Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

COVID-19 TEMPERATURE DEPENDENCE ANALYSIS USING LEVENBERG-MARQUARDT ALGORITHM

MAYURI JAIN,
Computer Engineering, AP Shah Institute of Technology, Thane, 400615, Maharashtra, India.

SUKHADA ALONI,
Computer Engineering, AP Shah Institute of Technology, Thane, 400615, Maharashtra, India.

PRAVIN ADIVAREKAR,
Computer Engineering, AP Shah Institute of Technology, Thane, 400615, Maharashtra, India.

RAMYA R B,
Computer Engineering, AP Shah Institute of Technology, Thane, 400615, Maharashtra, India.

MERLIN PRIYA JACOB
Computer Engineering, AP Shah Institute of Technology, Thane, 400615, Maharashtra, India.

Abstract

Different countries suffered from waves of the COVID-19 pandemic during different seasons of the year. It was seen in that the pandemic was just as pervasive in countries that experience colder temperatures and those that experience warmer temperatures. We present a study on the impact of regional temperatures on the COVID-19 pandemic. We applied the Levenberg-Marquardt technique to draw a relation between regional temperature and the peaks of the pandemic in a country. Countries in the Arctic Circle like Norway, Sweden, etc. That are higher in latitude experienced the peaks of the pandemic during extremely low temperatures. While countries in the equatorial region experienced peaks of the pandemic in the warmer climate. It was also observed that the behavior of the local people during these peaks was not different than their usual behavior. Hence, a change in the lifestyle of the people was also not a contributing factor to the peaks of the pandemic. As per our findings, the COVID-19 causing Coronavirus was not as persistent in temperatures ranging from 14C and 20C. But, the virus was seen to spread rapidly in the extremely low-temperature range of 0C to 13C and high-temperature range of 21C to 35C. With our algorithm that prediction was 81.1 % accurate.

Introduction

Around the world, the climate of a place is a factor that has been commonly linked to rising viral infections. We generally believe that a drastic switch in climatic conditions or a lower temperature results in the spread of viral infections [7,17]. While humans and most animals grow in any climate, the growth of most microbiological species is temperature dependent. Hence, controlling the growth rate of these species is possible in temperature-controlled environments [18].

The Coronavirus is a microbe that has caused havoc around the world. It led to a global pandemic called COVID-19 which stands for the Coronavirus Disease of 2019. This virus has long been a part of our ecosystem the COVID-19 causing strain called Severe Acute Respiratory Syndrome Coronavirus 2 (SARSCoV-2) was detected in late 2019. This has resulted in a lot of research being conducted on all fronts to combat the virus. Another major area of research during the pandemic has been data analysis.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

This field boomed as the proper study and validation of data could lead to creating better plans to deal with such unprecedented circumstances [5].

Studies that relate the dependence of temperature on the COVID-19 causing virus have provided varying results. The Coronavirus is an RNA-based virus. Research of the coronavirus revealed that Ultra-Violet (UV) radiation, extreme pH levels, and certain intense changes in the environment can kill the virus or make it weaker. It was seen that in a particular temperature range the spike protein of the virus which latches onto human clls becomes harmless. Studies have shown an impact on the spread of the virus when the atmospheric humidity is larger than 6gm/kg. But seasonal fluctuations have been seen to have little impact on the virus. The virus was prevalent in hot and cold countries alike.

