may not be linear. For a time series $x_1, x_2, \ldots x_n$, M-K test can be estimated by the following statistic *S*.

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^{n} sign\,(x_j - x_i)(j > i) \quad (1)$$

Here *n* denotes the number of data pointsm x_j and x_i are the data values in the series *i* and *j* (*j*>*i*) respectively. And sign(1) is the sign function varies in the range -1 to +1; if (.) > 0 then sign (.) = 1, if (.) = 0 then sign (.) = 0 and if (.) < 0 then sign (.)=1.

Here, if S > 0 then later observations in the time series

Table 1. District wise weather station locations

District	Location of weather stations		Spatial Information	
	Station No.	Location	Latitude	Longitude
Hamirpur	S1	Bhoranj	31.68°	76.52°
	S2	Hamirpur	31.70°	76.50°
	S3	Nadaun	31.78°	76.35°
Kangra	S4	Dehra	31.87°	76.32°
	S5	Dharmashala	32.22°	76.31°
	S6	Nurpur	32.18°	75.53°
	S7	Kangra	32.10°	76.27°
	S8	Malan	32.11°	76.41°
	S9	Palampur	32.10°	76.54°
Mandi	S10	Chachiot	31.39°	77.20°
	S11	Jogindernagar	31.99°	76.79°
	S12	Karsog	31.38°	77.20°
	S13	Mandi	31.70°	76.93°
	S14	Sarkaghat	31.70°	76.74°
	S15	Sundarnagar	31.53°	76.90°
Kullu	S16	Banjar	31.63°	77.34°
	S17	Bajaura	31.84°	77.16°

Table 2. Specification of scenarios

Scenarios	Characteristics
A1	Quick financial development, across the board social and social cooperation's around the world, fast augmentation of new advancements.
A2	Coordinated world, constantly expanding populace, monetary advancements on local levels.
B1	Fast monetary development as A1, accentuation on worldwide answers for financial, social and ecological solidness, decline in material force, presentation of clean and asset effective innovations.
B2	Persistent expanding populace yet more slow than A2, accentuation on neighborhood as opposed to worldwide answers for financial, social and natural soundness, middle of the road level of monetary turn of events.

tend to be larger than those that appear earlier in the series, while the reverse is true if S < 0. For n ≥ 10, statistic S is approximately distributed normally as documented by Mann and Kendall with the mean S equal 0 and the variance of S defined as-

M(S) = 0 (2)

$$Var\ (S) = \frac{n(n-1)(2n+5) - \Sigma_{f=1}^{r}(t_f)(f)(f-1)(2f+5)}{18} \quad (3)$$

Where r varies over the set of tied ranks and t_f is the number of times (i.e. frequency) that the rank r appears. The standard normal variable is defined as follows:

$$\begin{aligned} Z &= \frac{S-1}{\{VAR\ (S)\}^{1/2}} && if\ S > 0 \\ Z &= 0 && if\ S = 0 \quad (4) \\ Z &= \frac{S+1}{\{VAR\ (S)\}^{1/2}} && if\ S < 0 \end{aligned}$$

For Z > 0, it shows an increasing trend whereas for Z < 0, there is a decreasing trend. For a given confidence level α, data series would have statistically significant trend if |Z| > Z (1-α/2), where Z(1-α/2) represent the corresponding values of P = α/2 of standard normal distribution. The present study used the confidence level of 95%.

Sen's slant calculation: Sen's method (Sen 1968) isemployed to determine the magnitude (increase or decrease) of the current trend slope. It has its wide application in dealing with hydro-meteorological time series (El Nesr et al 2010, Gocic and Trajkovic 2013). For n pairs of sample data with constant time, the residual variance is calculated as-

$V_i = X_k - X_l/k-1$ for $i = 1,2,2,\ldots\ldots n$ (5)

