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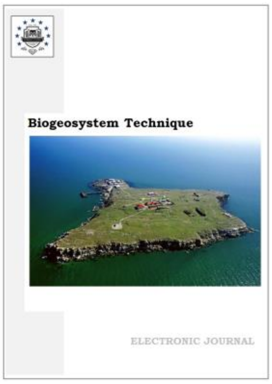

Comparative Case Study of Atmospheric Parameters over India and China during Covid 19 Lockdown

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Abstract

The novel coronavirus disease (Covid-19) was first reported in China on December 8, 2019, and in India on January 27, 2020, as per the World Health Organization (WHO). Government of India and China implemented rapid and stringent measures to contain the spread of COVID-19, which included lockdowns and restrictions on population's mobility. This study aims to investigate concentrations of NO_2 emission, stratospheric ozone status, and temperature before and during the lockdown in India and China. In India lockdown was implemented from March 22 to May 31 and in China from January 23 to April 8, 2020. NO_2 concentration, stratospheric ozone, and temperature of 2019 and 2020 were compared in both countries during the study period (January 1 – May 31). Our results showed a significant reduction in NO_2 concentration up to 4-16 % and 4-40 % over India and China respectively, during the lockdown period. We observed a similar percentage change in concentration of stratospheric ozone was 1-12 % in India as well as China. Similarly, the percentage reduction in temperature was 0-5 % and 1-94 % in India and China respectively. Further analysis of satellite data revealed that NO_2 emission decreased in April and May 2020 in India and from January to May 2020 in China. The study also showed a positive effect of lockdown on stratospheric ozone concentration, which increased during entire study period from January to May 2020 compared to 2019. While the COVID-19 lockdown had severe social and economic impacts, it positively impacted the natural environment.

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Keywords: Covid-19, NO_2, stratospheric ozone, temperature, Sentinel-5P satellite

1. Introduction

China notified WHO (World Health Organization) about several unusual pneumonia cases in Wuhan, a city in the central Hubei Province, in December (Gautam, Hens, 2020). It was identified as a new virus named SARS-CoV-2 and was announced by WHO (WHO, 2020a) on 7 January 2020. WHO declared a worldwide emergency for public health. China's government imposed a lockdown in Wuhan and other cities in Hubei to quarantine the center of COVID-19 outbreaks on 23 January 2020, commonly known as the Wuhan lockdown. The recent outbreak of corona virus disease has raised global concerns and led to total lockdowns in many countries. At the end of January 2020 and the beginning of February 2020, the situation in many countries such as Iran, Italy, etc., became terrifying and the number of deaths started increasing day by day. Starting in March 2020, the epidemic disease turned into a pandemic condition. By the end of March 2020, half of the world's population was undergoing different lockdowns (Muhammad et al., 2020). COVID-19 is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (WHO 2020a; Wang et al., 2020) and has an approximate fatality rate of 2-3 % (Rodriguez Morales et al., 2020). This virus can spread from infected people to non-infected people (Bherwani et al., 2020). The spread of the virus can be limited by wearing masks, maintaining social distancing, avoiding public gatherings and avoiding the use of public transport, etc, which have a high risk of virus contamination and spreading (WHO, 2020b; Bherwani et al., 2020; Gautam, 2020). To control the spread of COVID-19 various countries such as China and the Indian government announced a series of lockdowns from 23 January in China (BBC, 2020) and 24 March 2020 in India (Regen et al., 2020), which included closing schools, universities, restricting transportation and the movement of people between provinces. The economy of countries was affected negatively due to the COVID-19 lockdown, and also a severe decline in economic development due to restriction movement and transportation to control the spread of the virus. Due to a reduction in economic activities and vehicular transport, air pollution was also reduced (Wang and Su, 2020). That lead to considerable improvement in air quality in various countries such as Spain (Tobías et al., 2020), India (Gautam, 2020), Brazil (Nakada, Urban, 2020), and China (Sharma et al., 2020). The concentration of pollutants was also decreased obviously due to restrictions in anthropogenic activities. Air is a vital element for the survival of living beings, so it is necessary to keep it clean, pollutant-free, and safe to breathe. Due to various anthropogenic activities, air quality is decreasing leading to emission of harmful gases and air pollutants in higher concentration, which can damage the health of all living beings (Gautam, Hens, 2020a). The major air pollutants are particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), and carbon dioxide (CO_2) (Chen et al., 2007). NO_2 is one of the major air pollutants and also a precursor of ground-level tropospheric ozone, particulate matter, and acid rain (Bechle et al., 2013). It is emitted during the process of combustion of fossil fuels and transportation (Muhammad et al., 2020). In most of the regions with the increase in NO_2 concentration, O_3 declines as in urban-dominated regions, while the decline in NO_2 emission leads to an increase in O_3 as in rural areas (Dentener et al., 2020). The changes in NO_2 concentration in this lockdown period can provide an understanding into the achievability of air quality improvement when there were restrictions in emissions of harmful gases from anthropogenic activities and gives better regulatory plans to control air pollution. In this paper, we analyzed the variations in sentinel satellite data of ground-based NO_2 concentration, ozone and temperature from two countries i.e., China and India for the two past years (2019-2020) from January 1st to May 31st. Comparison of data in the last two years aids in understanding the potential effect of change in gaseous emissions during days with similar meteorology. The objective is to evaluate the relative variation in NO_2 emission and ozone concentration before and during the lockdown period to evaluate the impacts of COVID-19 lockdown conditions on the air quality of India and China.

2. Material and methods

2.1. Site description

India is the second most populated country in the world after China. The countries selected for the present study include India and China. India and China are parts of the Asia continent and are neighboring countries. India is situated north of the equator between 8°4′ north to 37°6′ north latitude and 68°7′ east to 97°25′ east longitude and occupies 3,286,927 km^2 areas. China occupies approx. 9,596,960 km^2 area located in the southeast region of the Asia continent.

