

Diagnostic Comparison of Changes in Air Quality over China before and during the COVID-19 Pandemic

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Research Article

Keywords: Air Quality, China, COVID-19, Pandemic, Black Carbon.

Posted Date: May 26th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-30482/v1>

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Abstract

The rapid spread of Covid-19 has affected the political, social, and economic sectors, which inevitably will also affect the environmental component. This contagious virus led the worldwide countries to make securities measures such as lockdown to reduce the spread of COVID-19 and protect human health. In contrast to the negative impacts of this virus on the economy, it has influenced the environment positively. As reported by station and program for monitoring the Earth, the air quality has improved after the lockdown. The present study compares the air level pollution one year before and during the spread of Coronavirus in China. Accordingly, we investigate the change of the concentrations of three air pollutants, namely, O₃, NO₂, and black carbon. The study of the measured parameter between December 2019 and March 2020 exhibit an apparent decrease in their concentrations because of the imposing lockdown of cities and restriction on chemical industries and factories.

1. Introductions

Incipient viruses are getting a challenge for people all around the world. Corona viruses are among them. These viruses affect humans, including other mammals and birds. The fast spreading of the COVID-19 cases has created a worldwide pandemic and brought lethal consequences (Wang et al., 2020). Coronaviruses are very infectious, cause tract diseases that will be lethal. Mild symptoms of corona include respiratory illness, cough, fever, etc., and can cause multiple organ failure and result in death. Four kinds of common coronavirus that causes infections in humans are 229E, NL63, OC43, and HKU1. Most of the people globally can develop a minimum of one amongst these over their lifetime. Three other coronaviruses emerged in animals and transmitted to humans and produced critical risks to human health. They are described as SARS-CoV, MERS-CoV, SARS-CoV-2. In step with the WHO, the first human cases of SARS-CoV were observed in southern China in November 2002. Previous studies revealed that SARS-CoV might have originated in bats then transmitted to other animals before infecting humans. According to the study done by WHO, MERS-CoV, has firstly appeared in September 2012 in an Asian country and it spread through the close contact of humans with camels as well as through human-to-human contact.

In late December 2019, a replacement coronavirus has appeared in Wuhan, Hubei Province, China i.e., SARS-CoV-2 causes COVID-19. The health administrators in Wuhan have observed a mass of cases of pneumonia, and the cause was linked to seafood and wet animals wholesale market situated in Wuhan city. It was also believed that the Wet market of Wuhan might not be the sole source of coronavirus. A recent study conducted by Società Italiana di Medicina Ambientale (SIMA) has indicated that the specificity of the important rate spread of the coronavirus in some zones of Northern Italy is seem related to air pollutions conditions (Martelletti & Martelletti, 2020).

On December 31, 2019, the Chinese Center for Disease Control and Prevention (China CDC) sent off a team to Wuhan to conduct an investigation, they doled out it and recorded the obtained results. They found the source of the pneumonia masses in patients and they detected the novel coronavirus in patients whose specimens were tested by the CDC. Prior, it was suggested that the patients who suffered by pneumonia and transmitted this virus may have visited the wet animal or seafood market where the animals sort of a bat, snakes, birds, etc., However, after this investigation, the researchers unveiled that some individuals infected with this virus do not show any record of a visit to the present wet or seafood market. Furthermore, this research revealed the human-to-human transmission capability of this new virus, which is caused by the close contact with an infected person liable to coughing, respiratory droplets of aerosols, or sneezing. These respiratory droplets enter the physical body by inhalation through the nose or mouth and then contaminating no infected persons. This virus belongs to the β group of coronaviruses. The Chinese Researchers named this virus as Wuhan coronavirus or 2019 novel coronavirus (2019-nCov). Around 210 countries and territories are affecting by COVID-19. The source of SARS-CoV-2 is not confirmed, but it is believed that it arose from bats.

In early January, the pandemic began to increase rapidly in many cases. It has affected the political, social, and economic sectors, which inevitably will also influence the environment. January 24, 2020, numerous countries have also reported the patients plagued by the same virus, which means that this virus exported to other countries via infected individuals coming from China. After that, the number of cases infected with COVID-19 continued to grow up to date, and the number of deaths caused by this virus exceeds the death amount caused by other types of coronaviruses. The number of confirmed cases crossed the mark of 1.5 million globally. Until now, no specific treatments exist to cure or vaccine to cater to COVID-19. However, symptoms will be treated in clinical conditions. In step with observations, the recovery time for patients varies from 2 weeks to 3-6 weeks in severe cases. People infected with COVID-19 generally develop symptoms, including respiratory signs and fever, on a median of 5-6 days after infection and during a period of 1 to 14 days. Symptoms and signs shown by patients are dry cough, fever and tiredness. Some patients also develop chest congestion, aches, and pains, diarrhea, runny nose and inflammatory disease.

As of April 14, the WHO has been reported 19, 20,918 confirmed cases and 1, 19,686 death cases worldwide (Table 1; Fig.1). Currently, every nation is trying to regulate and limit the transmission of SARS-CoV-2 in humans. On a global level, lockdown is adopted to prevent the public gathering, keep people at their homes and keep them aloof from their offices, public transports, etc.. In order to keep up social distancing, various other methods were adopted. In turn, the USA, Italy, Spain, China have been almost coms to rest. Streets, Malls, theatres, etc. are deserted, aircraft grounded, travel restricted. Factories shut down, events canceled and postponed, and all activities were blocked.

COVID-19 has dramatically impacted the world economy, the petrol barrel price has shut down and recently the benchmark US oil prices fell below zero for the first time in the whole history of the oil market. The coronavirus crisis is the leading cause that has pushed demand for oil after the airlines reduced services, and travel restrictions lowered the amount of petrol pump activity. Besides, the petrol stations

are now selling less fuel because of the containment, which dropped off the human consumption rate. The mining activities around the world were also closed because of coronavirus, which caused an increasing trend of metals prices. The tourism activities were also postponed in the whole world in order to stop the virus spread.