Where X_k and X_l are the data values at times k and l, (j > k), respectively. For each time period if there is one datum, then $N = n\ (n-1)/2$ whereas for multiple observations of one or more time periods, it is $N < n\ (n-1)/2$. Here N denotes the number of time periods. The n values of V_i is in the range of ascending order, and Sen's slope (or median of slope) is estimated as:

$$V_m = \begin{Bmatrix} V_{\left[\frac{n+1}{2}\right]} & \text{(if } n \text{ is odd)} \\ \dfrac{V_{\left[\frac{n}{2}\right]} - V_{\left[\frac{n+2}{2}\right]}}{2}, & \text{(if } n \text{ is even)} \end{Bmatrix} \quad (6)$$

The value of V_m indicates the steepness of the trendand its sign reflects data trend. With a specific probability, confidence interval (C_{in}) of V_m is determine to check whether slope has statistical difference than zero. The C_{in} for time slope can be calculated (Gilbert 1987) as:

$$C_{in} = Z'_{\alpha/2}\sqrt{Var\ (S)} \quad (7)$$

Here C_{in} is calculated with significance level (α) of 95% and 99% and $Var\ (S)$ is defined in Eq. (3).

RESULTS AND DISCUSSION

The present study is carried out by utilizing chosen shield factors and variety of change in the nearby predict and

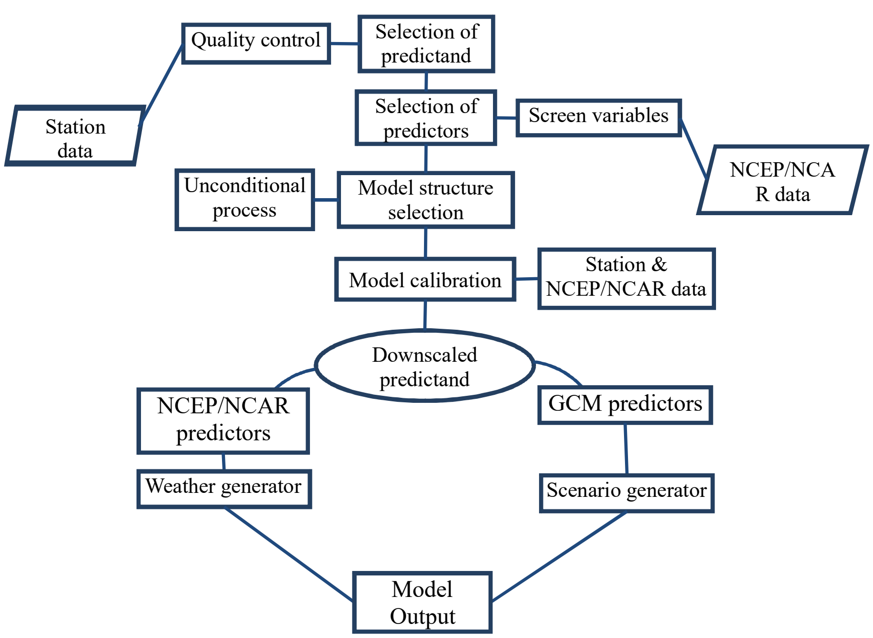

Fig. 2. Flowchart of downscaling procedure in SDSM

considering daily rainfall data, most extreme and least temperature for various stations pertaining to 1961-2001. Conditional procedure for precipitation and unconditional procedure for most extreme and least temperature were selected for model calibration. In unconditional procedure, an immediate connection between the predict and predicators are considered whereas conditional procedures are accomplished with intermediate process. Table 3 shown below illustrates the chosen predicators for model alignment at Beas basin. Table 4 depicts the representations of predictor's variables.

Trend Detection

The observed trends obtained for four districts of Beas basin (Hamirpur, Mandi, Kullu and Kangra) at different seasonal counts namelyannual, summer, monsoon and winter are summarized in Table 5. In the Hamirpur, the rainfall patterns shows a negative (–ve) trends predominantly for three seasonal counts while positive (+ve) trends exist during summer. Conversely, no trends are detected over the remaining three districts. Besides, others seasonal parameters such as T-min and T-max shows the +ve trends over the four districts at different seasonal counts except for Hamirpur where T-maxin the monsoon and winter are –ve. Figure 3 shows the overall observed rainfall trends over the four prevalent seasonal counts. It is observed that there is an increasing trends in the periodic rainfall, except for winter season where no trend is detected. Conversely, Figures 4 and 5 depict the periodic trends for T-max and T-min over the Beas basin. It is observed that both T-max and T-min follows an increasing trends over all seasonal counts except during the monsoon where both parameters are declining with certain degree.

