



# On the global trends and spread of the COVID-19 outbreak: preliminary assessment of the potential relation between location-specific temperature and UV index

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## Abstract

The novel coronavirus, since its first outbreak in December, has, up till now, affected approximately 114,542 people across 115 countries. Many international agencies are devoting efforts to enhance the understanding of the evolving COVID-19 outbreak on an international level, its influences, and preparedness. At present, COVID-19 appears to affect individuals through person-to-person means, like other commonly found cold or influenza viruses. It is widely known and acknowledged that viruses causing influenza peak during cold temperatures and gradually subside in the warmer temperature, owing to their seasonality. Thus, COVID-19, due to its regular flu-like symptoms, is also expected to show similar seasonality and subside as the global temperatures rise in the northern hemisphere with the onset of spring. Despite these speculations, however, the systematic analysis in the global perspective of the relation between COVID-19 spread and meteorological parameters is unavailable. Here, by analyzing the region- and city-specific affected global data and corresponding meteorological parameters, we show that there is an optimum range of temperature and UV index strongly affecting the spread and survival of the virus, whereas precipitation, relative humidity, cloud cover, etc. have no effect on the virus. Unavailability of pharmaceutical interventions would require greater preparedness and alert for the effective control of COVID-19. Under these conditions, the information provided here could be very helpful for the global community struggling to fight this global crisis. It is, however, important to note that the information presented here clearly lacks any physiological evidences, which may merit further investigation. Thus, any attempt for management, implementation, and evaluation strategies responding to the crisis arising due to the COVID-19 outbreak must not consider the evaluation presented here as the foremost factor.

**Keywords** Coronavirus · COVID-19 · Temperature · UV index · Non-physiological reaction

## Introduction

As of 10th March 2020, 114,814 confirmed cases of novel coronavirus (also called COVID-19) infection have been reported worldwide since its emergence in mid-December (Du

Toit 2020). Almost 70.3% are being reported from China alone, followed by Italy (8.0%), South Korea (6.5%), Iran (6.2%), France (1.2%), Spain (1%), Germany (1%), the USA (0.6%), and Japan (0.6%), constituting more than ~95% of the total reported confirmed cases. In a report released by the World Health Organization (WHO), a major goal and objective is outlined to rapidly disseminate the national (for China) and international planning on the preparedness in response to the increasing and ongoing outbreak of COVID-19. The virus traces its origin for the recent outbreak in China, when three samples for bronchoalveolar lavage were collected and detailed microbiological analysis confirmed that the virus had typical features resembling the coronavirus family. COVID-19 has a transmission characteristic typical of any other cold-causing influenza virus: human-to-human. As per the report published by the WHO, the common symptoms

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include fever, dry cough, fatigue, sputum production, shortness of breath, sore throat, headache, etc., which can be recognized as normal flu symptoms.

Since the beginning of the COVID-19 outbreak, extensive efforts have been constantly devoted to improving understanding about the virus. As a result, this virus, previously unknown to many, not only garnered tremendous research attention, but also became a household name within a span of merely 90 days. The outbreak has also brought many major cities in China to a standstill and resulted in the isolation of a large number of citizens in Italy. Such a curfew-like situation can be difficult to impose and may not yield the desired results under many circumstances (Fong et al. 2020), which is evident from the steps being taken by countries to contain further spread of the virus. At the same time, another prevalent issue is considering the COVID-19 features that are similar to common influenza viruses causing colds. The most common feature of common influenza viruses is seasonality, which implies that, during colder temperatures, influenza caused by viruses increases, which then subside with the warming of air temperature. This assumption, at this moment, is not backed by any robust analysis and scientific investigations. Under the circumstances of unobtainability of any pharmaceutical relief to treat the COVID-19 virus, specific information about the non-physiological causes augmenting the survival and spread of COVID-19 can be very valuable information for policy-makers dealing with management and effective control measures. Since the onset of the COVID-19 outbreak, a lot of attention has been paid to understanding cross-species transmission (Ji et al. 2020), efforts regarding the discovery, emergence, clinical diagnostic, and genomic characteristics of COVID-19 (Phan 2020), and initial public response (Patel et al. 2020). Further, there are requirements for details related to the necessity of maintaining regular physical activity while exercising precautions (Chen et al. 2020) and, more interestingly, even developing an accurate model to forecast the novel COVID-19 outbreak from small datasets (Fong et al. 2020). The relation of COVID-19 with meteorological parameters, which are very location-specific where outbreaks have been reported, however, has not been investigated. In this study, we analyzed the number of confirmed cases up till 7th March 2020 and investigated location-specific outbreaks with meteorological parameters, including temperature, relative humidity, UV index, and precipitation.

