SPATIO-TEMPORAL ANALYSIS OF CLIMATIC CONDITIONS TO EXPLORE THE COVID-19 EARLY EVOLUTION IN URBAN SITES IN SOUTH AMERICA

Dankiewicz Verónica[1], Suli Solange[1], Rusticucci Matilde[1], Mantilla Caicedo Gilma C.[2], Ayala Salvador[3], Caiman Patricia A.[4], Díaz Martín[5], Fontán Silvia[5], Chesini Francisco[6], Jiménez-Buitrago Diana[7], Barreto Pedraza Luis R.[8], Barrera Facundo[9]

[1]Universidad de Buenos Aires, Departamento de Ciencias de la Atmósfera y los Océanos (DCAO, FCEN, UBA); Instituto Nacional de Investigaciones Científicas y Técnicas (CONICET). Argentina.
[2]Pontificia Universidad Javeriana (PUJ), Sede Bogotá, Colombia; International Research Institute (IRI) for Climate and Society, Columbia University. United States.
[3]Universidad de Chile (UCh); Instituto de Salud Pública de Chile (ISP). Chile.
[4]Subred Integrada de Servicios Hospitalarios Centro Oriente ESE; Red Hospitalaria Bogotá Distrito Capital. Colombia.
[5]Universidad Nacional de La Matanza (UNLaM), Departamento de Ciencias de la Salud. Argentina.
[6]Universidad Metropolitana para la Educación y el Trabajo (UMET); Ministerio de Salud de Argentina. Argentina.
[7]Ministerio de Salud y Protección Social (MinSalud). Mesa de Variabilidad y Cambio Climático de la CONASA. Colombia.
[8]Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Subdirección de Meteorología; Mesa de Variabilidad y Cambio Climático de la CONASA. Colombia.
[9]Centre for Climate and Resilience Research (CR)2; Universidad de Concepción & Facultad de Ciencias (UdeC); Universidad Católica de la Santísima Concepción (UCSC). Chile.

Keywords: Climate variability, SARS-CoV-2, pandemic.

1) INTRODUCTION

Many viruses have existed in nature for decades without affecting humanity, and their recurrent spillover on animals and humans is due to anthropogenic activities (Crawford 2002; Tushar and Saxena 2020). In the twenty-first century, we have been dealing with the coronavirus (COVID-19) pandemic caused by the SARS-CoV-2 virus, which was reported in December 2019 in Wuhan, China (Lu et al., 2020; Zhu et al., 2019). Particularly, in the Americas region, the Pan American Health Organization (PAHO, 2020) reported more than 26 million confirmed cases and accounted for half of the deaths worldwide. Moreover, climate conditions can influence the trajectory of the pandemic, and the seasonal progression of the disease will lead to different implications across the globe, varying by hemisphere, region, and climatic zone (Ward et al., 2016; Lin et al., 2020). In this context and according to COVID-19, some studies have shown climate conditions as top predictors of other coronavirus illnesses (Dalziel et al., 2008). To deepen in the sapatio-temporal analysis of climatic factors in relation to COVID-19 morbidity, this work provides an approach of it in several urban sites in South America during the first nine months of the pandemic.

2) DATA AND METHODOLOGY

The study considered 14 urban sites (Fig. 1) with heterogeneous population distribution and dissimilar climatic and geographical conditions from Argentina, Chile and Colombia. We employed data of COVID-19 cases from each urban site. Additionally, we used national meteorological data, maximum, mean, and minimum temperature (Tmax, Tmean and Tmin), precipitation (Pp), and relative humidity (Hr). The period considered was March 2020 to November 2020. Exploratory analysis was carried out to analyze the possible associations with the COVID-19 data, new daily cases with symptoms (NCS) and rate of new daily cases with symptoms (rNCS). For each site, the daily incidence of NCS was analyzed per 1×10^5 inhabitants, namely rNCS, by the date of symptom onset (Argentina and Colombia) and by date of confirmation (Chile). Subsequently, seven- and 14-day moving averages (7rNCSma

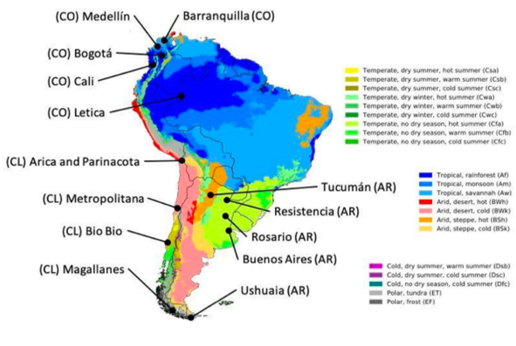

Figure 1: Climatic characterization and sites of study in South America. Add from Beck et al., 2018.

