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Pollution Monitoring Based on Vehicle-borne Particulate Quantum Lidar

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ABSTRACT

From February 7 to 10, 2018, due to unfavorable meteorological conditions, a process of air pollution occurred in Hefei and its surrounding areas, and moderate to severe pollution occurred in the municipal districts. Aiming at the pollution process in Hefei City, under the leadership of Hefei Environmental Protection Bureau and with the support of Hefei Environmental Protection Sub-bureau, four fixed observation points were selected to carry out all-weather environmental network monitoring pilot projects in Hefei municipal jurisdiction area. At the same time, a "mobile monitoring vehicle of atmospheric environmental pollution" was arranged to conduct all-weather walking observation to real-time monitor the spatial distribution and three-dimensional space of pollutants in Hefei urban area、inter-transport and space subsidence and diffusion. The RaySound Series Portable high-energy high-frequency lidar was used in the environmental networking monitoring in Hefei. The air quality in the observation area was evaluated comprehensively by using the mode of fixed vertical monitoring, plane scanning monitoring and mobile walking monitoring.

1. INTRODUCTION

As the main reason of air pollution, such as haze, aerosols or suspended particulates, especially fine particles, have an important impact on air pollution. For the measurement of particulate matter, some physical and chemical properties such as mass and concentration can be obtained by ground observation, but the spatial distribution information of particulate matter can not be obtained by ground measurement instruments. The vertical distribution of particulate matter can be mastered by means of sounding balloon and aircraft observation, but the operation cost is high and it is difficult to achieve data continuity [1]. Because the existing monitoring equipment in the station can not accurately judge the diffusion trend of atmospheric pollutants, in order to strengthen the capacity of building atmospheric pollution control monitoring and provide technical support for the action of air pollution control, it is urgent to add atmospheric particulate matter lidar and vehicle-borne particulate matter monitor. Atmospheric particulate matter lidar is mainly used for monitoring atmospheric transmission process, large-scale measurement in large areas, assisting vehicle-borne particulate matter monitor to realize the rapid moving monitoring of emission sources[2]. It monitors the main emission sources affecting atmospheric pollution in real time, including construction site dust, road dust, transport vehicle spraying, etc. and provides effective data support for pollution source analysis and related decision-making. In order to verify the feasibility of Lidar monitoring of pollutant sources, a Lidar Monitoring Experiment of pollutant sources was conducted in Hefei City by using vehicle-borne particulate matter quantum lidar.

2. METHODOLOGY

2.1 The lidar system

The basic principle of lidar detecting atmosphere is the mechanism of interaction between laser and atmosphere . Laser beams generated by lasers are emitted into the atmosphere. When they meet with air molecules, aerosols and other components in the atmosphere, they will scatter and absorb. A small part of the scattered energy (backscattered light) falls on the receiving telescope field of view and is received . Its basic principles can be expressed by formulas:

$$P(z) = \frac{\frac{CEO(z)\beta(z)T^2}{Z^2} + BG + AP}{DTC[P(Z)]}$$

In the formula, P (z) is the received signal, Z is the distance from the signal to the lidar, C is the constant of the lidar system, E is the energy of the laser pulse, the aperture is the backscattering coefficient, and R is the bidirectional transmittance. BG, AP, DTC and O (Z) represent background noise, residual pulse, detector delay correction and overlap factor correction respectively .

2.2 Inversion method of aerosol extinction coefficient

The inversion of aerosol extinction coefficient needs to solve the lidar equation.

$$P(z) = P_0 C z^{-2} [\beta_a(z) + \beta_m(z)] \exp\left[-2 \int_0^z \alpha_a(z') + \alpha_m(z') dz'\right]$$

Among them, P(z) is the receiving power at height z, C is the function of lidar system, B(z) is the backscattering coefficient, and A(z) is the extinction coefficient. Subscripts a and m are usually used to represent aerosols and atmospheric molecules. According to Rayleigh scattering theory, the backscattering coefficient of atmospheric molecules can be calculated from the standard molecular model. Assuming that the aerosol lidar ratio （$S_a = \frac{\alpha_a(z)}{\beta_a(z)} = 50\text{sr}$）and the atmospheric molecule （$S_m = \frac{\alpha_m(z)}{\beta_m(z)} = 8\pi/3$） , the aerosol extinction coefficient can be written as follows:

$$\alpha_a(z) = \frac{P(z)\exp\left[2\left(\frac{S_a}{S_m} - 1\right)\int_z^{z_c} \alpha_m(z)dz\right]}{\frac{p(z_c)}{\alpha_a(z_c) + \alpha_m(z_c)\frac{S_a}{S_m}} + 2\int_z^{z_c} P(z)\exp\left[2\left(\frac{S_a}{S_m} - 1\right)\int_z^{z_c} \alpha_m(z')dz'\right.} - \frac{S_a}{S_m}\alpha_m(z)$$

The distribution of aerosol backscattering coefficients can be obtained by inversion of lidar m-scattering echo signal with the above formula [3] .

