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Statistical analysis of mean maximum temperature and pattern of Chhattisgarh

Devendra Kumar Kurrey, Hulas Pathak and VK Choudhary

Abstract
Agriculture is influenced by temperature variability in a number of ways, including its heat wave, increase in maximum temperature, cold wave and frost etc To analyse, the present climate status, the long term weather data (1980-2020) viz, mean maximum temperature of different districts of Chhattisgarh were collected from the Department of Agrometeorology, College of Agriculture, Raipur. Analysed in excel tabular analysis. The highest increase in annual maximum temperature was observed at 33.29 ℃ in the year 2009, whereas the lowest maximum temperature was observed at 31.42 ℃ in the year 1990. it is also observed that the maximum temperature is increasing significantly at the rate of 0.0135 ℃ per year. The highest increase in annual temperature was observed in Sukma, Kondagaon, and Narayanpur observed for 0.0139 ℃ increase per year. The state average summer mean maximum temperature was observed as 37.42 ℃ over 40 years with 2.18 percent of the variability. The maximum temperature of June is more unstable, followed by March, April, and May. The state average winter mean maximum temperature was observed as 28.68 ℃ over 40 years with 1.95 percent of the variability. The state winter maximum temperature of January is more unstable, followed by December, October, and November. Plain and cultivation of high temperature-demanding crops is appropriate in Bastar Plateau districts, while cultivation of low temperature-demanding crops is more advantageous for farmers in Northern Hills districts.

Keywords: Temperature, variability, climate, crops, Chhattisgarh

1. Introduction
Global warming, erosion of ozone layer in stratosphere and impact of green house gases are the major consequences of climate change. According to another study in the 20th century, the global average surface temperature rise by 0.6 °C and would rise in the range of 1.4 °C to 5.8 °C by 2100. Average surface temperatures have increased across the regions in the range of 0.3 °C-0.8 °C over the past 100 years (IPCC, 2007) [1]. The annual average maximum temperature in South Asia is expected to rise by 1.4 °C-1.8 °C in 2030 and 2.1 °C-2.6 °C in 2050, whereas heat stressed areas in the region could rise by 12 percent in year 2030 and 21 percent in year 2050 (Tesfaye *et al.* 2017) [6]. The mean temperature change is predicted to be in the range of 2.33 °C to 4.78 °C with a doubling in carbon-di-oxide (CO2) concentrations (Watson *et al.* 1998) [7]. Climate change projections made for India indicates an overall increase in precipitation by 9-16% and temperature by 1-4 °C in the year 2050s (Krishna *et al.* 2011) [3]. Considering the future growth and development of India, the IPCC has projected a temperature rise from 0.5 °C to 1.2 °C by 2020, from 0.88 °C to 3.16 °C by 2050 and from 1.56 to 5.44 °C by 2080 for the Indian region. Keeping the view of this facts the study had been conducted to seek pattern and status of mean maximum temperature of Chhattisgarh state.

2. Method and Materials
The statistics are used secondary data which are collected from the Indian Meteorological Department and Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya (IGKV) and other publications the data is gathered from 1980 to 2020. The long-term gridded, daily and monthly maximum and minimum temperature data were used after average and aggregation as annual & seasonal maximum and minimum temperature (°C) data.

2.1 Trend Analysis
Trend analysis for selected variables were estimated with the help of linear equation. The linear trend was workout with the help of linear regression equations.

2.2 Linear regression equations

$Y = a + bx$

Where,
Y = weather data (rainfall/ maximum & minimum temperature)
a = intercept
b = slope
x = year/time

3. Results and Discussion

3.1 State level trend and pattern of changes in annual mean maximum temperature

Indian Meteorological Department observational data from 1980 to 2020 was used to analyse long-term changes in surface temperature in Chhattisgarh. Temperature records from 1980 onward were chosen. Fig 1 indicates the significantly increasing trend in the state-level temperature in time series. The highest increase in annual maximum temperature was observed at 33.29 ℃ in the year 2009, whereas the lowest maximum temperature was observed at 31.42 ℃ in the year 1990. it is also observed that the maximum temperature is increasing significantly at the rate of 0.0135 ℃ per year. The highest increase in annual temperature was observed in Sukma, Kondagaon, and Narayanpur observed for 0.0139 ℃ increase per year), Dantewada and Bastar observed for 0.0135 ℃ increase per year. However, no trend but an increasing pattern was observed for northern hills regions, i.e., district Surguja, Surajpur, Balrampur, and Koriya.

