Impact of climatic parameters on coronavirus disease 2019 pandemic progression in India: Analysis and prediction

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Received: July 31, 2020; **Accepted:** May 01, 2021

ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) is spreading very fast globally and various factors of it have to be analyzed. Climatic parameters play very crucial role in spreading of an epidemic, that is, COVID-19 worldwide. **Objective:** The aim of this study is to analyze the effect of climatic parameters (average temperature [AT], atmospheric pressure, relative humidity [RH], solar radiation [SR], and wind speed [WS]) on the COVID-19 epidemic during March 25, 2020, to June 15, 2020, in most affected states of India, that is, Maharashtra, Delhi, and Tamil Nadu. **Materials and Methods:** We quantitatively establish the correlation between climatic parameters and COVID-19 cases using statistical tests, that is, Kendall and Spearman rank correlation test. A comparative study of climatic parameters in the current COVID-19 period from previous 2 years (2018–2019) has been carried out. **Results:** The obtained results indicate that the numbers of cases are highly correlated with the AT ($r^2 > 0.6$, $P < 0.001$) in Delhi whereas a moderate correlation ($r^2 < 0.6$, $P < 0.001$) has been estimated for Maharashtra and Tamil Nadu. Similarly, an intermediate range of correlation coefficient has been observed for other climatic parameters. The range of climatic parameters has been found corresponding to maximum number of cases results as AT (25~40°C), RH (40~70%), AT (740~965 mmHg), SR (200–250 W/m^2), and WS (0.5~14 m/s). **Conclusion:** This study emphasizes that climatic parameters played a crucial role in COVID-19 progression in India. The outcomes of this study would be helpful to control COVID-19 not only in India but globally.

KEY WORDS: Coronavirus Disease 2019; Climatic Parameters; India; Correlation Coefficient; Epidemic Peak

INTRODUCTION

Coronavirus disease 2019 (COVID-19) has been declared as a worldwide pandemic by the World Health Organization (WHO) on March 11, 2020.[1] Globally, the first COVID-19 case was reported on December 31, 2019, in Wuhan (China).[2-5] At present, it has affected around 80% of world population and still growing at decent rate.[6] Investigations on COVID-19 indicate that it transmits through respiratory droplets, as well as human-to-human transition.[7-9] The common symptoms of COVID-19-infected patients are fever, cough, and respiratory disorders.[10] In worst conditions, it might results as serious health issues such as kidney failure and pneumonia which might cause death of patients.[11-13] The major concerns about COVID-19 are its tremendously growing cases and vulnerable community transmission in world. In addition, no vaccination of COVID-19 has been officially reported till date. Therefore, adequate precautions and preliminary research work on the factors affecting the spreading of COVID-19 might be helpful for the development of vaccination process of COVID-19. The previous studies indicate that climatic parameters (CPs) have the potential to determine the transition rate of a fatal epidemic, that is, COVID-19.[11-21] Recent studies suggest that the spreading of COVID-19 is highly correlated with the atmospheric factors such as temperature and humidity.[11,14-16] It has been reported

Access this article online	
Website: http://www.ijmsph.com	Quick Response code
DOI: 10.5455/ijmsph.2021.07121202001052021	

that abrupt change in climatic conditions and population might be responsible for virus transmission.[17-21] On the other hand, few studies have not accounted meteorological parameters as carriers of transition of COVID-19.[22-24] Another study indicates that the temperature and humidity can be responsible of transmission and existence of severe acute respiratory syndrome coronavirus (SARS-COV).[12,25-27] However, limited studies have been carried out in context of COVID-19 and climatic factors. Tosepu *et al*. have studied the correlation between weather and COVID-19 in Jakarta (Indonesia) in earliest stage of COVID-19[28] and predicted a connection between climatic factors (rainfall, temperature, and humidity) and COVID-19 transmission cases. A few numbers of such works have also been reported but all these studies have been performed at the earliest of COVID-19 transmission and incorporate only limited data set (up to April 2020).[29-31] Further, it is expected that this correlation also depends on geographical conditions of study area. So far, such reported studies are only limited to European countries.[32,33] Meanwhile, most of these studies are at the earlier stage of outbreak and also there is a paucity in South Asian country (India) as the number of cases is still increasing rapidly here. To the best of authors' knowledge, no such study has been carried out for South Asian countries till date. The present study provides a comprehensive statistical analysis of COVID-19 in India and its correlation with climatic factors using a significant dataset (publicly available).

In this paper, we study the effects of varying CPs on the spread of COVID-19 from March 15, 2020, to June 15, 2020, in India. The aim of this study is to analyze progression of COVID-19 in India and forecast the effect of COVID-19 on climatic conditions in subsequent times. Moreover, to obtain detailed analysis of the COVID-19, we have emphasized our study to three most COVID-19 affected states of India, that is, Maharashtra, Tamil Nadu, and Delhi. In addition, the strategies such as nationwide lockdown implemented by Indian government to reduce COVID-19 spreading have been quantitatively evaluated in climatic framework. In India, the first confirmed COVID-19 case was reported in Kerala on January 30, 2020.[34] The total confirmed cases has been raised up to 354,065 within 5 months in India, which is the highest number of confirmed COVID-19 cases in Asia and the fourth highest in world as on June 15, 2020.[6] It implies that COVID-19 is drastically spreading among 1.3 billions of people in India. Out of the total confirmed cases, 186,935 patients have been recovered and total 11,900 deaths in country till mid June 2020.[35] In anticipation, nationwide lockdown was imposed by Indian government in five phases.[34] During this lockdown period, all social activities such as transport, industries, and shopping malls had been strictly prohibited in India.[35]

MATERIALS AND METHODS

Study Area

India is the second highest populated country (13×10^8, 17.7% of worldwide) after China located at north of the equator between 8°4' north to 37°6' north latitude and 68°7' east to 97°25' east longitude. It stands as the seventh largest country in the world, with a total area of 3.28×10^6 km^2. It is surrounded by Arabian Sea (in west), Indian Ocean (in south), and Bay of Bengal (in east). The north-east region of India has been covered with the Himalayas. Figure 1 shows the study area. The study further focuses on the three most crucial states of India in COVID-19 transmission, that is, Delhi, Maharashtra, and Tamil Nadu. These are the three major states of India. The population of these states are 1.8×10^7, 1.23×10^8, and 7.7×10^7, respectively, as on 2019.[36] Most importantly, these three are most affected states of India from COVID-19 as on mid-June 2020.

Data Collection

The digital dataset for the COVID-19 in India has been obtained from Ministry of Health and Family Welfare (MoHFW)[35] and official website of COVID-19.[34] The data related to CPs (average temperature [AT], relative humidity [RH], atmospheric pressure [AP], solar radiation [SR], and wind speed [WS]) are authentically retrieved from official online portal of Central Pollution Control Board (CPCB).[37] Retrieved data of CPs and COVID-19 from the sources were not distributed normally. Therefore for estimating correlation coefficient between parameters, we use Kendall and spearman rank test. Further, SIR model has been used for the prediction of epidemic of COVID-19.[38,39] For interpretation of results and graphics, we utilized machine learning technique.

RESULTS

The spatial distribution of COVID-19 parameters (positive cases [PC], recovery, and death [DT]) during the lockdown in India is shown in Figure 2. The whole lockdown period has been categorized in two phases, that is, period-I (from March 25, 2020, to May 3, 2020) and period-II (from May 4 to June 15). Figure 2 clearly indicates that Delhi, Maharashtra, and Tamil Nadu are the most affected states of India from COVID-19 pandemic till mid-June 2020. The additional details of COVID-19 parameters during the different lockdown phases are mentioned in Table 1. On observing Table 1 carefully, it is clear that PC and mortality increase rapidly all over India during lockdown period. One more important observation is that the cases are still increasing as on June 15, 2020, and the saturation state of COVID-19 cases still not achieved in India.