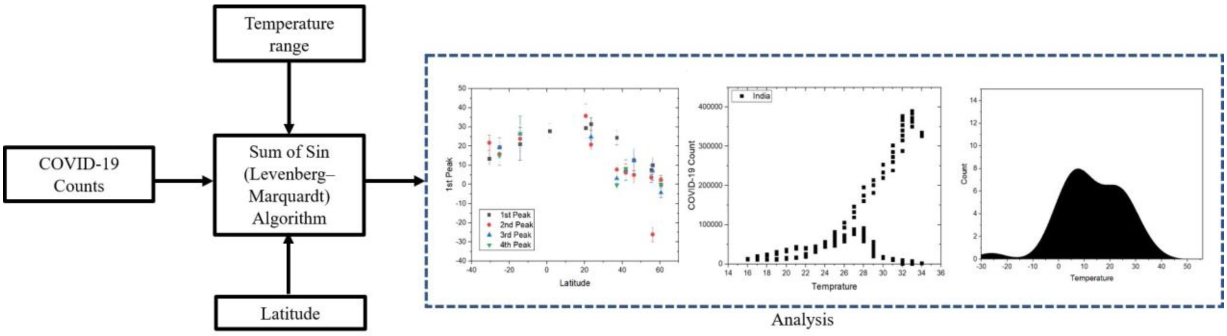

Fig.1. Concept diagram for our proposed method.

We gathered the number of COVID19 infections, latitudes of countries, and their temperature. The first-order Sum of Sine equation and Levenberg-Marquardt method was then used. The results of the impact of temperature and latitude of the COVID-19 cases in different countries were then obtained.

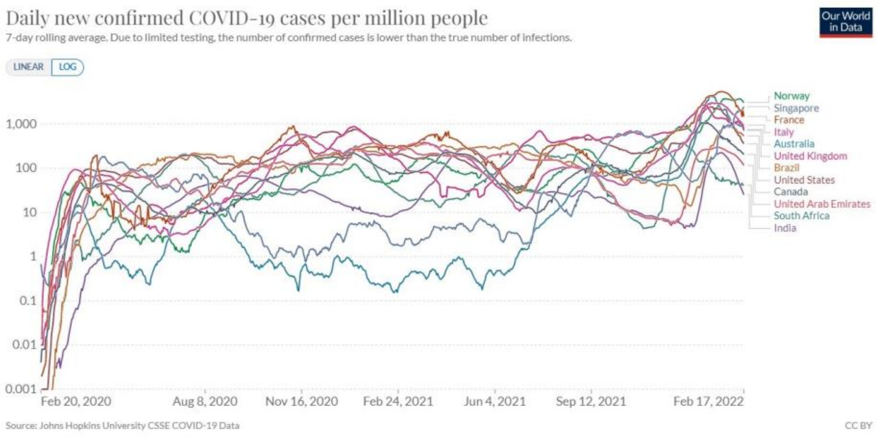

Fig.2. the seven-day average of new cases in 12 countries is plotted.

The X-axis represents the number of days and the Y-axis represents the cases in the logarithmic scale. The different countries are depicted in different colors.

Hence, in our proposed work we have applied an algorithm that uses the sum of the sine to create a relationship between the rise in COVID-19 cases and the temperature of a country based on its latitude. We studied the infection waves in 12 countries varying in latitude and temperature. Blinded tests with the data of 7 countries apart from the 12 used for training, were then used to validate our algorithm. A preprint of our proposed work has previously been published [19].

The flow of our proposed method is shown in Fig. 1. Initially, we gathered data about the infection cases, temperature conditions and latitude reported daily from 12 countries. To carry out our study on the data the first order fitting of the Sum of the Sine equation was done by applying the Levenberg Marquardt technique. As a part of our output, we obtained the effect of latitude and temperature on the rise in COVID-19 cases, the temperatures at which cases peaked in different countries.

