Climate and Covid-19 - Upgrade and solar radiation influences based on Brazil cases

Francisco Mendonça (✉ chico@ufpr.br)

Universidade Federal do Parana Setor de Ciencias da Terra <https://orcid.org/0000-0002-3107-8519>

Max Anjos

Universidade Federal do Parana Setor de Ciencias da Terra

Erika Collischonn

Universidade Federal de Pelotas

Pedro Murara

Universidade Federal da Fronteira do Sul

Deise Ely F.

Universidade Estadual de Londrina

Leila Limberger

Universidade Estadual do Oeste do Paraná

Lindberg Nascimento

Universidade Federal de Santa Catarina Centro de Filosofia e Ciencias Humanas

Gilson C. F. da Cruz

Universidade Estadual de Ponta Grossa

Wilson Roseghini

Universidade Federal do Parana

Aparecido R. Andrade

Universidade Estadual do Centro do Paraná

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Abstract

Background

COVID-19 has confirmed to be a pandemic with global and historical dimensions in the beginning of the 21st century. Climatic conditions are one of the environmental factors that influence communicable diseases, including viral diseases. Despite promising scientific advances into understanding the interaction between climate and COVID-19, a question remains: How can climate influence the pandemic of COVID-19?

Methods

It was updated the publications available on the climate and COVID-19 using Scopus, Web of Science, and PubMed database from January 1 to May 20, 2020. Statistical analysis, such normality and multicollinearity tests were performed between number of COVID-19 cases and climato-meteorological parameters (temperature, relative humidity, dew point temperature, atmosphere pressure, wind speed, wind gust, rainfall, and solar radiation, nebulosity and insolation ratio) in six Brazilian cities.

Results

This review reveals that temperature, relative humidity and absolute humidity alone do not able to explain the exponential number of COVID-19 cases. Most studies showed the SARS-CoV-2 satisfactorily can survive in a large range of temperature and humidity in temperature and tropical- humidity climates. Analyzing other meteorological parameter, insolation ratio that is related to the solar radiation and nebulosity, the results and in accordance with other studies suggest the transmission and contagion by SARS-CoV-2 seem to have been enhanced under from medium to low direct solar radiation and covered skies.

Conclusions

This study showed that the inclusion of other climatic variables, in addition to temperature and humidity, should guide future ecological models on the relationship between climate and COVID-19, especially the insolation ratio influences on the viral transmission in six Brazilian cities. Our findings may support public policies and coordinated actions to reduce and control of COVID-19.

Introduction

The novel Coronavirus (SARS-CoV-2) causes the historic pandemic of COVID-19. More than 4,8 million confirmed cases and over 323 thousand deaths worldwide, as May 20, 2020 (WHO, 2020). COVID-19 has spread rapidly across nearly all regions of the world, mainly due to its highly communicable nature and intense human mobility on a global scale. Many uncertainties and considerable ignorance remain regarding both the viral dynamics, control of transmission and treatment of the COVID-19.

The currently challenge puts in motion the multicausality as framework for analysis of the COVID-19 pandemic. The interaction between the physical-natural environment, social environment (way of life, mobility, urbanization, public policies, occupation density) and living environment (virus) has been best-documented (Besancenot, 2001; Sorre, 1951). Epidemiology suggests the climate and meteorological as environmental factors that have seasonal influence on viral diseases (National Academies of Sciences, 2020), either indirectly on individuals and human populations or directly on vectors and/or pathogens.

SARS-CoV-2 is part of a large viral family, of which four species are best known for the occurrence of common colds: i) Alpha coronavirus HCoV-229E (infecting humans and bats), ii) Alpha coronavirus HCoV-NL63, iii) Beta coronavirus HCoV-OC43 and, iv) Beta coronavirus HCoV-HKU1 (originating from infected rats) that are highly associated with climatic conditions and meteorological factors (Matoba et al., 2018).

Recent study showed that SARS-CoV-2 is highly stable at 4.0 °C, but sensitive to heat, so that with the incubation temperature increased to 70 °C, the time for virus inactivation was reduced to 5 min (Chin et al., 2020). Although recent researches have provided pioneering insights into the transmission of COVID-19 due to environmental factors (Ahmadi et al., 2020; Bukhari and Jameel, 2020; Caspi et al., 2020; Liu et al., 2020; Ma et al., 2020; Wang et al., 2020; Xie and Zhu, 2020), an optimum climate for SARS-CoV-2 for sub and tropical cities is still under discussion. Optimum climate affects the vital functions of virus within certain thresholds of physical parameters, such as temperature, humidity and insolation. Thus, studying what meteorological conditions influence the transmission, contagion, infectivity and survival of SARS-CoV-2 is of enormous relevance to improve the knowledge on the origin and spread of COVID-19 in different climates.

