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The transmission and distribution regulation of the urban black carbon aerosol in the middle reach of Yangtze River

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Research

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ABSTRACT

This paper uses the software Meteoinfolab, track analysis, correlation analysis, multiple model fitting and other methods, analyses of black carbon aerosol data from the middle reaches of the Yangtze River from July 2015 to June 2016. The results show as followed: The monthly mean mass concentration of black carbon aerosol in Wuhan areas is (3911±2100) ng/m^3,with the maximum mean in January and the minimum in July. Its spatial distribution law is showing a decreasing trend from the central city to suburban area and surrounding areas. The meteorological factors such as wind direction, wind speed and visibility had great influence on the black carbon concentration. The correlations between $PM_{2.5}$, PM_{10}, CO, SO_2 and BC were high, and the correlation coefficient was the highest in winter and lowest in spring. The back trajectory indicates that the summer air mass mainly from the northern region of China, the fall air group mainly from the Mediterranean region, the winter air masses mainly from Europe, Mongolia - Siberia high effect, will be part of the transfer to the pollution along the Yangtze River, together with the local bureau of pollutant source, the average concentration of carbon black is the highest level of the year. In spring, the upper air masses middle reaches of the Yangtze River mainly come from the far source, and the middle and low air masses come from the near source and the local source.

Keywords: Black carbon aerosol; Spatial and temporal distribution; Trajectory analysis; Correlation analysis; Wuhan; Model fitting

1. INTRODUCTION

Black carbon aerosol is one of the important elements in the atmosphere, mainly from the incomplete combustion of Carbonaceous Substances. Distributed rather unevenly around the world, black carbon aerosol has strong absorption of solar radiation from visible light to infrared spectrum, wider than greenhouse gases. It may change cloud reflectivity, indirectly affects the radiation balance between the earth and the atmosphere, thereby leading atmospheric warming; It provides activated carrier for pollutants, and accelerates the process of heterogeneous conversion and gas-particle conversion; It may increase the turbidity, and change the atmospheric visibility. And black carbon aerosol would alter the vertical effects and the stability of regional atmosphere, thereby casting impacts on the atmospheric circulation and water circulation between different regions. Black carbon aerosol plays significant parts both in atmospheric physical and chemical reaction process and atmospheric optical process, some researches hold that black carbon aerosol is a potential impact factor of global warming. Therefore, studies on black carbon aerosol attract much attention from researchers from various countries, among which the resource emissions, the spatial and temporal distribution regulation and the climate and environmental effects have been research focuses.

In order to master and manage the emission of black carbon, at present there are three (3) lists of global emission of black carbon, namely Aerocom list, SPEW list and ACCMIP list[13-14]. However, there exists underestimation of the surface atmospheric optical thickness and the concentration of black carbon in these lists[15]. Many scholars thereby make model improvement, for example, Wang Rong, from Peking University, established the PKU-BC-2007 list, based on the independently developed Global Database of Combustion Source, using the emission factor database of black carbon with independent measure or simulated forecasts, as a result, it shows that the high value area of the global black carbon emission places mainly in East Asia, South Asia, the middle and south areas of Africa and the Middle East[17]. And the issue of black carbon emission in China has aroused many scholars' attention,and they make the emission lists of black carbon aerosol in Mainland China[18], on the basis of which the 0.5°×0.5° spatial distribution map of the black carbon emission in China is generated, showing that the black carbon aerosol in air in China is mainly distributed in South China, North China and the Yangtze River regions[19], and Liaoning Province, Shangdong Province, Hebei Province, Henan Province, Shanxi Province, Jiangsu Province, Anhui Province and Hubei Province have high emissions.

At present, there are few studies on the trajectory analysis of air pollutants in the middle reaches of the Yangtze River. There is a lack of quantitative research on the temporal spatial distribution and source area composition of BC in this area.Therefore, this paper, exemplified by Wuhan City in Hubei Province, analyzes the transmission and distribution regulation of the black carbon aerosol, and further studies the key reasons and effects of the generation of black carbon aerosol in Wuhan central urban area, playing a practical role in the exploration of the spatial and temporal distribution of black carbon in the middle reach of Yangtze River. At the same time, it provides reference data for the combined control of combined air pollution prevention and control of the urban agglomeration in the middle reaches of the Yangtze River.

2. Sample collection and data source

2.1. Sampling site

This paper selected the middle reaches of the Yangtze River in Wuhan area as the study area, in order to avoid the interference of BC near the distance from the pollution source, selected the city green parks as sampling points (including the Hanyang Liberation Park, Zhongshan Park, Qiaokou park, Changqing Park, Yellow Crane Tower scenic spot, East Lake scenic area, Shahu Park, Shimen peak Park, South Canal Garden a total of 10 sampling points), their locations are shown in Fig.1.

2.2. Sampling instrument

The sampling instrument is the AE-51 black carbon aerosol monitoring instrument by American Magee

Scientific Company, and through continuous record (except power off or membrane change), the data are preserved in hard disc or external computer every five (5) minutes.