Literature Review

In a study done in 2020, when the research of COVID-19 was in its starting phase, Juni et al. [9] stated that temperature and latitude don't directly impact the spread of COVID-19. Although they mentioned that the two parameters will play a role in the future of the pandemic their findings at that time were contradictory to this statement. They also mentioned that higher temperatures may have little effect on the spread of the virus. Smit et al. [15] also did not see a very strong connection between the spread of the infection and the environmental factors. They state that the COVID-19 flu, seasonal flu, and influenza could be confused for each other. But in another study done in 2020 by Briz et al. [1] they found that the change in weather may result in a change in the spread of the droplets that cause the infection. However, even they did not find evidence that says that higher temperature will reduce the spread. However, Marvi et al. [10] have stated that extreme weather conditions can slow down the spread of the infection. They considered different factors such as density of population, testing, and the number of days the infection has prevailed in the country. Further, Runkle et al. [14], in 2020 did find a relation between temperature and humidity on the COVID-19 infection after their investigation. Goyal et al. [8] showed that only temperature may not be an accurate indicator of the COVID-19 spread. In colder reasons, the spread was an inverse parabola while in hotter regions it was exponential. The Auto-Regressive Integrated Moving Average (ARIMA) method was used by Demongeot et al. [6] to study the effect of temperature on COVID-19 cases in 21 countries. They found that the temperature will slow down the number of cases.

In 2021, Byun et al. [3] did a study to see if the transmissibility of COVID-19 cases was affected by the seasons. They studied the trends in 50 countries and saw that the transmissibility of the virus had an inverse relationship with the seasonal changes. They showed that the COVID-19 spread is dependent on the latitude and precipitation of a place. Burra et al. [2] established that there was a connection between the temperature of the country and the mortality rates and also the latitude and spread of COVID-19 in a country. They also proved that the genome sequence of the virus does not get affected by the temperature in the different geographical areas. A study done by Notari [11] states that the spread of the Coronavirus is reduced by almost 40 % at

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

temperatures of 25oC while at lower temperatures like 5oC it is higher. Finally, a study was done by Ren et al. [12] in China shows that the decrease in the cases in China was a primary result of the increase in temperatures. They state that colder places have higher COVID-19 dissemination. To conduct their study they used a method called Analysis of Variance.

Methodology

For our research, we collected the data of COVID-19 cases for 12 countries. The countries were from different continents and at different latitudes such as Italy, Norway, and France from Europe, South Africa from Africa, India, Singapore and the United Arab Emirates from Asia, Canada, Brazil and the United States of America from the Americas, the United Kingdom and finally Australia. While choosing the countries we considered their latitudes i.e. the position of these countries in the two hemispheres, the general demographic of the population i.e. the age, and lastly, the number of times the country saw an outbreak of cases. The data relating to the countries latitude was collected from the Simplemaps dataset [16].

The ”OurWorld” database [13] which hosts the data of around 207 countries was the source from which we obtained the information. The data was collected from 20 February 2020 to 17th February 2022. Figure 2 depicts the graph of the 7-day average rise in cases in every country. The dates ranging from 20 February 2020 to 17th February 2022 are given on the X-axis and the number of cases is given on the Y-axis. The Y-axis is in logarithmic form.

The temperature data were obtained from the datasets named Weather-Atlas and Climate-Data [4] from dates January 1, 2020, to May 18, 2021. Data ranging over the initial 1.5 years of the pandemic will provide a good estimate of the temperature impact on the virus as that’s when the virus was at its strongest and causing extremely severe health complications in a large part of the population. As shown in Fig. 3 (b), the minimum, maximum, and daily average temperatures of a country were obtained. To assess the peaks we performed a thorough study of the data. As the first step, we used equation 1 to calculate the slope (s) between the days.

$$S = \frac{Count\ on\ n^{th}\ Day\ -\ Count\ on\ (n-1)^{th}\ day}{n-(n-1)} \qquad (1)$$

The logic applied to find the first day on which the COVID-19 wave began in a country was as follows. First, we checked when the slope of the subsequent days went from positive to negative. Then, the number of infections one day before the change of slope was checked. If the cases were 50 % larger than the average of the previous 30 days then that day was considered to be the first day the rise in cases started. To perform our computations we used a computer with Intel Core i7 6700K Central Processing Unit (CPU) and 24 GB DDR4 RAM. The 2019a version of MATLAB was used to perform all the computations.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

Figure 4 (c) and (d) show two of the peaks that were plotted. We gave the most importance to peaks that were within 75 % of the maximum point of the bell-shaped curve. The rest of the nearby values were ignored to avoid any overfitting.