and 14rNCSma) were applied to smooth the dummy wave generated by data loading. In addition, the 7- and 14-day lags of the rNCS with a 7-days moving average (7rNCSL and 14rNCSL) were calculated considering the incubation period of the disease. Finally, the statistical distribution of the data was analyzed using the Shapiro-Wilk test (Razali and Wah, 2011; Wilks, 2011), and it was observed that variables did not maintain a normal distribution. Therefore, Spearman's non-parametric linear correlation (Wilks, 2011) was used to study the relationship between rNCS and different climatic variables. From this, the 'rho'(ρ) coefficient was obtained with confidence levels of 95% and 99%.

3) RESULTS

Firstly, the evolution of 7rNCSma was analyzed focusing on their peaks (Fig. 2). In the case of Chile, the first peak was reached in June in the Metropolitan Region, followed by Arica and Parinacota for the month of July. Magallanes displayed the highest value of the period with a rate of 104 cases × 10^5 inhab. in the month of October, and finally, Biobío, values did not show a sharp increase with an evident peak. According to Colombia, the first peak was reached in the first week of May in Leticia with a maximum rate of 140 cases × 10^5 inhab. The second peak occurred in Barranquilla with an increase in cases in mid-June and was maintained until early July. The third peak was seen in Bogotá at the end of July and was consistent until the beginning of August. In Cali, cases escalated in the third week of June until the beginning of August and remain almost constant, rising slightly again in late November. The next peak was evident in Medellín around mid-July. Later, in October, cases surged again in the first week of the month with a brief decrease in the second week, which increased again in the third week of the month and was maintained almost until the end of the month. When Argentina is considered, an early evolution of cases was noticed in Buenos Aires, finding three considerable 7rNCSma peaks between the end of July and the end of August (they are softened in the figure due to the scale used), when the temperature and Pp were minimal (not shown) due to the winter season. Likewise, late peaks were detected for Rosario, Tucumán, and Resistencia in late September and early October, when an increase in temperature and rainfall was expected (not shown). Moreover, Ushuaia recorded its maximum peak at the beginning of November (124 cases ×10^5 inhab.), when temperatures were on the rise and rains showed a marked decline (not shown).

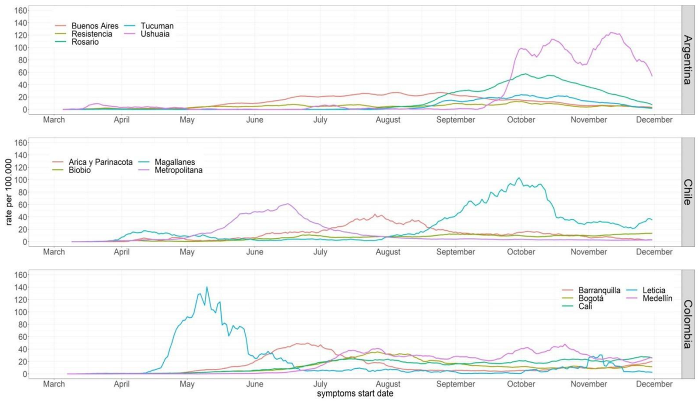

Figure 2: 7-day moving average rates rates of confirmed cases per 100,000 inhabitants (7rNCSma) by date of onset of symptoms (Argentina and Colombia) and by date of confirmation (Chile) for the sites analyzed from March to November 2020.

Site	%Hr	Pp	Tmax	Tmean	Tmin
Tucumán (AR)	-0.56**	-0.01	0.42**	0.33**	0.17**
Resistencia (AR)	-0.17**	-0.05	-0.09	-0.07	-0.04
Rosario (AR)	-0.43**	0.04	0.2**	0.14*	0.06
Buenos Aires (AR)	-0.07	-0.07	-0.61**	-0.63**	-0.59**
Ushuaia (AR)	-0.36**	-0.03	0.42**	0.37**	0.24**
Arica y Parinacota (CH)	0.33**	-	-0.85**	-0.83**	-0.67**
Metropolitana (CH)	0.65**	0.33**	-0.71**	-0.81**	-0.67**
Bíobío (CH)	-0.22**	-0.01	-0.24**	-0.23**	-0.19**
Magallanes (CH)	-0.35**	-0.12*	0.16*	0.22**	0.16**
Barranquilla (CO)	0.33**	0.13*	0.22**	0.32**	0.14*
Medellin (CO)	0.23**	-0.07	-0.34**	-0.34**	-0.35**
Bogota (CO)	0.12	0.07	-0.39**	-0.41**	-0.42**
Cali (CO)	-	-0.09	-0.19**	-0.22**	-0.23**
Leticia (CO)	0.09	0.15*	-0.05	-0.07	-0.06

