

# Investigating the spatio-temporal pattern of PM<sub>2.5</sub> concentrations in Jiangsu Province, China

Ahmad Hasnain<sup>1,2,3</sup>, Yehua Sheng<sup>1,2,3\*</sup>, Muhammad Zaffar Hashmi<sup>4</sup>, Uzair Aslam Bhatti<sup>5</sup>, Yong Zha<sup>1,2,3</sup>

<sup>1</sup> Key Laboratory of Virtual Geographic Environment, Ministry of Education, Nanjing Normal University, Nanjing 210023, China

<sup>2</sup> School of Geography, Nanjing Normal University, Nanjing 210023, China

<sup>3</sup> Jiangsu Center for Collaborative Innovation in Geographical Information, Resource Development and Application, Nanjing 210023, China

<sup>4</sup> Department of Chemistry, COMSATS University Islamabad, Pakistan

<sup>5</sup> School of Information and Communication Engineering, Hainan University, Haikou, China

**Abstract.** PM<sub>2.5</sub> is a typical air pollutant which has harmful health effects worldwide, particularly in the developing countries such as China due to significant air pollution. The objectives of this study were to investigate the spatio-temporal pattern of PM<sub>2.5</sub> concentration in Jiangsu Province, China. The data were collected from 72 monitoring stations between 2018-21 and the HYSPLIT model was used to study the transport pathways of air masses. According to the obtained results, the concentration of PM<sub>2.5</sub> was obvious during the study duration. The results show that the concentration of PM<sub>2.5</sub> was constantly decreased from 2018 to 2021, while the level of PM<sub>2.5</sub> was higher in winter and lower in summer in Jiangsu. The backward trajectory analysis revealed that the trajectories were originated from the Siberia, Russia and passed thorough Mongolia and northwestern parts of China then reached at the study spot. These air masses played a significant role in aerosol pathway and affect the air quality of Jiangsu.

**Keywords** Spatio-temporal · PM<sub>2.5</sub> · HYSPLIT model · Jiangsu province · China

## 1 Introduction

Aerosols are liquid or dense particles in the atmosphere with a diameter 0.001–100 μm, which are suspended for an extended time frame in the atmosphere. They can exert significant effect on public health, climate and the environment [1]. The particles, with an aerodynamic equivalent diameter ≤ 2.5 μm, which are more harmful to human health, have a larger surface area than those coarser particles. Global Burden of Disease reported that particulate matter is the fourth main risk factor in China and seventh in the world [2-5].

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\*Corresponding author: shengyehua@njnu.edu.cn

Air pollution is worldwide environmental issue, particularly in the developing countries such as China. Due to rapid development in different sectors, such as industries, transportation and massive energy consumption, haze pollution has frequently happened in the country [6]. Previously, it has been reported that 75.1% cities in China surpassed the annual air quality guidelines in 2016, and  $PM_{2.5}$  played a significant role during the corresponding days (MEEPRC 2016). The pollution level of  $PM_{2.5}$  during the mentioned period was three times higher compared to the global means. However, the strict prevention and control policies implemented by the Chinese government are also helpful in reducing and decreasing the air pollutant levels in the country [7].

As mentioned earlier in above lines the hazy days mostly occurred in the country, while it has been reported that the number of hazy days sharply increased in China. The most affected areas of the country are Yangtze River delta, the Yellow-Huai-Hai River region, the Pearl River delta and the Sichuan basin. The increment in  $PM_{2.5}$  concentrations in the atmosphere caused haze pollution, while the air pollution caused by  $PM_{2.5}$ , has harmful and toxic effects on human health, climate and the environment [7]. Currently, it is an important and difficult task to control haze pollution in the country, that require an urgent solution [8-10].

In this study, Jiangsu province has been selected as a study area. The objectives of this study were to investigate the spatio-temporal pattern of  $PM_{2.5}$  concentration using four years of data (2018-21) in Jiangsu Province, China. The backward trajectories were used to identify the transport pathways of air masses that affect the air quality of the province. Such attempts can be helpful to mitigate air pollution problems in the future.

## 2 Materials and methods

### 2.1 Study area

Jiangsu Province is a financial hub of the country, located within  $30^{\circ}45'$  to  $35^{\circ}20'$  N and  $116^{\circ}18'$  to  $121^{\circ}57'$  E. The province is an important part of the Yangtze River Delta, whose GDP reached  $9.96 \times 10^{12}$  yuan in 2019. Jiangsu is rich in different sectors such as industries, transportation, etc. It has 13 cities and a large population, an approximately 80.5 million.