2.3 Monitoring Mode

Fixed vertical monitoring

Long-term vertical measurements at fixed stations can be used to analyze the transport of pollutants in space. Combining with the wind field lidar, the pollutant transport ratio can be calculated and the local/external ratio of pollutants can be analyzed. Vertical measurements can be used to obtain the spatial and temporal evolution data of vertical particulate matter and to understand the distribution and variation of local PBL layer, which is an important model data for local pollutant models and early prediction.

Mobile Navigation Monitoring

Vehicle-borne lidar mobile navigation monitoring technology can quickly obtain the atmospheric particulate matter profile in the monitoring area. Combining meteorological and topographic macro-environmental conditions, it can effectively analyze the generation and disappearance process and transboundary transport of particulate matter pollution, which has important application value in the detection of regional particulate matter pollution. The causes of urban pollution can be analyzed by combining navigation survey with meteorological conditions, and the pollution situation in various areas of the city can also be visually reflected. Under the combined mode of fixed navigation monitoring and navigation monitoring, Integrated data can be obtained comprehensively.

Planar Scanning Monitoring

Lidar scanning measurement can detect and record the changes of pollution sources (local and external sources) within the radius of 4KM on average, and find the sources of horizontal particulate matter emissions. Scanning data can be displayed directly on the map, that is to say, it can monitor the regional particulate matter in real time.

2.4 Monitoring factors and monitoring methods

According to the cruise monitoring of Hefei's surrounding environment and main pollution source components, the temporal and spatial evolution of particulate matter, PM10 and PM2.5 concentration was selected as monitoring factors. The cruise scanning monitoring was used to analyze the test data in coordination with conventional meteorological parameters such as wind direction, wind speed, low cloud, air pressure and temperature.

2.5 Data Selection Requirements

It is helpful to analyze the causes of Urban Haze by analyzing the pollution sources around the monitoring time in the heavily polluted weather of the city through radar data analysis. The monitoring point is chosen as a high place with wide field of vision and as far away from the water vapor weight as possible. Continuous and uninterrupted scanning was used to analyze the time of different non-polluting point sources, temporary pollution sources and fixed pollution sources. Because of the effect of urban wind, pollution will spread with the wind. Vehicle-borne lidar can be used for flexible monitoring and emergency monitoring of illegal discharge, leakage discharge and unknown sources of pollution in key areas or industrial parks.

3. RESULTS

3.1 Fixed vertical monitoring

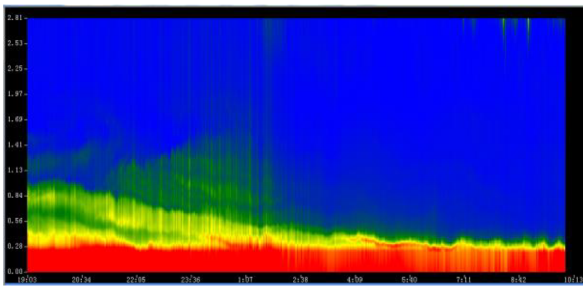

Fig.1 Vertical Monitoring and Analysis Chart of Backscatter Lidar of Hefei City from 11:00 on February 8, 2018 to 10:00 on February 9, 2018

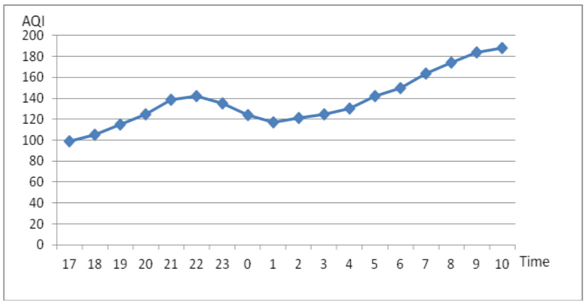

Fig.2 AQI Trend Map of State Control Points in Hefei from 17:00 on February 8, 2018 to 10:00 on February 9, 2018

According to Fig. 1, the inversion analysis map of fixed monitoring in Hefei from 19:03 on Feb. 8, 2018 to 10:13 on Feb. 9, 2018 shows that from 19:03 on Feb. 8, 2018 to early morning on Feb. 9, there exists diffusion and transmission of exotic pollutants about 600 meters above the air in Hefei, which layers clearly with the near surface layer, PBL layer gradually decreases, and the upper air pollution layer gradually subsides, until the early morning of Feb. 9. By the early morning of February 9, the upper pollution layer and the near-surface layer compounded, and the PBL layer gradually decreased from 19:00 on February 8 to about 600 m at high altitude until about 280 m in the early morning of February 9, and then remained basically unchanged. With the deposition of high-altitude pollution transmission and the decrease of mixing layer, while external pollution and local pollution are combined, the decrease of PBL layer is not conducive to the diffusion of pollution, resulting in the agglomeration of near-surface particulate pollution concentration.

Comparing with Figure 2, the trend of particulate matter basically represents the trend of AQI. The main reason for the increase of the monitoring index of the national control point on February 8 is the decrease of the mixed layer, which is not conducive to the diffusion of particulate matter. From the early morning of February 9, the monitoring data of the national control point began to rise, which is higher than that of February 8, Mainly in the case of lower mixed layer, the combination of external transmission pollution settlement and local pollution

3.2 Mobile Navigation Monitoring

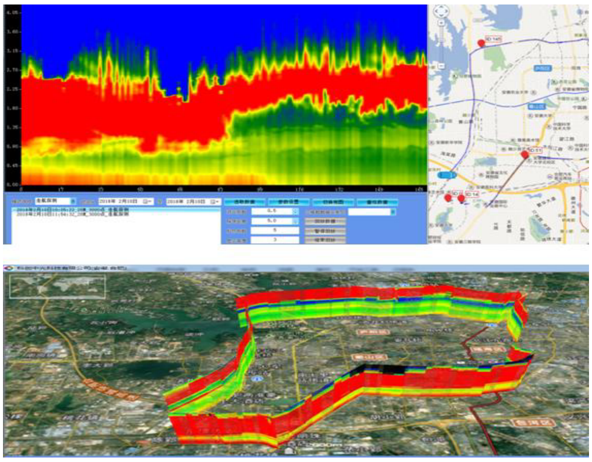

Fig.3 Inversion Chart of Navigation Monitoring at 10:05 on February 10, 2018 in Hefei City

Navigation monitoring was carried out at 10:05 on February 10, 2018. The wind speed was class 3, the direction was northeast ,and the air quality was moderately polluted. The navigation route was near the junction of Jade Road and Flourishing Avenue - Flourishing Avenue - Jinzhai South Road - Tongling Road - North Second Ring Road - West Second Ring Road - Jixian Road - Jixian Road and Luhua Road. From Fig. 3, it can be seen that there are thick clouds at about 2000m altitude during the voyage period. The atmospheric boundary layer changes with the change of monitoring road section. The influence of cloud height is greater. The thicker the cloud layer is, the lower the atmospheric boundary layer is, the worse the atmospheric diffusion condition is, and the concentration of particles near the ground increases. During the navigation monitoring period, there is a particulate matter pollution layer under the high-altitude clouds, the overall height is about 1000m. From the starting point of navigation to the intersection of Tongling Road and North Second Road, the regional clouds are relatively thick. , the layer height is lower and atmospheric boundary layer is about

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500 m. Then from Tongling Road to North Second Road, the cloud layer thickness decreases, the atmospheric boundary layer rises to about 800m, the atmospheric diffusion condition improves, and the concentration of particles near the ground decreases.

3.3 Planar Scanning Monitoring

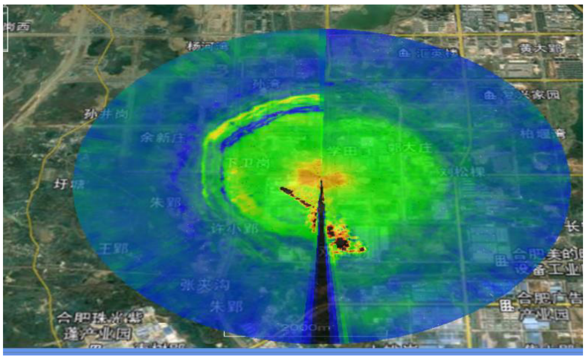

Fig.4 Feb. 10 21:43 Planar Scanning Analysis Chart

On February 10, 2018, 21:08-21:43, a plane scanning monitoring was carried out. The scanning angle was 5 degrees, the wind direction was northwest and wind speed was class 2, and the air quality index was in a good range. According to the results of plane scanning inversion of lidar ,the overall air quality is optimistic. It can be seen that in the spatial range of about 300 m horizontal distance and 100 vertical height at the scanning center, there is a higher concentration of particulate matter than other scanning areas, mainly near the ground. Under the influence of Northwest wind, the concentration of particles in the southeast direction of the scanning center is higher than that in the Northwest direction. It is suspected that there is a silent source near the scanning center with pollution source. Driven by the northwest wind direction, the particles diffuse to the southeast, resulting in higher concentration in the southeast region than that in the Northwest region[4].

3.4 Conclusion

In view of the long-term and mild pollution in this city, we can easily find that there are pollution mass transit over the city through radar data, and the pollution mass transit diffuses and settles. In addition, due to the influence of climate conditions, the PBL layer of the city is reduced, and the ability of pollutant diffusion is weak, which leads to the continuity of urban pollution[5]. The characteristics of vertical spatial boundary layer, pollutant capacity and pollutant input are obtained through integrated analysis of fixed monitoring, plane scanning and navigation monitoring. The spatial particle distribution in urban area is analyzed. At the same time, the monitoring results are basically consistent with the data released by the national control points, so as to get the precise sources and trends of pollution, and verify the feasibility and accuracy of lidar monitoring pollution sources.

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