These all activities generate every day high amount of pollutants in air, land and rivers, which reach easily ocean. The temporary suspend of these activities may have impacted positively the air quality. In order to understand how the economic impacts of Covid-19 have influenced the environment a diagnostic comparison between the air quality before and after Covid-19 is needed. Currently, numerous studies are undergoing to investigate the effect of confinement on environment, which could be helpful to standard individuals and partially offset the costs of these counter-COVID-19 measures. As an example, satellite pictures caught a pointy decision in pollution in many countries that have taken aggressive measures on the transmission of the virus.

Table 1. COVID-19 confirmed cases and deaths as of 14th April 2020 (WHO Report 2020)

Region	Confirmed Cases	Confirmed Deaths
Global	19,20,918	1,19,686
United States	5,87,337	23,649
Spain	1,70,009	17,756
Italy	1,59,516	20,465
China	82,249	3,341
India	10,363	339

Since a long time air pollution is affecting each and every part of the world. It is one of the biggest environmental and health problems worldwide. It could be a risk factor leading to death due to heart disease, attacks, respiratory infections, lung cancer, diabetes, and chronic pulmonary disease. (Suresh A, 2020; Bhardwaj P,2019) There are many reports, research articles, papers and analyses, which have explained a direct impact of air pollution in respiratory diseases (Guan et al., 2016; Li J et al., 2016; Komalkirti A et al., 2016; Schiavoni G et al., 2017). According to WHO, every year, around 7 million people die because of severe diseases caused by air pollution; disease includes stroke, cancers, heart disease and respiratory disease. Chemically, air pollutants can be presented as the vapor forms of inorganic pollutants, such as carbon monoxide (CO), ozone (O₃) nitrogen dioxide (NO₂), and sulfur dioxide (SO₂), or as the aerosols (Li J et al., 2016; Bloemsma L.D et al., 2016; A.Othmani et al., 2019).

NO₂, which is associated with mortality and morbidity, is a common tracer of industrial activity/air pollution (He et al., 2020a , b). Ordinarily, the concentration of NO₂ above 200 micrograms per cubic meter

has been considered as toxic gas (WHO 2018a). CO₂ is considered as another common tracer of air pollution (Hanaoka and Masui, 2019). In 2017, it was estimated that globally, air pollution contributed 9% of deaths, and it ranged from an occasional 2% across high-income countries to 15% across many countries in South and East Asia (Hannah et al., 2019). The particulate forms of air pollutants comprise of the most harmful forms of particulate matter (PM) include PM₁₀ (<10 µm), fine particles PM_{2.5} (<2.5 µm), and ultrafine particles (less than 0.1 µm or 100 nm), which can be released from diesel engines, volcanoes, unpaved roads, burning fields, etc. (Gautam S et al., 2016; Cohen A.J et al., 2015).

The European Environment Agency (EEA), has reported that air pollution causes more death annually than motor vehicle accidents (European Environment Agency, 2005). Scientists have reported that the reduction in NO₂ was first observed in Wuhan, China, spread across the country and then globally. NO₂ emissions in Central China were reduced by as much as around 30% (NASA, 2020). In addition, the European Space Agency (ESA) has recorded a 20 – 30% decrease in the fine particulate matter. After estimation, fine particulate matter becomes one of the most important air pollutants, in February 2020 compared to the previous three years.

According to Kai Chen et al., 2020, NO₂ dropped by 22.8 µg/m³ and 12.9 µg/m³ in Wuhan, China, due to quarantine. Owing China is world's largest emitter of carbon followed by USA and EU. Research work has shown that there is a major reduction in power consumption due to lockdown as industries and factories are into hibernation (Carbon Brief, 2020). In Europe CO₂ has dropped 58%, while the International Energy Agency (IEA) is projecting 7.5% annual reduction in the United States energy-related carbon emissions during 2020. The report published by Carbon Brief shows that the pandemic could result in CO₂ reduction globally in the region of 1,600 million metric tons compared to 2019, which roughly would equate to a 4 % fall in emissions. According to scientists from Royal Netherlands Meteorological Department, in Paris the concentration of NO₂ drop by 54%, while Rome, Madrid and Milan shows a drop of nearly 50%. The data have been monitored over Europe using the European Space Agency's Copernicus Sentinel-5P satellite (Forbes, 2020). After ten days of social distancing measures due to COVID-19, a reduction in PM₁₀ levels observed in Lombardy. In France, a major drop in NO_x is observed because of minimizing economic activity and transportation (Balken Green Energy News, 2020).

2. Materials And Methods

2.1 Study area

In this study, we focus on studying air quality in China before and after coronavirus. China is an east-Asian country, positioned north of the equator between 18°N and 54°N latitudes and 73°E and 135°E longitudes (Fig.2). The geo-coordinates of the country lie at 21°N and 78°E. China is the most populous country in the world, with over 1.428 billion in 2017. Across this large geographical scales and varying topography, the climate of the country is easily generalized, comprising a wide range of weather conditions. China's climate is generally dominated by dry seasons and wet monsoons, which cause pronounced temperature differences between the two seasons, winter and summer. Moreover, most of the

regions in the country are having starkly different microclimates. Regional difference in the climatic condition of the country is due to its highly complex topography. Asian countries remain disproportionately affected by toxic air and so-called pollution-related problems in consideration with a large population, crowded cities, industrial emissions, etc. Ways adopted for the rapid economic development in the country has led to severe air pollution. The main cause of air pollution in the country is due to the seriousness of pollution, especially in the metropolitan cities throughout the county.

2.2 Methodology

Ozone Monitoring Instrument (OMI) is a Dutch Finnish ozone monitoring image spectrometer (Table 2). The instrument is designated for distinguishing ozone and other atmospheric species. OMI sensor has a spectral region of 264 – 504 nm, a spectral resolution of 0.42 nm – 0.63 nm, and a resolution of 0.125×0.1250 . The high spectral and spatial resolution of the instrument is the key to the detection of air pollution of urban scale resolution. The acquisition of measurement from tropospheric and stratospheric levels of the earth's atmosphere is the main objective of the instrument's mission. MERRA-2 stands for Modern-Era Retrospective analysis for Research and Applications version 2. The MERRA project focuses on historical climate analyses for a broad range of weather and climate time scales and places the NASA Earth Observatory System (EOS) suite of observations in a climate context.