In this study, (i) we upgraded the available literature surround climate and COVID-19, highlighting the main climatological variables that may affect this disease, and (ii) we emphasized the relationship between the COVID-19 outbreak and climato-meteorological parameters in six capital Brazilian cities.

Methodology

Literature review procedure

It was updated the publications available on the climate and COVID-19 using Scopus, Web of Science, and PubMed database from January 1 to May 20, 2020. The search terms used into the database were "COVID-19" OR "Coronavirus" OR "Corona virus" OR "2019-nCoV" OR "SARS-CoV" OR "MERS-CoV" OR "Severe Acute Respiratory Syndrome" OR "Middle East Respiratory Syndrome", in combination with AND "Climate" AND "meteorological". English review

articles and research articles were considered as search filters. In this review, the preprint (no peer-review) papers were considered because an initial assessing of the dataset, methods and potential scientific contribution showed that their outcomes are similar to selected peer-reviewed articles.

Dataset and statistical analysis

To examine the effects of climate on the transmission and contagion by the SARS-CoV-2, it was performed a normalization test at eight Brazilian cities (São Paulo, Rio de Janeiro, Brasília, Recife, Fortaleza, Manaus) with different types of climate, combining climatic parameters and number of COVID-19 cases. The weather data were daily mean maximum temperature (Tmax), minimum temperature (Tmin), maximum relative humidity (RHmax), minimum relative humidity (RHmin), maximum Dew point temperature (DPmax), minimum Dew point temperature (DPmin), maximum atmosphere pressure (APmax), minimum atmosphere pressure (APmin), wind speed (WS), Wind gust (WG), rainfall (RA), and solar radiation (SR) provided by the National Meteorological Brazilian Institute (INMET) from Jan 30 to May 8, 2020. In additional, it was calculated the insolation ratio at each city by the following equation (<http://biomet.ucdavis.edu/biomet/Radiation/Wton.htm>):

$$\frac{n}{N} = 2 \left(\frac{R_s}{R_a} - 0.25 \right), \quad (1)$$

where n is the hours of bright sunshine, N is the bright sunshine to potential bright sunshine, and R_s/R_a is the estimated ratio of surface to extraterrestrial solar radiation ($\text{MJ m}^{-2} \text{ day}^{-1}$). The daily values of solar brightness are related to the radiation and potential hours of sunshine relative to latitude and season (Snyder, 2001). Geospatially daily average amount of the total solar radiation at each city were extracted from the POWER Data Access Viewer (DAV) Web Mapping Application managed by the NASA Langley Research Center (LaRC) POWER Project funded through the NASA Earth Science/Applied Science Program.

Regarding the COVID-19 data, it was used the number daily of confirmed cases from Brazil-IO web platform (<https://brasil.io/dataset/covid19/caso/>), a collaborative project that manages bulletin and reporting of the coronavirus cases noticed by the municipal governments and Brazilian Health Ministry. As we recognized that there is a significant inaccuracy between the number of real COVID-19 cases and notified ones (underreporting) in Brazilian context, we used three sampled periods to the climatic parameters data, as follows: i) without time lag (CC1), (ii) a week of time lag (CC7), and (iii) two weeks of time lag (CC14). CC1 refers to daily values of COVID-19 cases as published officially, CC7 meets the epidemiological week, and CC14 is related with initial infection SAR-COV-2 period.

The Shapiro-Wilk and Anderson-Darling tests were applied to evaluate whether the sampled of data follows a normality distribution. Table 1 shows most cites had not a normal distribution ($p\text{-value} < 0,005$), suggesting the application of multicollinearity. This test evaluates when relative significant correlation coefficients can not represent the intensity, in which an independent variable is to able to explain the dependent variables.

Table 1
Description of Shapiro-Wilk and Anderson-Darling values for climatic parameters in six Brazilian cities.

