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# Characteristics of Air Pollution and Their Relationship with Meteorological Parameters: Northern Versus Southern Cities of China

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**Abstract:** Air pollution shows a generally decreasing trend from the north to the south in China since 2013 (GB3095-2012, the current standard for monitoring). However, an opposite observation was recorded in 2017, especially in winter. In this study, we collected monitoring data of six air pollutants in 2016 and 2017, from a northern city (Beijing) and a southern city (Nanjing) for comparison. As air pollution was highly dependent upon meteorological conditions, we further analyzed their relationships to explain this abnormal phenomenon. Seasonal averaged $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$ were negatively correlated with wind scale (WS) while 8-h $O_3$ exhibited an opposite relationship. Relative humidity (RH) has opposite effects on the concentrations of different pollutants in Beijing and Nanjing. The 8-h $O_3$ showed the closest positive correlation with temperature (T), which is due to its formation mechanism. In Beijing, decreased RH, together with more wind from northwest in winter, resulted in an improved air quality in 2017. In Nanjing, WS, RH, T, and wind direction fluctuated within a narrow range in each season, leading to relatively stable pollutant concentrations. These results suggest that meteorological conditions are important factors to evaluate the air quality and implement control measures.

**Keywords:** air pollution; meteorological parameters; Beijing; Nanjing

## 1. Introduction

Over the past decades, China has achieved great progress in social and economic areas and has attracted worldwide attention. Due to this rapid development, however, China has been experiencing severe air pollution problems, which in turn threatens the sustainable development [1–3]. Air pollutants pose timely issues and potential risks to human health and ecosystem. It has been widely demonstrated that exposure to polluted air could increase the morbidity of many illnesses and induce premature mortality [4,5]. For example, Rohde and Muller [6] estimated that ambient air pollution caused 1.6 million premature deaths over China in 2014.

Air pollution in China has raised great concern from the government, the public, and scientists [7]. The most stringent regulation "Air Pollution Prevention Action Plan" was enacted on September 10, 2013 and implemented on 1 January 2015. Since 2013, the real-time monitoring of six air pollutants, i.e., particles with an aerodynamic diameter equal to or less than 2.5 μm ($PM_{2.5}$), particles with an aerodynamic diameter equal to or less than 10 μm ($PM_{10}$), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$),

carbon monoxide (CO), and ozone ($O_3$), have been conducted and corresponding data were released to the public in major Chinese cities. Although the total concentrations of these air pollutants decreased significantly in recent years, unfortunately, the pollution levels in most Chinese cities still exceed the standards recommended by the World Health Organization [8]. According to the monitoring data, air quality in northern China is poorer than that in southern China (Bulletin of the Ministry of Ecology and Environment, http://www.mee.gov.cn/hjzl/zghjzkgb/lnzghjzkgb/index.shtml). This could be partially explained by the winter heating and unfavorable dispersion conditions in northern cities. Interestingly, in the year 2017, particularly in winter, visible and detectable improvement in air quality was recorded in the northern city Beijing, even better than that in many southern cities. However, to our knowledge, there is no case study focused on this abnormal phenomenon as well as the underlying mechanisms.

Air pollution is affected by multiple factors, including pollutant emissions, meteorological conditions, terrain, pollutant transport, and transformation [9–11]. Previous studies revealed that both pollutant emissions and meteorological conditions dominated pollutant concentration trends [12,13]. Beside emission control, favorable meteorological conditions have significant impacts on air quality by determining dispersion conditions and thus atmospheric environmental capacity [14]. Local and regional meteorology (e.g., wind speed and wind direction) are responsible for the spatial and temporal distribution of air pollutants [15]. Furthermore, weather conditions (e.g., temperature and relative humidity) also play an important role in chemical reactions, and then change the reacted pollutant concentrations [16]. He et al. [17] reported that more than 70% of the daily concentration variation over China could be explained by the meteorological conditions. However, there is still a knowledge gap between meteorological parameters and their impacts on concentrations of air pollutants in a specific region.

Therefore, the aim of the present study was to clarify the interactions between meteorological factors and ambient air quality, and unfold the reasons why Beijing had increased "blue skies" in 2017. We first collected the concentrations of six criteria air pollutants in 2016 and 2017, from Beijing and the southern city Nanjing [18]. In comparison, Nanjing is a major city in the well-developed Yangtze River Delta in Southern China, which is also experiencing serious air pollution [19,20]. Simultaneously we investigated the meteorological data (including temperature, relative humidity, wind scale, and wind direction), and then explored the relationship between air pollution and these parameters. Our results can provide a better understanding of the mechanisms that lead to or reduce pollution, and enhance the accuracy of air pollution forecast under various meteorological conditions.