2.2. Datasets

2.2.1. Sentinel-5P data

TROPOMI is a passive-sensing hyperspectral nadir-viewing imager onboard Sentinel-5 Precursor (S-5P) satellite, launched on October 13, 2017. The S-5P is a near-polar sun-synchronous orbit satellite flying at a height of 817 km, with an overpass local time at ascending node (LTAN) of 13:30 and a repeat cycle of 17 d (KNMI, 2017). The TROPOMI works in a non-filtering push broom setup, with an instantaneous field of view of 108◦ and an estimated time of around 1s. The outcome is an area with width approximately 2600 km, an along-track goal of 7 km, and day by day worldwide inclusion (KNMI, 2017). It has four separate spectrometers, measuring the ultraviolet (UV), UV–visible (UV-VIS), near-infrared (NIR), and short-wavelength infrared (SWIR) spectral bands, of which the NIR and SWIR bands are new compared to its predecessor OMI (Veefkind et al., 2012). The NO_2 sections are inferred utilizing TROPOMI's UV–VIS spectrometer backscattered sunlight-based radiation estimations in the 405–465 nm frequency range (van Geffen et al., 2015; van Geffen et al., 2019). The swath area is partitioned into 450 individual valuation pixels, which bring about a close nadir resolution of 7×3.5 km. The total NO_2 slant column density is retrieved from Level 1b UV–VIS radiance and solar irradiance spectra utilizing the DOAS strategy (Platt and Stutz, 2008). The NO_2 retrieval and assimilation scheme and the data product have been described in detail (Eskes et al., 2019; van Geffen et al., 2015; van Geffen et al., 2019; Veefkind et al., 2012). The TROPOMI NO_2 processing system is based on the algorithm developments for the DOMINO-2 product and for the EU QA4ECV NO_2 reprocessed dataset for OMI and has been adopted for TROPOMI. The Assimilation-modelling system uses the 3-dimensional global TM5-MP chemistry transport model at a resolution of a 1x1 degree as an essential element. In this research, near real-time NO_2 concentrations images were created using the google earth engine. These images were pre-processed, corrected, and stored in the google earth engine database.

2.2.2. CFSR

The Climate Forecast System, NCEP version 2 (CFSv2) is an upgraded version of CFS version 1 (CFSv1). It is a reanalysis product first developed as part of the Climate Forecast System by NCEP in 2004 with quasi-global coverage and is a fully coupled atmosphere-ocean–land model used by NCEP for seasonal prediction (Saha et al., 2014). CFSR has a 3D variational analysis scheme of the upper-air atmospheric state with 64 vertical levels and a horizontal resolution of 38 km spanning the period 1 January 1979 to the present day (Saha et al., 2014).

2.2.3. Analysis of data

Statistical analysis of data was performed using Microsoft Excel. Two-tailed Student' t-statistic was applied to the data of 2019 and 2020. The study revealed a significant difference ($p<0.05$) in NO_2 concentration between both the year's understudy with the confidence of 95 %. Descriptive statistical analysis of the data (for 2019 and 2020) was carried out for the calculation of mean and standard deviation.

3. Result and discussion

3.1. NO_2 level in India

The data presented in figure 1 depicts the NO_2 concentration (mol/km^2) in India, before (1 January to 21 March 2020) and during the lockdown (22 March to 31 May 2020). The average concentration of NO_2 in India varied between 61-77 and 62-68 mol/km^2 during the study period 2019 and 2020 respectively. A major significant reduction was found in the NO_2 concentration level ($P < 0.005$). The highest reduction was found on April 1 to 10 April 2020 with respect to 2019 in the same period was 16% (Figure 2). However, the average reduction varied between 1-16 % during the entire study period. The marked reduction was observed in NO_2 level in India during the lockdown period (22 March to 31 May 2020) i.e., 4-16 % (Figure 2). Similarly, the corresponding decrease before the period of lockdown (1 January to 21 March) was 1-13 %. This reduction in NO2 concentration during the lockdown period was attributed to the decreased vehicular movement (Figures 1, 2).