The variation in CPs (24 h average value) of during the period of 3 months (April 25 to June 15) has been observed

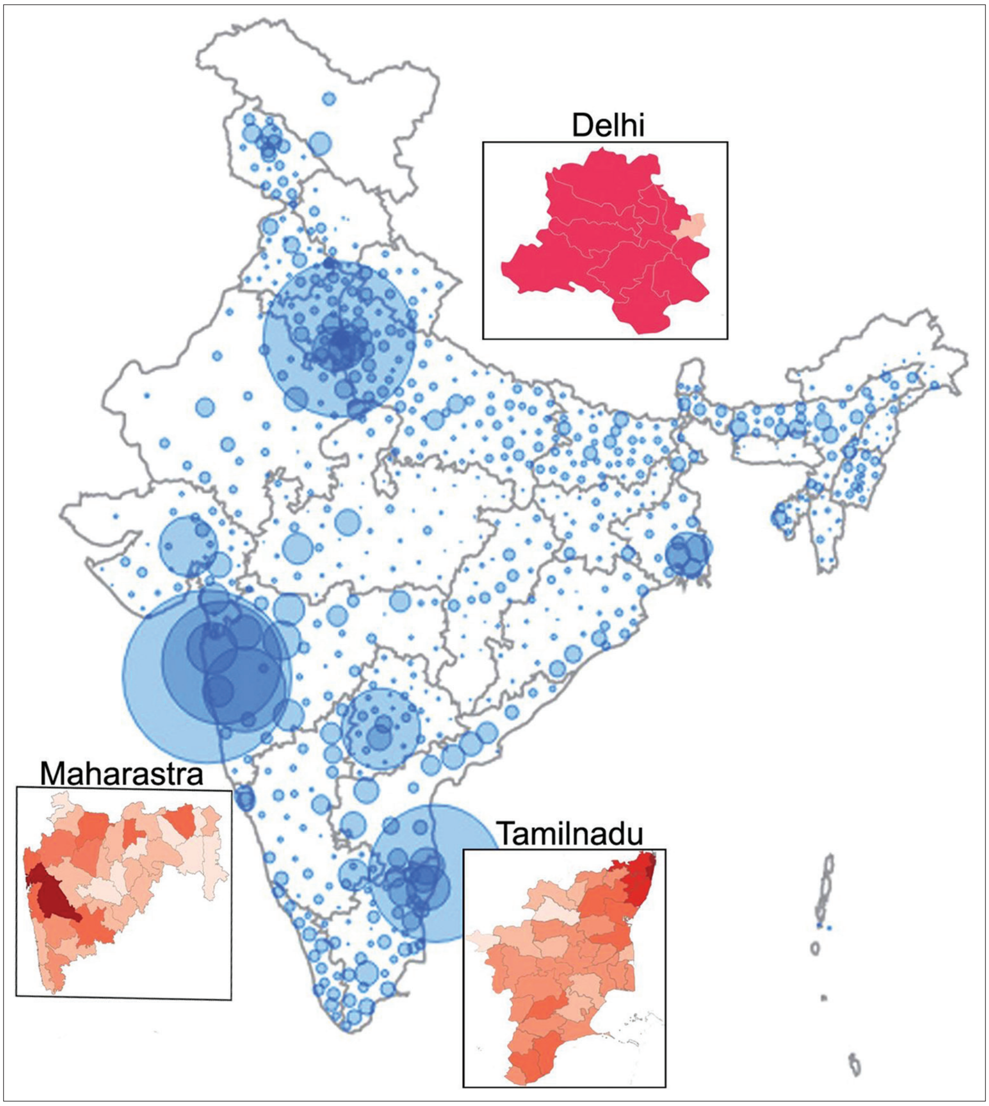


Figure 1: COVID-19 outbreak in India

for previous 3 years (2018–2020) for three states of India, that is, Maharashtra, Delhi, and Tamil Nadu, as illustrated in Figure 3a-c. We have observed similar trends in 2020 as compared to 2018 and 2019. However, a unique quantitative variation in CPs has been noticed for year 2020. AT significantly reduces with respect to previous years in the range of 5.2~10.4%. Moreover, the RH represents ascending trend in all 3 years with relative difference (2.4–40%). It is an intuition that this variation is correlated with the COVID-19 pandemic up to some extent. Moreover, the study of variation of CPs has been carried out during lockdown period in Maharashtra, Delhi, and Tamil Nadu. Corresponding parameters have been tabulated in Table 2. It depicts that the implementation of lockdown is a factor for considerable variations in CPs and air quality.

CPs (AT, AP, RH, SR, and WS) play an important role in stability of environment. To quantify the correlation between COVID-19 spread and CPs, we have statistically analyzed the data and estimated correlation coefficient between CPs and COVID-19 parameters using Spearman rank test and Kendall test, as shown in Table 3. It was observed that the number of PC was highly correlated with AT for Delhi ($r^2 > 0.6$) whereas moderate correlation is observed for Tamil Nadu and Maharashtra ($r^2 < 0.6$) with significant level of 0.1% ($P < 0.001$).

In addition, the significant correlation between RH and PC was observed for the three states, that is, positive correlation ($r^2 > 0.6$, $P < 0.001$) and intermediate correlation for Delhi ($P > 0.1$) and Maharashtra ($r^2 < 0.6$). However, SR is not significantly correlated with COVID parameters. Meanwhile, it is observed that WS affects COVID-19 cases as the corresponding correlation coefficient is positive. In brief, the obtained statistical results for most of the CPs were found very significant with $P < 0.001$ in India. It is further observed that the mortality rate is growing with time. The CPs were showed a moderate correlation with DT. To have more clear insight, the scattered correlation matrices of CPs and COVID-19 parameters for Delhi, Maharashtra, and Tamil Nadu shown in

