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# Correlation between climate indicators and COVID-19 pandemic in New York, USA

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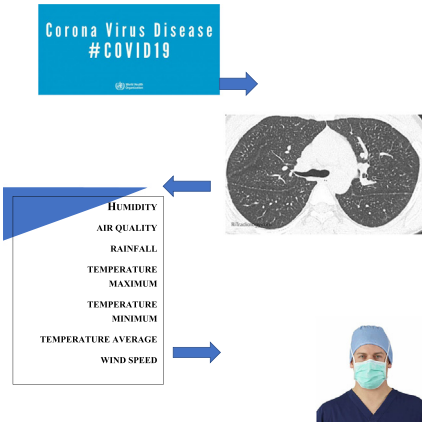
## HIGHLIGHTS

- The study examines the impact of climate indicators on COVID-19 epidemic in New York City.
- Average temperature, minimum temperature and air quality have significant correlation with COVID-19 epidemic.
- Currently there is no scientific evidence that warm weather would suppress COVID-19 epidemic.

## GRAPHICAL ABSTRACT

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## ABSTRACT

This study analyzed the association between COVID-19 and climate indicators in New York City, USA. We used secondary published data from New York city health services and National weather service, USA. The climate indicators included in the study are average temperature, minimum temperature, maximum temperature, rainfall, average humidity, wind speed, and air quality. Kendall and Spearman rank correlation tests were chosen for data analysis. We find that average temperature, minimum temperature, and air quality were significantly associated with the COVID-19 pandemic. The findings of this study will help World Health Organization and health regulators such as Center for Disease Control (CDC) to combat COVID-19 in New York and the rest of the world.



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## 1. Introduction

On December 31, 2019, the World Health Organization (WHO) reportedly received information about an epidemic with unidentified etiology (Deepak et al., 2020) from Wuhan, Hubei, China (Zhu et al., 2020). On February 11, 2020, this epidemic was officially named as COVID-19 and was acknowledged as an infectious disease resulting in public health emergency, as it quickly spread within China and to further 24 countries is situated geographically between 42.937084° N and − 75.6107° E (Anderson et al., 2020). Clinical studies relating to COVID-19 reported that most patients suffer from difficulty in breathing and pneumonia (Holshue et al., 2020; Perlman, 2020). Symptoms reported in clinical treatments were similar to other coronavirus illnesses such as MERS and SARS e.g. cough, fever, and difficulty in breathing due to respiratory disorder, and in worst-case scenario COVID-19 causes kidney failure, pneumonia, and even death (Wang et al., 2020).

In the USA, the first COVID-19 patient was reported in the Washington State on January 15, 2020, and coronavirus quickly spread throughout the country as the USA became the epicenter with most deaths and the most number of patients or cases which are seen on map in Fig. 1. And after Wisconsin reported its first death on April 13, 2020, all 50 states had at least one casualty from COVID-19 in the USA. As of April 13, 2020 New York (195,749), Florida (123,019) and New Jersey (64,584) are worst-hit states in America. New York state quickly became epicenter within the USA with the majority of cases and deaths reported in New York City, which reported its first case on March 1, 2020, and after initial days saw a rapid rise in the number of patients and deaths from March 12, 2020, onwards. Similar quick spread of COVID-19 in Italy, France, and South Korea, led to WHO declaring it as a pandemic (Cucinotta and Vanelli, 2020).

Current studies have shown that the transmission route of COVID-19 is bat-human, with intermediate host yet to be identified; it was transmitted mainly by respiratory droplets, as well as human-human transmission (Ge et al., 2013; Huang et al., 2020). Climate conditions are classified as top predictors of coronavirus illnesses (Dalziel et al., 2018) as wind speed, humidity, temperature and wind speed are critical in the transmission of infectious diseases (Yuan et al., 2006). Bull (1980) reported that pneumonia's mortality rate is highly correlated with weather changes.

## 2. Research methodology

New York City is the capital of New York state and is described as media, cultural and financial hub of the world. New York is one of the densely populated cities in the USA with 8.54 million people residing within 302.6 squares miles and is situated geographically between 42.937084° N and − 75.6107° E. Dataset for COVID-19 is taken from March 1, 2020 – April 12, 2020, from COVID-19 data archive from the New York City health department. And data for climate indicators was taken from National weather service, USA. Dataset for the climate indicators includes temperature, humidity, wind speed, air quality, and rainfall. As the data was not normally distributed therefore Kendall and Spearman rank correlation tests were utilized to examine the correlation between variables.

