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Short-term Impact of Weather Parameters on COVID-19 Cases in 25 States and Union Territories of India

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ABSTRACT: To investigate the impact of the meteorological parameters (MPs) and COVID-19, the study is divided into two-stage i.e. early stage (24 March 2020 to 30 April 2020) and later stage (1 May 2020 to 15 June 2020). The key issues of this analysis were to derive meteorological parameters for the selected states and union territories. To solve the above issues and to understand the effect of meteorological parameters on COVID-19, we used re-analysis data derived from satellite. Maharashtra was highly affected with 107958 people infected with an exponential growth after 30 March 2020. Tamilnadu, Delhi and Gujrat were also highly affected whereas Andaman & Nicobar Island, Chandigarh, Chhattisgarh, Goa were weekly influenced due to relatively low population. The statistical significance relations were also investigated by adopting the Spearman and Kendall rank correlation analysis between COVID-19 cases and MPs. The Maharashtra, Telangana, Tamilnadu, Andhra Pradesh, West Bengal and Odisha, etc., were strongly influenced by absolute Humidity, whereas Temperature is found to be strongly associated in the Delhi, Rajasthan, Uttar Pradesh, J& K Haryana, Punjab, Chandigarh, etc. It is observed that 97 % to 98 % of new cases were reported in the temperature range between 24°C to 32°C for both stages. In the case of RH, 92 % to 93 % of new infections were found to be in the range of relative humidity between 30 % to 80 % and approximate 87 % to 88 % and 98 % to 96 % of contribution in the new COVID-19 cases were observed in the AH range 10 g /m^3 to 20 g /m^3 and a temperature range between 24 °C to 32 °C respectively.

Keywords: COVID-19, Relative Humidity, Absolute Humidity, Correlations, Meteorological Parameters, Temperature.

I. INTRODUCTION

Severe acute respiratory syndrome coronavirus (SARS-CoV-2) or Coronavirus disease (COVID 19) was first identified in Wuhan, Hubei province of China, on 31 December 2019 [1]. Fever, fatigue, sneezing, coughing, sore throat, headache, and shortness of breath were common symptoms of SARS-CoV-2 [2]. Generally, the symptoms and signs of the virus in any infected person are developed within 5-6 days of infection [3]. Asymptomatic infection was also reported with rare or no symptoms of infection on the date of identification [4]. This virus can be transmitted from an infected person to a healthy one, by respiratory droplets produced during coughing, sneezing, talking, and any other direct close contact activity. Other modes of transmission of the virus are through the contact of contaminated surfaces [5, 6]. Earlier reports revealed that the incubation period of the virus is the ranges between 2 to 14 days (with a mean period of 5-6 days) on the non-living object surfaces [7]. Social distancing, lockdown, regular sanitization, and quarantine processes are few safety majors taken to prevent the transmission of the virus among the masses [8, 9].
According to the world health organization, 75,53, 182 confirmed cases and 4,23,349 deaths worldwide reported as on 14 June 2020 out of which 3,08,993 confirmed cases and 8,884 deaths were only from India, and the recovery rate of 48.20% [10]. On 25 March 2020, the Indian government declared nationwide lockdown to prevent human to human transmission of the virus. Respiratory droplets produced from an infected person during coughing and sneezing can travel up to a few meters from the source of emission [11]. Although smaller droplets can travel tens of meters in a contained environment. Laboratory experiments have reported the viability period of the virus up to 3 hours on the aerosol and several days on the object surface, depending on the nature of the surface [12]. Studies also suggested the airborne transmission of SARS-CoV-2 under the favorable environment to the virus it can spread as an airborne disease as proposed in the case of previous SARS. Although airborne transmission is not yet clearly established for the coronavirus the earlier studies are supporting its probable airborne infection[13]. Weather and climatic conditions are one of the several possible factors influencing the transmission of the coronavirus [14]. Meteorological parameters can affect the transmission and viability of SARS-CoV-2 as suggested in previous studies and laboratory experiments for other coronaviruses and influenza viruses [15]
However, there is a scarcity of evidence that provides the contribution of meteorological conditions to the transmission of SARS-CoV-2, but statistical studies investigated the dependency of the spread of the virus on the weather conditions [16]. The suitable condition for the sustainability of the virus is found to be in 13 – 24°C temperature range and 50 - 80% relative humidity (RH) range, with 19°C temperature and 75% RH most suitable for the survival of SARS-CoV-2 [17, 18]. In the present study, we are investigating the impact of the meteorological parameters (temperature and Absolute humidity) on the transmission of the SARS-CoV-2 for 22 States and 3 Union Territories (UTs) of India under different geological and climatic conditions.