Table 2 : Details of Satellite Data used for current study

Satellite Sensor	Resolution	Duration
OMI (Ozone Monitoring Instrument)	0.25 degree	December to March 2019 and 2020
MERRA - 2 Model	0.5×0.625 degree	December to March 2019 and 2020

For the study of total column ozone, the TOMS-like OMT03e product has been used. It selects the best pixel data from the good quality level-2 total column ozone data (OMT03). This product data falls in the 0.25×0.25 -degree global grids. For the study of the tropospheric column, NO2OMNO2d data product has been selected. It is a Level-3 Gridded Product where pixel-level data of good quality are falling into 0.25×0.25 degree global grids. This product contains Tropospheric Column NO₂, for all atmospheric conditions, with less than 30 percent cloud fraction. Black Carbon is one of the primary constituent components of atmospheric aerosols. Black carbon aerosols are highly absorbing and an essential factor in radiative forcing and radiative transfer. For the study of Black carbon, the M2TMNXAER product has been selected.

Monthly averaged data from January to March are used for the study from the years 2019 and 2020. During the processing and the interpretation of satellite data, the GIS tool has been used primarily for mapping and for managing the geographical data information in a database. High-level languages are used for analyzing and visualizing the satellite-derived data products for the study. MATLAB and ORIGIN software has been used for numerical computation of the data.

3. Results And Discussion

Three parameters influencing parameters namely; the ozone (O_3), the Nitrogen Dioxide (NO_2) and Black Carbon have harmful impacts on environmental safety due to their toxic effect on fauna and flora. In this context, it seems important to study their variation before and after the spread of Corona virus and to predict the main relation between their concentrations and the spread of Corona virus . A comparative study of the obtained rates before and after the spread of corona virus was reported.

3.1. Ozone (O_3)

Ozone is a gas made up of 3 atoms of oxygen. It occurs naturally in the uppermost layer of the atmosphere, i.e., stratosphere and at ground level due to chemical reactions. Ozone is formed in a lower atmosphere near the earth's surface by the reaction of air pollutants released from vehicles, industries, chemical plants, and from other sources. These air pollutants react chemically in the presence of sunlight and form ozone. Stratospheric ozone is good as it protects us from the harmful ultraviolet radiation coming from the sun. It forms a protective layer that acts as a barrier against UV rays of the sun. Exposure of UV radiation can cause skin allergy, irritation in eyes, skin cancer, etc.

Conversely, the ozone layer which is present at ground level is very harmful to us. It acts as an air pollutant because of its adverse effects on humans and the environment. The life of individuals most at risk from inhaling air containing harmful ozone includes individuals who have asthma, workers, older children who are active outdoors. In addition, ground-level ozone affects ecosystems and vegetation, including forests, grasslands, and parks, including wildlife and wilderness areas.

The O_3 level change measured in china from December 2019 to March 2020 is illustrated was studied. Figure 3 shows the level of O_3 fell in China during lockdown because of the COVID-19 spread. In December 2019, the level of O_3 over China was very high due to the high amount of pollutant generated from practiced human activities. A significant decline of O_3 was observed in January 2020, the imposing lockdown of cities and restriction on chemical industries and factories a have positively influenced the current situation where a decrease of O_3 was obtained. In February 2020, the level is almost the same as January, whereas there is a significant increase in O_3 level characterized in March 2020 when the Government resumed some of the industrial activities. In light of these results, we can highlight the dependence of the change of O_3 level to the industrial activities.

According to figure 4, there is an apparent increase in the mean concentration of ozone from December to March. As the results point, the mean concentration decreases before December 30, 2018, and again increases on December 30, 2019. An ozone maximum of 326.91 DU mean concentration was recorded in March as compared with the lowest 293.20 DU in December. Over the years, the mean concentration of ozone is increasing in China.

Figure.5 shows a significant increase in the mean concentration of Ozone in China during the period of the lockdown. The mean concentration of ozone varies from 307.87 to 336.60 DU from December to March. The comparison of the obtained results of the mean concentration of ozone during COVID-19 lockdown with the mean concentration of last year (Fig.4; table 3) reveals that the mean concentration of ozone is less important during the lockdown, which is certainly due to the decline of human-made emissions. Whereas, the variation of ozone reached about 11% in January 2020 because of the severe restrictions imposed by China in this month. In contrast, this percentage has decreased and reached 6% in February and 3% in March 2020. Some factories were resumed in the late February and March.

Table 3. Mean Concentration and variation of Ozone

Month	2018-2019	2019-2020	Variation	%
December	293.20	307.87	14.66	5%
January	294.83	326.38	31.55	11%
February	310.99	330.70	19.71	6%
March	326.91	335.60	8.68	3%

3.2. Nitrogen Dioxide (NO₂)

Nitrogen dioxide is one of a component of a bunch of gaseous air pollutants. It is produced by various human activities like traffic, combustion of nitrogen-containing fuels, and many more.(A.Othmani, et al., 2019; C. Lopez, et al., 2020). Once nitrogen is released into the air, it reacts with oxygen present in the air at very high temperatures. Moreover, Nitrogen dioxide reacts with water to form nitric acid, which is extremely corrosive (.T. M. Guamushig et al.,2019; C.-P. Lopez et al.,2019; Tituana JC. et al.,2018) If individuals inhale nitrogen dioxide, it proceeds through the upper respiratory tract and reaches lungs where it can react with water present in the lungs and forms nitric acid, which is extremely toxic in high quantity and causes tissue damage. Nitrogen dioxide is also one of the greenhouse gases, it contributes to global warming, and if NO₂ reacts in the atmosphere with sulfur dioxide, it forms acid rain, which contributes to the depletion of the ozone layer.(Jose J et al., 2020)

