



# Climate effects on the COVID-19 outbreak: a comparative analysis between the UAE and Switzerland

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## Abstract

The main aim of the present study is to disclose the similarities or differences of the climate effects on the COVID-19 outbreak in two countries, which have different climatic conditions. Using the correlation modeling, the results revealed that some climatic factors, such as the ULR, temperature, and CH<sub>4</sub> in the UAE and aerosol index and NO<sub>2</sub> in Switzerland have positive lagged correlations with the outburst of COVID-19 by intensifying role within – 9, – 7, and – 2 days. The mitigating role was also observed for ozone/solar radiation and temperature/long-wave radiation in the UAE and Switzerland, respectively. The initial hypotheses of the research have confirmed the correlations between new cases of COVID-19 and ULR and aerosol indices in the UAE and Switzerland. However, the main finding revealed that the climate effects on the COVID-19 outbreak show different roles in the different countries, locating in dissimilar climatic zones. Accordingly, the COVID-19 can be intensified by increases of the ULR and temperature in an arid region, while it can be exactly mitigated by increases of these factors in a temperate area. This finding may be useful for future researches for identifying the essential influencing factors for the mitigating COVID-19 outbreak.

**Keywords** Climatic factors · Correlation test · COVID-19 outbreak · United Arab Emirates · Switzerland · COVID-19 · Climatology

## Introduction

Coronavirus disease 2019 (COVID-19) is a newly emerged type of pneumonia in Wuhan, China at the end of 2019, officially announced as a global pandemic on February 20, 2020, by the World Health Organization (WHO) (Shahzad et al. 2020; Alhazzani et al. 2020). Several studies have reported mixed findings regarding the determinants and causing factors of COVID-19 to provide useful implications and to take control of the spread (e.g., Doğan et al. 2020;

Bhadra et al. 2020; Roy et al. 2020). For example, Rahman et al. (2020) demonstrated the potential linkages between the spread of COVID-19 disease and the geospatial factors. In this regard, environmental factors, such as climatic variables, can strongly be interesting for disease outbreaks by spatial and temporal patterns (Ficetola and Rubolini 2020). Understanding the drivers of COVID-19 contagion is essential to predict the progress of a disease outbreak in the absence of containment measures (Jung et al. 2020).

The recent literature evaluated the effects of climatic factors, such as the temperature and air quality on the Coronavirus outbreak (Iqbal et al. 2020, Guo et al. 2020, Ma et al. 2020, Xie and Zhu 2020). For instance, Shi et al. (2020) revealed a biphasic relationship between the daily-confirmed cases rate of COVID-19 and daily temperature (with a peak at 10 °C) in some provinces of Mainland China. Besides, Şah in (2020) found that the lagged correlations could be observed between COVID-19 and climatic status, such as wind speed in some cities of Turkey. Furthermore, Ahmadi et al. (2020) claimed that areas with low values of wind speed, humidity, and solar radiation

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exposure to a high rate of COVID-19 infection in the provinces of Iran.

In Singapore and based on the limited data (from January to May 2020), Pani et al. (2020) revealed that some climatic factors (e.g., temperature, dew point, relative humidity, absolute humidity, and water vapor) have a positive correlation with COVID-19 pandemic. In empirical research, Doğan et al. (2020) revealed that among the weather indicators, the temperature had a negative correlation, while humidity and air quality highlighted a positive lagged correlation with daily new cases of COVID-19 in New Jersey from 1 March to 7 July 2020. For some different countries, Caspi et al. (2020) demonstrated a negative correlation between warmer climate and COVID-19 spread rate. Some other researchers have found different results regarding climate and Coronavirus disease. For example, Jahangiri et al. (2020) explored that the increased COVID-19 cases in the province levels of Iran are not related to the colder climate. Therefore, Xie and Zhu (2020) noted that there is no evidence about the COVID-19 outbreak decline in the warmer weather in the city levels of China. Meanwhile, scholars found that although specific humidity is the main element for influenza transmission (Lowen and Steel 2014), it may drive different changes for pandemic size and duration (Baker et al. 2020).

It seems that the different effects of climatic factors on the COVID-19 status need to be more clarified in the dissimilar regions of the world. Indeed, the effect of climatic conditions on COVID-19 outbreak is still controversial (Pani et al. 2020) because the pieces of evidence published on COVID-19 so far has not certainly detected the key role of the climatic variables (e.g., Gunthe et al. 2020, Gupta et al. 2020a, Gupta et al. 2020b, Xie and Zhu 2020). Furthermore, observational evidence of literature available to date has not yet sufficiently revealed the climate-related modulation for a significant factor influencing the COVID-19 infection (Smit et al. 2020).

As mentioned by Shakil et al. (2020), further researches should use the global data sources and methodologies through cross-country analysis to understand similarities and differences in the findings and country settings. Hence, the present study attempts to model the correlations between the diurnal climatic factors (i.e., mean daily surface pressure, temperature, upward long-wave radiation flux (ULR), upward solar radiation flux (USR), relative humidity (RH), specific humidity (SH), precipitation rate, evaporation rate, surface Omega, cloud coverage, NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, CO, CH<sub>4</sub>, and aerosol index) and daily new confirmed cases of COVID-19 by considering country-level data in the United Arab Emirates (UAE) and Switzerland. Using the correlation model, the main aim of the study is to distinguish similarities or differences in the climate effects on the COVID-19 outbreak in the study areas.

