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THE ANALYSIS OF PHYSICAL FEATURE OF AEROSOL PARTICLES IN AUTUMN OVER SHIJIAZHUANG AREA

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Abstract

Based on the aerosol data observed by aircraft in convective boundary layer(at altitudes below 4000m above the ground) under different weather conditions during autumn in 1990 over Shijiazhuang area, the daily change of number density of aerosol particles and quality concentration in horizontal and vertical direction are analyzed. The results show that the aerosol particles are of local ones under clear air over Shijiazhuang area. The concentration of aerosol particles is from 0. 15 $\times10^{-9}$ to 0. 85 $\times10^{-9}$g.cm^{-3}. The characteristic value of spectral distribution N_0 is from 1.5×10^5 to 5.5×10^5g. cm^{-3}, and λ value is from 13 to 15 μm^{-1} below 4000 meters. The upward transport of aerosol particles is limited, and its distribution occurred discontinuity due to the inversion layer.

The daily change of aerosol number density in the morning was greater than that in the afternoon, but the particle spectra broadened in the afternoon. The spectral distribution of aerosol particles was affected for the city effect. The number density of aerosol particles over the city area was 15% -30% higher than that over the rural areas.

Key Words: Aerosol particle; Number density; Quality concentration; Distribution character

PREFACE

Aerosol not only has a significant impact on the local environment, but also the atmospheric radiation process, and microphysical process of cloud and rain. Through these processes, it affects the weather, even climate change [1]. Therefore, in recent years, problems about the formation, diffusion, transportation and sedimentation of atmospheric aerosol have caused wide concern [2]. In this paper, based on the aircraft detection data of aerosol in Hebei southern plain areas from Weather Modification Office of Hebei Province in the fall of 1990, the distribution of atmospheric aerosol particles under different weather conditions were analyzed. And thus the sources, diffusion, transportation rules of aerosol particles were preliminary studied.

1. DATA OBSERVATION AND WEATHER BACKGROUND

There were 4 aircraft observations in autumn of 1990 on Shijiazhuang area. The first, at 10:47 on the 26th September it took off from Shijiazhuang airport, along Shijiazhuang, Yuanshi, Lincheng, Yongnian, Handan, Quzhou, Neiqiu, Lincheng, Gaocheng , Shijiazhuang, Landing at the Shijiazhuang airport at 12:01. Flight height is generally 3700-4000 m, and we took samples from 11:54 to 12:01, concluding the flight from Gaocheng to Shijiazhuang airport and landing period. Second, it took off from Shijiazhuang airport at 10:16 on the 4th October, a circle along Shijiazhuang, Yuanshi, Luancheng, Gaocheng, Zhengding, Shijiazhuang, landing at the Shijiazhuang airport at 11:25. Flight altitude was 400-1200m. Sampling time

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was in the whole flight. Third, it took off at 5:00 pm, along the same flight route of the morning. Flight altitude was 390 ~ 2000m, continuous sampling throughout the flight. Fourth, departure time was 9:15 on the 18th October from Shijiazhuang Airport. It flied around the Shijiazhuang airport with flight altitude of 500 - 3000m, continuous sampling. The modified An-26 aircraft was used to observe, equipped with PMS particle detector (ASSP probe can continuously detect aerosol particles with diameter of 0.12-3.12μm) and the temperature self-recording apparatus.

The weather conditions during 4 observations were as follows: the observation area was located in the front of trough in 26th September, with visibility of 8km, clouds mainly as op and s cloud, while the westerly trough affected Hebei Province that day. Cloud forms in work area was Sc and As, with height of 4000m. Light rain fell the day after 14 o'clock; It's sunny day in October 4th, with south wind blowing in Shijiazhuang, the wind speed 3-4m·s^{-1}, visibility 14km. The airport has large smoke at low altitude, poor visibility as it was the autumn harvest time in suburb of Shijiazhuang, and farmers burn a lot of straw; It's sunny days in 18th October, with visibility of 12km.

2. THE INFLUENCE OF WEATHER CONDITION ON THE AEROSOL DISTRIBUTION

The quality concentration of aerosol particles is calculated by the formula $M=\frac{\pi}{6}\sum N(D)D^3\rho$. D is the equivalent spherical particle diameter; N(D) is the number of particles with diameter of D in per cubic centimeter; ρ is the density of aerosol particles, with the average of 2.5g·cm^{-3}. The quality concentration change of aerosol particle with height in different weather conditions is showed in Figure 1.

It can be seen from figure 1 that the quality concentration distribution of aerosol particles showed a negative exponential decrease with height below 2000m in a clear day, with surface concentration of 0.85 × 10^{-9} g·cm^{-3}; It was still a negative exponential distribution below 1000m when half of the sky was cloudy but the concentration on the ground fell to 0.58 × 10^{-9} g·cm^{-3}. The negative exponential distribution at the low layer was damaged in cloudy days because of the strong convection in the atmosphere. The distribution of aerosol particles in clouds showed two peaks. One was 0.78 × 10^{-9} g·cm^{-3} at the height of 4000m, another 0.55 × 10^{-9} g·cm^{-3} at the height of 6000m. It can be seen that weather conditions have great influence on delivery of aerosol particles from the lower to the upper layer. In the sunny days aerosols are delivered upward by particle diffusion or turbulence movement, but in rainy days a large number of aerosol particles are delivered to the top of cloud by a strong atmospheric convection because of the wind.