Unlike in 2019, the level of NO₂ did not rise after the Chinese New Year in 2020. As illustrated in Fig.6, the satellite images of China amid COVID-19 showed a reduction of the level of NO₂ over it. The map shows the variation in NO₂ concentration in blue, yellow, green, sea green, orange, and red. Red and blue color shows a high concentration of NO₂, while orange color shows the low concentration. In December 2018, the blue color was more as compared to December 2019; this shows that the level of NO₂ concentration in December 2018 is higher than in December 2019. The reduction of NO₂ started in December 2019 in

Wuhan and then spread to the rest of the country (NASA, 2020). Nevertheless, in February 2019 and February 2020, no significant change is observed. Typically, there are lower levels of NO₂ during February in China around Chinese New Year. These important reduce in percentages can be depending on the closure of many businesses and factories for celebration. Moreover, there is a large difference seen in March. Indeed, in March 2020, there is a considerable reduction observed in NO₂ concentration compared to the obtained concentration in March 2019.

The time-series analysis shows the national average monthly mean NO₂ from December 2018 to March 2019 in china. The concentration of NO₂ was found higher in late January, which can be attributed to the meteorological conditions in winter and some other anthropogenic activities such as winter heating. In fact, as heating increases the amount of coal used that adds up in the concentration of NO₂. Further, the large reduction has been observed in February and March due to the environmental effects such as the seasonal variation, the atmospheric temperature and the humidity. Most of these factors were comparatively high that accelerate the oxidization of NO₂ in the air. (Wang et al., 2020).

From the time series data presented in Figure. 8, it is well noticed that the concentration of NO₂ has decreased gradually in late January following the enforced quarantine measures and widespread lockdown in the country. However, from the beginning of March, the NO₂ levels have risen up again as china has eased restriction measures and movement ramps up. NO₂ is classified among the hazardous air pollutant; its long-term exposure can cause many respiratory diseases including hypertension, heart and cardiovascular diseases and even death. This pollutant can be primarily generated through anthropogenic sources such as traffic and power plants including some natural phenomenon like lightening and soil processes. According to a recent study, the long-term exposure of NO₂ may be one of the most significant contributors to deaths caused by COVID-19 pandemic. (Ogen et al., 2020).

3.3 Black Carbon

Black Carbon is a chemical component, released from diesel engines and gas mainly. It is formed by the process of incomplete combustion of fossil fuel, biomass and biofuels. Black carbon is considered as a significant contributor to climate change. It is emitted by both natural factors and human activities. It warms the air by absorbing solar energy and hence counts in one of the significant climate change pollutants. Black Carbon tends to hasten the melting of ice; hence when it falls on snow, it warms the snow and also its sooty nature darkens the surface of ice and snow. When Black Carbon enters the body, it causes cancer, cardiovascular disease, and birth defects.

China, along with India, comprises 25-35% of global Black Carbon emission. The usage of biofuels and coal is very high to satisfy the humankind demand in China, which results in the emission of a considerable amount of Black Carbon, which has fell in China by around 25% over the four weeks in January 2020 during the lockdown.

4. Conclusion

This study provides an analysis of changes in Air Quality over China during the COVID-19 pandemic concerning the period from December 2018 to March 2020. Three parameters were evaluated namely; O₃, NO₂ and Black Carbon. Results showed an increase in the mean concentration of O₃ during the pandemic compared to the last year. The increase in the mean concentration of O₃ is most significant in March 2020, just after the removal of lockdown and other restrictions. O₃ levels during COVID-19 over china are studied by using a TOMS-like OMT03e product. Whereas the mean concentration of NO₂ has decreased during the lockdown period due to the restrictions imposed by the government and the impediment of economic activities during the lockdown period. After downsizing the restrictions in some regions, a progressive increase in pollutants level was obtained. Therefore, more time is required for passing through this problem.

China is the largest emitter of CO₂ and other greenhouse gases. As regards biogenic VOC, isoprene closely associates with ozone and other pollutants with NO₂ and Black Carbon. Up to date, there is no evidence of a direct relation between climate change and the emergence of transmission of Corona Virus. However, a deep understanding of the influence of main impacts of COVID-19 lockdown on other parameters is definitively required.

Declarations

Acknowledgements

Analyses and visualization used in this study were produced with online data systems, developed and maintained by NASA space GES-DISC.

Competing interests: The authors declare no competing interests.

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Figures

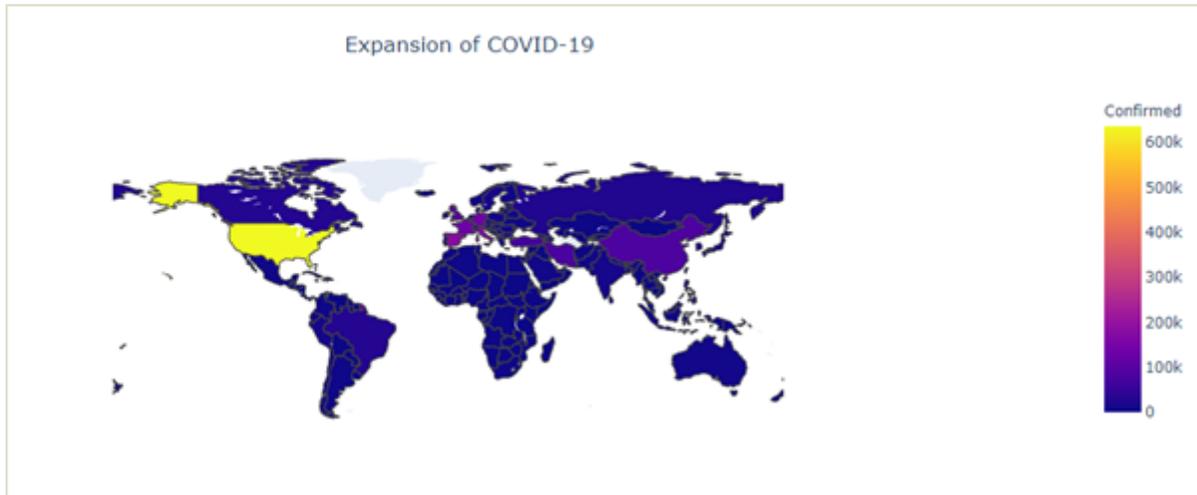


Figure 1

Pattern of COVID-19 confirmed cases as of 14th April 2020. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors

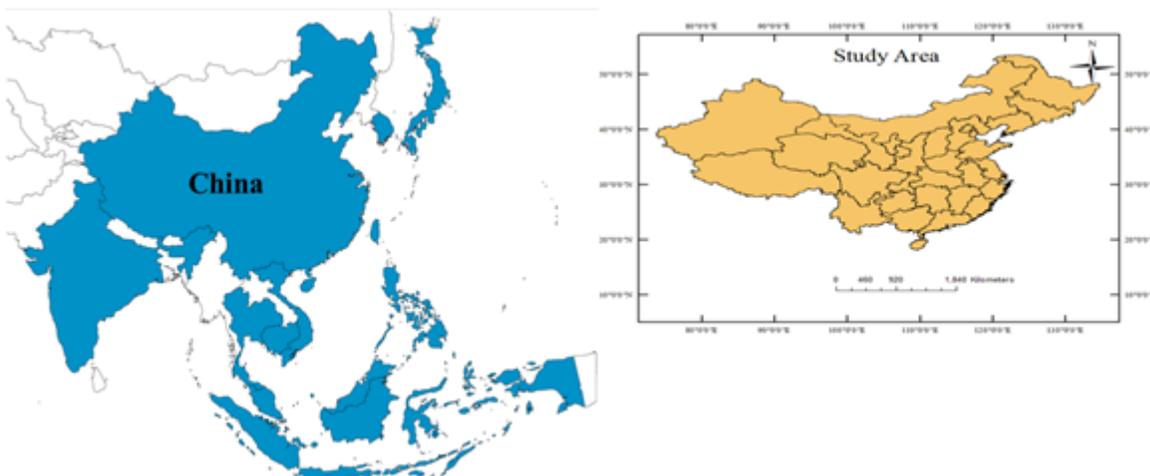


Figure 2

Study Area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors

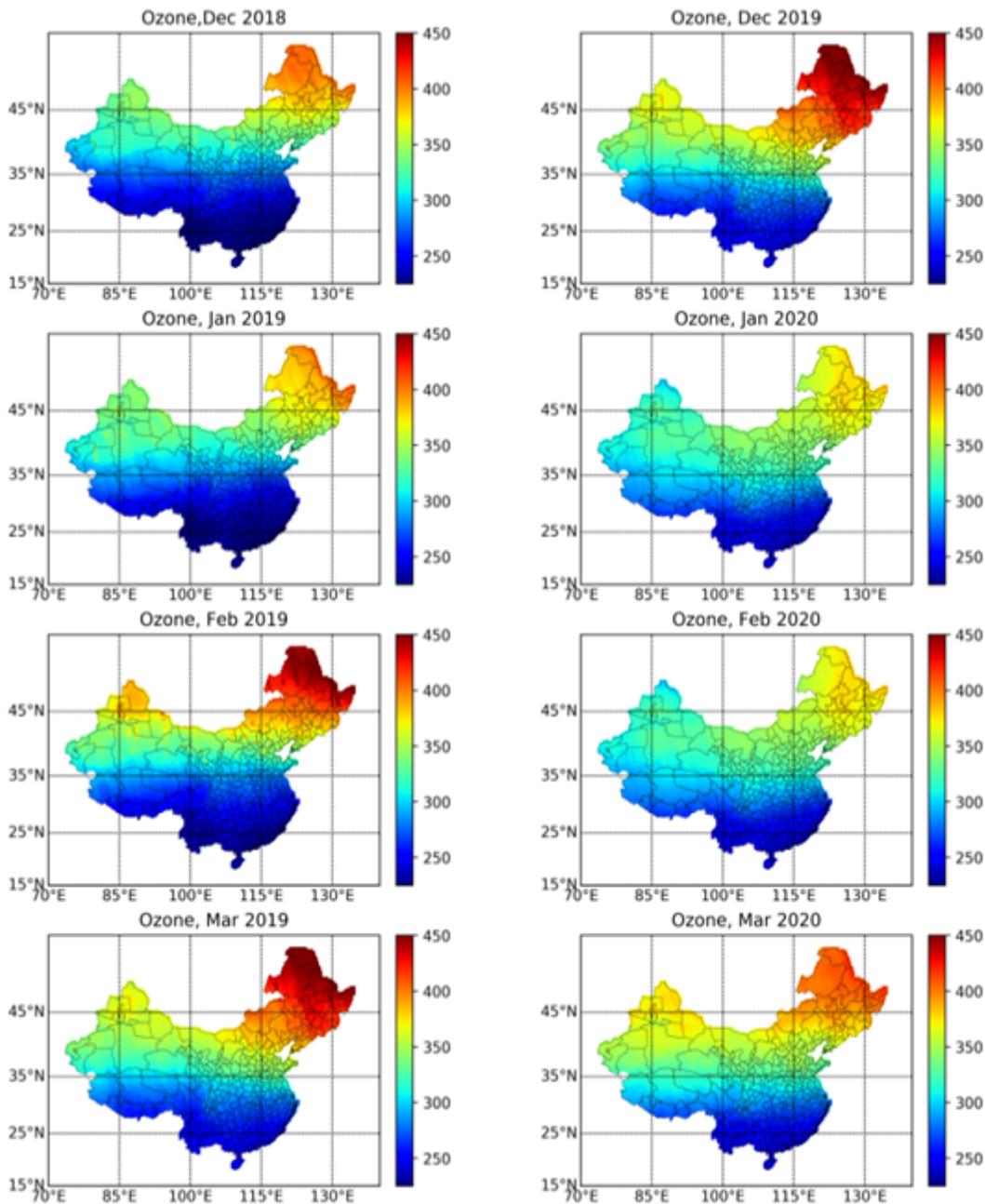


Figure 3

Image showing the status of O₃ before and amid COVID-19 restrictions. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors

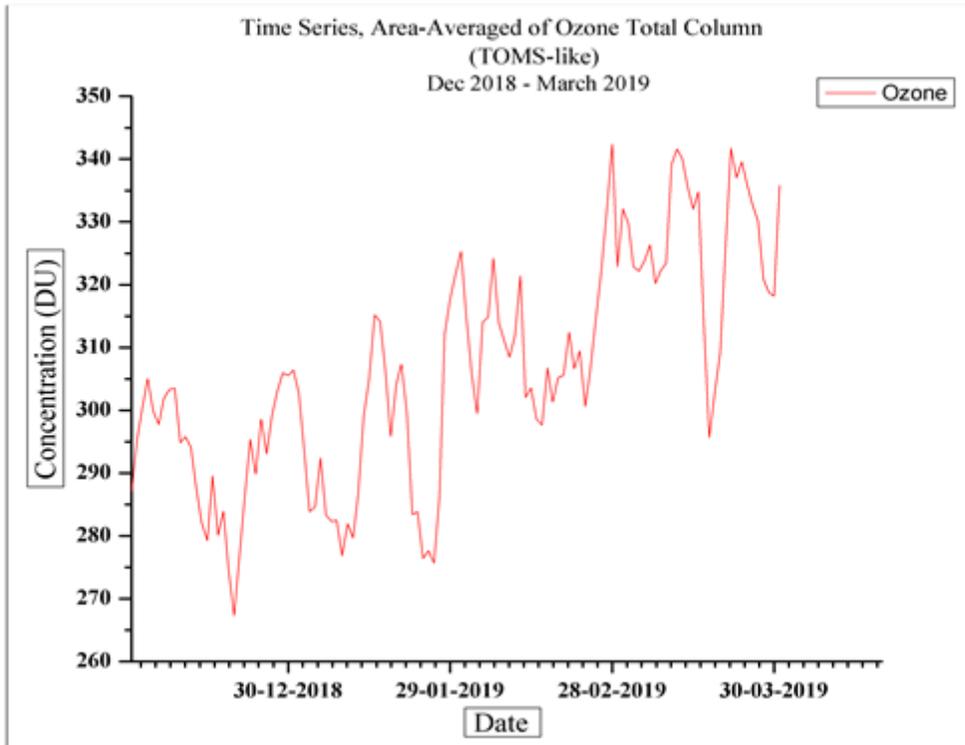


Figure 4

Time Series of Area Averaged Total Column Ozone during Dec 2018- March 2019.