Once we had gotten the day on which the COVID-19 peaks of the different countries occurred we noted the temperatures in those countries on those days. Figure 4 (a) shows the plot of the days of which the peaks occurred versus the latitude. After many efforts and investigations for different data fit, the Levenberg-Marquardt algorithm and first-order Sum of the Sine equation obtained the maximum value of goodness for data fitting. The best coefficient of determination R2 was almost equal to 1. The fitting obtained is given by equation f(x) = a1∗sin(b1∗x+c1). Where, coefficients having 95 % confidence are, a1 = 28.57 (min = 27.09, max = 30.06), b1 = 0.03015 (min = 0.02891, max = 0.03138) and c1 = 1.482 (min = 1.429, max = 1.535).

Results and discussions

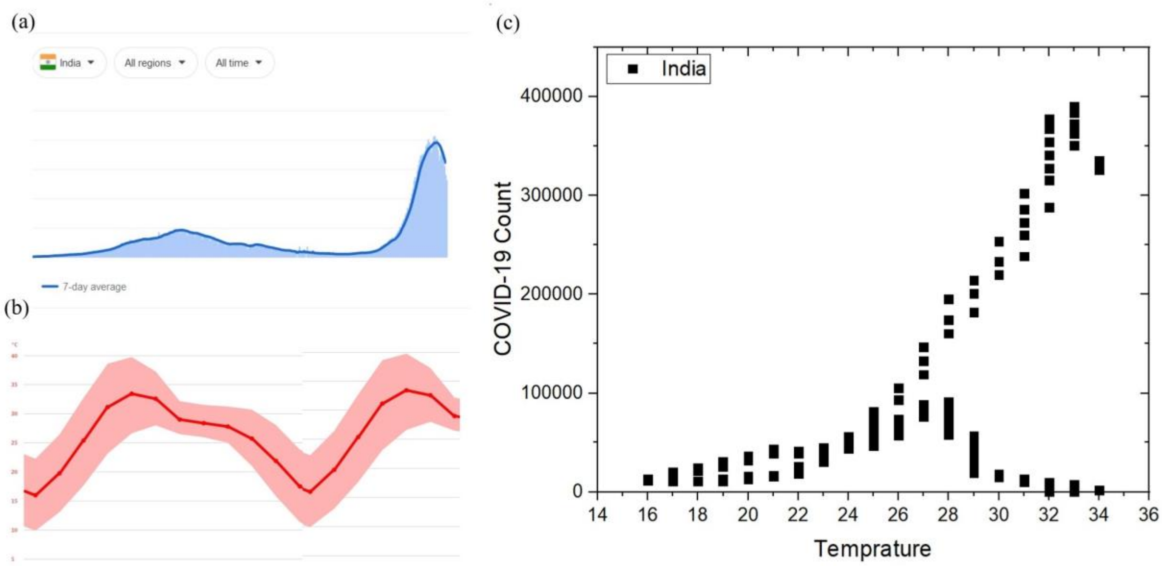

Fig.3. the impact of temperature on the daily increase in cases in India.

(a) The seven-day average rise in cases shows two peaks between 20 February 2020 till 18 May 2021. (b) The average temperature in India in the specified period. The break in the grey lines shows the start of a new year. (c) Temperature versus the number of cases. In India, temperatures below 21oC witness very few cases while the 27oC and 35o temperature range witnessed two distributions, one going to 4-Lakh cases and the other to none.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