## Materials and methods

To better understand the demographic distribution of COVID-19 on the global scale, we used data that were not derived for any in situ measurements or monitoring. Instead, we captured the country-/region-dependent spread from alerts generated by the Program for Monitoring Emerging Diseases (ProMED),

which is a community-based online reporting system (Yadav et al. 2020). The very fact that reports in the ProMED are fully screened by a group of expert members for its validity makes the reports reliable to be used in scientific publishing (Fisher et al. 2012). We used the key word “COVID-19” with the option enabled for subject and post; for exclusions, see also the ProMED-mail database. Thereafter, we selectively screened the number of infected cases listed for each country from 2nd February 2020, where the accumulated infected cases were already provided. As shown in Table 1, we considered the cumulative dataset for 85 locations, including the highly affected provinces in China, South Korea, Italy, Iran, France, Germany, the USA, Spain, and Japan. Further, the meteorological data for minimum, maximum, and average temperature (in °C); relative humidity (in %), UV index (an index indicating the strength of sunburn-producing UV radiation), precipitation (in mm), and cloud cover were obtained from the website <https://www.worldweatheronline.com> (last accessed 10th March 2020, 04:30 h IST), which is dedicated to providing global weather content and has been used by previous researchers (Ibekwe and Ukou 2019). The providers claim to cover around 3 million sites across the globe, and the data are used by many organizations. While it is difficult to independently verify the quality and accuracy of the data, random validation for a few cities with actual measurements in the past have given a strong agreement between the two datasets. To obtain the data for a specific city, we applied the search criteria by narrowing on the province/region and then querying the most affected cities in the respective province/region obtained from various other data sources. Thus, we are of the strong opinion that the meteorological data presented here are not only the true representation of the city/place with infected cases, but also give an accurate indication of the relation between the number of confirmed cases and the meteorological parameters.

Further, for the countries with more than 500 confirmed cases, we only chose cities that constituted more than 70% of the total confirmed cases for that respective country. Thus, we scrutinized a total of 107,351 confirmed cases across 85 locations.

Once the data were obtained, we prepared scatter plots between the number of confirmed cases and various meteorological parameters. Further, by applying various statistical fits, the dependence of virus spread on individual meteorological parameters was investigated, as discussed below.

## Assessment

Figure 1 shows the relation between the number of confirmed cases and temperature assessed for more than 10,000 cases globally, constituting ~85 individual locations. As can be seen from Fig. 1a, the data points are clearly following the log

**Table 1** List of countries and provinces in China considered for this study and corresponding maximum, minimum, and average temperature, relative humidity (RH), and UV index. The results were averaged for January and February

Region/Province/City	Number of Cases	January											
		Temp (max)	Temp (average)	Temp (min)	RH	Precipitation	Rainy Days	Cloud Coverage	UV-Index	Temp (max)	Temp (average)	Temp (min)	RH
Hubei	66907	9	7	4	74	157.3	21	63%	4	16	13	9	66
Daegu	5381	7	4	0	68	137.1	12	49	1	9	5	1	62
Guangdong	1349	23	19	13	64	42.5	14	46	5	21	19	14	73
Gyeonggi	141	5	3	-1	71	90.4	9	55	1	7	4	-1	69
Henan	1272	10	5	1	59	20	5	46	3	8	6	2	58
Seoul	120	5	3	0	55	82.1	7	48	1	7	4	0	56
Zhejiang	1205	8	6	3	81	97.5	23	70	3	15	12	8	71
Barcelona	72	14	12	10	65	262.9	7	32	4	16	14	11	75
Hunan	1018	9	8	5	82	154	19	68	4	15	13	9	80
Álava	122	13	10	6	77	66.9	17	53	3	15	12	8	75
Anhui	990	7	6	3	82	148	22	72	2	14	11	7	71
Madrid	578	11	9	6	68	54.2	11	44	4	18	13	9	63
Jiangxi	935	11	10	7	79	143.5	21	66	4	15	13	9	77
La Rioja	102	8	6	3	79	59.5	15	51	3	13	10	6	74
Shandong	756	6	4	0	57	27.3	4	41	3	11	8	3	52
Florida	13	23	19	12	78	209.2	28	50	4	26	20	11	76
Jiangsu	631	8	6	3	79	113	23	73	3	13	11	6	70
Texas	13	16	15	12	78	116	20	46	4	16	15	12	77
Chongqing	576	13	12	9	64	36.1	16	60	3	15	13	10	68
California	105	13	10	5	53	4	2.1	16	4	17	13	7	37
Sichuan	538	13	11	7	62	10	15	54	3	16	13	9	60
Washington	136	9	6	2	65	77.2	12	44	2	10	7	3	64
Heilongjiang	480	-12	-15	-20	93	8.9	2	63	2	-8	-11	-17	92
New York	106	6	4	1	61	99.9	16	48	1	7	5	1	62
Beijing	413	4	2	-2	45	1.6	1	29	3	7	5	1	45
Île-de-France	104	9	8	5	79	43.1	15	57	3	11	9	7	74
Massachusetts	28	3	1	-4	73	71.6	12	50	2	3	1	-4	72
Shanghai	337	11	9	5	71	116.9	20	65	3	14	12	7	66
Auvergne-Rhône-Alpes	102	9	7	3	78	40.3	10	45	3	12	10	5	71
Hebei	318	5	2	-3	52	7.7	1	38	3	10	6	1	44
Hauts-de-France	173	8	7	4	83	26.6	17	53	3	10	8	4	77
Fujian	296	18	15	10	79	14.4	10	59	4	18	16	10	80
Grand Est	250	8	6	3	81	23.3	12	44	3	10	8	4	75
Guangxi	252	20	18	14	71	34	15	66	5	21	19	15	75
Bourgogne-Franche-Comté	129	8	5	2	85	78	12	51	3	10	7	4	80
Shaanxi	245	8	6	1	57	7.6	5	46	2	15	11	5	39
North Rhine-Westphalia	484	8	6	3	83	35.6	17	57	3	9	8	4	78
Yunnan	174	11	8	2	70	71.1	12	28	2	13	10	5	65