Future Projection

The analysis for climate projections are divided into three time frames each having 30 years of data. These includes 2020s (2011- 2040), 2050s (2041-2070) and2080s (2071-2100), the designations 2020s, 2050s and 2080s are based on the data centering 2025, 2055 and 2085. The observed data periods1961-1985 and 1986-2001 were used for calibration and validation respectively against the projections data. Figure 6 shows the overall variations based on

Table 3. Predictors and predict at Beas basin

Predict and	Predictors
T-min	Ncepp 500as, ncepp_zhas, ncepp8_vas, ncepp 8thas, nceptempas,ncepphumas
T-max	Ncepp 500as, nceppzhas, nceprhumas, ncepp5_zas, ncepp8thas, ncepshumas, nceptempas
Precipitation	Ncepp_uas, ncepp_zas, ncepp_thas, ncepp5_uas, ncepp8_uas, ncepshumas

Table 4. Representation of predictor variables

Predictors	Description
Nceprhumas	Near surface relativehumidity
Ncepp5zhas	Divergence
Ncepp_uas	Zonal velocity component
Ncepp_zas	Surface velocity
Ncepp5_uas	Zonal velocity
Ncepp_vas	Surface meridional velocity
Ncepshumas	Near surface specific humidity
Ncepshumas	Surface specific humidity
Ncepp_vas	Meridional velocity component
Nceptempas	Mean temperature
Ncepp500as	Geopotential height

Table 5. Observed trends reported over four districts in Beas basin

Stations (Beas Basin)		Seasonal counts and their respective trends			
		Annual	Summer	Monsoon	Winter
Hamirpur	Rainfall	-ve	+ve	-ve	-ve
	T-min	+ve	+ve	+ve	+ve
	T-max	+ve	+ve	-ve	-ve
Kullu	Rainfall	No trend	+ve	No trend	No trend
	T-min	+ve	+ve	+ve	+ve
	T-max	+ve	+ve	+ve	+ve
Kangra	Rainfall	+ve	+ve	+ve	+ve
	T-min	+ve	+ve	+ve	+ve
	T-max	+ve	+ve	+ve	+ve
Mandi	Rainfall	No trend	No trend	No trend	No trend
	T-min	+ve	+ve	+ve	+ve
	T-max	+ve	+ve	+ve	+ve