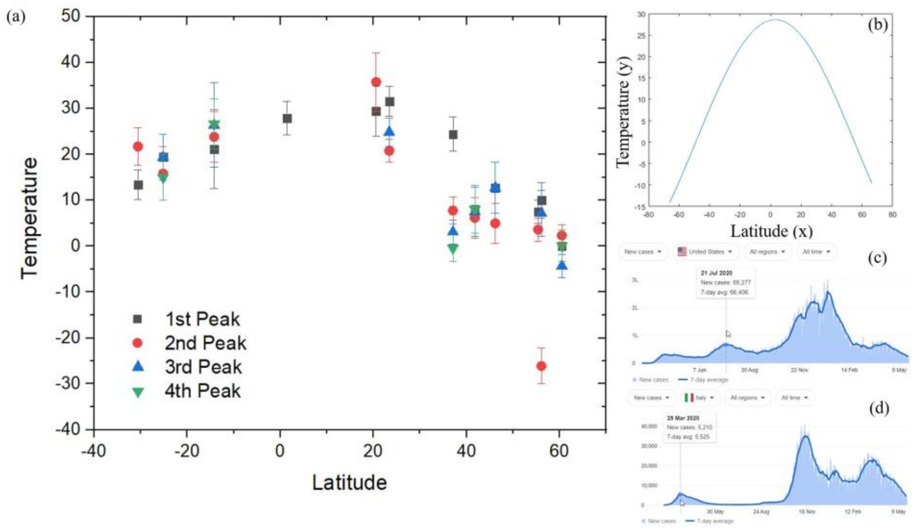

Fig.4. (a) The graph of latitude versus temperature in 12 countries.

As the geographical location of the countries increases towards the north or south the temperature at which the peaks occur decreases. (b) The graph of latitude versus temperature was obtained after applying our prosed method. (c) COVID-19 cases in the United States of America depicting the second wave. (d) COVID-19 cases in Italy depicting the first wave.

The analysis of the effect of temperature on the COVID-19 cases in India has been shown in Fig. 3. In Fig. 3 (a) we can see the distribution curve of the seven-day average value of COVID-19 cases in India from 20th February 2020 to 18th May 2021. Next, Fig. 3 (b) shows the distribution curve of the average temperature in India in the same period as the number of cases. In these graphs, the ending of a year is represented by a break in the grey lines. Finally, Fig. 3 (c) shows the analysis of temperature and rise in COVID-19 cases. It can be seen that the temperatures falling in the range of 27 to 35 degrees Celsius resulted in two different distributions. As we can see, one distribution led to an increase of almost 4-Lakh cases per day while the other distribution led to none.

The relation between the latitude of the countries and their temperature can be seen in Fig. 4 (a). It can be seen how the increases in latitude towards the North or South of the equator show a decrease in temperature at which the COVID-19 peaks occur. In the distribution, Canada is seen to have a peak at -30 degrees Celsius and Singapore is seen to have only one peak. Figure 4 (b) shows the latitude versus temperature graph. The Levenberg-Marquardt and first-order Sum of the Sine method was used to best fit the data points from Fig. 4 (a). Figure 4 (c) shows the COVID-19 incidents in the United States of America. From this graph, we can see that the second peak occurred on July 21, 2020, with 66,406 average cases. In Fig. 4 (d) the first peak in Italy is seen to be on 25th March 2020 with an average of 5525 cases.

The average number of cases values are the seven-day averages.

From Fig. 5 (a) we can see that COVID-19 cases were split into two parts based on

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

the impact of temperature. COVID-19 cases occurred in regions that experience a low-temperature range of 0oC to 13oC and also regions with a high temperature range of 21oC to 35oC. The peaks of different countries at specific temperatures are shown in Fig. 5 (b). Around 8 countries are seen to have their maximum COVID-19 cases at a temperature of 7oC and around 7 countries saw their peak at 25oC. This proves that COVID-19 follows a b-modal pattern in terms of the impact of temperature.