II. METHODOLOGY

State-wise data daily cases active and cumulative cases of COVID-19 were gathered from the official website of the Ministry of Health and Family Welfare, Government of India (https://www.mohfw.gov.in) (Fig. 1).

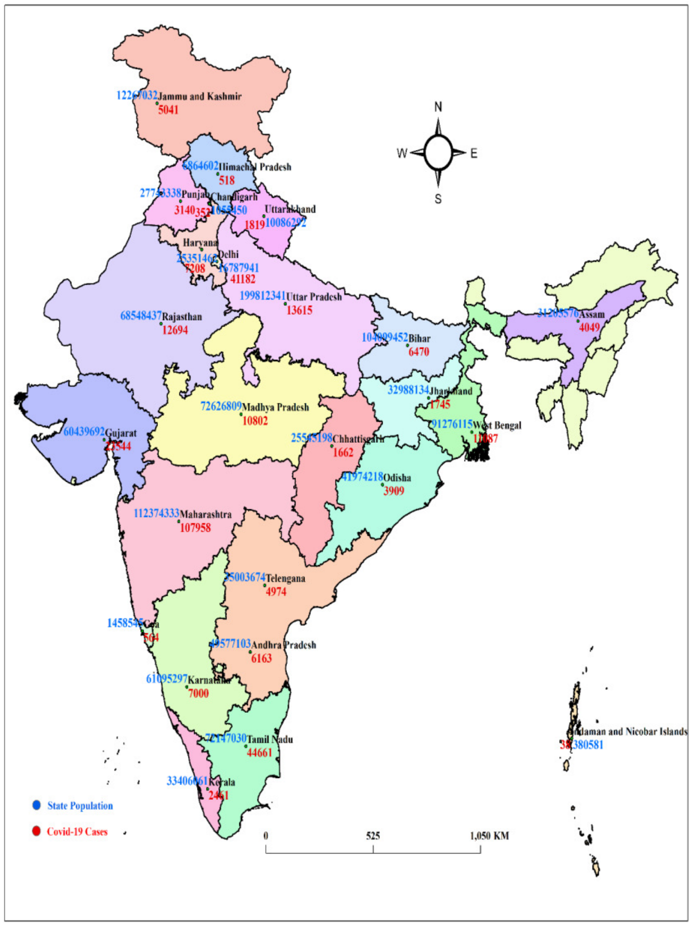

Fig. 1. Overview of COVID-19 cases and population in the selected 22 states and 3 Union Tertiaries in India.

Hourly reanalysis dataset of meteorological parameters was obtained from the European Environment Agency (ERA 5) dataset of the European Centre for Medium-Range Weather Forecasts (ECMWF). It provides the global coverage of different meteorological parameters obtained from different models and observations across the globe [19]. Temperature and relative humidity datasets are available with 0.1° × 0.1° resolution at 2 m vertical height above the ground level, and 0.25° × 0.25° at 1000 hPa pressure level respectively. Obtained dataset later masked out for different states and UTs of India using ncdf4 package of R and area average of spatial data calculated using OpenGrADS.

Absolute humidity (AH; in g m^{-3}) estimated with the help of obtained meteorological parameters using the Clausius-Clapeyron equation described as [20].

$$AH = 18.02 \times RH \times \frac{2.1674 \times \exp\left(\frac{17.67 \times T}{T + 243.5}\right)}{273.15 + T} \quad (1)$$

Spearman's and Kendall's rank correlation coefficient tests used in the present study to measure the strength and direction of the association between two parameters. Spearman's rank correlation is the nonparametric (distribution-free) test. Spearman's correlation parameter rho (also expressed by r_s) can be calculated using the following relation:

$$r_s = 1 - 6 \times \frac{\Sigma d_i^2}{n(n^2 - 1)} \quad (2)$$

Where d_i is defined as the difference between the rank of two parameters and n is the number of alternatives, the value of the rank coefficient lies within the range -1 to +1 (showing positive and negative correlation respectively).