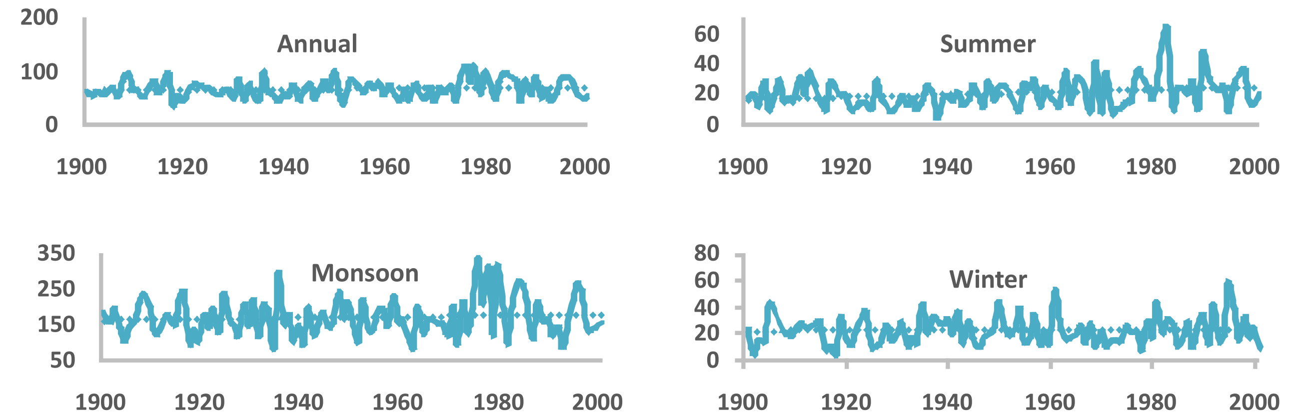

Fig. 3. Estimated mean daily rainfall pattern over the period of 101 years (1901 to 2001) in the Beas basin for different seasonal counts

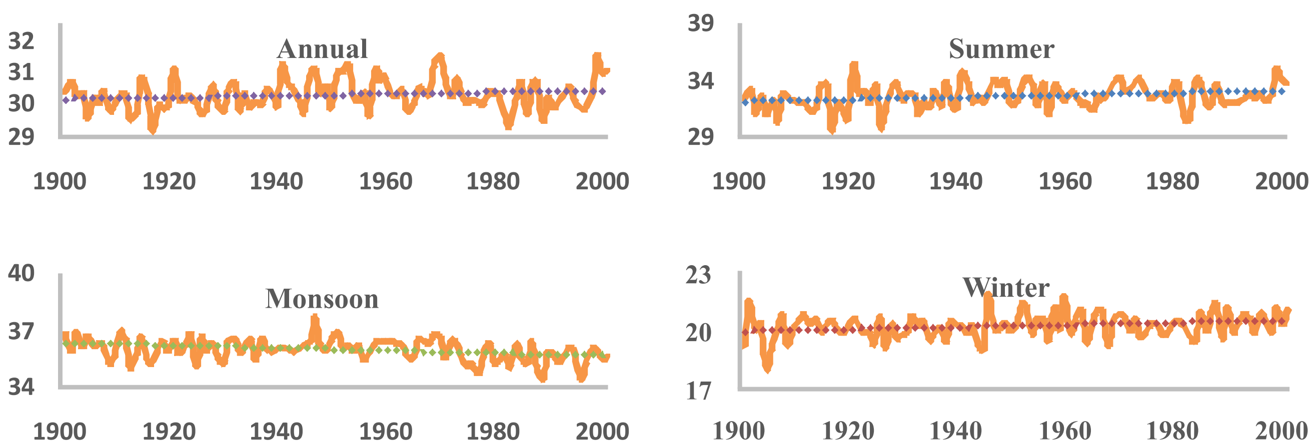

Fig. 4. Estimated mean daily pattern of T-max over the period of 101 years (1901 to 2001) in the Beas basin for different seasonal counts

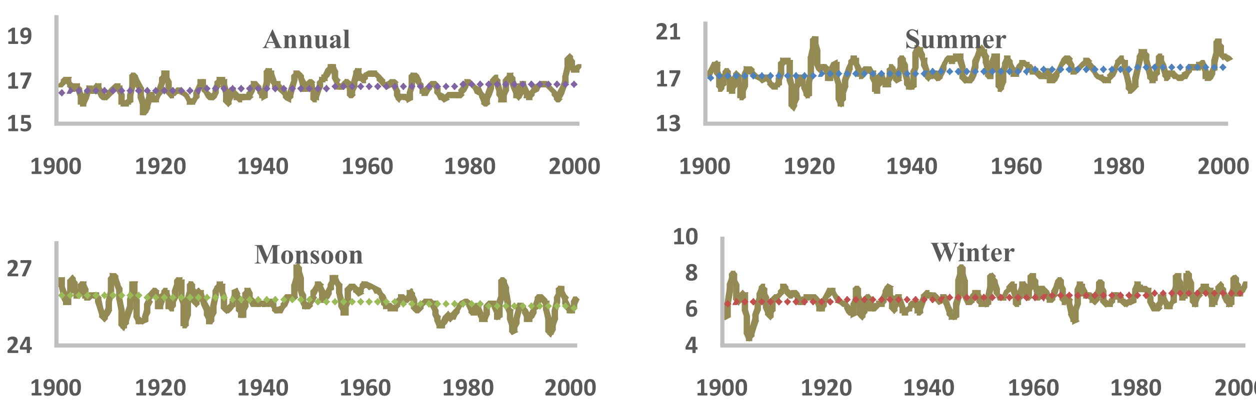

Fig. 5. Estimated mean daily pattern of T-min over the period of 101 years (1901 to 2001) in the Beas basin for different seasonal counts