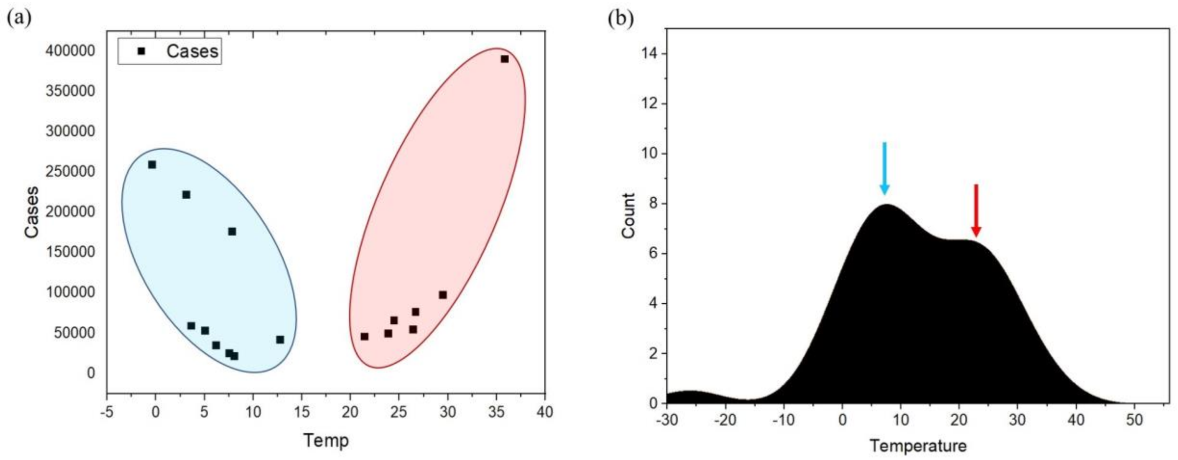

Fig.5. The impact of the temperature of the rise on COVID-19 cases in different countries.

(a) The temperature is divided into two parts, light-blue depicts low temperature, and light-pink depicts high temperature. (b) The histogram shows the temperatures at which the COVID-19 peaks occurred in different countries. The X-axis shows the temperature and Y-axis shows the countries.

Table 1. Blind testing was done for seven countries and their results of the predicted temperature and corresponding accuracy were obtained.

Country Name	Latitude	Temperature at peak (actual)	Temperature at peak (predicted)	Error	Prediction Accuracy
Argentina	-38.4	13	9.10	3.90	0.700
Kuwait	29.3	19.6	20.63	-1.03	0.950
New Zealand	-40.9	16	6.62	9.38	0.414
France	46.2	8.6	9.98	-1.38	0.861
Italy	41.9	11	13.03	-2.03	0.844
Indonesia	-0.8	27	26.72	0.28	0.990
Egypt	26.8	20	21.85	-1.85	0.916

In our testing phase, we took seven countries, apart from the ones in our list of 12 countries, to perform blind testing. The results obtained for each of these countries are given in Table 1. Initially, we distributed the countries on the basis of their latitudes. The countries were selected such that an equal number of high latitude countries like New Zealand and low latitude countries like Indonesia (-0.8) were selected for proper distribution. During testing, the positive and negative values of temperature were considered equally. Next, the temperature for which the pandemic will peak for the countries with different latitudes was evaluated. We applied the $f(x) = a1*\sin(b1*x+c1)$ to calculate the projected temperature at the prospective pandemic peaks using the values of a1, b1 and c1. Except for New Zealand, which had a prediction accuracy of 41.1 %, our model was able to achieve maximum accuracy of up to 99 % for the rest of the countries. In the majority of the cases, with New Zealand as an extreme exception, the prediction accuracy was greater than 70 %. We believe that the low population density and only one peak in cases in the specified period could be a cause of this inaccuracy.

Any virus that is in existence tends to adapt and mutate because of herd immunization. Due to this, the prediction of all COVID-19 peaks may not be feasible using just the latitude-based approach. For the purpose of temperature dependency, we took the data for 1.5 years and in this time period, it was seen that countries experienced an average of four peaks in the COVID-19 infections. From our study, we discovered that temperature does not have a direct effect on the worldwide COVID-19 cases. But, a combination of latitude with temperature can most definitely help us establish which month of the year a certain country should expect a rise in the number of infections. With the information in hand, countries will be able to be better equipped to deal with a sudden large increase of cases.