## Data and methods

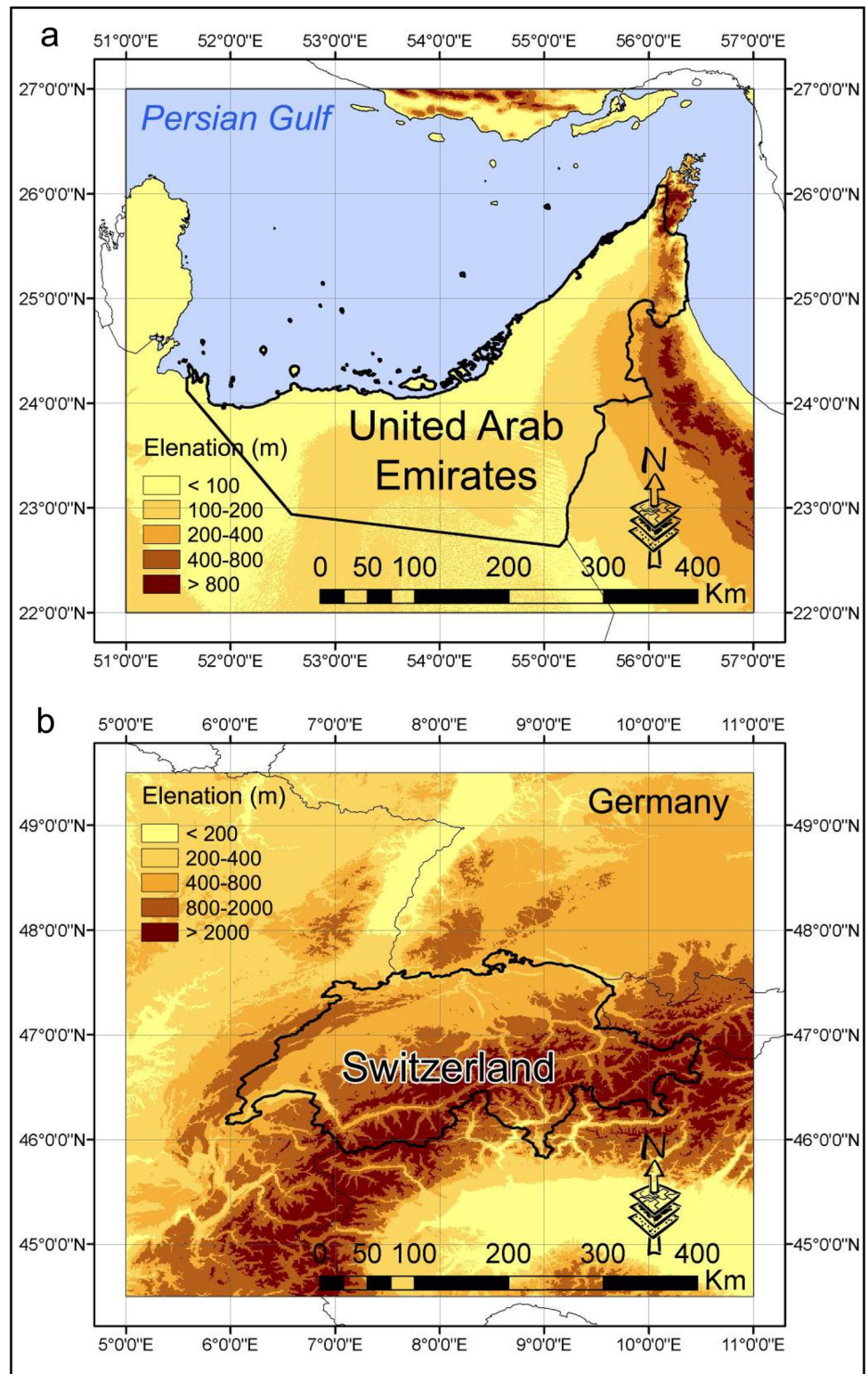
### Study area

In the present research, two specific countries, namely the United Arab Emirates (UAE) and Switzerland were taken into account to study areas (Fig. 1). The United Arab Emirates (UAE) is a northeastern part of the Arabian Peninsula. Its surface area is over 70,000 km<sup>2</sup> and is approximately lied between latitude 23° N to 26° N and longitude 52° E to 56° E. The UAE has nearly 1300 km of coastline. Active coastal Sabkhas or salt flats characterize the littoral zone of the UAE (Dougherty et al. 2009). According to the global digital elevation model (GDEM 2011) data, except for the eastern mountains, most of the country has shallow altitudes lower than 200 m above sea level (a.s.l.). Therefore, Switzerland comprised two main geographical parts of the Alp Mountains and the Swiss plateau. Its surface area is over 40,000 km<sup>2</sup> and is approximately lied between latitude 46° N to 48° N and longitude 06° E to 10° E. Alpine elevations characterize the littoral zone of Switzerland. Owing to GDEM, the country has a mean middle altitude 500–1000 m a.s.l. in the northern plateau and a mean high altitude 1000–2000 m a.s.l. in the southern elevations.

According to the climate classification of Köppen–Geiger, proposed by Beck et al. (2018) and Peel et al. (2007), the UAE is located in the hot arid desert zone (BWh) and Switzerland is located in the fully humid cool temperate zone (Cfc). The total annual precipitation and mean annual temperature of the UAE (Switzerland) were recorded as 130 (1400) mm and 25 (7) °C, respectively, derived from a global database of WorldClim (Hijmans et al. 2005). The UAE climatology is mainly influenced by the persistence of subtropical high pressure (STHP) resulted in hot and arid conditions. The distribution of precipitation, as rainfall pattern occurred in winter (Dougherty et al. 2009), is controlled by the interaction of the subtropical air masses and Mediterranean westerly currents and the Siberian high pressure. However, the climate of the Alpine region is characterized by a high degree of complexity, due to the interactions between the mountains and the general circulation of the atmosphere, which results in features such as gravity wave breaking, blocking highs and föhn winds (Beniston 2007).

The reason for the selection of the aforementioned two countries firstly depended on the different climatic status (as mentioned above) to examine the outbreak variability facing to different climatic zones. According to the literature, a lower lethality rate of COVID-19 in spring months has been observed in Equatorial temperate countries compared with European nontemperate areas (Carta et al. 2020). In the next steps, we attempt to remove the other parametrical effects of economy and demography.

**Fig. 1** Digital elevation and geographical position of the study areas **a** UAE and **b** Switzerland



Hence, the second reason related to the similar globalized econometrics, e.g., the high global ranking of mean annual GDP per capita over 40,000 US\$ after World Bank (2019),

similar very high human development index (values above 0.8 in 2019), similar size of population (8–10 M), and

similar size of total confirmed cases of COVID-19 in the October 25, 2020 (103–123 k).

## Data setting and modeling

Using the correlation modeling, both constant relation (Pearson's test) and lag correlation were analyzed between the dependent and independent variables in the SPSS program to expose the possible direct effects. The correlation modeling that is used in the present study is in line with the methodology of the worldwide researches performed to distinct the climatic role on the COVID-19 outbreak, such as Shi et al. (2020), Şahin (2020), Pani et al. (2020), Caspi et al. (2020), Lin et al. (2020), and Doğan et al. (2020).

In this regard, the dependent variable of daily new confirmed cases of COVID-19 was considered for 233 days from March 01, 2020, up to October 25, 2020, which were collected at the country-level from Coronavirus source data maintained by Our World in Data (OWID 2020) via <https://ourworldindata.org/coronavirus-source-data>. The reason for the data restriction before March 01, 2020, relates to the absence of large numbers of reported total confirmed cases in both countries (below 20 cases).

The independent climatic factors were assumed as the latest diurnal time series extracted from two global databases. On this basis, ten variables, namely surface pressure (Pascals), surface temperature (deg K), upward long-wave radiation flux (ULR) ( $W/m^2$ ), upward solar radiation flux (USR) ( $W/m^2$ ), relative humidity (RH) (%), specific humidity (SH) (Kg/Kg), precipitation rate ( $Kg/m^2/s$ ), evaporation rate ( $W/m^2$ ), surface Omega (Pascal/s), and cloud coverage (%) were collected from the Asia Pacific Data Research Center (APDRC) data

set, hosted by the National Oceanic and Atmospheric Administration (NOAA) via <http://apdrc.soest.hawaii.edu/las/getUI.do>, which has been defined by some scholars e.g., Rabbani et al. (2020). All aforementioned variables, by diurnal scale, were extracted based on the geographical position and coordination of each country.

