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Projected climate change under different scenarios in central region of Punjab, India

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ABSTRACT

The regional climate model viz. PRECIS(**P**roviding **R**egional **C**limates for **I**mpact **S**tudies) model was used to downscale the future climatic data for the central region of Punjab, India.The projected data for the 21st century under different scenarios was corrected by using the climate data recorded for the 1971-1990 at meteorological station of Punjab Agricultural University, Ludhiana (Central Region of Punjab) and baseline data derived from PRECIS model. The corrected data was then analyzed on annual, seasonal and monthly basis to quantify the changes in maximum and minimum temperature and rainfall. The projected data showed increase inmaximum and minimum temperature where as an irregular trend in rainfall was observed.It was projected that maximum and minimum temperature and rainfall would increase linearly under the A1B scenario for the mid century. At the end of the century, the rise in maximum and minimum temperature in B2 scenario will continue but at slower rate than the A1B and A2 scenarios. There would be deficit of rainfall by 78 and 30 % during the winter season under the A2 and B2 scenarios of the end century.

Keyword: Climate change, PRECIS model, A1B scenario, A2 scenario and B2 scenario

Over the last century, earth has experienced changes in climate due to increase in temperature and CO_2 concentration as a result of anthropogenic factors including changes in land use pattern (Islam and Sikka, 2010) and emission of green house gases (GHG) from industrial as well as agriculture sector (Rozenweig and Hillel, 1998). The increased GHGs concentration in lower atmosphere of the earth is likely to determine earth's average temperature or warming, influence precipitation and storm patterns as well as raising in the sea levels (IPCC 2007; Dash and Hunt 2007; Rajendran and Kitoh, 2008). The global warming potential (GWP) of various GHG's, i.e., of CO_2, CH_4 and N_2O is 1, 21 and 310, respectively (Recosky *et al*,2000). The visible footprints of these changes i.e. the increase in frequency of occurrence of extreme events (heat / cold wave, flood, drought etc.) have already been observed (Meehl *et al,* 2007).

Throughout the 21st century, India is projected to experience warming above the global mean (Rupakumar *et al,* 2006). There are projections that global CO_2 and temperature levels are going to increase under various scenarios of climate change (McCarthy *et al*, 2001). In India an increase in annual mean and maximum temperatures by about 0.7 and 0.8 °C, respectively has been reported by Dash *et al* (2007). A warming trend has been observed along the west coast, in central India, the interior peninsula and Northeast India. Region wise analysis of temperature in India (Islam and Sikka, 2010) showed a maximum increase in maximum temperature in the west coast (by 1.2 °C), followed by north-east (by 1.0 °C), western Himalayas (by 0.9 °C), north central (by 0.6 °C), north-west (by 0.6 °C), east coast (by 0.6 °C) and interior peninsula (by 0.5 °C).

The region to region variation in climate is driven by the uneven distribution of solar heating, the individual responses of the atmosphere, oceans and land surface, the interactions between these, and the physical characteristics of the regions (Christensen *et al*, 2007). Increasingly reliable regional climate change projections are now available for many regions of the world due to advances in modeling and understanding of the physical processes of the climate system.

Keeping these different scenarios in mind, the results of the regional climate simulation model i.e. PRECIS (Providing Regional Climate for Impact Studies) have been presented in this paper under different scenarios (A1B, A2 and B2) for the mid and end of 21st century.

MATERIALS AND METHODS

The baseline (1961-1990) and projected (2021-2100) meteorological data for central region of the Punjab i.e.