The data used for our study came from different countries and it consisted only of the number of cases, latitude, and temperature information of the countries. The available data was what the governments of those countries have publicly disclosed. Hence, if any sort of hampering was done to the data by the governments of intermediate agencies then our analysis could be harmed resulting in the wrong predictions. Even limited testing, which results in lower number of daily cases than can hamper the prediction. Further, we have not considered the density and lifestyle of the population of the countries. The number of people and whether the people abide by COVID-19 norms such as maintaining social distance, wearing masks, get vaccinated were not taken into account.

As the latitude and temperatures are not constant even in different regions of one country. We hope that our study can help scientific researchers in such large countries, such as the United States and India, conduct a similar analysis in different states of the country.

Conclusions

In our work, we collected the temperature and COVID-19 infections data for 12 countries. Using the Levenberg-Marquardt algorithm and the first-order sum of the sine equation we developed an equation that could predict at which temperatures the peaks of the COVID-19 infection would occur in a country based on their latitudes. To validate our model we used a blind testing method with the data of 7 countries. From this, we noticed that for 6

ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

out of the 7 countries our algorithm performed with more than 70 % prediction accuracy. The maximum prediction accuracy was 99 % and the average prediction accuracy we obtained was 81.1 %. As for temperature, we noticed that COVID-19 had somewhat of a bi-modal behavior. The virus spread rapidly in both extremely low temperatures (0oC to 13oC) and extremely high temperatures (21oC to 35oC). We have presented this study intending to make a meaningful contribution to both the society and scientific community. We believe that if every country obtained its specific temperature ranges it will be able to be better equipped to fight the spread of the pandemic.

Declarations

Funding information

There was no funding provided for the proposed work.

Conflicts of interest

The authors of the manuscript, M. A. Jain, S. S. Aloni, and P. P. Adivarekar, state that they have no conflicting interests to declare.

Code availability

The codes will be provided in the public domain upon publication of the manuscript.

Data availability

The data will be provided in the public domain upon publication of the manuscript.

Authors' contributions

P. P. Adivarekar (PA) and S. S. Aloni (SA) conceptualized the project. M. A. Jain (MJ) did all of the literature reading and data collection. PA, SA, and MJ carried out the formal analysis. MJ and SA were in charge of the coding. SA and MJ prepared the original draft of the manuscript. PA reviewed and edited the work. PA and SA were in charge of the visualization.

Ethics approval

All authors affirm that the manuscript satisfies the following statements: 1) This is the author's original work, which has not previously been published elsewhere. 2) The paper is not being considered for publication elsewhere at the moment. 3) The work accurately and completely reflects the author's own research and analysis. 4) The work appropriately acknowledges the significant contributions of co-authors and co-researchers. 5) The findings are adequately contextualized in relation to prior and existing research.

Consent to participate

This work contains no animal or human experiments conducted by any of the authors. Because there were no human volunteers, informed consent was not necessary. The Institute Ethical Committee and the relevant authorities granted the necessary licenses.

Consent for publication

Wherever applicable, the authors obtained all relevant consents for publishing from participants.

References

[1] Briz-Red´on, A., Serrano-Aroca,´ A.: The effect of climate on the spread of the´ covid-19 pandemic: A review of findings, and statistical and modelling techniques. Progress in Physical Geography: Earth and Environment 44(5), 591–604 (2020)

[2] Burra, P., Soto-D´ıaz, K., Chalen, I., Gonzalez-Ricon, R.J., Istanto, D., CaetanoAnoll´es, G.: Temperature and latitude correlate with sars-cov-2 epidemiological variables but not with genomic change worldwide. Evolutionary Bioinformatics 17, 1176934321989,695 (2021)