Furthermore, about six variables, namely nitrous dioxide ( $NO_2$ ) concentration (1/cm), Sulfur dioxide ( $SO_2$ ) concentration (DU), ozone ( $O_3$ ) concentration (DU), carbon monoxide (CO) mole fraction (ppbv), methane ( $CH_4$ ) mole fraction (ppbv), and UV aerosol index (unit-less) were extracted from Geospatial Interactive Online Visualization, and Analysis Infrastructure (Giovanni) remotely sensed database, hosted by the Goddard Earth Sciences Data and information services center of National Aeronautics and Space Administration (NASA/GES) via <http://giovanni.sci.gsfc.nasa.gov/giovanni>, which has been used by some scholars e.g., Daneshvar et al. (2019).

## Results

### Data estimations

#### COVID-19 data

Based on the number of reported cases, on October 25, 2020, the COVID-19 outbreak was recorded in the United Arab Emirates (Switzerland) by a total of 123,764 (103,323) confirmed cases and 475 (1876) total deaths (OWID 2020). On this basis, the United Arab Emirates and Switzerland have a mortality rate of 0.4% and 1.8%

**Table 1** Summarized mean daily values of COVID-19 and all climatic factors in the UAE and Switzerland based on 233 days (1 March to 25 October 2020)

Factor	Unit	UAE	Switzerland
New daily cases of COVID-19	(Person)	532	447
Nitrous dioxide ( $NO_2$ )	(1/cm)	4.6E+15	4.4E+15
Methane ( $CH_4$ )	(ppbv)	1877	1926
Carbon monoxide (CO)	(ppbv)	117	112
Sulfur dioxide ( $SO_2$ )	(DU)	0.13	0.01
UV aerosol index	(Unitless)	1.42	0.26
Ozone ( $O_3$ )	(DU)	280	328
Cloud coverage	(%)	17	42
Upward long-wave radiation flux (ULR)	( $W/m^2$ )	312	236
Upward solar radiation flux (USR)	( $W/m^2$ )	106	137
Surface Omega	(Pascal/s)	− 0.02	0.04
Surface temperature	(deg K)	308	291
Relative humidity (RH)	(%)	33.1	0.1
Specific humidity (SH)	(Kg/Kg)	0.01	0.01
Surface pressure	(Pascals)	99,223	92,150
Evaporation rate	( $W/m^2$ )	463	141
Precipitation rate	( $Kg/m^2/s$ )	5.1E-04	7.1E-03

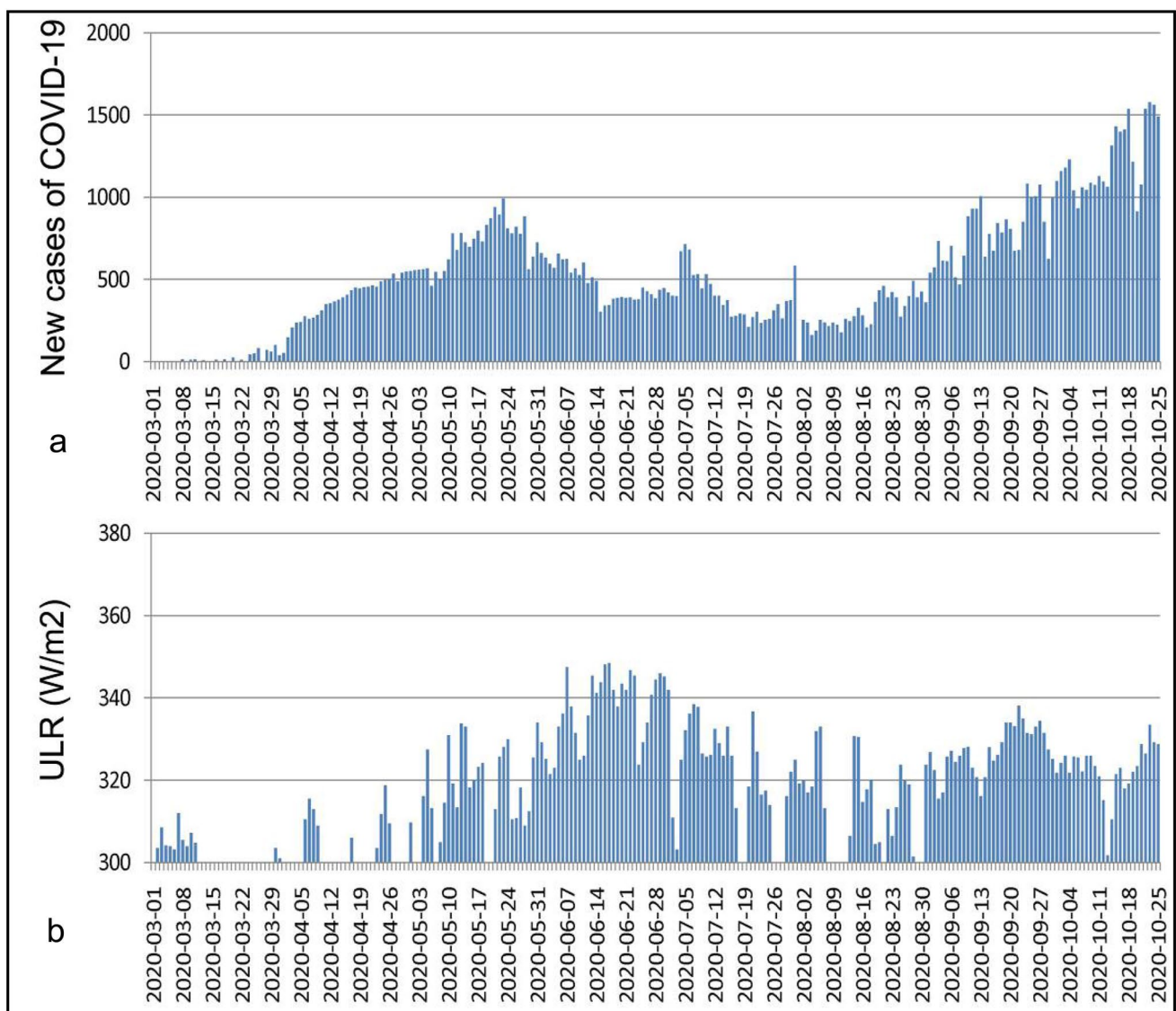
of total confirmed cases. The mortality rate in Switzerland is higher than in the UAE, which probably depends on the older age group of the population (population > 65 years in UAE and Switzerland are about 1.1% and 18.4%, respectively) and needs different self-sufficient research.

In the present research, the mean daily values of new confirmed cases were calculated as 532 and 447 cases for UAE and Switzerland within 233 days (from 1 March to 25 October), respectively (Table 1). The mean value of global new daily cases based on 211 contaminated countries was estimated equal to 847 cases at the same time. Hence, both countries of the study area similarly are in the middle to lower contagion conditions. Besides, the trends in the COVID-19 time series revealed that both countries

experienced two peaks of disease outburst (Figs. 2, 3). In the UAE, the trend peaks were recorded on 15–25 May and 15–25 October, while the mentioned increases in Switzerland registered on 10–20 March and 15–25 October.