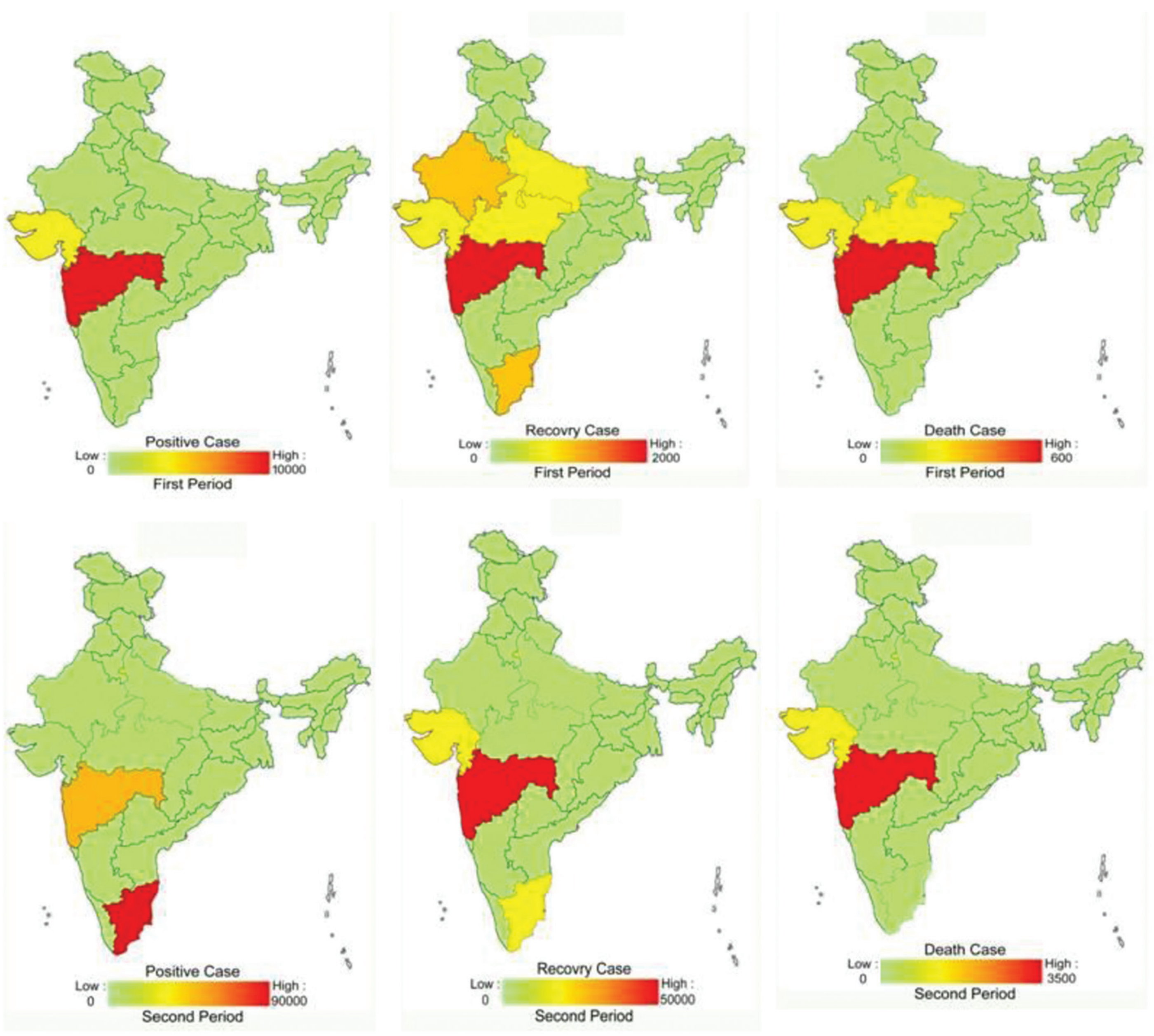


Figure 2: Spatial distribution of COVID-19 parameters in India

Figure 4a-c. It is observed that the maximum PC have been reported within the AT range (25~40°C). Similarly, the most frequent ranges for other CPs corresponding to most number of PC are 40~70%, 740~965 mmHg, and 200~250 W/m^2 for RH, AP, and SR, respectively. Particularly, a wide range for WS (0.5~14 m/s) has been calculated for having maximum no. of PC from Delhi to Tamil Nadu and varying with latitude. In lower latitude, the no. of PC is high within the range of WS (10~14 m/s) although for northern region at higher latitude, it is observed (0.5~1.5 m/s). This leads to conclude that the areas experience such climatically condition have been mostly affected by COVID-19.

Figure 5 represents the time series of no. of PC and mortality during lockdown period (March 25–June 15) for three crucial states of India, that is, Delhi, Maharashtra, and Tamil Nadu. The corresponding plot indicates that variation in PC and mortality cases increases exponentially with respect to time. Figure 6 provides a prediction of the number of COVID-19 cases in subsequent times in Delhi. The epidemic peak for COVID-19 in Delhi has been predicted on October 2020.[38]

DISCUSSION

The CPs (AT, RH, AP, SR, and WS) are one of the crucial factors for in COVID-19 dissemination in India. On analyzing the available COVID-19 dataset, we have observed that the number of COVID-19 cases is still growing significantly despite imposing containment strategies, that is, lockdown in

Table 1: Details of COVID-19 parameters during different phases of lockdown

Lockdown phase in India	I period		II period		
	I phase (March 25–April 14)	II phase (April 15–May 3)	III phase (May 4–May 17)	IV phase (May 18–May 31)	V phase (June 1–June 15)
India (20.59 N, 78.96 E)					
PC	11,485	31,294	52,920	94,949	152,423
Mortality	396	1067	1562	2380	4512
Recovered cases	1365	10,398	25,032	55,067	88,461
Delhi (28.70 N, 72.87 E)					
PC	1561	2988	5206	10,089	22,985
Mortality	30	34	84	327	925
Recovered cases	31	1331	2840	4276	7949
Maharashtra (19.75 N, 75.71 E)					
PC	2680	10,294	20,079	34,602	43,089
Mortality	178	370	650	1088	1842
Recovered cases	259	1856	5573	21,641	26,720
Tamil Nadu (11.12 N, 78.65 E)					
PC	1204	1819	8201	11,110	24,170
Mortality	12	18	49	97	303
Recovered cases	81	1298	2793	8585	12,587

PC: Positive case, COVID-19: Coronavirus disease 2019

Table 2: Relative difference between CPs for year 2018–2020 (March 25–June 15)

CPs	Delhi			Maharashtra			Tamil Nadu		
	Avg. 2020	Relative difference (%)		Avg. 2020	Relative difference (%)		Avg. 2020	Relative difference (%)	
		2018–2019	2019–2020		2018–2019	2019–2020		2018–2019	2019–2020
AT	29	9.5	10.45	31.64	5.2	5.99	28.9	8.6	7.4
RH	50.59	2.4	38	68.07	2.4	2.4	66.27	11.54	21.09
AP	982.38	18	0.17	734.68	40.18	40.19	749.8	33.85	31.8
WS	0.78	92.3	41.02	0.113	21.9	22.2	9.482	77.28	75.84
SR	189.23	13.8	17.6	158.28	29.9	60.1	242.72	7.7	10.2

AT: Average temperature, RH: Relative humidity, AP: Atmospheric pressure, SR: Solar radiation, WS: Wind speed

Table 3: Correlation coefficients between CPs with COVID-19 parameters

Test	CPs	Delhi		Maharashtra		Tamil Nadu	
		PC	Mortality	PC	Mortality	PC	Mortality
Spearman correlation coefficient	AT	0.821	0.753	0.099	0.071	–0.550	–0.536
	RH	0.054	–0.209	–0.438	–0.473	0.615	0.560
	AP	–0.842	–0.736	–0.784	–0.797	–0.799	–0.774
	WS	0.326	0.047	0.421	0.413	0.733	0.722
	SR	0.334	0.270	–0.297	–0.294	–0.329	–0.413
Kendall correlation coefficient	AT	0.635	0.635	0.081	0.056	–0.390	–0.398
	RH	0.030	–0.172	–0.310	–0.334	0.465	0.423
	AP	–0.646	–0.563	–0.580	–0.602	–0.559	–0.559
	WS	0.200	0.040	0.263	0.256	0.529	0.550
	SR	0.214	0.187	–0.176	–0.180	–0.228	–0.302

AT: Average temperature, RH: Relative humidity, AP: Atmospheric pressure, SR: Solar radiation, WS: Wind speed

India. It clearly indicates that there are some other factors (CPs) other than social activities which are influencing COVID-19 transmission in India. It has been also observed that transmission rate of COVID-19 is highest in three states of India, that is, Maharashtra, Delhi, and Tamil Nadu. In Delhi, the number of cases is positively correlated with

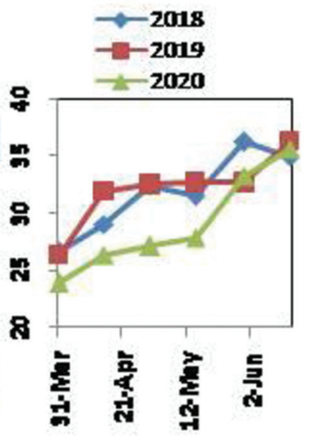
AVERAGE TEMPERATURE

2019

SUN	MON	TUE	WED	THU	FRI	SAT	AV
26.1	24.5	25.0	26.4	28.6	30.7	32.3	
30.0	28.8	29.5	30.5	31.8	32.9	33.3	
30.6	29.2	30.6	33.3	34.1	31.9	32.9	
33.3	35.1	26.3	23.9	26.2	28.9	30.9	
33.1	33.9	36.0	35.1	34.8	35.8	36.3	
36.3	34.5	35.3	33.7	31.9	30.7	31.1	
35.1	33.1	33.3	34.3	35.0	35.4	33.3	
32.7	32.1	30.1	28.6	29.4	27.9	27.7	
31.2	33.1	34.5	33.1	32.2	28.8	32.2	
33.3	34.7	34.8	36.0	37.2	36.6	36.4	
36.5	35.0	35.0	36.8	36.5	33.9	36.2	
36.3	38.0	38.2	34.8	36.1	37.0	37.5	