City		BRASILIA	FORTALEZA	MANAUS	RECIFE	RIO DE JANEIRO	SAO PAULO
Code station		86715	81758	81730	81958	86887	86910
Latitude		-15,78	-3,81	-3,10	-8,05	-22,98	-23,49
Longitude		-47,92	-38,53	-60,01	-34,95	-43,19	-46,62
Alt (m)		1,161	30	49	11	26	786
		P-value	P-value	P-value	P-value	P-value	P-value
Shapiro-Wilk (W)	Tmax (°C)	0,001	0,048	0,346	< 0,0001	0,050	0,025
	Tmin (°C)	0,165	0,022	0,065	< 0,0001	0,078	0,035
	RHmax (°C)	0,001	0,306	0,001	< 0,0001	0,013	0,001
	RHmin (°C)	0,005	0,279	0,003	< 0,0001	0,001	0,001
	DPmax (°C)	< 0,0001	0,061	0,009	0,000	0,076	0,008
	DPmin (°C)	< 0,0001	0,082	0,039	< 0,0001	0,082	0,010
	APmax (hPa)	< 0,0001	0,398	< 0,0001	0,000	0,007	< 0,0001
	APmin (hPa)	< 0,0001	0,549	< 0,0001	0,001	0,007	< 0,0001
	WS (ms ⁻¹)	0,022	0,001	0,000	-	0,000	0,004
	WG (ms ⁻¹)	0,009	0,003	< 0,0001	-	0,055	0,107
	SR (kJ/m ²)	0,102	0,001	0,224	0,004	0,045	0,442
	RA (mm)	0,003	0,003	< 0,0001	< 0,0001	< 0,0001	< 0,0001
	n/N	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	0,000
	confirmed cases	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001
	cases per day	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001
Anderson-Darling (A ²)	Tmax (°C)	0,004	0,067	0,509	< 0,0001	0,026	0,053
	Tmin (°C)	0,424	0,021	0,083	< 0,0001	0,024	0,066
	RHmax (°C)	0,000	0,429	0,005	< 0,0001	0,002	< 0,0001
	RHmin (°C)	0,007	0,430	0,011	< 0,0001	< 0,0001	< 0,0001
	DPmax (°C)	< 0,0001	0,034	0,017	< 0,0001	0,077	0,005
	DPmin (°C)	< 0,0001	0,087	0,057	< 0,0001	0,094	0,005
	APmax (hPa)	< 0,0001	0,547	< 0,0001	0,000	0,004	< 0,0001
	APmin (hPa)	< 0,0001	0,842	< 0,0001	0,000	0,004	< 0,0001
	WS (ms ⁻¹)	0,030	0,016	< 0,0001	-	< 0,0001	0,002
	WG (ms ⁻¹)	0,011	0,009	< 0,0001	-	0,054	0,018
	SR (kJ/m ²)	0,156	0,000	0,292	0,004	0,051	0,452
	RA (mm)	0,011	0,014	< 0,0001	< 0,0001	< 0,0001	< 0,0001
	n/N	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001
	confirmed cases	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001
	cases per day	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001

Results And Discussion

Upgrade climate and COVID-19

According to specialized literature, air temperature (Ta), relative humidity (RH), and absolute humidity (AH) are the main climatic and meteorological parameters to address the influence of climate on the proliferation, transmission, incidence, survival, and variations of the SARS-CoV-2 (Ahmadi et al., 2020; Bukhari and Jameel, 2020; Casanova et al., 2010; Caspi et al., 2020; Liu et al., 2020; Ma et al., 2020; Wang et al., 2020; Xie and Zhu, 2020). The emphasis of

these studies has been placed on the establishment of thresholds, or climatic optimum, extracted from statistical associations between meteorological parameters measured in meteorological stations (outdoor environment) or controlled in laboratories (indoor environment) and confirmed cases of COVID-19 (and other types of Coronavirus) (Table 2).

Table 2
Climate and COVID-19 – Literature review until April 15, 2020.