Another nonparametric test estimated is Kendall's rank correlation test. It measures the ordinal association between two measured variables. It is denoted by tau (τ), and it can be estimated using the following relation:

$$\tau = \frac{[(\text{concor}) - (\text{discor})]}{0.5 \times n \times (n-1)}$$

(3)

Where *concor* and *discor* represent the number of concordant and discordant pairs, respectively. The *n* represents the number of pairs. The value of τ also ranges from -1 to +1 similar to Spearman's coefficient (r_s). Both correlation coefficients are calculated using the R function *cor.test ( )* used to compute the correlation coefficient between two variables.

III. RESULT AND DISCUSSION

A. Variation of total COVID-19 cases and meteorological parameters

For batter understanding the daily variation of total COVID-19 cases, the study is divided into two stages: early-stage (24 March 2020 to 30 April 2020) and later stage (1 May 2020 to 15 June 2020) (Fig. 2a) for selected 22 States and 3 UTs in India. Maharashtra (M.H.), Tamilnadu, Delhi, Gujrat were highly impacted as compare to Himachal Pradesh (H.P.), Chhattisgarh, Chandigarh, Andaman & Nicobar Island (ANI) and Goa in both stages during the current pandemic situation. Its possible causes could be the population density and climate, economic factors, and mitigation strategies of the respective localities [21]. Exponential growth in total

COVID-19 cases was reported from 10 April 2020 onwards and reached to highest levels by 15 June 2020 (Fig. 2a). The comparative study of background meteorological parameters (MPs) such as Temperature, Relative Humidity (RH) and Absolute Humidity (AH) was also performed (Fig. 2 b to 2d), which governs the human comfort and COVID-19 infections [17, 18, 20]. The data shows that the temperature in the Telangana (31.25 ±1.02°C), M.H. (31.00 ± 1.4°C), Gujrat (30.90 ± 2.06°C), Andhra Pradesh (30.53 ± 0.82°C), Tamilnadu (29.83 ± 0.73°C) and Rajasthan (29.49 ± 3.06°C) were reported close to the threshold values 32°C of the temperature (Fig. 3a) and Jammu & Kashmir (J & K; -6.04± 2.60°C, H.P.; 3.97 ± 2.60°C) and Uttarakhand (U. K.; 11.13 ± 1.83°C) were reported during the early stage, but in a later stage the highest temperature was observed in the Rajasthan (33.89 ± 1.22°C) and the lowest temperature was in the J & K (0.63 ± 2.14°C). Whereas in the case of relative humidity, the high level was observed in the Goa (78.39 ± 3.61 %), J & K (75.621 ±6.77 %), and Kerala (75.50 ± 4.75%) and lowest in the Rajasthan (35.11 ± 11.20 %) during an early stage. In the later stage Kerala, Goa, ANI, and Chhattisgarh, but lower values of RH were reported in the Rajasthan (Fig. 2c). The AH plays a significant role in the transmissions of the viral disease [22], the high values of the AH were Goa (21.42 ±1.19 g /m^3), Kerala (21.01 ± 0.78 g/m^3) and ANI (20.94 ± 0.98 g/m^3) and the lower AH were reported in the J & K (2.42 ± 0.46 g /m^3), H. P. (4.32 ± 0.77 g/m^3) and U.K (6.32 ± 1.05 g/m^3).

