Correlation between PM concentrations and meteorological conditions in Chengdu based on in-situ observations

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Abstract. Atmospheric aerosol particle plays a vital role in the Earth’s radiation budget, affecting human health by raising air pollution events, which have become remarkably common in megacities of China. Three sites in Chengdu city were selected for measurement of air quality index(AQI) and pollutants like PM$_{2.5}$, PM$_{10}$, SO$_2$, NO$_2$, whose concentrations were indicators of air quality. The association between air pollution in terms of AQI (pollutants’ concentrations) and meteorological conditions like Relative Humidity(RH) and Wind Velocity(WV) have been evaluated in this study. The results show that AQI peaked on June 22$^{nd}$ and Jul 16$^{th}$, when PM$_{2.5}$ and PM$_{10}$ dominated. Further analysis reveals that only PM$_{2.5}$ and PM$_{10}$ are related to RH. In particular, PM$_{2.5}$(PM$_{10}$) intends to decrease when RH increases with a coefficient of -0.4(-0.57). However, there is no evident co-variation between RH and SO$_2$(NO$_2$). The results also indicate that concentration of NO$_2$ decreases when WV increases with a coefficient of -0.66. By contrast, corresponding relationship between PM$_{2.5}$(PM$_{10}$) and WV is less evident.

1. Introduction
Atmospheric aerosol, a suspension of fine solid particles or liquid droplets in the air, plays an important role in the Earth’s energy budget (Suzuki et al, 2019). Though aerosol particles’ total radiative forcing is still uncertain, they could be highly toxic and harmful substances endangering human health (Lee et al. 2018). Rapid economic development in the past forty years has led to massive fossil consumption in China. Haze events occurred more frequently due to increase in aerosol emission from fuel combustion, especially in basin cities. Other than local emission and basin topography, previous studies indicated that meteorological conditions unfavorable for aerosol removal may partially relate to haze events (Wu et al., 2019). There were also evidences showing that meteorological conditions, such as wind velocity (WV) and relative humidity (RH), are related to atmospheric aerosol particles redistribution in many previous studies (Wang et al, 2019). Some of them revealed that precipitation will lead to an end of haze event because of the wet deposition (Yang et al, 2019).

However, many of those studies focused on mega cities in north or south part of China (Cheng, Li, Hong et al 2016). Based on an in-situ study (Wu et al 2019), the meteorological condition, especially the WV, plays a pivotal role for haze events in Beijing.

As a typical basin city located in southwest of China, Chengdu city has suffered serious haze events in the past decades (Liao et al., 2017; Tao et al., 2014; Wang et al.,2018). Chengdu ranked 15th with annual average PM$_{2.5}$ of 86.3, which is more than twice of the national standard. However, few studies discussed the possible correlation between meteorological condition and haze events in Chengdu city.

In this study, we used in-situ monitoring data, such as AQI and mass concentration of pollutants, as indicator of haze events to analyze the dominant pollutants during the haze events, and the possible change in regard to meteorological conditions. Section 2 includes a brief introduction of data,
methodology and geographic environment of Chengdu City. Section 3 provides analysis of the relationship between pollutants and meteorological conditions. The last section contains conclusion and discussion.

2. Data and Methodology

![Map of elevation near Chengdu City, Sichuan Province. The black ‘+’ marks stand for three stations: Liangyansi, Shi Lidian, Jun Pingjie, respectively. Contoured color stands for DEM ranges from 0 to 4000. It shows that Sichuan province is surrounded by mountains, especially high in the west. The region covered is 95°E~110°E and 25°N~35°N.](image)

This study focuses on influence of relative humidity and wind velocity on pollutants in Chengdu, China. As an indicator of pollution events, AQI, as well as particle mass concentrations of PM2.5, PM10, NO2, SO2, is acquired from three stations located in Chengdu City. These three stations, specifically Lingyansi (103°61′E, 31.01′N), Shilidian (104°1′E, 30.66′N), and Jun Pingjie (104°165′E, 30.68′N), are located in Sichuan Basin surrounded by Tibetan Plateau, Yunnan-Guizhou Plateau, Dabashan, Wushan and Daloushan mountains. In-situ observation of surface particle mass concentration and AQI are acquired on hourly basis from the website(datacenter.mee.gov.cn) hosted by Ministry of Ecology and Environment of China.