percentage change in PPT for both A2 and B2 scenarios in the Beas basin. For 2020s it was observed that the mean monthly precipitations is decrease for all months excepts for February, September, October and November for both A2 and B2 scenarios, out of which maximum precipitation is observed in September. The magnitude of maximum and minimum percentage rise and fall of the mean monthly precipitation is found to be +19.38 % and -9.68% for 2020s for A2 scenario while for B2 scenario the it is found to be +17.67 % and -11.31% respectively. As shown in Figure 5 the precipitation patterns for summer, monsoon, winter and annual for 2020s, 2050s and 2080s for both the scenarios is expected toshows a declination in the near feature.

As shown in Figure 7, there is a rise in mean monthly maximum temperature (Tmax) for 2020s, 2050s and 2080s against the baseline periods for both the scenarios. Besides, there is an incremental rise in Tmax for 2020s and 2050s except for 2080s where it is reduce in B2 scenario. For 2020s Tmax labels rise by+5.12% and +5.34% respectively during March, and fall by -2.95% and -2.91% in May for A2 and B2 Scenarios. Similarly, the same patterns are observed for 2050s but with further rise and fall i.e. rise by +7.68% (A2 scenario) and +11.53% (B2 scenario) and fall by -3.98% and -4.66% for A2 and B2 scenarios. For 2080s Tmax rise by +9.44% for A2 scenario and +8.24% for B2 scenario. Among seasonal counts, the winter season shows to increase more corresponding to 2050s by +3.84% and +7.24%. Figure 8 displays the percentage trends of mean monthly minimum temperature (Tmin). In the 2020s and based on both the scenarios, it indicates that the pattern of Tmin is more or less close to the baseline periods. However, for 2050s and 2080s the pattern of Tmin is expected to rise particularly during the months of February and December. Overall, the highest change in Tmin is indicated in the 2050s with the rise by +52.56% in December for A2 scenario and by +31.13% in winter season for B2 scenario. Conversely, for all seasonal counts the pattern remains more or less close to baseline periods except for winter season where it indicates to rise in 2050s.

Rainfall erosivity factor: The magnitude and intensity of rainfall is subjected to rill soil loss rate and that can be accomplished by an important factor known as rainfall erosivity factor (or R-factor). For accurate estimation of R-Factor, it is essential to calculate at regional scale using the available rainfall data. For more details on R-factor, the readers may find somewhere in the works earlier researchers (Ninyerola et al 2006, Capolongo et al 2008,Calvo-Alvarado et al 2014). In the present study, the method adopted for R-

