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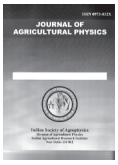

Research Article

Projections in Extreme Maximum and Minimum Temperature Events for Jalandhar District of Punjab

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ABSTRACT

Climate change is a massive threat to the food security worldwide. The climate change at a particular region can be examined through extreme weather event and agriculture largely depends on the caprice weather particularly extreme weather events. The present study was undertaken to analyze near, mid and long term projections in maximum and minimum temperature using Ensemble Global Circulation Models (GCM) under RCP 8.5 scenario. The projections indicated an increase in both the maximum and minimum temperature. The number of heat waves days (more than 45 °C) are likely to increase to1014 days by the end of 21st century compared to baseline values. The number of severe cold wave days with minimum temperature of less than 0 °C is likely to increase to 82 days compared to baseline by the end of 21st century. The information produced from this study will assist in developing early warning systems and preparation of contingency plans for the district.

Key words: Extreme temperature, GCM, Ensemble, Jalandhar, RCP 8.5

Introduction

Global warming induced climate change has inevitable threat to the human civilization in the recent era. The increase in global earth surface temperature is driven by the anthropogenic activities which increase carbon dioxide concentration into the atmosphere. Consequently, the global mean surface temperature has risen by 1.18°C since late 19th century (NOAA, 2021).This climate change is likely to increase the frequency and intensity of the extreme weather events which are of utmost concern for agrarian and civic society (Bal *et al.,* 2017). According to Singh and Patwardhan (2012), total number of extreme climatic events has been significantly increasing in India.

Extreme events like droughts and heat waves negatively affect agricultural production implicating livelihood and food security of communities. Some regions which immediately experience the extreme event are directly affected, whereas some regions in other parts of the world, suffer from indirect consequences like reduced exports of agricultural products and higher food prices (GFSP, 2015; Puma *et al.,* 2015). Hirabayashi *et al*. (2008) projected the possibility of hydrological drought and increase in the risk of floods in humid monsoon regions of South Asia, and also rise in the frequency of extremely hot days over East Asia and South Asia (Rajendran and Kitoh, 2008; Orlowsky and seneviratne, 2011).

Increase in extreme weather events like heat and cold waves have adverse implications on agriculture in several ways (Sharma *et al.*, 2013). In case of livestock, heat wave is the unavoidable climate variable affecting its milk production and productivity loss is estimated to be 1.6 million tonnes in 2020 and 15 million tonnes in 2050, from current

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levels. Also, the reduction in milk production is projected to be higher in crossbreds (0.61%) followed by buffaloes (0.5%) and indigenous breeds (0.4%) (Srivatsava, 2010).

The occurrence of extreme temperature conditions pose a serious question about whether the frequency or intensity of such events may change in future. The statistical aspects of such extremes can be projected using climate models. The maximum increase in extreme temperature by 1-4°C in the coastal region for 2030's and decrease in the frequency of cyclones but increase in cyclonic intensity is expected (MoEF, 2010).Some of other global models have predicted greater frequency of extreme warm days and lower frequency of extreme cold days associated with a warmer mean climate, a decrease in diurnal temperature range associated with higher night temperatures, increased precipitation intensity, mid-continent summer drying, decreasing daily variability of surface temperature in winter, and increasing variability of northern mid-latitude summer surface temperatures (Meehl *et al.,* 2000). The present study aims to study the possible changes of future temperature extremes under RCP8.5 scenario of climate change using GCM Ensemble model for Jalandhar district of Punjab.

Material and Methods

The baseline (1980-2005) and projected (2031-2095) temperature for Jalandhar district of the Punjab was downscaled using global circulation model by Climate Change, Agriculture and Food security (http://www.ccafs-climate.org/). The geographical location of Jalandhar is 31°19′32″ N 75°34′75″ E and lies at 242m above mean sea level in central plain zone of Punjab, India with warm and temperate climate.The daily data for maximum and minimum temperature for the baseline period (1980-2005) and projected data for RCP 8.5 scenario for near-term (2031-2050), mid-term (2051-2070) and long term (2071-2095) were downscaled using GCM Ensemble model. Thereafter, equations for the different months were derived from the daily simulated data (baseline period) and actual meteorological data for the period 1980-2000 and then validated using data of five years (2001-2005) by adopting Linear scaling (Chen *et al.,* 2011) as given below:

$$T_{corr} = T_{modelled} + [T_{obs(m)} - T_{modelled(m)}]$$

Where,

T_{corr} = Corrected Temperature

$T_{modelled}$ = Baseline temperature modeled by GCM

$T_{obs(m)}$ = Mean of observed temperature

$T_{modelled(m)}$ = Mean of modeled baseline temperature

Further, the projected weather data was corrected by using the derived equation. The corrected weather data were then analyzed on annual and monthly basis to quantify the changes in maximum temperature (°C) and minimum temperature (°C) from the baseline period. The extreme temperature indices used are as below:

a) Heat wave refers to a period of temperatures (4.0°C to 5.0°C) higher than the normal while temperature ≥ 5.0 °C from normal is called severe heat wave. According to India Meteorological Department (IMD) heat wave is considered when the maximum temperature of a station reaches ≥ 40°C for plain regions (http://www.chandigarhmausam.in/uploads/Learn%20Meteorology.pdf).