Table 1 (continued)

Baden-Wuerttemberg	204	7	5	2	79	27.2	13	45	3	9	7	3	74
Hainan	168	22	22	18	78	37.8	26	56	5	23	22	19	80
Bavaria	256	6	4	0	76	41.6	10	46	3	8	6	2	71
Guizhou	146	11	9	5	82	96.2	20	71	2	13	11	7	83
Mazandaran	633	12	10	5	67	71	14	43	4	14	11	6	68
Tianjin	136	5	2	-2	46	2.3	2	33	3	8	5	1	51
Gilan	524	12	10	7	77	291	21	56	4	13	10	6	72
Shanxi	133	1	0	-4	67	24.7	1	39	2	8	5	0	43
Qom	712	9	7	3	59	35.7	11	35	2	13	10	5	47
Liaoning	122	-5	-7	-12	80	3.9	1	32	2	0	-2	-7	66
Esfahan	601	9	6	2	49	7.4	5	21	3	13	10	4	37
Hong Kong	95	20	19	16	74	21.6	15	47	5	20	19	16	78
Markazi	389	7	5	2	51	25.6	10	35	2	10	8	4	45
Jilin	93	-9	-13	-18	90	9.5	3	52	2	-6	-8	-13	78
Tehran	1945	7	5	1	53	25	11	32	3	10	7	2	48
Gansu	91	2	-1	-5	66	5.6	4	30	2	7	4	-2	39
Milan (Lombardia)	506	9	7	5	69	55.5	6	35	3	14	11	7	58
Xinjiang	76	-5	-8	-12	76	24	5	35	1	-1	-3	-7	68
Piacenza (Emilia Romagna)	602	9	7	3	82	58	10	40	3	13	10	5	69
Inner Mongolia	75	-6	-9	-14	79	10	1	38	2	1	-3	-8	61
Lodi (Lombardia)	928	9	7	4	78	38.3	6	35	3	13	10	6	67
Ningxia	73	0	2	-5	55	3	2	29	2	7	3	-1	30
Brescia (Lombardia)	739	9	7	4	72	25.8	5	34	3	12	10	6	63
Taipei	39	19	17	13	75	57	22	60	4	20	19	14	71
Bergamo (Lombardia)	1245	9	7	3	68	35.9	5	30	3	12	10	5	60
Qinghai	18	-1	-5	-11	60	3	7	28	2	5	-1	-8	38
Cremona (Lombardia)	916	9	7	4	81	26.9	6	37	3	13	7	6	68
Aichi	670	11	10	7	59	68	20	46	3	11	9	6	56
Switzerland	268	8	4	-1	77	38.6	11	36	2	9	6	1	77
Hokkaidō	4189	11	9	6	54	95.3	14	51	2	13	10	7	48
UK	209	9	8	5	80	67.2	16	62	3	10	8	5	70
Tokyo	1180	11	9	5	54	106.7	17	49	2	13	10	7	47
Netherlands	188	8	7	4	85	80.2	21	64	2	9	7	5	77
Busan	97	9	7	4	61	108.2	13	48	3	10	8	4	58
Belgium	169	8	6	3	83	36.8	17	54	3	9	7	4	78
Gyeongbuk	1081	8	5	2	71	95.8	9	45	2	9	7	3	67
Sweden	161	5	4	0	79	31.7	18	55	1	4	3	0	75
Chungnam	98	7	4	0	72	61.7	10	53	1	9	6	1	70
Norway	156	2	1	-5	85	47.3	6	51	1	2	1	-3	74
Singapore	138	29	28	26	79	146.5	27	56	7	30	28	26	77
Malaysia	93	33	30	23	74	192.7	30	51	6	34	30	23	72
Bahrain	85	19	18	15	63	16.6	7	18	5	20	19	17	64
Austria	79	4	3	0	77	18.2	7	44	3	9	7	4	64
Australia	63	26	24	21	77	196.8	24	55	7	25	23	20	75
Kuwait	61	18	16	14	51	0	0	13	5	19	17	15	49
Thailand	50	35	32	28	50	9.8	14	24	7	35	32	27	51