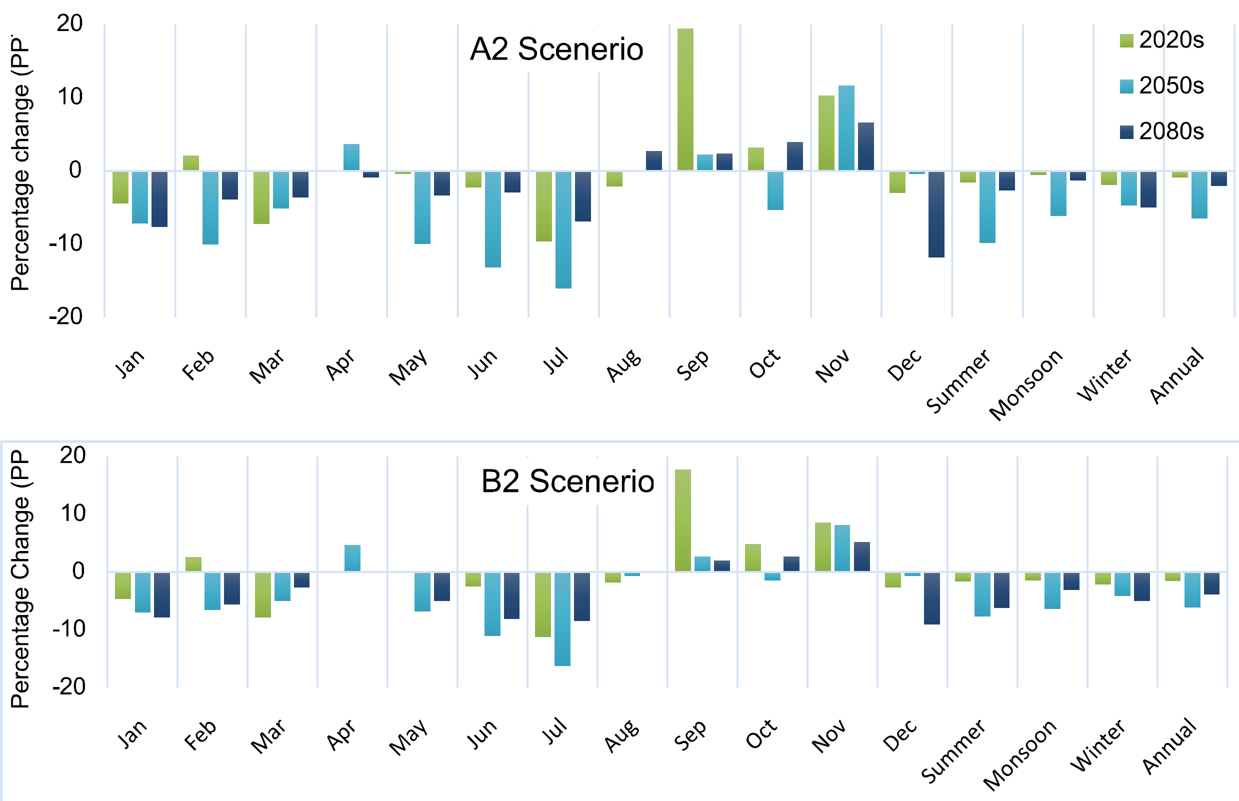

Fig. 6. Projected Change in Precipitation (PPT) for mean monthly, summer, monsoon, winter and annually in the Beas basin

