Impact of COVID-19 on Air Quality in Central and Eastern China

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Research Letter

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Abstract

The focus of this paper is mainly on COVID-19's impact on the air quality in central and eastern China using MCD19A2 aerosol optical depth (AOD) product data as well as the impact of human activities (mainly traffic behavior) on air quality. The main conclusions are the following: Significant data are still missing in MCD19A2 AOD product data, which led to the abnormal increase of AOD in southern China in February and the decline of analysis accuracy in AOD and air quality; COVID-19 had the important impact on air quality index (AQI) and peak congestion delay index (PCDI), resulting in the precipitous decrease of AQI and PCDI in Q1 2020, and the peaks of the AQI during the epidemic period were almost closely related to people's activities. AQI, PM2.5, and NO_2 was significantly positively correlated with PCDI. Therefore, the alleviation of traffic congestion plays an important role in improving the air quality.

1. Introduction

COVID-19, which broke out in Wuhan, China in December 2019, has spread to more than 200 countries and regions. On January 29, 2020, all 31 provinces, autonomous regions, and cities in mainland China activated a first-level response to a public health emergency. COVID-19 had a great impact on economy, life, education, and transportation. To contain COVID-19, cities were placed on lockdown, "quarantine" measures were taken in almost all residential areas, and online teaching became the main instructional mode in universities, middle schools, and primary schools. Extensive research on COVID-19 has been carried out since.

As the World's largest developing country, China's air quality has always been a focus of attention, and thus air quality in China during COVID-19 was studied. NO_2 concentration in southern China decreased unprecedentedly in the period of initial containment of the COVID-19 outbreak in January–April 2020, according to TROPOMI and OMI (Bauwens, 2020; Shi, 2020); moderate resolution imaging spectrometer (MODIS) satellite retrievals of aerosol optical depth (AOD) showed a marked increase over the Beijing-Tianjin-Hebei (BHT) region during the Winter 2019–2020 COVID-19 period, compared with the previous Winter (Nichol et al., 2020). The community multi-scale air quality model was used to study the change in PM2.5 in the North China Plain under the emission-reduction scenario from January 1 to February 12, 2020, and the analysis showed that the benefits of emission reductions were overwhelmed by adverse meteorology and severe air pollution events were not avoided(Wang et al., 2020); the haze levels during the initial COVID period was driven by increase in secondary pollution, based on comprehensive measurements and modeling(Huang et al., 2020).

The present study was mainly focused on the air quality of provinces with higher economic development levels in central and eastern China during the initial COVID period as well as on the impact on air quality caused by human activities (mainly traffic behaviors).

2. Materials And Methods

2.1 Study area and time

Figure 1 shows the study area, i.e., the mainland in eastern and central China (excluding Hainan and Taiwan), which includes 11 eastern provinces and six central provinces. The study area has a concentrated population distribution, a relatively developed economy, traffic congestion, and poor air quality. At the same time, Wuhan (the city in which the COVID-19 outbreak began), Beijing, Shanghai, and Guangzhou (China's largest cities) and Jinan (the capital of Shandong Province and a “second-tier” city) were selected as examples for detailed analyses.

The lockdown in Wuhan began on January 23, 2020, and then on April 8, Wuhan began to lift its coronavirus lockdown; therefore, the research period of this paper was from January to April 2020.

2.2 Data

Air quality data: The ground monitoring data of 841 air quality monitoring stations in the study area were used, as shown in Figure 1. The air quality index (AQI) released by China's online air quality monitoring and analysis platform (https://www.aqistudy.cn/) included six pollutants (PM2.5, PM10, SO_2, NO_2, CO, and O_3) and the AQI; the statistical data for all seven parameters were counted hourly.

Remote-sensing data: MCD19A2 (1-km resolution) aerosol optical depth (AOD) products of the MODIS sensor (https://ladsweb.modaps.eosdis.nasa.gov/search/).

