CLIMATE AND COVID-19 IN THE STATE OF PARANÁ (BRAZIL)

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Abstract: The relationship between climate and diseases is a classic theme in the field of climatology and epidemiology. In this context, the present study sought to analyze, from a spatial and temporal approach, the transmission and mortality by COVID-19 in the State of Paraná (Brazil), in relation to climate dynamics during the pandemic and their interactions. The results allowed to identify : 1) the transmission dynamics over time, 2) the variation in the number of cases in relation to predominant types of weather. The climate its one of the components of a complex system of multicausalities : it isn't the determining factor in the transmission process of COVID-19.

Keywords: Climate, COVID-19, Paraná State, Brazil.

Résumé : La relation entre le climat et les maladies est un thème classique dans le domaine de la climatologie et de l'épidémiologie. Dans ce contexte, la présente étude a cherché à analyser, à partir d'une approche spatiale et temporelle, la transmission et la mortalité par COVID-19 dans l'État du Paraná (Brésil) en relation avec la dynamique climatique au cours de la pandémie et leurs interactions. Les résultats ont permis d'identifier : 1) la dynamique de transmission dans le temps, 2) la variation du nombre de cas en rapport aux types de temps prédominants. Le climat est l'un des composants d'un système complexe de multi causalités : il n'est pas le facteur déterminant dans le processus de transmission de la COVID-19.

Mots-clés : Climat,COVID -19, État du Paraná, Brésil.

1. Introduction

The relationship between climate and respiratory diseases is a classic topic in the field of climatology and epidemiology. Several studies have proven the intricate relationship between the occurrence of infectious diseases and climatic seasonality in different climates around the globe (Fisman, 2007; Lowen and Steel, 2014), in addition to the effects of the variability of some climatic variables (temperature and relative humidity of the air, for example) in disease transmission. Although the influence of seasonal cycles and environmental patterns are well known on the influenza virus (Tamerius *et al*., 2013), which causes the common flu and epidemics. Other types of pathogens can also present this characteristic and have its effects related to the variability of climate elements, including the coronavirus, according to Chan *et al.* (2011).

In recent years, humanity has experienced a new public health emergency caused by the emergence of a new human coronavirus (SARS-CoV-2), which causes the severe acute respiratory syndrome called COVID-19 (Coronavirus Disease 2019). The disease probably emerged in the month of December 2019 in the city of Wuhan, Hubei province, China (Yuen *et al*., 2020), and has spread across the entire planet. The disease has seriously affected the economic and social development of several nations around the world and has even been officially declared a global pandemic on March 11, 2020 by the World Health Organization (WMO, 2022).

The speed at which the virus has been transmitted and spread over time and space has disturbed scientists and alarmed the general population, especially the elderly and those with comorbidities (hypertensive, diabetic, immunoexpressed, *etc.*). However, it should be noted that coronaviruses (CoVs) are a large family of viruses with a single-stranded RNA genome, already well known in academia, and cause respiratory, gastrointestinal, liver and neurological diseases (Weiss and Leibowitz, 2011), being generally associated with common colds (Matoba *et al*., 2018). However, COVID-19 clearly differs from other respiratory syndromes in terms of infectious period, transmissibility, clinical severity and speed of dissemination in communities, considerably increasing the susceptibility of the population to contracting the disease and the risks related to the disease (Shi *et al*., 2020; Wilder-Smith *et al*., 2020).

Since the beginning of the pandemic, several scholars have tried to establish relationships between the climate and the rapid spread and contagion of the population by SARS-CoV-2 in different countries and places with the temporal bias (Araujo and Naimi, 2020; Auler *et al*., 2020, among many others). In this context, the present study highlights an analysis, from a spatial and temporal approach of the transmission, contagion and mortality by COVID-19 in the State of Paraná (Brazil). The study deals with the climate dynamics during the pandemic in a multicausal perspective and was prepared in accordance with the pathogenic complexes (Sorre, 1984), with climate being one of the important elements in this approach (Besancenot, 2001).

2. Methodology

2.1. Study area and prior research knowledge

Paraná is located in the southern region of Brazil, has a population of about 11.5 million inhabitants and is characterized by two predominant climate types according to the Köppen classification (Mendonça and Danni-Oliveira, 2007): Cfa (humid temperate climate with hot summer) and Cfb (humid temperate climate with cool summer). In the territory under study, intense dynamics prevail in atmospheric terms, susceptible to variability and extreme events, in addition to having recorded an episode of meteorological and hydrological drought during the 2020-2021 biennium, which coincided with the pandemic period.