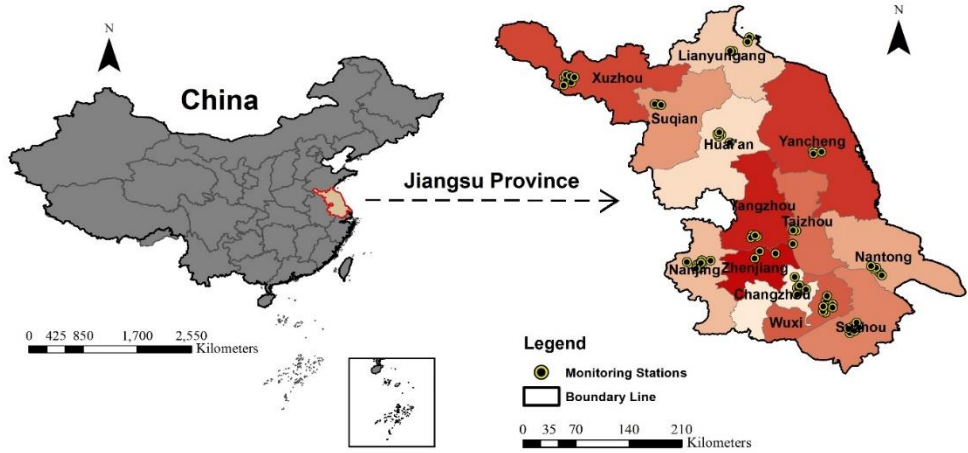
Fig. 1 shows the geographical location of Jiangsu province and 72  $PM_{2.5}$  monitoring stations, which are scattered over 13 cities of the province.

### 2.2 Data

In this work, daily average concentration of  $PM_{2.5}$  was used and the data were taken from the China Environmental Monitoring Station (CNEMC 2019). To investigate the spatio-temporal pattern of  $PM_{2.5}$ , the data were collected between 2018-21 through 72 monitoring stations.

### 2.3 HYSPLIT model

The backward trajectories were analyzed to track the transport pathways of air masses using the HYSPLIT model (<https://ready.arl.noaa.gov/HYSPLIT.php>). The model has been commonly used to analyze the sources of pollutants and their transport pathways. In this work, the daily 72-hour backward trajectory was analyzed, started every 6 h each day during the study period.



**Fig. 1.** Study area and PM<sub>2.5</sub> monitoring stations.

### 3 Results and discussion

#### 3.1 Spatio-temporal pattern of PM<sub>2.5</sub>

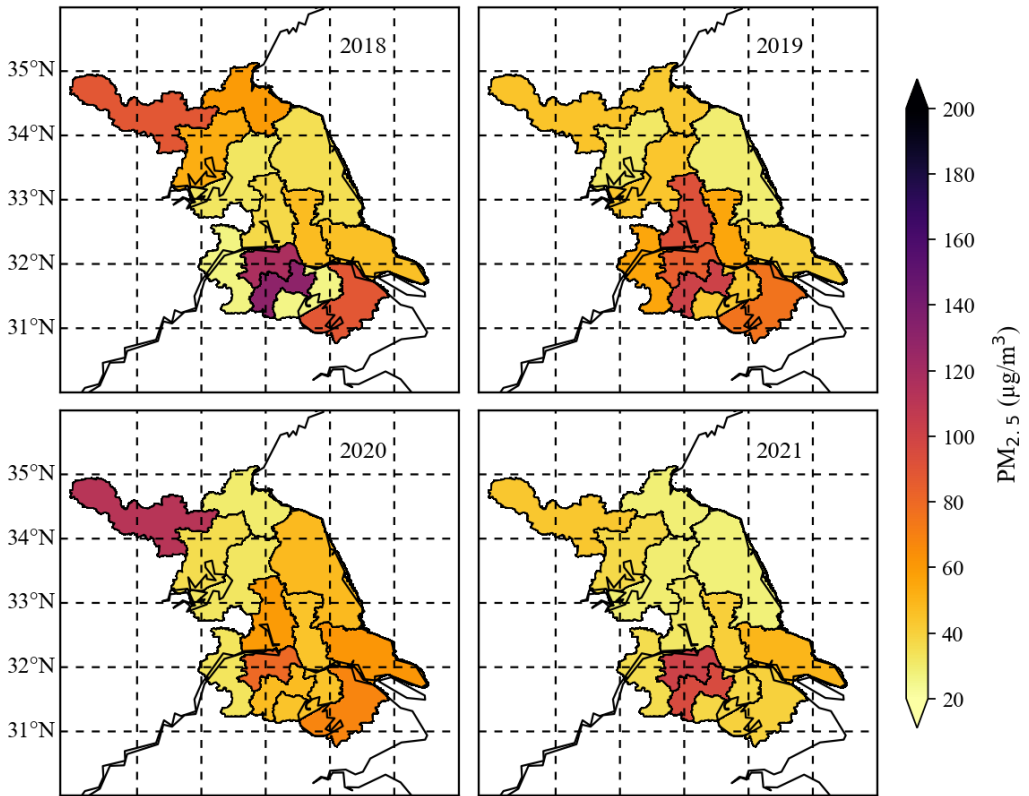
Using the daily average concentration of PM<sub>2.5</sub> from 2018 to 2021, the results demonstrate that the concentration level of PM<sub>2.5</sub> gradually reduced from 2018 to 2021 in Jiangsu province. The annual average concentration values of PM<sub>2.5</sub> were 47.49 µg/m<sup>3</sup> in 2018, 43.14 µg/m<sup>3</sup> in 2019, 37.03 µg/m<sup>3</sup> in 2020, 33.28 µg/m<sup>3</sup> in 2021 (Table 1). The results suggest that the concentrations of PM<sub>2.5</sub> progressively decreased from 2018 to 2021, which can be attributed to the strict prevention and control policies imposed by the Government of China. It can be noted that the most decreasing value was observed from 2018 to 2019 compared with the other years. (Table 1).