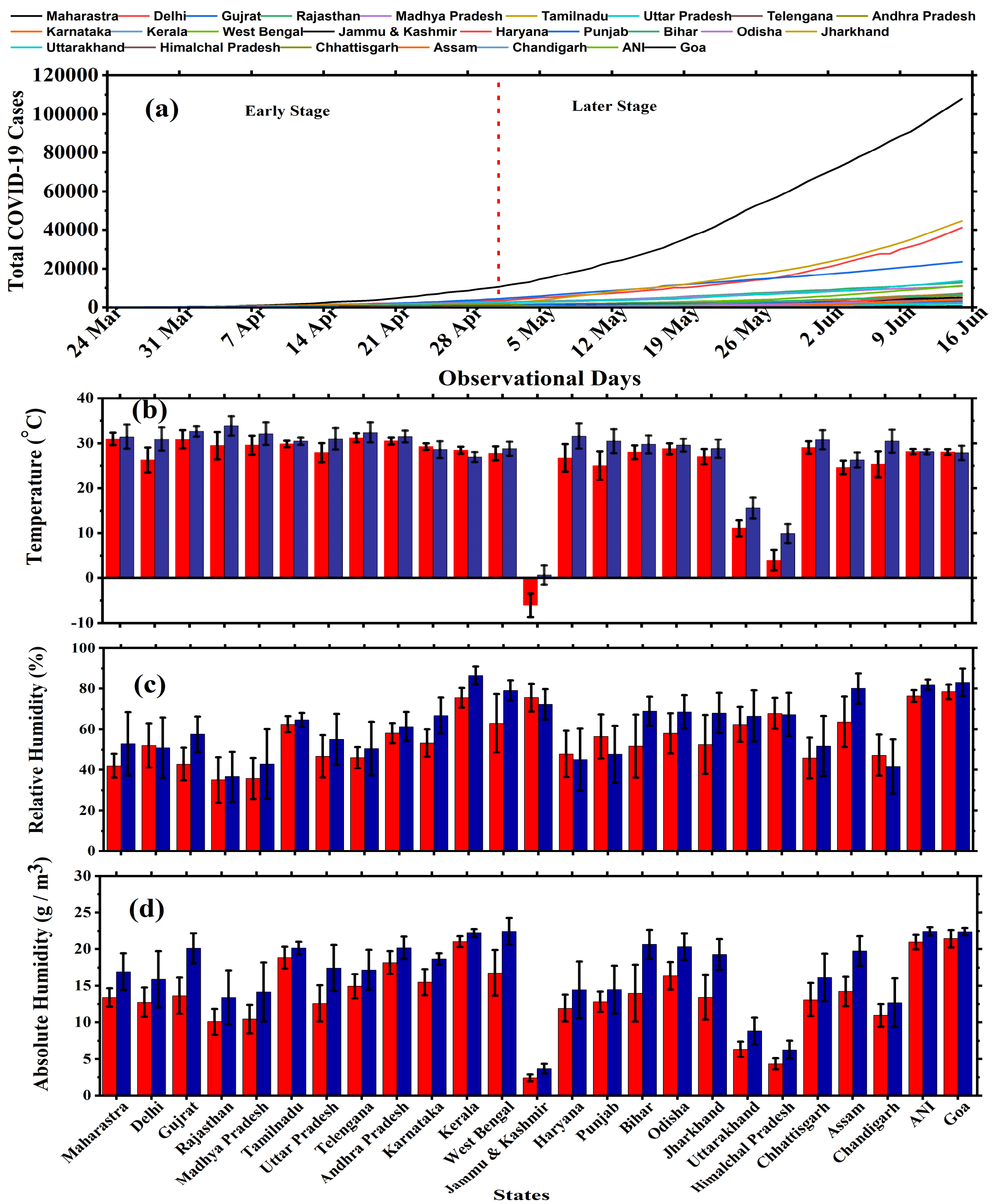

Fig. 2. Daily variation of COVID-19 cases in 22 states and 3 Union Territories (UTs) of India during early-stage (24 March to 30 April 2020) and later stage (1 May 2020 to 15 June 2020) (a), state-wise comparative variations of temperature (b), Relative Humidity (c) and absolute humidity in both stages of transmission.

B. Correlation between COVID-19 cases and background meteorological parameters

Table 1 represents the Spearman and Kendall rank correlation analysis between COVID-19 cases and MPs. Temperature is the significant parameter for humans and ecosystems that can govern the public-health, epidemic growth, and control phenomenon [23]. In our Analysis, Delhi, RJ, U.P., J & K, U.K., H. P., Haryana, Chandigarh show a strong and significant correlation with temperature, whereas some other states like M.H., Gujrat, Telangana, Madhya Pradesh, Tamilnadu, Andhra Pradesh, Karnataka, West Bengal, Odisha, Bihar, Jharkhand, Assam, ANI, and Goa were strongly associated with AH for both correlation analysis. We can say that MPs have a significant relation with the spread of COVID-19 in India. [21] also find a strong Pearson's correlation with AH and T for the Indian perspective, whereas [20] observed a Spearman and Kendall rank correlation between COVID-19 and MPs over Singapore.

Table 1: The nonlinear correlation between COVID-19 and meteorological parameters from 24 March 2020 to 15 June 2020 in selected 22 states and 3 union territories.