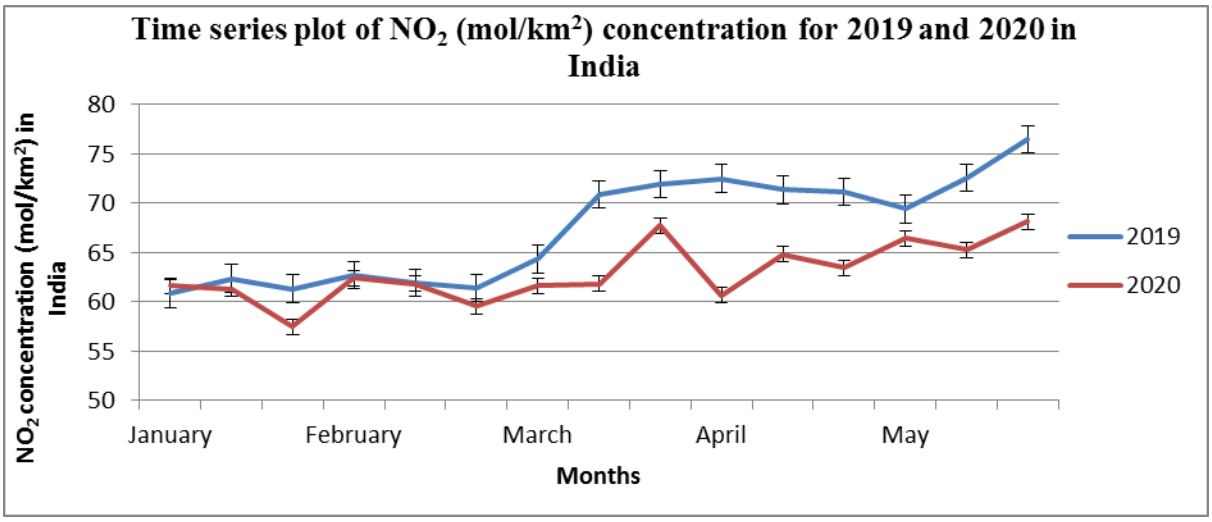

Fig. 1. NO_2 concentration (mol/km^2) for the year 2019 and 2020 in India

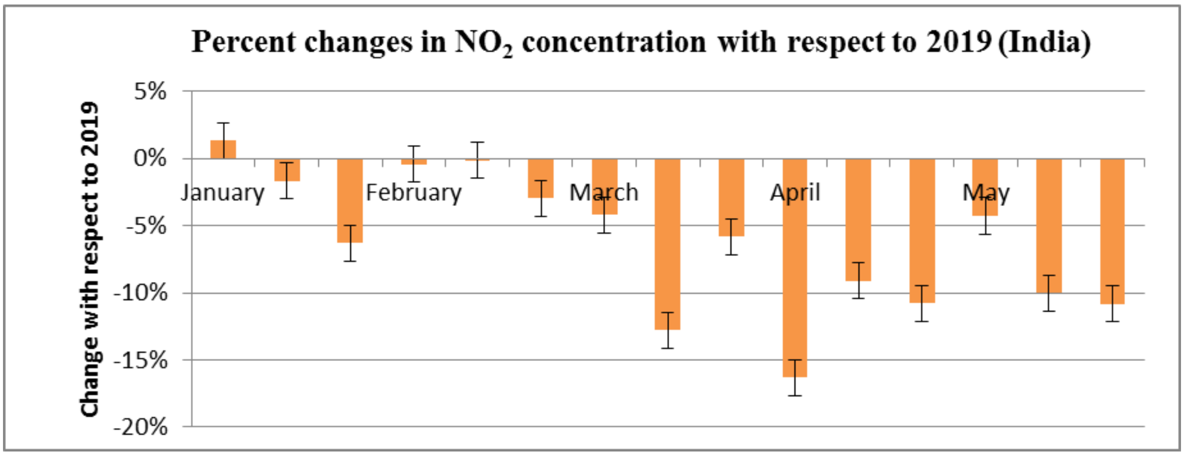

Fig. 2. Total percentage change in NO_2 level of the year 2020 (Jan-May) with respect to 2019

3.2. Ozone (stratospheric) in India

In India, there was a significant increase in Ozone level (mol/m^2), which was considerably higher in 2020 compared to 2019 in India. The average ozone concentration during the study period varied between 0.107-124 and 116-130 in the study period of 2019 and 2020 respectively (Figure 3). A significant increase was found in Ozone level ($P < 0.005$) in 2020 as compared to 2019 across India. The average increase in Ozone concentration varied between 1-12 % (Figure 4) with respect to 2019 in the study period. The marked highest increase was observed from April 1 to April 10, 2020 (12 %). The percent increment in the lockdown period was 1 to 12 % with respect to 2019 in the same period (Figure 4). The increase in ozone levels in India was associated with a decrease in NO2 levels, as they have an inverse relationship.

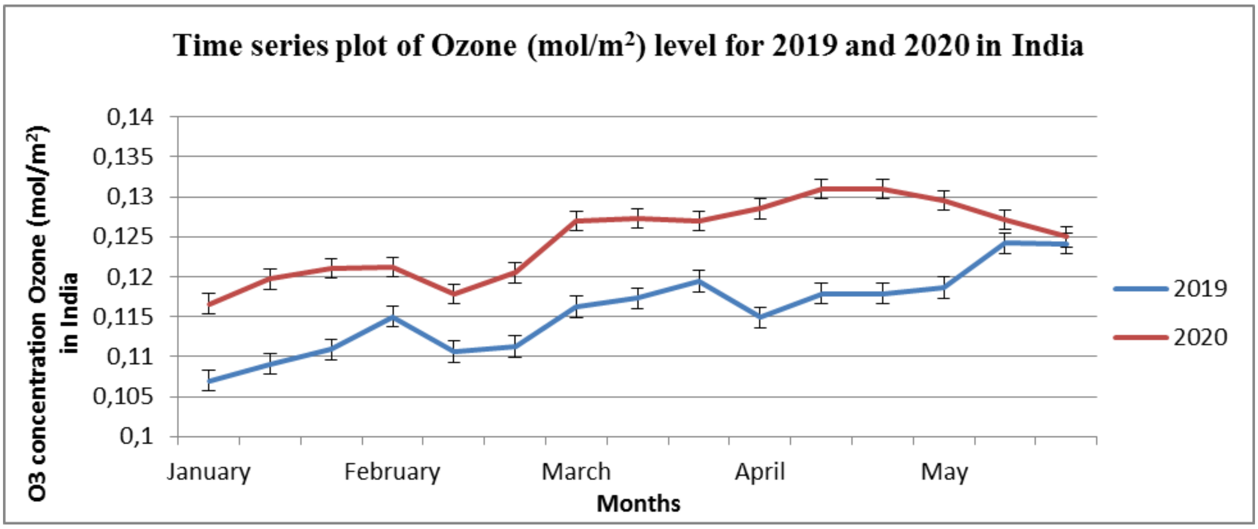

Fig 3. Time series plot of Ozone (mol/m²) level for 2019 and 2020 in India

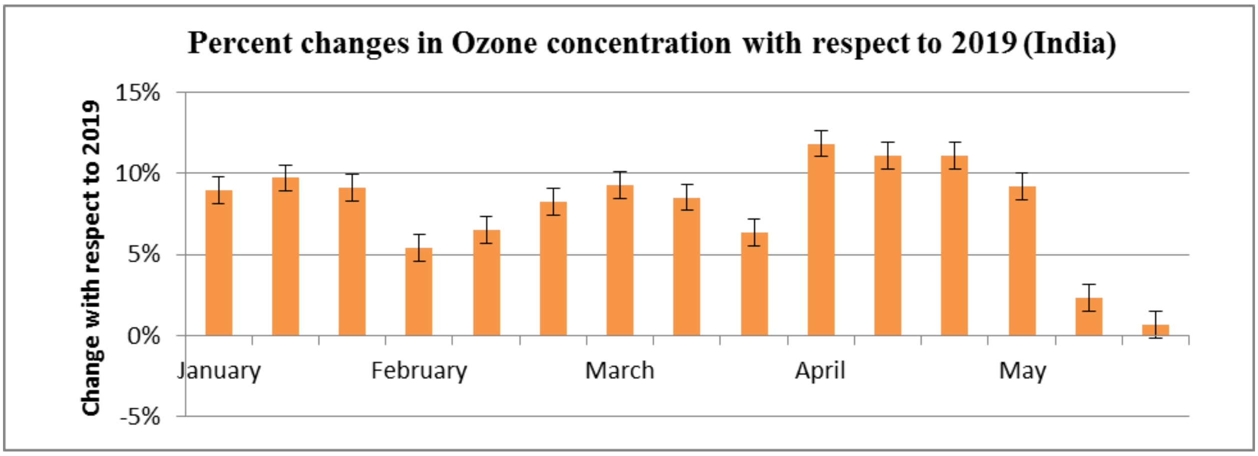

Fig 4. Total percentage change in Ozone level of the year 2020 (Jan- May) with respect to 2019