Peak delay index of road network: The peak congestion delay index (PCDI) is the evaluation index of the degree of urban congestion, generally 7:00–9:00 during the morning peak and 17:00–19:00 during the evening peak, which is an intuitive performance of urban traffic operation status and a representation of exhaust emissions (from Amap).

2.3 Data preprocessing

The MCD19A2 AOD products in the study area were processed. First, the AOD data of different orbits (generally, there are more than three tracks of data in daily AOD data) were combined into the daily AOD; then, the 10-d and monthly AOD data were synthesized. The principles of synthesizing daily, 10-d, and monthly AOD data were the following: The influence of missing data (without data) was not considered and the mean value of AOD data was counted only when AOD had data.

The average of AOD, PM2.5, and NO_2 by all monitoring stations in five cities were separately taken as the observed values of urban air quality parameters.

3. Results

3.1 Changes in AOD Levels for the COVID-19 Period

As shown in Figure 2 a and b, after the outbreak of covid-19, the AOD levels of Fujian province, Guangzhou province, Zhejiang province, and Beijing increased in February compared with that in January, while the AOD in other regions decreased.

The ground monitoring AQI and PM2.5 data for Guangzhou (the capital of Fujian Province) from January to February 2020 were counted in 10-d intervals (the monthly difference of AOD was greater than 0), as shown in Figure 3a; daily AOD (January 1, 2020), 10-d AOD (early January 2020), and monthly AOD (January 2020) data are shown in Figure 3b; No data area in early February in 2020 and difference greater than 0 area is shown in Figure 3c.

It can be seen from Figure 3a that the AQI and PM2.5 of Guangzhou City decreased successively in early, middle, and late January, and then rebounded after reaching its lowest value in the first 10 d of February (also shown in Figure 3a). Significant amounts of AOD data were missing (Figures 3b and c). The AOD in February increased more than that in January was largely located in the areas where AOD data were missing in the first 10 days of February (Figures 3c). The AOD data of Guangzhou city from early and middle January 2020 were seriously missing (with high AQI and PM2.5 levels), and the AOD data from early February were missing completely (the lowest point), which may have led to the monthly AOD in February being larger than that in January.

3.2 Cities air quality

a AOD for 5 cities from Jan. to Apr. 2020 b. AQI, PM2.5 and NO2 in Wuhan in 2020 and 2019

Figure 4a shows the AQI in February 2020 after the outbreak of COVID-19 had decreased significantly compared with that in January, except for Beijing and especially Jinan. The AQI in Jinan decreased from 140.8 in January 2020 to 76.9 in February, reaching the lowest monthly mean value in the same period since observation records began being kept (2014). In February and March 2020, the AQI was relatively low and rebounded significantly in April.

Figure 4b shows that all parameters dropped precipitously after the lockdown on January 23, 2020; the NO_2 value (which mainly comes from exhaust gas) in Q1 2020, in particular, was much lower than that in Q1 2019. According to Amap, on April 8, 2020 (end of lockdown), the PCDI of Wuhan increased by 7.87% compared with the previous day, and even exceeded the value on April 8, 2019; in other words, the data reveal that human activities have a great impact on air quality.

3.3 Impact of people's activities on air quality

Figure 5 AQI and main human activities in Jinan City from January 1, 2020 to April 30, 2020.

It can be seen from Figure 5 that the areas of high AQI value corresponded to people's activities from January 24, 2020 (when Shandong Province launched its first-level response to the major public health paroxysmal incident of COVID-19) to April 30, 2020. That is to say, the AQI that peaked during the epidemic period were closely related to people's activities.