The knowledge obtained until the moment of carrying out the research on COVID-19 and its relationship with the climate was collected and systematized (Wilder-Smith *et al*., 2020; Zaitchik *et al*., 2020; WMO, 2022). The particularities of Brazil and the study area (Prata *et al*., 2020; Martinuci *et al*., 2020), and aspects of the tropical world were also taken into account during the investigation (Mendonça, 2020).

2.2. Data collection and analysis

For the elaboration of this study, the survey and collection of official data on cases and mortality by COVID-19 was carried out with SESA/PR - Paraná State Health Department - for the period from March 2020 to August 2021. Although official, the data contained sub notifications and data damming in some cases, such as Curitiba, which readjusted its case data on December 16, 2020 (increase of 14 thousand cases) and March 7, 2021 (more than 40 thousand cases in one day). Such data were organized by quarters and mapped by cities, based on ArcGIS Pro software, for further spatial analysis of the results. At the same time, the 4 cities in Paraná (Figure 2) that had the most registered cases of COVID-19 were selected: Curitiba, Londrina, Maringá and Foz do Iguaçu, to carry out the survey and analysis of meteorological data, and subsequent correlation with the cases of the disease.

To complement the climate analysis, the results of the SACER – Climate Alert System for Respiratory Diseases (LABOCLIMA, 2022) were used. It is a platform developed by Climatology Laboratory of the Federal University of Paraná during the pandemic to evaluate in the epidemiological weeks the parameters and climatic thresholds (from temperature and humidity) of transmission based on the relationship between the climate and COVID-19. The analysis was carried out in an integrated way, observing all the variables on a daily and weekly level. It is worth noting that the historical series was from March 2020 to May 2021, but the SACER data appear in the chart only after its implementation (April 19, 2020), as it was not produced before that. The Foz do Iguaçu Meteorological Station had problems in generating some data in this period, but it was maintained because it is an important city and was covered by the SACER platform.

3. Results

3.1. Temporal evolution of the spatial distribution of COVID-19 in Paraná

Regarding the dynamics of COVID-19 in the State of Paraná, it was observed, in the first pandemic quarter (since March 2020), a concentration of cases in cities near to the state capital (Curitiba) and in some cities to the north and west. In the second semester there is an expansion of this area and by cities generally located along the transport axes to the North-RMC-East (RMC: Metropolitan Region of Curitiba). In the second quarter, there is also an expansion in relation to the number of cities affected, leaving a small portion of cities without records in the period from June to August 2020, as well as in the third quarter. In the fourth quarter, between December 2020 and February 2021, all cities in the State were affected by COVID-19 to a lesser or greater extent. A pattern of fewer cases and a lower proportion of incidence of the disease in the Center-South region of the state can be seen in all quarters, and Figure 1 summarizes the information described.

