The Year Earth Changed

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Abstract

With the COVID-19 raging around the world, many countries and regions have promulgated lockdown policies. In the process, we found that the environment changed. In this project, we mainly analyzed the effect of lockdown policy on air quality (AQI) in India and California and carbon dioxide emission in China, the U.S and India. We found that policies contributed to a significant reduction in the AQI, both in heavily polluted areas and in lightly polluted areas. We also found a decrease in daily CO2 emission during COVID-19 period and reductions of yearly CO2 emissions in the U.S and India. The increase of yearly CO2 emission in China was slower in 2020 than the previous years. The result implies that the lockdown policy contributed to an improvement of air quality and a decrease of CO2 emission. Our analysis emphasizes the importance of continued enforcement of air quality and greenhouse gas emission to protect the public health and the planet earth.

Introduction

In December 2019, a contagious coronavirus swept around the world. The World Health Organization (WHO) declared COVID-19 as a global pandemic. It is the first time in history that people all over the world were required to stay at home. The unprecedented global pause has substantially affected the natural world and human society. Released ahead of Earth day 2021, the documentary The Year Earth Changed [1] surveys the consequence of the lockdown on the planet, revealing that the pandemic significantly improved worldwide air quality and reduced global greenhouse gas emission. In this study, we investigated whether the claim is actually backed by data. We analyzed air quality in cities of India and the U.S and carbon dioxide emissions data in three countries producing the most CO2. We found a remarkable response of our nature when people worked from home and travel was limited. We provided visualizations and analysis to help researchers to gather insights about air pollution and climate progress. Measurements of this moment play an important role to remind us of what we need to do after the pandemic.

Zander et al. [2] analyzed meteorological variations and found that COVID- 19 caused a great reduction on nitrogen dioxide emission level. Jesse et al. [3] investigated the air quality data in

urban counties and counties instituting early non-essential business closures in the United States and showed a decrease of air pollution during the COVID-19 period. Pandey [4] showed a reduction of air pollution in India during COVID-19 period. We studied their methodologies and applied them in our analysis. Compared to their studies, our analysis is geographically broad, including three countries across the world. We also conducted historical analysis of yearly CO2 emission from 2014 to 2020, providing insights on the impact of CO2 on climate change.

Methodology

Analysis of Air Quality in India and California

We obtained daily air data for each city in India from 2015 to 2022 [4], including PM2.5, PM10, NO, NO2, NOx, NH3, CO, SO2, O3, Benzene, Toluene, Xylene, AQI and AQI_Bucket. Based on these data, we analyzed the air quality of each city in India before and after the regional lockdown period, 2020.03.25 - 2020.05.31 [5], and studied how the regional lockdown policy impacted the air quality in India. In data preparation, we found a lot of incomplete and malformated data in the dataset. Based on the missing value of each air pollution indicator, we counted the proportion of missing values of total rows and visualized it in a heat map. As shown in Fig. 1, 61% of Xylene data is missing and all the other indicators have a tolerable amount of missing data, so we chose to combine the Benzene, Toluene, and Xylene levels, which are all benzene pollution, into one column named BTX. Among all the Indian cities in the dataset, we focused on a few cities with poorer air quality than the others, including Ahmedabad, Bengaluru, Chennai, Delhi, Hyderabad and Mumbai.

To exclude factors that might affect the air quality of India, we listed all the data of each type of pollution (PM2.5, PM10, NO, NO2, NOx, NH3, CO, SO2, O3, Benzene, Toluene, Xylene, AQI and AQI_Bucket) in Fig. 2 to see if the data distribution is stable. In Fig. 2, we observed seasonal effects on PM 2.5 and PM 10. The pollution level is higher in winter than summer. This pattern has continued to this day, so we can assume that it may not change during the lockdown period. Additionally, SO2 emission started increasing in 2017. Notice that SO2 level rose in 2015 and came back to a normal level after a few months, we applied the assumption that the rise in 2017 would not affect the result of our experiment. We also applied the same assumption to BTX level as it has the same pattern. Because the lockdown policy occurs in the spring when the PM2.5 and PM10 do not change much, we can pay all attention to comparing the level of AQI before and after the lockdown period. Once we had the preliminary preparations, we used the time of lockdown as the standard to study the changes in air quality. With plotting the AQI value during the 2020, we can compare the AQL level before and after the lockdown policy. By analyzing the difference of those data, we can get the effect of policy on air quality.