State (Population)	Met Para.	Spearman's rank correlation				Kendall's rank correlation			
		Total COVID-19 cases		COVID-19 New cases		Total COVID-19 cases		COVID-19 New cases	
		r– values	p- values	r – values	p- values	r – values	p-values	r-values	p- values
Maharashtra (112,374,333)	T1	0.08	0.48	0.14	0.20	0.15*	0.04	0.17*	0.02
	AH1	0.72**	<0.01	0.65**	<0.01	0.56**	<0.01	0.49**	<0.01
Delhi (16,787,941)	T2	0.71**	<0.01	0.57**	<0.01	0.56**	<0.01	0.41**	<0.01
	AH2	0.49**	<0.01	0.42**	<0.01	0.36**	<0.01	0.30**	<0.01
Gujarat (60,439,692)	T3	0.42**	<0.01	0.41**	<0.01	0.31**	<0.01	0.29**	<0.01
	AH3	0.86**	<0.01	0.81**	<0.01	0.70**	<0.01	0.62**	<0.01
Rajasthan (68,548,437)	T4	0.67**	<0.01	0.66**	<0.01	0.53**	<0.01	0.49**	<0.01
	AH4	0.53**	<0.01	0.34**	<0.01	0.41**	<0.01	0.24**	<0.01
Madhya Pradesh (72,626,809)	T5	0.44**	<0.01	0.53**	<0.01	0.37**	<0.01	0.38**	<0.01
	AH5	0.53**	<0.01	0.27*	0.01	0.43**	<0.01	0.20**	<0.01
Tamil Nadu (72,147,030)	T6	0.27*	<0.01	0.18	0.11	0.22**	<0.01	0.14	<0.07
	AH6	0.45**	<0.01	0.36**	<0.01	0.31**	<0.01	0.24**	<0.01
Uttar Pradesh (199,812,341))	T7	0.65**	<0.01	0.53**	<0.01	0.49**	<0.01	0.38**	<0.01
	AH7	0.72**	<0.01	0.53**	<0.01	0.56**	<0.01	0.38**	<0.01
Telangana (35,193,978)	T8	0.27*	0.01	-0.03	0.79	0.26**	<0.01	-0.01	0.87
	AH8	0.61**	<0.01	0.41**	<0.01	0.46**	<0.01	0.28**	<0.01
Andhra Pradesh (49,386,799)	T9	0.38**	<0.01	0.17	0.12	0.32**	<0.01	0.14	0.07
	AH9	0.62**	<0.01	0.47**	<0.01	0.47**	<0.01	0.33**	<0.01
Karnataka (61,095,297)	T10	-0.21*	0.05	-0.24*	0.02	-0.12	0.12	-0.15	0.05
	AH 10	0.84**	<0.01	0.78**	<0.01	0.66**	<0.01	0.57**	<0.01
Kerala (33,406,061)	T11	-0.77**	<0.01	-0.59**	<0.01	-0.59**	<0.01	-0.41**	<0.01
	AH 11	0.57**	<0.01	0.13	0.24	0.42**	<0.01	0.07	0.36
West Bengal (91,276,115)	T12	0.30**	<0.01	0.28**	<0.01	0.19**	<0.01	0.17*	0.02
	AH 12	0.87**	<0.01	0.80**	<0.01	0.71**	<0.01	0.64**	<0.01
Jammu and Kashmir (12,541,302)	T13	0.94**	<0.01	0.82**	<0.01	0.77**	<0.01	0.63**	<0.01
	AH 13	0.82**	<0.01	0.74**	<0.01	0.63**	<0.01	0.55**	<0.01
Haryana (25,351,462)	T14	0.70**	<0.01	0.44**	<0.01	0.55**	<0.01	0.32**	<0.01
	AH 14	0.44**	<0.01	0.47**	<0.01	0.32**	<0.01	0.33**	<0.01
Punjab (27,743,338)	T15	0.76**	<0.01	0.39**	<0.01	0.60**	<0.01	0.27**	<0.01
	AH15	0.38**	<0.01	0.48**	<0.01	0.26**	<0.01	0.32**	<0.01
Bihar (104,099,452)	T16	0.48**	<0.01	0.41**	<0.01	0.33**	<0.01	0.26**	<0.01
	AH 16	0.91**	<0.01	0.85**	<0.01	0.75**	<0.01	0.65**	<0.01
Odisha (41,974,218)	T17	0.13	0.26	0.13	0.23	0.10	0.20	0.10	0.17
	AH 17	0.83**	<0.01	0.76**	<0.01	0.63**	<0.01	0.56**	<0.01
Jharkhand (32,988,134)	T18	0.44**	<0.01	0.40**	<0.01	0.31**	<0.01	0.28**	<0.01
	AH 18	0.88**	<0.01	0.72**	<0.01	0.72**	<0.01	0.55**	<0.01
Uttarakhand (10,086,292)	T19	0.84**	<0.01	0.63**	<0.01	0.66**	<0.01	0.44**	<0.01
	AH 19	0.76**	<0.01	0.55**	<0.01	0.61**	<0.01	0.39**	<0.01
Himachal Pradesh (6,864,602)	T20	0.89**	<0.01	0.72**	<0.01	0.73**	<0.01	0.55**	<0.01
	AH 20	0.79**	<0.01	0.56**	<0.01	0.62**	<0.01	0.41**	<0.01
Chhattisgarh (25,545,198)	T21	0.36**	<0.01	0.31**	<0.01	0.29**	<0.01	0.23**	<0.01
	AH 21	0.57**	<0.01	0.14	0.20	0.42**	<0.01	0.10	0.23
Assam (31,205,576)	T22	0.35**	<0.01	0.36**	<0.01	0.24**	<0.01	0.26**	<0.01
	AH 22	0.93**	<0.01	0.71**	<0.01	0.78**	<0.01	0.53**	<0.01
Chandigarh (1,055,450)	T23	0.75**	<0.01	0.38**	<0.01	0.59**	<0.01	0.28**	<0.01
	AH 23	0.38**	<0.01	0.23*	0.04	0.27**	<0.01	0.16*	0.04
Andaman and Nicobar Islands (380,581)	T24	0.10	0.36	0.18	0.11	0.09	0.30	0.14	0.12
	AH 24	0.72**	<0.01	-0.20	0.07	0.60**	<0.01	-0.16	0.07
Goa (1,458,545)	T25	-0.19	0.09	-0.33**	<0.01	-0.08	0.34	-0.24**	<0.01
	AH 25	0.38**	<0.01	0.21	0.06	0.26**	<0.01	0.16	0.06

Where AH: Absolute Humidity, T: Temperature

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

C. Distribution of COVID-19 new cases along with MPs

The data clearly show that below 22°C and above 36°C the cases are only about 1% to 2% but 97 % to 98 % of new cases were reported in between 24°C to 32°C for both stage and the maximum number of infection were reported at 32°C and reduce at further high temperature (Fig. 3a). In the case of RH, 92 % to 93 % of new infections were reported between 30 % to 80% and only 7% to 8% of cases were reported in the below 30% and above 80% in both stages. 29% and 20% of new cases were reported at 30% (RH) and 65% (RH) during observations (Fig. 3b). [18] observed 50% to 80% RH range is ideal for the spread of COVID-19, in which 75 % (RH) was most conductive over China. The AH also play a crucial role in the growth of COVID-19 virus, approximately 88% of infection were reported between the AH range 10 g/m^3 to 20 g/m^3, however, 12 % and 4% of infections were reported bellow 10 g/m^3 and above 20 g /m^3. 0% and 8% infections in both early and later stages respectively. [17] Found that the spread of the COVID-19 virus is conductive bellow 10 g/m^3 and they expect to decrease the infections due to the monsoon /environment factor. But here the situation is quite different the number of infections is still increasing may be due to the high population, migration toward their native places, environment factors, the efficiency of lockdown and mitigation strategies, etc.