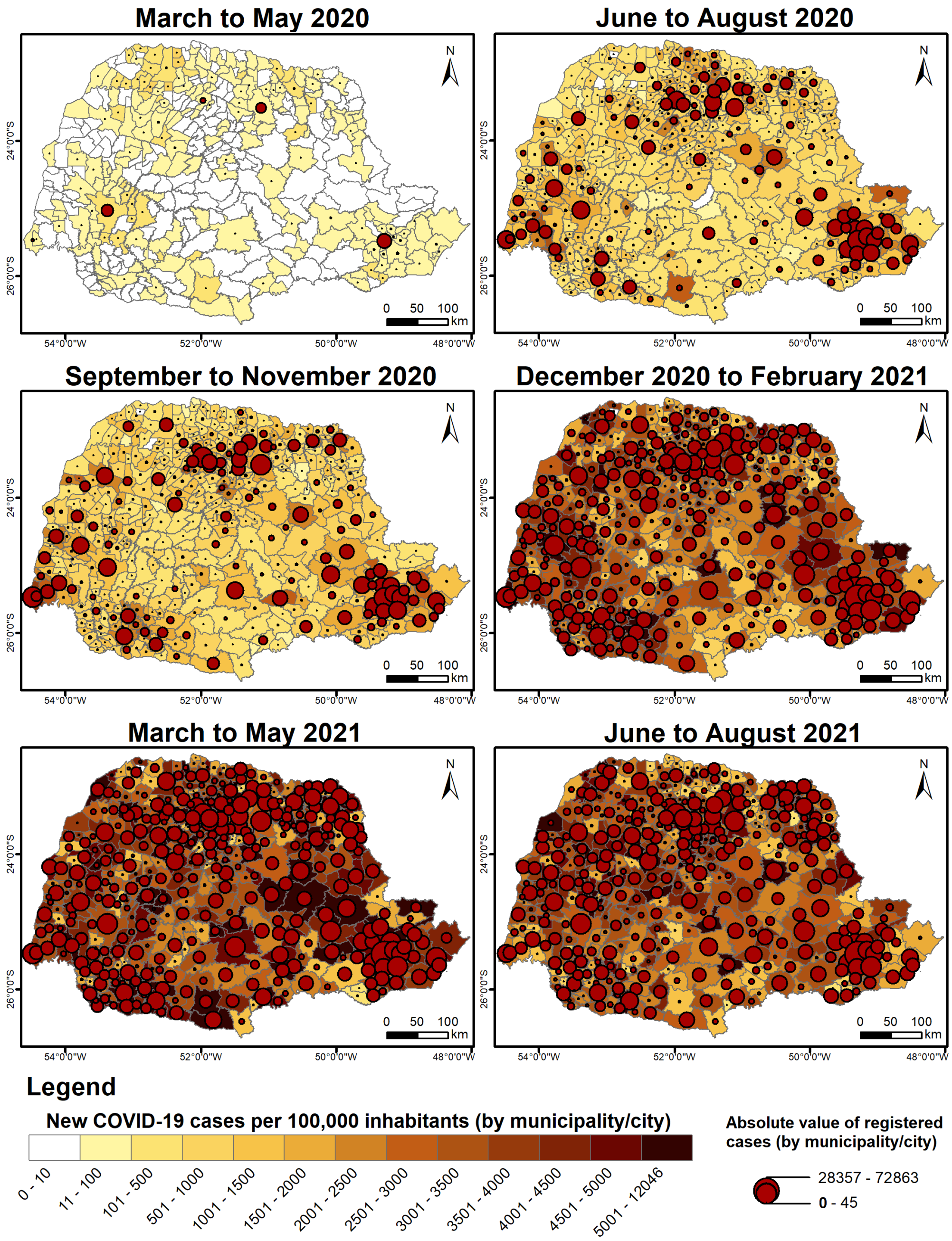

figure 1. Quarterly maps of the temporal and spatial dynamics of COVID-19 cases in the State of Paraná (2020-2021).

The distribution of deaths recorded by COVID-19 followed, in the State of Paraná, the dynamics of cases and transmission, with results similar to Figure 1. It is important to note that the last three quarters (December 2020 to August 2021) were much more contagious and lethal than the first months of the pandemic, referring to issues such as the relaxation of social isolation measures and the entry of new variants of the virus. On August 31, 2021, although vaccination has finally advanced in Brazil, only 28.9% of the population of Paraná had access to the two recommended doses of the vaccine (and were immunized). By the end of 2020, all 399 municipalities in the state were affected by the pandemic, with no exception. In this scenario, there are several possibilities to analyze the temporal and spatial dynamics of the disease and, in a multicausal perspective and considering the different pathogenic complexes involved in the occurrence of

COVID-19, the climate must be considered as one of the variables involved in the process of transmission – not necessarily being the main factor. Figure 2 depicts the variability of meteorological elements and climate alert levels (SACER – low to high) for the four cities with the highest number of COVID-19 cases in Paraná.

3.2. Relationship between COVID-19 and climate variability

The Figure 2 depicts the variability of meteorological elements and climate alert levels (SACER – low to high) for the four cities with the highest number of COVID-19 cases in Paraná. In general terms, COVID-19 cases and deaths in the State of Paraná had a significant increase in two main waves/periods: in the beginning of the winter of 2020 and in the end of the summer of 2021. Although seasonally distinct, the first wave of cases occurred a few days after the advance of high intensity cold waves, which affected the State in the months of July and August. In these months, the performance of the Atlantic Polar Air Mass (mPa) stands out, which advanced on August 21, 2020 and caused a drop in temperatures, even causing snow precipitation in some cities in the state. The wind and intense cold, which lead to the agglomeration of people in closed and poorly ventilated environments, added to the less restrictive measures that were adopted this month, may be associated with the increase in the number of cases in the period.