2020

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		24.1	24.9	24.3	22.7	23.1	
24.2	24.0	24.8	25.3	25.0	24.2	24.5	
25.2	26.9	25.9	25.9	25.5	26.5	27.6	
27.5	27.9	28.7	29.1	28.8	28.5	26.8	
26.4	25.5	26.3	26.9	27.0	27.5	28.2	
25.4	25.7	26.8	28.2	28.8	28.9	28.1	
26.5	26.4	28.1	27.5	27.5	29.2	30.0	
26.5	27.0	28.0	27.7	27.9	28.3	28.8	
29.1	28.9	29.2	29.4	30.1	30.6	34.9	
39.7	38.7	39.3	39.5	36.1	33.5	33.5	
31.1	32.4	34.1	34.8	33.6	33.9	34.6	
34.0	35.5	37.4	37.7	37.3	38.0	35.5	
36.4	38.5						



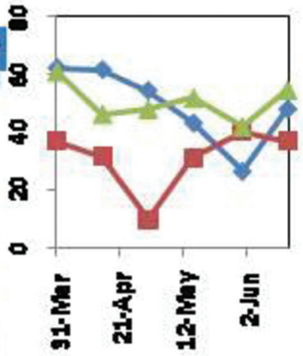
RELATIVE HUMIDITY

2019

SUN	MON	TUE	WED	THU	FRI	SAT	AV
35.3	43.8	40.7	36.8	38.0	41.0	36.6	
29.6	29.4	29.8	28.7	31.5	31.7	30.7	
46.6	40.0	36.1	32.8	27.4	32.5	28.4	
27.3	24.0	45.4	34.1	2.5	2.5	2.5	
2.5	2.5	2.5	2.5	2.5	2.5	2.5	
2.5	20.5	21.4	29.8	34.9	37.5	30.4	
19.9	21.4	23.7	23.7	22.7	22.1	30.1	
32.1	37.7	46.1	56.4	52.8	60.8	63.7	
42.8	36.2	32.5	39.1	48.5	63.6	42.6	
32.8	28.4	22.9	25.1	25.5	27.8	36.6	
47.2	46.2	45.3	40.6	35.3	45.0	39.5	
33.8	29.6	24.4	39.6	39.4	28.5	24.4	

2020

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		62.5	63.0	62.6	69.3	68.2	
57.8	55.9	54.1	53.5	51.9	47.0	50.0	
50.9	46.7	47.9	43.3	45.8	44.7	43.4	
43.1	44.3	43.7	38.4	38.0	38.4	48.6	
50.2	51.4	48.5	44.3	43.8	46.5	42.4	
54.8	58.8	54.4	51.4	48.9	52.3	52.6	
59.7	57.6	50.1	47.6	45.9	45.8	46.0	
54.7	55.3	51.2	54.4	56.9	47.6	42.9	
42.7	40.5	37.6	33.7	33.8	36.4	36.5	
34.1	35.1	34.5	34.6	48.3	55.8	57.1	
68.5	63.3	58.0	53.7	57.5	55.6	56.7	
56.7	53.9	49.8	48.9	50.8	50.3	59.1	
57.6	48.1						



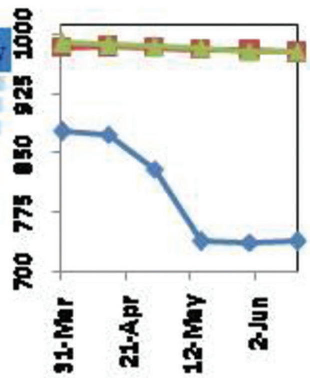
ATMOSPHERIC PRESSURE

2019

SUN	MON	TUE	WED	THU	FRI	SAT	AV
983	982	982	981	982	982	982	
982	982	981	982	982	981	983	
986	983	983	986	986	984	986	
985	984	984	984	984	984	984	
983	981	982	981	981	981	981	
981	980	977	977	979	981	983	
983	980	979	979	978	979	982	
981	980	981	982	983	983	983	
983	983	982	980	980	981	981	
979	979	978	977	976	976	976	
976	977	977	977	977	980	978	
976	973	973	976	976	975	975	

2020

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		987	987	988	990	990	
988	988	987	986	986	988	988	
988	987	985	986	986	987	988	
986	984	984	984	982	982	984	
983	984	985	983	982	981	981	
984	987	987	984	983	981	981	
983	984	982	982	982	981	981	
983	984	983	982	981	981	979	
978	977	977	976	975	975	977	
977	977	975	974	976	979	980	
982	983	981	979	978	978	978	
977	977	976	976	975	974	974	
976	974						



WIND SPEED

2019

SUN	MON	TUE	WED	THU	FRI	SAT	AV
1.22	1.2	1.19	0.84	0.46	0.49	0.54	
1.77	1.61	0.68	0.66	0.68	0.82	1.01	
2.49	1.17	0.78	0.65	0.61	0.95	1.3	
1.39	1.17	2.56	1.99	0.73	0.7	0.55	
0.77	0.73	0.76	1.28	1.33	0.82	1.97	
1.55	0.75	0.89	0.71	1.92	1.32	0.62	
0.52	0.6	0.82	1.03	1.2	1.17	0.63	
0.84	0.86	0.58	0.94	0.57	1.03	0.72	
0.71	0.67	0.73	0.54	0.82	1.21	1.74	
1.13	1.08	1.14	0.8	0.86	0.94	1.7	
2.61	3.49	2.51	1.25	1.25	1.28	0.71	
0.58	0.64	0.91	2.69	0.9	1.14	1.24	

2020

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		0.66	0.49	1.98	0.78	0.66	
0.53	0.58	0.56	0.57	0.66	0.47	0.40	
0.70	0.51	0.70	0.39	0.51	0.39	0.55	
0.56	0.66	0.46	0.50	0.55	0.99	1.44	
0.67	0.97	0.62	0.49	0.53	0.54	0.79	
1.51	1.82	0.98	0.67	0.75	1.22	1.66	
1.28	0.95	0.55	0.81	0.90	0.80	0.97	
1.40	1.04	1.13	0.59	0.75	0.55	0.49	
0.50	0.48	0.49	0.50	0.54	0.50	0.60	
0.61	0.79	0.93	1.16	1.87	1.81	1.08	
1.16	0.82	0.78	0.80	0.88	0.89	0.81	
0.93	0.64	0.54	0.84	0.89	0.73	0.81	
0.86	0.60						

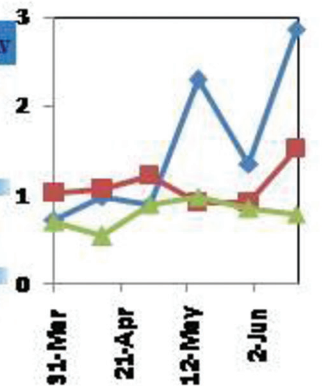


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Figure 3: (a) Status of daily (24 hrs.) average of meteorological parameters from 24th March to 15th June for Delhi