Table 1
Correlation coefficient between AQI, PM2.5 and NO_2 with PCDI

	Fitting method	AQI	PM2.5	NO2
PCDI	Linear	0.3284	0.4820	0.8091
	Quadratic polynomial	0.3345	0.4950	0.8402

The correlation coefficient between AQI, PM2.5, and NO_2 with PCDI is reported in Table 1 and all P values are <0.05. This demonstrates that AQI, PM2.5, and NO_2 have a positive correlation with PCDI. According to the source analysis of PM2.5 in Beijing, Jinan, and Hangzhou, exhaust gases surpassed coal combustion as the main source of PM2.5 pollution in cities, and some industries were shut down during COVID-19, which led to the high correlation between PCDI and NO_2. Source analysis of PM2.5 also indicated that exhaust emissions had a great impact on urban air quality.

4. Conclusions

This study is, to the best of our knowledge, the first error analysis using MCD19A2 AOD product data to analyze air quality during the COVID-19 outbreak in central and eastern China, as well as to assess the impact of human activities (mainly traffic behavior) on air quality. It was found that the missing data in the MCD19A2 AOD product data led to the abnormal increase of AOD in southern China in February and the decline of analysis accuracy in AOD and air quality. COVID-19 resulted in the precipitous decrease of AQI and PCDI in Q1 2020, and the peaks of the AQI during the epidemic period were almost closely related to people's activities. AQI, PM2.5 and NO_2 were significantly positively correlated with PCDI. Therefore, the alleviation of traffic congestion plays an important role in improving air quality.

Declarations

Author Contributions:

Haixia Feng was involved in the research design and finalized the paper; Erwei Ning was involved in software and validation; Jian Li and Haiying Feng analyzed the data; Qi Wang gave useful comments that improved the paper.

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Conflicts of Interest:

The authors declare no conflicts of interest.