### Climate data

From the climactic point, the study areas have some essential differences. For instance, the mean daily values of surface temperature in the study period were estimated to equal 308 and 291 degrees K, revealing an approximately 17 degrees gradient. Subsequently, a great difference is evident between the relative humidity of both countries



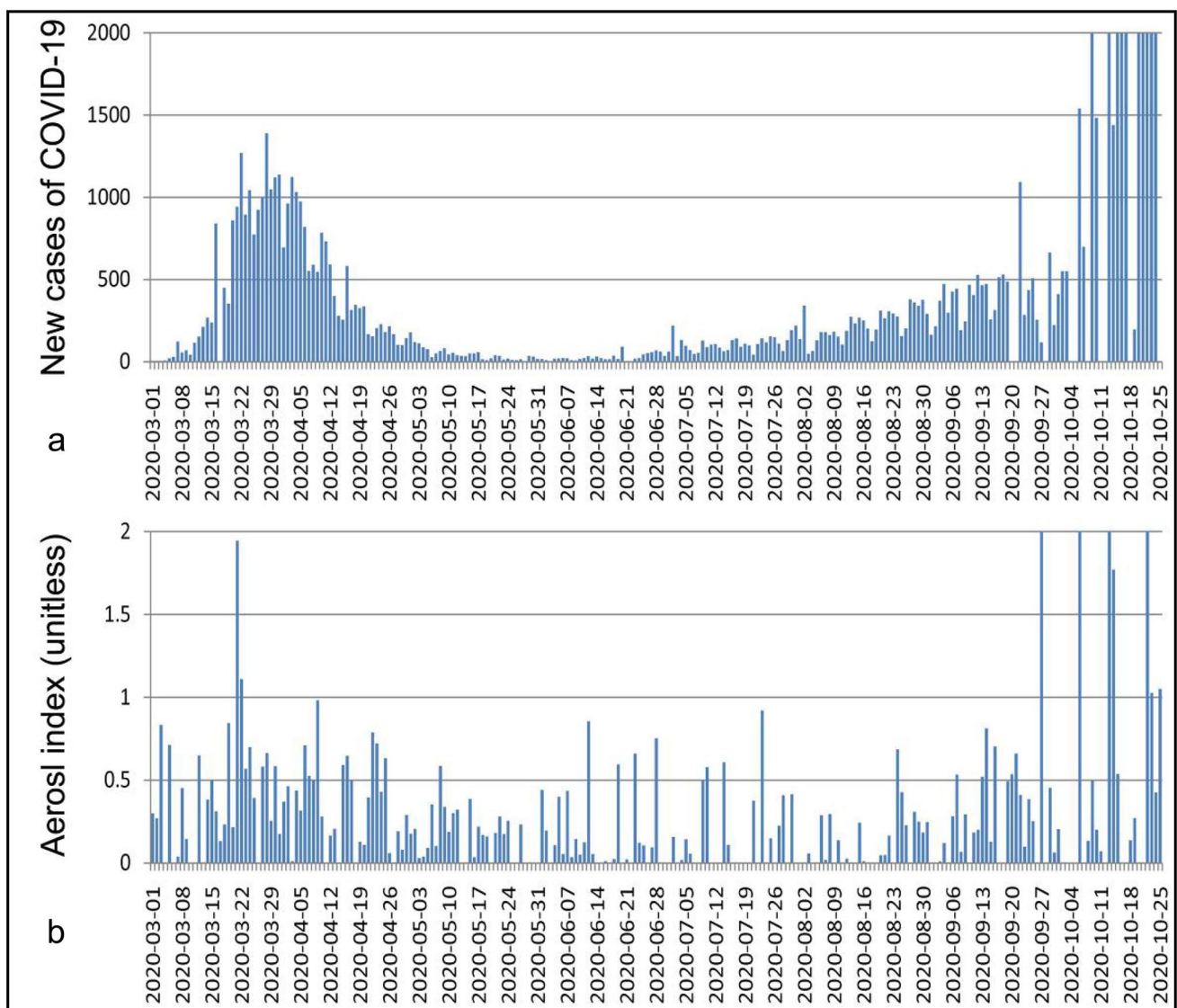
**Fig. 2** Diurnal time series of data in the UAE from 01 March 2020 to 25 October 2020 **a** new confirmed cases of COVID-19 and **b** upward long-wave radiation (ULR)

with a 33% variation (Table 1). The mean daily statistics of some other climatic factors, such as surface pressure, evaporation rate, ULR, sulfur dioxide, and UV aerosol index have the higher values in the UAE compared with Switzerland with the gradients of  $\sim 7000$  Pascals,  $322 \text{ W/m}^2$ ,  $76 \text{ W/m}^2$ ,  $0.12 \text{ DU}$ , and  $1.16$ . Conversely, the mean daily statistics of some other climatic factors such as cloud coverage, USR, ozone, and methane concentrations have the lower values in the UAE compared with Switzerland with the gradients of 25%,  $31 \text{ W/m}^2$ ,  $48 \text{ DU}$ , and  $49 \text{ ppbv}$ . Concluding, the UAE compared with Switzerland revealed a very hot and arid condition based on the surface temperature, pressure, evaporation, and ULR values during the study period (233 days).

## Data correlations

### Constant correlation test

In the first step, the diurnal plots of time series were produced. Diurnal time series of two sampling dependent and independent data from 01 March 2020 to 25 October 2020 are shown in Figs. 2, 3 for new confirmed cases of COVID-19 and upward long-wave radiation (ULR) in the UAE and new confirmed cases of COVID-19 and UV aerosol index in Switzerland. Based on the synchronizing peaks of the time series (see Figs. 2, s3), we could observe a simple possible relationship between the variables. For instance, we could retain a few hypotheses, demonstrating the correlations



**Fig. 3** Diurnal time series of data in Switzerland from 01 March 2020 to 25 October 2020 **a** new confirmed cases of COVID-19 and **b** UV aerosol index