## 2. Methods

### 2.1. Study Cities

Beijing (39°90′ N, 116°40′ E) and Nanjing (32°07′ N, 118°78′ E) were selected in this study (Figure 1). Beijing, the capital of China, is located in the northern part of North China Plain (NCP) and is surrounded by the Taihang and the Yanshan mountains to the northeast, northwest, and southwest sides. Nanjing is the provincial capital of Jiangsu and one of the major cities in the Yangtze River Delta (YRD), South China. Both NCP and YRD have suffered from severe air pollution problems in recent years. Beijing and Nanjing are representative cities in these two regions, respectively, due to their high population density and well developed economies [21]. However, the meteorological conditions in these two cities are dramatically different. Beijing has a typical monsoon-influenced climate, characterized by hot, humid summer and cold, dry, and windy winter [22]. Spring and fall in Beijing could be affected by sandstorms from the Mongolian Gobi Desert [23]. Differently, Nanjing is located in the subtropical humid climate area, with moist summer and winter. Therefore, the different climatic conditions of these two cities could provide typical examples for studying the relationships between atmospheric pollutants and meteorological parameters in China.
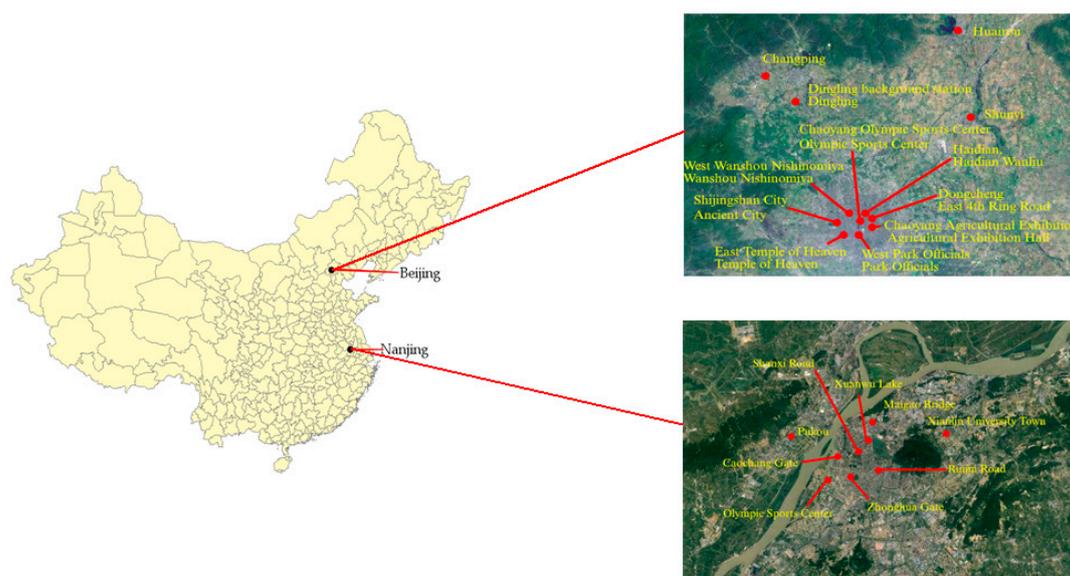
**Figure 1.** Sampling sites in Beijing and Nanjing on Google maps.

*2.2. Data*

Hourly concentrations of air pollutants including $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, $NO_2$, and $O_3$ in Beijing and Nanjing from March 2016 to February 2018 were collected from http://www.cnemc.cn/. Meteorological parameters, including temperature (T), relative humidity (RH), wind direction, and wind scale (WS) were also acquired during the same period from the website of the China Meteorological Data Sharing Service System Administration (http://data.cma.cn/site/index.html). A sanity check was conducted on the initial data to delete any problematic data points. Valid hourly average parameters were then averaged using data from nine national air quality monitoring sites in Nanjing (i.e., Pukou, Xianlin University Town, Maigao Bridge, Ruijin Road, Shanxi Road, Caochang Gate, Olympic Sports Center, Zhonghua Gate, Xuanwu Lake). As for Beijing, there were 21 national air quality monitoring sites in different districts (i.e., Dingling background station, Dingling, Changping, Huairou, Shijingshan City, Ancient City, Shunyi, Chaoyang Olympic Sports Center, Olympic Sports Center, West Park Officials, Park Officials, Haidian, Haidian Wanliu, Dongcheng, East 4th Ring Road, Chaoyang Agricultural Exhibition Hall, Agricultural Exhibition Hall, West Wanshou Nishinomiya, Wanshou Nishinomiya, East Temple of Heaven, Temple of Heaven). Daily average meteorological parameters and pollutant concentrations were calculated only when there were more than 16 h of valid data within that day. The daily $O_3$ concentrations were calculated by averaging the maximum concentrations of 8-h (8-h $O_3$). Four seasons were defined as the following categories: spring (March to May), summer (June to August), fall (September to November), and winter (December to February). Pearson correlation analyses were then conducted between each meteorological parameter (T, RH, and WS) and pollutant concentration for each season in each city whereby we used routines of the software MATLAB. Besides, we screened out the heavily polluted days (when the ambient air quality index was more than 150), determined their wind direction as the one with the highest frequency, and calculated the cumulative contribution ratios of each wind direction. Eight wind directions were categorized in this study: N (337.5–22.5°), NE (22.5–67.5°), E (67.5–112.5°), SE (112.5–157.5°), S (157.5–202.5°), SW (202.5–247.5°), W (247.5–292.5°), NW (292.5–337.5°).

## 3. Results and Discussion

*3.1. Data Overview*

Figure 2 shows the annual mean concentrations of $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, $NO_2$, and 8-h $O_3$ in Beijing and Nanjing during the study period. For all six air pollutants (except 8-h $O_3$ in Beijing and $NO_2$

in Nanjing), downward trends were observed in their annual averaged concentrations, indicating the positive effects of China's National Air Pollution Control Action Plan since 2013. However, air pollution needs to be controlled continuously, as evidenced by the frequent occurrence of polluted days in both Beijing and Nanjing. For example, the annual averaged $PM_{2.5}$ concentrations in 2017 were 49.6 μg $m^{-3}$ (Beijing) and 43.3 μg $m^{-3}$ (Nanjing), respectively, far exceeding the Chinese Ambient Air Quality Standards (CAAQS: 15 μg $m^{-3}$ for Grade I and 35 μg $m^{-3}$ for Grade II). Similarly, the annual average concentrations of $PM_{10}$ in 2017 were also higher than the CAAQS Grade II (70 μg $m^{-3}$). Further, the daily average concentrations of $PM_{2.5}$ and $PM_{10}$ in 2017 still often exceeded the 24 h standards (Beijing: 69 days and 25 days, Nanjing: 45 days and 28 days, respectively) (Figures 3–6). As for the gaseous species, their concentrations in Nanjing were generally higher than those in Beijing, especially in 2017. This result was quite different from that reported in previous studies, which may be partially explained by the policy factors [24]. Policies of emission reduction (e.g., replacing coal supply with gas supply, upgrading of industrial structure) were implemented more effectively in Beijing than Nanjing these years [25,26]. Generally, $SO_2$ and CO concentrations in both Beijing and Nanjing met the Grade II annual or daily standards of CAAQS. The annual averaged $NO_2$ concentration in Beijing was higher than that in Nanjing in 2016, while contrasting results were observed in 2017. Nanjing had higher 8-h $O_3$ concentrations than Beijing, which was in compliance with their latitudinal distribution. It should be noted that the concentrations of 8-h $O_3$ in both cities have not been decreased markedly, and thus more attention should be paid to the control of $O_3$ and the risks of population exposure to $O_3$.
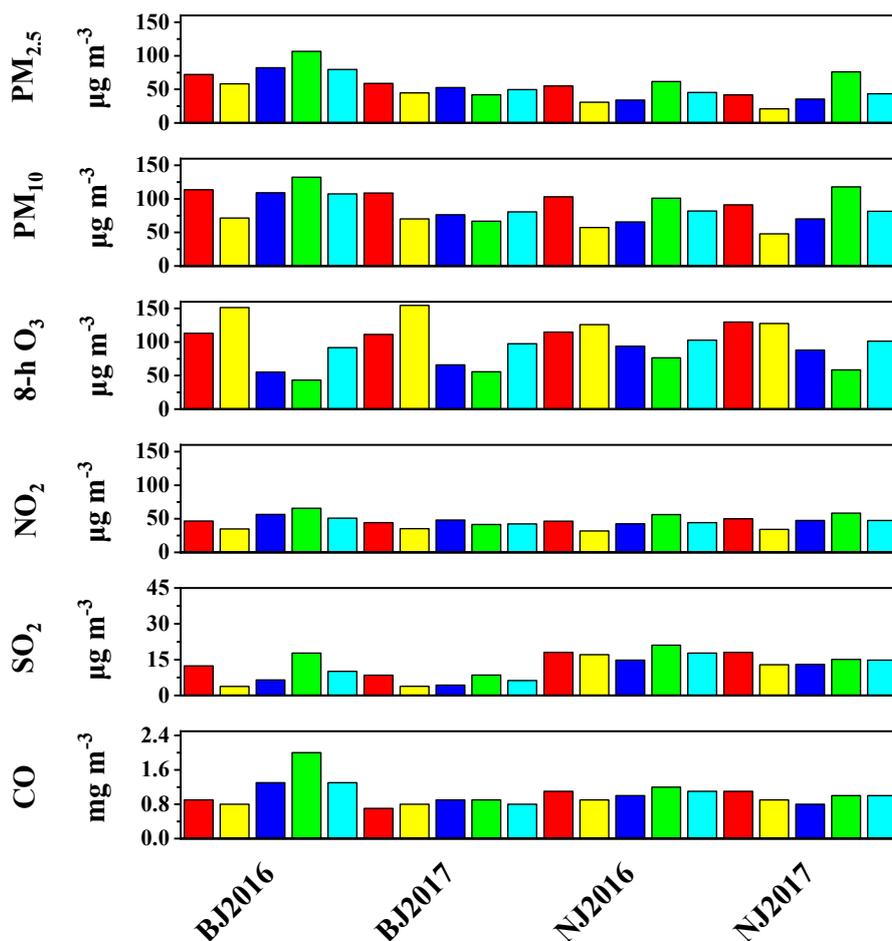


**Figure 2.** Seasonal and annual average concentrations of six criteria air pollutants in different cities and years. Red, yellow, dark blue, green, and light blue represent spring, summer, fall, winter, and annual values, respectively.
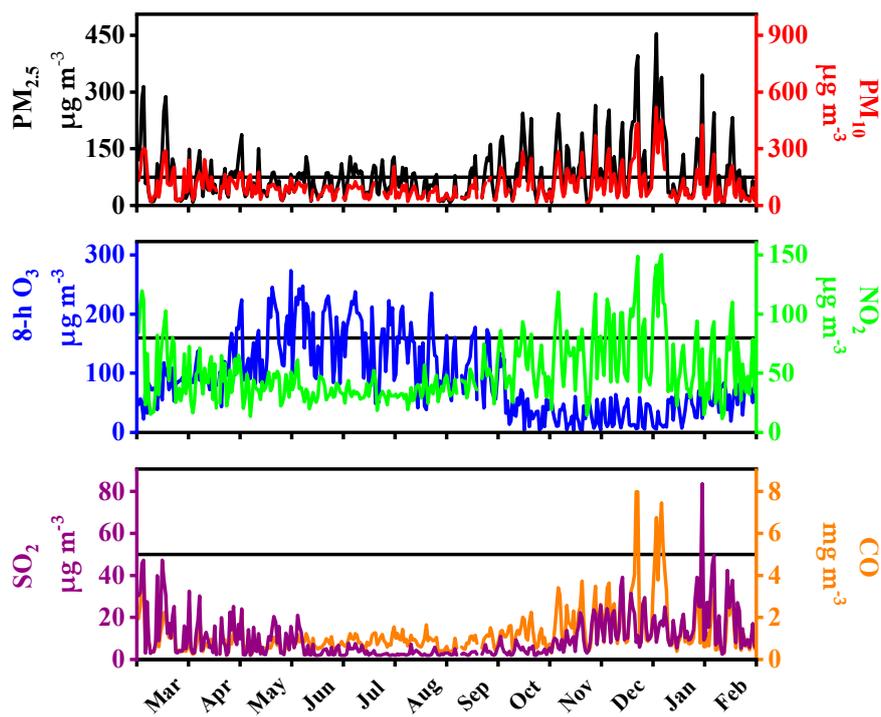
**Figure 3.** Daily average concentrations of $PM_{2.5}$, $PM_{10}$, CO, $NO_2$, $SO_2$, and 8-h $O_3$ in Beijing in 2016. The horizontal black lines represent the Grade II daily standards of Chinese Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$, $PM_{10}$, $NO_2$, and 8-h $O_3$, the Grade I daily standards of CAAQS for $SO_2$ and CO.
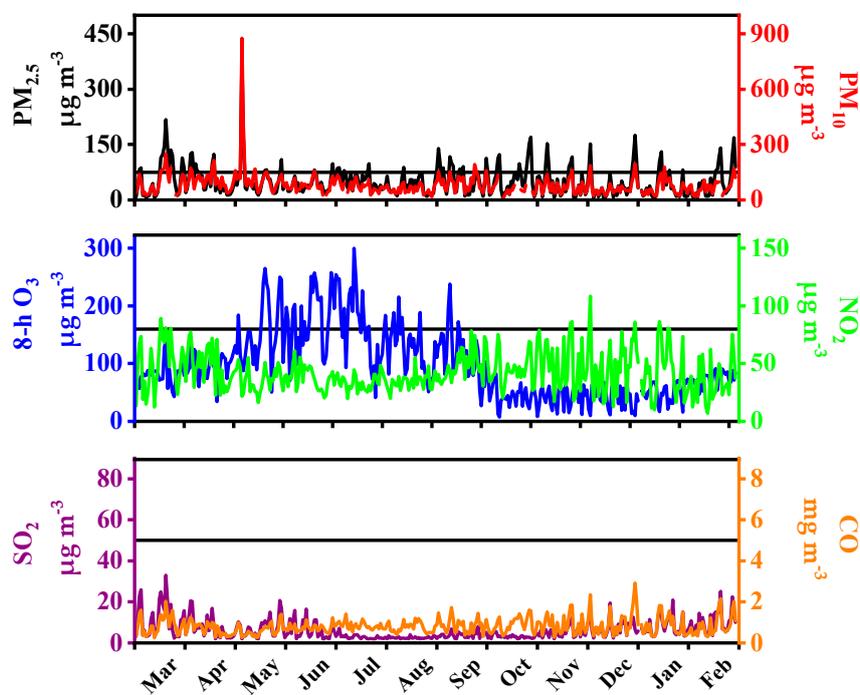


**Figure 4.** Daily average concentrations of $PM_{2.5}$, $PM_{10}$, CO, $NO_2$, $SO_2$, and 8-h $O_3$ in Beijing in 2017. The horizontal black lines represent the Grade II daily standards of Chinese Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$, $PM_{10}$, $NO_2$, and 8-h $O_3$, the Grade I daily standards of CAAQS for $SO_2$ and CO.
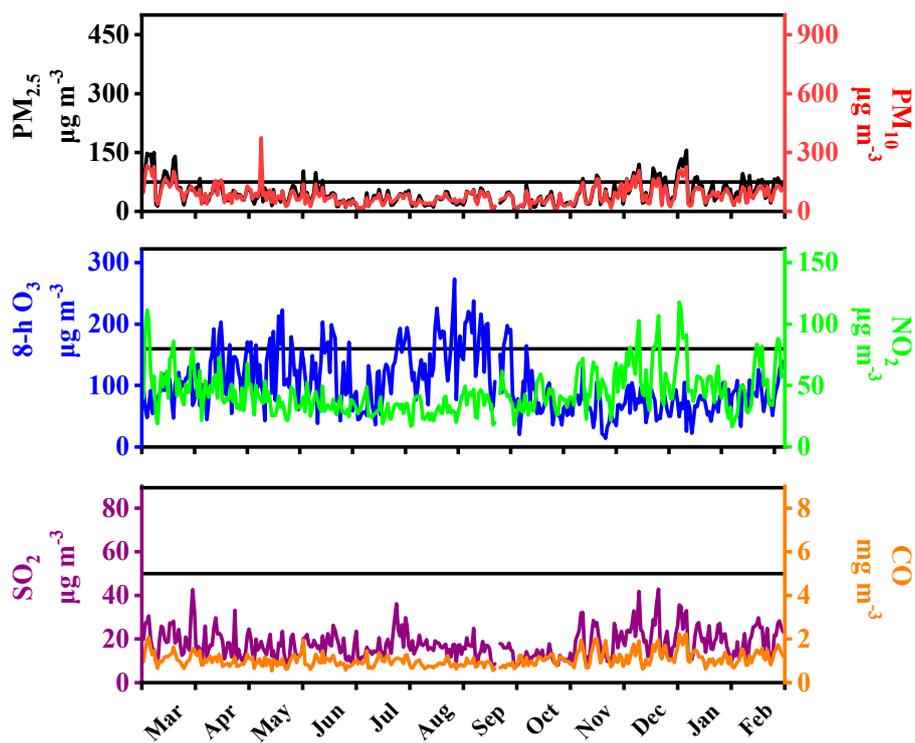
**Figure 5.** Daily average concentrations of PM$_{2.5}$, PM$_{10}$, CO, NO$_2$, SO$_2$, and 8-h O$_3$ in Nanjing in 2016. The horizontal black lines represent the Grade II daily standards of Chinese Ambient Air Quality Standards (CAAQS) for PM$_{2.5}$, PM$_{10}$, NO$_2$, and 8-h O$_3$, the Grade I daily standards of CAAQS for SO$_2$ and CO.
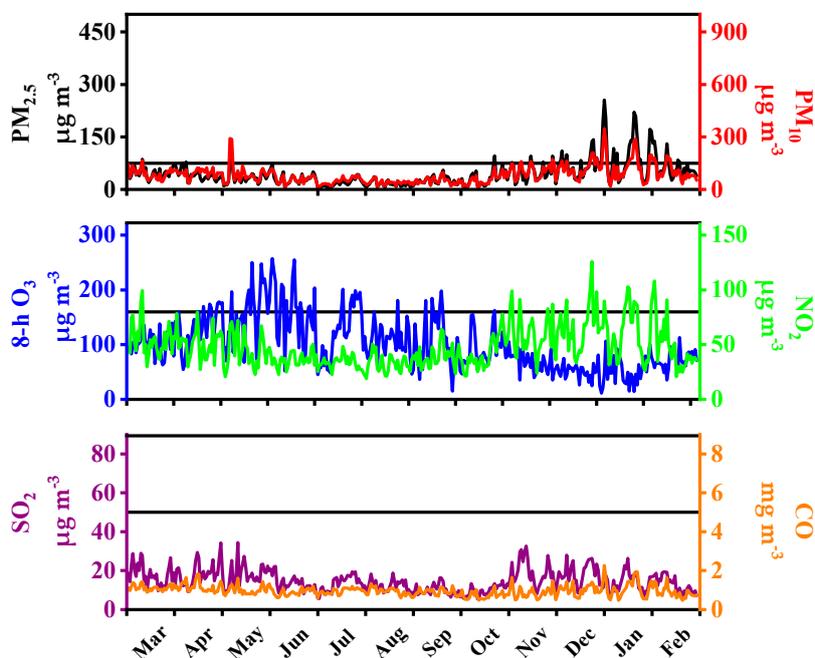


**Figure 6.** Daily average concentrations of PM$_{2.5}$, PM$_{10}$, CO, NO$_2$, SO$_2$, and 8-h O$_3$ in Nanjing in 2017. The horizontal black lines represent the Grade II daily standards of Chinese Ambient Air Quality Standards (CAAQS) for PM$_{2.5}$, PM$_{10}$, NO$_2$, and 8-h O$_3$, the Grade I daily standards of CAAQS for SO$_2$ and CO.

Meteorological condition is an important factor affecting the distribution of air pollutants. Figure 7 shows the statistical average of meteorological parameters including temperature (T), relative humidity (RH), and wind scale (WS). The southern city Nanjing is warmer than Beijing, with the annual average temperature 16.9 vs. 13.6 °C in 2016 and 18.0 vs. 13.5 °C in 2017. Nanjing also had higher annual RH than Beijing, especially in winter. Besides, the annual average WS was higher in Nanjing, which may be related to thunderstorms and typhoons. Our results are consistent with those of Zhang et al. [27] who found that Beijing had the lowest annual average wind speed, although its daily maximum wind speed was the highest among three megacities in China.
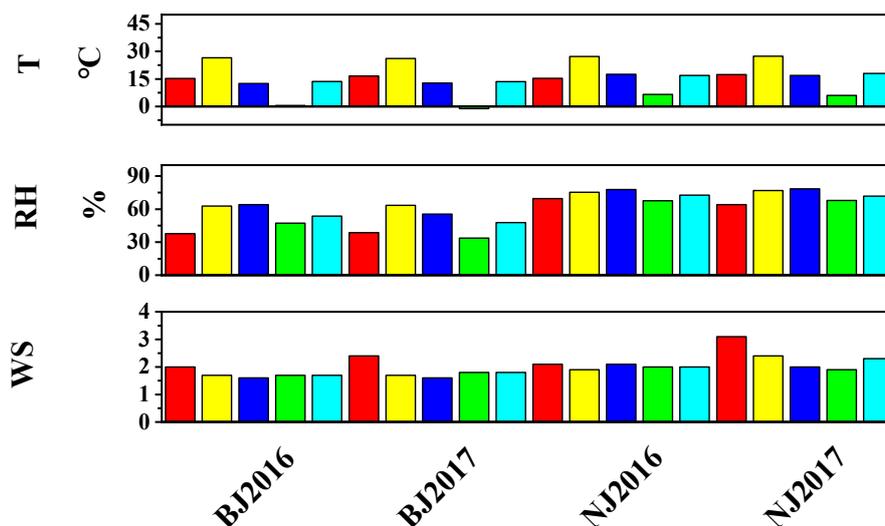


**Figure 7.** Seasonal and annual average measurements of ambient temperature (T, °C), relative humidity (RH, %), and surface wind scale (WS) in different cities and years. Red, yellow, dark blue, green, and light blue represent spring, summer, fall, winter, and annual values, respectively.

### 3.2. Hourly Variations of Pollutants in Two Cities

In this study, the annual mean concentrations of each hour within a daily cycle were analyzed to explore the characteristics of diurnal variation in six air pollutants (Figure 8). $PM_{10}$ concentrations exhibited two peaks in both Beijing and Nanjing. $PM_{10}$ reached its first peak value in the morning, in accordance with the morning rush hours as well as the peaks of $NO_2$ and CO, indicating that primary emissions make an important contribution during this period. After that, the concentrations of $PM_{10}$ decreased, fell to the trough value in the afternoon, and then peaked again during the evening rush hours. It should be noted that the peak/trough time occurred a little later in Nanjing than that in Beijing, which corresponds to the different life/work schedules between these two cities (i.e., people that live in North China, generally wake up earlier and have an earlier bedtime than those in a southern city). $PM_{2.5}$ revealed a trend similar to, but less obvious than, that of $PM_{10}$, especially at the rush hours, indicating the greater contributions of vehicle emissions to $PM_{10}$ pollution. Besides, the bimodal patterns of $PM_{10}$ and $PM_{2.5}$ were opposite to the changes of boundary layer height [28]. These results collectively indicate that both atmospheric boundary layer height and anthropogenic emissions greatly affect the concentrations of air pollutants.

$SO_2$ concentrations showed a unimodal pattern in Nanjing: the peak value appeared at around 10:00 am, mainly because of the increased emissions and the unfavorable diffusion conditions. In the evening (1:00–2:00 am), due to the diesel vehicle emissions, high $SO_2$ concentrations were consistent with high levels of $PM_{10}$, $PM_{2.5}$, $NO_2$, and CO in Beijing. As CO can be adopted as an indicator of boundary layer height (i.e., an increase in CO indicates a decrease in boundary layer height [29]), unfavorable diffusion conditions also resulted in high concentrations of these pollutants shortly after midnight. Diurnal variation of CO also exerted a double-peak curve, implying that automobile

exhaust was the main source of CO [30]. Further, the hourly average concentrations of CO were higher in Beijing than those in Nanjing in 2016, while contrasting results were recorded in the year 2017. Such differences could be ascribed, at least partially, to the traffic control measures enforced in Beijing. The diurnal changes of $NO_2$ were similar to those of CO, implying their same source from vehicle emissions [31]. Apart from diffusion conditions, the reduced $NO_2$ in the afternoon could be explained by the enhanced solar radiation for photolysis [32]. Different from other pollutants, $O_3$ concentrations showed a trough value at around 7:00–8:00 am. With increasing temperature and solar radiation in the afternoon, an obvious photochemical reaction occurred (i.e., NOx + volatile organic compounds (VOCs) + $hv \rightarrow O_3$ [33]), as evidenced by the sharply increased $O_3$ concentrations accompanied by the decreased $NO_2$ and CO concentrations.
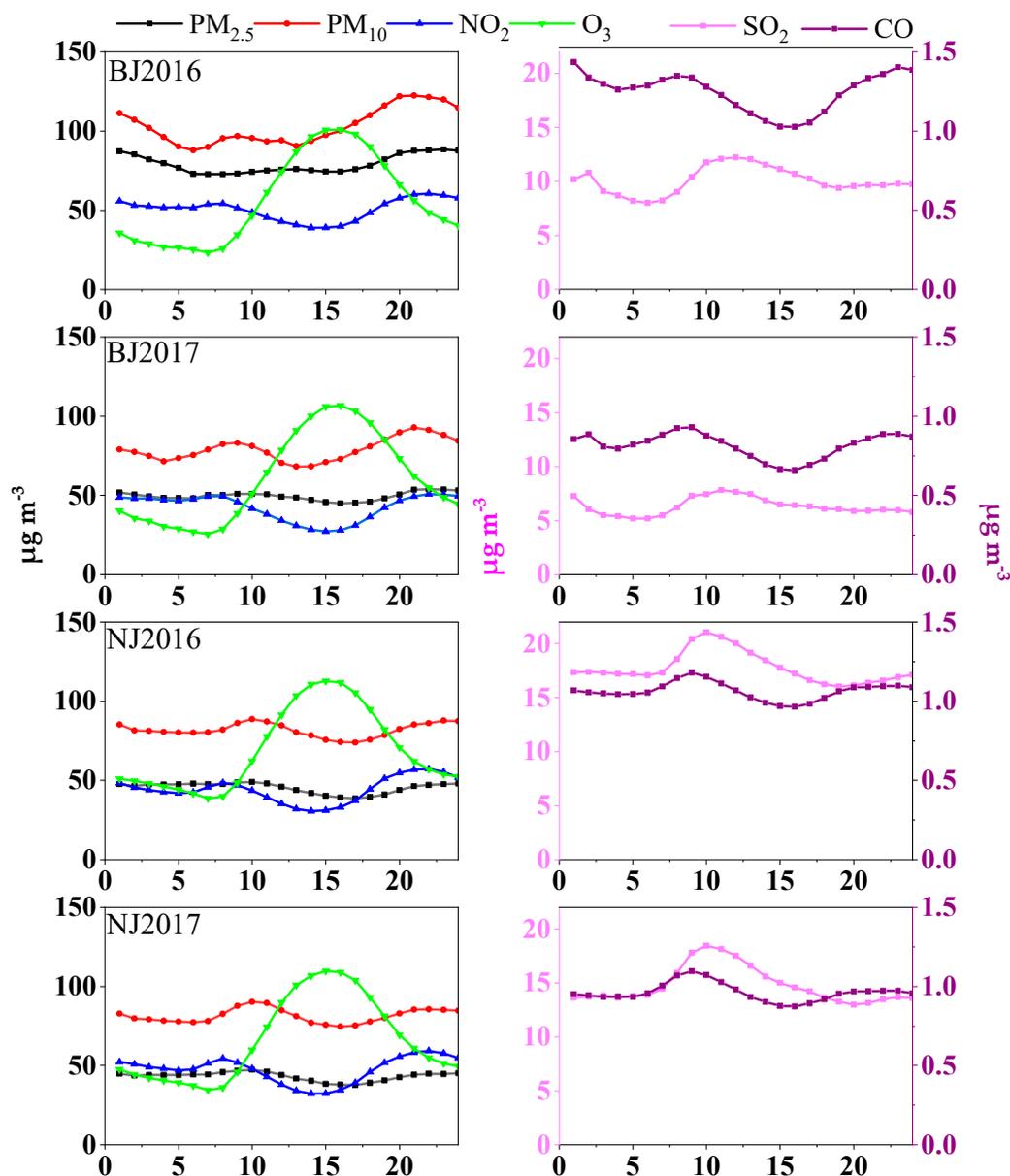


**Figure 8.** Diurnal variation of six criteria air pollutants in different cities and years.

### 3.3. Seasonal Variations of Air Pollutants and Meteorological Parameters

As air pollutants and meteorological conditions varied greatly in different temporal scales, Figures 2 and 7 also show the seasonal variations of all pollutants and meteorological parameters. Generally,

the concentrations of $PM_{2.5}$ peaked in winter, followed by spring or fall, and summer, successively. In Beijing, this may be related to the coal-burning central heating, leading to more $PM_{2.5}$ emissions in winter. Further, temperature inversion layers led to a reduced exchange between the atmospheric boundary layer and the free troposphere, and seasonal changes in vertical temperature gradient also accounted for the observed winter pollution. Besides, rainy weather in summer is conductive to scavenging the air pollutants [34]. In 2017, however, $PM_{2.5}$ concentrations decreased significantly in Beijing in every season, especially in winter, with much lower average $PM_{2.5}$ concentrations (42.0 µg $m^{-3}$) than those in other seasons. Therefore, marked improvement in air quality in Beijing has been recorded, and the public had witnessed many clear and blue sky days during that period. $PM_{10}$ had similar downward changes as $PM_{2.5}$ in Beijing in the year of 2017, while its highest concentrations often appeared in spring or winter. Similarly, $NO_2$ and $SO_2$ concentrations in Beijing and Nanjing were often highest in spring or winter, while lowest in summer. In contrast, the highest 8-h $O_3$ concentrations occurred in summer (except in NJ2017), followed by spring, fall, and winter, which has lower solar radiation and is unfavorable for $O_3$ production [35]. In both cities, average CO concentrations in all seasons were comparable.

As expected, T, RH, and WS also showed remarkable seasonal variations. Average temperatures of Nanjing in all seasons were higher than those in Beijing. In both cities, the values of T peaked in summer, followed by spring, fall, and winter (except NJ2016), although the differences among seasons were smaller in Nanjing, especially between spring and fall. In Beijing, summer and fall had higher average RH than spring and winter. The lowest RH value was recorded in the winter of 2017 (33.7%). Significantly higher levels of RH were observed in Nanjing in all seasons, with narrow ranges (64.0%–78.4%). Identically, Beijing had lower seasonal average WS, which was higher in spring and winter and lower in summer and fall. In Nanjing, WS was very close among all seasons except in the spring of 2017. Seasonal distributions of wind direction in Beijing and Nanjing were analyzed (data not shown). In Beijing, southwest and northeast winds were prevalent in 2016, although north wind was frequent in winter with large wind speed. Southwest wind dominated wind direction in the spring, summer, and winter of 2017, while northeast wind dominated in fall. It should be noted that northwest wind occurred frequently in the winter of 2017. Since there are few anthropogenic emissions upwind of Beijing, clean wind from northwestern diluted the pollutants from industrial areas in southwest and northeast, resulting in reduced air pollutants. In Nanjing, the wind was mostly from east in each season. North wind was slightly more frequent in fall and winter, which could transport pollutants from many large chemical plants located to the north of Nanjing. Besides, north wind near surface was not strong enough to blow the pollutants away [36].

### 3.4. Correlation between Air Pollutants and Meteorological Factors

To better understand the relationship between pollutants ($PM_{2.5}$, $PM_{10}$, $SO_2$, CO, $NO_2$, and 8-h $O_3$) and meteorological factors (T, RH, and WS), regression analyses were conducted across different seasons to calculate their correlation coefficients (Figure 9). In both Beijing and Nanjing, concentrations of most air pollutants (except 8-h $O_3$) were negatively correlated with WS in all seasons, with a few exceptions in summer. WS determines horizontal transportation distance per unit time. Air pollutants began to accumulate under the stagnant weather conditions. The higher the WS, the more effective in pollutant removal. Generally, gaseous pollutants are more likely to be diluted or reacted than particulate pollutants [37], and thus stronger correlations exist between WS and gaseous pollutants than those between WS and $PM_{2.5}$/$PM_{10}$. Han et al. [38] also found that wind speed was the most important meteorological factor affecting pollutant distribution. For the secondary pollutant $O_3$, however, the dilution of particulate pollutants by wind could increase solar radiation, and then facilitate $O_3$ formation [39]. As a result, 8-h $O_3$ concentrations had a positive relation with WS.
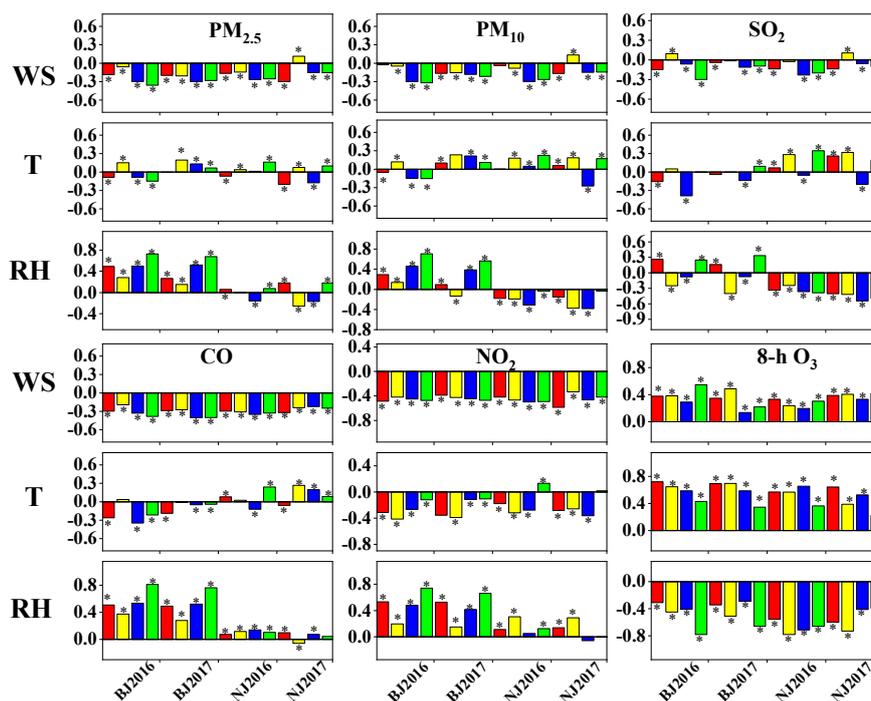
**Figure 9.** Correlations between six criteria air pollutants and meteorological factors: surface wind scale (**WS**), ambient temperature (**T**), and relative humidity (**RH**). Red, yellow, blue, and green represent spring, summer, fall, and winter, respectively. * indicates the significant level at 95%.

The relationships between air pollutants and RH were complicated. In Beijing, $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$ concentrations were positively correlated with RH in most cases, especially in winter. Under high humidity conditions, aerosols can absorb more semi-volatile species for growth, thus leading to an increase in PM concentrations [40]. In addition, high RH favors the formation of temperature inversion, which makes the atmospheric stratification stable and hinders the vertical diffusion of pollutants [41]. However, in high RH seasons in Beijing (e.g., summer) or moist Nanjing, $PM_{2.5}$, $PM_{10}$, and soluble $SO_2$ (with high Henry constant 1.64 bar [42]) had negative correlations with RH, which could be partially explained by the wet scavenging effects [43]. Although we did not collect rainfall data, the association of high RH with precipitation has been demonstrated in southern China, which can facilitate pollutant deposition [44]. The concentrations of 8-h $O_3$ were negatively correlated with RH in all seasons in both cities. Cloud cover was positively correlated with relative humidity, thus high RH always reduces the UV light intensity, which drives the $O_3$ concentrations and the surface air temperature [45]. As expected, 8-h $O_3$ had the strongest positive correlation with T, which was due to the important role of temperature in $O_3$ formation [46]. In contrast, $NO_2$ values were negatively correlated with T, which was due to the transformation of $NO_2$ to $O_3$ and the vertical dispersion under high temperature conditions [47]. Only weak correlations were observed between T and other air pollutants.

In general, $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$ had a higher correlation with WS and RH, while 8-h $O_3$ was more closely related to T and RH. Such relationships are consistent with those of Wagner [48] who found that WS affected primary pollutants ($PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$) but T influenced secondary pollutant $O_3$. In Beijing, although $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$ concentrations decreased significantly from the year 2016 to 2017, seasonal average WS showed only a slight increase, indicating the limited role of WS in the air quality improvement in 2017. Nevertheless, RH was lower in the fall and winter of 2017 than that in 2016, which might contribute greatly to the downward trend in these five pollutants on a yearly basis. In the case of 8-h $O_3$, decreased RH in fall and winter, together with increased T in spring and fall, resulted in increased 8-h $O_3$ concentrations in the year 2017 in Beijing. In Nanjing,

WS, RH, and T fluctuated between 2016 and 2017 in the same season, with relatively narrow ranges, leading to relatively stable concentrations of $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, $NO_2$, and 8-h $O_3$ in 2017.

*3.5. Contribution of Wind Directions to Heavily Polluted Days*

Apart from WS, T, and RH, wind directions are thought to affect air quality greatly. We further analyzed the contributions of wind directions in heavily polluted days (i.e., the heavily polluted days of each wind direction divided by the total heavily polluted days in Beijing or Nanjing each year, Figure 10). In 2016, southwest and northeast winds contributed the majority of the heavily polluted days in Beijing, followed by east wind. The contributions of wind directions in 2017 were generally different, with an obviously increased proportion of southwest wind. Such patterns could be explained by regional transport. Baoding, Shijiazhuang, and Handan, the major industrial cities in North China, are located to the southwest of Beijing. There are also many heavy industrial cities located to the northeast of Beijing, such as Shenyang, Anshan, and Fushun. Wind from these directions transports pollutants and worsens the air quality of Beijing. These results are consistent with the findings of Ma et al. [49] and Zhang et al. [50]. In addition, Beijing is located on the northern edge of the North China Plain, surrounded by mountains on three sides. When southwest or northeast wind dominated, the diffusion and dilution of pollutants would be hindered, which might be another reason why these wind directions deteriorate air pollution in Beijing. In Nanjing, heavy air pollution was most closely related to east wind, followed by southwest wind, northwest wind, and north wind. A series of cities including Suzhou, Changzhou, Wuxi, and Zhenjiang constitute the industrial center of the Yangtze River Delta, located to the east and southeast of Nanjing. Besides, there are a few large petrochemical plants in the north of Nanjing. These results collectively indicate the importance of regional transport in pollutant concentrations.
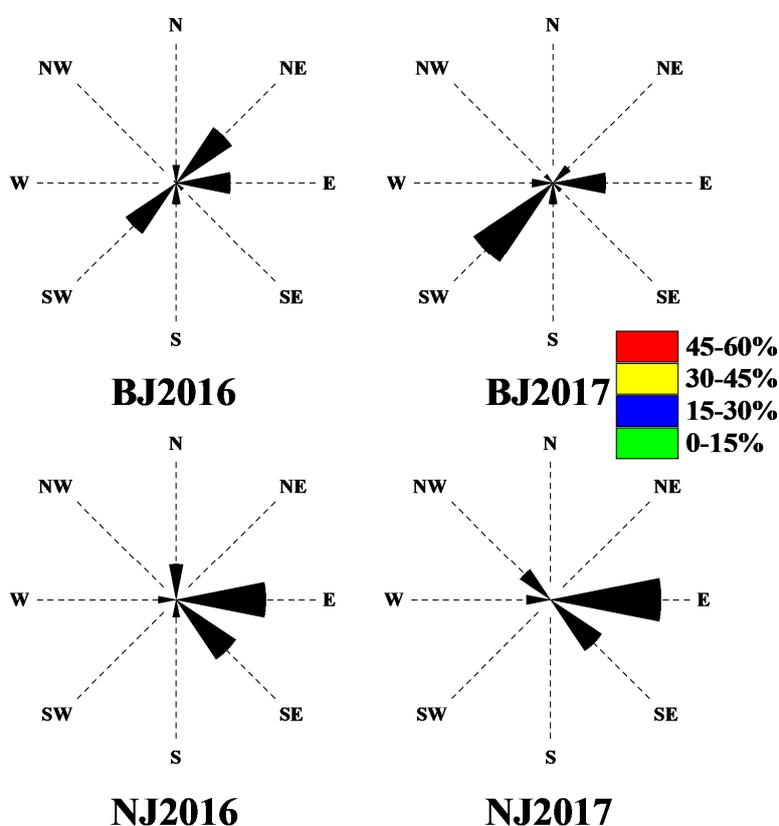


**Figure 10.** Distributions of heavily polluted days (when the ambient air quality index was more than 150) according to their respective wind directions.

## 4. Conclusions

This paper comparatively analyzed the temporal characteristics of air pollutants from March, 2016 to February, 2018, in a northern (Beijing) and a southern (Nanjing) city in China. Generally, there were downward trends in the annual mean concentrations of $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$, implying the effective implementation of emission reduction targets. Conversely, the concentrations of 8-h $O_3$ exerted a stable or even upward trend, and thus more attention should be paid to the exposure of humans to $O_3$ in these cities.

As expected, Beijing experienced more severe air pollution problems than Nanjing in 2016, which may be associated with the winter heating and unfavorable dispersion conditions in northern cities. However, in 2017, the concentrations of most air pollutants were lower in Beijing than those in Nanjing. Therefore, meteorological data during the same period were collected to explore their relationship with air pollutants. Our results reveal that $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, and $NO_2$ are generally correlated with WS and RH, while 8-h $O_3$ is correlated to T and anti-correlated to RH. A slight increase in seasonal average WS, marked decrease in RH, as well as the more frequent northwest wind in winter, resulted in an improved air quality in BJ2017. In contrast, WS, RH, T, and wind direction remained relatively constant between 2016 and 2017 in the same season, leading to relatively stable concentrations of $PM_{2.5}$, $PM_{10}$, $SO_2$, CO, $NO_2$, and 8-h $O_3$ in NJ2017. Our results suggest that meteorological conditions play an important role in ambient air pollution, which should be considered in decision-making processes.

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