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Figures

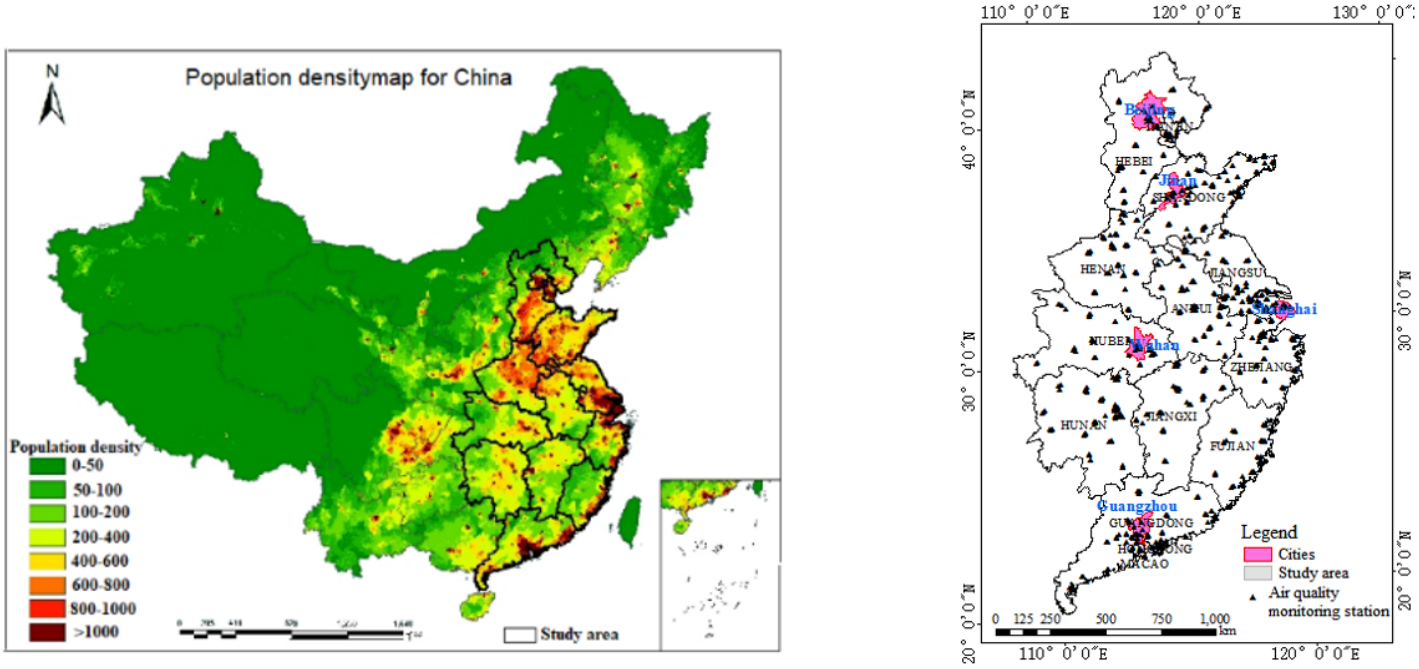

Figure 1

Population density (people per km2) map for China in 2015 (http://www.resdc.cn/DOI/DOI.aspx?DOIid=32), and study area (including ground air quality monitoring station) 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.