3.3. Temperature in India

The temperature was less affected due to the lockdown. The temperature varied between 14-31°C and 14-30°C during the study period 2019 and 2020 respectively (Figure 5). Reduction in temperature was observed to be 0-5 % with respect to 2019. The highest reduction (5 %) was observed in the month of March 21 to April 10, 2020, during the period of lockdown (Figure 6).

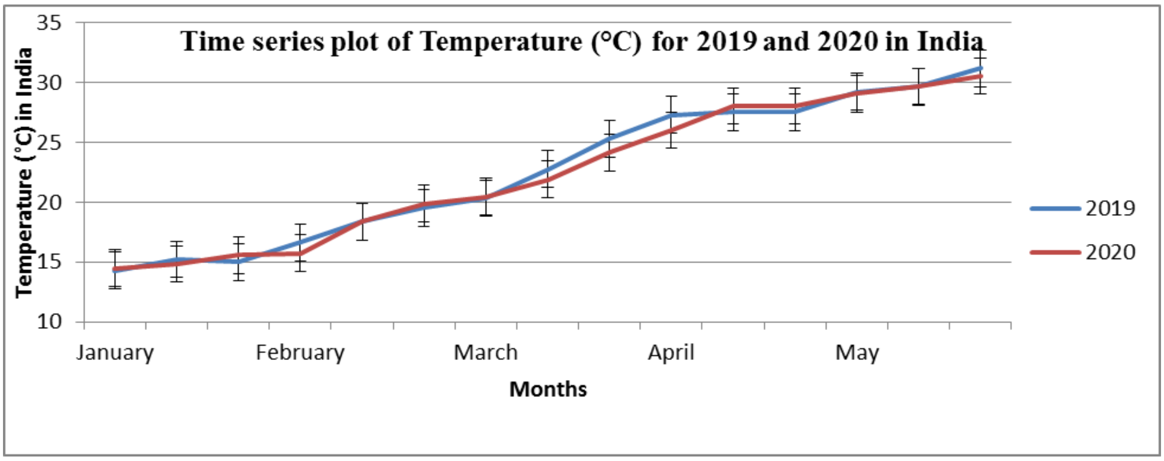

Fig 5. Time series plot of Temperature (°C) for 2019 and 2020 in India

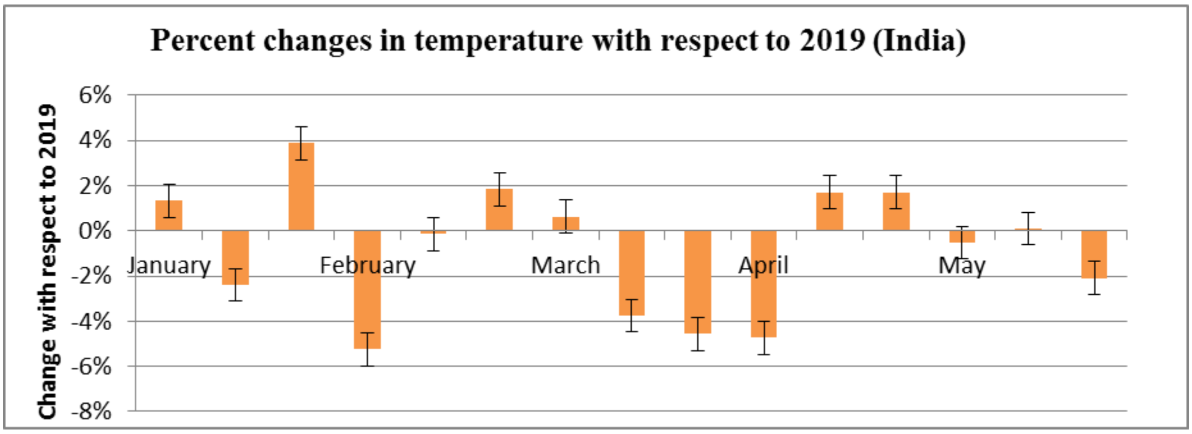

Fig 6. Total percentage change in Temperature (°C) of the year 2020 (Jan-May) with respect to 2019

3.4. NO_2 level in China

NO_2 concentration (mol/km²) in China, during (22 January to 8 April, 2020) and after (9 April to May 31, 2020) the partial lockdown represented in figure 7, illustrating that NO_2 concentration varied between 84-135 and 61-92 mol/km² during the entire study period of 2019 and 2020 respectively. A significant reduction was observed in NO_2 concentration ($P < 0.005$). Average reduction in the entire study period was 4-40 % with respect to 2019. The highest significant (40 %) reduction was found in the period of 21 January to 31 January, 2020 (Figure 8). Due to low industrial and vehicular activities, a significant reduction in NO_2 level was found in the partial lockdown period.