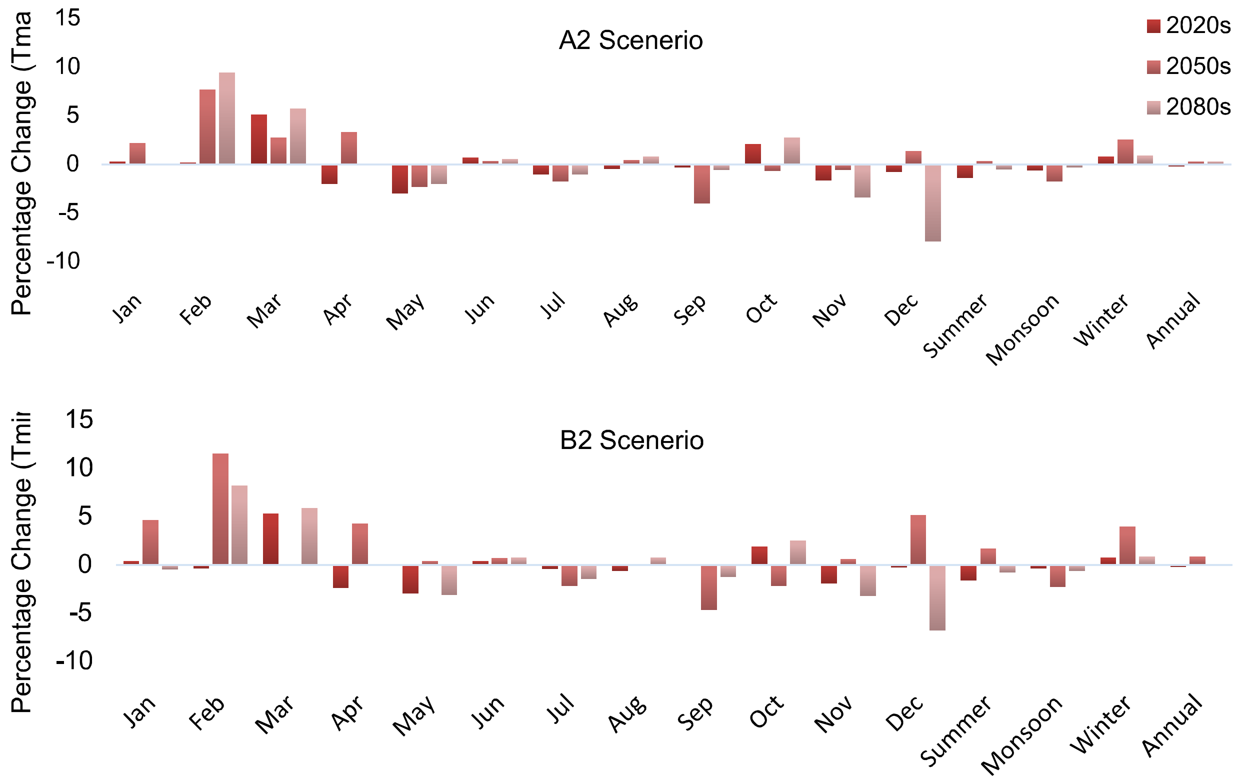

Fig. 7. Projected change in maximum temperature (T-max) in for mean monthly, summer, monsoon, winter and annually in the Beas basin