**Table 1** (continued)

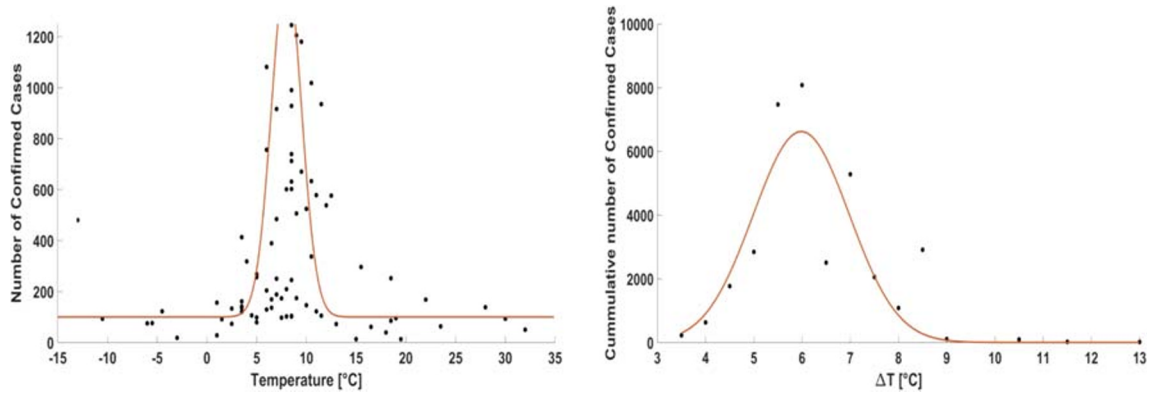
Region/Province/City	February											
	Precipitation	Rainy Days	Cloud Coverage	UV-Index	Temp (max)	Temp (average)	Temp (min)	RH	Precipitation	Rainy Days	Cloud Coverage	UV-Index
Hubei	77.5	13	51	3	12.5	10	6.5	70	117.4	17	25.815	3.5
Daegu	52.9	9	37	3	8	4.5	0.5	65	95	10.5	43	2
Guangdong	227	16	60	5	22	19	13.5	68.5	134.75	15	53	5
Gyeonggi	106.2	7	41	3	6	3.5	-1	70	98.3	8	48	2
Henan	31.9	7	51	4	9	5.5	1.5	58.5	25.95	6	48.5	3.5
Seoul	70.4	9	37	3	6	3.5	0	55.5	76.25	8	42.5	2
Zhejiang	103.9	16	51	3	11.5	9	5.5	76	100.7	19.5	60.5	3
Barcelona	2.2	6	22	4	15	13	10.5	70	132.55	6.5	27	4
Hunan	231.1	18	67	3	12	10.5	7	81	192.55	18.5	67.5	3.5
Álava	47.7	12	37	3	14	11	7	76	57.3	14.5	45	3
Anhui	46.5	12	45	3	10.5	8.5	5	76.5	97.25	17	58.5	2.5
Madrid	0.8	3	19	2	14.5	11	7.5	65.5	27.5	7	31.5	3
Jiangxi	182	16	58	3	13	11.5	8	78	162.75	18.5	62	3.5
La Rioja	9.6	9	33	3	10.5	8	4.5	76.5	34.55	12	42	3
Shandong	25.6	6	35	4	8.5	6	1.5	54.5	26.45	5	38	3.5
Florida	275.6	28	56	5	24.5	19.5	11.5	77	242.4	28	53	4.5
Jiangsu	36.7	9	46	2	10.5	8.5	4.5	74.5	74.85	16	59.5	2.5
Texas	40.4	16	51	5	16	15	12	77.5	78.2	18	48.5	4.5
Chongqing	76.5	22	63	4	14	12.5	9.5	66	56.3	19	61.5	3.5
California	1.3	1	14	5	15	11.5	6	45	2.65	1.55	15	4.5
Sichuan	9.2	13	49	5	14.5	12	8	61	9.6	14	51.5	4
Washington	118.9	16	54	1	9.5	6.5	2.5	64.5	98.05	14	49	1.5
Heilongjiang	26.6	4	64	1	-10	-13	-18.5	92.5	17.75	3	63.5	1.5
New York	122.8	17	59	1	6.5	4.5	1	61.5	111.35	16.5	53.5	1
Beijing	28.6	2	29	2	5.5	3.5	-0.5	45	15.1	1.5	29	2.5
Île-de-France	157.6	25	72	2	10	8.5	6	76.5	100.35	20	64.5	2.5
Massachusetts	87.4	12	54	1	3	1	-4	72.5	79.5	12	52	1.5
Shanghai	52.8	10	45	3	12.5	10.5	6	68.5	84.85	15	55	3
Auvergne-Rhône-Alpes	55.2	18	48	3	10.5	8.5	4	74.5	47.75	14	46.5	3
Hebei	13.9	3	27	4	7.5	4	-1	48	10.8	2	32.5	3.5
Hauts-de-France	116.5	25	71	2	9	7.5	4	80	71.55	21	62	2.5
Fujian	63	10	54	5	18	15.5	10	79.5	38.7	10	56.5	4.5
Grand Est	188.7	22	63	3	9	7	3.5	78	106	17	53.5	3

