

Characteristics of low visibility during the Spring Festival in the Su-Wan region and investigation of its multifactorial causes—Integrated analysis of air pollution and meteorological conditions based on multi-source data

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Abstract. During the Spring Festival, the concentrated setting off of fireworks and the large-scale population movement can cause short-term drastic fluctuations in regional air quality and visibility. This study, conducted in Jiangsu and Anhui, used hourly air quality monitoring data from 2023 to 2025 before and after the Spring Festival, along with ERA5 meteorological reanalysis data, and applied time series and correlation analysis to explore the spatiotemporal distribution and driving factors of air pollution and low visibility during the Spring Festival. The results showed that the PM_{2.5} concentration in the study area during the Spring Festival was generally higher than that before the festival, with an increase of 52% in 2024. The interannual differences were closely related to the intensity of firework control policies. Setting off fireworks on New Year's Eve could increase PM_{2.5} by 95% to 618% within hours (with significant interannual variations), making it the dominant factor contributing to the short-term pollution spike. However, the reduction in traffic emissions during the Spring Festival (NO₂ decreased by 20% to 34%) was not the main cause of the increase in PM_{2.5}. Visibility was jointly regulated by PM_{2.5} and relative humidity. In a high-humidity environment (RH > 80%), medium concentrations of particulate matter could trigger low visibility events. These results can support differentiated firework control and joint air pollution prevention in Jiangsu and Anhui during the Spring Festival.

Keywords: Anhui-Jiangsu region, during the Spring Festival, air pollution, low visibility, fireworks, multi-factor causes

1. Introduction

The Su-Wan region is located in the eastern part of China, with a dense population, concentrated industries and a well-developed transportation network. It is an important part of the Yangtze River Delta region. Affected by the winter monsoon from East Asia and the urban heat island effect, the atmospheric layer structure in this region is stable in winter, with frequent inversion and overall poor diffusion conditions, resulting in frequent occurrences of air pollution and low visibility events [1, 2]. At the same time, the Spring

Festival, as the most important traditional festival in China, is often accompanied by large-scale population movements and concentrated fireworks and firecracker burning, which cause significant short-term fluctuations in the regional atmospheric environment. With the continuous advancement of China's ecological civilization construction, public awareness of environmental air quality has significantly increased. In the early part of this century, most cities across the country set off fireworks during the Spring Festival, which extensively exacerbated air pollution and reduced atmospheric visibility. As a result, many regions successively introduced policies for restricting or prohibiting the setting off of fireworks, and the regional pollution situation has been significantly improved. However, in the past two years, in order to inherit traditional New Year customs and create a festival atmosphere, many cities have moderately relaxed the control over fireworks setting off. How to balance the needs of folk customs and air pollution control has become a practical problem that current environmental management urgently needs to solve.

Numerous studies have confirmed the adverse effects of firecracker burning on the environment: Wang et al. [3] conducted a study in Nanjing and found that the large-scale concentrated burning of fireworks and firecrackers could cause the concentration of PM_{1.0} to increase at a rate of 15.5 μg/(m³·h), and the visibility to drop at a rate of 1.625 km/h. Jin et al. [4] pointed out that the burning of fireworks and firecrackers on New Year's Eve can increase the concentrations of PM₁₀, SO₂, and NO₂, and seriously affect the environmental air quality under poor atmospheric diffusion conditions. Compared with regular periods, the pollutant concentrations during the Spring Festival are prone to sudden increases in a short period of time, and the visibility drops sharply. This not only affects the regional air quality but also interferes with the operation of highways and air transportation, and poses a threat to the health of residents' respiratory systems [5].

In conclusion, conducting in-depth research on the characteristics and causal mechanisms of air pollution and low visibility during the Spring Festival in the Jiangsu-Anhui region is of great significance for formulating differentiated control policies for fireworks and firecrackers, optimizing traffic emission reduction plans during the Spring Festival travel rush, and improving regional air quality.

2. Literature review

Spring Festival air pollution driven by human activities remains a key research topic in atmospheric environmental science. Domestic and international scholars have conducted a large number of observational and simulation studies on aspects such as emission characteristics of fireworks, the role of meteorological conditions, and quantitative estimation of source contributions.

In terms of the direct pollution effects of fireworks and firecrackers, earlier studies by Zhang et al. [1] through comparative observations under different meteorological conditions revealed that concentrated burning in stable weather conditions could cause a several-fold increase in PM_{2.5} concentration, which was the core cause of the sudden increase in pollution during the New Year's Eve. Subsequent intensified observations in typical cities across the country further confirmed this pattern: Huang et al. [5] in Beijing's intensified observations during the Spring Festival confirmed that concentrated emissions during the festival could significantly alter the overall air quality of the city, Wang et al. [3] in Nanjing's hourly observations showed that the PM_{1.0} concentration rose at a speed of 15.5 μg/(m³·h) during the burning period, accompanied by a rapid decrease in visibility, Jin's [4] research also pointed out that the New Year's Eve burning would simultaneously increase the concentrations of various pollutants such as PM₁₀ and SO₂, and in unfavorable diffusion conditions, it is prone to forming persistent pollution.

At the level of emission contribution and component characteristics, previous studies have conducted multi-dimensional quantitative analysis of the source contribution magnitude of fireworks. Zhao et al. [6]

conducted a study in Anhui Province based on the $PM_{2.5}/CO$ ratio method, showing that the absolute contribution of fireworks to $PM_{2.5}$ could reach 4 to 701 $\mu g/m^3$, and spatially, it presented a distribution pattern of Central Anhui > Northern Anhui > Southern Anhui. Lu et al. [7] through chemical component analysis found that the impact of fireworks burning on NO_2 concentration was very limited, but it had a significant contribution to fine particulate matter and characteristic tracer components such as potassium ions. This difference in pollutant response has also become an important basis for identifying the contribution of the burning source.

The Yangtze River Delta features complex aerosol chemical compositions and prominent seasonal variation of $PM_{2.5}$, which forms a complicated atmospheric background for festival-related pollution episodes [8].

Meteorology dominates the severity and persistence of festival pollution events. Jia et al. [9] from the perspective of large-scale circulation research indicated that in winter, the Yangtze River Delta region was affected by weak transport of cold and dry air from the north, resulting in overall deviations in atmospheric diffusion conditions. The region was already prone to pollutant accumulation, and this background further amplified the environmental effects of concentrated emissions during festivals. Li et al. [10] in their research on the Beijing-Tianjin-Hebei and surrounding areas also showed that in 2024, the pollution situation in many areas across the country was relatively severe. During the New Year's Eve night, the hourly $PM_{2.5}$ concentration in over 250 cities exceeded 150 $\mu g/m^3$. This was also closely related to unfavorable meteorological diffusion conditions.

Overall, the existing studies mostly focus on the pollution characteristics of a single city or a single cause for analysis. Few comprehensive investigations have targeted the Jiangsu-Anhui region to examine combined air pollution and low visibility risks arising from the interaction of fireworks combustion, holiday travel traffic emissions and meteorological backgrounds. Therefore, this paper focuses on the multi-source data analysis in the Jiangsu-Anhui region in order to fill the research gap in this area and provide scientific support for the prevention of festival pollution.

3. Materials and methods

3.1. Source of data

The data used in this study fall into three categories:

(1) Air quality data: Obtained from the National Urban Air Quality Real-time Release Platform (<https://quotsoft.net/air/>), which includes hourly concentration data of $PM_{2.5}$, PM_{10} , NO_2 , CO , SO_2 , O_3 and other pollutants in 29 cities in Jiangsu and Anhui provinces [1, 3].

(2) Meteorological data: Derived from the ERA5 reanalysis data of the European Centre for Medium-Range Weather Forecasts [9], including 2m air temperature, 2m dew point temperature, 10m wind field and surface air pressure, with a temporal and spatial resolution of hourly and $0.25^\circ \times 0.25^\circ$.

(3) Information on the Spring Festival date and fireworks control policies comes from public reports and government documents [6]. The study period spans from January 25 to February 15 of the following year for 2023–2025 (about 20 days before and after the Spring Festival), totaling roughly 60 days per year.

3.2. Research methods

The visibility estimation adopts the Koschmieder formula:

$$V = 3.912/\sigma \quad (1)$$

where σ is the extinction coefficient [10]. The extinction coefficient is calculated by correcting the PM_{2.5} mass concentration and relative humidity using the hygroscopic growth factor, with the dry extinction efficiency set at 3.2 m²/g. The relative humidity is calculated using the August-Roche-Magnus formula based on the 2m air temperature and dew point temperature from ERA5 [9]. The study employs time series, stage comparison, spatial difference, and Pearson correlation analyses [7] to reveal the contributions of various factors to air pollution and low visibility during the Spring Festival from multiple perspectives.

The correlation between PM_{2.5} and NO₂ was calculated using the Pearson correlation coefficient, with the formula:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{[\sum (x_i - \bar{x})^2] \cdot [\sum (y_i - \bar{y})^2]}} \quad (2)$$

where x_i and y_i are the hourly average concentrations of PM_{2.5} and NO₂, respectively, in the Jiangsu-Anhui region during the Spring Festival period (from the 25th day of the 12th lunar month to the 15th day of the 1st lunar month) for each year, and n is the sample size (approximately 500 hours per year).

4. Results and methods

4.1. The temporal variation characteristics of PM_{2.5} and CO during the Spring Festival

Based on the hourly regional average concentrations over a three-year period (Figure 1), there are significant inter-annual differences in the PM_{2.5} pollution levels in the Jiangsu-Anhui region during the Spring Festival: The average PM_{2.5} concentration during the 2024 Spring Festival reached 77.5 µg/m³, significantly higher than 47.1 µg/m³ in 2023 and 57.4 µg/m³ in 2025, compared to the pre-festival baseline level, the concentration increase in 2024 was 52%, the highest among the three years. This phenomenon is consistent with the findings of Li et al. on a national scale [10], which suggest that the relaxation of fireworks and firecracker control in many areas that year was an important factor contributing to the overall increase in regional pollution. CO, as a typical tracer for incomplete combustion of fossil fuels and biomass, shows a strong synchronicity in its concentration changes with PM_{2.5}, especially with concentration peaks occurring simultaneously on New Year's Eve, indicating that the two pollutants mainly come from the same source of combustion emissions [1, 7].

By further calculating the average values for the three stages: before the festival, during the Spring Festival holiday, and after the festival (Table 1), it can be observed that the PM_{2.5} concentration changes exhibit a typical "Spring Festival effect": in 2023, the concentration gradually increased across the three stages, rising from 43.7 µg/m³ before the festival to 48.2 µg/m³ after the festival, in 2024, it presented a sudden rise and then a sudden drop, with the concentration during the festival jumping significantly from before the festival and then rapidly falling back to 27.2 µg/m³ after the festival, in 2025, the overall pattern was similar to that of 2024, with the concentration during the festival (57.4 µg/m³) being significantly higher than the levels before and after the festival. The changes over the three years collectively indicate that the pollution emissions during the Spring Festival have a significant short-term pulse characteristic [3, 5]. The significant drops in the concentration after the festival in 2023 and 2025 also directly reflect the pattern in which the centralized emissions of fireworks and firecrackers stop after the holiday and the pollution level gradually subsides.

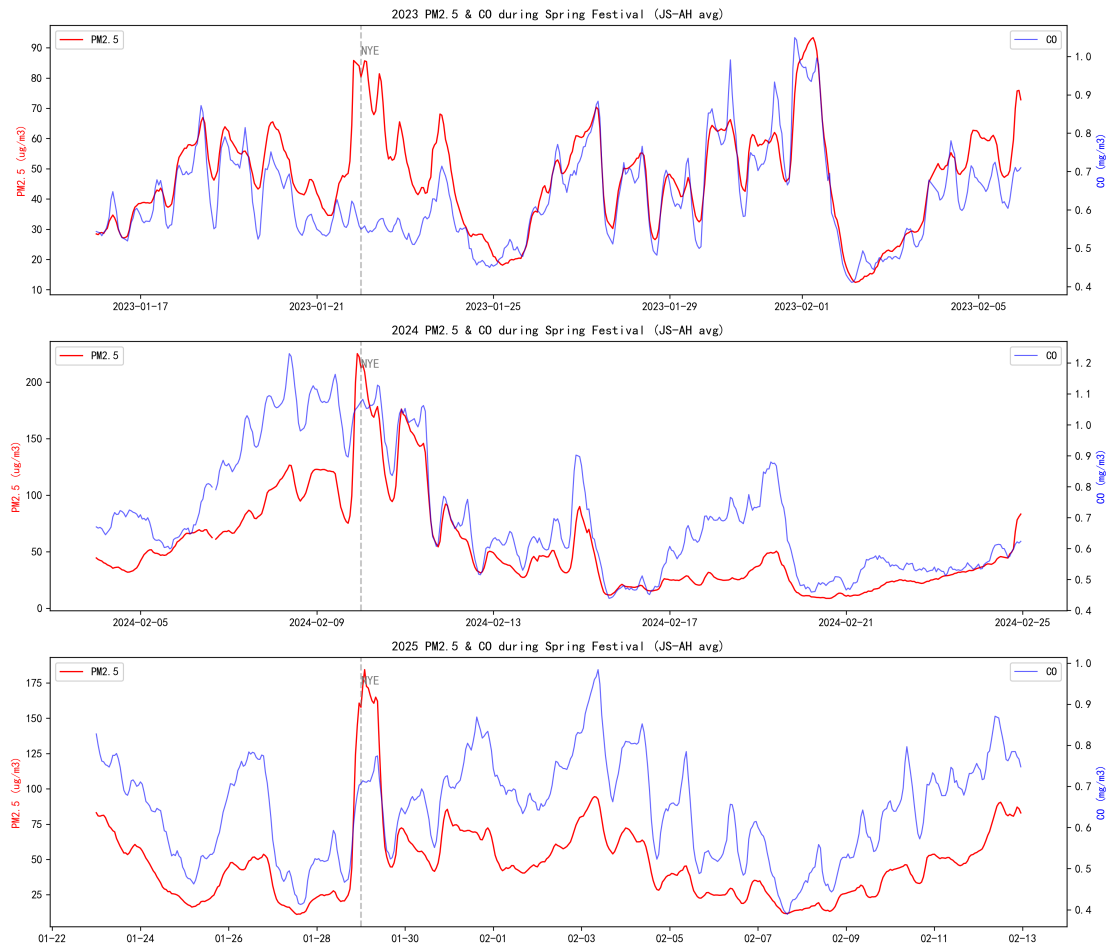


Figure 1. Hourly variations of PM_{2.5} and CO during the Spring Festival period in the Jiangsu-Anhui region (2023–2025)

Table 1. Comparison of pollutant mean values in the Spring Festival period in Jiangsu and Anhui regions					
Year	Phase	PM _{2.5} (μg/m ³)	PM10 (μg/m ³)	NO ₂ (μg/m ³)	CO (mg/m ³)
2023	Pre-Festival	43.7	83.3	23.4	0.63
	Spring Festival	47.1	89.1	15.5	0.61
	Post-Festival	48.2	85.3	30.8	0.67
2024	Pre-Festival	51.1	60.3	19.9	0.70
	Spring Festival	77.5	102.2	20.2	0.80
	Post-Festival	27.2	38.6	15.6	0.59
2025	Pre-Festival	42.3	61.1	21.3	0.63
	Spring Festival	57.4	79.1	14.1	0.68
	Post-Festival	36.9	62.3	22.1	0.61

Note: Based on the first day of each year, the research period is divided into three phases: the pre-festival period (more than 4 days before the first day), the festival period (from the first day to the 8th day), and the post-festival period (from the 9th day onwards).

4.2. Spatial differences in PM_{2.5} levels between Jiangsu and Anhui provinces

By comparing the daily average PM_{2.5} concentration sequences during the Spring Festival in Jiangsu and Anhui provinces from 2023 to 2025 (Figure 2), it can be observed that the pollution evolution trends in the two provinces are highly synchronous. The peaks all occur during the night of the New Year's Eve and the early morning of the first day, indicating that the pollution process during the Spring Festival has a significant regional contiguous feature, and it does not occur independently in a single city. The main reason for this spatial coordination is the superposition of similar emissions and regional transport [6, 9].

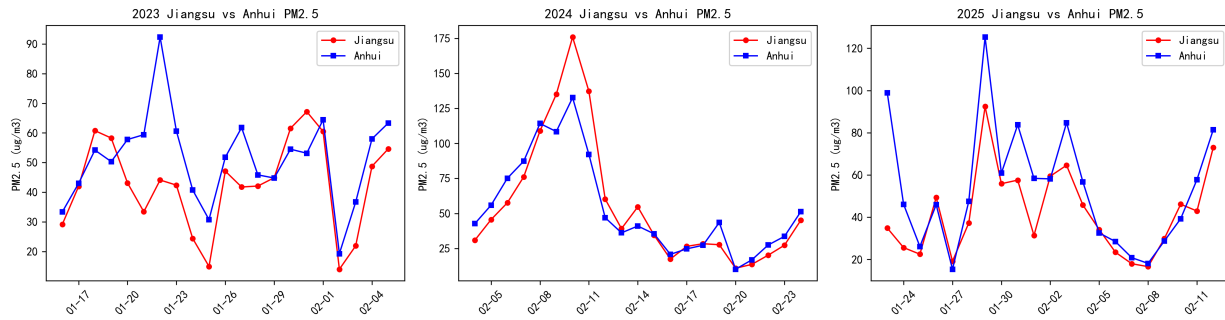


Figure 2. Comparison of daily mean PM_{2.5} between Jiangsu and Anhui provinces during the Spring Festival period (2023–2025)

From the perspective of the overall concentration level, the average PM_{2.5} value in Anhui Province during the Spring Festival was slightly higher than that in Jiangsu Province. Over the three years, a consistent gradient feature of higher values in the north and lower values in the south was observed. The potential influencing factors for this inter-provincial difference mainly include the following three points: First, in some cities in the northern part of Anhui Province, the control measures for fireworks and firecrackers are relatively lenient, and during the Spring Festival, the scattered burning for folk sacrifices is more common, resulting in a generally higher intensity of local emission sources, Second, in the areas north of the Huai River, there are decentralized heating emissions in winter, which further raised the basic concentration of particulate matter, Third, due to the transport effect of the northerly prevailing wind in winter, pollutants in the northern region tend to accumulate and linger in the border area between Jiangsu and Anhui. The peak pollution occurrence times in the two provinces were highly coincident, which also indirectly confirmed that the centralized burning of fireworks and firecrackers is the core driving factor triggering the synchronous increase of regional pollution (Figure 2).

4.3. The impact of fireworks and firecrackers on PM_{2.5}

From the hourly concentration evolution from the daytime of New Year's Eve to the early morning of the first day (Figure 3), PM_{2.5} shows a clear three-stage uplift pattern. Over the three years, it consistently exhibited a rapid increase in concentration starting from the period of firecracker setting off. The average PM_{2.5} concentration during the daytime of New Year's Eve 2023 was 43 µg/m³, rising to 74 µg/m³ on New Year's Eve night, and reaching 84 µg/m³ by the early morning of the first day, with an overall increase of approximately 95%, in 2024, due to the relatively high pollution base in the previous period, the concentrations in all time periods were at a high level. The daytime concentration reached 100 µg/m³, and at the New Year's Eve night, it further rose to 161 µg/m³, with the peak at 196 µg/m³ in the early morning of the first day, with a relative increase of approximately 96%, in 2025, the air quality during the daytime of New Year's Eve was relatively good (24 µg/m³), with the relative increase brought by the firecracker setting off being the most prominent.

The concentration soared to $174 \mu\text{g}/\text{m}^3$ in the early morning of the first day, with an increase of more than 6 times. This short-term jump feature is consistent with the long-term observation results in many domestic regions [1, 5], fully demonstrating that the concentrated firecracker setting off is the most direct trigger for the sudden increase of $\text{PM}_{2.5}$ during the Spring Festival. However, the differences in the increase rates between the two years are significant. The reasons might be that in 2023, compared to 2025, the control over the firecracker setting off was stricter, or there was a cold air front passing through on New Year's Eve, facilitating the dispersion of pollutants. The specific reasons need to be analyzed with the corresponding meteorological data and policy guidelines for auxiliary analysis.

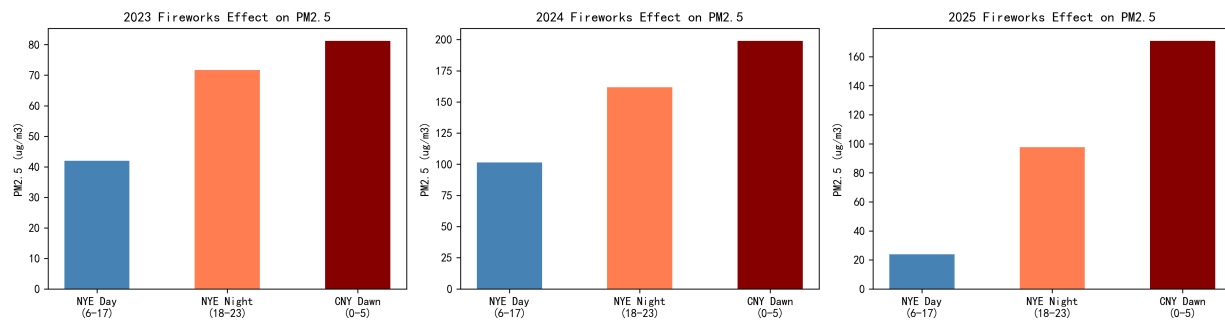


Figure 3. Three-stage changes in $\text{PM}_{2.5}$ concentration from New Year's Eve daytime to New Year's Day dawn (2023–2025)

A further comparison of the pollution duration over the three years reveals that the peak level of $\text{PM}_{2.5}$ after the fireworks display in 2023 was relatively lower and the recovery speed was faster, while the high concentrations in 2024 and 2025 persisted for a longer period. This difference is essentially regulated by meteorological diffusion conditions: when the atmospheric diffusion conditions are favorable, the particles generated by the fireworks display can be quickly diluted and are less likely to cause persistent pollution, conversely, in stable weather conditions, pollutants will accumulate continuously, exacerbating the pollution level [1]. From the perspective of pollutant component characteristics, the contribution of fireworks display to NO_2 is very limited, but it has a very strong effect on the increase in fine particulate matter concentration. This component difference also indirectly confirms the contribution characteristics of the emission sources [7]. Based on the $\text{PM}_{2.5}/\text{CO}$ ratio method, Zhao et al. [6] estimated source contributions and showed that during the concentrated fireworks display period, fireworks contributed an average of $159 \mu\text{g}/\text{m}^3$ to $\text{PM}_{2.5}$, which is basically consistent with the concentration increment observed in this study. Similar findings regarding sharp fine-particle pollution induced by firework combustion have also been reported in nearby Suzhou city [11].

4.4. Analysis of the impact of traffic emissions during the Spring Festival travel rush

As a characteristic tracer of urban traffic emissions, NO_2 concentration changes can indirectly reflect the intensity of vehicle activities [7]. Its evolution pattern can assist in determining the contribution of traffic sources to $\text{PM}_{2.5}$. As illustrated in (Figure 4), in 2023 and 2025, the NO_2 concentration showed a significant downward trend from before the festival to the Spring Festival holiday. It dropped to its lowest value a few days after New Year's Eve, corresponding to the outflow of urban population and a significant reduction in traffic activities during the Spring Festival travel period. Meanwhile, $\text{PM}_{2.5}$ significantly increased during the same period. The change trends of the two are different. Based on the hourly paired samples (2023: $n = 494$, 2024: $n = 504$, 2025: $n = 504$), the Pearson correlation coefficients between $\text{PM}_{2.5}$ and NO_2 were 0.566, 0.612, and 0.297 respectively, all passing the significance test ($p < 0.01$). Overall, it was a moderately weak

correlation, indicating that traffic emissions were not the dominant contributing source for the increase in $\text{PM}_{2.5}$ during the Spring Festival. This further highlights the driving effect of fireworks and firecracker setting off on $\text{PM}_{2.5}$, as shown in Figure 4.

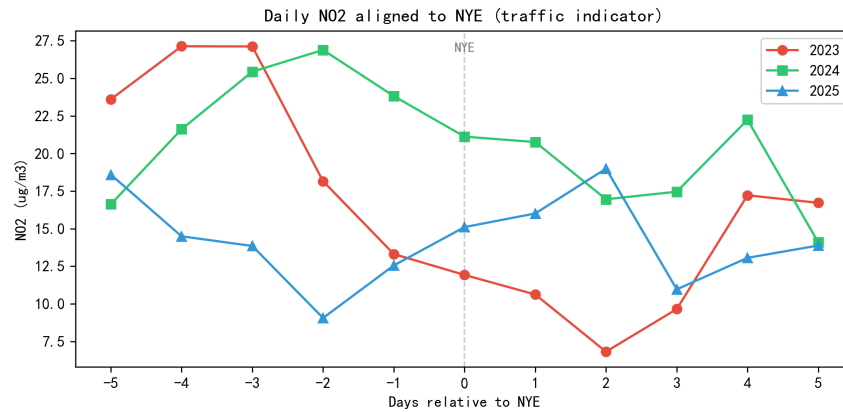


Figure 4. Daily mean NO_2 concentration aligned to New Year's Eve during the Spring Festival period (2023–2025)

In 2024, the decrease in NO_2 levels from before the holiday to the Spring Festival was significantly less than in the other two years. The concentration remained basically the same, while $\text{PM}_{2.5}$ levels rose sharply. This further confirmed that the main cause of the abnormal increase in $\text{PM}_{2.5}$ that year was the fireworks display rather than traffic emissions. The NO_2 concentration gradually rose in the later period of the holiday, corresponding to the recovery of traffic emissions brought about by the return trip during the post-holiday rush.

4.5. Characteristics and influencing factors of visibility changes

The sequence of visibility estimated using the Koschmieder formula in combination with ERA5 meteorological data [12] shows that the atmospheric visibility in the Jiangsu-Anhui region during the Spring Festival was not solely determined by the particulate matter concentration, but was the result of the combined effect of $\text{PM}_{2.5}$ and relative humidity (Figure 5). The visibility during the Spring Festival period fluctuated relatively little overall, with the average values for the pre-festival, festival, and post-festival stages being 22.4 km, 21.0 km, and 20.8 km respectively. The variation was not significant, and during these periods, the $\text{PM}_{2.5}$ concentration and relative humidity (RH ranging from 58% to 61%) remained stable, without any significant enhancement of extinction conditions.

The low visibility event that occurred before the New Year in 2024 better demonstrated the regulatory role of humidity: at that time, the $\text{PM}_{2.5}$ concentration in the area was only $51 \mu\text{g}/\text{m}^3$, much lower than $78 \mu\text{g}/\text{m}^3$ during the Spring Festival holiday, but the relative humidity reached 83%. Eventually, the visibility dropped to 7.7 km. The core mechanism of this phenomenon lies in the hygroscopic growth of fine particulate matter under high humidity conditions, where the equivalent particle size increases significantly, thereby enhancing the atmospheric extinction capacity, and ultimately causing a sharp drop in visibility. It can be seen that the low visibility event during the Spring Festival cannot be simply attributed to the increase in particulate matter pollution, the amplification effect of relative humidity is also a key influencing factor [1, 12]. Wang et al. [3] also observed in the same period in Nanjing that the rate of visibility decline during the fireworks display

period could reach 1.625 km/h, indicating that the fine particulate matter emitted during the fireworks display can rapidly deteriorate visibility within a short time.

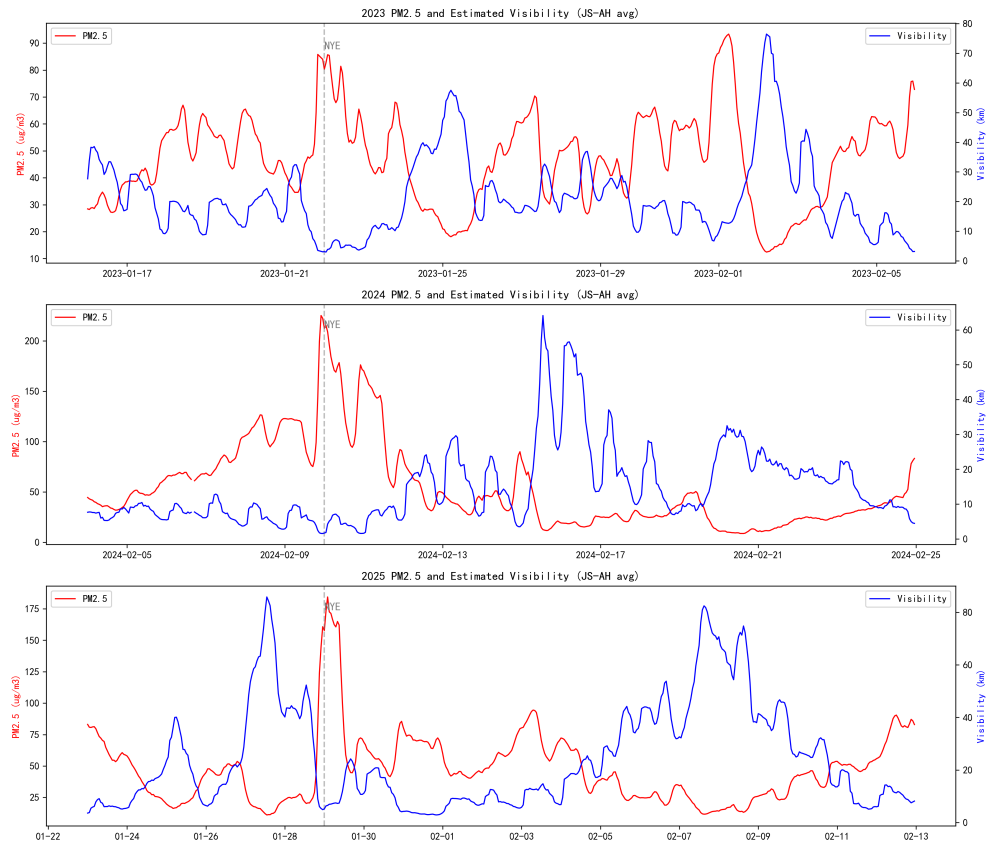


Figure 5. Hourly PM_{2.5} and estimated visibility during the Spring Festival period in the Jiangsu-Anhui region (2023–2025)

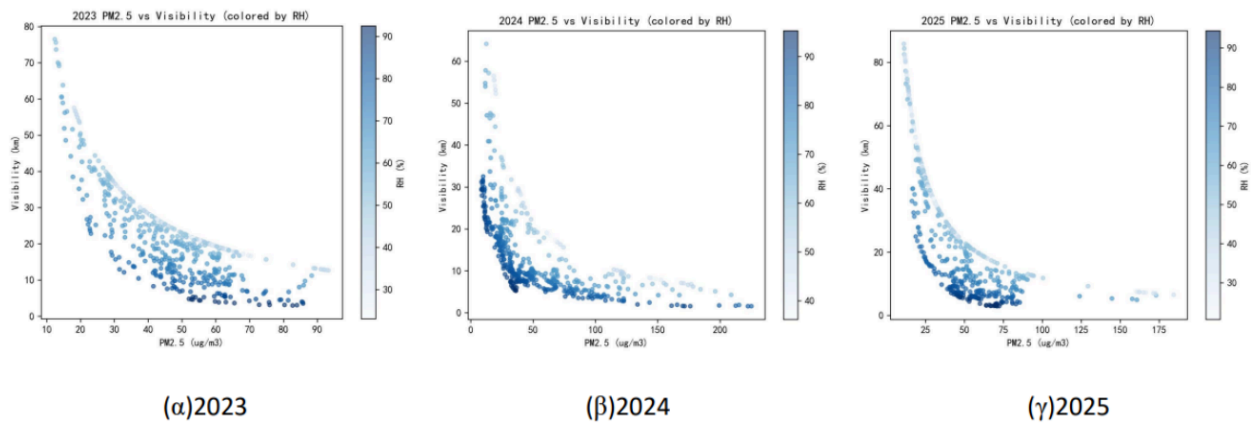


Figure 6. Scatter plot of PM_{2.5} versus estimated visibility colored by relative humidity (2023-2025)

In the post-festival period of 2025, visibility reached 35.0 km, the highest in three years. The corresponding PM_{2.5} level is 37 µg/m³ and the relative humidity is only 49%. The joint modulating effect of PM_{2.5} and relative humidity on visibility can be visualized from the scatter-plot analysis (Figure 6). The scatter plot (Figure 6) shows a significant negative correlation between PM_{2.5} and visibility. However, under the same

PM_{2.5} concentration, the visibility in high-humidity conditions is significantly lower than that in low-humidity conditions, which reveals the important regulatory role of relative humidity in this process.

5. Discussion

5.1. Multifactor coupling mechanism

Based on the above results, a multi-factor coupling mechanism for air pollution and low visibility during the Spring Festival in the Jiangsu-Anhui region can be established. From the perspective of the large-scale circulation background, the winter in the Yangtze River Delta is affected by the weak transport of cold and dry air from the north, and the overall atmospheric diffusion conditions of the region are poor, providing the basic meteorological conditions for the accumulation and maintenance of pollution [9]. This also makes it difficult for the pollutants emitted during the concentrated period to be rapidly diluted and dispersed. From the perspective of human emissions, the centralized burning of fireworks is the direct driving factor triggering the short-term sharp increase of PM_{2.5}, and its pulse-like emission characteristics directly determine the pollution peak from New Year's Eve to the first day of the Lunar New Year. In contrast, the impact of Spring Festival travel rush emissions shows obvious time differences: NO₂ concentration changes indicate that traffic contributions are concentrated in the two peaks of returning home before the festival and returning after the festival, while the emission intensity during the holiday has significantly decreased and is not the dominant factor causing the pollution increase during the festival. At the local scale, wind speed and relative humidity are the key factors regulating the evolution of the pollution process and visibility changes: Wind speed directly determines the diffusion rate of pollutants and affects the duration of the pollution peak, relative humidity, through the effect of particle absorption growth, significantly increases the atmospheric extinction effect and reduces visibility under the same particle concentration, and is an important regulating factor for low visibility events [12].

5.2. Limitations and prospects of the study

This study still has several aspects that need to be improved. Firstly, the visibility data is estimated using the Koschmieder formula combined with ERA5 reanalysis data [12], without verification against ground-measured visibility data. Although it can reflect the overall trend, it may have certain deviations from the actual observation values in extreme high-humidity and dense fog scenarios. Secondly, the emission contribution of fireworks is only indirectly estimated from the sudden increase in PM_{2.5} concentration, without corresponding emission inventories and chemical component data, making it difficult to separate the influence of meteorological conditions and emission changes. Future research can collect PM_{2.5} samples and use K⁺, Cl⁻, etc., as characteristic tracer components to conduct more precise source analysis [6]. Thirdly, the study only covers three Spring Festival periods from 2023 to 2025, with a limited sample size. The persuasiveness of attribution to factors such as policy adjustments and interannual meteorological differences is still insufficient.

Further research can be further deepened in two aspects: On one hand, methods such as the PMF receptor model and WRF-Chem numerical simulation can be introduced [4] to quantitatively break down the contribution ratios of different sources such as fireworks, transportation, and industry, on the other hand, the research time series can be extended, and more years of control policies and pollution processes can be included to enhance the universality and reliability of the conclusions.

6. Summary and conclusion

Based on the air quality monitoring data during the pre- and post- Spring Festival periods in the Jiangsu-Anhui region from 2023 to 2025 and the ERA5 meteorological reanalysis data, this paper summarizes the spatiotemporal variation characteristics of air pollution and visibility during the Spring Festival, and explores the coupling mechanism of multiple factors. The main conclusions obtained are as follows:

Firstly, during the Spring Festival in the Jiangsu-Anhui region, the PM_{2.5} concentration was generally higher than the pre-festival levels, and there were significant inter-annual differences. Among them, 2024 witnessed the most severe pollution, with the concentration rising from 51.1 µg/m³ before the festival to 77.5 µg/m³ during the holiday, an increase of 52%, in 2023 and 2025, the increases were 8% and 36% respectively. The pollution evolution trends in Jiangsu and Anhui provinces were highly synchronous, indicating that the pollution process had a regional contiguous feature rather than occurring independently in individual cities. The inter-annual concentration differences might mainly be related to the tightness or looseness of the control policies on fireworks and firecrackers in different regions.

Secondly, the concentrated fireworks display on New Year's Eve is the direct driving factor for the sudden increase of PM_{2.5}. During the fireworks display period, the PM_{2.5} concentration can increase by over 95% within several hours. In 2025, due to the relatively lower base concentration before the festival, the relative increase was more prominent. As a tracer for incomplete combustion, the CO concentration peaks simultaneously with PM_{2.5}, confirming that the two types of pollutants come from the same source of combustion emissions. This pattern is also consistent with the existing research conclusions [1, 5].

Thirdly, the traffic emissions during the Spring Festival travel rush are not the primary cause of the increase in PM_{2.5} during the holiday period. During the Spring Festival, the concentration of NO₂ decreased by 20% to 34%, indicating a significant reduction in urban traffic activity intensity. However, at the same time, PM_{2.5} showed an upward trend. The contrasting changes between these two indicators provide evidence that the burning of fireworks and firecrackers is the main contributor to the increase in pollution during the holiday.

Fourth, visibility is jointly regulated by PM_{2.5} and relative humidity, rather than solely determined by the concentration of particulate matter. A typical case of low visibility before the 2024 festival was as follows: at that time, the PM_{2.5} concentration was only 51 µg/m³, but the relative humidity reached 83%, resulting in visibility dropping to 7.7 km, conversely, in the post-festival period of 2025, the PM_{2.5} concentration was 37 µg/m³, and with relative humidity only 49%, visibility rose to 35.0 km. This indicates that a high-humidity environment significantly amplifies the scattering effect through the hygroscopic growth of particulate matter. Assessing the risk of low visibility cannot merely rely on the concentration of particulate matter.

In conclusion, the air pollution in the Jiangsu-Anhui region during the Spring Festival was mainly driven by the concentrated emissions from fireworks and firecrackers. The contribution of traffic emissions was relatively limited. The low visibility was the result of the combined effect of particulate matter pollution and meteorological conditions. It is recommended to implement differentiated control policies for fireworks and firecrackers based on local conditions during the Spring Festival. At the same time, enhanced low-visibility warnings should be implemented in high-humidity weather to ensure the safety of regional traffic and public health.

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