District-wise mean maximum temperature, coefficient of variation, and standard deviation over 40 years (1980 to 2019) data shown in Table 1 As per the data presented in the Table, the average (AVG) mean maximum temperature of Chhattisgarh state is 32.27 ℃, the coefficient of variation (CV) is observed as 1.250 percent, and the standard deviation (SD) of 40 years mean maximum temperature is around 0.400 ℃. The highest increase in annual mean maximum temperature was observed over Rajnandgaon and Korba district, which has around 32.99 ℃ and 32.88 ℃, respectively. Followed by mean maximum lowest temperature was recorded for Surajpur 31.71 ℃ and Surguja 31.70 ℃ as given in the Table.

The highest variability in mean maximum annual temperature was observed as 1.425, and 1.423 Percent for Surguja and Jashpur districts, respectively, and the lowest variability in mean annual maximum temperature was observed as 1.020 and 1.049 percent for Bastar and Dantewada districts, respectively.

The highest mean deviation over 40 years on mean maximum temperature was observed for Surguja and Jashpur as 0.452 ℃ and 0.451 ℃, respectively. The lowest mean deviation from the mean maximum annual temperature was observed for Sukma and Kondagaon as 0.339 ℃ and 0.348 ℃, respectively.

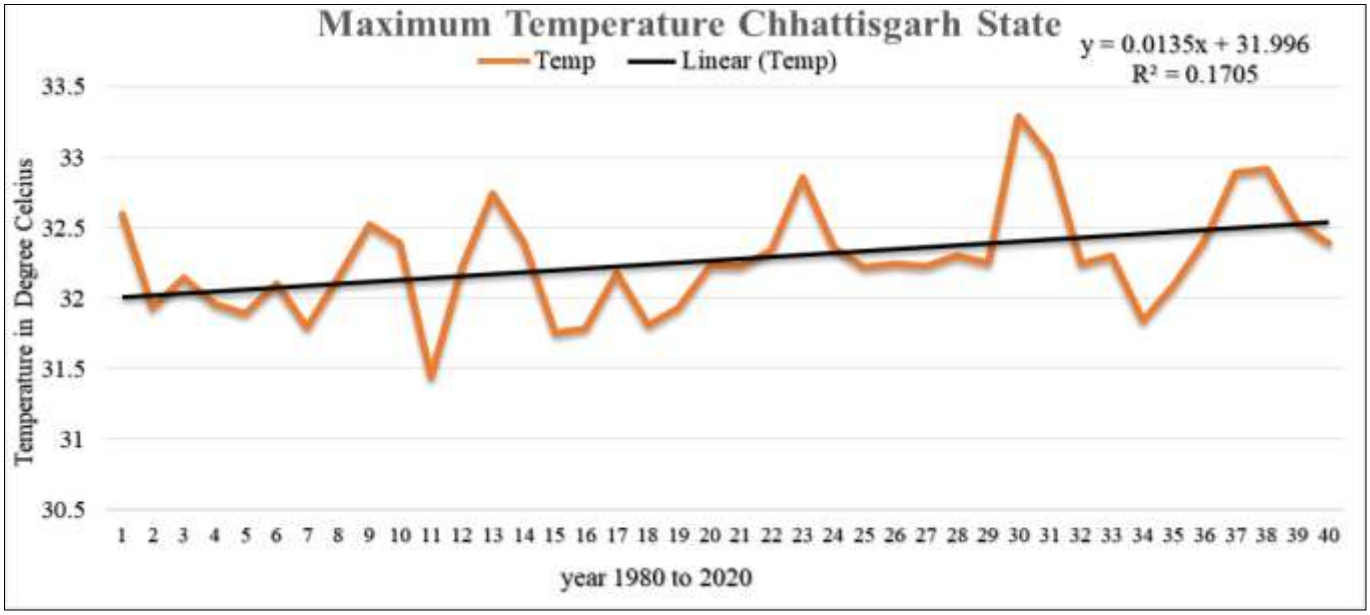

Fig 1: State-level maximum mean temperature

Table 1: District-wise annual maximum mean temperature and variability

Mean Maximum Annual Temperature							
SN	**District**	**Parameter**	**Statistics**	**SN**	**District**	**Parameter**	**Statistics**
1	Balod	Average Temp ℃	32.527	15	Kanker	Average Temp ℃	32.527
		SD	0.408			SD	0.408
		CV in %	1.255			CV in %	1.255
2	Balodabazar	Average Temp ℃	32.612	16	Kondagaon	Average Temp ℃	32.831
		SD	0.384			SD	0.348
		CV in %	1.177			CV in %	1.060
3	Balrampur	Average Temp ℃	31.825	17	Korba	Average Temp ℃	31.882
		SD	0.446			SD	0.432