Table 1 (continued)

Guangxi	63.3	19	67	5	20.5	18.5	14.5	73	48.65	17	66.5	5
Bourgogne-Franche-Comté	127.6	20	63	3	9	6	3	82.5	102.8	16	57	3
Shaanxi	16	6	30	5	11.5	8.5	3	48	11.8	5.5	38	3.5
North Rhine-Westphalia	155.3	23	72	2	8.5	7	3.5	80.5	95.45	20	64.5	2.5
Yunnan	39.7	14	27	4	12	9	3.5	67.5	55.4	13	27.5	3
Baden-Wuerttemberg	179.5	18	64	2	8	6	2.5	76.5	103.35	15.5	54.5	2.5
Hainan	40.8	23	59	6	22.5	22	18.5	79	39.3	24.5	57.5	5.5
Bavaria	218.4	19	62	2	7	5	1	73.5	130	14.5	54	2.5
Guizhou	113.6	25	76	4	12	10	6	82.5	104.9	22.5	73.5	3
Mazandaran	262.7	12	41	4	13	10.5	5.5	67.5	166.85	13	42	4
Tianjin	23.6	3	30	2	6.5	3.5	-0.5	48.5	12.95	2.5	31.5	2.5
Gilan	243.9	11	47	4	12.5	10	6.5	74.5	267.45	16	51.5	4
Shanxi	12.2	4	25	3	4.5	2.5	-2	55	18.45	2.5	32	2.5
Qom	40.6	6	24	4	11	8.5	4	53	38.15	8.5	29.5	3
Liaoning	33.5	1	39	1	-2.5	-4.5	-9.5	73	18.7	1	35.5	1.5
Esfahan	5.2	3	13	5	11	8	3	43	6.3	4	17	4
Hong Kong	45.9	16	52	6	20	19	16	76	33.75	15.5	49.5	5.5
Markazi	149.2	10	28	4	8.5	6.5	3	48	87.4	10	31.5	3
Jilin	8.5	2	48	1	-7.5	-10.5	-15.5	84	9	2.5	50	1.5
Tehran	164.3	11	32	4	8.5	6	1.5	50.5	94.65	11	32	3.5
Gansu	6.6	4	21	3	4.5	1.5	-3.5	52.5	6.1	4	25.5	2.5
Milan (Lombardia)	8.4	8	27	2	11.5	9	6	63.5	31.95	7	31	2.5
Xinjiang	17.5	5	33	2	-3	-5.5	-9.5	72	20.75	5	34	1.5
Piacenza (Emilia Romagna)	2.6	3	28	2	11	8.5	4	75.5	30.3	6.5	34	2.5
Inner Mongolia	0	0	22	2	-2.5	-6	-11	70	5	0.5	30	2
Lodi (Lombardia)	2.9	7	28	2	11	8.5	5	72.5	20.6	6.5	31.5	2.5
Ningxia	0	0	14	2	3.5	2.5	-3	42.5	1.5	1	21.5	2
Brescia (Lombardia)	3.8	5	28	2	10.5	8.5	5	67.5	14.8	5	31	2.5
Taipei	49.8	21	53	5	19.5	18	13.5	73	53.4	21.5	56.5	4.5
Bergamo (Lombardia)	9.2	10	24	2	10.5	8.5	4	64	22.55	7.5	27	2.5
Qinghai	3	3	25	2	2	-3	-9.5	49	3	5	26.5	2
Cremona (Lombardia)	1.6	3	29	2	11	7	5	74.5	14.25	4.5	33	2.5
Aichi	65.6	13	36	2	11	9.5	6.5	57.5	66.8	16.5	41	2.5
Switzerland	134.9	19	56	3	8.5	5	0	77	86.75	15	46	2.5
Hokkaidō	31.4	14	40	4	12	9.5	6.5	51	63.35	14	45.5	3
UK	125.8	21	67	2	9.5	8	5	75	96.5	18.5	64.5	2.5
Tokyo	41.4	16	40	3	12	9.5	6	50.5	74.05	16.5	44.5	2.5