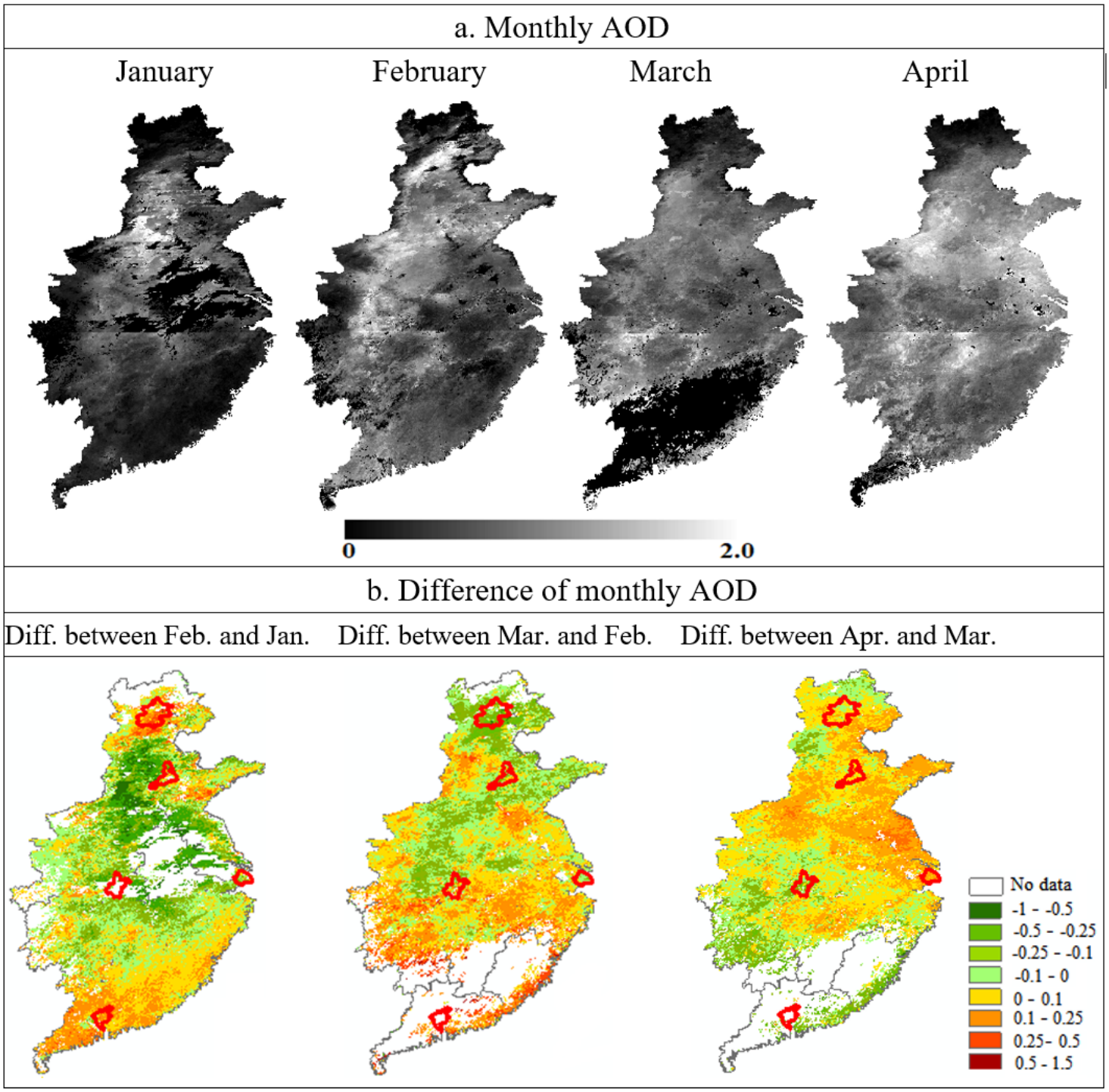

Figure 2

Monthly AOD in eastern and central China. A shows the synthesized monthly AOD from January to April in 2020, respectively, and b shows the difference of monthly AOD, respectively. The green shows that the difference of AOD in this area