## 3. Results and discussion

Fig. 2 observes a sharp increase, both in daily new cases and total confirmed cases for New York City from March 12, 2020, onwards. The first week beginning from March 1, 2020 to March 7, 2020, confirmed cases are 12, which rose to 185 until the second week on March 14, 2020, 8,115 until the end of third week, 30,765 until the fourth week, 60,850 until the fifth week on April 4, 2020 and 104,410 until April 12, 2020.

Fig. 3 shows the maximum, minimum, and average temperature. Lowest maximum temperature of 44 °F (highest maximum 77 °F), lowest average temperature was 35.2 °F (maximum average 59.3 °F) and the minimum lowest temperature was 26 °F (highest lowest 56 °F), average lowest wind speed 6.1 mph (maximum average 21.6 mph), average lowest humidity 25.8% (highest average humidity 91.8%) and average lowest rainfall 0 mm (average highest rain fall is 1.44 mm) are the statistical indicators of New York City.

Table 1 indicates empirical estimations of seven weather indicators. For Kendal correlation test minimum temperature and average air

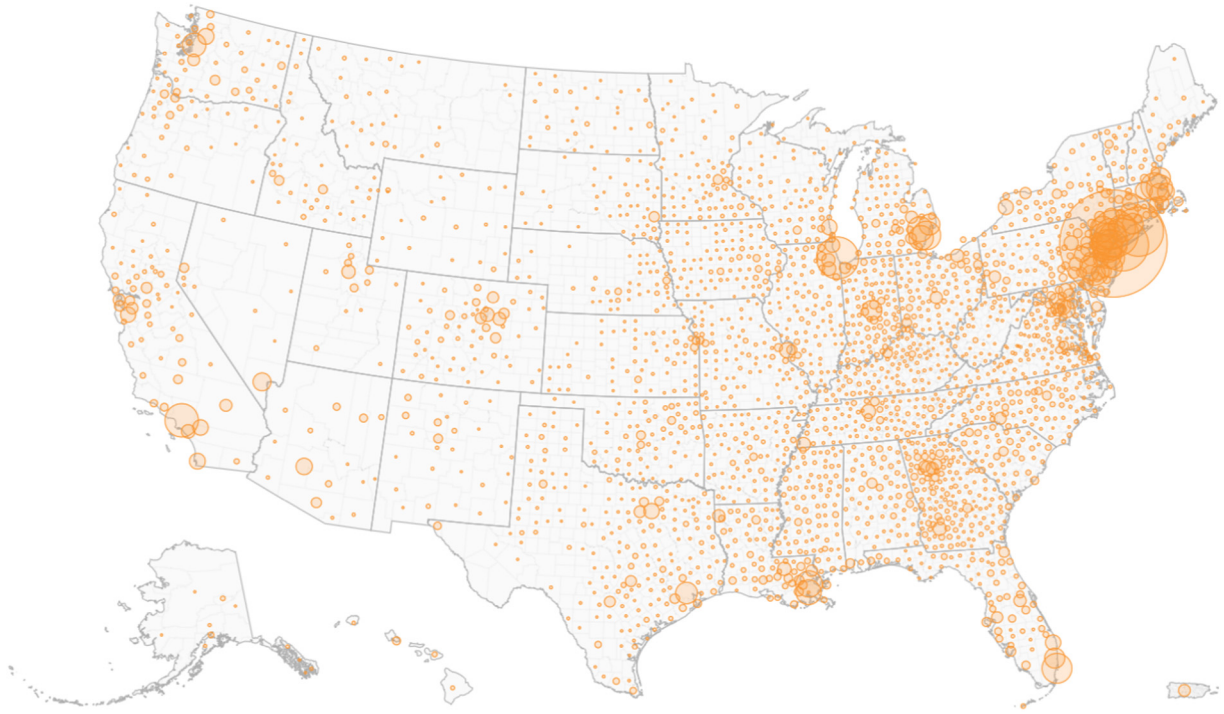

**Fig. 1.** COVID-19 outbreak in the U.S.A. (Source: USA Today).

quality are significant for new cases, and average temperature, minimum temperature, and average air quality are significant for total cases and average temperature and air quality are significant for mortality among New York citizens. For the Spearman test, average temperature and average air quality are significant for new cases and average temperature and average air quality are significant for the total number of cases, also average temperature and air quality are significant for mortality.