AVERAGE TEMPERATURE

2019

SUN	MON	TUE	WED	THU	FRI	SAT	AV
26.2	25.7	25.1	23.2	23.6	23.6	26.2	
24.5	24.4	23.8	23.8	23.9	24.2	24.9	
24.6	24.5	25.0	24.8	25.4	24.5	27.7	
25.6	24.0	22.9	22.5	23.5	23.2	22.6	
22.8	22.5	23.0	22.2	23.1	22.8	22.8	
21.8	20.7	23.9	38.7	39.4	38.2	39.3	
39.7	39.5	41.2	41.4	41.3	41.0	41.3	
41.1	41.0	40.9	38.9	41.4	41.4	40.6	
41.3	41.4	41.0	42.2	41.9	42.1	42.4	
41.2	43.4	43.6	41.1	40.3	38.2	36.5	
38.8	36.7	33.9	37.0	37.9	35.5	35.2	
36.7	35.4	34.8	34.8	33.9	34.6	34.9	

2020

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		30.8	33.0	31.5	32.1	32.6	
32.8	32.9	32.9	31.6	34.9	30.5	30.8	
27.6	33.6	33.1	32.7	29.1	34.1	31.7	
34.0	33.1	36.7	33.7	34.6	36.9	34.4	
29.8	31.8	32.2	31.5	32.4	32.0	32.9	
32.2	31.1	29.8	31.4	31.6	31.8	33.1	
34.5	34.1	34.3	32.1	31.5	32.1	32.3	
29.6	31.0	32.5	32.0	32.7	33.5	32.8	
30.9	33.3	32.6	33.6	32.9	33.9	34.9	
35.4	35.7	35.1	36.2	36.1	36.6	34.4	
32.1	31.9	32.3	29.9	31.0	32.9	33.6	
33.9	34.5	34.9	33.4	30.7	30.3	30.7	
31.1	29.4						

RELATIVE HUMIDITY

SUN	MON	TUE	WED	THU	FRI	SAT	AV
33.67	34.34	22.64	38.58	31.82	32.18	30.36	
33.8	30.7	37.5	36.8	39.1	34.9	31.5	
34.9	36.2	38.1	36.8	33.0	33.7	26.9	
31.4	34.1	33.6	39.3	36.5	40.0	41.6	
41.5	40.7	38.3	40.1	38.9	36.6	38.0	
36	36	38	27.4	30.7	31.3	27.3	
27.5	28.0	27.9	27.4	27.5	27.9	30.2	
31.1	30.9	31.5	36.0	30.9	28.7	29.0	
28.5	30.5	33.4	32.8	34.8	33.3	28.4	
30.5	27.3	27.6	28.4	32.5	36.1	40.3	
34.6	39.6	45.1	35.6	34.2	38.7	40.7	
35.2	27.7	17.1	6.6	24.3	36.9	34.8	

SUN	MON	TUE	WED	THU	FRI	SAT	AV.
		71.5	74.6	76.1	72.4	60.3	
59.3	64.5	71.2	72.3	72.1	73.5	76.3	
78.6	78.7	77.9	74.4	74.3	75.9	74.0	
79.0	78.7	74.1	75.5	76.9	78.8	74.4	
73.1	61.7	72.3	68.9	74.7	75.8	73.7	
70.7	72.5	71.2	73.3	75.4	73.7	74.4	
74.7	74.2	71.4	78.9	74.1	73.0	73.3	
74.5	76.3	73.8	73.8	71.3	71.6	74.1	
72.4	71.9	70.5	71.1	71.9	72.0	74.1	
76.2	76.5	76.2	73.3	71.4	73.5	73.9	
70.1	55.1	50.8	39.0	42.0	27.2	17.2	
20.2	23.1	31.0	48.1	60.5	62.0	62.6	
62.0	70.8						

ATMOSPHERIC PRESSURE

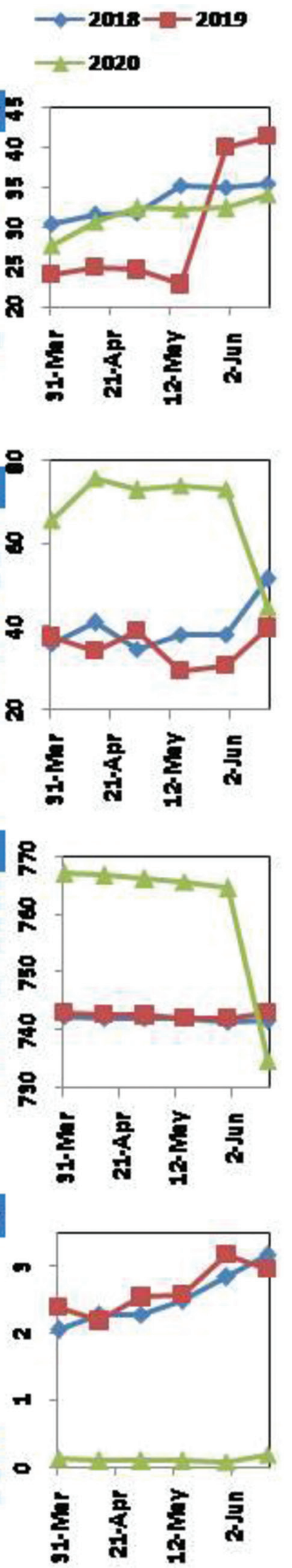
SUN	MON	TUE	WED	THU	FRI	SAT	AV
743	743	743	743	743	743	743	
743	743	743	743	743	743	743	
743	742	743	743	743	743	743	
743	743	743	743	743	743	742	
742	742	742	746	741	742	743	
743	742	742	742	742	742	742	
743	742	742	742	742	742	742	
742	742	742	742	742	742	742	
742	742	742	742	742	742	742	
742	742	742	742	742	742	742	
742	742	742	742	742	742	742	
742	742	742	742	742	742	742	

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		765	765	766	768	767	
766	766	767	767	766	766	766	
767	768	767	768	768	767	768	
767	766	766	767	766	766	766	
766	765	767	766	766	766	766	
766	767	768	766	766	767	766	
766	766	767	765	766	766	766	
766	767	766	765	764	764	764	
764	764	763	763	764	765	765	
765	766	766	766	765	765	765	
765	734	735	736	735	734	734	
734	733	733	734	735	736	735	
735	736						

WIND SPEED

SUN	MON	TUE	WED	THU	FRI	SAT	AV
2.25	2.29	2.14	2.11	2.57	2.12	2.2	
2.48	2.35	2.37	2.37	1.91	2.35	2.36	
2.31	1.77	2.45	2.16	2.31	2.52	2.32	
2.31	2.32	2.23	2.08	1.69	2.36	2.9	
2.13	2.27	2.54	2.36	2.32	2.4	2.6	
2.75	3.04	3.55	3.28	2.97	2.72	2.37	
2.59	2.8	2.84	2.59	2.46	2.48	3.09	
3.19	2.88	3.15	3.12	2.82	2.21	3	
3.5	2.85	2.95	3.18	3.09	3.44	3.7	
3.02	2.83	3.4	4.08	3.82	2.77	2.98	
2.68	2.89	3.25	2.97	3.53	3.76	4.25	
4.7	4.34	4.86	5.16	5.26	4.85	4.95	

SUN	MON	TUE	WED	THU	FRI	SAT	AV
		0.09	0.1	0.08	0.08	0.13	
0.08	0.09	0.1	0.11	0.11	0.09	0.15	
0.08	0.11	0.09	0.1	0.1	0.07	0.08	
0.08	0.07	0.08	0.09	0.17	0.07	0.08	
0.11	0.08	0.11	0.08	0.09	0.09	0.07	
0.08	0.13	0.07	0.06	0.07	0.26	0.06	
0.05	0.07	0.06	0.08	0.07	0.07	0.06	
0.06	0.07	0.07	0.07	0.07	0.06	0.1	
0.06	0.07	0.07	0.09	0.09	0.18	0.23	
0.12	0.09	1.17	0.11	0.18	0.14	0.15	
0.22	0.3	0.3	0.3	0.3	0.3	0.3	
0.3	0.3	0.3	0.3	0.3	0.3	0.3	
0.3	0.3						



b

Figure 3: (b) Status of daily (24 hrs.) average of meteorological parameters from 24th March to 15th June for Maharashtra (*Continued*)