[3] Byun, W.S., Heo, S.W., Jo, G., Kim, J.W., Kim, S., Lee, S., Park, H.E., Baek,J.H.: Is coronavirus disease (covid-19) seasonal? a critical analysis of empirical and epidemiological studies at global and local scales. Environmental Research p. 110972 (2021)

[4] Contributers, O.: climate-data.org (2021). URL https://en.climate-data.org/

[5] Cvetkovi´c, V.M., Nikoli´c, N., Radovanovi´c Nenadi´c, U., Ocal, A., K Noji, E.,¨ Zeˇcevi´c, M.: Preparedness and preventive behaviors for a pandemic disaster caused by covid-19 in serbia. International journal of environmental research and public health 17(11), 4124 (2020)

[6] Demongeot, J., Flet-Berliac, Y., Seligmann, H.: Temperature decreases spread parameters of the new covid-19 case dynamics. Biology 9(5), 94 (2020)

[7] Geller, C., Varbanov, M., Duval, R.E.: Human coronaviruses: insights into environmental resistance and its influence on the development of new antiseptic strategies. Viruses 4(11), 3044–3068 (2012)

[8] Goyal, S., Malinas, M.: The effect of temperature on the spread of covid-19. Journalof Student Research 9(2) (2020)

[9] Ju¨ni, P., Rothenbu¨hler, M., Bobos, P., Thorpe, K.E., da Costa, B.R., Fisman,D.N., Slutsky, A.S., Gesink, D.: Impact of climate and public health interventions on the covid-19 pandemic: a prospective cohort study. Cmaj 192(21), E566–E573 (2020)

[10] Marvi, M., Arfeen, A., Rauf, Z.: Demystifying a hidden trend: Do temperaturevariations affect covid-19 spread? Available at SSRN 3567084 (2020)

[11] Notari, A.: Temperature dependence of covid-19 transmission. Science of The TotalEnvironment 763, 144,390 (2021)

[12] Ren, M., Pei, R., Jiangtulu, B., Chen, J., Xue, T., Shen, G., Yuan, X., Li, K.,Lan, C., Chen, Z., et al.: Contribution of temperature increase to restrain the transmission of covid-19. The Innovation 2(1), 100,071 (2021)

[13] Ritchie, H., Ortiz-Ospina, E., Beltekian, D., Mathieu, E., Hasell, J., Macdonald,B., Giattino, C., Appel, C., Rod´es-Guirao, L., Roser, M., et al.: Coronavirus pandemic (covid-19) - statistics and research (2021). URL https://ourworldindata.org/coronavirus

[14] Runkle, J.D., Sugg, M.M., Leeper, R.D., Rao, Y., Matthews, J.L., Rennie, J.J.: Short-term effects of specific humidity and temperature on covid-19 morbidity in select us cities. Science of the Total Environment 740, 140,093 (2020)

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:55 Issue:05:2022
DOI 10.17605/OSF.IO/8ZCMB

[15] Smit, A.J., Fitchett, J.M., Engelbrecht, F.A., Scholes, R.J., Dzhivhuho, G., Sweijd,N.A.: Winter is coming: a southern hemisphere perspective of the environmental drivers of sars-cov-2 and the potential seasonality of covid-19. International journal of environmental research and public health 17(16), 5634 (2020)

[16] Software, P.: World cities database (2010). URL https://simplemaps.com/data/world-cities

[17] Tang, J., Lai, F., Wong, F., Hon, K.: Incidence of common respiratory viral infections related to climate factors in hospitalized children in hong kong. Epidemiology & Infection 138(2), 226–235 (2010)

[18] Taylor, F.: Ecology and evolution of physiological time in insects. The American Naturalist 117(1), 1–23 (1981)

[19] Jain, Mayuri, Sukhada Aloni, and Pravin Adivarekar. "Data analysis of COVID-19 wave peaks in relation to latitude and temperature for multiple nations." medRxiv (2021).