The meteorological data is from a global atmospheric reanalysis, the European Centre for Medium-Range Weather Forecasts (ECMWF). The reanalysis used is ERA-interim. It covers the data-rich period since 1989 and will continue to be extended forward in time until 31 August, 2019. The gridded data with 0.125°x0.125° is chosen. It provides reanalysis of meteorological conditions of 36 pressure levels at four times (2a.m., 8a.m., 14p.m., and 20 p.m.) on daily basis. In this study, relative humidity and wind velocity were averaged by a 3x3 windows which locate near the stations mentioned above. Reanalysis data at level 950hPa and 500hPa at 14 p.m in August, 2016 are involved in this study.

In order to reveal the effects of meteorological condition on particle mass concentration and AQI, data has been preprocessed using RH and WV bins. Specifically, RH(WV) are averaged in bins of 2%(0.1m/s), for example, mean value of all cases with RH ranged from 0 to 2% is representing these cases.
3. Results

3.1 Trend of Particle Mass Concentration

Figure 2. Trend of mass concentration of different pollutants and AQI during June, July, and August in 2016. Red for SO\textsubscript{2}, purple for PM2.5, green for PM10, black line for NO\textsubscript{2}, yellow for AQI. The value of mass concentration is the mean of that from the three stations.

The average value measured from three ground stations in Chengdu, Ling Yansi, Jun Pingjie, and Shi Lidian stations, are presented in Figure 2. The variables illustrated in figures 2 include air quality index (AQI), SO\textsubscript{2}, NO\textsubscript{2}, PM2.5 and PM10 acquired at 14:00 p.m. It shows that concentrations of SO\textsubscript{2} are relatively lower than other components of pollution while AQI and PM10's are the highest. Probably because of well-conducted desulfurization, SO\textsubscript{2} maintains the lowest and most stable concentration among all. The variation of AQI seems to be corresponding to PM10 during this summer. PM2.5 and NO\textsubscript{2} has the similar trend as PM10 and AQI. On the other hand, the concentration of SO\textsubscript{2} is loosely correlated with other four variables. The pollution events in Chengdu might be directly or indirectly induced by various emission, such as dust of construction, consumption of fossil fuel, etc.

3.2 WV effects on pollutants

Figure 3. Relationship between concentration of different pollutant and WV at 950hPa. Marks of blue circle, red cross, yellow asterisk, purple plus sign, green point stand for AQI, NO\textsubscript{2}, PM\textsubscript{2.5}, PM\textsubscript{10} and SO\textsubscript{2} respectively. Average value of WV and particle concentration within WV bins of 0-0.1m/s, 0.1-0.2 m/s, ... 4.9-5.0m/s are illustrated.
As illustrated in Figure 3, AQI and mass concentration of difference pollutants decrease when wind velocity (WV) at 950hPa increases. The concentration of pollutants barely changes when WV varies from 0m/s to 2m/s. However, the concentration of PM$_{10}$ falls from nearly 120 to around 30 as WV increases from 2.5m/s to 4.7m/s. AQI also evidently drops from 110 to 30 at the same range of WV. In addition, NO$_2$ is evidently correlated to in wind velocity with a coefficient of -0.66. However, the R square of AQI, PM$_{2.5}$, SO$_2$, PM$_{10}$, are all less than 0.2, which indicates they are loosely connected to WV. The geographic feature of Chengdu may explain such results, since surrounded by mountains, the relatively low WV has low influence on the suspension of aerosol.

![Figure 4](image)

**Figure 4.** Relationship between concentration of different pollutant and WV. The same as figure 3 but for WV at 500hPa.

Meteorological conditions at 500hPa usually represent the meso-scale system, and wind velocity at 500hPa is much greater than that of near surface--up to nearly 16m/s. As illustrated in Figure 4, SO2 seems to be the least affected one, maintaining a value below 20. The mass concentration of all pollutants and AQI stay fairly stable, except the peak when WV reaches 6.5m/s. Concentration of PM10 maintains an initial level of approximately 70 as WV changes from 0m/s to 16m/s. As for PM2.5, the concentration slightly changes from 40 to 25. Overall, AQI as well as all other pollutants show a coefficient between -0.228 and -1.257. Therefore, evidence does not support a strong relationship between aerosol distribution and WV at 500hPa.

### 3.3 RH effects on pollutants

![Figure 5](image)

**Figure 5.** Relationship between concentration of different pollutant and relative humidity (RH) at 950hPa. Marks of blue plus sign, red rectangle, yellow cross, purple point and green asterisk stand for PM$_{10}$, PM$_{2.5}$, AQI, SO$_2$ and NO$_2$ respectively. Average value of RH and particle concentration within RH bins from 30-32%,32-34%... 98-100% is illustrated.
The concentrations of PM$_{2.5}$ (PM$_{10}$) peak when RH at 950hPa reaches roughly 43 (56). Apart from the high values, the rest appears to have fairly the same level of particle concentration. At the concentration level around 40 for PM$_{2.5}$, the RH value nearly varies from 45 to 100, while most PM$_{10}$ concentrations fall within the range 50 to 80. PM$_{10}$ concentration falls by 30 when the RH increases from 40 to 100, while PM$_{2.5}$ drops by 10. Fitting result shows a coefficient value of 0.4 for PM$_{10}$.

Air quality index roughly follows the trend of PM2.5 and PM10. Most concentration values fall in the range 50 to 70. It has high pollution level when RH is around 42, 57, 87, and 100. It is probably due to the fact that when the RH is low, the aerosol particle can combine with tiny water droplets in the air to form aerosol suspension, while when the relative humidity is high, increased precipitation will wash away the particles, causing high RH results in lower pollution. The concentration of SO2 is barely swayed. The relationship shows a coefficient of -0.03963, nearly horizontal. Usually, the emitted gases have experienced desulphurization so that the concentration of SO2 will be considerably lower than that of other pollutants. Therefore, RH exerts smaller effect on the dispersion and suspension of SO2.

![Figure 6](image_url)  
Figure 6. Relationship between concentration of different pollutants and relative humidity (RH), same as figure 5 but for RH at 500 hPa.

This graph takes RH data from pressure level 500. Overall, there is a strong negative connection between RH and PM2.5, PM10, and AQI. The variation in PM2.5 roughly follows that of PM10 and AQI. The peak values appear around RH value of 22. When the RH is greater than 40, the correlation becomes less obvious. On average, the concentration of PM2.5 and PM10 drops by 20 when RH increases from 10 to 80.

The coefficient for the correlation between RH and PM10 is -0.65, with a R square value of 0.603. The coefficient for the correlation between RH and PM2.5 is -0.4, with a R square value of 0.65. Such a trend may be due to the fact that Chengdu has high precipitation. Rain can wash away the pollutants in the air and significantly lower particle concentration. Therefore, the aerosol concentration high in the sky is more negatively correlated with relative humidity. This relationship is also discovered in Sun, Ni, et al’s article, which also illustrates the effect of precipitation on aerosol concentration. SO2 concentration continues to be lowest in value, all below 20, and most stable. Similarly, the trend of NO2 also appears to be independent in regard to the change in RH. Different from the near-surface data, NO2 here shows almost no relationship with variation in humidity level, with a coefficient and R square of -0.065 and 0.016, respectively. Overall, it changes by 10 as RH increases to 80.

4 Conclusion and discussion
Chengdu city is constantly suffering from pollution events, while its humidity is relatively high but surface wind velocity is low in the summertime—partially due to the surrounding plateaus and mountains (Tao et al., 2014; Wang et al.2019). Previous studies revealed that the temperature, moisture and precipitation conditions of Chengdu favored the formation of pollution events. This study is based on the analysis of in-situ observation and relative humidity (RH) and near
surface wind velocity (WV) from ECMWF reanalysis datasets. The purpose is to evaluate the effects of RH (WV) on pollution events.

Near-surface wind velocity is well related to the suspension of NO2. However, the indicators, such as AQI and concentration of PM10 and PM2.5, do not seem to be influenced by increasing WV. The mass concentration of PM10 and PM2.5 may have somehow been influenced by meso-scale system when WV at 500hPa increases. A relative low RH condition assists the formation of aerosol particles, which is usually positively correlated with RH. Yet the results revealed that aerosol particle mass concentration has a negative correlation to RH at 950hPa. Since ground observation is more likely to be contaminated by the emission source nearby, these conclusions still need to be verified using local emission inventory. In addition, RH is relatively high in Chengdu during summertime, situations with lower RH is poorly represented.

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