b) Cold wave refers to a period when minimum temperatures is 4.0 to 5.0 °C lower than the normal while temperature ≤ 5.0 °C from normal is called severe cold wave. According to India Meteorological Department (IMD) cold wave is considered when the minimum temperature of a station is reaches < 10 °C for plain regions.

The weather data over the near, mid and long-term were analyzed to check the mode of changes in occurrence of extremes temperature events at Jalandhar.

Results

The modelled baseline data (1980-2000) was used to find the correction factor for the bias removal. The correction factor was then validated using weather data from 2001-2005. Figure 1 shows the comparison between the actual, modelled and corrected model data. It is clear that the biases existed between the observed and modelled data for both maximum and minimum temperature. Therefore, the

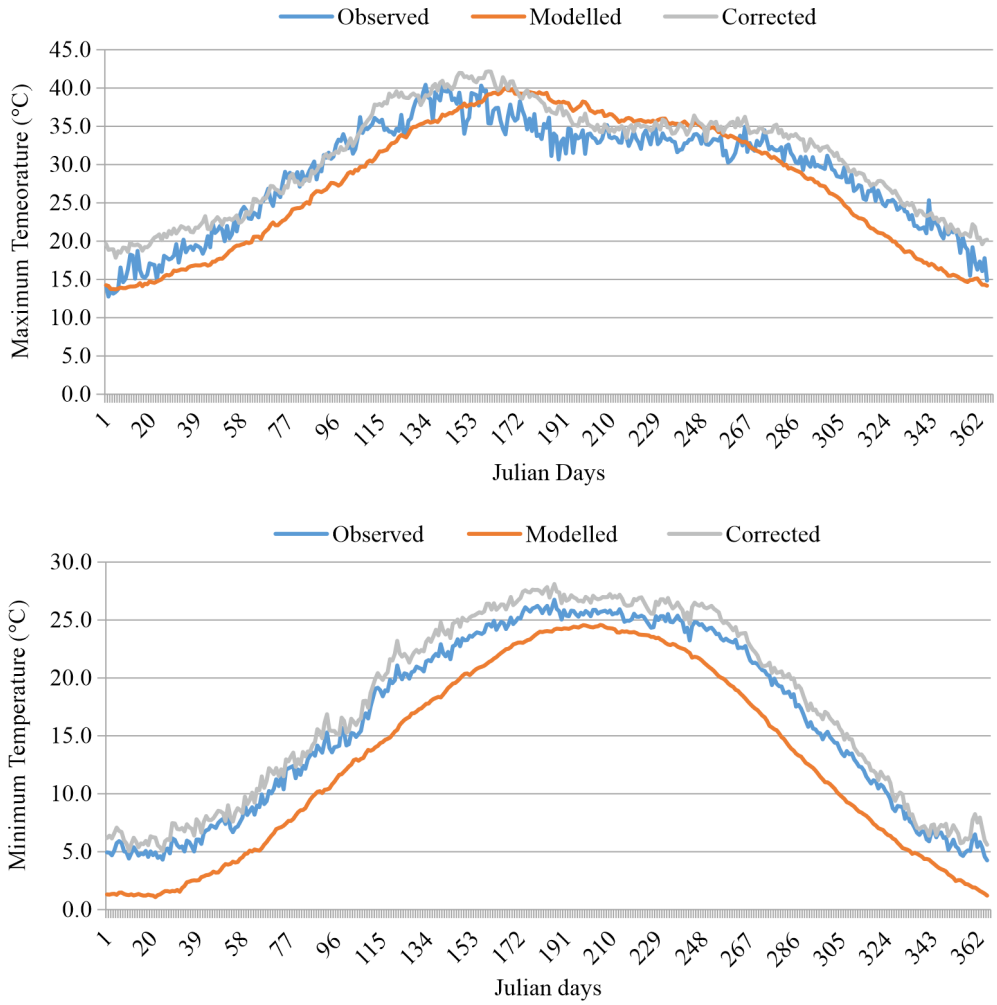

Fig. 1. Observed, modelled and corrected baseline data for Jalandhar

modelled data was corrected in order to reduce these biases. The results showed that the modelled maximum and minimum temperature data came close to the actual data after correction. The results obtain were in agreement with the findings of Mehraj *et al*. (2018) who submitted that the correction factors derived using linear scaling approach were better to bring modelled data close to the observed data.