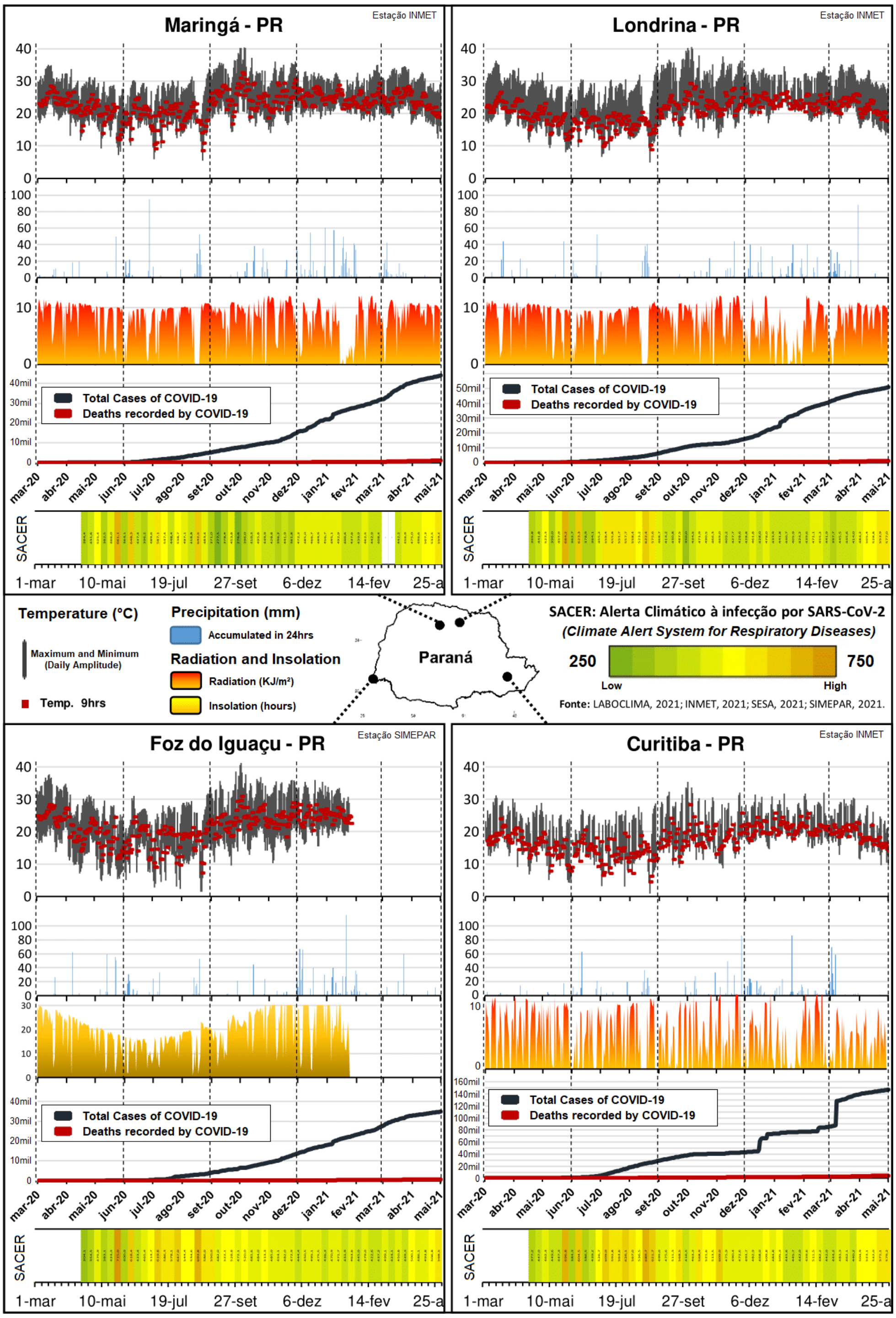

figure 2. Climate and COVID-19: daily and weekly situation of the main cities in the State of Paraná.