**Table 1.** PM<sub>2.5</sub> concentrations (µg/m<sup>3</sup>) during the four years and seasons in Jiangsu Province.

PM <sub>2.5</sub>	2018	2019	2020	2021	Spring	Summer	Autumn	Winter
Maximum	305.04	213.79	318.27	232.17	263.13	140.40	249.13	318.27
Average	47.49	43.14	37.03	33.38	41.60	27.85	35.92	55.95
Minimum	1.00	1.50	1.00	1.13	2.22	1.00	1.50	2.88

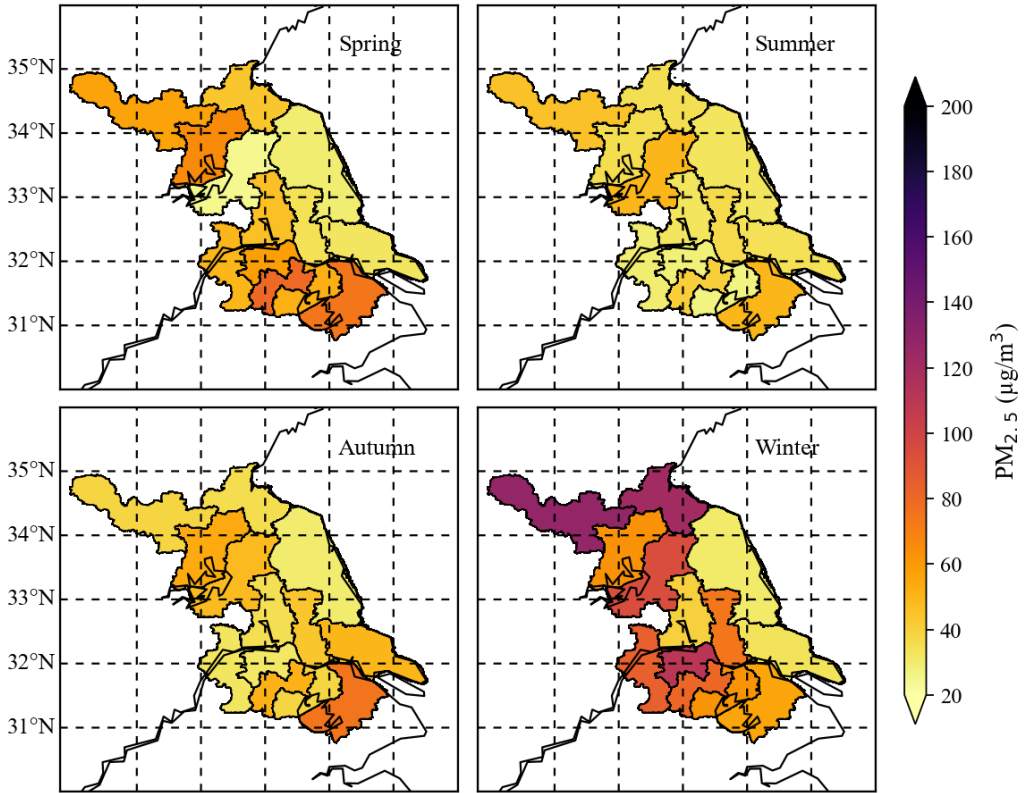
It has been reported that the level of PM<sub>2.5</sub> was observed higher in developed areas with more emission sources, while the areas with well vegetation and greenery, were found with