**Table 2** Constant correlations between independent climatic factors and COVID-19 data in the UAE and Switzerland

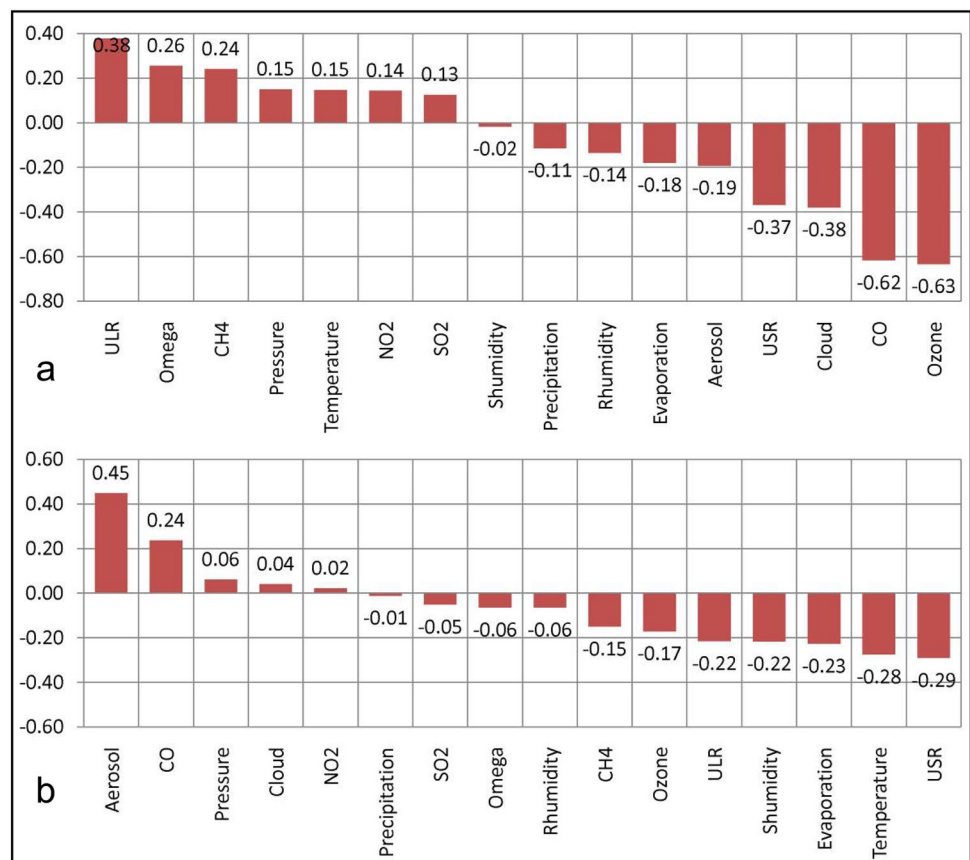
Factor	New confirmed cases of COVID-19	
	UAE	Switzerland
NO <sub>2</sub>	0.14	0.02
CH <sub>4</sub>	0.24	− 0.15
CO	− 0.62	0.24
SO <sub>2</sub>	0.13	− 0.05
Aerosol	− 0.19	0.45
Ozone	− 0.63	− 0.17
Cloud	− 0.38	0.04
ULR	0.38	− 0.22
USR	− 0.37	− 0.29
Omega	0.26	− 0.06
Temperature	0.15	− 0.28
RH	− 0.14	− 0.06
SH	− 0.02	− 0.22
Pressure	0.15	0.06
Evaporation	− 0.18	− 0.23
Precipitation	− 0.11	− 0.01

No. of province cases: 233

between new cases of COVID-19 and ULR and aerosol indices in the UAE and Switzerland. To examine similar assumptions, the constant correlations (contemporary) between the new cases of COVID-19 and 16 climatic factors were estimated by the Pearson test through two study areas (Table 2).

The results confirmed the constant relationships (with a significant level of  $R < -0.25$  or  $R > 0.25$  at confidence 90%) between confirmed cases and two climatic factors (ULR and Omega) positively, and four climatic factors (ozone, CO, cloud coverage, and USR) negatively in the UAE. Therefore, the constant relationships were observed between confirmed cases and one climatic factor (aerosol index) positively, and two climatic factors (USR and temperature) negatively in Switzerland (Fig. 4). Hence, within two countries, only two climatic factors, namely upward solar radiation (USR) and NO<sub>2</sub> have commonly been associated with the COVID-19 outbreak. In the other words, the higher values of upward solar radiation (USR) or the lower values of Nitrous dioxide (NO<sub>2</sub>) in both countries relate to the lower values of new cases of COVID-19, mitigating the outbreak effects. Besides, other climatic factors, e.g., precipitation, have not any significant constant correlation with COVID-19 in the study areas.

**Fig. 4** A diagram for the constant relationships between the new confirmed cases of COVID-19 and 16 climatic variables in **a** UAE and **b** Switzerland



**Table 3** Lag correlations between new cases of COVID-19 and 16 climatic factors within 14 lag days in the UAE

Lag (day)	NO <sub>2</sub>	CH <sub>4</sub>	CO	SO <sub>2</sub>	Aerosol	Ozone	Cloud	ULR	USR	Omega	Temperature	RH	SH	Pressure	Evaporation	Precipitation
-14	-0.09	0.02	-0.30	0.03	-0.11	-0.30	-0.09	0.25	-0.14	0.04	0.26	-0.04	0.28	-0.17	0.10	-0.01
-13	-0.01	0.01	0.00	0.03	0.00	-0.05	0.03	0.00	0.02	-0.04	0.04	-0.02	0.02	-0.03	0.02	0.00
-12	-0.04	0.01	-0.08	0.00	-0.04	-0.12	-0.01	0.06	-0.03	0.05	0.05	0.00	0.07	-0.04	0.01	0.00
-11	-0.09	0.12	-0.15	0.10	-0.04	-0.12	-0.13	0.20	-0.19	-0.08	0.18	-0.14	0.04	-0.11	0.01	-0.01
-10	0.03	0.07	-0.06	0.05	-0.02	-0.08	-0.06	0.09	-0.09	0.03	0.09	-0.08	0.02	-0.04	0.02	0.00
-9	-0.08	0.18	-0.35	0.11	-0.05	-0.42	-0.22	0.41	-0.28	-0.09	0.41	-0.23	0.25	-0.25	0.04	-0.03
-8	-0.01	0.06	-0.06	0.09	0.03	-0.09	0.01	0.10	-0.04	-0.12	0.21	-0.13	0.11	-0.17	0.10	0.01
-7	-0.06	0.12	-0.48	0.12	-0.14	-0.48	-0.18	0.38	-0.24	0.03	0.35	-0.11	0.32	-0.20	0.03	-0.04
-6	-0.04	0.06	-0.02	0.05	0.02	-0.15	0.06	0.05	0.02	-0.10	0.15	-0.08	0.08	-0.15	0.06	0.01
-5	-0.05	-0.02	-0.20	0.04	-0.06	-0.28	-0.04	0.14	-0.04	0.06	0.15	-0.05	0.12	-0.06	0.02	0.00
-4	0.04	0.04	-0.08	0.04	-0.09	-0.07	-0.11	0.11	-0.14	0.01	0.05	-0.06	0.00	0.01	-0.03	0.00
-3	-0.01	0.07	-0.04	0.04	-0.04	-0.16	-0.07	0.11	-0.09	-0.03	0.10	-0.06	0.05	-0.05	0.02	0.00
-2	-0.08	0.24	-0.33	0.18	-0.12	-0.33	-0.25	0.37	-0.32	-0.01	0.24	-0.16	0.12	-0.10	-0.04	-0.04
-1	0.06	0.02	-0.07	0.09	0.03	-0.06	0.01	0.10	-0.03	-0.03	0.17	-0.15	0.04	-0.13	0.06	-0.03
0	-0.10	0.22	-0.60	0.30	-0.20	-0.68	-0.26	0.56	-0.37	0.09	0.47	-0.23	0.29	-0.22	-0.01	-0.05

**Table 4** Lag correlations between new cases of COVID-19 and 16 climatic factors within 14 lag days in the Switzerland

Lag (day)	NO <sub>2</sub>	CH <sub>4</sub>	CO	SO <sub>2</sub>	Aerosol	Ozone	Cloud	ULR	USR	Omega	Temperature	RH	SH	Pressure	Evaporation	Precipitation
-14	0.11	-0.08	-0.01	-0.04	0.00	-0.17	0.08	-0.11	-0.19	0.05	-0.17	0.05	-0.18	0.10	-0.20	-0.10
-13	0.01	-0.09	0.05	-0.02	0.05	-0.01	-0.01	-0.03	-0.09	0.01	-0.09	0.01	-0.09	0.04	-0.07	-0.03
-12	0.10	-0.02	0.04	-0.05	0.00	-0.03	0.08	-0.13	-0.11	0.00	-0.15	0.00	-0.12	-0.03	-0.15	-0.04
-11	0.01	-0.03	0.05	-0.05	0.06	-0.01	-0.06	-0.01	-0.10	0.03	-0.12	0.03	-0.11	0.04	-0.08	-0.08
-10	0.07	-0.06	0.03	-0.08	0.02	-0.04	-0.02	-0.02	-0.09	0.02	-0.08	0.02	-0.07	0.01	-0.09	-0.06
-9	0.01	-0.12	0.10	0.01	0.06	-0.02	-0.03	-0.04	-0.15	0.03	-0.14	0.03	-0.14	0.02	-0.11	-0.08
-8	-0.02	-0.05	0.07	0.01	0.06	0.04	-0.01	-0.02	-0.03	-0.03	-0.07	-0.03	-0.07	-0.03	-0.07	-0.03
-7	-0.07	-0.05	0.09	-0.08	0.07	-0.02	-0.07	-0.05	-0.17	0.00	-0.24	0.00	-0.21	-0.06	-0.17	-0.09
-6	-0.02	-0.07	0.10	-0.03	0.05	0.06	-0.04	-0.03	-0.02	-0.03	-0.10	-0.03	-0.08	-0.03	-0.07	-0.01
-5	-0.05	-0.04	0.10	-0.03	0.03	0.04	-0.08	-0.04	-0.13	0.03	-0.21	0.03	-0.17	-0.08	-0.13	-0.06
-4	-0.01	-0.07	0.09	-0.01	0.06	0.02	-0.08	0.00	-0.07	0.00	-0.14	0.00	-0.11	0.00	-0.11	-0.06
-3	-0.09	-0.06	0.09	-0.03	0.00	-0.16	0.04	-0.14	-0.14	-0.08	-0.13	-0.08	-0.10	0.03	-0.04	-0.06
-2	0.19	-0.16	0.13	-0.03	0.46	-0.05	0.12	-0.27	-0.12	-0.12	-0.16	-0.12	-0.10	0.05	-0.16	0.00
-1	-0.11	-0.07	0.11	-0.05	0.04	-0.10	0.07	-0.14	-0.08	-0.10	-0.11	-0.10	-0.08	-0.02	-0.08	-0.03
0	0.01	-0.08	0.23	-0.06	0.48	-0.11	0.04	-0.26	-0.30	-0.13	-0.32	-0.13	-0.23	0.03	-0.26	-0.10



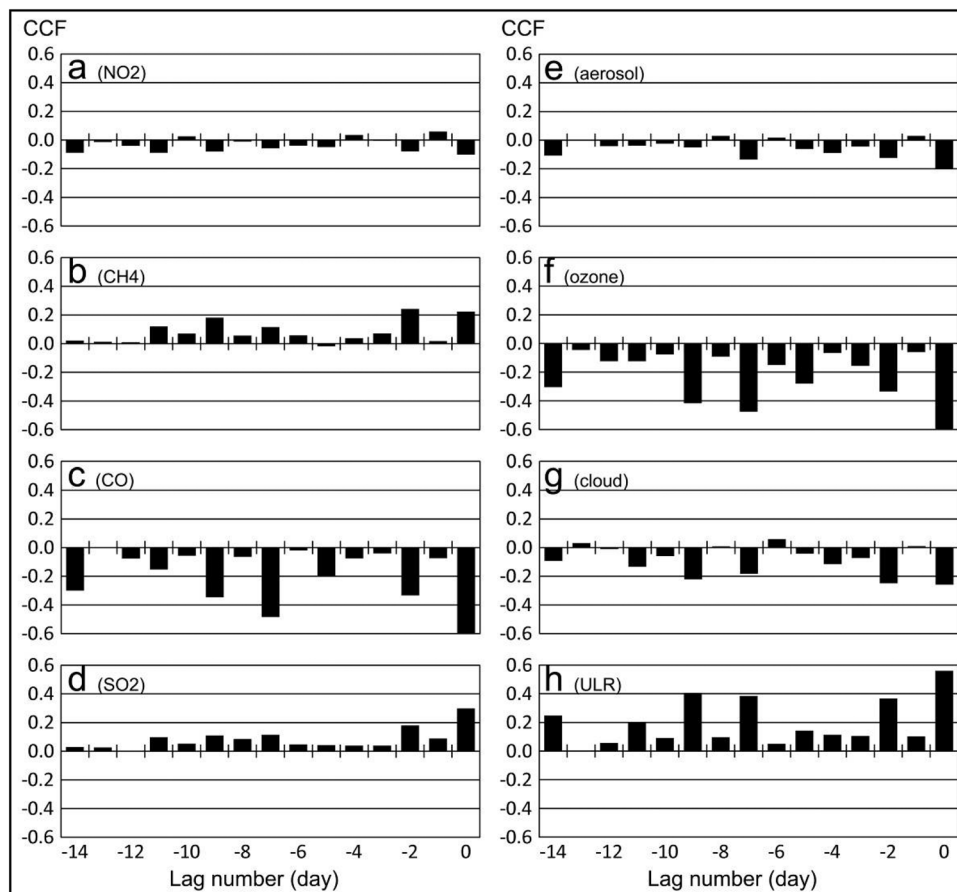
**Lag correlation test**

In addition to constant correlations (contemporary), we need to examine the possible lag correlations, revealing the temporal delays. For this purpose, the crossed correlation functions were assumed to expose the lagged correlations. Owing to the incubation period of COVID-19, which is about 2–14 days (Pirouz et al. 2020), it could be expected that the initial effects of some climatic factors on the outburst of COVID-19 cases can be delayed within two weeks. Hence, the lagged times for climatic factors were considered as 14 days before the measures new cases of COVID-19. In this regard, lag correlations between new cases of COVID-19 and 16 climatic factors were estimated within 14 lagged days in the UAE and Switzerland (Tables 3, 4). The results revealed that within 9, 7, and 2 days before the outburst of COVID-19 some climatic factors have significant alterations ( $CCF > 0.25$  or  $CCF < -0.25$ ). In this regard, the sudden increase of the ULR, temperature, and  $CH_4$  and the sudden decrease of ozone, CO, and the USR were observed through the aforementioned lagged times in the UAE (Figs. 5, 6). Nevertheless, the gradual increase in aerosol index and  $NO_2$  values in addition to the gradual decrease of the ULR and

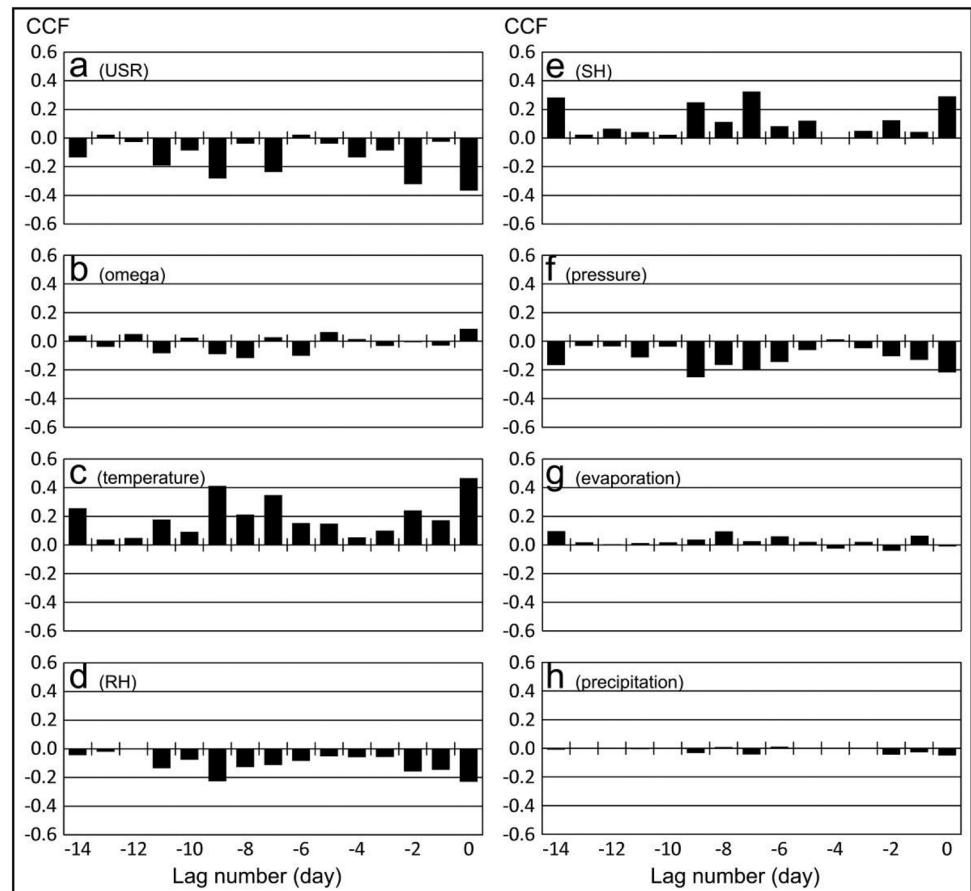
temperature were observed before the COVID-19 outburst in Switzerland (Figs. 7, 8).

The contradictory results of the correlation analysis revealed an essential supposition demonstrating that the climatic effects on the COVID-19 outbreak are different in the different countries, which are located in unlike climatic zones. In an arid Middle Eastern country (like UAE in 23–26° N), the COVID-19 can be intensified by increases of the ULR, temperature, and methane values, while in a temperate European country (like Switzerland in 46–48° N), COVID-19 can be intensified by increases of the aerosol and  $NO_2$  values. Conversely, the mitigation factors for COVID-19 can be categorized as intensifying the cloud coverage, ozone release, and solar radiation in the arid regions. The mitigation measures also can be considered as enhancing the long-wave radiations, surface temperature, and evaporation rate in the central European zones.

**Fig. 5** Diurnal lag correlations in UAE between new cases of COVID-19 and **a**  $NO_2$ , **b**  $CH_4$ , **c** CO, **d**  $SO_2$ , **e** aerosol, **f** ozone, **g** cloud cover, and **h** ULR



**Fig. 6** Diurnal lag correlations in UAE between new cases of COVID-19 and **a** USR, **b** omega, **c** temperature, **d** relative humidity (RH), **e** specific humidity (SH), **f** pressure, **g** evaporation, and **h** precipitation

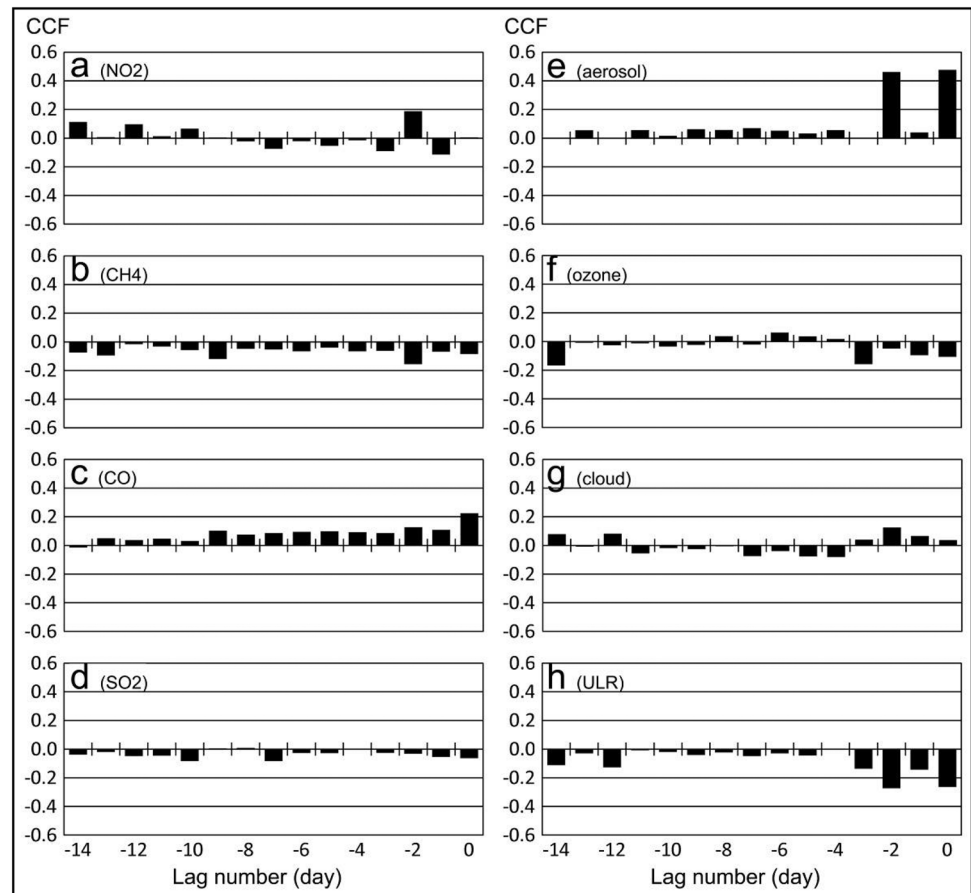


## Discussion

Our finding revealed that the climatic effects on the COVID-19 outbreak are different in the different countries, which are located in unlike climatic zones. The COVID-19 can be intensified by increases of the ULR and temperature in an arid region, while it can be exactly mitigated by increases of these factors in a temperate area. Some scholars have obtained like results, which reflect contradictory findings. For instance, Ma et al. (2020) revealed a positive association with COVID-19 daily death for temperature range, but a negative association for relative humidity in Wuhan, China. Contrarily, Iqbal et al. (2020) revealed that the decrease in the new COVID-19 infections in Wuhan city has no significant relationship with the increase of the temperature values. Gupta et al. (2020a) suggested that hot and dry regions in the lower altitudes of India are more prone to infection by COVID-19 transmission.

Also, different results are observed in research by Lin et al. (2020), illustrating the negative correlations between the new confirmed cases of COVID-19 and some climatic factors (e.g., temperature and humidity) in Brazil, Peru, and South Africa, and the positive correlations between the COVID-19 and temperature in India, Mexico, and the US. Hence, we are in line with different results conducted by various studies regarding the climatic conditions and COVID-19 outbreak. For example, we found that the lower values of Nitrous dioxide ( $\text{NO}_2$ ) in both countries relate to the lower values of new cases of COVID-19, mitigating the outbreak effects same as Ogen (2020), which have noted the exposure to  $\text{NO}_2$  increases on the COVID-19 in Italy, Spain, France, and Germany. Moreover, we found that some climatic factors e.g., precipitation has not any significant constant correlation with COVID-19, which is in accordant to Sobral et al. (2020), revealing no association between precipitation and COVID-19 outbreak.

**Fig. 7** Diurnal lag correlations in Switzerland between new cases of COVID-19 and **a** NO<sub>2</sub>, **b** CH<sub>4</sub>, **c** CO, **d** SO<sub>2</sub>, **e** aerosol, **f** ozone, **g** cloud cover, and **h** ULR

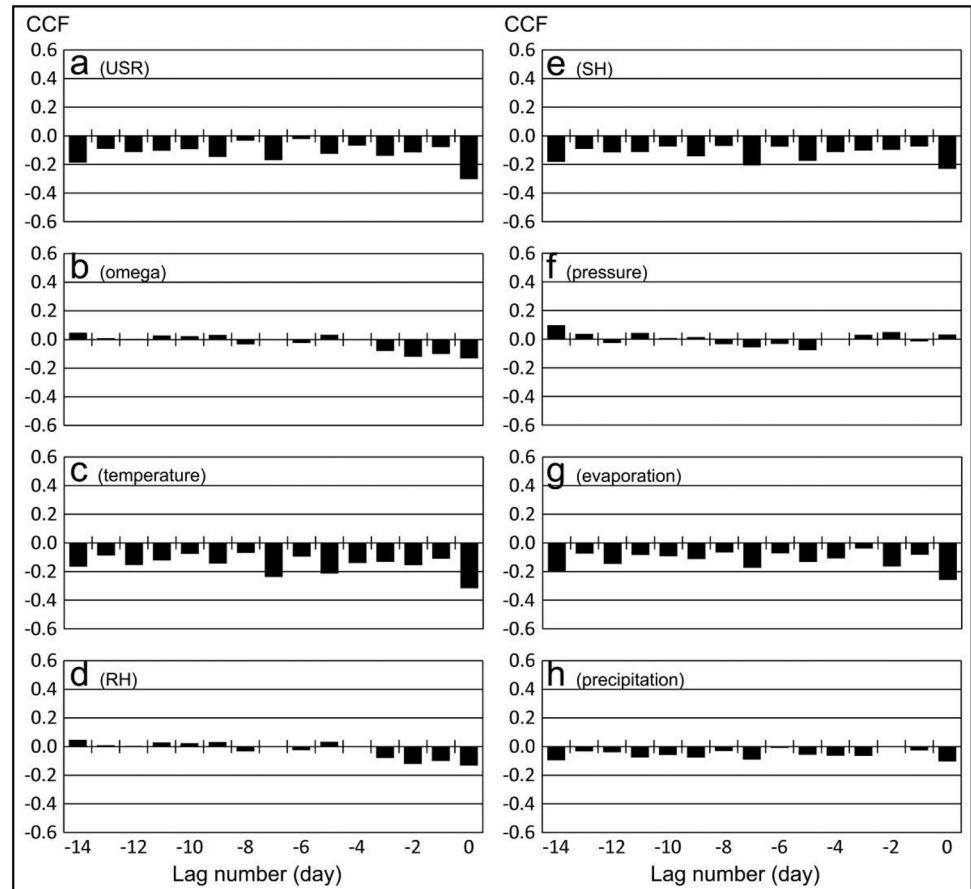


## Conclusion

The main aim of the present study is to assess country-level climatic effects on the COVID-19 outbreak with a comparative aspect between two specific countries, namely the United Arab Emirates (UAE) and Switzerland. Both countries have experienced some precious courses regarding the outbreak. Since ongoing the worldwide pandemic status, the UAE as a frontier country in the Middle East rapidly reacted to the outbreak in March 2020 with strict and harsh preventive measurements (Bloukh et al. 2020). As well in Switzerland, about two weeks after the first report of COVID-19 infection on March 13, the Federal Council started to tightly control the border to the surrounding countries (Willi et al. 2020), and the first lockdown policy was taken to decide

after 15 March (Sciré et al. 2020). The results confirmed the positive relationships between confirmed cases of COVID-19 and ULR and aerosol index in the UAE and Switzerland, respectively. Hence, the initial hypotheses of the research, concerning the correlations between new cases of COVID-19 and ULR and aerosol indices in the study areas were confirmed. However, our finding revealed that the climatic effects on the COVID-19 outbreak are different in the different countries, which are located in unlike climatic zones. The COVID-19 can be intensified by increases of the ULR and temperature in an arid region, while it can be exactly mitigated by increases of these factors in a temperate area. This finding may be useful for future researches for identifying the essential influencing factors for the mitigating COVID-19 outbreak.

**Fig. 8** Diurnal lag correlations in Switzerland between new cases of COVID-19 and **a** USR, **b** omega, **c** temperature, **d** relative humidity (RH), **e** specific humidity (SH), **f** pressure, **g** evaporation, and **h** precipitation



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**Data availability** The data that support the findings of this study are available from the corresponding author upon request.

## Compliance with ethical standards

**Conflict of interests** The authors declare that they have no Competing interests.

**Ethics approval and consent to participate** This article does not contain any studies with participants performed by any of the authors.

**Informed consent** Informed consent was obtained from individual participant included in the study.

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