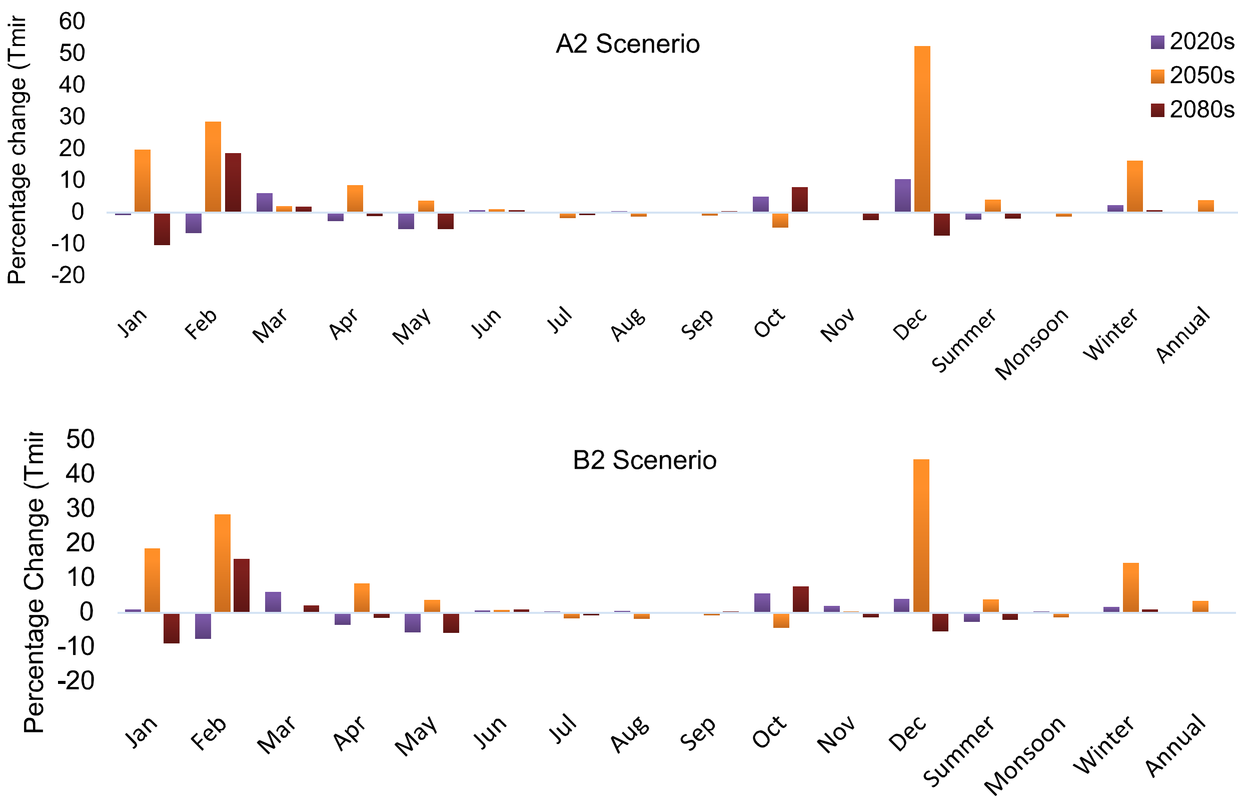

Fig. 8. Projected change in minimum temperature (T-min) for mean monthly, summer, monsoon, winter and annually in the Beas basin

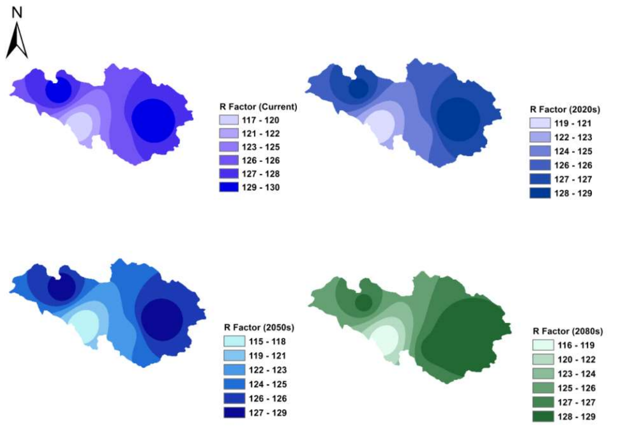

Fig. 9. R-factor (MJ.cm/ha^{-1}.h^{-1}.yr^{-1}) for current, 2020s, 2050s and 2080s in the Beas basin, H.P, India

factor estimation is based on the modified Fourier series obtained by Tiwari et al (2015) as it has more or less provides similar rainfall pattern. Figure 9 shows the resultant probability of R-factor trends for 2020s, 2050s and 2080s in corresponds to current trends.

CONCLUSION

The present study reports on the probable impacts on the environmental shift in the Beas Basin, H.P, India due to impending changes in the patterns of climate parameters. The changes on conditional impacts of PPT, T-max and T-min are predicted over the Beas basin using HadCM3 GCM for A2 and B2 scenarios considering the periods 2011-2100.SDSM indicates a decreasing and increasing trends for rainfall patterns for A2 and B2 emission scenarios, the decrease in trends is higher for 2020s (2011-2040) and an increasing trends is observed for 2050s (2041-2070) while the patterns is more or less were comparatively closer to baseline periods for 2080s (2071-2100). Nevertheless, the T-max is expected to increase by 2050s and 2080s while T-min is comparatively expected to increase rapidly during 2050s only. Furthermore, based on the R-factor (rill in soil rate loss due to change in rainfall pattern is likely to remain more or less consistent by 2100 with the near magnitude of 119 MJ.cm/ha^{-1}.h^{-1}.yr^{-1}. The model results for climate variables shows decent consistency within the IPCC change predictions. The downscaled results is pertinent to uncertainties and were expected to be associated with the downscaled model (SDSM), hence the results are indicative of possible changes in the future rather than actual prediction. Overall, the results presented in the paper can still provide a valuable inputs to decision maker to counteract vulnerability of the ecology in the Beas basin hydrology which is important for mitigation strategies. In future various other downscaling techniques and in-addition other significant operational climate parameters may be investigated for effective prediction accuracy.

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