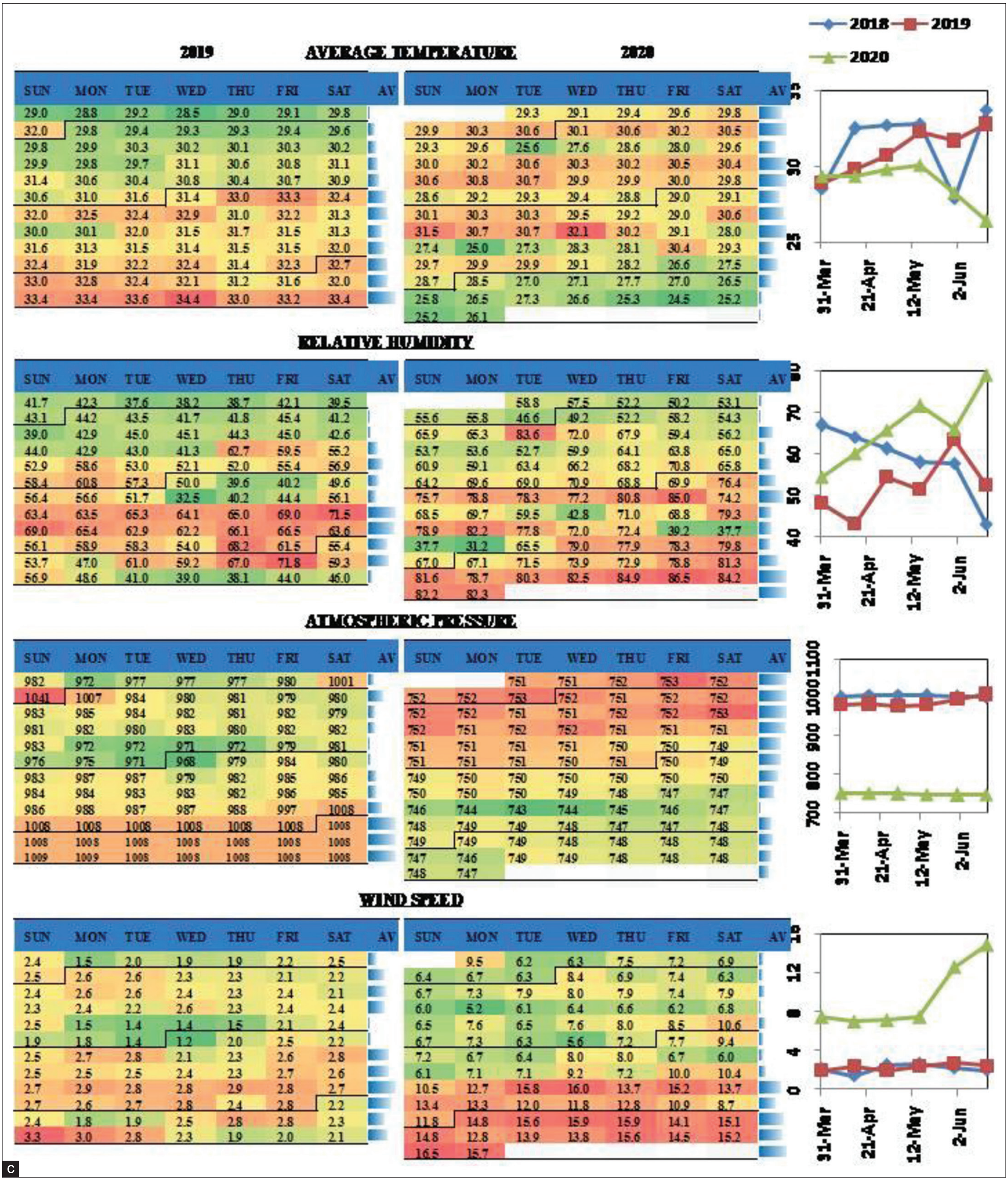


Figure 3: (c) Status of daily (24 hrs.) average of meteorological parameters from 24th March to 15th June for Tamilnadu (*Continued*)

AT ($r^2 > 0.6$) whereas the correlation is moderate for other two states. Similarly, all other CPs (AP, RH, SR, and WS) show critical correlation with transmission of COVID-19 in India with 0.1% of significance level ($p < 0.001$). Further, the substantial variations of CPs have also been observed in the past 3 years. On comparing the AT (daily average

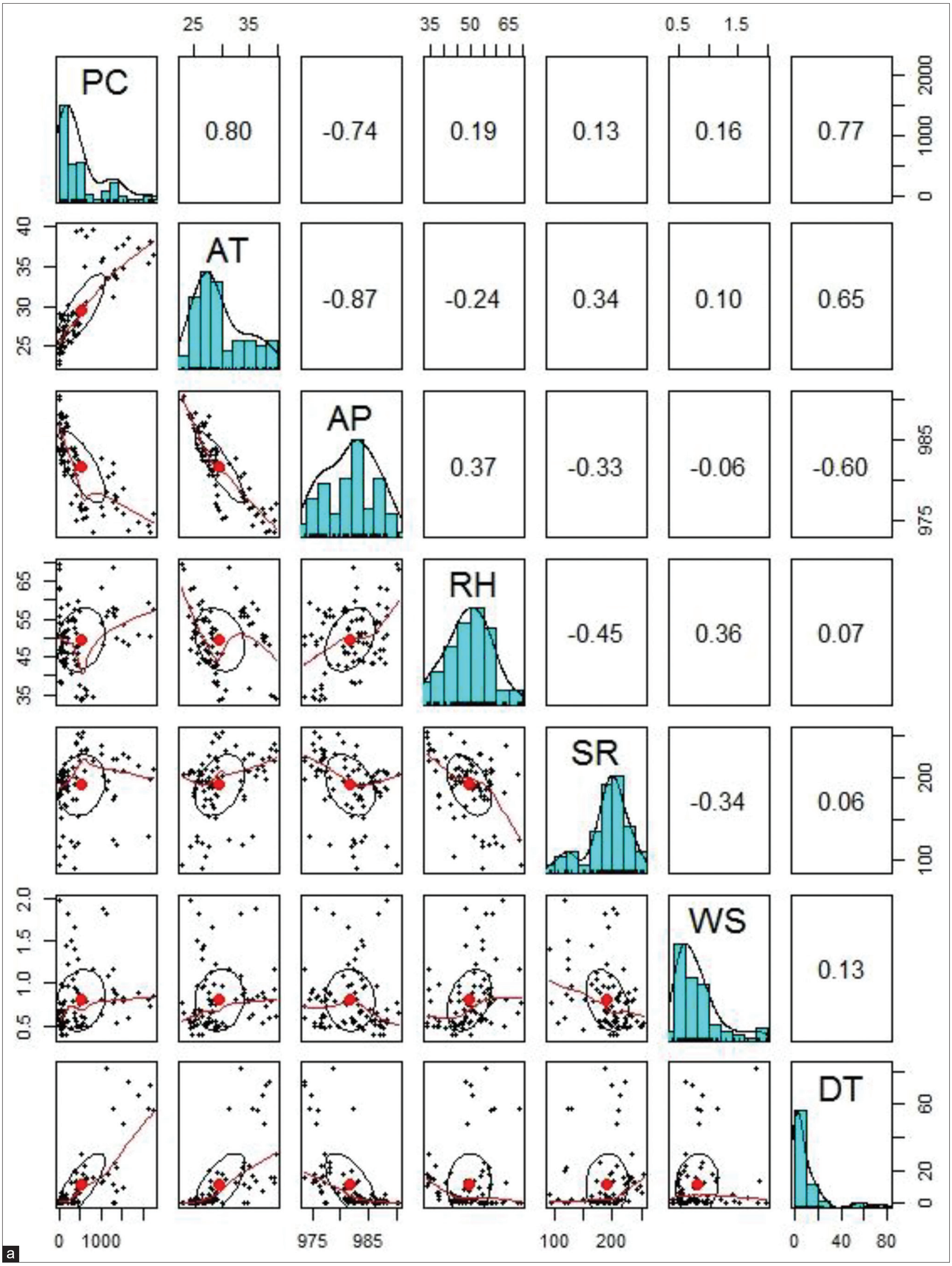


Figure 4: (a) Scattered correlation matrices of meteorological parameters and COVID-19 from 25th March to 15th June for Delhi