*Table I: Values of Spearman's correlation coefficient between dependent variable: rNCS moving average 7-days (7rNCSma) and independent (meteorological data). Significant values at 5% (1%) are indicate with * (**).*

Correlations between meteorological variables and 7rNCSma per site are summarized in Table I at both 5 and 1% level of significance and they vary according to the place and the variable studied. These correlations were also applied to 14rNCSma, 7rNCSL and 14rNCSL and similar results were found, with no overall differences (not shown). In the case of temperature, a significant correlation was observed at all sites, except Resistencia and Leticia. At eight sites these significant correlations were negative and at only four sites they were positive. In addition, the three main sites (Buenos Aires, Bogota, and Metropolitana) showed a higher (and negative) significant correlation with temperature compared to other meteorological variables. In those sites that are close to the borders with other countries (Leticia with Brazil, Resistencia with Paraguay, and Arica y Parinacota with Peru), as well as the case of the main sites where airports with the highest passenger traffic are located, correlations found can be explained by the flow of people rather than by meteorological variables. The sites in southern South America (Magallanes and Ushuaia) showed the opposite behavior to Arica and Parinacota (northern Chile) in terms of significant correlations between the rNCS and Hr and temperatures. In general, Hr presented significant correlations in most of the sites, which were negative, except in the two northernmost sites in Chile and Colombia, where they were positive. The correlations between COVID-19 cases and Pp were only significant for Metropolitana and Magallanes in Chile and Barranquilla and Leticia in Colombia, with small rho coefficients and different signs.

4) CONCLUSIONS

This work presents an exploratory analysis of climatic factors in relation to COVID-19 morbidity in urban sites in South America during the first nine months of the pandemic. Our results revealed that the temperatures and relative humidity were significantly associated with the rates of new COVID-19 cases in most of the sites studied, while precipitation was significantly associated only in four sites. However, different behaviors were found between rNCS and climatic variables, which makes it difficult to provide a generalized conclusion for all the sites studied. It is worth noting that correlations found gave us an idea of the relationship between meteorological variables and the rate of COVID-19 cases; however, they do not indicate causality. Future studies with longer data series and the inclusion of other determinants that influence the spread of the virus (i.e., flow of people and transport and health and economic measures) will allow a better understanding of the role of climatic and non-climatic factors in the development of the COVID-19 epidemic in these latitudes.

Agradecimientos

Proyecto UBACyT 2018 20020170100357BA.

REFERENCES

Beck, H.E., Zimmermann, N.E., McVicar, T.R., at al., 2018: Present and future köppen-geiger climate classification maps at 1-km resolution. Sci. Data 5 (1). https://doi.org/10.1038/sdata.2018.214.

Crawford D., 2002: The Invisible Enemy: A Natural History of Viruses. Oxford University Press Inc. NY, 2002.

Dalziel, B.D., Kissler, S., Gog, J.R., et al., 2018: Urbanization and humidity shape the intensity of influenza epidemics in U.S. cities. Science 362, 75–79.

Lin, S., Fu, Y., Jia, X., et al., 2020: Discovering Correlations between the COVID-19 Epidemic Spread and Climate. International Journal of Environmental Research and Public Health, 17(21):7958.

Lu, R., Zhao, X., Li, J., et al., 2020: Genomic characterization and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet 395 (10224), 565–574.

PAHO, 2020: COVID-19 - PAHO / WHO Response, Report 36 (30 November 2020). World Meteorological Organization.

Razali, N.M. & Wah, Y.B., 2011: Power Comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling Tests. Journal of Statistical Modeling and Analytics, 2, 21-33.

Tushar, Y. and Saxena, S.K., 2020: Transmission Cycle of SARS-CoV and SARS-CoV-2. In Coronavirus Disease 2019 (COVID-19): Epidemiology, Pathogenesis, Diagnosis, and Therapeutics. Ch.4. 1st Ed. Springer.

Ward, P.J., Kummu, M., Lall, U., 2016: Flood frequencies and durations and their response to El Niño Southern Oscillation: Global analysis. Journal of Hydrology, 539, 358-378

Wilks D.S., 2006: Statistical methods in the atmospheric sciences. In International Geophysics Series (Vol. 100). 3rd ed., 2011. ISBN 978-0-12-385022-5

Zhu, N., Zhang, D., Wang, W., et al., 2019: A novel coronavirus from patients with pneumonia in China. N. E. J. Med. 2020