**Table 1** (continued)

Netherlands	173	25	76	2	8.5	7	4.5	81	126.6	23	70	2
Busan	89.6	8	35	3	9.5	7.5	4	59.5	98.9	10.5	41.5	3
Belgium	158.4	24	73	2	8.5	6.5	3.5	80.5	97.6	20.5	63.5	2.5
Gyeongbuk	59.8	11	42	2	8.5	6	2.5	69	77.8	10	43.5	2
Sweden	43.8	16	63	1	4.5	3.5	0	77	37.75	17	59	1
Chungnam	29.1	10	44	4	8	5	0.5	71	45.4	10	48.5	2.5
Norway	83.8	7	56	1	2	1	-4	79.5	65.55	6.5	53.5	1
Singapore	162.7	22	50	7	29.5	28	26	78	154.6	24.5	53	7
Malaysia	78.4	23	42	8	33.5	30	23	73	135.55	26.5	46.5	7
Bahrain	0	0	11	5	19.5	18.5	16	63.5	8.3	3.5	14.5	5
Austria	52.2	15	52	2	6.5	5	2	70.5	35.2	11	48	2.5
Australia	568	26	61	6	25.5	23.5	20.5	76	382.4	25	58	6.5
Kuwait	10	8	16	5	18.5	16.5	14.5	50	5	4	14.5	5
Thailand	13	12	21	8	35	32	27.5	50.5	11.4	13	22.5	7.5



**Fig. 1** Scatter plot of temperature and total number of confirmed cases up till 7th March 2020. Temperature data have been obtained from the online dataset as mentioned in the ‘Materials and methods’ section and were averaged over January and February 2020. **a** Scatter plot between average daily temperature and number of confirmed cases. The line

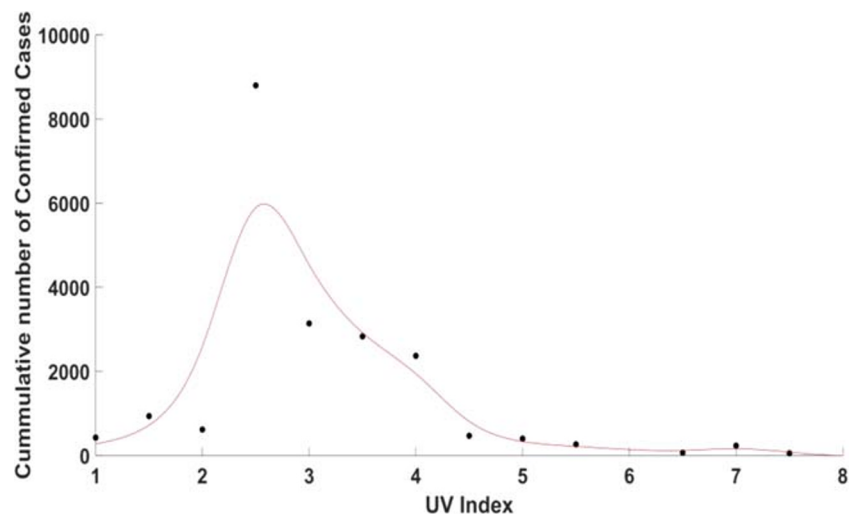
shows the log normal fit to the data ( $N = 85$ ;  $R^2 = 0.35$ ). **b** Scatter plot of the difference between the maximum and minimum daily temperatures and accumulated number of confirmed cases. The orange line shows the log normal fit to the data ( $N = 14$ ;  $R^2 = 0.74$ ). All the fits are statistically significant

normal fit, with very narrow distribution. The point of Wuhan, where the maximum confirmed cases are reported, also lies within the peak (not shown in the figure). As evident from the figure, it clearly appears that the temperature range of 5–15 °C comprises almost 90% of the total confirmed cases. With very small  $\sigma$  value of the distribution, it is very apparent that the temperature band for community infection is, indeed, very narrow. Previous studies have clearly demonstrated that lower temperatures are directly related to influenza virus activity (Deyle et al. 2016; Ianevski et al. 2019; Roussel et al. 2016). Thus, it is clear that increasing temperature may have some clear indication for the reduction in the number of infected cases. Further, to understand if the diurnal variations in temperature, in addition to daily maximum temperature, has any impact on the infection among the community, we calculated the difference between the daily maximum and minimum temperatures and plotted it against the cumulative number of confirmed cases for respective temperature difference values (Fig. 1b). It is evident from the figure that the pronounced diurnal