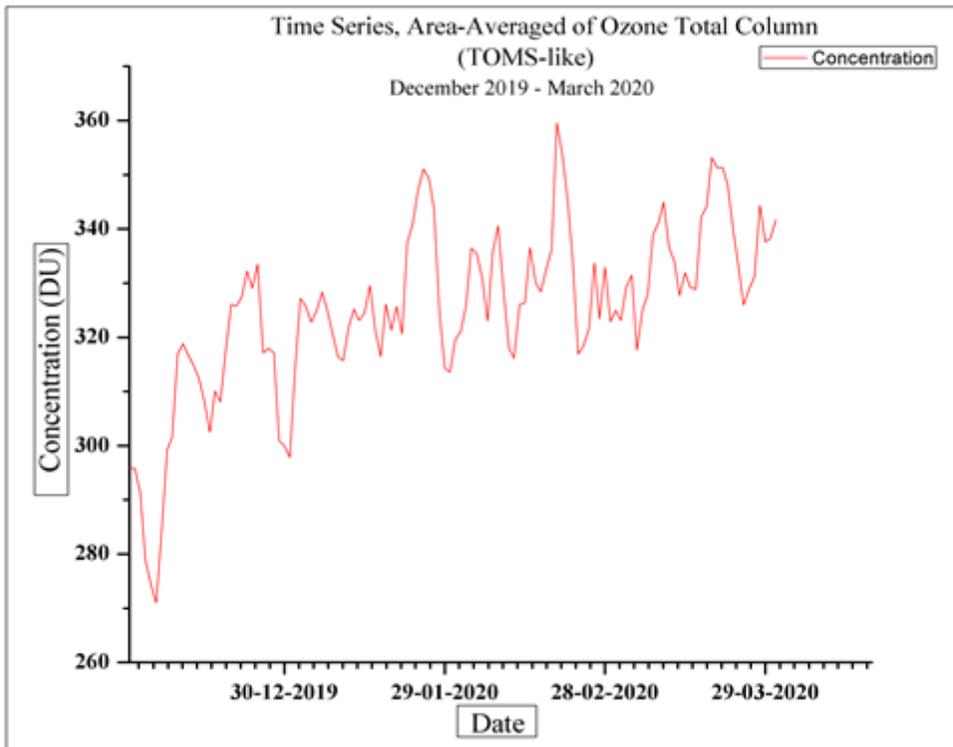


Figure 5

Time Series of Area Averaged Total Column Ozone during Dec2019- March 2020

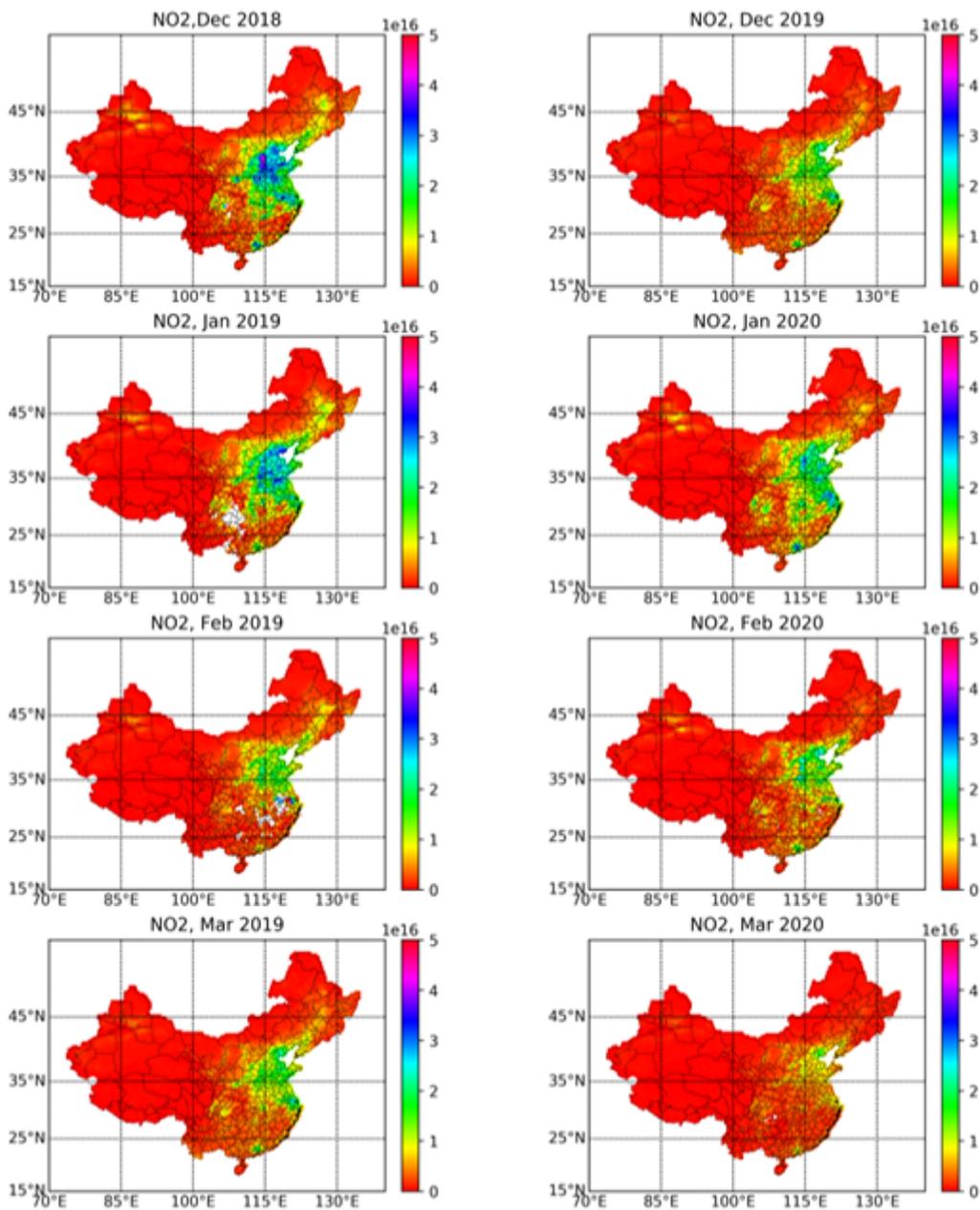


Figure 6

Image showing the status of NO₂ before and amid COVID-19 restrictions Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors

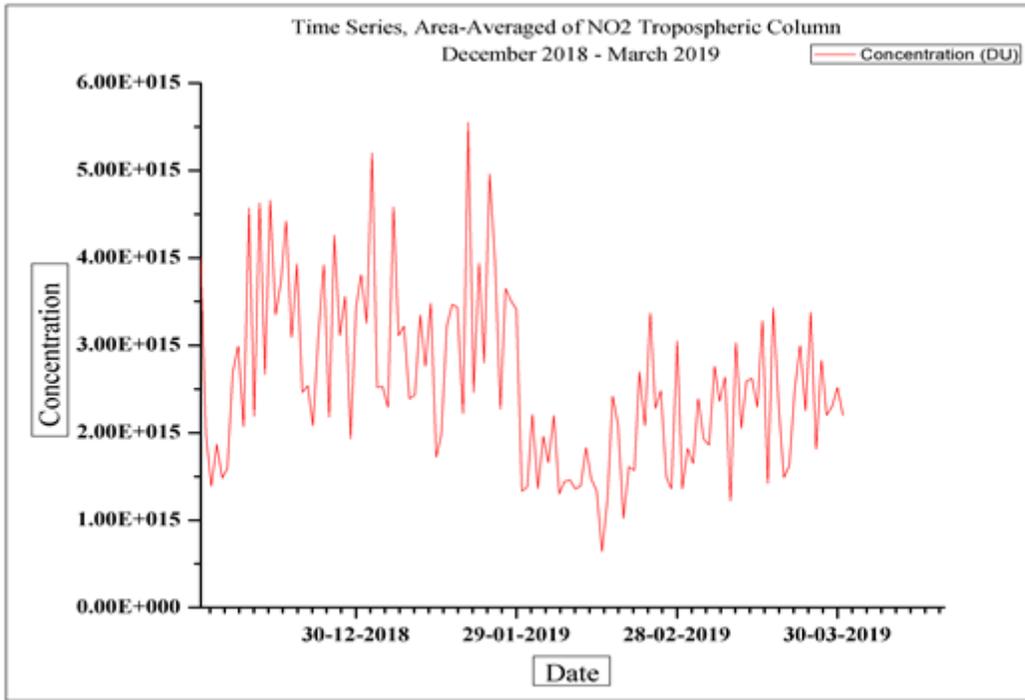


Figure 7

Time Series of Area Averaged NO₂ during Dec 2018- March 2019

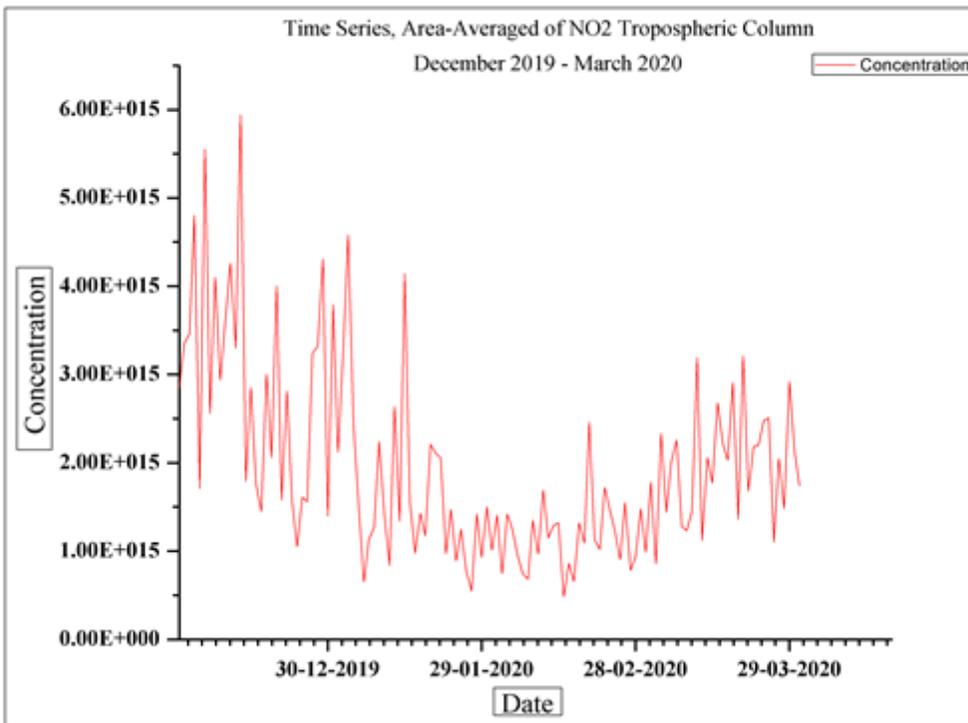


Figure 8

Time Series of Area Averaged NO₂ during Dec2019- March 2020

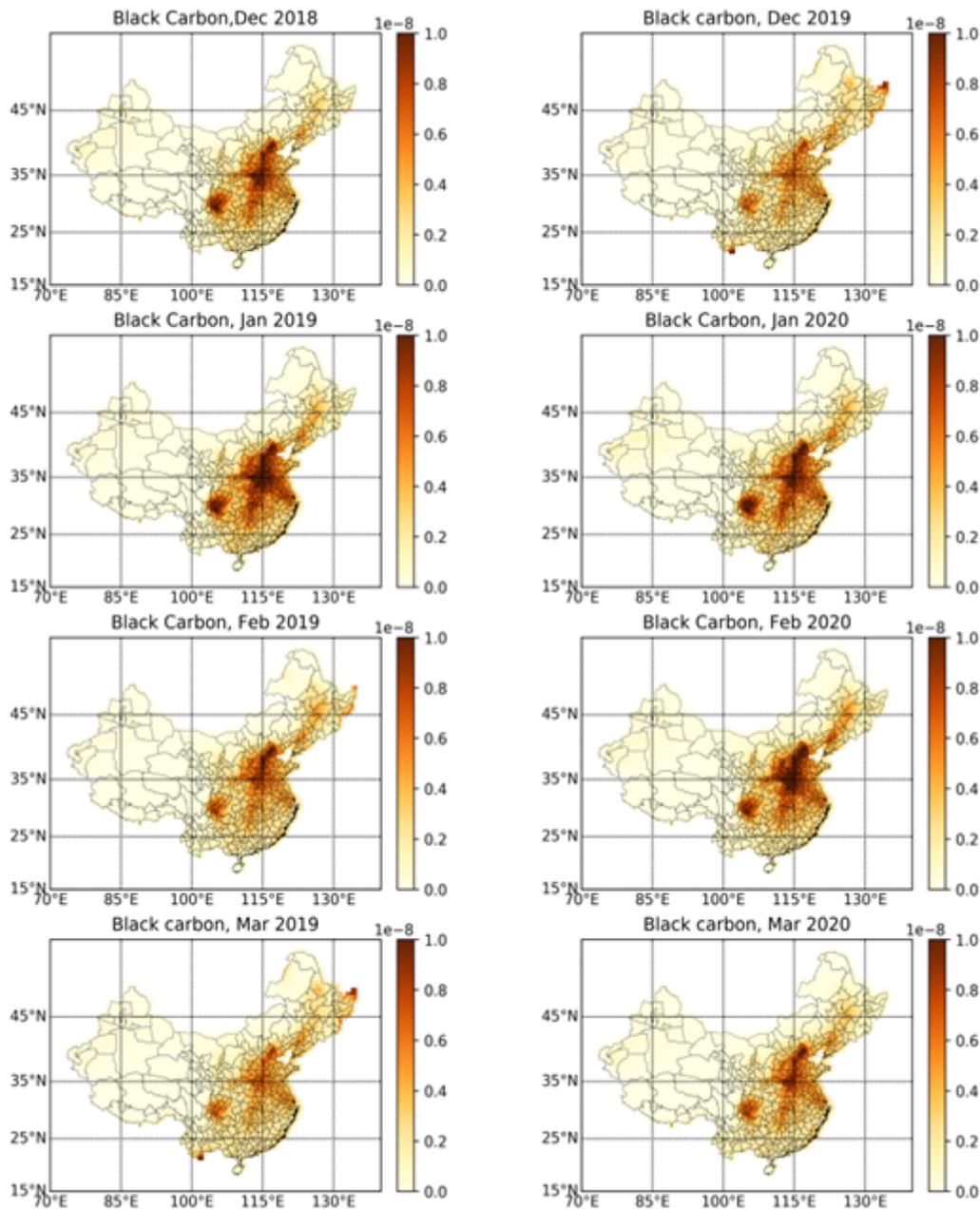


Figure 9

Image showing the status of Black Carbon before and amid COVID-19 restrictions. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors