



Spatio-temporal Variation and Driving Factors of PM_{2.5}-O₃ Compound Pollution in Anhui Province from 2015 to 2023

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ABSTRACT

In order to explore the characteristics and driving factors of PM_{2.5} and O₃ compound pollution in 16 prefecture-level cities in Anhui Province, multidimensional statistics, Pearson correlation coefficient and HYSPLIT model were used to analyze the cities in Anhui Province from 2015 to 2023. The results show that: From the spatial and temporal distribution, the cumulative occurrence of PM_{2.5}-O₃ compound pollution in cities of Anhui Province from 2015 to 2023 was 8-361 days, mainly concentrated in April-October, and the number of days of compound pollution in winter was the least. In Huaibei, Huainan, Suzhou, Bengbu, Chuzhou, Bozhou appear more frequently, Huangshan, Tongling, Xuancheng, Chizhou, Wuhu appear less frequently; The days of compound pollution were significantly positively correlated with PM_{2.5} and NO₂, which are two key control parameters affecting the days of compound pollution; HYSPLIT model shows that the regional transmission in cities near Hefei also has an important impact on PM_{2.5}-O₃ compound pollution, mainly from the northeast. From 2015 to 2023 the fluctuation of PM_{2.5} concentration in Anhui province decreased and O₃ concentration increased, and the synergistic relationship between the two became increasingly obvious, the meteorological data had a certain impact on the days of compound pollution.

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INTRODUCTION

With the rapid social and economic development in recent years, high-density fine particle (PM_{2.5}) pollution has appeared in many regions of China (Wang et al., 2014), affecting global climate change, regional environment and human health. In order to control the pollution of PM_{2.5}, China's air pollution control has promulgated the Action Plan for Prevention and Control of Air Pollution (2013-2017), the Three-Year Action Plan for Winning the Battle for the Blue Sky (2018-2020), and as of 2020, the overall improvement of the national air quality (Sun et al., 2021), in particular, PM_{2.5} decreased significantly, but ozone (O₃) pollution still showed a gradual upward trend (Lu et al., 2020). At present, China's atmospheric pollution has been localized, single urban pollution to PM_{2.5}-O₃ compound pollution excess, seriously restricting the sustainable development of regional socio-economic (Ye et al., 2021). PM_{2.5}, O₃ pollution prevention and control has become the key to China's air pollution control (Zhao et al., 2021).

Among major atmospheric pollutants, PM_{2.5} and O₃ are two key pollutants that contribute to atmospheric compound pollution (Wang et al., 2019). The first-level index of daily maximum 8h average concentration (MDA8) of O₃ was 100 µg/m³, and the second-level was 160 µg/m³.

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The first-level index of daily average concentration of $PM_{2.5}$ was $75 \mu\text{g}/\text{m}^3$, and the second-level was $35 \mu\text{g}/\text{m}^3$. From 2015 to 2023, the number of days with $PM_{2.5}$ and O_3 concentrations exceeding the secondary limit ('double exceeding') in Anhui Province was only 12 days (1 day in 2015, 9 days in 2017 and 2 days in 2018), which was only 0.4 % of all observation days. In order to ensure the feasibility of the analysis, this paper lowered the threshold to $PM_{2.5}$ daily average $>35 \mu\text{g}/\text{m}^3$ and O_3 -MDA8 $>100 \mu\text{g}/\text{m}^3$ which was defined as $PM_{2.5}$ - O_3 compound pollution day (Ding et al., 2024).

Since, the relationship between $PM_{2.5}$ and O_3 is complex and varied in different regions, seasons, and studies. several scholars have explored the causes of $PM_{2.5}$ and O_3 and meteorological factors: (1) the impacts of $PM_{2.5}$ and O_3 on the effects of human health risks were investigated in China (Li et al., 2024; Hao et al., 2024; Huang et al., 2024; Chen et al., 2025; Yin et al., 2019). The results showed that the treatment of $PM_{2.5}$ was slightly effective, but the pollution of O_3 was still increasing, which continued to threaten the health of residents and significantly increased the risk of premature death. About 850,000 and 75,000 premature deaths were caused by $PM_{2.5}$ and O_3 pollution, respectively, resulting in economic losses of \$ 485.3 billion and \$ 7.6 billion. Among them, the health risks of $PM_{2.5}$ and O_3 exposure in population-intensive cities are higher, the period from April to September was the synergistic health control period of compound pollution; (2) the meteorological factors affecting the composite pollution were analysed based on the Pearson's correlation coefficient (Liu et al., 2024; Sun et al., 2023; Hou et al., 2023; Song et al., 2023; Jing et al., 2023) and KZ filtering respectively and found that the meteorological factors affecting the compound pollution occurring in Henan Province, North China, Beijing-Tianjin-Hebei, and the neighboring regions mainly depend on wind speed, wind direction, surface temperature and relative humidity; (3) the changes of daily average $PM_{2.5}$ concentration showed "double peak" changes (one peak appears at 9 : 00 and 23 : 00 respectively), while O_3 concentration showed "single peak" changes were pointed out (Liu et al., 2023; Han et al., 2024; Luo et al., 2021) while O_3 shows a 'single peak' characteristic, and the two pollutants display opposing trends; (4) the correlation coefficients of $PM_{2.5}$ and O_3 were analyzed, which showed that the two have obvious seasonality (Chen et al., 2022; Zhang et al., 2022). In summer, they are generally higher than other seasons. In winter, they are mainly negatively correlated. The correlation between $PM_{2.5}$ and O_3 is increasingly close, and the synergistic effect is becoming more and more pronounced; (5) the generation of O_3 is in the control area of VOCs were analyzed that by studying the emission of volatile organic compounds during air pollution (Sun et al., 2025; Ning et al., 2024; Bian et al., 2023; Feng et al., 2018; Tai et al., 2021) and pointed out that surface O_3 was generated by complex photochemical reactions between NO and VOCs under sunlight irradiation, and its formation rate was regulated by meteorological conditions such as light, temperature, humidity and wind speed. In areas where NO is enriched and VOCs are relatively insufficient, O_3 formation is in the 'VOC control area'. In addition, O_3 affects global crop photosynthesis, growth and yield. China should reduce emissions through multiple pathways and strengthen the control of volatile organic compounds; (6) the interaction of $PM_{2.5}$ and O_3 composite pollution in different dimensions were analyzed (Liu et al., 2024) found that during the period of O_3 pollution, both $PM_{2.5}$ and O_3 showed significant positive correlation, and with the increase of photochemical reaction intensity, the concentration and contribution of secondary $PM_{2.5}$ increased, and primary $PM_{2.5}$ also showed dramatic daily variation characteristics.

Anhui Province is one of the eight major agricultural provinces, with the reputation of "central granary" (Wang et al., 2018), which is of great significance to the national agricultural development. Existing studies have analyzed a single pollution index on a time scale and the research time is short (5-7a), and ignore the dynamic evolution law and cross-regional transmission of the compound pollution of the two. Therefore, based on the air quality test results of 16 prefecture-level cities in Anhui Province from 2015 to 2023, this paper aims to

analyze the temporal and spatial variation characteristics of $PM_{2.5}$ and O_3 concentrations, and trace the pollution contribution rate of transmission channels, so as to provide theoretical basis and decision support for the coordinated prevention and control of $PM_{2.5}$ and O_3 pollution in Anhui Province.

MATERIAL AND METHOD

The study area is 16 prefecture-level cities in Anhui Province. Anhui Province belongs to East China, range from $29^{\circ}41'N$ to $34^{\circ}38'N$, $114^{\circ}54'E$ to $119^{\circ}37'E$, in the transition area between warm temperate zone and subtropical zone, north of the Huaihe River belongs to the warm temperate semi-moist monsoon climate, and south of the subtropical humid monsoon climate (Wang et al., 2018). The terrain is high in the southwest and low in the northeast, and the topography is different from the north and south, which are complicated and diversified.

The study area is 16 prefecture-level cities in Anhui Province, and the hourly concentration data of O_3 , $PM_{2.5}$, CO , and NO_2 from January 1, 2015 to December 31, 2023 were obtained from China National Environmental Monitoring Center (<https://www.cnemc.cn/sssj/>). The seasons were classified using the meteorological industry standard *Climate Season Classification* (QX/T152-2012) of the China Meteorological Administration (CMA), i.e., March-May is spring, June-August is summer, September-November is fall, and December-February of the following year is winter.

Month-by-month and year-by-year meteorological data: mean temperature (T), mean precipitation (Pre), and horizontal wind speed (WS) for the same period for the 16 cities were obtained from the National Center for Environmental Information (NCEI) under the National Oceanic and Atmospheric Administration (NOAA), USA. [National Centers for Environmental Information \(NCEI\)](#). The total population (POP) and per capita GDP of each city from 2015-2023 were obtained from the Anhui Provincial Statistical Yearbook.

In the field of natural science, Pearson correlation coefficient is widely used to analyze the correlation between the complexity of multiple factors, and has a wide range of application. In the Pearson correlation analysis, for the two variables X and Y, several sets of data can be obtained through experiments, denoted by (X_i, Y_i) ($i = 1, 2, \dots, n$). The Pearson correlation coefficient is defined as the quotient of the covariance and standard deviation of the estimated sample. The mathematical expression of the correlation coefficient is (Sun et al., 2025):

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}}$$

In the formula: X, Y are the mean values of m test values.

The value of r is between -1 and 1. If $r > 0$, it shows that the two variables are positively correlated. If $r < 0$, it shows that there is a negative correlation between the two variables, and the greater the absolute value of r, the stronger the correlation: if $r = 0$, it indicates that there is no linear correlation between the two. It is generally believed that the correlation coefficient is not related or very weakly related in 0~0.2; 0.2~0.4 is weak correlation; 0.4~0.6 is moderate correlation; there is a strong correlation between 0.6~0.8; 0.8~1 is extremely strong correlation.

Based on the TrajStat tool in MeteoInfo software, the backward trajectory analysis and cluster analysis of Hefei City were carried out (Wang et al., 2009). The receiving point is the central point of the main urban area of Hefei City, the provincial capital ($117^{\circ} 17'E$, $31^{\circ} 52'N$), and 500 m selected as the starting height of the simulation. The 24-hour backward trajectory of $PM_{2.5}$ - O_3 pollution day in 2023 was simulated, and the angular distance algorithm was selected

to cluster the backward trajectory of PM_{2.5}-O₃ pollution (Li et al., 2024).

RESULTS AND DISCUSSION

Changes in annual average PM_{2.5} and O₃-8h concentrations in Anhui Province from 2015 to 2023, as shown in Figure-1. Temporally, the PM_{2.5} concentration in Anhui Province showed a decreasing trend, from 54.88 µg/m³ in 2015 to 36.16 µg/m³ in 2023, a decrease of 34.1%. From 2017 to 2018, the most obvious decrease was observed, from 56.43 µg/m³ to 48.97 µg/m³, or 13.2%, which is presumed to be related to the *Implementation Opinions on Third Party Governance of Environmental Pollution* issued by Anhui Province in 2017. The O₃-8h 90th percentile showed an increasing trend from 2015 to 2023, from 115.99 µg/m³ to 150.9 µg/m³, with an annual growth rate of 30.1%. Among them, from 2015 to 2019 and 2021 to 2023 showed an increasing trend, from 2019 to 2021 showed a decreasing trend.

As shown in Figure-2, from the spatial point of view the annual average high value of the 90th percentile concentration of PM_{2.5} and O₃-8h in Anhui Province is concentrated in the north-central part, and the low value is concentrated in the south. From the perspective of urban scale, the annual average concentration of PM_{2.5} in Hefei, Chuzhou, Tongling and Ma'anshan decreased greatly, from 65.25 µg/m³ to 35.31 µg/m³, 62.10 µg/m³ to 34.98 µg/m³, 58.09 µg/m³ to 33.68 µg/m³, 61.49 µg/m³ to 36.27 µg/m³, respectively, with a corresponding decrease of 45.88%, 43.68%, 42.02% and 41.00%, respectively. The decrease in Huainan, Fuyang and Chizhou was relatively low, and their concentrations decreased from 50.68 µg/m³ to 40.24 µg/m³, 51.82 µg/m³ to 41.66 µg/m³, 34.27 µg/m³ to 33.36 µg/m³, respectively, and the corresponding decreases were 20.61%, 19.60% and 2.66%, respectively. The concentrations of O₃-8h were higher in Huaibei, Huainan, Suzhou, Fuyang, Bengbu and Bozhou, with an average of more than 110 µg/m³ in 7 years. From 118.02 µg/m³ to 124.06 µg/m³, from 89.70 µg/m³ to 124.06 µg/m³, from 91.78 µg/m³ to 118.42 µg/m³, from 110.97 µg/m³ to 118.86 µg/m³, from 89.92 µg/m³ to 122.20 µg/m³, from 89.92 µg/m³ to 122.20 µg/m³, from 83.03 µg/m³ to 116.35 µg/m³, respectively. The corresponding increase rates were 5.11%, 38.31%, 29.02%, 7.11%, 35.90%

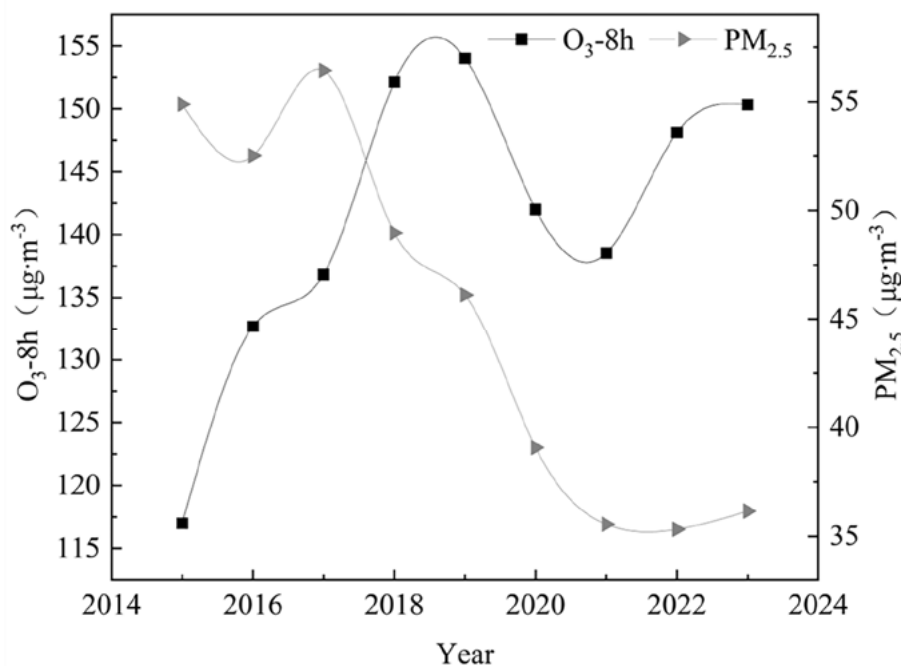


Fig. 1. Time series of the mean PM_{2.5} concentration and O₃-8h 90th percentile concentration in Anhui Province from 2015 to 2023