Change in maximum temperature

The decadal changes in the mean monthly temperature during different time periods in the future have been presented in the Table 1. The data shows that decadal mean monthly maximum temperature would increase for Jalandhar in the near and long term. This change for the decades 2031-40, 2041-50, 2051-60, 2061-70, 2071-80 and 2081-95 would be -0.1 to 7.2, -0.1 to 7.4, 0.3 to 7.5, 0.7 to 7.8, 1.2 to 8.1 and 1.1 to 8.0°C respectively as compared to the baselines during different months of the year. In the near term, maximum decadal change is expected for the July month, whereas for the mid and long term, June month is expected to have maximum change from its baseline as compared to other months. Rise in maximum temperature might increase the water demand of the crops due to more evaporative losses. Any change in evapotranspiration likely to have a profound effect on agriculture and water resource planning (Ali and Adham, 2007). Also increase in temperature affects the crops by increasing pest infestation, shifting in weeds, reducing crop duration, affecting microbial population and their activity (Malhi *et al*., 2020).

Table 1. Projected decadal shift in mean monthly maximum temperature (°C) under RCP 8.5 at Jalandhar

Month	Baseline	Near term		Mid term		Long term	
		2031-40	2041-50	2051-60	2061-70	2071-80	2081-95
Jan	17.9	17.8	18.2	18.5	18.8	19.0	19.3
		(-0.1)	(+3.0)	(+0.6)	(+0.9)	(+1.2)	(+1.4)
Feb	20.8	23.5	23.9	24.2	24.6	24.9	25.1
		(+2.7)	(+3.0)	(+3.4)	(+3.7)	(+4.0)	(+4.3)
Mar	25.7	29.8	30.1	30.5	30.8	31.1	31.3
		(+4.1)	(+4.4)	(+4.7)	(+5.1)	(+5.3)	(+5.5)
Apr	32.9	35.6	35.9	36.3	36.6	36.8	36.9
		(+2.6)	(+3.0)	(+3.4)	(+3.7)	(+3.9)	(+4.0)
May	37.8	43.1	43.5	43.9	44.2	44.4	44.6
		(+5.3)	(+5.8)	(+6.1)	(+6.4)	(+6.6)	(+6.8)
Jun	38.1	45.0	45.2	45.6	45.9	46.2	46.4
		(+6.9)	(+7.2)	(+7.5)	(+7.8)	(+8.1)	(+8.3)
Jul	34.1	41.3	41.5	41.6	41.7	41.9	42.1
		(+7.2)	(+7.4)	(+7.5)	(+7.6)	(+7.8)	(+8.0)
Aug	33.3	40.0	40.3	40.5	40.8	40.9	41.1
		(+6.8)	(+7.0)	(+7.3)	(+7.5)	(+7.7)	(+7.8)
Sep	33.2	38.3	38.6	38.9	39.2	39.3	39.4
		(+5.1)	(+5.5)	(+5.8)	(+6.1)	(+6.2)	(+6.3)
Oct	31.1	34.8	35.1	35.4	35.8	36.1	36.2
		(+3.7)	(+4.0)	(+4.4)	(+4.7)	(+5.0)	(+5.1)
Nov	25.9	25.4	25.8	26.2	26.6	26.8	27.0
		(-0.5)	(-0.1)	(+0.3)	(+0.7)	(+0.9)	(+1.1)
Dec	20.4	22.8	23.2	23.6	23.9	24.2	24.3
		(+2.4)	(+2.8)	(+3.2)	(+3.5)	(+3.8)	(+3.9)

Change in minimum temperature

The decadal changes in the mean monthly minimum temperature during different time periods in the future have been presented in the Table 2. The data shows that decadal mean monthly maximum temperature would increase for most of the months for Jalandhar in the near and long term. This change for the decades 2031-40, 2041-50, 2051-60, 2061-70, 2071-80 and 2081-95 would be -2.4 to 5.3, -2.1 to 5.6, -0.6 to 5.8, -1.5 to 6.0, -1.3 to 6.1 and -1.1 to 6.1^{o}C, respectively as compared to the baselines during different months of the year. In the near term, maximum decadal change is expected for the May month followed by June and July. The increasing minimum temperature would increase in yield losses due to high photorespiration losses. Increase in minimum temperature decreases crop yield by decreasing photosynthetic function, sugar and starch content (Loka & Oosterhuis, 2010; Turnbull *et al*., 2002), increasing respiration rate (Mohammed & Tarpley, 2009b), inducing male sterility and low pollen viability and hastening crop maturity (Mohammed & Tarpley, 2009a).