In addition to the weather and climate mentioned above, one must also consider the intensification of the fragility of the respiratory tract in winter situations and the greater occurrence of different types of influenza. At the height of the first wave, SACER recorded much higher levels of climate alert for the four cities evaluated, with high values greater than 550 and which even exceeded 650.

In the case of the second wave of cases, when there was a significant increase in the number of COVID-19 records (after January 2021), there was a predominance of hotter days and one less rainy than in the previous year. SACER started to register higher levels of weather alert from the end of February, which may have favored the spread of the disease, which was already on the rise over the following months. However, although it may have contributed, the main trigger of this process may have been the relaxation of preventive measures by the population, which was intensified by the entry of new, more transmissible variants of the virus (strain P.1). In this circumstance, climate dynamics had the potential to affect, for example, human behavior, an important factor that influences contact between people and social isolation, preventing (or facilitating) the transmission of the disease by droplets expelled by contaminated users.

Thus, it was noted that the spread of the virus through the territory occurred in dependence on territorial structures and dynamics, a process very similar to that verified by Martinuci et al. (2020). Curitiba, due to the greater concentration of national and international air connections through airports, in addition to the high population, was the location that recorded the first cases of COVID-19 and the reflexes of the new strains at the beginning of 2021, a performance that is in accordance with the models systematized by Spengler et al. (2021). Maringá and Londrina, cities relatively close together in the north of the state and with a Cfa-type climate (according to the Köppen classification), showed similar behavior, both from the climatic point of view and in the records of cases and deaths from the disease. Foz do Iguaçu, being located in a border region with Argentina and Paraguay, which were closed until October 15, 2020, had the first wave much milder than the second, even though SACER recorded higher levels of climate risk in the winter.

Therefore, although the underreporting and damming of data may have hindered the analysis a little, it was possible to recognize the climate as one of the components of a complex system of multicausalities, but which did not prove to be the determining factor in the transmission process of COVID-19. In that regard, it is worth mentioning the climatic/meteorological influence on the virus (direct influence) has not yet been clearly proven, especially since the transmission and contamination of the disease occurred in practically under the different climatic types of the Planet. Zaitchik et al. (2020) show that «Early studies of weather, seasonality, and environmental influences on COVID-19 have yielded inconsistent and confusing results», and among other issues, the «Government interventions rather than meteorological factors primarily curb COVID-19 spread» (WMO, 2022). Transmission was shown to be influenced by many factors including socioeconomic, demographic and environmental aspects, and the climate can influence this process and the behavior of society (indirect influence) (Byun *et al*., 2021).

4. Conclusion

From the research carried out, it was possible to observe the dynamics of transmission of COVID-19 over time in the State of Paraná, as well as to highlight the variation in the number of cases/deaths in relation to atmospheric conditions and prevailing climate alert levels. Specifically, transmission was found to intensify during the autumn and winter season, although it was also important during spring and summer.

Regarding this issue, the direct and indirect influences of the climate on the behavior of the population, especially with regard to social isolation, were evidenced in the study, considering them as complementary factors of a multicausal relationship. Based on the results obtained here, progress should be made in understanding the other factors for a better understanding of the dynamics of the pandemic, such as barrier gestures (respected or not), emergence of new variants of COVID-19, epidemiological and contagious aspects of the virus, and others, based on new scientific advances and recent literature. Science must greatly advance in the investigation of the relationship between climate and COVID19, both in the direct and indirect influence on the pathogen and on human organisms and their population.

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Bibliography

Araujo, M. B., & Naimi, B., 2020 : Spread of SARS-CoV-2 Coronavirus likely to be constrained by climate. *MedRxiv*.

Auler, A. C., Cássaro, F. A. M., Da Silva, V. O., & Pires, L. F., 2020 : Evidence that high temperatures and intermediate relative humidity might favor the spread of COVID-19 in tropical climate: a case study for the most affected Brazilian cities. *Science of the Total Environment*, 729, 139090.

Besancenot, J. P., 2015 : *Climat et santé* (Medicine et santé). Presses universitaires de France.

Byun, W. S., Heo, S. W., Jo, G., Kim, J. W., Kim, S., Lee, S., ... ?? & Baek, J. H., 2021. : Is coronavirus disease (COVID-19) seasonal? A critical analysis of empirical and epidemiological studies at global and local scales. *Environmental Research*, 196, 110972.