lower  $PM_{2.5}$  levels (Sun et al. 2013). Besides the effects of urbanization, the geographical location and industrial zones also showed considerable impacts. Fig. 2. shows the annual average concentrations of  $PM_{2.5}$  during the study period.



**Fig. 2.** Yearly  $PM_{2.5}$  concentration in 2018, 2019, 2020 and 2021 in Jiangsu Province.

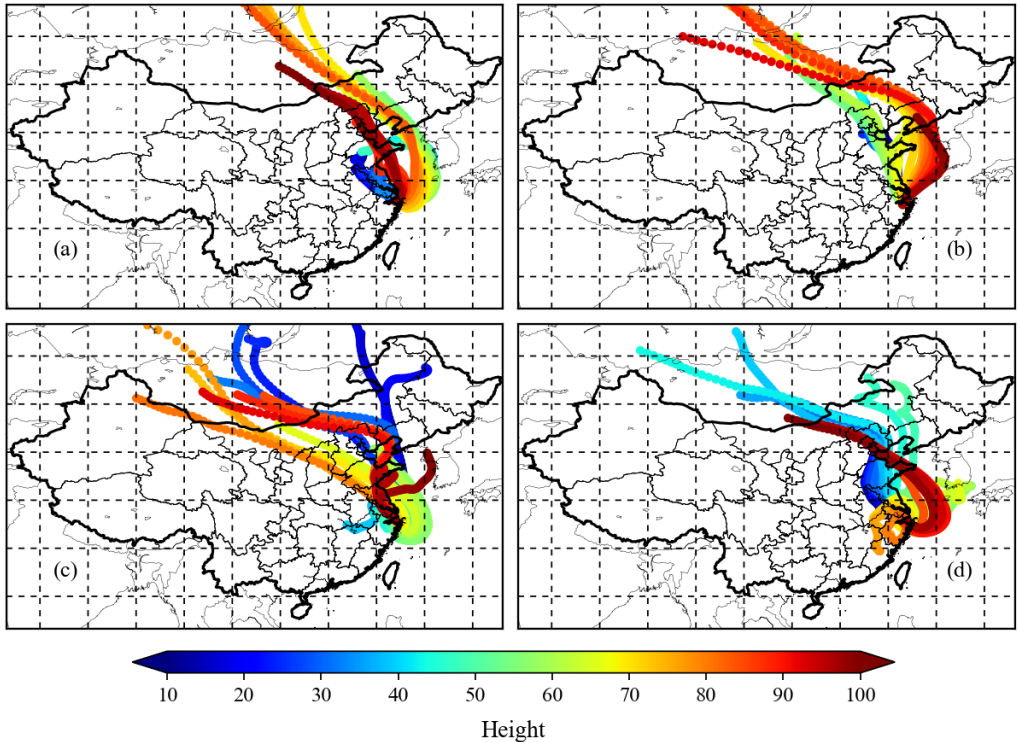
Seasonally, the highest concentration of  $PM_{2.5}$  was found in winter, while the lowest was in summer. The average concentration of  $PM_{2.5}$  was  $41.60 \mu\text{g}/\text{m}^3$  in spring (March–May),  $27.85 \mu\text{g}/\text{m}^3$  in summer (June–August),  $35.92 \mu\text{g}/\text{m}^3$  in autumn (August–October) and  $55.95 \mu\text{g}/\text{m}^3$  in winter (December–February). Thus, the highest and lowest concentration values for  $PM_{2.5}$  were found in winter and summer, respectively in Jiangsu. A study addressed by Cheng et al. (2017) indicated that winter was found with the highest concentration of  $PM_{2.5}$ , while summer experienced the lowest  $PM_{2.5}$  levels, which support our findings. Moreover, the difference between the summer and winter concentrations was noticeable, while a slight difference in  $PM_{2.5}$  was found between spring and autumn (Table 1). Fig. 3. shows the seasonal concentration pattern of  $PM_{2.5}$  in Jiangsu Province.