		CV in %	1.400			CV in %	1.354
4	Bastar	Average Temp ℃	32.504	18	Koriya	Average Temp ℃	31.577
		SD	0.331			SD	0.437
		CV in %	1.020			CV in %	1.383
5	Bemetara	Average Temp ℃	32.224	19	Mahasamund	Average Temp ℃	32.507
		SD	0.420			SD	0.382
		CV in %	1.303			CV in %	1.176
6	Bijapur	Average Temp ℃	33.014	20	Mungeli	Average Temp ℃	31.964
		SD	0.429			SD	0.436
		CV in %	1.300			CV in %	1.363
7	Bilaspur	Average Temp ℃	31.882	21	Narayanpur	Average Temp ℃	32.831
		SD	0.432			SD	0.348
		CV in %	1.354			CV in %	1.060
8	Dantewada	Average Temp ℃	32.170	22	Raigarh	Average Temp ℃	32.059
		SD	0.337			SD	0.417
		CV in %	1.049			CV in %	1.300
9	Dhamtari	Average Temp ℃	32.527	23	Raipur	Average Temp ℃	32.224
		SD	0.408			SD	0.423
		CV in %	1.255			CV in %	1.312
10	Durg	Average Temp ℃	32.224	24	Rajnandgaon	Average Temp ℃	32.990
		SD	0.420			SD	0.427
		CV in %	1.303			CV in %	1.295
11	Gariyaband	Average Temp ℃	32.641	25	Sukma	Average Temp ℃	32.169
		SD	0.368			SD	0.339
		CV in %	1.127			CV in %	1.052
12	Janjgir Champa	Average Temp ℃	**32.507**	26	Surajpur	Average Temp ℃	31.704
		SD	0.382			SD	0.436
		CV in %	1.176			CV in %	1.376
13	Jashpur	Average Temp ℃	31.715	27	Surguja	Average Temp ℃	31.717
		SD	0.451			SD	0.452
		CV in %	1.423			CV in %	1.425
14	Kabirdham	Average Temp ℃	31.964	28	Chhattisgarh	Average Temp ℃	32.270
		SD	0.436			SD	0.400
		CV in %	1.363			CV in %	1.250

Source: Derived from the calculation

The temperature in the Bastar Plateau and Chhattisgarh Plain regions was 1 to 2 degrees higher than in the Northern Hills region, with more significant variation in the Northern Hills districts. Based on data from the past 40 years, it has been determined that the Chhattisgarh Plain and cultivation of high temperature-demanding crops is appropriate in Bastar Plateau districts, while cultivation of low temperature-demanding crops is more advantageous for farmers in Northern Hills districts.