2.3. Sample collection and data processing

The one-year collection time is from July 2015 to June 2016.According to the validity of the sample data statistics demanded by the environmental air quality standard, there are at least 60 daily values evenly distributed every year, 5 daily value evenly distributed every month, total to six hundred (600) samples of black carbon aerosol, of which twenty-six (26) samples are invalid, so the sample validity in this study is 95.67%.In order to decrease the fierce fluctuations of the observed value caused by the instability of the instrument or the workers in the data station, the original observed data are pre-treated by five-spot triple smoothing, and then generate the hourly mean by the smoothed five-minute average data, then applied in the subsequent data analysis.

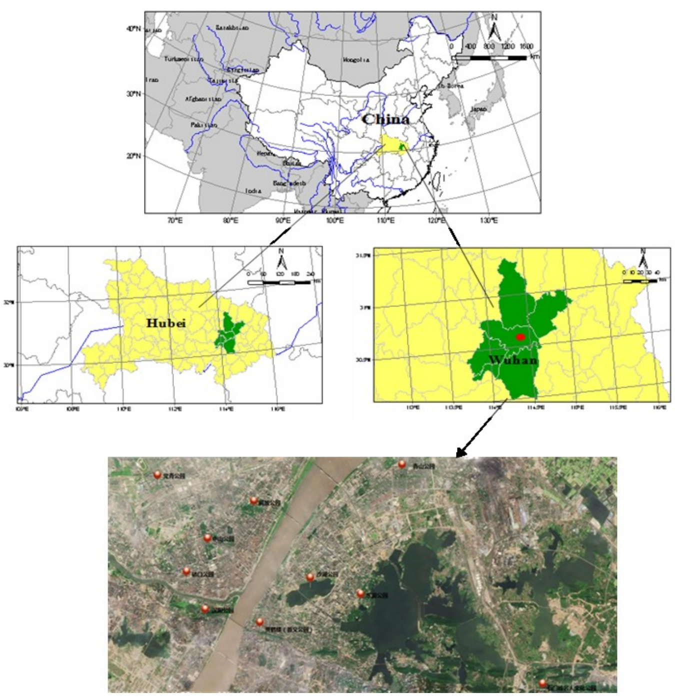

Fig.1 Distribution of Sampling Points in Central Urban Area of Wuhan

Wind speed, visibility, temperature and pressure data are derived from the global data assimilation system provided by http://www. meicmodel.org/, which represents the conventional meteorological data serving the HYSPLIT model. The relevant air pollutants ($PM_{2.5}$, PM_{10}, SO_2, NO_2, O_3, CO) data were selected from the air quality data released by(http:// www.whepb.gov.cn/) Wuhan Environmental Protection Bureau website.

2.4. Analysis method

The statistical methods used in this paper are correlation analysis, regression analysis and multiple models fitting analysis. Meanwhile, the HYSPLIT multi point forward trajectory model is used to analyze the transmission path of BC for trajectory analysis.

The HYSPLIT model is a professional model for the analysis and calculation of the transport, diffusion and settlement trajectory of atmospheric pollutants[20], reflecting the characteristics of the air flow. In this study, the target latitude and longitude is set at 30.55° E and 114.32° N, the simulation range is 0-10000m, and the average flow field in the atmospheric boundary layer is 500m height[21]. It can not only represent the characteristics of air flow (wind), but also reduce the impact of the ground friction on[22] .

3. Analysis and Discussion

3.1 Time variation of BC in the middle reaches of the Yangtze River

3.1.1 Time variation of BC in Wuhan

(1) Diurnal variation characteristics

According to the continuous observation data of BC in Wuhan area from July 2015 to June 2016, 81% of the data is distributed in the range of 2000~6000ng/ m^3. As shown in Fig.2, there is a better trend of centralization.

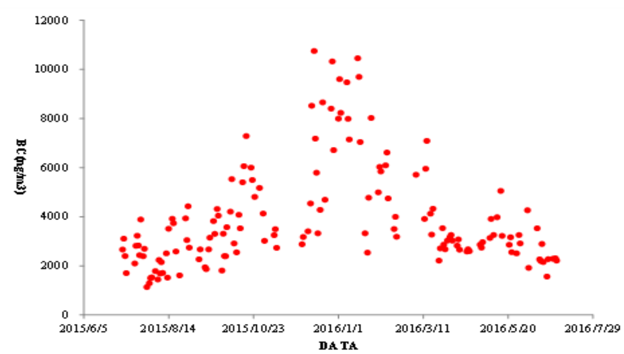

Fig.2 Time Series of the Mass Concentration of BC in Wuhan City

(2) Features of Monthly Variation

The average BC concentration of BC in each month was found in Figure 3, showing a single peak distribution. In January, the concentration was the highest, 7403ng/m^3, and the lowest in July, 2354ng/m^3.

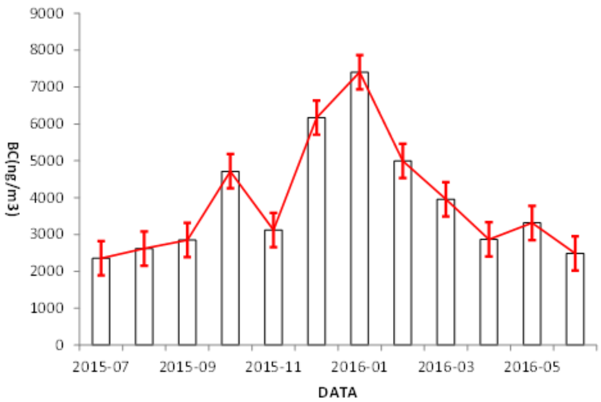

Fig.3 Monthly Variation of the Mass Concentration in Wuhan City

(3) Features of Quarterly Variation

The seasonal distribution of BC mass concentration is the highest in winter, followed by autumn and spring, and lowest in summer, which is basically consistent with the variation rule of BC mass concentration monthly average in every month.

3.1.2 Time variation of BC in the middle reaches of the Yangtze River

(1) Comparison with some foreign cities

The daily mean of BC mass concentration in Wuhan was 3911 (1135~10742) ng/m^3, compared with some cities in other countries (Table.1), and at the middle low level.

Table.1 Contrast results of BC concentration in foreign observation stations

Observation Point	Type	Time	Average Mass Concentration(ug/m^{-3})
Puṇyanagara(India)[23]	Urban Area	2005-2010	3.58±1.55
Paris(France)[24]	Urban Area	2010	1.66
New York(USA)	Suburban	2006-2010	0.38
Canada[26]	Halifax	2012	1.8
Swedan[27]	Urban Area	2007	1.4
City of New York(USA)[28]		2004.01.12-2004.02.05	1.38
Dakar (the Republic of Senegal)[29]		2008.06-2009.07	10.5±3.5
New Delhi(India) [30]		2011.01-2011.12	6.7±5.7
Kathmandu(Nepal)[31]		2009.05-2010.04	8.6±4.4
Wuhan(PRC)(this study)	Central City	2014.12-2016.6	3.91±2.1

(2) Comparison with some cities in China

The seasonal characteristics of BC aerosol are affected by the composition of the emission sources and the seasonal changes in the meteorological factors. The high BC concentration in winter is related to the increase of human activities related to family heating and other adverse weather conditions such as inversion and high stability in winter. The low concentration of BC in summer may be related to frequent atmospheric convection, which is similar to the seasonal variation of BC concentration observed in Nanjing and Hefei (Fig.4). The black carbon concentration in Nanjing[32] is mostly lower than 7000ng/m^3, and the average concentration is 221-24686 ng/m^3 per hour, with an annual average value of 4157 ng/m^3, reaching the lowest in June, July and August. Xiaolin Zhang[33] observed the mass concentration of BC in Hefei from June 2012 to May 2013, the monthly mean from 2 to 1 ug/m^3 in July 2012 and 6 to 2.6 ug/m^3 in January 2013. The average BC mass concentration in Hefei was the highest in winter, 2 times higher than that in summer, followed by autumn and spring.

This result is the same as the time variation characteristics of BC concentration in the Yangtze River Delta and the Pearl River Delta region. Verma[34] studied the time variation of black carbon in the Pearl River Delta region of Guangzhou, and revealed that the black carbon concentration in summer is 47002300ng/m^3.B.L. Zhuang[32] carried out a continuous measurement of BC in Nanjing city in 2012. It was found that BC had obvious seasonal characteristics, high in spring and autumn and low in summer, and more than 75% data samples were between 1000-6000ng/m^3.This result is the same as the change of BC concentration time[35] in the Yangtze River Delta, and the winter is high, summer is low, and the fluctuation of autumn and spring season is more intense. That autumn and winter haze frequent season, the lower atmospheric boundary layer, the wind speed is small and the stability of the weather more, temperature inversion phenomenon, is not conducive to the spread of pollutants such as particulate matter BC, resulting in higher concentrations of BC. The meteorological factors (wind direction and precipitation) in summer are conducive to the diffusion, and the concentration is low.

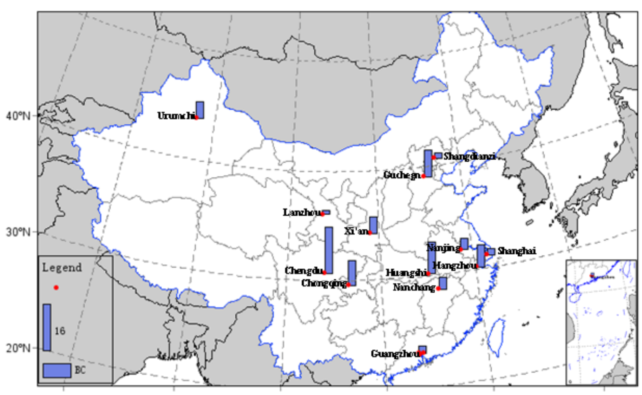

Fig.4 The Comparison of the Observed Result of the BC Aerosol in Different Domestic Cities

3.2 Vertical spatial distribution of mass concentration of black carbon in the middle reaches of the Yangtze River

As the height layer changes, the mass concentration of black carbon also changes, as shown in Fig.5.

As Fig.5 shows, the mass concentration of black carbon changes with the level. Fig.2 is based on MEIC model data cluster on the resolution of 0.25° × 0.25° , and the mass concentration of black carbon at levels of 1.000hPa, 0.9950hPa, 0.9870hPa, 0.9700hPa is respectively shown in Fig 5(a), Fig 5(b), Fig 5(c), Fig 5(d). In Fig.5, from 1.000hPa to 0.9700hPa, with the increase of height, the spatial distribution scale of the mass concentration of black carbon and the average mass concentration decrease gradually.

In Fig.5(a), at 1.000hPa, the spatial distribution of the black carbon is wide, mainly in Wuhan Urban Area and its surrounding areas, the mass concentration of which reaches 200g/s in Wuhan City region, and 60-80g/s, 40-60 g/s, 40-60 g/s, 20-40 g/s respectively in Caidian region, Huangpi region, Jiangxia region and Hannan region. The nearer the regions is from Wuhan central city, the lower the mass concentration of black carbon is in the surrounding regions.

The Fig.5(b) shows the spatial distribution of the mass concentration of black carbon at the 0.9950hPa. In Fig.5(b), the highest mass concentration of black carbon comes in the central city, reaching 10g/s, and 2-5g/s in surrounding regions like Caidian, Jiangxia, Hannan; except Daye and Xiantao, the surrounding cities and counties has little black carbon distribution. In Fig.5(c), at 0.9870hPa, the mass concentration of black carbon is higher in Wuhan central urban area and its near regions, and other regions have distribution of the mass concentration of black carbon, arriving at 1g/s.

The Fig.5(d) shows the spatial distribution of mass concentration of BC at 0.9700 hPa. Compared to Fig.5(a), Fig.5(b), Fig.5(c), the mass concentration of BC in Fig.5(d) clearly reduces. With the high height from the ground, the wind speed over the studied region is higher than the other three levels, therefore, the black carbon aerosol in space will spread to the surroundings, whose mass concentration is between 0.01g/s and 0.03g/s, while the mass concentration of BC in Wuhan central urban area is between 0.09g/s and 0.1g/s.

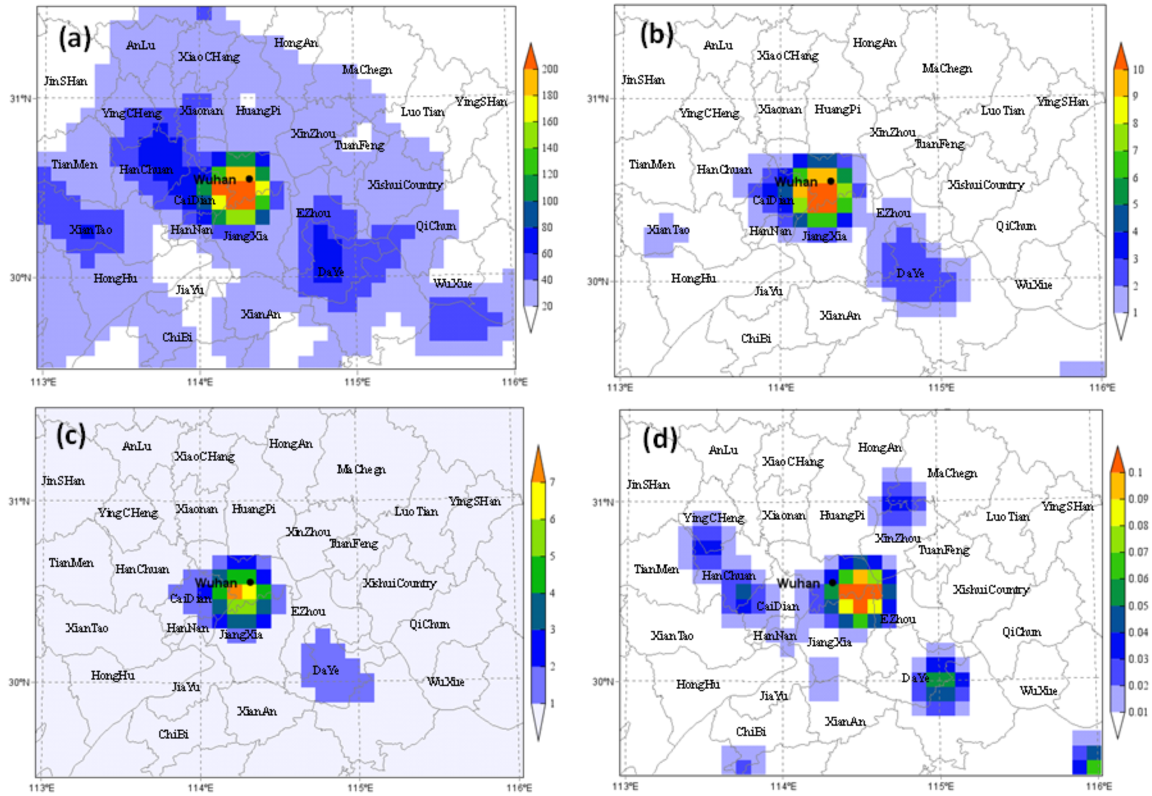

Fig.5 Vertical spatial distribution of mass concentration of BC in Wuhan area (unit: g/s)
（a）1.000hPa;（b）0.9950hPa;（c）0.9870hPa; （d）0.9700hPa

From the above analysis, the mass concentration of BC in Wuhan shows a decreasing trend in the spatial distribution from the central urban area to the suburban area and the surrounding area. There is great discrepancy in the mass concentration of BC between different levels: the mass concentration of BC is largest near atmospheric surface, and the mass concentration of BC gradually decreases with the increase of height. It is explained that BC substance, a kind of air suspension, can begin the deposition process in the vertical direction with dry deposition and wet deposition of the atmosphere, therefore, the above distribution regulation is found in vertical direction.

3.3 Analysis of the Meteorological Effect on Mass Concentration of BC

This paper chooses the data of WD, WS, VSB, T and AP to represent the conventional meteorological data of Wuhan region, and make relevant analysis with the observed data of BC from July, 2015 to June, 2016.

3.3.1 The Relationship between the Mass Concentration of BC and WD and WS

The Relationship Between the Mass Concentration of BC and WD and WS is shown in Fig.6.

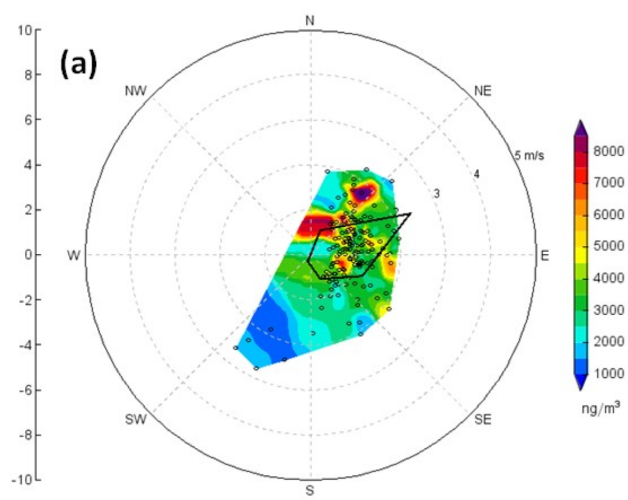

Fig.6 The Distribution of the Relationship Between the Mass Concentration of BC and WD and WS (Unit: ng/m³)

Table. 2 The Analysis of the Correlation Between BC and T, VSB and AP

		BC	T	AP	VSB
BC	Pearson Correlation	1	-.626**	.523**	-.529**
	Significance（bilateral）	/	.000	.000	.000
	N	152	152	152	152
T	Pearson Correlation	-.626**	1	-.914**	.241**
	Significance（bilateral）	.000	/	.000	.003
	N	152	152	152	152
AP	Pearson Correlation	.523**	-.914**	1	-.083
	Significance（bilateral）	.000	.000	/	.309
	N	152	152	152	152
VSB	Pearson Correlation	-.529**	.241**	-.083	1
	Significance（bilateral）	.000	.003	.309	/
	N	152	152	152	152

Note：* represents the significant correlation (bilateral) at level 0.05；**represents the significant correlation (bilateral) at level 0.01.

When the WD is north-northeast, and the WS 2m/s, the mass concentration of BC is up to its peak, more than 8000ng/m^3; when the WD is north-northwest and the WS 1m/s, the mass concentration of BC is 7000 to 8000ng/m^3; the mass concentration of BC is in concentrated distribution of 3000 to 4000 ng/m^3 when the WS is 1 to 2m/s; and when the WD is southwest-south, and the WS 2 to 3m/s, the mass concentration of BC is at its bottom of 1000ng/m^3.

With the increase of wind speed, BC is diluted and its mass concentration decreases. Therefore, there is a negative correlation between BC and local small wind speed, that is, BC emission sources are easy to enrich BC pollutants under relatively stable weather conditions. Ramachandran and Rajesh[36] also noted the negative correlation between BC and wind speed in the urban area of Ahmedabad, India.

3.3.2 The Relationship between the Mass Concentration of BC and the Other Meteorological Factors

At the significance level of 0.01, BC is highly relevant with T, VSB and AP, the correlation coefficient of which is respectively -0.626, -0.529, 0.523, shown in Table.2.

Then the correlation coefficient between BC and T, VSB and AP in different seasons is analyzed with the result shown in Table.3.

Table 3 The Correlation Coefficients Between AP, VSB and T

Season	Correlation Coefficient		
	Between BC and AP	Between BC and VSB	Between BC and T
Summer	0.333	-0.712	-0.291
Autumn	0.103	-0.516	-0.074
Winter	-0.107	-0.698	-0.099
Spring	0.463	-0.426	-0.338

The largest absolute values of the correlation coefficient between BC and T and AP are in spring, and the largest one between the mass concentration of BC and VSB is in summer and winter. Compared with winter, spring has higher temperature, lower AP, more precipitation and lower mass concentration of BC, but the winter does otherwise. The comprehensive effect between this variation and the seasonal correlation between pollutant and BC leads to the feature of temporal variation that the mass concentration of BC is higher in winter and lower in spring.

It indicates that, in meteorological factors, the VSB has the biggest influence on the mass concentration of BC, and this is identical with that $PM_{2.5}$ in pollutant is the main influence on the mass concentration of BC.

3.4 The Correlation Analysis between Other Air Pollutant

The correlation Analysis is made between the Observed Data of BC from July, 2015 to June, 2016 in Wuhan region and the data of pollutant($PM_{2.5}$、PM_{10}、SO_2、NO_2、O_3、CO) during the same time. The result shows that BC is all positively correlated with $PM_{2.5}$, moderate positive correlated with PM_{10}, CO, SO_2, NO_2, and moderate negative with O_3, the correlation coefficients of which are 0.863, 0.657, 0.647, 0.518, 0.466, -0.366 respectively.

It is inferred that the source of BC aerosol is mainly from the human activities, specially including kinds of fuel combustion source, the mobile source typical of motor vehicle exhaust. Yet under certain conditions, the O_3 in the air is apt to chemical reaction with O, NO, NO_2 and others, and then NO_2 is consumed while the O_3 increases, in other words, the variation tends of O_3 and NO_2 is contrary.

Table.4 correlation coefficient of BC and other pollutants in different seasons, the correlation between BC and $PM_{2.5}$, PM_{10} and CO is higher in autumn and winter, and lower in spring and summer, with the highest one in winter and the lowest one in spring. This variation is identical with the seasonal distribution trend of the mass concentration of BC aerosol, which further shows that $PM_{2.5}$, PM_{10} and CO are the main sources of BC aerosol in Wuhan urban area.

Table. 4 The Correlation Coefficients between BC and $PM_{2.5}$, PM_{10} and CO

season	Correlation coefficients		
	Between BC and $PM_{2.5}$	Between BC and PM_{10}	Between BC and CO
summer	0.81	0.73	0.36
autumn	0.60	0.66	0.70
winter	0.89	0.67	0.81
spring	0.63	0.55	0.33

In summer, winter and spring, the correlation coefficient between BC and $PM_{2.5}$ is the largest among the three, indicating that $PM_{2.5}$ has a greater contribution to BC concentration. In autumn, the correlation coefficient between BC and CO is the largest, which is 0.7. Currently, the correlation coefficient between BC and $PM_{2.5}$ is the lowest among the three.

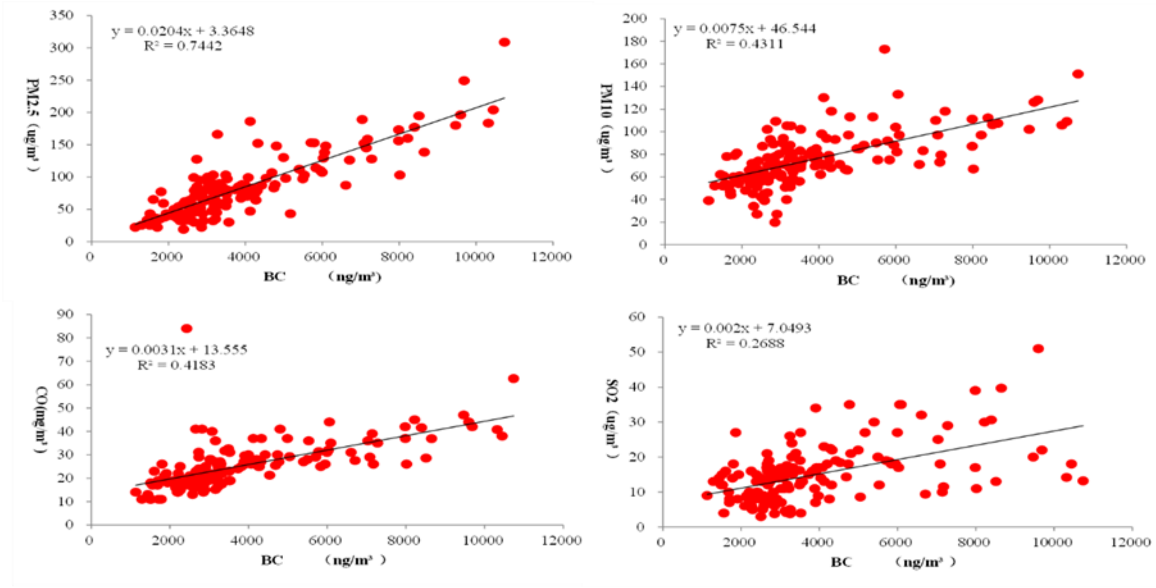

Fig.7 correlation analysis of mass concentration of BC and main air pollutants
（a）BC and $PM_{2.5}$;（b）BC and PM_{10};（c）BC and CO;（d）BC and SO_2

BC and CO are interconnected by combustion process, so their changes are similar, showing a positive correlation (Table.4), indicating that common combustion sources are carried by similar atmospheric circulation. The air quality is relatively cold in winter / autumn, which leads to the better correlation between BC and CO, and the depth of the mixed layer is relatively shallow.

There is a negative correlation between black carbon and ozone, and Chao Chen[31] is considered to be mainly related to solar radiation. The intensity of solar radiation affects the intensity of convection in the atmosphere, which indirectly affects the mass concentration of black carbon. When the solar radiation is strong, the black carbon aerosol is not easy to gather because of the convection in the atmosphere, and the strong solar radiation can also promote the formation of O_3.

3.4.1 The Modeling Analysis Between BC and Other Air Pollutants

Making BC the dependent variable and $PM_{2.5}$, PM_{10}, CO, O_3, SO_2, NO_2 the independent variable, this paper studies the linear relation between them by using the SPSS multiple linear stepwise regression analysis. Use 11 models to make contrast, namely, the linear model, the logarithmic model, the reciprocal model, the quadratic model, the cubic model(the parabolic model), the composite model, the power function model, the S-shaped model, growth model, exponential model and the logistic model, of which the model with the largest correlation coefficient is chosen.

(1) The Model Analysis of the Individual Pollutant

Putting the data of $PM_{2.5}$ and BC into the SPSS leads the corresponding summary of model and parameter estimates and the regression equation model diagram, shown in Fig.8.

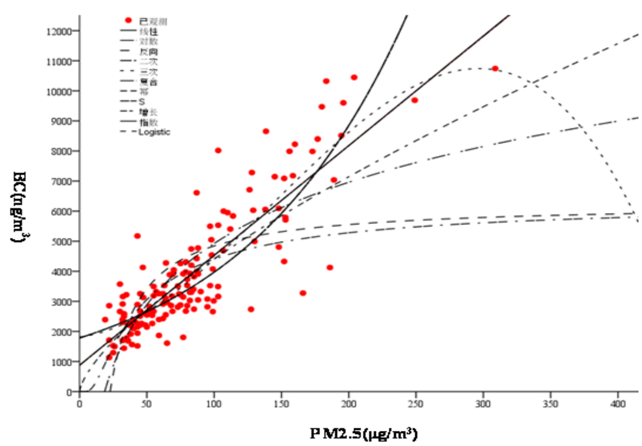

Fig.8 Regression Equation Models between BC and $PM_{2.5}$

In the models, the largest R^2, 0.755, is obtained by the cubic model, and the F value is 152.036, P value is 0.00 consistent with the test, and the expression is followed as:

$$Y=4.922X_3+0.271X_2+0.001X+1817.59 \qquad (1)$$

Y refers to BC, X to $PM_{2.5}$

The same way tells that the correlation between BC and PM_{10} and CO both use the cubic model, where the R^2 is the largest that is, the fitting degree is the best. The expression is followed as:

$$Y=-179.966X_3+2.803X_2-0.01X+5588.061 \qquad (2)$$

Y refers to BC, X to PM_{10}

$$Y=-160.752X_3+11.229X_2-0.11X+2454.995 \qquad (3)$$

Y refers to BC, X to CO

(2) The Modeling Analysis of the Pollutants

The regression equation can be built, where X_1 refers to $PM_{2.5}$, X_2 to PM_{10}, X_3 to SO_2, the multiple linear regression equation over the model is followed as:

$$Y=1493.322+43.623X_1-24.505X_2+40.12X_3 \qquad (4)$$

After T test, the probability (P) values of b_1, b_2 and b_3 are 0.000, 0.000 and 0.003, respectively. According to the given significance of 0.10, they all have significant significance. At the same time, the VIF value is less than 10, the empiric value (Neteretal, 1985), and the multiple collinearity of the variables in the equation are not obvious.

3.5 Using backward trajectory analysis of the source and path of BC in the middle reaches of the Yangtze River

In addition to local pollution sources, black carbon pollution in a region is also related to external pollution sources. In certain weather conditions, foreign pollutants will be transported to the area with the air flow, affecting the level of black carbon concentration. Therefore, the representative dates of the period with heavier black carbon pollution in the four seasons of July 17, October 17, January 17, 2016 and April 17, 2015 are selected, and the mixed single particle Lagrange comprehensive trajectory Mode (HYSPLIT4) on Wuhan air block motion trajectory analysis to understand the BC source and path. Fig. 9 shows the 168h retrograde trajectory in different regions of Wuhan. Among them, the red, blue and green represent the back trajectory of 100m, 500m and 750m respectively.

1. In July 17, 2015. The air masses of the three levels are mainly from the north, originated from Inner Mongolia, Far East and Yellow Sea regions of China, respectively, and they travel in heavily polluted areas such as Hebei, Shaanxi, Shanxi, Anhui and Henan, with short routes and low air quality at the later stage, Easy to carry air pollutants to the middle reaches of the Yangtze River to form a gathering.
2. In October 17, 2015. The three air masses at 100m, 500m and 750m have similar origins - the Mediterranean Sea and highly consistent movement routes. After arriving in Mongolia through Central Asia, they reach the southeastern region of the Yangtze River through southeastern Inner Mongolia, Shanxi and Henan provinces.
3. In January 17, 2016. Similar to Fig. 9-b, the air masses at three altitudes come mainly from the northwestern European continent. After long-distance transportation to the east, they reach the Mongolian region. After being affected by the high pressure of Mongolia-Siberia, the air masses at all three levels go southwards through Inner Mongolia, Shanxi, Henan reached the middle reaches of the Yangtze River. This route passes through the traditional pollution area of our country and is an important transport channel for pollution. Under the superposition of traditional pollution season in winter, the average concentration of black carbon in the middle reaches of the Yangtze River during this period is at a high level throughout the year.
4. April 17, 2016. Compared to the air masses at 500 m above sea level originated in Central Asia, air masses at altitudes of 100 m and 750 m come from the more remote areas of eastern Europe and the western part of Russia. However, the 500m and 750m air masses were transported to the middle reaches of the Yangtze River along

the Xinjiang-Qinghai-Shaanxi-Henan "western passageways" while the 100-meter commercial air masses were transported to the southeastern reaches of the Yangtze River in the southeast direction through the "northern passageway."

The summer air masses mainly come from the northern part of China and the Yangtze River, where the air pollutants near Hebei, Shaanxi, Shanxi, Anhui and Henan are concentrated. The autumn air masses mainly come from the Mediterranean region and pass through the regions of Inner Mongolia, Shanxi in the northwest of Central Asia, Henan and other places to reach the middle reaches of the Yangtze River region; The air mass in winter mainly came from Europe. Affected by the high pressure of Mongolia and Siberia, part of the pollution along the way was transported to the middle reaches of the Yangtze River. Combined with the local bureaucratic pollutants, the average concentration of black carbon was at the highest level in the whole year. The spring mid-high altitude air masses in the middle reaches of the Yangtze River mainly come from the far-source, low-medium air masses come from near-source and local source. The result is similar to the result of B.L. Zhuang [32], both of which are inland cities. In 2012, the air mass in Nanjing mainly came from long distance transport in the northeast. Xiaolin Zhang et al. [33] carried out a trajectory analysis of BC in Hefei from June 2012 to May 2013 and found that there are mainly three types of black carbon pollution from local areas, from the North China Plain to long-distance transportation from the Yangtze River Delta.

4. CONCLUSION

BC was measured continuously in Wuhan in July 2015 to June 2016. Compared with inland cities such as Nanjing and Hefei, the BC concentration was lower than that in some domestic cities.

BC has obvious seasonal, high in winter and low in summer；The BC concentrations are in normal distribution, over 81% of the data samples are between 2000-6000 ng/m^3, the lowest frequency appears in the summer and the high concentration appears in the winter; When the wind direction is north-northeast and the wind speed is 2m/s, the mass concentration of black carbon is the largest and greater than 8000ng/m^3. When the wind direction is north-northwest and the wind speed is 1m/s, the mass concentration of black carbon is 7000-800ng/m^3; When the wind speed is 1-2m/s, the concentration of black carbon is concentrated in the range of 3000-4000 ng/m^3. When the wind direction is southwest and southwest, the minimum concentration of black carbon is 1000ng / m^3 when the wind speed is 2-3m/s.

The absolute values of the correlation coefficients between BC and temperature and air pressure all appeared in spring, while those with the highest visibility appeared in summer and winter.

Autumn and winter BC and $PM_{2.5}$, PM_{10}, CO correlation is high, but in the spring and summer correlation is low.

In general, the summer air masses in the middle reaches of the Yangtze River come mainly from the waters around the North Pacific, fall from northern and eastern Canada, from the Arctic regions near Russia and Canada in winter, and from spring to spring when the air masses are scattered mainly from Canada.

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