Table 1 : Changes in maximum temperature (°C) for the mid and end century for different scenarios and their deviation from baseline period

Month/ Season	Baseline (1971-1990)	Mid century (2021-2050)	End century (2071-2100)		
		A1B	A1B	A2	B2
January	18.7	18.3(-0.4)*	21.3(+2.6)	23.2(+4.5)	20.1(+1.4)
February	20.9	27.6(+6.7)	31.3(+10.4)	33.5(+12.6)	30.4(+9.5)
March	26.1	41.6(+15.5)	43.7(+17.6)	46.4(+20.3)	43.3(+17.2)
April	34.4	48.1(+13.7)	50.8(+16.4)	52.5(+18.1)	50.4(+16.0)
May	38.6	54.5(+15.9)	57.4(+18.8)	55.6(+17.0)	54.0(+15.4)
June	38.6	47.8(+9.2)	49.6(+11.0)	44.4(+5.8)	43.3(+4.7)
July	34.4	33.8(-0.6)	36.2(+1.8)	34.7(+0.3)	33.6(-0.8)
August	33.4	31.6(-1.8)	34.6(+1.2)	34.1(+0.7)	33.1(-0.3)
September	33.6	31.2(-2.4)	34.7(+1.1)	32.4(-1.2)	30.3(-3.3)
October	31.9	24.9(-7.0)	29.7(-2.2)	26.5(-5.4)	24.0(-7.9)
November	26.5	18.1(-8.4)	20.6(-5.9)	19.9(-6.6)	16.5(-10.0)
December	20.6	15.0(-5.6)	17.6(-3.0)	19.0(-1.6)	16.1(-4.5)
Kharif	35.1	37.3(+2.2)	40.4(+5.3)	38.0(+2.9)	36.4(+1.3)
Rabi	24.5	28.0(+3.5)	30.9(+6.4)	32.4(+7.9)	29.3(+4.8)
Annual	29.8	32.7(+2.9)*	35.6(+5.8)	35.2(+5.4)	32.9(+3.1)

* Figures in parenthesis indicate the change in °C temperature from the baseline period

Ludhiana was downscaled using PRECIS (Providing Regional Climates for Impact Studies) model prepared by IITM, Pune. Ludhiana is situated at 30°54' N latitude and 75°56' E longitude and 247m above mean sea level. The daily data for maximum temperature, minimum temperature and rainfall for the baseline period (1961-1990) and projected data for A1B scenario for mid century (2021-2050) and for A1B, A2 and B2 scenarios for the end of 21st century (2071-2100) was downscaled using this model. Thereafter correction factor was derived from the daily simulated data (1971-1990) and actual meteorological data (1971-1990) and further the projected weather data for the mid and end century was corrected by applying correction factor.

Then the corrected weather data was analyzed on annual,*kharif* season, *rabi* season and monthly basis to quantify the changes in maximum temperature (°C), minimum temperature (°C) and rainfall (mm) from the baseline period. The annual maximum and minimum temperature and rainfall data were further regressed to quantify the rate of increase / decrease in the temperature and rainfall during the mid and upto the end of 21st century under different scenarios of climate change.

RESULTS AND DISCUSSION

Changes in maximum temperature

The differences in maximum temperature, minimum temperature and rainfall from their baseline during the mid (2021-2050) andend (2071-2100) of 21st century under different scenarios as predicted by the PRECIS-model, averaged over the central region of Punjab are given in Table 1.

The projections indicate that annual maximum temperature will increase by 2.9 °C during the mid century. Also, a warming trend will be observed towards the end of century (2071-2100) under different scenarios. At the end of century, annual maximum temperature will be higher by 5.8, 5.4 °C and 3.1 °C in the A1B, A2 and B2 scenario as compared to the baseline period (29.8 °C). Increase in maximum temperature will be higher for the *rabi* season as compared to the *kharif* season. The rate of increase would also vary with the time of century. For example, at A1B of mid of century, A1B, A2 and B2 scenarios of the end century, the increase in maximum temperature would be 2.2, 5.3, 2.9 and 1.3 °C, respectivelyfrom baseline maximum temperature of 35.1 °C during *kharif* season; and 3.5, 6.4, 7.9 and 4.8 °C, respectively from baseline maximum temperature of24.5 °C during the *rabi* season.