3.2 District-wise summer mean maximum temperature

The state average summer mean maximum temperature was observed as 37.42 ℃ over 40 years with 2.18 percent of the variability. The maximum temperature of June is more unstable, followed by March, April, and May.

Table 2 presents that Narayanpur had maximum mean temperature of 35.87 ℃ during March, and Rajnandgaon district saw maximum mean temperature during April (39.49 ℃), May (41.83 ℃), June (37.89 ℃) and summer season (38.58 ℃). Month June has seen more unstable for the district Surguja at 5.37 percent, followed by March Kabirdham (4.38 percent), April Jashpur (3.77 percent), and summer season Balrampur (2.30 percent).

Table 2 District-wise summer mean maximum temperature and variability Average Temperature in Degree Celsius and Coefficient of variation in percent)

SN	Districts	Parameter	March	April	May	June	Summer T Max
1	Balod	AVG	34.8975	38.925	40.9425	36.415	37.795
		CV	3.65088	3.240331	3.172782	5.081641	2.23022973
2	Balodabazar	AVG	34.6625	39.165	41.1125	36.9575	37.974375
		CV	4.013462	3.395769	3.08064	5.098816	2.23289846
3	Balrampur	AVG	33.6175	38.52	40.2675	36.675	37.27
		CV	4.343326	3.665496	2.775066	5.29271	2.30875303
4	Bastar	AVG	35.0775	37.8925	39.2575	35.135	36.840625
		CV	2.483241	2.503192	3.218505	4.19679	1.83156839
5	Bemetara	AVG	34.1325	38.725	41.09	36.855	37.700625
		CV	4.098202	3.380141	3.026389	5.223066	2.28860064
6	Bijapur	AVG	35.735	38.52	39.9675	35.6275	37.4625
		CV	2.559062	2.575333	3.717177	4.512782	2.05534539
7	Bilaspur	AVG	33.695	38.335	40.3675	36.4525	37.2125
		CV	4.361226	3.648077	2.962549	5.357506	2.37161962
8	Dantewada	AVG	34.2775	36.625	37.8575	34.595	35.83875
		CV	2.247023	2.397256	3.357849	3.995896	1.84097095
9	Dhamtari	AVG	34.8975	38.925	40.9425	36.415	37.795
		CV	3.65088	3.240331	3.172782	5.081641	2.23022973
10	Durg	AVG	34.1325	38.725	41.09	36.855	37.700625
		CV	4.098202	3.380141	3.026389	5.223066	2.28860064
11	Gariyaband	AVG	35.1425	39.08	40.8975	36.46	37.895
		CV	3.383634	2.838021	3.120539	4.64802	2.00597561
12	Janjgir Champa	AVG	34.65	39.0525	40.8275	36.695	37.80625
		CV	3.883792	3.25666	3.085566	4.913979	2.16995882
13	Jashpur	AVG	33.49	38.21	40.0125	36.325	37.009375
		CV	4.34753	3.776635	3.185984	5.338741	2.38203657
14	Kabirdham	AVG	33.6475	38.4825	40.9575	36.9925	37.52
		CV	4.38607	3.554881	2.703347	5.270087	2.3383255
15	Kanker	AVG	34.8975	38.925	40.9425	36.415	37.795
		CV	3.65088	3.240331	3.172782	5.081641	2.23022973
16	Kondagaon	AVG	35.875	39.1675	40.6625	35.6675	37.843125
		CV	2.81433	2.711251	3.202099	4.509204	1.89881348
17	Korba	AVG	33.695	38.335	40.3675	36.4525	37.2125
		CV	4.361226	3.648077	2.962549	5.357506	2.37161962
18	Koriya	AVG	32.8325	38.01	40.3025	37.0175	37.040625
		CV	4.671244	3.655323	2.715501	5.288134	2.34376755
19	Mahasamund	AVG	34.65	39.0525	40.8275	36.695	37.80625
		CV	3.883792	3.25666	3.085566	4.913979	2.16995882
20	Mungeli	AVG	33.6475	38.4825	40.9575	36.9925	37.52
		CV	4.38607	3.554881	2.703347	5.270087	2.3383255
21	Narayanpur	AVG	35.875	39.1675	40.6625	35.6675	37.843125
		CV	2.81433	2.711251	3.202099	4.509204	1.89881348
22	Raigarh	AVG	33.6575	38.26	40.27	37.085	37.318125
		CV	3.97223	3.370452	3.122962	5.139147	2.22034316
23	Raipur	AVG	33.6925	38.4125	41.0175	37.665	37.696875
		CV	4.01692	3.350193	3.078473	5.143943	2.26500658
24	Rajnandgaon	AVG	35.12	39.4975	41.83	37.8975	38.58625
		CV	3.780802	3.081889	2.987903	5.071684	2.16537708
25	Sukma	AVG	34.08	36.4525	37.7925	35.1275	35.863125
		CV	2.247354	2.42358	3.249009	4.161056	1.85883893
26	Surajpur	AVG	32.7475	37.9225	40.25	37.53	37.1125
		CV	4.424652	3.645056	2.698256	5.073543	2.25192167
27	Surguja	AVG	33.6525	38.3225	40.055	36.0725	37.025625
		CV	4.302072	3.75182	3.167272	5.377268	2.38289556