To study the overall impact of lockdown policy on air quality, we acquired the air quality data in California of the U.S. The average AQI of California is about 95% better than India, so our study can reflect that the COVID-19 lockdown not only affected the air quality in areas with relatively polluted air, but also in areas with good air quality.

	Missing Values	% of Total Values
Xylene	18109	61.300000
PM10	11140	37.700000
NH3	10328	35.000000
Toluene	8041	27.200000
Benzene	5623	19.000000
AQI	4681	15.900000
AQI_Bucket	4681	15.900000
PM2.5	4598	15.600000
NOx	4185	14.200000
O3	4022	13.600000
SO2	3854	13.100000
NO2	3585	12.100000
NO	3582	12.100000
CO	2059	7.000000

Fig. 1. Analysis of Missing Values in Daily Air Quality Index of India

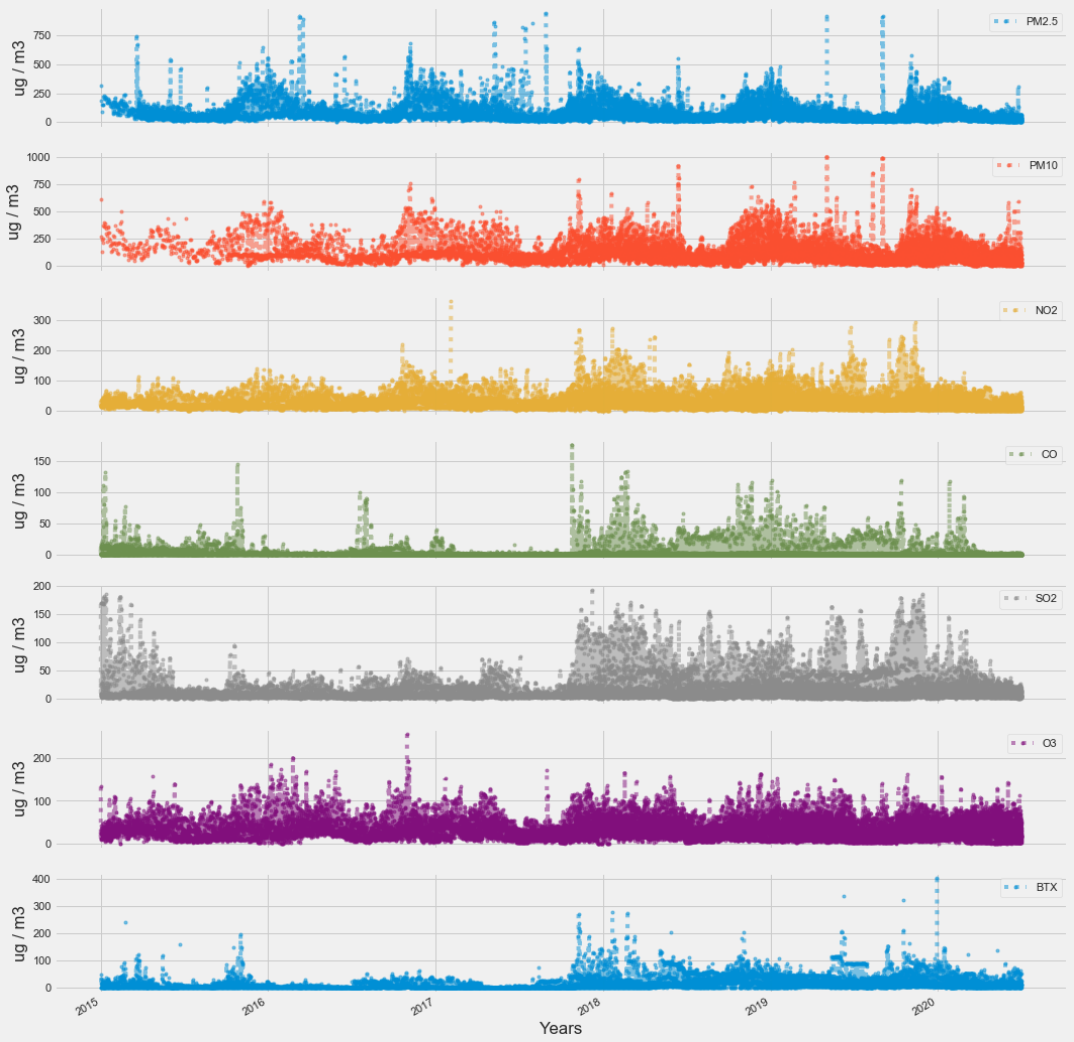

Fig. 2. Indian Air Pollution Distribution

Analysis of Carbon Dioxide Emission in China, the U.S and India

We chose China, the U.S and India to be the research countries in our study, as they are the countries producing the most CO2 across the world [6]. They are also geographically far, so we chose these three countries as representatives in our study. We obtained daily CO2 emission data in the three countries from Jan 1 2019 to Dec 30 2020 through Carbon Monitor [7], a website that updates daily global CO2 emissions regularly. The dataset is 5.6 MB, including the date, sector and emission value for each country. The data is measured from a diverse range of activities, including electrical power generation, industrial production, ground transportation, residential activity, domestic aviation, and international aviation. As people are required to stay at home and travel is limited, we focused on CO2 emission from ground transportation and aviation activities. These emissions contributed to 9% of CO2 emission in China, 36% emissions in the U.S, and 11% emissions in India. To analyze the CO2 emission change in a short period, we investigated the lockdown period of each country. Indian COVID-19 lockdown period is Mar