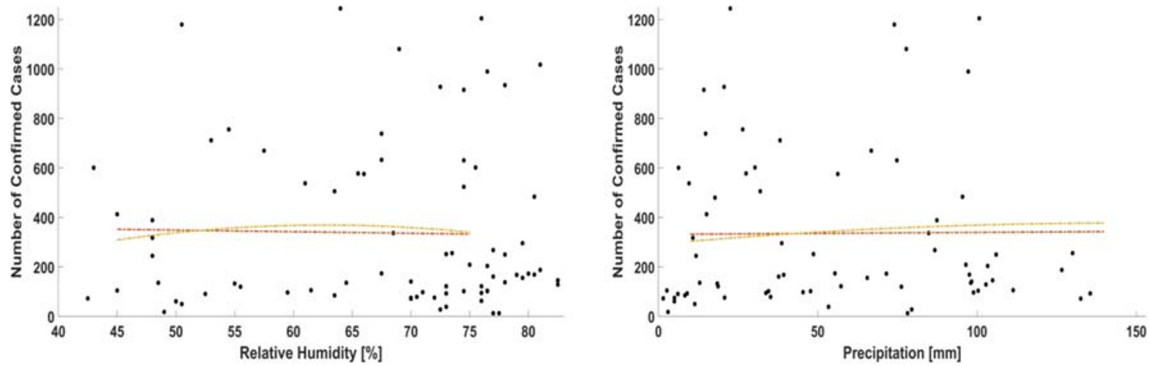
variations with a difference of  $\sim 7$  °C between the maximum and minimum temperatures have shown a consistent decrease in community infection. However, further investigations are required on if such a trend is also evident for warmer and relatively colder regions.

Further, interestingly, we also found a very strong relation between UV index and number of confirmed cases. As shown in Fig. 2, it is evident that the number cumulative cases were found to be highest for a UV index of 2.5 and gradually decreased from a UV index of 3.5. For the areas where the UV index was higher than 5, the number of confirmed infected cases decreased further. It has been documented that higher temperature or prolonged exposure to UVC radiation lowers the virus infectivity (Ianevski et al. 2019). This is mainly resulting from the fact that increased temperatures and prolonged exposure to UV radiation are unable to kill the retinal pigment epithelium (RPE) layer of the cells. Warmer winters in Europe and the USA have been associated with reduced influenza virus activities (Ballester et al. 2016). As

**Fig. 2** Scatter plot between cumulative confirmed cases and UV index (refer to the ‘Materials and methods’ section for more details). The daily UV index for the months of January and February was obtained from the source mentioned in the ‘Materials and methods’ section. The daily UV index data for the months of January and February were further averaged. The line indicates the spline fit to the data ( $N = 14$ ;  $R^2 = 0.63$ )







**Fig. 3** Scatter plot between meteorological parameters and number of confirmed cases up till 7th March 2020. **a** Scatter plot between relative humidity (%) and number of confirmed cases, with the orange and red lines indicating squared and linear fit, respectively ( $N = 85$ ;  $R^2 = 0.0005$

for linear fit and  $R^2 = 0.007$  for squared fit). **b** Same as **a** but for precipitation ( $N = 85$ ;  $R^2 = 0.0002$  for linear fit and  $R^2 = 0.01$  for squared fit)