Source: Derived from analysis

3.3 District-wise winter mean maximum temperature

The state average winter mean maximum temperature was observed as 28.68 ℃ over 40 years with 1.95 percent of the variability. The state winter maximum temperature of January is more unstable, followed by December, October, and November.

Table 3 revealed that Balodabazar experienced a maximum winter mean temperature of 31.81 ℃ during October, Narayanpur and Kondagaon district saw maximum winter mean temperature during November at 31.10 ℃. Bijapur district has seen maximum winter mean temperature on December and winter mean maximum temperature i.e. around 29.17 ℃ and 30.19 ℃ respectively. District Rajnanadgoan has seen more unstable in month January during four months

of the winter season for district Rajnandgoan at 4.99 percent, followed by December Koriya (3.86 percent), January Koriya (4.99 percent), and Surguja district has more unstable during winter season Surguja at 2.30 percent.

Table 3 District wise winter mean maximum temperature
(Average Temperature in Degree Celcius and Coefficient of variation in percent)

SN	District	Parameter	October	November	December	January	Max winter
1	Balod	AVG	31.6325	29.5825	27.3	27.3325	28.96188
		CV	2.536332	2.357661	3.408759	4.054657	1.917788
2	Balodabazar	AVG	31.81	29.6075	26.9825	26.8025	28.80063
		CV	2.45508	2.327046	3.340523	4.166778	1.910222
3	Balrampur	AVG	31.155	28.74	25.765	25.055	27.67875
		CV	2.66231	2.285353	3.711148	4.556768	2.134597
4	Bastar	AVG	31.4125	30.02	28.5675	28.8525	29.71313
		CV	2.445446	2.10309	2.757823	3.02745	1.635394
5	Bemetara	AVG	31.5725	29.3525	26.7175	26.2725	28.47875
		CV	2.607978	2.462609	3.543771	4.282668	1.981151
6	Bijapur	AVG	31.63	30.42	29.1725	29.5675	30.1975
		CV	2.768122	2.325874	2.938787	3.08252	1.936061
7	Bilaspur	AVG	31.22	28.92	26.1475	25.72	28.00188
		CV	2.622025	2.400879	3.620115	4.428937	2.032697
8	Dantewada	AVG	31.205	29.9225	28.665	28.8475	29.66
		CV	2.478091	2.147051	2.635606	2.768854	1.622506
9	Dhamtari	AVG	31.6325	29.5825	27.3	27.3325	28.96188
		CV	2.536332	2.357661	3.408759	4.054657	1.917788
10	Durg	AVG	31.5725	29.3525	26.7175	26.2725	28.47875
		CV	2.607978	2.462609	3.543771	4.282668	1.981151
11	Gariyaband	AVG	31.66	29.555	27.2825	27.485	28.99563
		CV	2.452515	2.243035	3.248429	3.808596	1.917679
12	Janjgir Champa	AVG	31.6175	29.425	26.9175	26.835	28.69875
		CV	2.409642	2.33328	3.324806	4.061304	1.928002
13	Jashpur	AVG	31.0175	28.57	25.7825	25.41	27.695
		CV	2.58109	2.504766	3.678426	4.623787	2.243707
14	Kabirdham	AVG	31.4075	29.085	26.225	25.625	28.08563
		CV	2.684157	2.52953	3.66316	4.4825	2.031663
15	Kanker	AVG	31.6325	29.5825	27.3	27.3325	28.96188
		CV	2.536332	2.357661	3.408759	4.054657	1.917788
16	Kondagaon	AVG	31.6125	30.1025	28.465	28.845	29.75625