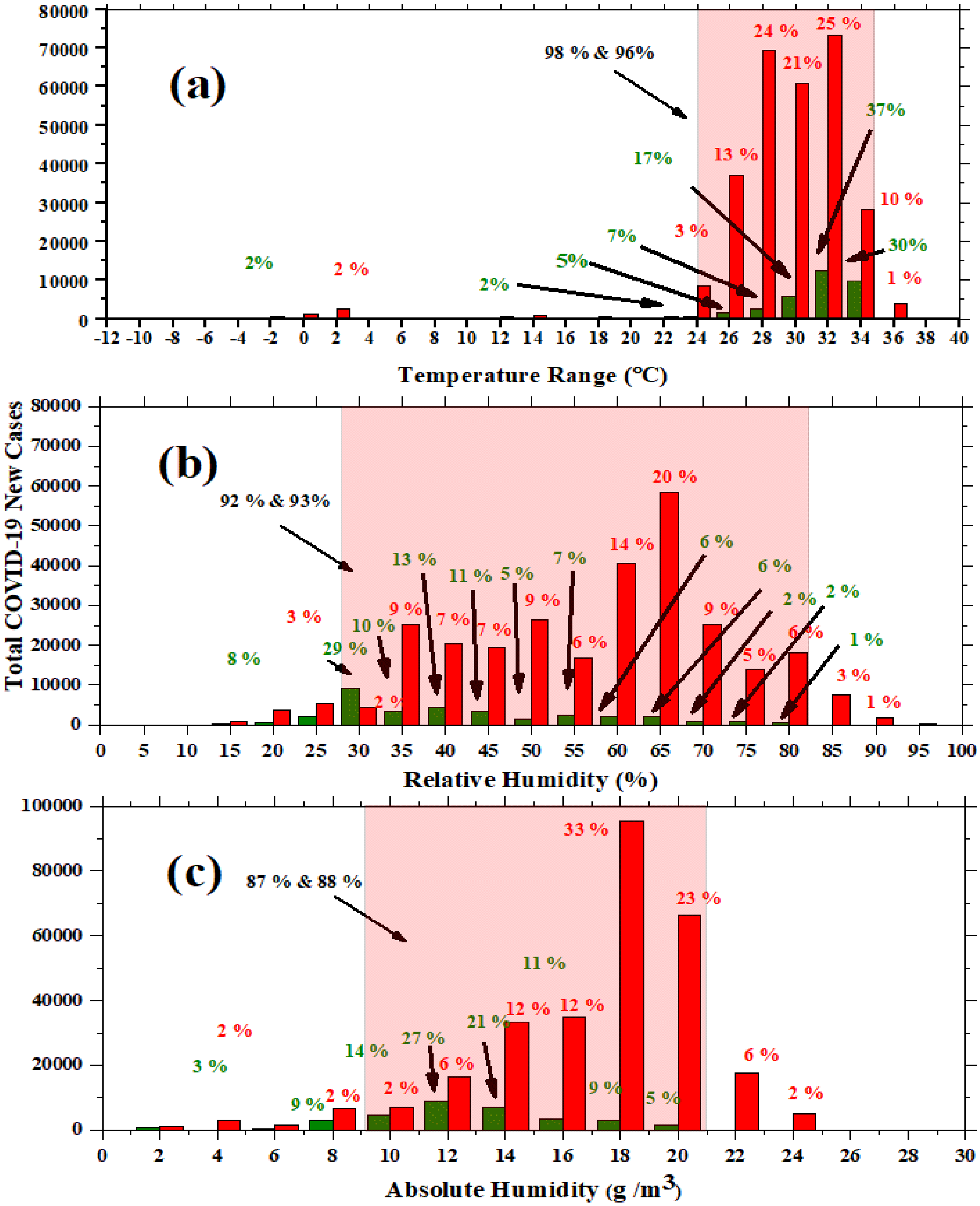

Fig. 3. Distribution Total COVID-19 new cases along with temperature (a) Relative Humidity (b) absolute Humidity.

IV. CONCLUSION

The main objective of the planned study was to investigate the associative nature between COVID-19 and MPs over selected 22 states and 3 UTs of India by adopting various statistical approaches. Our results claimed that T and AH have a strong and significant association with the COVID-19 new cases as well as total COVID-19 cases. The most favourable environment condition for COVID-19 transmission was found AH (10 g/m^3 to 20 g /m^3) and T (24°C to 32°C) and have approximate 87 % to 88 % and 98 % to 96 % of contribution in the new COIVD-19 cases in both stages respectively. However, 92 % to 93 % of COVID-19 cases were reported in the RH range between 30% to 80% in both stages. AH is highly correlated in the M.H., Telangana, Tamilnadu, Andhra Pradesh, West Bengal, and Odisha, etc. whereas T is found to be strongly associated with the Delhi, Rajasthan, Uttar Pradesh, J&K Haryana, Punjab, Chandigarh, etc.

V. FUTURE SCOPE

This study was carried out over the 22 states and 3 Union territories in India, to get a better understanding of the possible transmission of COVID-19 cases with the background meteorological parameters in the early and later stages. Now based on the outcomes of this study, we have the following future plan and suggestions.

— The current study will be quite helpful to understand the seasonal variation of COVID-19 in different seasons i.e. monsoon (June to August), post-monsoon (September to October), and winter (January and February).

— Based on the background meteorological condition, this study can contribute in the future COVID-19 mitigation policies by governments and organizations.

— This study is also helpful to make a reliable COVID-19 prediction model based on the meteorological parameters.

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Conflict of Interest. The authors confirm that there are no known conflicts of interest associated with this Publication of this paper.

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