**Fig. 3.** PM<sub>2.5</sub> concentration in spring, summer, autumn and winter in Jiangsu Province.

### 3.2 Backward trajectories analysis

In this work, the backward trajectories were analyzed to track the transport pathways of air masses during the study period (Fig. 4). The long-range air masses (cluster a) originating from the Siberia that passes through Mongolia and the Beijing-Tianjin-Hebei region and then reached at the study spot. Like cluster (a), cluster (b) consists of long-range air masses coming from the Siberia that passing through North Mongolia and Liaoning Province then reached Jiangsu. Cluster (c) also comprises long-distance air masses originating from Russia that arrives at the study spot after passing through Mongolia, Inner Mongolia and the Beijing-Tianjin-Hebei region. Cluster (d) is coming from Russia that passes through Central Mongolia and Inner Mongolia than reaches and influences the air quality of Jiangsu Province. Overall, the major source regions of these clusters are Russia and Mongolia, after originating and coming from mentioned areas, these long-range air masses influence the air quality of Jiangsu.



**Fig. 4.** Backward trajectories over Jiangsu Province (a) 2018, (b) 2019, (c) 2020 and (d) 2021.

## 4 Conclusions

In the current research, we analyzed the 2018-21  $PM_{2.5}$  concentration data of Jiangsu Province, China. The data were retrieved from 72 monitoring stations. According to our results, the concentration levels of  $PM_{2.5}$  was constantly decreased from 2018 to 2021. The concentration of  $PM_{2.5}$  was observed at its low level in summer and higher in winter. The backward trajectory analysis indicate that the long-distance air masses originated from the Siberia, Russia, that passes through Mongolia, Inner Mongolia and the Beijing-Tianjin-Hebei region than influence the air quality of Jiangsu. These findings provide credible outcomes and are helpful to deal and mitigate air pollution issues in the future.

## References

1. A. Hasnain, Y. Sheng, M.Z. Hashmi, U.A. Bhatti, Z. Ahmed, Y. Zha, *Assessing the ambient air quality patterns associated to the COVID-19 outbreak in the Yangtze River Delta: A random forest approach*, Chemosphere, 314, 137638 (2023)
2. M. Aamir et al., *Predicting the Environmental Change of Carbon Emission Patterns in South Asia: A Deep Learning Approach Using BiLSTM*, Atmosphere, 13, 12 (2022)
3. S. Fei, R.A. Wagan, A. Hasnain, A. Hussain, U.A. Bhatti, E. Elahi, *Spatiotemporal impact of the COVID-19 pandemic lockdown on air quality pattern in Nanjing, China*, Front. Environ. Sci. **10** (2022)

4. G. Wu et al., *COVID-19 and Air Pollution: Air Quality Impact in 13 Cities of the Jiangsu Province of China*, Pol. J. of Environ. Stud. **31**, (5) 4907–4916 (2022)
5. G. Wu et al., *COVID-19 and Air Pollution: Air Quality Impact in 13 Cities of the Jiangsu Province of China*, Pol. J. of Environ. Stud. **31**, (5), 4907–4916 (2022)
6. L. He, Z. Zhong, F. Yin, D. Wang, *Impact of Energy Consumption on Air Quality in Jiangsu Province of China*, Sustain. **10**, (2), 94 (2018)
7. L. Robertson, L. Zhou, K. Chen, *Temperature, Air Pollution and Fatal Unintentional Injuries in Jiangsu Province China, 2015-2017* (2020)
8. Y. Wu, Q. Zhan, Q. Zhao, *Long-term Air Pollution Exposure Impact on COVID-19 Morbidity in China*, Aerosol Air Qual. Res. **21**, (1), 200413 (2021)
9. L.P.C. Galvan, U.A. Bhatti, C.C. Campo, R.A.S. Trujillo, *The Nexus Between CO<sub>2</sub> Emission, Economic Growth, Trade Openness: Evidences From Middle-Income Trap Countries*, Front. Environ. Sci. **10** (2022)
10. U. Bhatti et al., *A Pre- to Post-COVID-19 Change of Air Quality Patterns in Anhui Province Using Path Analysis and Regression*, Pol. J. of Environ. Stud. **31**, (5), 4029–4042 (2022)