		CV	2.507992	2.110816	2.954493	3.312523	1.709756
17	Korba	AVG	31.22	28.92	26.1475	25.72	28.00188
		CV	2.622025	2.400879	3.620115	4.428937	2.032697
18	Koriya	AVG	31.2175	28.5225	25.2525	24.315	27.32688
		CV	2.696215	2.318324	3.862768	4.993614	2.124284
19	Mahasamund	AVG	31.6175	29.425	26.9175	26.835	28.69875
		CV	2.409642	2.33328	3.324806	4.061304	1.928002
20	Mungeli	AVG	31.4075	29.085	26.225	25.625	28.08563
		CV	2.684157	2.52953	3.66316	4.4825	2.031663
21	Narayanpur	AVG	31.6125	30.1025	28.465	28.845	29.75625
		CV	2.507992	2.110816	2.954493	3.312523	1.709756
22	Raigarh	AVG	31.435	29.0775	26.535	26.0375	28.27125
		CV	2.575125	2.456585	3.22271	4.186699	2.067099
23	Raipur	AVG	31.755	29.52	26.9325	26.2375	28.61125
		CV	2.757001	2.477999	3.406437	4.074469	2.002463
24	Rajnandgaon	AVG	32.195	30.31	28.21	27.7925	29.62688
		CV	2.966218	2.614323	3.178322	3.828536	2.037054
25	Sukma	AVG	31.3225	30.01	28.775	28.7425	29.7125
		CV	2.559543	2.286643	2.466869	2.739376	1.639645
26	Surajpur	AVG	31.3725	28.855	25.7825	24.61	27.655
		CV	2.92573	2.279079	3.523861	4.748083	2.080781
27	Surguja	AVG	30.9425	28.48	25.705	25.4625	27.6475
		CV	2.520895	2.567287	3.763696	4.617501	2.267987

Source: Derived from analysis

In Rabi season, The optimal soil temperature for seed germination ranges between 68- and 86-degrees Fahrenheit (20 and 30 degrees Celsius). Furthermore, different plant species have different thermal requirements for planting and development. Increased minimum temperatures have a greater impact on grain yield than on vegetative growth due to the effects of increased temperature. These effects are manifested by a higher rate of senescence, which reduces the crop's

capacity to produce grain or fruit efficiently.

Conclusion

Over the past four decades, the data revealed that various districts had experienced a significant increase in maximum and lowest temperatures. But spatially, the changes are not uniform among districts, and spatially temperature trends exhibited a significantly higher degree of geographic coherence and statistically significant warming as both maximum and lowest temperatures increased. In parts of Bastar Plateau and Northern Hills regions, there is a slight change in the cropping pattern due to an increase in temperature or less rainfall in the monsoon, as the area under maize is increasing due to reasonable price and market availability. Mostly stability has been found in the temperature of Dantewada and Bastar, due to which constant temperature-demanding crops can be promoted in this region. Therefore, temperature-tolerant varieties should be developed in districts with high variations in temperature, like Jashpur and Surguja districts.

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