Table 2 : Changes in minimum temperature (°C) for the mid and end century for different scenarios and their deviation from baseline period

Month/ Season	Baseline (1971-1990)	Mid century (2021-2050)	End century (2071-2100)		
		A1B	A1B	A2	B2
January	5.2	1.2(-4.0)*	3.2(-2.0)	2.3(-2.9)	0.7(-4.5)
February	6.9	6.6(-0.3)	10.2(+3.3)	10.4(+3.5)	8.3(+1.4)
March	11.1	18.3(+7.2)	20.9(+9.8)	22.3(+11.2)	19.8(+8.7)
April	16.8	27.3(+10.5)	30.0(+13.2)	30.9(+14.1)	29.6(+12.8)
May	21.8	36.1(+14.4)	39.5(+17.8)	39.4(+17.7)	36.8(+15.1)
June	25.3	36.6(+11.3)	39.0(+13.7)	35.9(+10.6)	34.8(+9.5)
July	25.6	29.4(+3.8)	31.2(+5.6)	30.5(+4.9)	29.6(+4.0)
August	25.0	28.8(+3.8)	30.9(+5.9)	30.3(+5.3)	29.4(+4.4)
September	22.2	28.1(+6.0)	31.0(+8.9)	30.1(+8.0)	28.8(+6.7)
October	16.0	21.0(+5.1)	24.9(+9.0)	23.4(+7.5)	22.1(+6.2)
November	10.0	12.8(+2.8)	14.8(+4.8)	11.2(+1.2)	10.1(+0.1)
December	6.0	3.2(-2.8)	5.2(-0.8)	3.1(-2.9)	1.7(-4.3)
Kharif	22.6	30.0(+7.4)	32.7(+10.1)	31.6(+9.0)	30.2(+7.6)
Rabi	9.3	11.6(+2.3)	14.0(+4.7)	13.4(+4.1)	11.6(+2.3)
Annual	16.0	20.9(+4.9)*	23.4(+7.4)	22.5(+6.5)	21.0(+5.0)

* Figures in parenthesis indicate the change in °C temperature from the baseline period

Maximum temperature for mid century and B2 scenario of end century will be higher than baseline period from January to June except January month of mid century where it will be lowered by 0.4 °C than baseline maximum temperature of 18.7 °C (Table 1). After June onwards, from July to December there would be decrease in maximum temperature from baseline period. Higher maximum temperature than baseline period would be observed till September and August in A1B and A2 scenario of end century, in later months it would decrease than baseline till end of the year. May will be the hottest month having highest mean maximum temperature in all the scenarios.

Rupakumar *et al* (2006) projected a temperature rise of 2.9-4.1 °C for India under B2 and A2 scenario in 2080's relative to 1970's, whereas Krishankumar *et al* (2011) reported warming of 3.5-4.3 °C over the same period for A1B scenario. Chaturvedi *et al* (2012) also predicted the warming in India by 1.7-2.0 °C by 2030's and 3.3-4.8°C by 2080's relative to pre-industrial periods.

Changes in minimum temperature

The PRECIS model projections indicate that the annual minimum temperature may increase by 4.9 °C in the mid century. Also, a warming trend was observed towards the end of century (2071-2100) under different scenarios (Table 2). At the end of century, annual minimumtemperature may be higher by 7.4, 6.5°C and 5.0°C under the A1B, A2 and B2 scenarios, respectively as compared to the baseline period (16.0°C).

Increase in minimum temperature will be higher for the *rabi* season as compared to the *kharif* season. The rate of increase would also vary with the time of century. For example, under A1B of mid century and under A1B, A2 and B2 scenario of the end century, the increase in minimum temperature would be 7.4, 10.1, 9.0 and 7.6°C, respectively from baseline minimum temperature of 22.6 °C during *kharif* season; and 2.3, 4.7, 4.1 and 2.3°C, respectively as compared to baseline minimum temperature of 9.3 °C during the *rabi* season.

January would be the coolest month in all the scenarios having lowest minimum temperature (0.7 to 3.2 °C) (Table 2). Minimum temperature will be higher than baseline in all the months of the year except January,February and December for the A1B scenario of mid century. The minimum temperature may be lowered by 4.0, 0.3and 2.8 °C than the baseline temperature of 5.22, 6.87 and 5.99 °C, respectively during month of January, February and December.