25 2020 - May 31 2020 [5]. However, China and the U.S did not mandate a national-wise lockdown policy, so we chose to use the lockdown periods in representative areas in these two countries. For the U.S, We chose New York State as the representative area, so the lockdown period is Mar 19 2020 - June 18 2020 [8] [9]. For China, we chose Wuhan to be the representative area, so the lockdown period is Jan 23 2020 - Mar 25 2020 [10]. Then, we calculated statistics for the emissions before and during the lockdown period in 2019 and 2020 and reported both absolute differences and percentage change.

We also downloaded historical yearly CO2 emission data from 1990 to 2018 through Climate Watch [11], a website that provides open climate data to show climate progress of countries. In this dataset, we focused on the emission values from 2014 to 2018 for comparison. Combining the historical yearly emission and the daily emission from 2019 to 2020, we analyzed the trend of yearly CO2 emission in China, U.S, and India within six years and plotted a line chart for each country.

Results

Analysis of Air Quality in India and California

In Fig. 3 and Fig. 4, two black vertical lines in both images were used to denote the first phase of lockdown in India and California and the variation of various pollutant levels are shown, from Jan 2019 to Jul 2020. Compared with the AQI value of California, all the above Indian cities have a dangerously high level of pollution. After Mar 25 2020, we observed a clear decline of AQI value in all the cities under lockdown. As AQI levels have a significant drop after the lockdown policy was posted, we concluded that the lockdown policy has a very positive impact on air pollution in both India and California.

Except for all those experiments, we also test the average AQI value of all those cities before and after the lockdown policy. The AQI value dropped 66.8% in Ahmedabad, 29.2% in Bengaluru, 22.5% in Chennai, 52.8% in Delhi, 29.8% in Hyderabad, and 50.3% in Mumbai. In California, the AQI value dropped 39.1% in Fresno, 50.3% in Los Angeles, and 7.7% in Oakland.