For the current research project, the occurrence of COVID-19 in New York city is analyzed by climate change patterns. Our findings estimate that minimum temperature and average temperature are correlated with the spread of COVID-19 in New York city. Previous studies of Tan et al. (2005) and Vandini et al. (2013) support our findings. Shi et al. (2020) also researched climate indicators and stated that temperature serves as a driver for the COVID-19. As a cultural and financial capital of the world, New York city also oversees high mobility from local as well as constituents from other major places to seek employment and business opportunities. Humidity is another contributor for the spread of COVID-19 as it contributed in the rapid transmission within New York City and empirical estimations of this study will be useful in the outcome of efforts to suppress COVID-19. According to official census data, New York City is resident to 8.54 million people with population increasing at 4.6% per year and 26,403 residents living per square mile. The reason for such a dense population is the average life expectancy of New York residents, which is 80.9 years, this is 2.2 years longer than the national average of life expectancy in America. Such statistics make New York an ideal epicenter for the spread of infectious diseases (Zu et al., 2020).

Humidity and temperature also play significant role in the seasonal spread of coronaviruses (Sajadi et al., 2020). Wang et al. (2020) also reported similar findings for the case of China. COVID-19 outbreak from Wuhan showed a strong association between disease spread and weather conditions, with predictions that warm weather will play an important role in suppressing the virus. Other meteorological indicators such as wind speed, air quality, and humidity also affect the spread of infectious diseases. Furthermore, air temperature also contributes towards the transmission of the virus (Chen et al., 2020). Ma et al. (2020) suggested that humidity and temperature will play an important role in mortality rate from COVID-19 as climate indicators and temperature correlate with the spread of COVID-19 (Poole, 2020).

This study, despite strong evidence of climate indicators' association with COVID-19, provides the following limitations. First, more variables are needed to conduct a comprehensive study as COVID-19 is an infectious disease and it is affected by many variables such as social distancing, people's endurance and availability of health facilities. Second, data about personal hygiene indicators such as hand wash needs to be explored in further studies.

## 4. Conclusion

Climate indicators are integral in the fight against COVID-19 in New York. This study finds that average temperature, minimum temperature, and air quality are significant correlated with COVID-19 pandemic and will be useful in suppressing COVID-19. Also, significance of air quality implies that green environment policies should be promoted as it would reduce the spread of infectious diseases such as COVID-19. Current study is of exploratory nature and in order to conduct a comprehensive investigation, future research direction should examine daily carbon emission data as current lockdown measures have greatly reduced carbon emissions. Another research direction is to include regional and cross-country investigations for most affected countries to provide better insight for the fight against COVID-19.

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## CRediT authorship contribution statement

**Muhammad Farhan Bashir:** Data curation, Writing - original draft. **Benjiang Ma:** Resources. **Dr. Bilal:** Conceptualization, Software, Writing - review & editing. **Bushra Komal:** Writing - review & editing. **Muhammad Adnan Bashir:** Project administration.**Duojiao Tan:**Funding acquisition.**Madiha Bashir:**Validation, Software.

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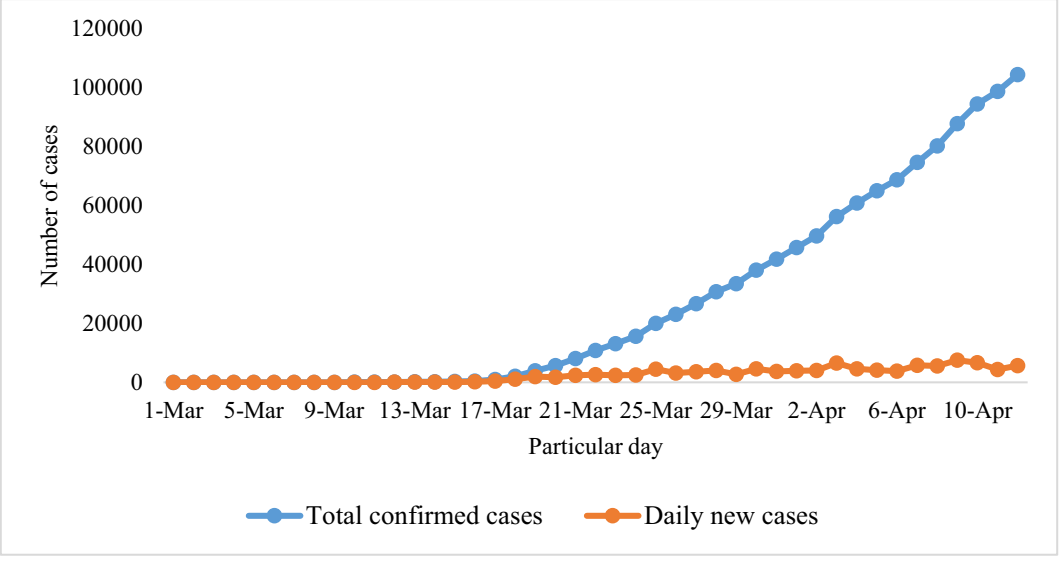