References	Type article	Country	Tested environment	Range			Target Virus	Outcome
				Temperature	Relative humidity	Absolute humidity		
Tan et al., 2005	Published	China, Taiyuan	Outdoor environment	16–28 °C	–	–	SARS	The optimum environmental may encourage virus growth. There is a higher possibility for SARS to reoccur in spring than that in autumn and winter.
Casanova et al., 2010	Published	China	Laboratory	20 than at 4 °C	20–50 - 80%	–	SARS-CoV	For temperature, the viruses were inactivated more rapidly on surfaces and all humidity levels.
Van Doremalen et al., 2013	Published	USA	Laboratory	20 °C	40%	–	MERS-CoV	MERS-CoV was more stable at low temperature and low humidity conditions.
Xie & Zhu, 2020	Published	China	Outdoor environment	< 3.0 x > 3.0°C	–	–	SARS-COV-2	The mean temperature has a positive linear relationship with the number of COVID-19 cases with a threshold of 3 °C.
Chan et al., 2011	Published	China	Laboratory	22–25.0 °C	40–50%	–	SARS-COV	Low temperature and humidity may facilitate COVID-19 transmission.
Bukhari et al., 2020	Preprint	USA	Outdoor environment	3–17 °C	-	3–9 g/m3	SARS-COV-2	COVID-19 would not spread in warm humid regions.
Sajadi et al., 2020	Preprint	USA	Outdoor environment	5–11 °C	3–6 g/kg	4–7 g/m3	SARS-COV-2	Established significant community spread in cities and regions along a narrow east-west distribution roughly along the 30-50° N' corridor.
Wang et al., 2020	Preprint	Iran	Outdoor environment	6.7–12.4 °C	35–50%	-	SARS-COV-2	The arrival of summer and rainy season can effectively reduce the transmission of COVID-19.
Luo et al., 2020	Preprint	China	Outdoor environment	–	–	< 9 g/m3	SARS-COV-2	Yielded positive relationship with local exponential growth of COVID-19.
Ma et al., 2020	Published	China	Outdoor environment	1.8–18.7 °C	59–97%	4.27 – 11.63 g/m3	SARS-COV-2	Absolute humidity is negatively associated with daily death counts of COVID-19, but positively associated with temperature.
Araujo and Naimi, 2020	Preprint	China	Outdoor environment	-4.01-15.58°C	40–50%	-	SARS-COV-2	Temperate warm and cold climates are more favorable to spread of the virus, whereas arid and tropical climates are less favorable.
Auler et al., 2020	Published	Brazil	Outdoor environment	27.5°C	80%		SARS-COV-2	High mean temperatures and intermediate relative humidity influenced the COVID-19 transmission rate.
Prata et al., 2020	Published	Brazil	Outdoor environment	< 25.0 °C			SARS-COV-2	There is no evidence supporting that case counts of COVID-19 could decline when the weather becomes warmer, in temperatures is above 25.8 °C.

An increase in Ta to reduction in the spread of COVID-19 has been reported by medical studies (Araujo and Naimi, 2020; Bukhari and Jameel, 2020; Oliveiros et al., 2020; Wang et al., 2020). Timing of these studies matches with winter that dominated the greatest development of pandemic in the Northern Hemisphere (Table 2), in which suggests the temperate climates (hot and cold) are more favorable to the spread of COVID-19 than arid and tropical climates (Araujo and Naimi, 2020). However, some studies showed that high Ta could not decrease cases of COVID-19 (Bukhari and Jameel, 2020; Xie and Zhu, 2020). It was demonstrated that the gradual increase of 1.0 °C in the average Ta (> 3.0 °C) had no significant effect on the number of daily COVID-19 cases in 122 Chinese cities (Xie and Zhu, 2020). For non-tropical countries (30°N and above), it was identified an increase in cases of COVID-19 with Ta higher than 18.0°C, although most COVID-19 tests (90%) were between 3.0 and 17.0°C (Bukhari and Jameel, 2020).

The initial studies showed inclusion on temperature influences on COVID-19 spread in Brazil. Auler et al., (2020) reported that high (27.5 °C) temperature influenced the COVID-19 transmission rate in six capital Brazilian cities. Prata et al., (2020) suggested that there is no evidence supporting that case counts of COVID-19 could decline when the weather becomes warmer, in temperatures above 25.8 °C. They showed a negative linear relationship between temperatures and daily cumulative confirmed cases of COVID-19 in the range from 16.8 °C to 27.4 °C in 27 state capital cities of Brazil.

The literature review identified both positive and negative associations between RH and number of COVID-19 cases in recent studies, which indicates that RH does not shape the spread of SARS-CoV-2. The most obvious explanation is the RH content is inversely proportional to Ta, which puts the variation of the number of COVID-19 cases to Ta variation. The increased AH, by contrast, could impact the COVID-19 case curve because it facilitates the interaction between

the virus and water droplets and aerosols (in the air and on surfaces), intensifying environmental transmission of SARS-CoV-2. Even so, the recent studies do not indicate that trend (Auler et al., 2020; Bukhari and Jameel, 2020; Luo et al., 2020; Ma et al., 2020). Even though, 90% of COVID-19 cases from countries located at latitudes above 30°N had been reported in places with AH below 9 g/m³ (Bukhari and Jameel, 2020), the daily reduction in COVID-19 mortality cases was associated with high levels of AH (8–11 g/m³) in Wuhan, China (pandemic onset), after controlling for effects of air pollution and other conditions, as reported by Ma et. al., (2020).

This review reveals that Ta, RH and AH alone do not able to explain the variation of number COVID-19 cases and predict its behavior to different climatic zones because the thresholds of these parameters that could result in the establishment of an optimal climate for transmission and contagion of SARS-CoV-2 are undefined. Outcomes from COVID 19 – related studies are carried out in outdoor environment and indoor environments (laboratories). This latter is limited to controlled contamination environments and generally do not include in the analytical model all climatic variables (solar radiation, nebulosity, precipitation and air pollutants), which have an important role in the configuration of outdoor environments. Hence, the inclusion of other climatic variables, in addition to temperature and humidity, should guide future ecological models on the relationship between climate and COVID-19.

Descriptive analysis

The correlation coefficient values from multicollinearity test showed most cities have a strong correlation between climatic and number of COVID-19 cases for CC2 and CC14 periods, as illustrated in Table 2. Each city exhibited a particular behavior in term of climatic variable and COVID-19 cases. The São Luís, Fortaleza, Manaus, and Recife, localized around 0° lat with dominated equatorial climate, showed significantly positive and negative association with number of COVID-19 cases ($r > 0,70$) for Tmax, Tmin, RHmax, RHmin, and WS. On the other hand, DPmax, DPmin, Tmax, Tmin and SR presented a greater correlation with COVID-19 cases in the central (Brasília) southeast (Rio de Janeiro and São Paulo) cities. Overall, these results suggest that the climatic parameters had greater association with variation of exponential curve of COVID-19 cases were Tmax, Tmin, DPmax followed by SR and WS. Further studies are needed to address the integrated climatic variable analysis, e.g., the types of weather and COVID-19 cases. It was highlighted the time lag of CC14 revealed a suitable way to evaluate the correlation between number of COVID-19 cases and climatic parameters, as shown in Table 3.

Table 3
Description of multicollinearity's correlation coefficient values and climatic parameters in six Brazilian cities.

	FORTALEZA			MANAUS			RECIFE			BRASILIA			RIO DE JANEIRO			SA
	CC1	CC7	CC14	CC1	CC7	CC14	CC1	CC7	CC14	CC1	CC7	CC14	CC1	CC7	CC14	CC
Tmax	-0,587	-0,665	-0,599	-0,232	-0,613	-0,726	-0,594	-0,785	-0,867	-0,502	-0,518	-0,584	-0,268	-0,526	-0,781	-0,7
Tmin	-0,584	-0,678	-0,609	-0,226	-0,625	-0,679	-0,609	-0,789	-0,868	-0,539	-0,514	-0,552	-0,306	-0,577	-0,811	-0,7
RHmax	0,389	0,622	0,612	0,210	0,588	0,582	0,405	0,704	0,819	-0,009	0,046	0,105	-0,194	-0,214	-0,465	-0,7
RHmin	0,406	0,601	0,570	0,191	0,534	0,585	0,419	0,718	0,828	0,022	0,118	0,257	-0,177	-0,182	-0,418	-0,7
DPmax	-0,395	-0,383	-0,265	-0,026	-0,025	-0,137	-0,187	0,101	0,352	-0,506	-0,549	-0,706	-0,435	-0,718	-0,907	-0,7
DPmin	-0,320	-0,345	-0,295	-0,032	-0,036	-0,076	-0,128	0,164	0,390	-0,442	-0,438	-0,587	-0,443	-0,734	-0,922	-0,7
WS	-0,058	-0,383	-0,292	-0,214	-0,617	-0,439	-	-	-	0,094	0,422	0,428	-0,240	-0,396	-0,625	-0,7
SR	0,430	0,711	0,659	-0,181	-0,530	-0,792	0,063	-0,082	-0,039	-0,111	-0,165	-0,170	-0,337	-0,877	-0,935	-0,7
RA	0,361	0,459	0,410	0,070	0,236	-0,088	0,242	0,583	0,573	-0,067	-0,011	0,037	-0,128	-0,279	-0,501	-0,7
n/N	-0,263	-0,299	-0,258	0,103	0,119	-0,174	-0,266	-0,352	-0,273	0,136	0,208	0,241	0,156	-0,199	-0,323	0,3
COVID-19 Cases per day	0,812	0,812	0,812	0,700	0,700	0,700	0,721	0,791	0,791	0,714	0,791	0,737	0,644	0,622	0,638	0,7