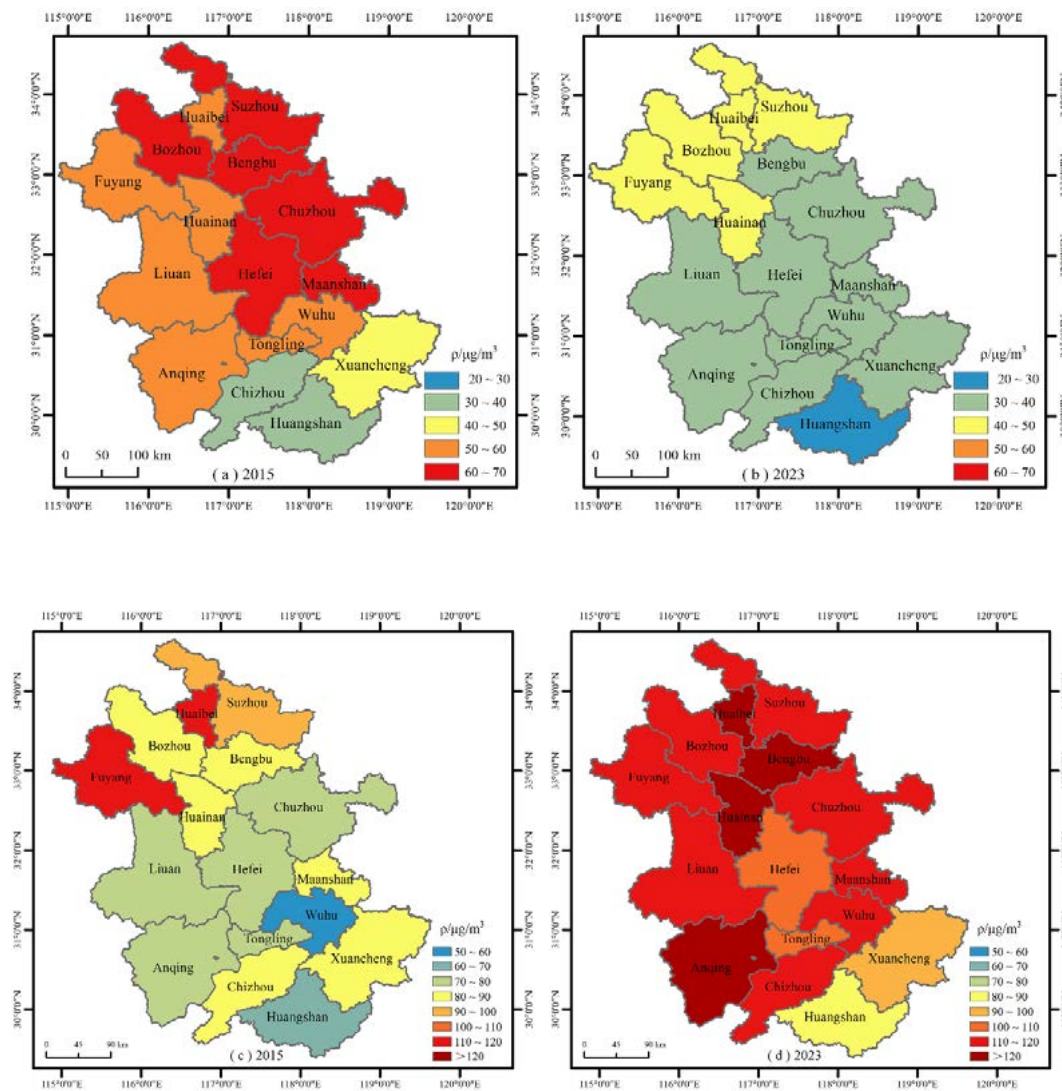


Fig. 2. Spatial distributions of annual mean $PM_{2.5}$ and 90th percentile O_3 -8h concentrations in Anhui Province in 2015 and 2023. (a, b) $PM_{2.5}$ in 2015 and 2023; (c, d) O_3 -8h in 2015 and 2023.

and 40.14%, respectively. The concentration of Huangshan was the lowest, with an average of $77.45 \mu g/m^3$ in 7 years, increasing from $61.63 \mu g/m^3$ to $81.22 \mu g/m^3$, an increase of 31.78%.

The average daily concentration of $PM_{2.5}$ and O_3 in Anhui Province from 2015 to 2023 (Figure-3) showed an opposite trend, with the increase of $PM_{2.5}$ concentration, the diffusion of particles and the inhibition of the chemical reaction of O_3 by reflection increasing (Wu et al., 2021), and the concentration of O_3 decreasing. In one day, the peaks of $PM_{2.5}$ and O_3 alternated, and the change of $PM_{2.5}$ concentration showed a “bimodal” distribution, with the highest concentration from 0:00 to 9:00, and the pollutants emitted on the ground by the inverse temperature effect between 0:00 and 9:00 were concentrated in the inversion layer, leading to the increase of concentration; at night, the heavy diesel vehicles had frequent activities, and the vehicle exhaust produced a large amount of pollutants. The frequent activities of heavy diesel vehicles at night, vehicle exhaust produces a large amount of $PM_{2.5}$, which makes the concentration of $PM_{2.5}$ increase. The daily maximum value is $50.17 \mu g/m^3$ at 9:00, then decreases from 10:00 to 16:00, with a minimum value of $39.68 \mu g/m^3$, and then rises again, with a second peak at $49.26 \mu g/m^3$ at 23:00. The concentration of O_3 exhibits a “single-peak”

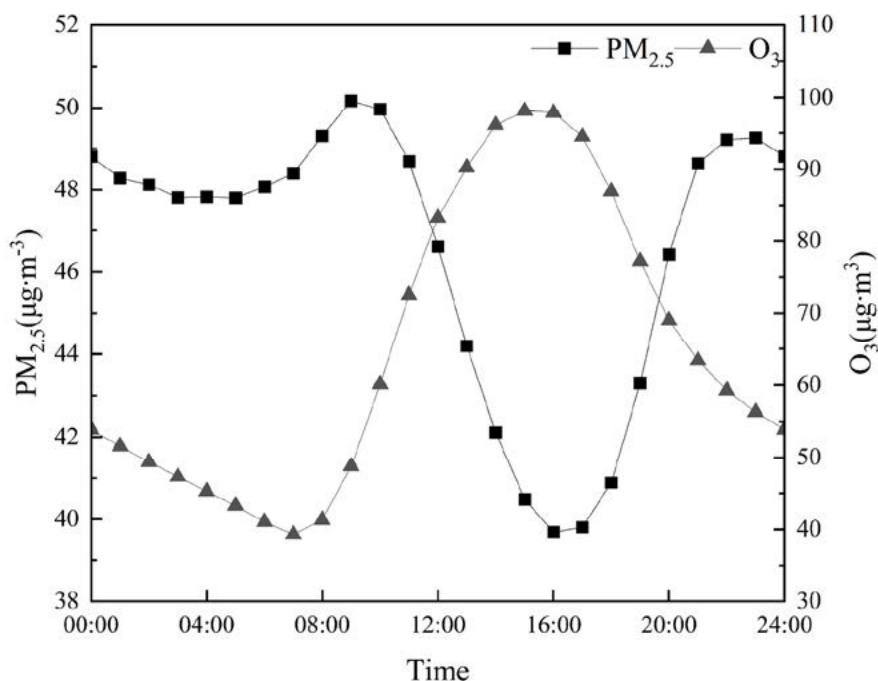


Fig. 3. Diurnal variation of PM_{2.5} and O₃ concentrations in Anhui Province from 2015 to 2023

variation, with concentrations between 14:00 and 17:00, which was related to the solar radiation and temperature, with the strongest light intensity in the afternoon, and the temperature rising in favor of ozone production. The minimum value of 39.32 µg/m³ occurred at 7:00, and the maximum value of 98.12 µg/m³ was reached at 15:00 after a rising trend from 8:00 to 15:00, and then a decreasing trend was observed from 15:00 to 23:00.

The number of days when PM_{2.5} and O₃ compound pollution appeared in Anhui Province from 2015 to 2023. The cumulative occurrence of compound pollution in 16 cities in Anhui Province during 9 years ranged from 8 to 361 days. The cities with more than 200d of compound pollution include Huaibei (361d), Huainan (263d), Suzhou (257d), Bengbu (255d), Chuzhou (240d), and Bozhou (229d), which are heavily polluted by industrial waste gas. Less polluted cities include Huangshan City (8d), Tongling City (52d), Xuancheng City (76d), Chizhou City (118d), and Wuhu City (123d).

Fig.4 shows the inter-annual and intra-annual trends of PM_{2.5}-O₃ compound pollution in Anhui Province. As depicted in Figure-4a, from the interannual compound pollution change trend graph, in general, the number of exceeding days of PM_{2.5} in Anhui Province gradually decreased from 2015 to 2023, and the number of exceeding days decreased from 4125d in 2015 to 2263d in 2023, with an average annual decrease of 12.9d in each city. From 2015 to 2018 and 2020 to 2023, the number of exceeding days of O₃ continued to increase, and the total number of exceeding days in Anhui Province is 871d by 2023, with an average annual rise of 5.07d per city. The overall trend of PM_{2.5}-O₃ compound pollution shows a decreasing trend from 2015 to 2023, and the total number of days of compound pollution is 81d in 2023.

The ratio of the number of exceeding days of O₃ and PM_{2.5} from 2015 to 2023 is respectively 0.271, 0.391, 0.393, 0.457, 0.460, 0.498, 0.424, 0.636, and 0.630, and the continued high value of the ratio from 2015 to 2020 indicates an increase in ozone pollution, with an improvement from 2022 to 2023. Figure-4b illustrates trend of compound pollution changes during the year, the compound pollution days were concentrated in April-October. The months with the most PM_{2.5}-O₃ compound pollution during the year were, in order of magnitude, May (634d), June

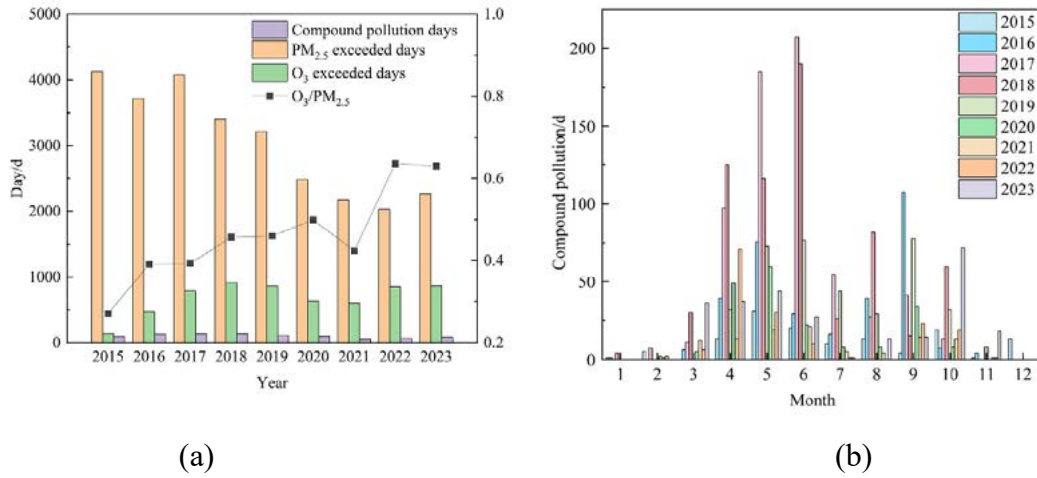


Fig. 4. Trend of interannual and intraannual $PM_{2.5}$ - O_3 compound pollution in Anhui Province from 2015 to 2023 (a) Interannual compound pollution change trend; (b) Trend chart of compound pollution during the year

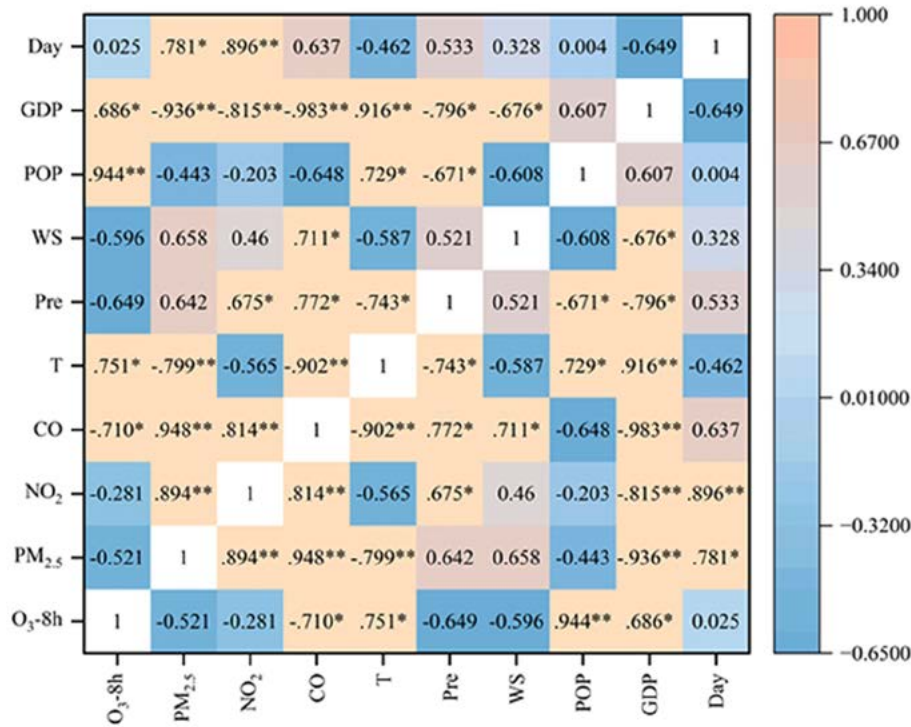


Fig. 5. Compound pollution and impact factors correlation in 16 cities from 2015 to 2023

(603d), April (476d), and September (330d), and it basically did not occur in the winter season.

Based on the complex influence of the impact factors on the number of compound pollution days, the correlation coefficients of the impact factors and the number of compound pollution days were calculated for 16 cities from 2015 to 2023, and the degree of correlation between them was verified, as shown in Figure-5. The results showed that the number of compound pollution days showed negative correlation with temperature and GDP; and positive correlation with O_3 -8h, $PM_{2.5}$, NO_2 , CO, Pre, WS, and POP. Among them, the correlation coefficient between the number of compound polluted days and NO_2 is 0.896, showing a highly significant positive correlation; the correlation coefficient with $PM_{2.5}$ is 0.781, showing a significant positive correlation; the correlation coefficients with CO and GDP are 0.637 and -0.649, showing a

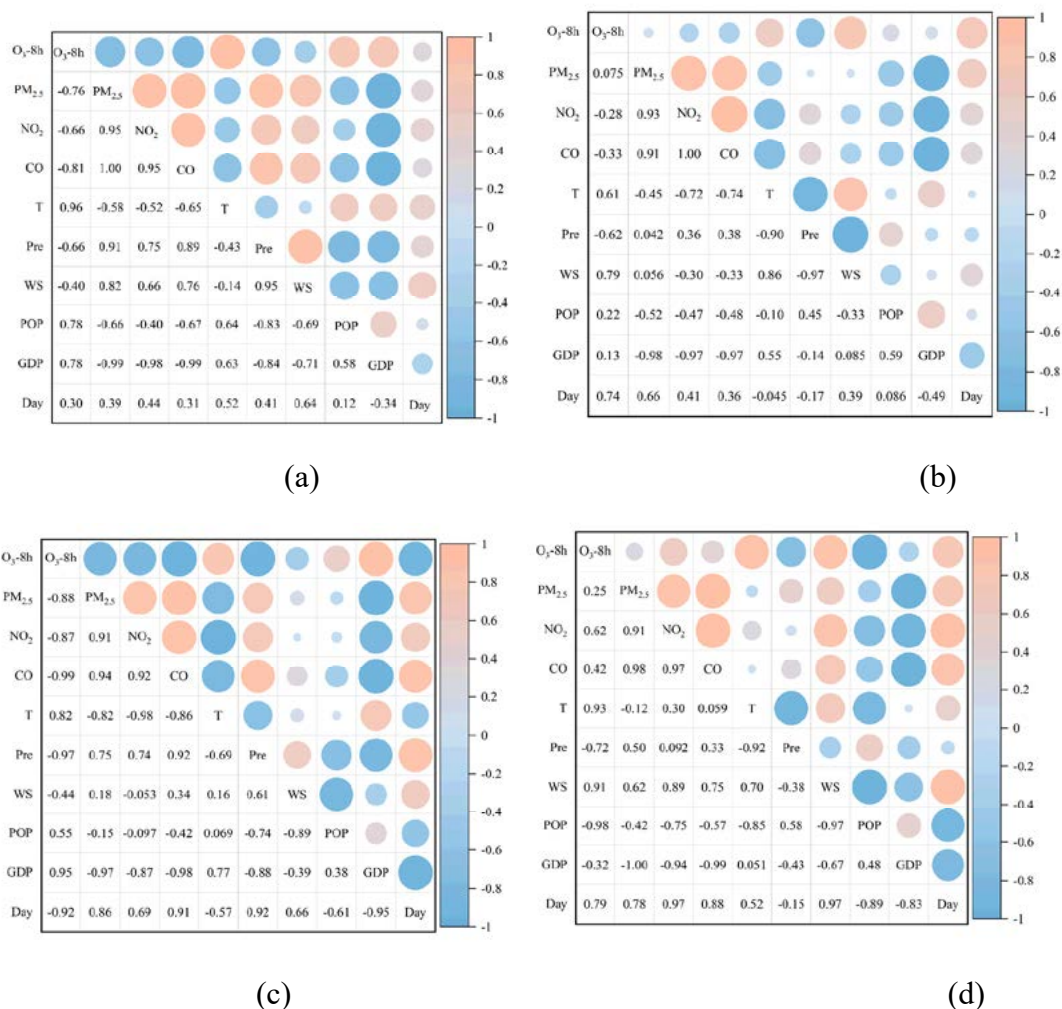


Fig. 6. Correlation of compound pollution and impact factors in all seasons in Anhui Province from 2015 to 2023 (a) Spring; (b) Summer; (c) Autumn; (d) Winter

strong correlation; the correlation coefficients with precipitation and temperature are 0.533 and -0.462, showing a moderate correlation; The correlation coefficients with O₃-8h and POP are 0.025 and 0.004, showing weak correlation. Thus PM_{2.5} and NO₂ are two key control parameters affecting the number of compound pollution days.

In order to study the correlation between the number of compound pollution days and meteorological and economic factors, meteorological data, POP and GDP data corresponding to each season of 16 cities were selected (Figure-6). As shown in Figure-6(a), the Huaibei Plain in Anhui Province has a dry climate in the spring, and its drought range is expanding. The northwest airflow is prevalent and the Jianghuai region is often affected by the Jianghuai cyclone, which is conducive to long-distance dust transport and local dust transport (Lv et al., 2023). It is easy to bring northern pollution precursors, resulting in increased pollutant accumulation when wind speed increases; the correlation between wind speed and pollution days in spring was the strongest ($r=0.64$), showing the characteristics of the greater the wind speed, the more pollution days. In spring, Anhui rain belt is located in the Jianghuai region (Huang et al., 2020), where soil is too wet and agricultural machinery cannot be operate. Farmers often burn straw in a short time without rain, so that CO and PM_{2.5} rise (the correlation between pre and CO, PM_{2.5} is 0.89 and 0.91, respectively, and the correlation between temperature and the CO, PM_{2.5}

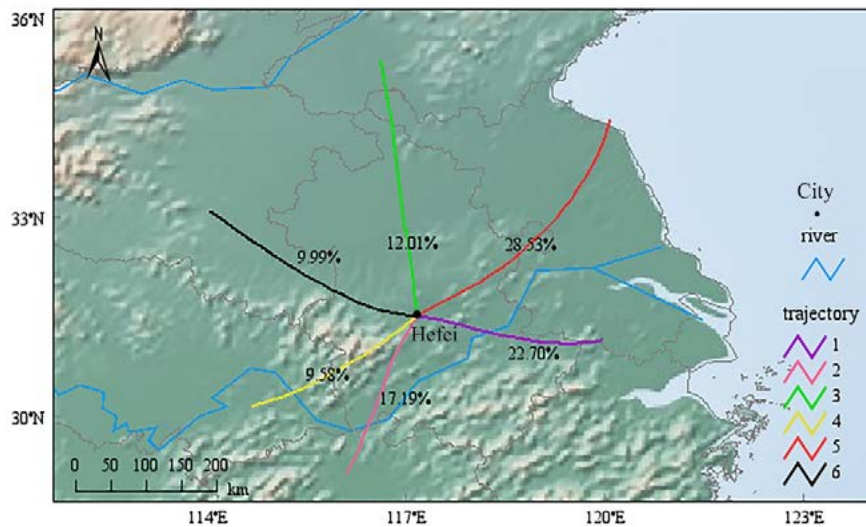


Fig. 7. Back trajectory change of air mass in Hefei under $PM_{2.5}$ - O_3 compound pollution in 2023

is -0.65 and -0.58 , respectively). The correlation between pollution days and economic factors in this season is relatively weak.

As shown in Figure-6(b), the strong solar radiation and high temperature weather in summer lead to the increase of photochemical reaction rate and the increase of precursor emission (Wang et al., 2020). The correlation coefficient between pollution days and O_3 -8h, $PM_{2.5}$ reaching the level of strong correlation, indicating that the two are the primary control variables driving the compound pollution in summer ($PM_{2.5}$ - O_3 synergistic exceeding standard), but the correlation coefficient between the two is only 0.075, the correlation is very weak. NO_2 ($r=0.41$), CO ($r=0.36$) and WS ($r=0.39$) showed a moderate positive correlation with the number of compound pollution days, indicating that primary emissions such as traffic exhaust and industrial combustion were still important sources of pollution in summer. At the same time, high temperature and rainy weather are conducive to the diffusion of particulate matter, which indirectly affects the concentration of $PM_{2.5}$ and O_3 , while the scavenging effect and convective diffusion caused by precipitation offset the potential promoting effect of high temperature on photochemical reaction, making temperature and precipitation negatively and weakly correlated with compound pollution days.

As shown in Figure-6(c), in autumn, due to the active typhoon brought a lot of water vapor to Anhui Province after entering the inland. Under the influence of topography, the water vapor rose and condensed to form topographic rain. At the same time, the mountains may hinder the diffusion of $PM_{2.5}$, resulting in the accumulation of pollutants in the basin (the correlation between pre and $PM_{2.5}$ is 0.75). Typhoon may transport straw burning pollutants from surrounding provinces such as Jiangsu and Henan to Anhui, and the low-pressure system before precipitation will accelerate the transmission of pollutants. The precipitation scavenging effect is less than the pollutant emission and inhibition effect (Zhong et al., 2017; Lu et al., 2014), so that the pollution day does not decrease but increases ($r=0.92$). O_3 -8h and GDP were strongly negatively correlated with pollution days ($r=-0.92$, -0.95), indicating that the reduction effect of autumn temperature reduction, photochemical reaction weakening and economic level improvement jointly inhibited the occurrence of compound pollution.

As shown in Figure-6(d), due to the large proportion of industry in Anhui Province, coal heating is selected to maintain indoor temperature in winter. Coal combustion emits a large amount of exhaust gas, which affects air pollution. In winter, people will choose to commute to

drive, so that NO_2 ($r=0.97$) and CO ($r=0.88$) are strongly positively correlated with the number of days of compound pollution. In winter, heavy pollution air masses in the upper reaches of Beijing, Tianjin and Henan moved southward with high winds, and were forced by topography to lift near-surface pollutants to high altitudes, and then returned to the ground with sinking airflow under certain weather conditions, indicating that the increase of wind speed in winter is induced to the accumulation of pollutants ($r=0.97$). There was a strong negative correlation between POP and GDP ($r=-0.89$, -0.83) indicating that higher economic level areas had cleaner heating methods and stricter emission control, which significantly reduced pollution days. The winter control factor has been driven by meteorological factors to economic factors.

To explore the regional transportation problem of $\text{PM}_{2.5}$ - O_3 compound pollution, this paper takes Hefei, the capital city of Anhui Province in 2023 as an example to calculate the air mass pollution change of compound pollution (Figure-7). Among them, C1 accounted for 22.7%, originating in Huzhou, via Xuancheng, Wuhu and Tongling; C2 with 17.2%, originating eastern Nanchang, via Jiujiang and Anqing; C3 has the longest trajectory, with a percentage of 12.0%, originating from Jining, via Huaibei, Suzhou and Huainan; C4 accounts for 9.6%, originating in the southern Wuhan, via Huanggang, Huangshi and Tongcheng; C5 accounts for 28.5%, originating from the south of Lianyungang, via Huai'an and Chuzhou; and C6 accounts for 10.0%, originating from the north of Xinyang City, via the counties of Xinyang and Liu 'an. This indicates that the pollution transmission from nearby cities in the east of Hefei also has an important influence on the $\text{PM}_{2.5}$ - O_3 compound pollution.

DISCUSSION

Anhui Province is located in the central and eastern part of China. It is an important part of the Yangtze River Delta Economic Zone and a key hub for regional pollutant transmission. Its atmospheric environmental quality directly affects the ecological security and joint prevention and control effectiveness of the Yangtze River Delta region. Currently the province $\text{PM}_{2.5}$. The concentration has been steadily improved, but the O_3 concentration is on the rise, and the compound pollution has become a key issue that restricts the continuous improvement of air quality. This study provides scientific support for the precise implementation of zoning classification prevention and control and coordinated emission reduction strategies in Anhui Province, and also provides reference for the compound pollution control of similar climate and location characteristics in the Yangtze River Delta and even the whole country.

From 2015 to 2023 the average annual $\text{PM}_{2.5}$ concentration in Anhui Province decreased by 34.11%, while O_3 showed a fluctuating upward trend, which was highly consistent with the research conclusions (Wu et al., 2024), revealing that Anhui Province is in the stage of 'PM_{2.5} continuous improvement and O₃ pollution prominent'. Spatially, $\text{PM}_{2.5}$ in Hefei and Chuzhou decreased by more than 40%, while O_3 in Wuhu, Anqing and Liu'an increased more significantly, supplementing the research gap at the provincial scale (Wang et al., 2026). The diurnal variation of $\text{PM}_{2.5}$ and O_3 showed a reverse characteristic: $\text{PM}_{2.5}$ showed a bimodal distribution with a peak at 9:00, and O_3 showed a single peak distribution with a peak at 14:00-17:00, which was consistent with the existing research (Zhu et al., 2025). O_3 production has obvious diurnal variation. In the morning, O_3 production is in the VOCs-controlled area. With the advance of photochemical reaction in the morning, NO_x is gradually consumed, the ratio of VOCs/ NO_x is gradually increased, and the ultraviolet light at noon is enhanced. O_3 is transformed into a VOCs- NO_x synergistic control area, which is further transformed into a NO_x controlled area in the afternoon (Yu et al., 2023). It indicates that O_3 is regulated by both NO and VOCs.

The number of compound pollution days is concentrated in April-October, and almost does not appear in winter (Guo et al., 2026), it shows that the warm season is the high incidence period of $\text{PM}_{2.5}$ - O_3 compound pollution., due to the weak photochemical activity in winter,

the contribution of secondary pollution is low, and almost no compound pollution occurs. The correlation results show that the number of days of compound pollution and NO_2 , $\text{PM}_{2.5}$. There is a significant positive correlation, which is consistent with the existing research conclusions (Wang et al., 2023). NO_2 is the core driving factor of compound pollution, so the synergistic emission reduction of precursors is the key to prevention and control. The correlation between $\text{PM}_{2.5}$ and O_3 in summer is different from the existing research (Wu et al., 2024). There is only a very weak positive correlation between the two. There is a Meiyu period in summer in Anhui Province, with more precipitation, high humidity and inhibited photochemical reaction. When the accumulation of $\text{PM}_{2.5}$ is high, O_3 is at a low value under the influence of weak photochemistry, showing a negative correlation, while the high value of O_3 during the summer drought period will promote the formation of $\text{PM}_{2.5}$, showing a positive correlation, and the two offset each other. At the same time, in summer, northern Anhui is affected by industrial emissions, and the composite pollution is high, while the background concentration of $\text{PM}_{2.5}$ in southern Anhui is low, and O_3 is affected by cross-regional effects. The two are negatively correlated, and the positive and negative values at the provincial scale are offset, and the correlation between the two is small.

The regional transport results are consistent with the research of (Zhu et al., 2025). Due to the dense cities in northern Anhui and the junction of Jiangsu and Anhui, the emission intensity of precursors is high, and there is no obvious blocking in the plain terrain, the prevailing wind in summer will promote the cross-city transport of pollutants (Chen et al., 2025). The transported precursors such as NO_x and VOCs will further strengthen the local photochemical reaction and simultaneously generate O_3 and secondary $\text{PM}_{2.5}$, resulting in a significant contribution of cross-regional transmission to composite pollution in the region. Therefore, it is necessary to give priority to the control of industrial and mobile source NO_x in Huaibei, Suzhou, Bengbu and other high-risk areas of compound pollution, and simultaneously control dust pollution; in Hefei, Chuzhou and other O_3 rising cities, the focus is on optimizing the energy structure and strictly controlling the fugitive emission of VOCs; Huainan and Fuyang, where $\text{PM}_{2.5}$ reduction is insufficient, strengthen the deep management of industrial sources and clean energy substitution; ecological zones such as Huangshan and Chizhou are strictly guarded against mobile source pollution caused by tourism. At the same time, in the cross-border sensitive areas of Jiangsu and Anhui, promote the joint prevention and control of industrial waste gas and straw burning in the two provinces.

CONCLUSIONS

The average annual change in $\text{PM}_{2.5}$ concentration in Anhui Province from 2015 to 2023 shows a decreasing trend, while the change in O_3 concentration shows a fluctuating upward trend. The cities with more obvious decreases in the annual average change value of $\text{PM}_{2.5}$ concentration during the study period include Hefei, Chuzhou, Tongling, and Maanshan; the cities with more obvious increases in the annual average change value of O_3 concentration include Wuhu, Anqing, and Liuan. The daily average changes of $\text{PM}_{2.5}$ and O_3 showed the opposite trend, with the peaks of the two alternately, the daily concentration of $\text{PM}_{2.5}$ shows a 'double-peak' distribution, which reaches the highest at 9:00; the daily concentration of O_3 shows a 'single peak' change, which reaches the highest at 14:00-17:00. Compound pollution days are concentrated in April-October, with the highest number of days occurring in May (634d), June (603d), April (476d), September (330d). It shows that meteorological factors such as precipitation, light and wind speed in the warm season have a greater influence on the number of compound pollution days than economic factors such as GDP and POP. The number of days of compound pollution occurring in Anhui Province from 2015 to 2023 shows a significant positive correlation with NO_2 and $\text{PM}_{2.5}$. Regional transport also affects $\text{PM}_{2.5}$ - O_3 compound

pollution, and Hefei, for example, also has a significant contribution to its $\text{PM}_{2.5}\text{-O}_3$ compound pollution from its eastern periphery, with the largest contribution from trajectories originating in the southern part of Lianyungang.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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