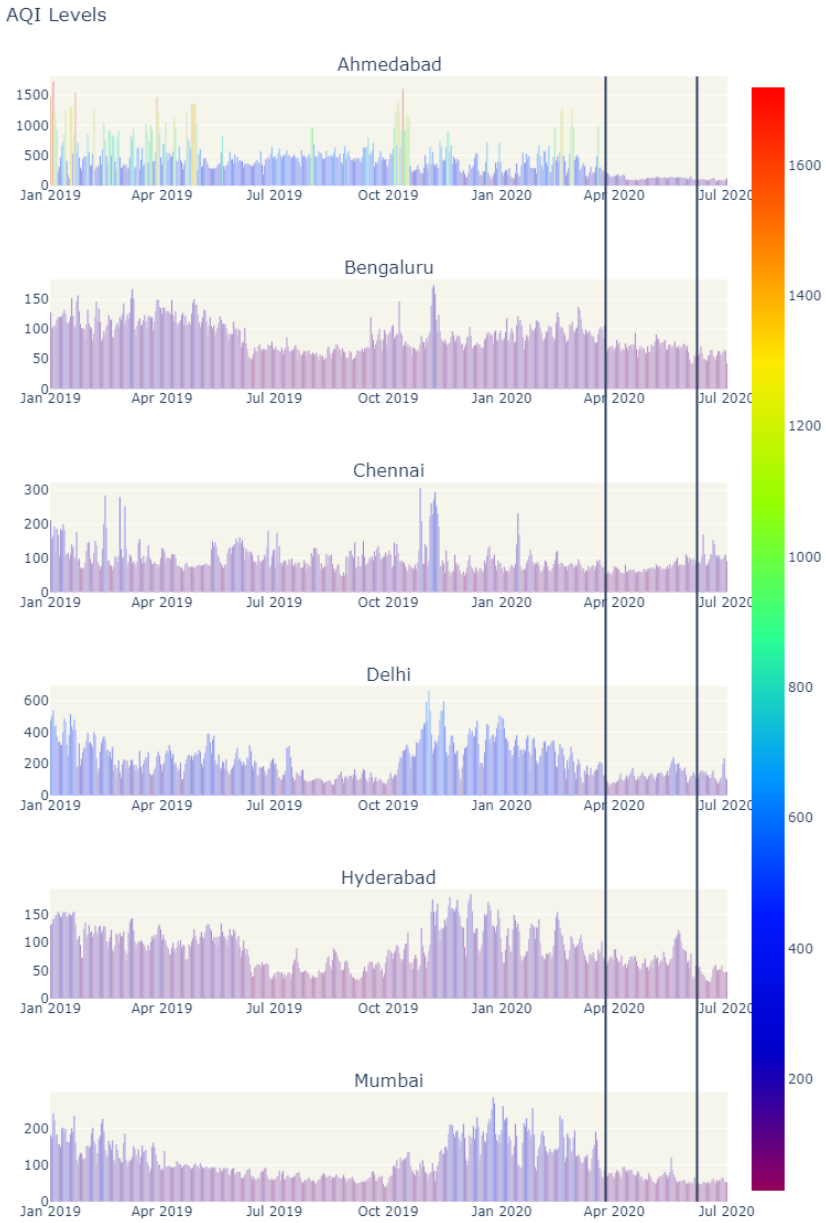

Fig 3. The AQI value before and after the Lockdown period of India

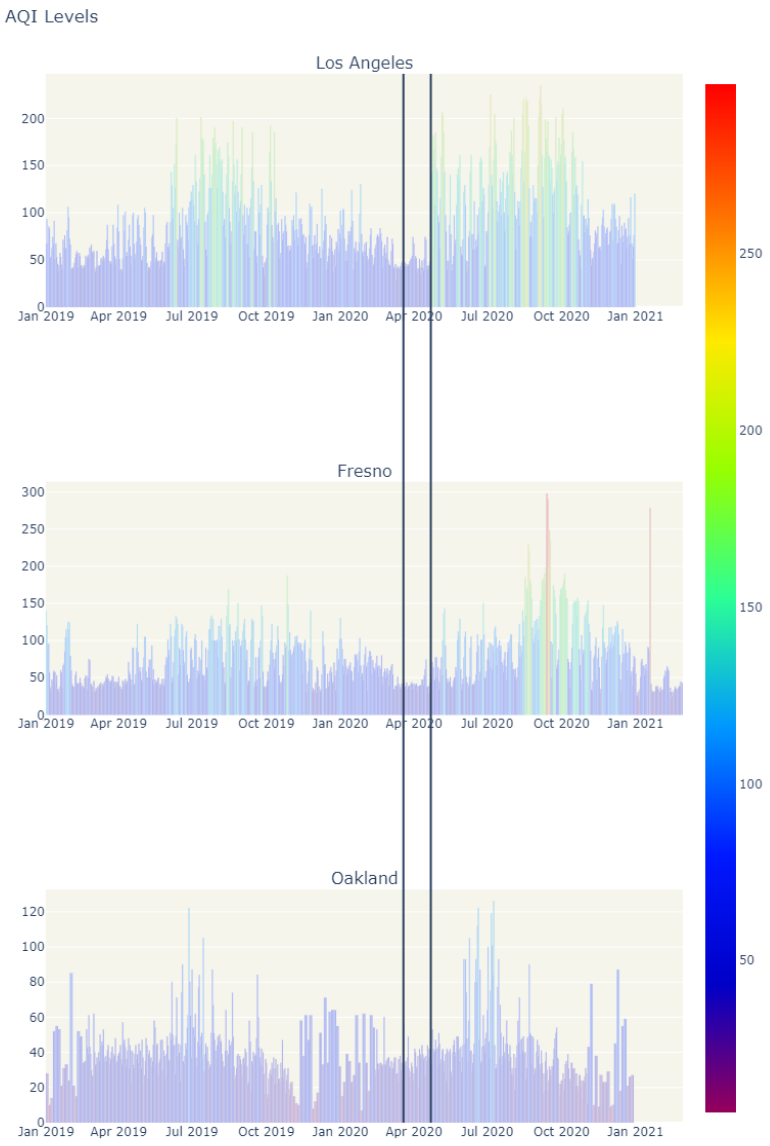

Fig 4. The AQI value before and after the Lockdown period of California

Analysis of Carbon Dioxide Emission in China, the U.S and India

In Table 1 and 2, we illustrated CO2 emission differences in 2019 compared to 2020, both before and during the COVID-19 lockdown period. Compared to 2019, the average CO2 emission from ground transportation and aviation during pre-lockdown period in 2020 is 10% lower in China, 10% lower in India, and 5% lower in the U.S. However, during the lockdown period, we observed more significant reductions. Average CO2 emission from ground transportation and aviation was reduced 34% in China, 38% in India, and 22% in the U.S.