is less than 0, that is, AOD is lower than last that in the previous month; and red shows the AOD is higher than that in the previous month. 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

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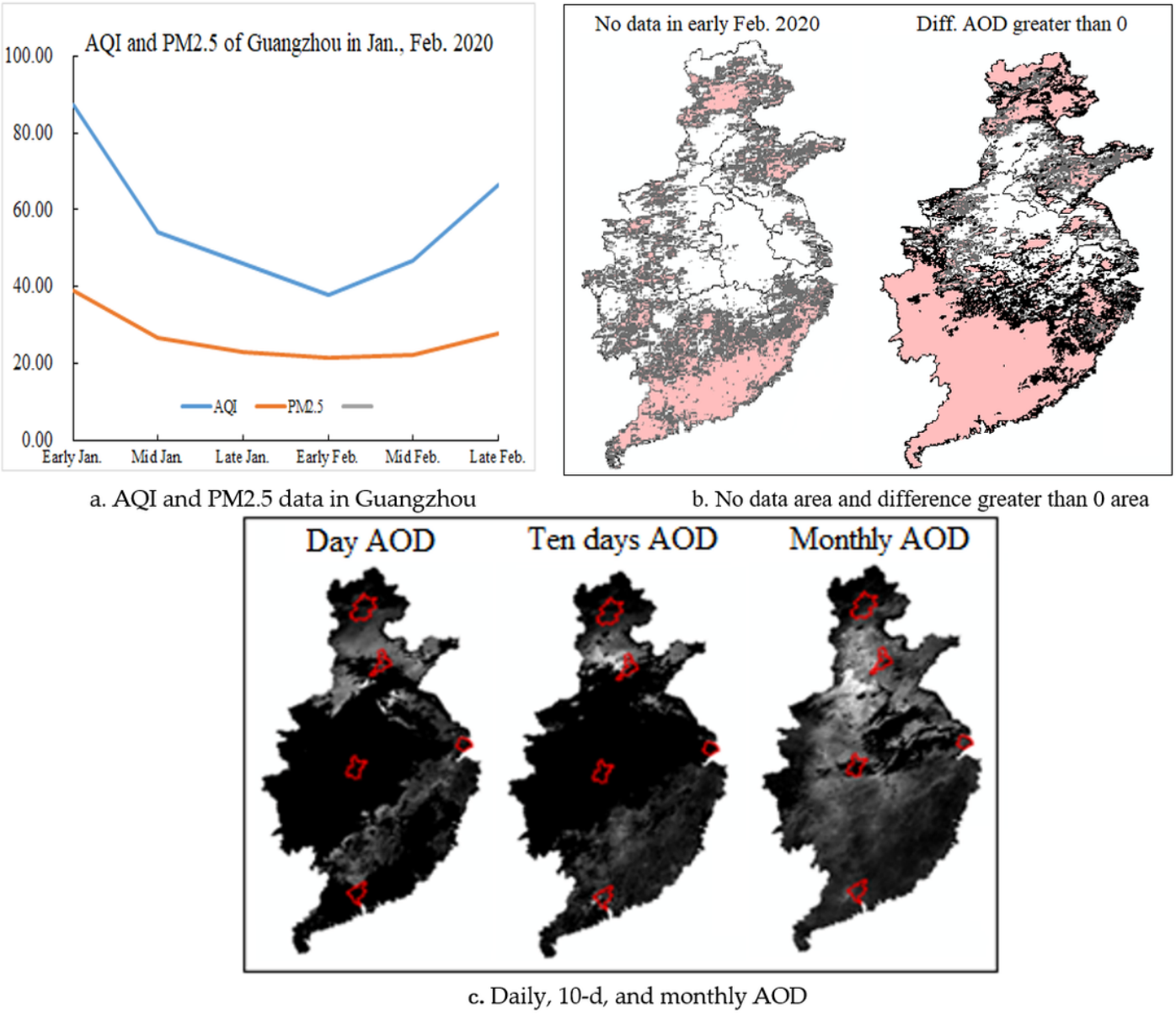