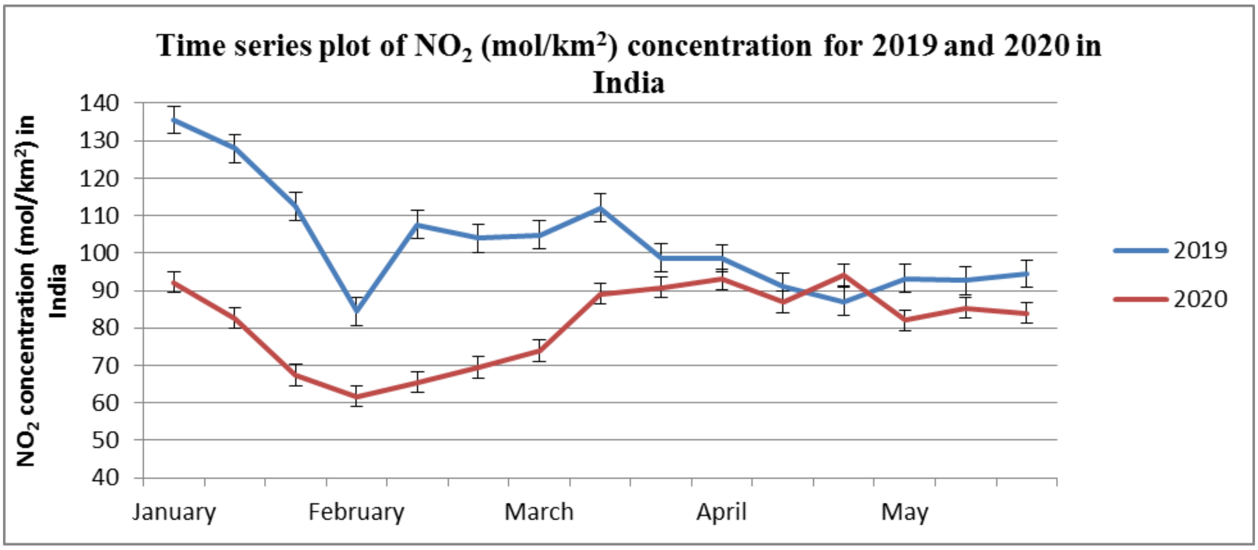

Fig 7. NO_2 concentration (mol/km²) for the year 2019 and 2020 in China

3.5. Ozone (stratospheric) level in China

In China, there was a significant increase in ozone level (mol/m2) in 2020 when compared to 2019. The study period was from 1st January to 31st May, and the ozone concentration ranged from 0.141-0.165 in 2019 and 0.143-0.162 in 2020 (Figure 9). During the study period, there was a 1-12 % percentage change in the ozone concentration. The highest percentage change (increase) in ozone concentration compared to 2019 was 11 % observed from 1st May to 10th May 2020 (Figure 10).

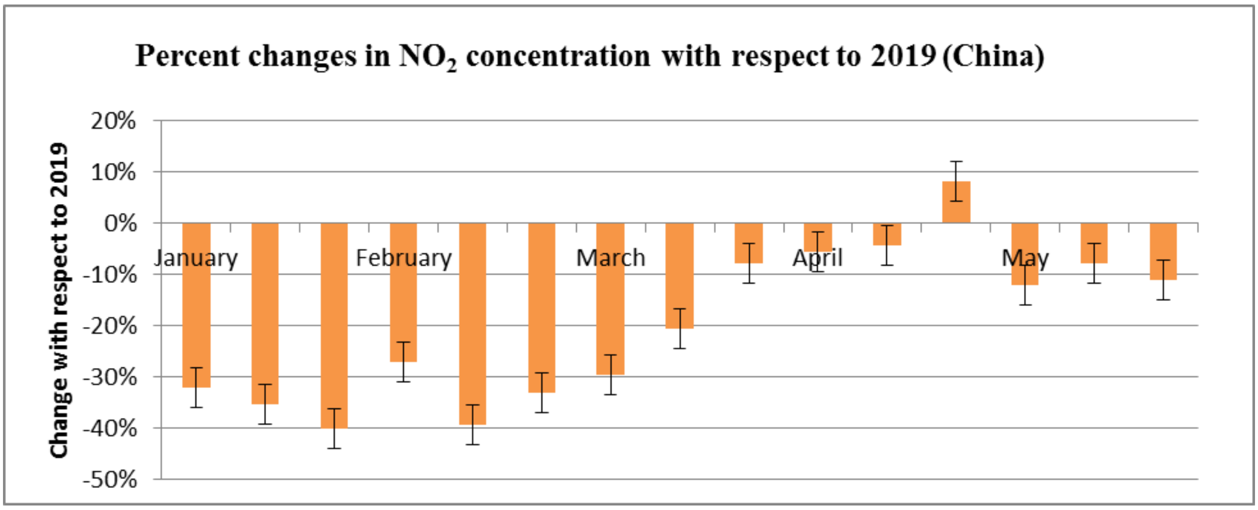

Fig 8. Total percentage change in NO_2 level of the year 2020 (Jan-May) with respect to 2019