COVID-19 cases and linkages with insolation

To examine the effects of insolation (L) and direct solar radiation (DSR) associated with Nebulosity (Nb) on the origin of COVID-19 spread, the Figs. 1a-f show daily values of L ratio and number of COVID-19 cases in six Brazilian cities started in January 30, 2020, when WHO decreed that COVID-19 had become an Emergency of Public Health of International Importance. We recorded the extended incubation period up to 20 days before the first notified case to analyze the insolation conditions during the possible initial days of transmission and contagion by the SARS-CoV-2. Most cities presented cumulative daily L ratio of 0.0 during the incubation period of the first case of community spread, indicating that, on average, somewhat more than half of the L ratio of the days leading up to the cases recorded with medium to high Nb (low L and low DSR).

Since mid-March this year, new cases of COVID-19 from community spread have been confirmed in Brazilian cities in almost all regions of the country all in hot and humid regions (Table 4). The first records of autochthonous transmission of COVID-19 in these cities occurred during the summer and beginning of the southern autumn. The maximum monthly average Ta (above 30.0°C) in the period between January and April 2020 in these cities suggests that high Ta, even in this seasonality, may not limit the survival and transmission of SARS-CoV-2 in tropical environments. The fact that these cities reported the initial phase of pandemic in the middle of summer and in the early autumn encourages the development of new studies in the coming weeks and months, since Ta has not yet proved to be limiting to the spread of the SARS-CoV-2.

Table 4
Brazil - Climate and COVID-19 cases (partial) until 2020/04/12.

City	Latitude	Climate type*	First case Covid-19	Case registration**	Registration Deaths**	Lethality rate***
Manaus	3°s	Am	13-mar-20	1053	52	49.3
Fortaleza	3°S	Aw	15-mar-20	1747	74	42.3
Recife	8°S	Am	12-mar-20	960	65	67.7
Brasília	15°S	Aw	7-mar-20	614	14	22.8
Rio de Janeiro	22°S	Aw	5-mar-20	2855	170	59.5
São Paulo	23°S	Cfa	26-fev-20	6352	588	92.5
BRASIL	5°N/34°S	A – B – C	26-fev-20	22318	1230	55.1
Note: *Climatic groups according to Köppen-Geiger climate classification. ** Data refer to the states, whereas most cases were registered in the capital cities. ***Lethality rate obtained by the ratio between 1000 confirmed cases and the number of deaths.						

These results suggest the transmission and contagion by SARS-CoV-2 seem to have been enhanced under from medium to low DSR. Ahmadi et al., (2020) also found high rate of infection of COVID-19 associated with low SR in five Iranian providences. Sagripanti (2007) reported that the inactivation of viruses in the environment by high solar ultraviolet radiation (UV-C) plays a role in the seasonal occurrence of influenza pandemics. We suggest the need for studies and immediate advances regarding the influence of insolation on the ecology of the vector related to SARS-CoV-2, a fact that may affect public policies and coordinated actions to reduce and control of COVID-19.

Conclusion

Climate conditions are one of the environmental factors that influence the ecology and pathogens of living beings, such as the Coronavirus (SARS-CoV-2). The literature review related to climate and COVID-19 was upgraded and revealed that air temperature (Ta), relative humidity (RH) and absolute humidity (AH) to be three main climatic and meteorological variables that have been most used to study the influence of climate on the SARS-CoV-2 (and other influenza-like viruses), since the beginning of the COVID-19 pandemic. However, Ta, RH and AH alone do not able to explain the variation of number of COVID-19 cases and predict its behavior to different climatic zones because the thresholds of these parameters, that could result in the establishment of an optimal climate for transmission and contagion of SARS-CoV-2, are still undefined.

In accordance with previous studies, we observed the initial and increasing of number COVID-19 cases was associated with Low L ratio in six capital Brazilian cities, suggesting a possible effect of L on the transmission of SARS-CoV-2 by outdoor environment.

With a basis in multicausality, this paper contributes to a better understanding of COVID-19, which, in the absence of studies and measures to contain this serious pandemic, can act towards the control of viral transmission. Given its urgency, it behooves us to expand our knowledge concerning the virus. It is hoped that the information we have presented can contribute to this expansion.

Declarations

Competing interests

The authors declare that they have no competing interests.

Author's contributions

F.M.M.A designed the idea and wrote the paper P.M.; surveyed the articles D.L.F, L.L, L.N.Jr, G. C, F, W. R, A. A analyzed data re-review the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Brazil - Insolation ratio and cases of COVID-19 in six capital cities (a-f) from 31/01 to 05/04/2020.