a. AQI and PM2.5 data in Guangzhou

b. No data area and difference greater than 0 area

c. Daily, 10-d, and monthly AOD

Figure 3

Comparative analysis of ground monitoring and AOD data. A shows the ground monitoring AQI and PM2.5 data in Guangzhou, and b shows no data area in early February and difference greater than 0 area between February and January, and c shows the day AOD (January 1, 2020), 10-d AOD (early January 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.

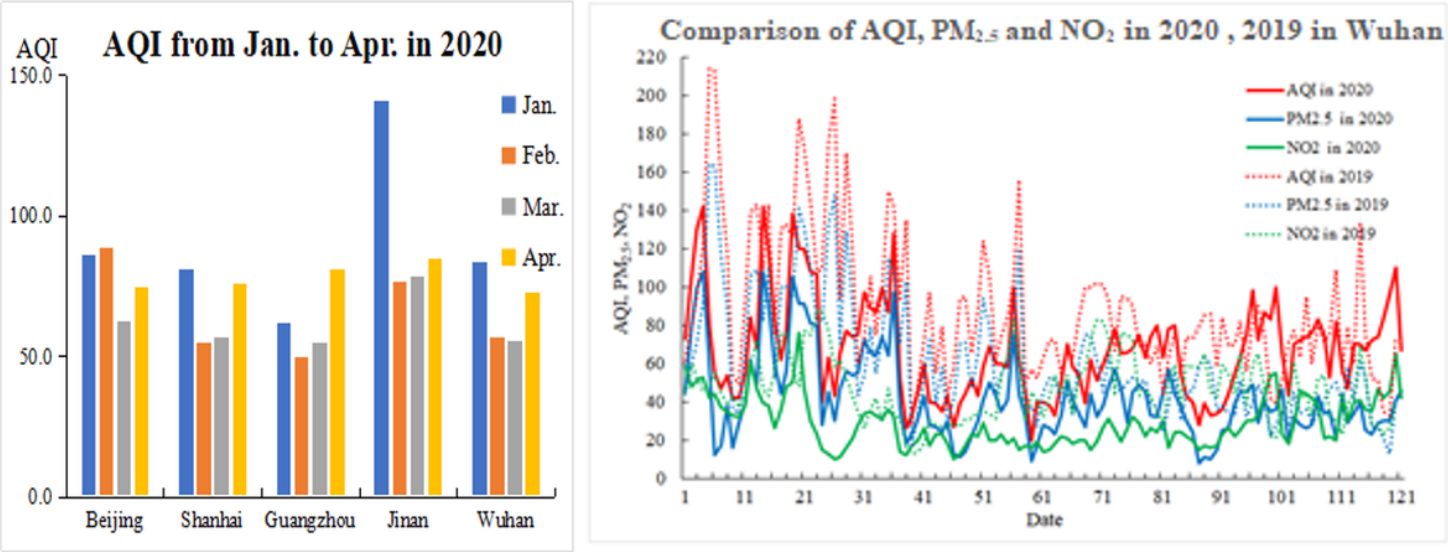

Figure 4

AOD of cities from January to April. A shows the AOD for or 5 cities from Jan. to Apr. 2020, and b shows the Comparison of AQI, PM2.5 and NO2 in 2020, 2019 in Wuhan.

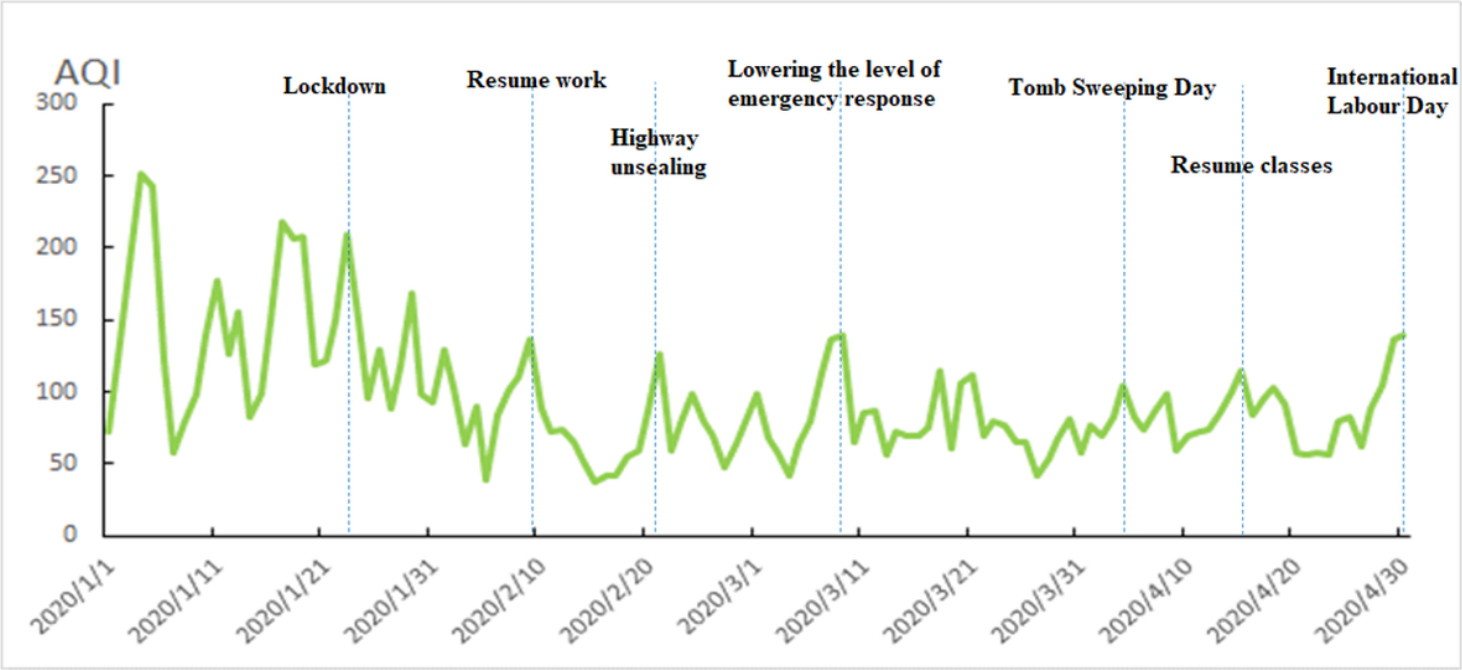

Figure 5

AQI and main human activities in Jinan City from January 1, 2020 to April 30, 2020.