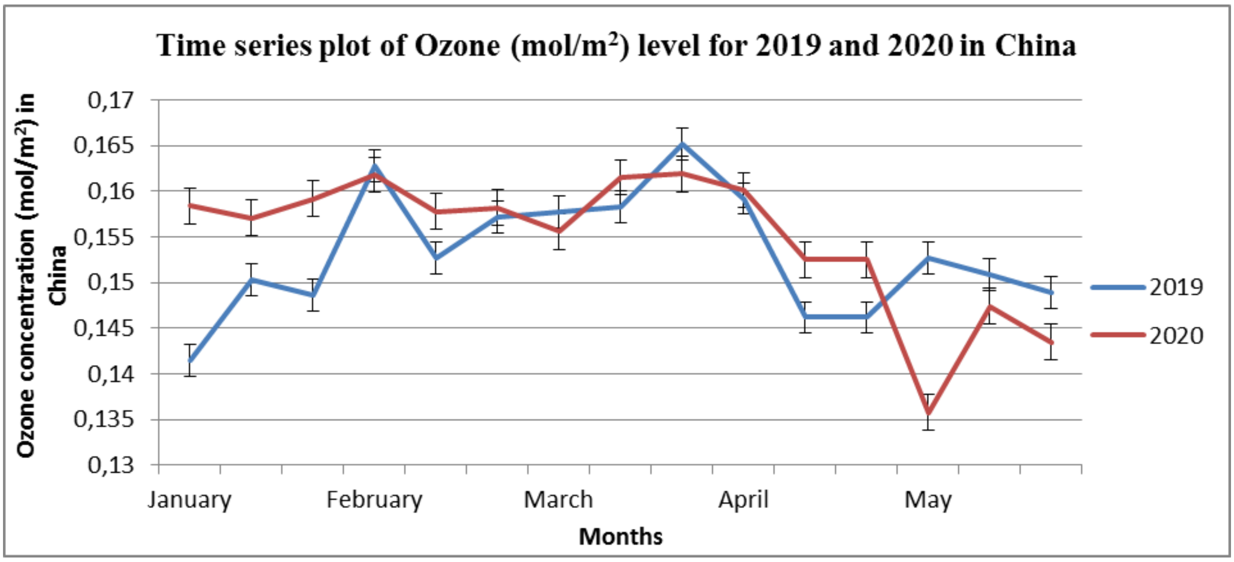

Fig 9. Time series plot of Ozone (mol/m²) level for 2019 and 2020 in India

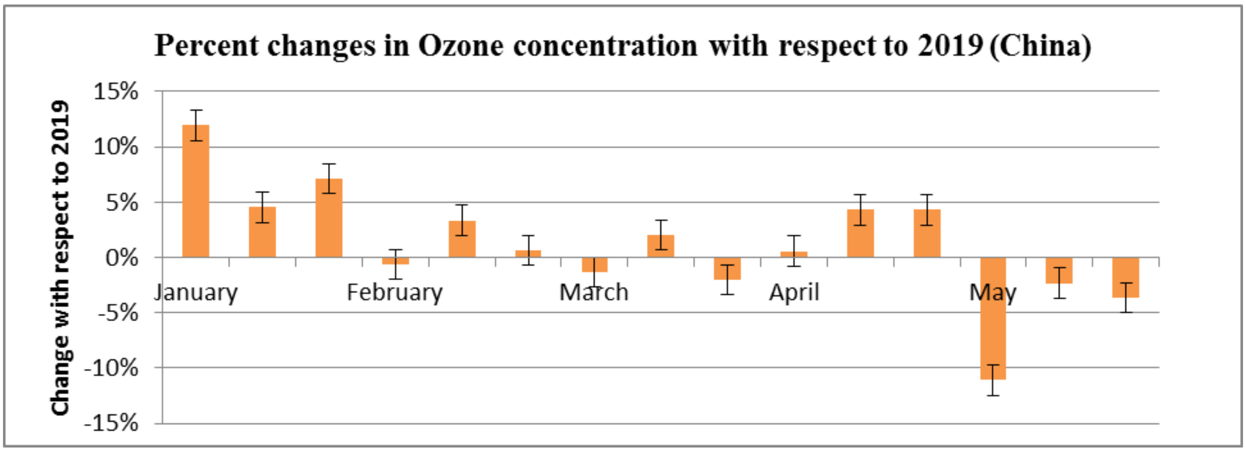

Fig 10. Total percentage change in Ozone level of the year 2020 (Jan- May) with respect to 2019

3.6. Temperature in China

The temperature range between -9°C to 15°C was observed in both 2019 and 2020, as demonstrated in Figure 11. Reduction in temperature varied between 1-94 % in entire study period (1 January – 31 May). The highest significant reduction from 11 March to 21 March, 2020 was 94 % (Figure 12) during which only essential services were allowed due to partial lockdown. This corresponded to a partial lockdown period that allowed only essential services to operate.