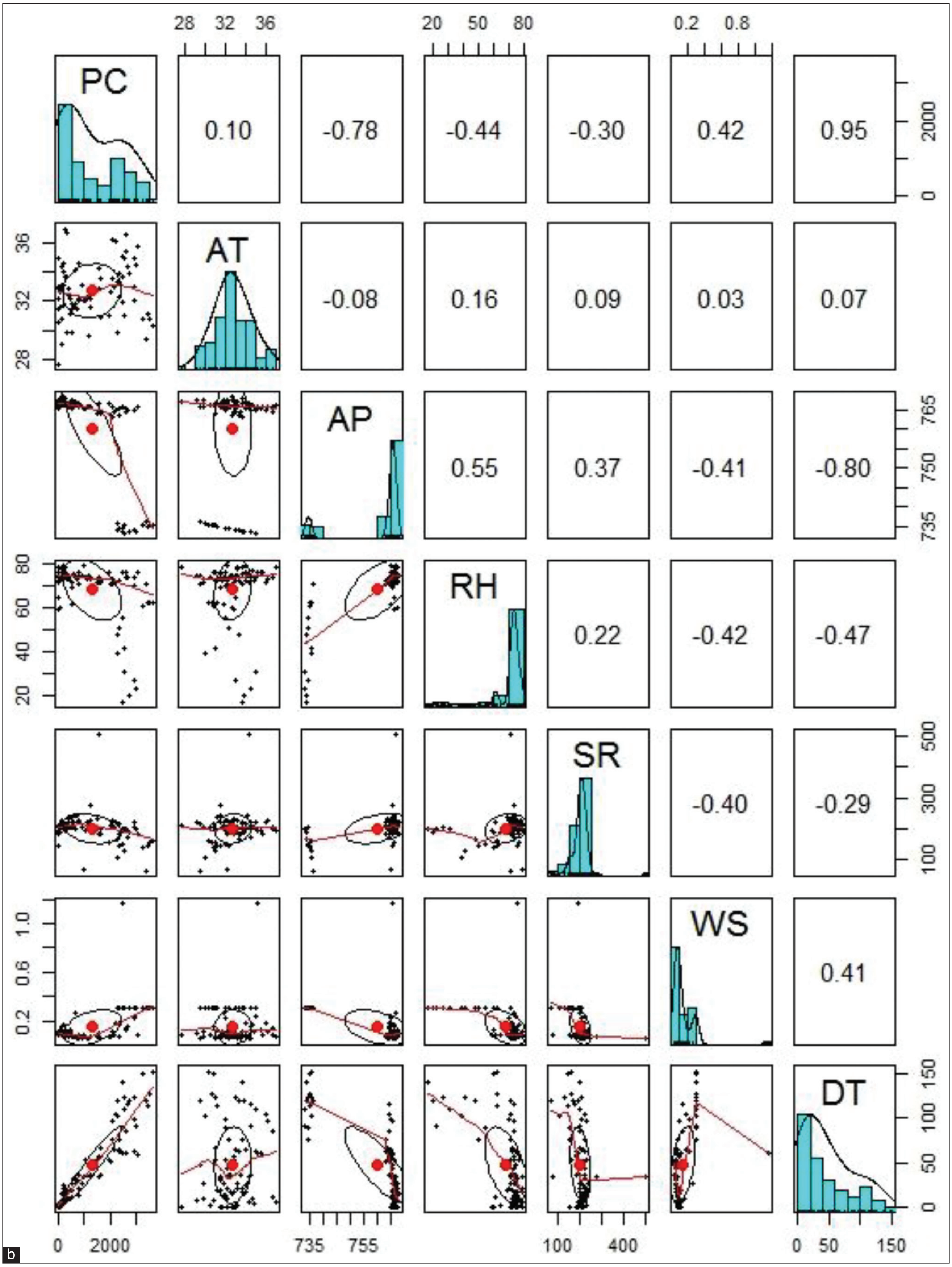


Figure 4: (b) Scattered correlation matrices of meteorological parameters and COVID-19 from 25th March to 15th June for Maharashtra (*Continued*)