**Fig. 2.** Cases of COVID-19 in New York.

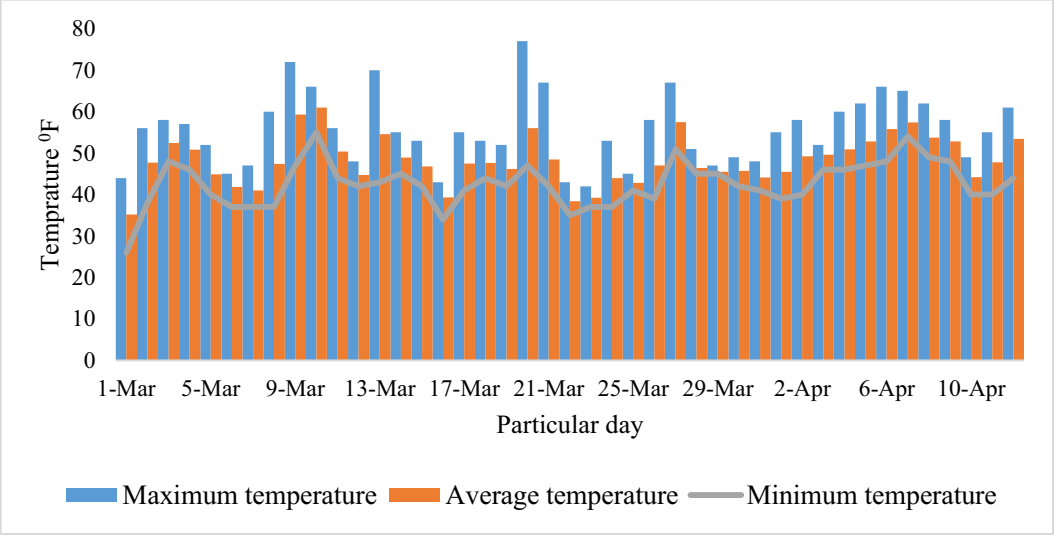


**Fig. 3.** Variations in minimum, maximum, and average temperatures.

**Table 1**
Empirical results.

| | Climate Variables | New Cases | Total Cases | Mortality |
|---|---|---|---|---|
| Kendall Correlation Coefficient | Temperature Maximum | 0.041 | 0.168 | 0.185 |
| | Temperature Average | 0.186 | 0.289** | 0.294* |
| | Temperature Minimum | 0.248* | 0.248* | 0.254 |
| | Humidity | −0.063 | −0.154 | −0.148 |
| | Wind Speed | 0.137 | 0.097 | 0.057 |
| | Air Quality | −0.537*** | −0.531*** | −0.531** |
| | Rainfall | −0.219 | −0.153 | −0.106 |
| Spearman Correlation Coefficient | Temperature Maximum | 0.060 | 0.224 | 0.218 |
| | Temperature Average | 0.268 | 0.379* | 0.393* |
| | Temperature Minimum | 0.335* | 0.317 | 0.326 |
| | Humidity | −0.111 | −0.216 | −0.205 |
| | Wind Speed | 0.172 | 0.097 | 0.049 |
| | Air Quality | −0.684*** | −0.667*** | −0.659** |
| | Rainfall | −0.287 | −0.196 | −0.153 |

***, **, * stands for 1%, 5% and 10% level of significance.

## References


Anderson, R.M., Heesterbeek, H., Klinkenberg, D., Hollingsworth, T.D., 2020. How will country-based mitigation measures influence the course of the COVID-19 epidemic? Lancet 395, 931–934.