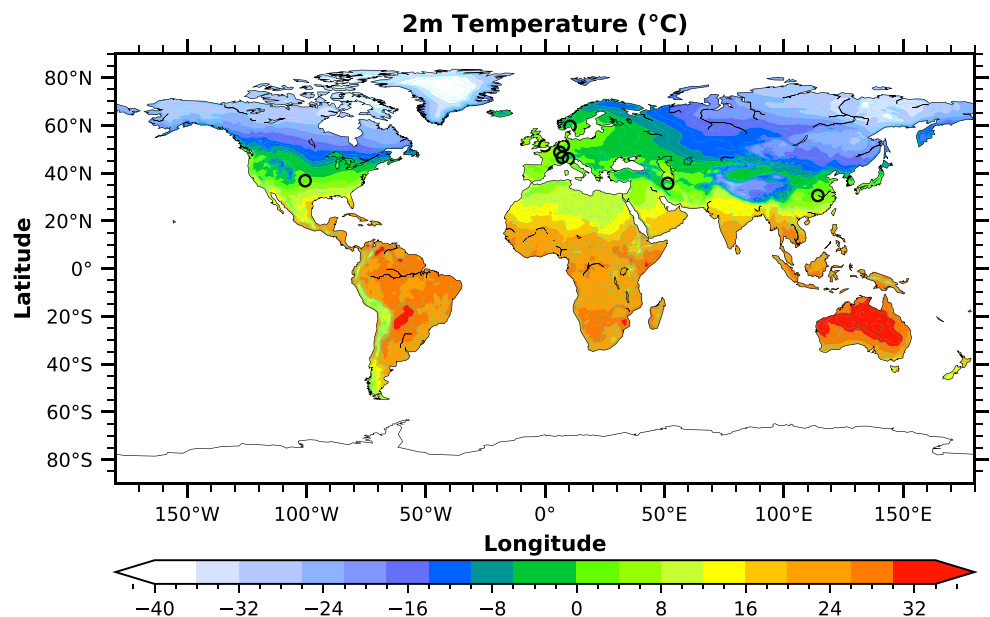
shown in Fig. 3, we did not observe any strong dependence between the relative humidity and precipitation and community infection.

### Concluding remarks

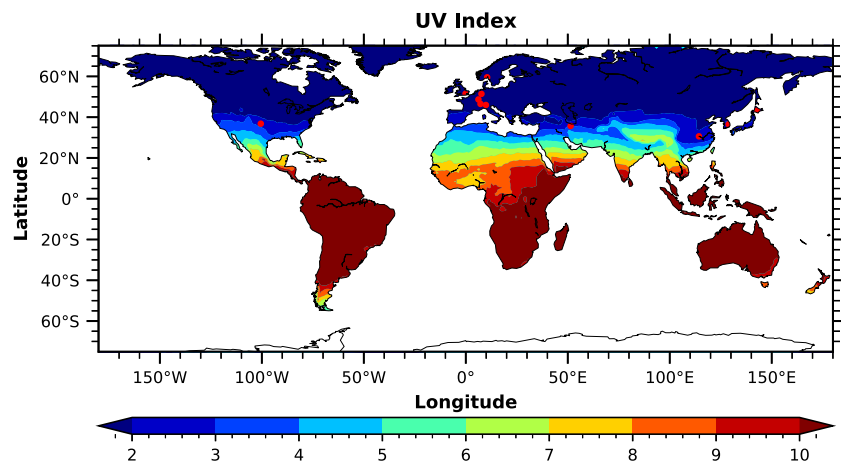
While the world is putting every possible effort into tackling the global epidemic situation resulting from the novel COVID-19 outbreak, very little information is available about the novel virus. Under this situation, in this study, we presented the possible dependence between the infection within a community and the temperature and UV index. By analyzing the data up to 7th March 2020 by considering more than 80 locations comprising of a number of confirmed cases and location-specific meteorological data, we showed that the spread of the virus is strongly dependent on the temperature and UV index. There is a very narrow temperature band of 3–

12 °C where 90% of the total confirmed cases are agglomerated. As can be seen from Fig. 4, major outbreaks across the globe are located in the temperature areas lying in the range consistent with our analysis. Most importantly, increase of the UV index has also shown a decrease in the number of cases. This is evident from the fact that the global UV index map averaged over 5 days for representation purposes clearly shows a relatively lower UV index for the most affected areas (Fig. 5). This, in our opinion, is a very striking feature of our findings and we believe that artificial UV radiation could be one of the effective ways for sterilizing built-up environments for reducing spread amongst the community. While we believe that we are not presenting any physiological evidences for the decrease in community infections of COVID-19 due to increase in temperature and UV index, we strongly believe that this information could be very useful, particularly when pharmaceutical interventions are not possible at this moment to deal with the global crisis. It is important, however, to note

**Fig. 4** Global map of the average temperature for January and February 2020, with the countries affected by more than 1000 cases as of 9th March 2020 indicated by the black circles. Importantly, countries, regions and locations severely affected are in a very narrow band of latitude



**Fig. 5** Similar to Fig. 4 but representing the UV index and locations indicated by the dots. Again, a very narrow band of UV index is clearly evident for the locations that are severely affected



that the information provided here is very preliminary and is not based on any physiological studies involving either confirmed cases and/or viruses. We advise that preparedness and other measures should take this study only for information purposes and propose further detailed physiological studies.

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