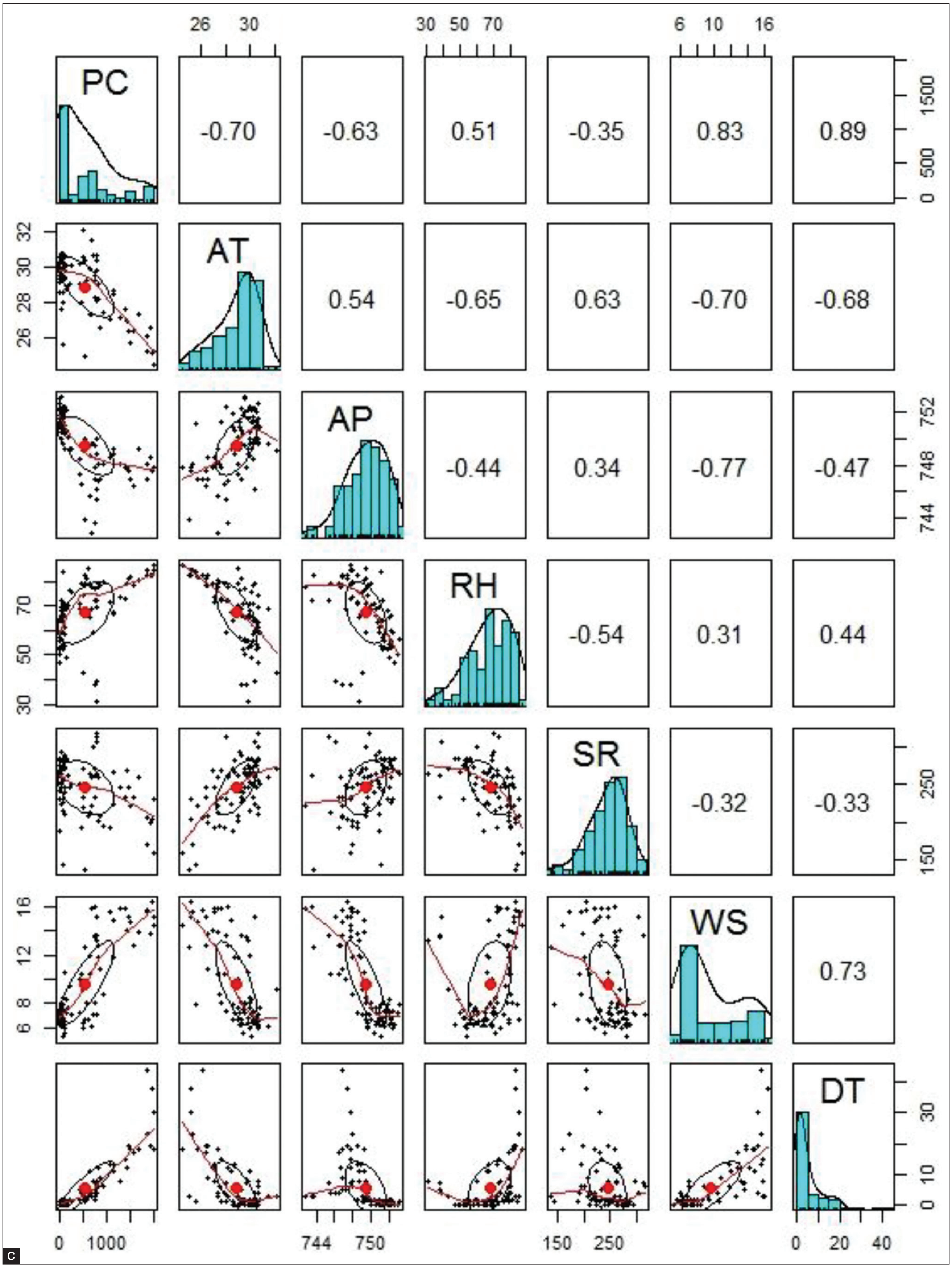


Figure 4: (c) Scattered correlation matrices of meteorological parameters and COVID-19 from 25th March to 15th June for Tamilnadu (*Continued*)

of 24 h) of previous 3 years (2018–2020), a unique trend (decreasing comparatively) is observed. Moreover, the range of CPs has been found corresponding to maximum number of cases results as AT (25~40°C), RH (40~70%), AT (740~965

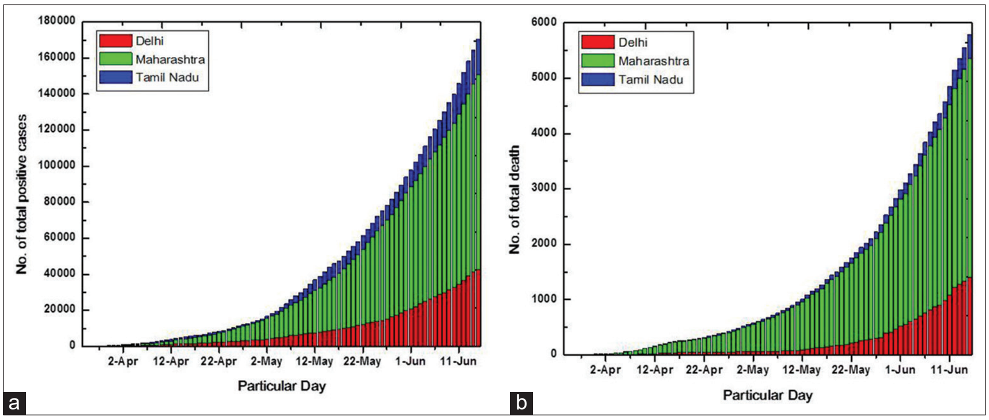


Figure 5: Time series of number of positive cases and death

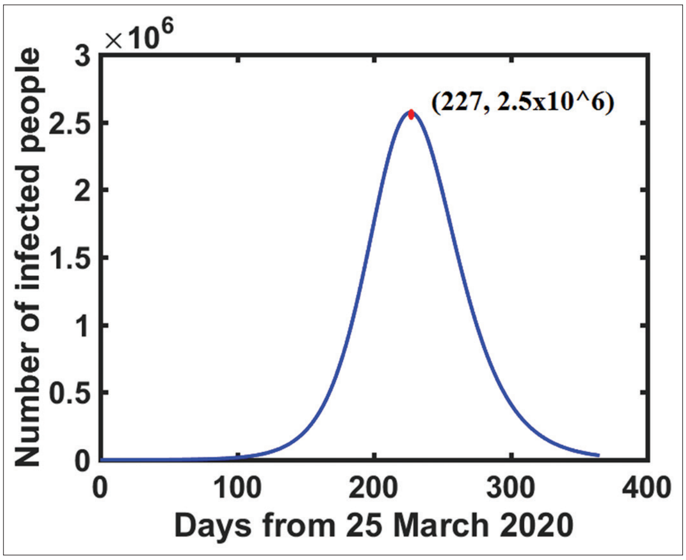


Figure 6: COVID-19 epidemic peak prediction for Delhi using SIR model

mmHg), SR (200–250 W/m^2), and WS (0.5~14 m/s). It signifies that for the maximum transition of COVID-19, a susceptible weathers condition is required. In addition, the epidemic peak (highest number of cases) in New Delhi (capital of India) has been predicted around October 2020–November 2020. It implies that COVID-19 transmission decreases in winter in India which compliments the results obtained from correlation tests.

Various studies have been carried out in context of COVID-19 and CPs recently. Shi *et al.* observed reverse correlation of COVID-19 factors with temperature and found a smooth increase of PC with rising temperature.[26] It has also concluded that warm weather might suppress COVID-19 epidemic progression.[28,40] In this study, we have observed positive correlation of PC with temperature during the study period in India. In addition, we have determined a dynamic range of AT (25~40°C) for maximum transition of COVID-19 epidemic in India.

In another recent study (conducted in Indonesia), the PCs were found to be slightly correlated with minimum, maximum, and AT with correlation coefficient (0.12, 0.23, and 0.392), respectively.[29] Similar results have obtained for New York City correlation coefficient with minimum maximum and AT was 0.06, 0.268, and 0.339, respectively.[24] These studies suggested that PCs do not correlate significantly with humidity and rainfall in their respective study area. Whereas, in present study, we have found high correlation with humidity for Tamil Nadu and Maharashtra as it is a coastal area of India and moderated correlation for Delhi. This discrepancy has been raised because these two studies have been carried out at very early stage of COVD-19 progression. On the other hand, a larger dataset has been analyzed in the present study.

In perspective of India, several studies have been reported analyzing the mitigation strategies, health policies for controlling COVID-19 in India.[40-42] Kumar *et al.* found a positive association with temperature and mixed association with RH.[40] In the present study, we found a reverse correlation coefficient with AP, SR –0.078 and –0.34, respectively, and also determined a range of 740~965 mmHg and 200~250 W/m^2 for AP and SR, respectively, for maximum PCs. Moreover, the present study depicts a wide range for WS (0.5~14 m/s) for maximum transition of COVID-19. It suggests that SARS-COV virus might be airborne.

Despite the enthusiastic outcomes of this study, there are further specific factors (people emigration, various government policies for containment, etc.) which must be considered to obtain a more accurate prediction of COVID-19 epidemic parameters. Nevertheless, this study has the potential to enhance the current understanding of COVID-19 spreading and will help for the advancement of vaccination process of COVID-19.

CONCLUSION

The present study provides a comprehensive analysis of COVID-19 dissemination and its statistical correlation with CPs in India during a time period of 90 days. On the basis of this study, it is concluded that CPs have played a decent role in COVID-19 progression in India. In addition, we found a wide range of WS for transition of SARS-COV virus. It indicates that SARS-COV-2 virus might be airborne. Further, this study indicates that the COVID-19 containment policy, that is, lockdown adapted in India leads to reduced pollution level, improves climatic conditions in the past few months. Such exceptional changes have never been observed in nature before in short time duration. Therefore, one can expect that the lockdown would be effective for better public health and sustainable development of nature in future.

ACKNOWLEDGMENT

Authors would like to thank the CPCB, Ministry of Environment, Forest and Climate Change, and Ministry of Human Resources and Development, Government of India.

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How to cite this article: Deyal N, Tiwari V, Bisht NS. Impact of climatic parameters on coronavirus disease 2019 pandemic progression in India: Analysis and prediction. Int J Med Sci Public Health 2021;10(1):68-81.

Source of Support: Nil, **Conflicts of Interest: N**one declared.