Bull, G., 1980. The weather and deaths from pneumonia. Lancet 315, 1405–1408.

Chen, B., Liang, H., Yuan, X., Hu, Y., Xu, M., Zhao, Y., 2020. Roles of Meteorological Conditions in COVID-19 Transmission on a Worldwide Scale. medRxiv.

Cucinotta, D., Vanelli, M., 2020. WHO declares COVID-19 a pandemic. Acta bio-medica: Atenei Parmensis 91, 157.

Dalziel, B.D., Kissler, S., Gog, J.R., Viboud, C., Bjørnstad, O.N., Metcalf, C.J.E., 2018. Urbanization and humidity shape the intensity of influenza epidemics in U.S. cities. Science 362, 75–79.

Deepak, A.D., Hasan, K.S., Joshua, L.M.D., Victor, N.F.D., David, A.M., Erin, A.B., 2020. COVID-19 for the cardiologist: a current review of the virology, clinical epidemiology, cardiac and other clinical manifestations and potential therapeutic strategies. JACC; Basic to Translational science.

Ge, Y., Li, J., Yang, X., Chmura, A., Zhu, G., Epstein, J., Mazet, J., Hu, B., Zhang, W., Peng, C., 2013. Isolation and characterization of a bat SARS-like coronavirus that uses the ACE2 receptor. Nature 503 (7477), 535–538 2013.

Holshue, M.L., DeBolt, C., Lindquist, S., Lofy, K.H., Wiesman, J., Bruce, H., 2020. First case of 2019 novel coronavirus in the United States. N. Engl. J. Med. 382, 929–936.

Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Zhang, L., Fan, G., Xu, J., Gu, X., 2020. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 395 (10223), 497–506.

Ma, Y., Zhao, Y., Liu, J., He, X., Wang, B., Fu, S., 2020. Effects of Temperature Variation and Humidity on the Mortality of COVID-19 in Wuhan. medRxiv.

Perlman, S., 2020. Another Decade, another Coronavirus. Mass Medical Soc.

Poole, L., 2020. Seasonal influences on the spread of SARS-CoV-2 (COVID19), causality, and Forecastabililty (3-15-2020). Causality, and Forecastabililty 3-15–2020 (March 15, 2020).

Sajadi, M.M., Habibzadeh, P., Vintzileos, A., Shokouhi, S., Miralles-Wilhelm, F., Amoroso, A., 2020. Temperature and Latitude Analysis to Predict Potential Spread and Seasonality for COVID-19 (Available at SSRN 3550308).

Shi, P., Dong, Y., Yan, H., Li, X., Zhao, C., Liu, W., 2020. The Impact of Temperature and Absolute Humidity on the Coronavirus Disease 2019 (COVID-19) Outbreak Evidence from China. medRxiv.

Tan, J., Mu, L., Huang, J., Yu, S., Chen, B., Yin, J., 2005. An initial investigation of the association between the SARS outbreak and weather: with the view of the environmental temperature and its variation. J. Epidemiol. Community Health 59, 186–192.

Vandini, S., Corvaglia, L., Alessandroni, R., Aquilano, G., Marsico, C., Spinelli, M., 2013. Respiratory syncytial virus infection in infants and correlation with meteorological factors and air pollutants. Ital. J. Pediatr. 39 (1).

Wang, Y., Wang, Y., Chen, Y., Qin, Q., 2020. Unique epidemiological and clinical features of the emerging 2019 novel coronavirus pneumonia (COVID-19) implicate special control measures. J. Med. Virol. 92, 568–576.

Yuan, J., Yun, H., Lan, W., Wang, W., Sullivan, S.G., Jia, S., Bittles, A.H., 2006. A climatologic investigation of the SARS-CoV outbreak in Beijing, China. Am. J. Infect. Control 34 (4), 234–236.

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., 2020. A novel coronavirus from patients with pneumonia in China, 2019. N. Engl. J. Med. 382, 727–733.

Zu, Z.Y., Jiang, M.D., Xu, P.P., Chen, W., Ni, Q.Q., Lu, G.M., 2020. Coronavirus disease 2019 (COVID-19): a perspective from China. Radiology, 200490.