Chan, K. H., Peiris, J. M., Lam, S. Y., Poon, L. L. M., Yuen, K. Y., & Seto, W. H., 2011 : The effects of temperature and relative humidity on the viability of the SARS coronavirus. *Advances in virology*,

Fisman, D. N., 2007: Seasonality of infectious diseases. *Annu. Rev. Public Health*, 28, 127-143.

Laboclima, 2022 : *Laboratório de Climatologia*. UFPR. http://www.terra.ufpr.br/portal/laboclima/

Lowen, A. C., & Steel, J., 2014 : Roles of humidity and temperature in shaping influenza seasonality. *Journal of virology*, 88(14), 7692-7695.

Martinuci, O. S., Endlich, Â. M., Montanher, O. C., Felini, M. G., Rigoldi, K. C., Caraminan, L. M., ... & Ferreira, M. R., 2020 : Dispersão da covid-19 no estado do paraná. *Hygeia-Revista Brasileira de Geografia Médica e da Saúde*, 251-262.

Matoba, Y., Aoki, Y., Tanaka, S., Unno, M., Komabayashi, K., Ikeda, T., ??& Mizuta, K., 2018 : The trends of human coronaviruses in Yamagata, Japan, in 2015 to 2016: Occurrence of OC43 outbreak in June 2016. *Japanese Journal of Infectious Diseases*, JJID-2017.

Mendonça, F. ; Danni-Oliveira, I.M. 2007. Climatologia : Noções básicas e climas do Brasil. São Paulo : Oficina de Textos.

Mendonça, F., 2020 : Mudanças climáticas e saúde – Concepções, desafios e particularidades do mundo tropical. In: Murara, P. G. S.; Aleixo, N. C. R. *Clima e saúde no Brasil*. Jundiaí/SP: Paco Editorial, 309-336.

Nitsche, P. R., Caramori, P. H., Ricce, W. S., & Pinto, L. D., 2019 : *Atlas climático do estado do Paraná*. Londrina, PR: IAPAR.

Prata, D. N., Rodrigues, W., & Bermejo, P. H., 2020 : Temperature significantly changes COVID-19 transmission in (sub) tropical cities of Brazil. *Science of the Total Environment*, 729, 138862.

Shi, Y., Yu, X., Zhao, H., Wang, H., Zhao, R., & Sheng, J., 2020 : Host susceptibility to severe COVID-19 and establishment of a host risk score: findings of 487 cases outside Wuhan. *Critical care*, 24(1), 1-4.

Sorre, M., 1984: *A adaptação ao meio climático e biossocial–geografia psicológica*. Max Sorre. São Paulo: Ática, (46).

Spengler, H. C., Loch, G. V., & Scarpin, C. T., 2021 : SEIR Subregion Model Analysis: a case study of Curitiba. *IEEE Latin America Transactions*, 19(6), 1050-1056.

Tamerius, J. D., Shaman, J., Alonso, W. J., Bloom-Feshbach, K., Uejio, C. K., Comrie, A., & Viboud, C., 2013 : Environmental predictors of seasonal influenza epidemics across temperate and tropical climates. *PLoS pathogens*, 9(3), e1003194.

Weiss, S. R., & Leibowitz, J. L., 2011: Coronavirus pathogenesis. *Advances in virus research*, 81, 85-164.

WHO, 2022: *World Health Organization*. Responding to Community Spread of COVID-19. https://www.who.int/

Wilder-Smith, A., Chiew, C. J., & Lee, V. J., 2020 : Can we contain the COVID-19 outbreak with the same measures as for SARS?. *The lancet infectious diseases*, 20(5), e102-e107.

Yuen, K. S., Ye, Z. W., Fung, S. Y., Chan, C. P., & Jin, D. Y., 2020 : SARS-CoV-2 and COVID-19: The most important research questions. *Cell & bioscience*, 10(1), 1-5.

Zaitchik, B. F., Sweijd, N., Shumake-Guillemot, J., Morse, A., Gordon, C., Marty, A., ... & Rodó, X., 2020 : A framework for research linking weather, climate and COVID-19. *Nature communications*, 11(1), 1-3.