Table 3 : Changes in rainfall (mm) for the mid and end century for different scenarios and their deviation from baseline period

Month/ Season	Baseline (1971-1990)	Mid century (2021-2050)	End century (2071-2100)		
		A1B	A1B	A2	B2
January	25	22(-3)*	21(-4)	7(-18)	12(-13)
February	30	13(-17)	19(-11)	7(-23)	8(-22)
March	26	19(-7)	23(-3)	11(-15)	20(-6)
April	19	22(-3)	19(0)	10(-9)	15(-4)
May	23	24(+1)	22(-1)	26(+3)	26(+3)
June	66	123(+57)	124(+58)	185(+119)	188(+122)
July	229	281(+52)	358(+128)	255(+26)	279(+50)
August	186	245(+59)	296(+110)	228(+42)	216(+30)
September	103	162(+59)	155(+52)	214(+111)	223(+120)
October	7	77(+70)	73(+66)	86(+79)	103(+96)
November	10	59(+49)	62(+52)	25(+15)	27(+17)
December	18	29(+11)	33(+15)	10(-8)	15(-3)
Kharif	614	912(+298)	1027(+413)	995(+381)	1035(+421)
Rabi	128	165(+37)	172(+44)	72(-56)	98(-30)
Annual	741	1075(+334)*	1204(+463)	1066(+325)	1131(+390)

* Figures in parenthesis indicate the change in mm rainfall from the baseline period

At the end of century (2071-2100),the minimum temperature under the three scenarios i.e. A1B, A2 and B2 may get lowered than the baseline minimum temperature by the 2.0,2.9 and 4.5 ^{o}C, respectively in the month of January and by 0.8 , 2.9 and 4.3 ^{o}C, respectively in the month of December. The remaining months from February to November may experience higher minimum temperature during the end of the century. The rise in temperature would be higher in the end century than mid century.

Changes in rainfall

The rainfall projections of 21st century by PRECIS model indicate that the annual rainfall will increase by 333 mm as compared to the baseline rainfall of 741 mm in the mid century (Table 3). At the end of century, annual rainfall will be higher from the baseline period by 463 mmin the A1B scenario, 325 mm in the A2 scenario and390 mm in the B2 scenario.Increase in rainfall will be higher for the *kharif* season as compared to the *rabi* season.During the baseline period, rainfall was 614 mm during *kharif* and 128 mm during *rabi* season, which would increase respectively by 298 mm (32.6%) and 37 mm (22.7 %) by the mid century. The *kharif* season rainfall for the end century may be increased by 413 mm (40.2 %), 381 mm (38.3 %), 421 mm (40.7 %) for A1B, A2 and B2 scenarios, respectively. The A1B scenario predict the rise in rainfall by 44mm (25.9 %) whereas A2 and B2 scenario predict decrease in rainfall by 56 mm (78.3%) and 30 mm (30.8%), respectively during the *rabi* season.The rainfall may be reduced than the baseline upto the month of April, after which it is projected to increase under all the scenarios (Table 3). Highest amount of rainfall is predicted for the month of July.

Rajendran and Kitoh (2008) also projected high rainfall events by the end of century. The trends of heavy (Palmer and Raisanen, 2002; Goswami *et al,* 2006) or in some places reduced precipitation (Kitoh *et al,* 2008) have also been observed in some other studies.Precipitation is projected to increase from 4 to 5 % by 2030's and 6 to 14 % towards end of century (2080's) (Chaturvedi *et al,*2012).

CONCLUSION

The PRECIS model projections indicate that the maximum and minimum temperature would increase under A1B, A2 and B2 scenarios by mid and end of 21st century. By the mid and end of 21st century projections reveal an increase in the incidence of extreme of high (in the months of March, April, May and June) and low (in the months of December and January) temperature events thereby indicating increase in heat wave and frost conditions in crops. Higher rainfall

as compared to baseline is likely to be experienced during the mid and end of the 21st century. However, uneven distribution of the rainfall may be projected.

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