Fig. 5 provides a visualization of the trend of CO2 emissions from 2014 to 2020. We observed that China, the country with the most emission, still increased its emission during 2020 but the incrementation is much slower than previous years, and we observed a significant drop of emission in India and U.S in 2020.

	Country	2019 pre-Lockdown Mean	2020 pre-Lockdown Mean	Difference in Previous and Current Mean (percentage change)
0	China	0.92	0.83	-0.09(-10%)
1	US	1.70	1.61	-0.09(-5%)
2	India	0.29	0.26	-0.03(-10%)

Table 1. CO2 emission from ground transportation and aviation during pre-lockdown period in 2019 and 2020

	Country	2019 Lockdown Mean	2020 Lockdown Mean	Difference in Previous and Current Mean (percentage change)
0	China	0.93	0.61	-0.32(-34%)
1	US	1.75	1.36	-0.39(-22%)
2	India	0.29	0.18	-0.11(-38%)

Table 2. CO2 emission from ground transportation and aviation during lockdown period in 2019 and 2020

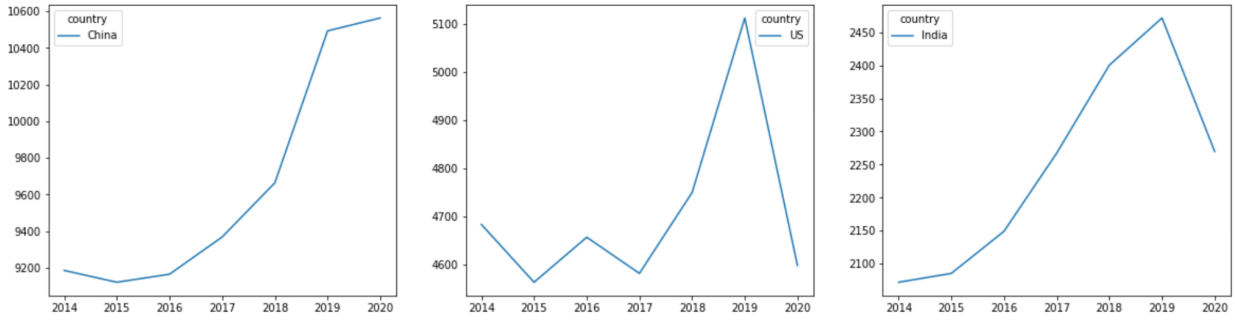

Fig. 5. Yearly CO2 emission from 2014 - 2020 in China, the U.S and India

Discussion

Our findings present evidence that, during the COVID-19 pandemic, air pollution has declined across India and California and CO2 emission has declined in the U.S and India. In China, the CO2 emission still increases but the growth in 2020 is much slower than previous years. Decreases in CO2 are likely associated with reduced ground transportation and aviation as people working remotely and travels were limited.

In our analysis, we only studied correlation rather than causation of environmental change and COVID-19 lockdowns. Our study also lacks the consideration of weather and large-scale events

that could potentially impact the pollution level. It is possible that the overall pollution decline we observed in 2020 compared to 2019 were associated with short-term weather conditions or large-scale events.

Conclusion

To study the impact of COVID-19 lockdown on environmental changes, we analyzed the air pollution in India and California and showed a decrease of AQI level in both areas during COVID-19 lockdown period. We analyzed the CO2 emissions in China, the U.S and India and found a decrease in average emission during COVID-19 period and reductions of yearly CO2 emissions in the U.S and India. The increase of yearly CO2 emission in China was slower in 2020 than the previous years. Air pollution and CO2 emission have important health implications. Our analysis emphasizes the importance of continued enforcement of air quality and greenhouse gas emission to protect the public health and the planet earth.

Future Work

In future work, we should study the causation of COVID-19 lockdown and environmental changes. We should also investigate the impact of weather and large-scale events on environmental changes to improve the accuracy of our analysis.

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