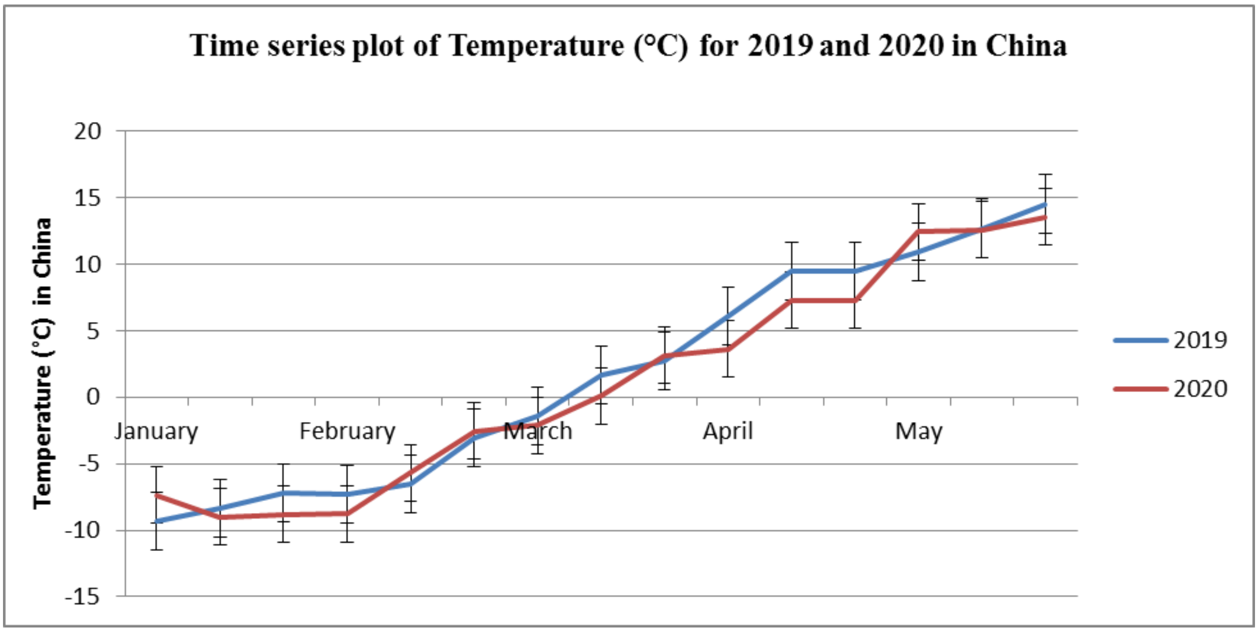

Fig 11. Time series plot of Temperature (°C) for 2019 and 2020 in India

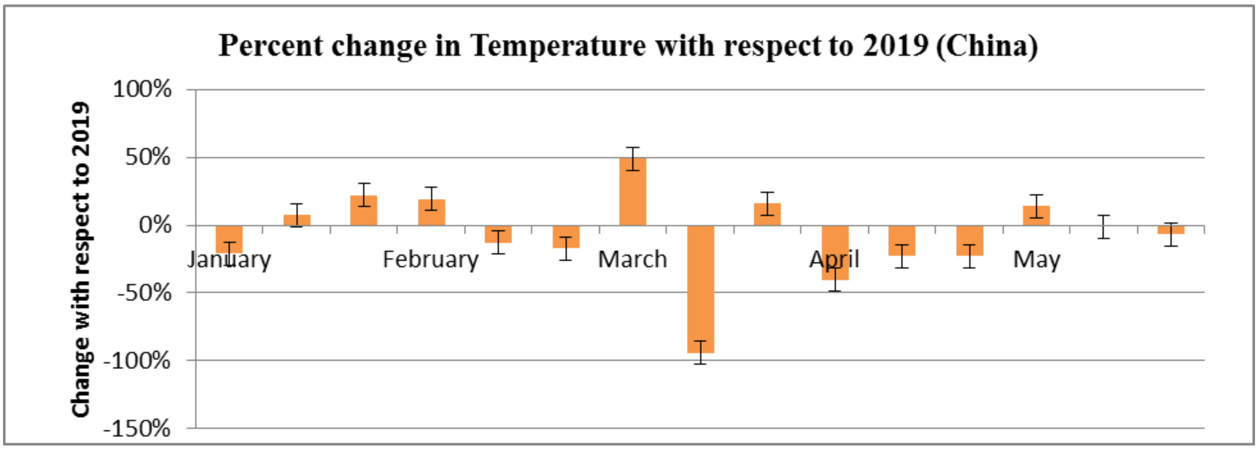

Fig 12. Total percentage change in Temperature (°C) of the year 2020 (Jan-May) with respect to 2019

3.7. NO_2 Tropospheric column from sentinel data

Figure 13 depicts sentinel images of NO_2 emission in India and China before, during, and after lockdown from 1 January to 31 May of both the year (2019 and 2020). According to this data, NO_2 emission has been reduced in April and May, 2020 as compared to 2019 in India. Similarly, in China NO_2 emission was reduced from January to May 2020 as compared to 2019.

That justifies that NO_2 emission was significantly reduced in the lockdown period in India and China during and after the lockdown period. The effect of lockdown is apparent on NO_2 emission on both the countries due to restrictions on industries and transport that led to less NO_2 emission.

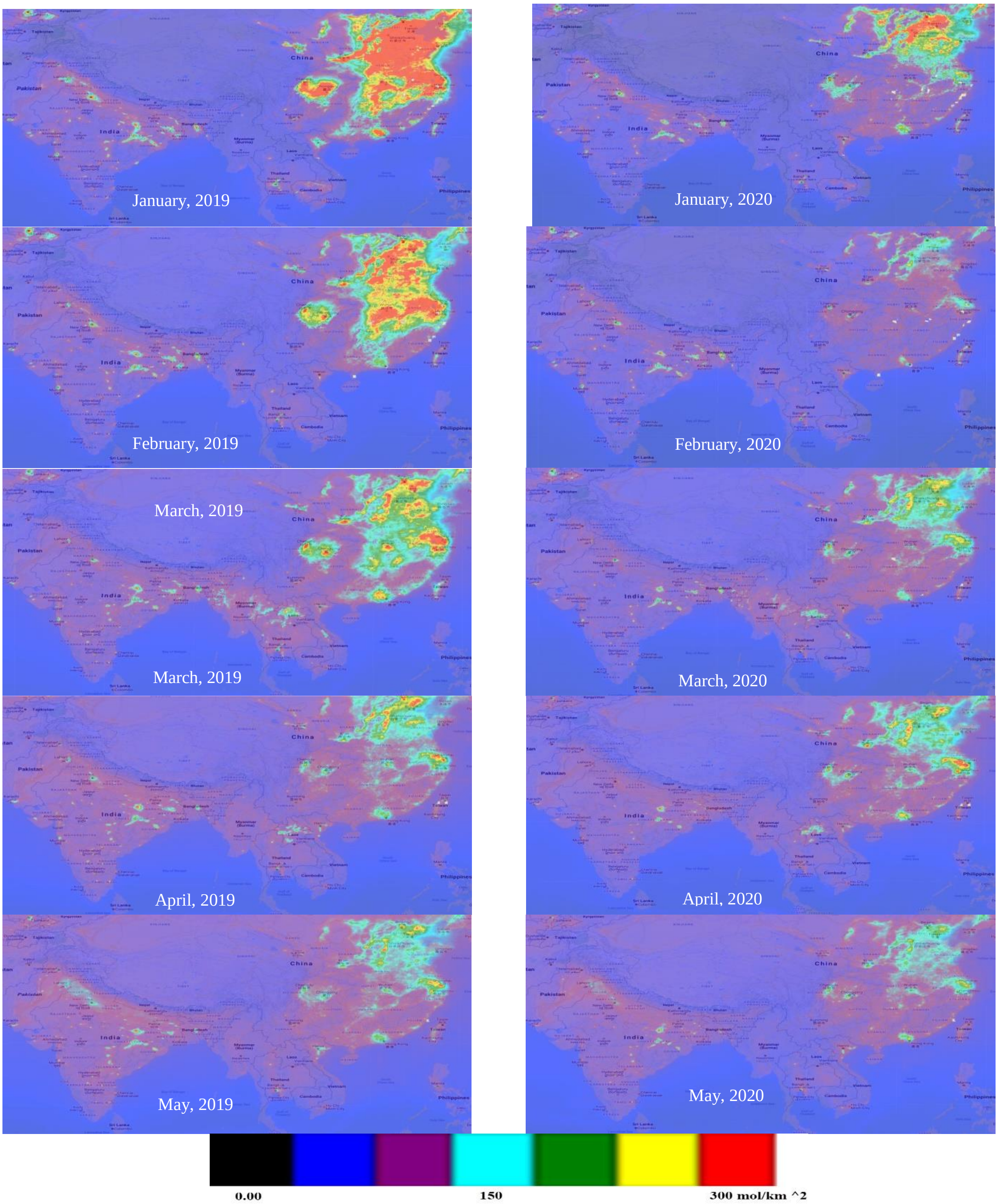

Fig. 13. NO_2 emissions in India and China before, during, and after the COVID-19 lockdown, based on data derived from Sentinel data