Projected occurrence of heat wave and cold wave events

The occurrence of extremes of maximum (40-45°C and >45°C) and minimum (0-7°C) temperature during near, mid and end term at Jalandhar under RCP8.5 have been given in Table 3. The number of days having maximum temperature within the range 38-40°C, 40-45°C and >45°C were projected to increase during 2031-50 as compared to the baseline period. After this period, the number of days with maximum temperature range 38-40°C may decrease, whereas, within range 40-45°C and >45°C are likely

Table 2. Projected decadal shift in mean monthly minimum temperature (^{O}C) under RCP 8.5 at Jalandhar

Month	Baseline	Near term		Mid term		Long term	
		2031-40	2041-50	2051-60	2061-70	2071-80	2081-95
Jan	5.1	3.9	4.3	4.6	4.8	5.0	5.3
		(-1.3)	(-0.9)	(-0.6)	(-0.3)	(-0.1)	(+0.1)
Feb	7.1	9.3	9.6	9.9	10.1	10.3	10.4
		(+2.3)	(+2.6)	(+2.8)	(+3.1)	(+3.2)	(+3.3)
Mar	11.6	13.7	14.0	14.3	14.5	14.7	14.9
		(+2.1)	(+2.4)	(+2.7)	(+2.9)	(+3.1)	(+3.2)
Apr	16.8	19.3	19.7	20.0	20.2	20.3	20.4
		(+2.5)	(+2.9)	(+3.2)	(+3.4)	(+3.5)	(+3.6)
May	21.9	27.2	27.5	27.7	27.9	28.0	28.0
		(+5.3)	(+5.6)	(+5.8)	(+6.0)	(+6.1)	(+6.1)
Jun	25.0	29.8	30.1	30.4	30.5	30.7	30.8
		(+4.8)	(+5.1)	(+5.3)	(+5.5)	(+5.6)	(+5.8)
Jul	25.8	29.8	30.1	30.4	30.6	30.7	30.8
		(+4.0)	(+4.3)	(+4.6)	(+4.8)	(+4.9)	(+5.0)
Aug	25.1	29.3	29.6	29.8	30.0	30.1	30.2
		(+4.2)	(+4.5)	(+4.7)	(+4.8)	(+5.0)	(+5.0)
Sep	23.1	25.4	25.8	26.1	26.3	26.4	26.6
		(+2.3)	(+2.6)	(+2.9)	(+3.1)	(+3.3)	(+3.4)
Oct	17.3	20.4	20.7	21.0	21.2	21.3	21.4
		(+3.1)	(+3.4)	(+3.7)	(+3.9)	(+4.1)	(+4.2)
Nov	10.9	8.5	8.9	9.2	9.5	9.7	9.8
		(-2.4)	(-2.1)	(-1.7)	(-1.5)	(-1.3)	(-1.1)
Dec	6.1	9.5	9.9	10.2	10.4	10.6	10.7
		(+3.5)	(+3.8)	(+4.1)	(+4.3)	(+4.5)	(+4.6)

Table 3. Projected occurrence of heat waves (number of days) and cold waves (number of days) under RCP 8.5 at Jalandhar

Period	No. of heat waves			No. of cold waves			
	38-40°C	40-45°C	>45°C	5-7°C	2-5°C	0-2°C	<0°C
Baseline (1980-2005)	862	461	9	645	830	250	23
2031-50	1813	1109	168	643	513	113	80
2051-70	1135	1436	708	383	453	40	80
2071-95	1330	1711	1014	515	443	30	82

to increase in during the 2051-70. By the time period 2071-95, further, an increase is projected in number of days within all the three temperature ranges. It is inferred that extreme positive departure from the normal maximum temperature results in heat waves and number of heat wave days like to increase in future scenario. The number of days with maximum temperature of >45°C may go up to 708 and 1014 in mid and end term scenarios, respectively as compared to baseline value of 9. The results obtained were accorded with findings of Rao *et al.* (2018) and Kaur and Kaur (2021).

The model simulated an increase in the number of days with minimum temperature value of <0°C during near, mid and end term period. However,

number of days with minimum temperature ranging 0-7°C was expected to decrease indicating increase in the severity of cold waves.

Conclusion

The analysis of the Ensemble model simulated data indicated paramount changes for the incidence of extreme temperature events in the Jalandhar district of Punjab. The incidence of heat wave days having temperature ranging 40-45°C and >45°C and cold waves with temperature <0°C would unfavorably affect the crop growth and production by altering dry matter partitioning, enhances respiration rate and shortening of crop duration. The number of days with temperature >44°C are expected to increase by 2-3 times than near term while the number of days with temperature <0°C are expected to increase by 1.1times indicating profound hotter than colder climate in future. Different adaptation strategies need to be identified to combat with these changes for various sectors which are going to be adversely affected by these changes in future.

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