3.8. Stratospheric ozone column from sentinel data

Sentinel images of stratospheric ozone emission in India and China before, during, and after lockdown from 1 January to 31 May of both the year (2019 and 2020). According to the data of sentinel images, stratospheric ozone concentration in 2020 was higher than 2019 in both the countries from January to May (Figure 14). The effect of lockdown is apparent on Ozone concentration on both the countries due to restrictions on industries and transport that led to increase in stratospheric ozone concentration.

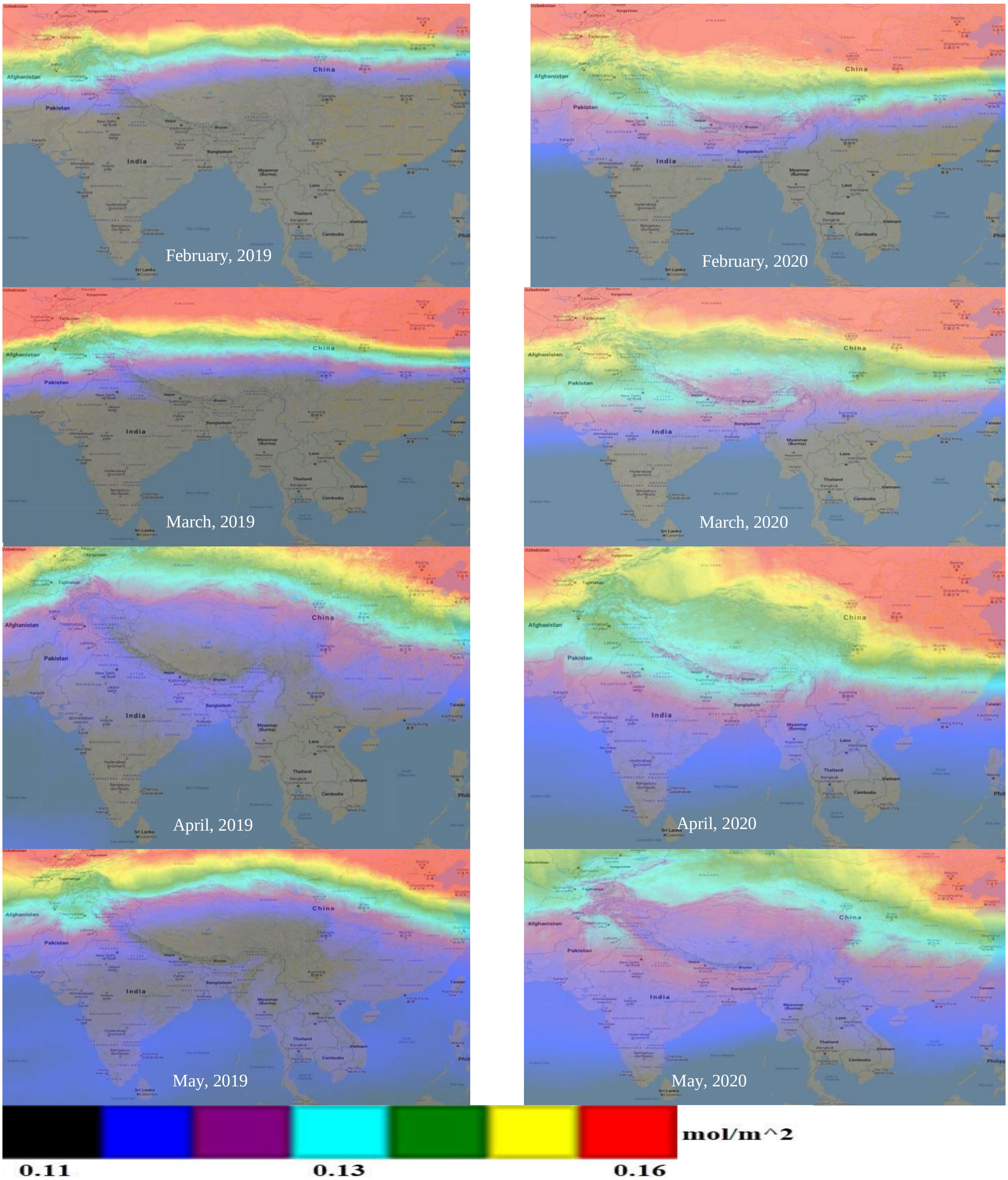

Fig 14. Stratospheric ozone concentration in India and China before, during, and after the COVID-19 lockdown, based on data derived from Sentinel data.

4. Conclusion

The findings of this study suggest that the COVID-19 lockdown had a significant impact on anthropogenic activities such as transportation and industrial activities, resulting in reduced NO2 emissions and an increase in stratospheric ozone concentration, as well as a decrease in global temperature rise. Comparing NO_2 emissions from 2020 to 2019, India and China saw significant reductions, with India's total reduction being 94 % from January to May, and China's total reduction being 298 % in the same period. Stratospheric ozone concentration increased significantly in both India and China, by 118 % and 18 %, respectively, and this also affected the temperature in both countries. The total temperature reduction in the same period was 12 % and

112% in India and China, respectively. The COVID-19 lockdown significantly impacted NO_2 emissions, ozone concentration, and temperature due to restrictions on transportation and decreased fuel combustion. While economic and social concerns were associated with the lockdown, the improvement in air quality can be seen as a positive consequence of COVID-19.

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