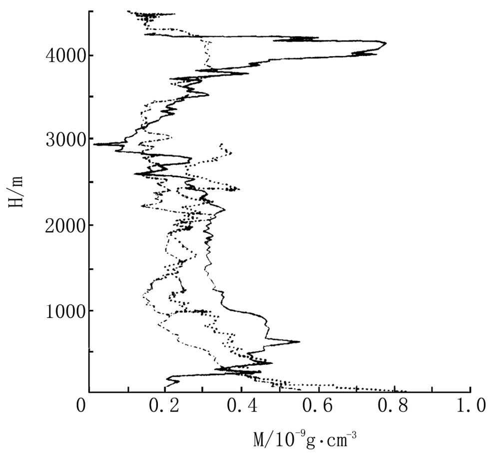

Fig. 1 The quality concentration distribution of aerosols with height; the real line: 26th September in 1990; the dash and dot line: 9th October in 1990; the dashed line:18th October in 1990.

3. THE INFLUENCE OF WEATHER CONDITION ON THE AEROSOL DISTRIBUTION

Temperature inversion can prevent the exchange of upper and lower air, so that distribution of aerosol particles has layer characteristics (seen Figure 2).

It can be seen from the temperature data that strong inversion layer appeared at the height from 600m to 800m in that day. The number density of aerosol particles had a low value of 1.5×10^4 per cubic centimeter below the inversion layer, but a peak of 3.2×10^4 per cubic centimeter above the inversion layer.

Temperature inversion layer not only affect the number density of aerosol particles, but also has an impact on spectral characteristic. The size spectrum

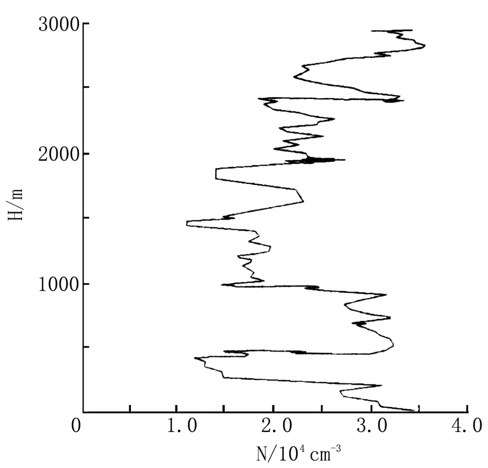

Fig 2. Number density distribution of aerosols with height

of aerosol particles was fitted by the following empirical formula: $N=N_0\cdot\exp(-\lambda\cdot D)$. N is the particle number density with diameter of D, in units of cm^{-3} μm^{-1}. The parameters of N_0 and λ were fitted by observation data. In order to study the change with the height of the aerosol particles, slope parameters λ (μm^{-1}) and intercept parameters (cm^{-3} μm^{-1}) below and above the altitude of 500 m were obtained by the observation data. The average particle spectrum was shown in Figure 3.

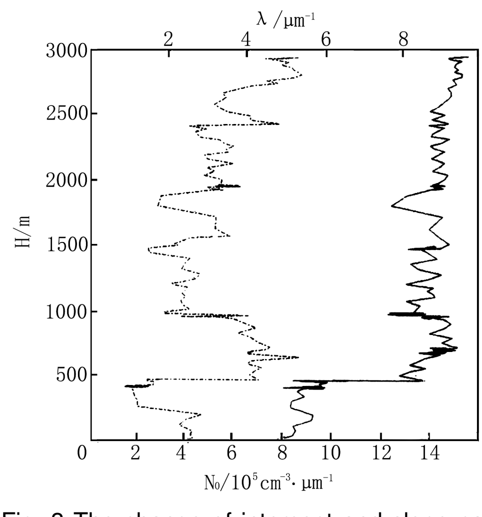

Fig. 3 The change of intercept and slope parameters with height in clear days; the real line: λ; the dash and dot line: N_0

The λ value varied with height can be divided into two parts. In 500-3000 level ,the value is between 13-15μm^{-1},and 8-9μm^{-1} below 500m. We can find that the discontinuous point of λ emerged right under the strong thermal inversion layer compared with temperature level. N_0 increases as height, with a value of 1.6×10^5—5.5×10^5 $cm^{-3}\cdot\mu m^{-1}$, and there is an obvious peak in the strong inversion level with a value of 4.5×10^5 $cm^{-3}\cdot\mu m^{-1}$. This may cause more big particles below 500m with wide spectrum, and the spectrum is relatively narrow above 500m, with many particles in the inversion level. The atmospheric turbulence movement is determined by the momentum transmission and the air mass buoyancy generated from the inhomogeneous heated air. In the condition of no wind and temperature inversion, the turbulence movement is weaken, so that the particles exchanging process in the inversion level is constrained. In the upward spreading transportation process through the inversion level, it is difficult for bigger particles to pass through the inversion level because of strong inertia and average dropping velocity. At the same time, the stable air in the inversion level makes particles to be more apt to stay in.

4. DAILY VARIATION OF AEROSOL PARTICLES

The strength of the turbulence movement in the atmosphere is determined by the value of temperature vertical decreasing rate. When the sky is clear without wind, aerosol concentration has negative correlation with stability. Affected by the daily variation of radiation, the aerosol particles distribution in atmospheric boundary varied daily. At 10 am in October 4th, from the aircraft observation data, we can see the atmosphere vertical decreasing rate below 1300m is 5.5 $C\cdot km^{-1}$,and increased to 7$C\cdot km^{-1}$ when it comes to 5 pm. Aerosol particles number density and quality concentration change with the turbulence movement increasing. The quality concentration shows negative index distribution below 1300m in the morning while in the afternoon it increases with height below 2000m (Fig. 4). The variety of particle number density is corresponding with quality concentration.

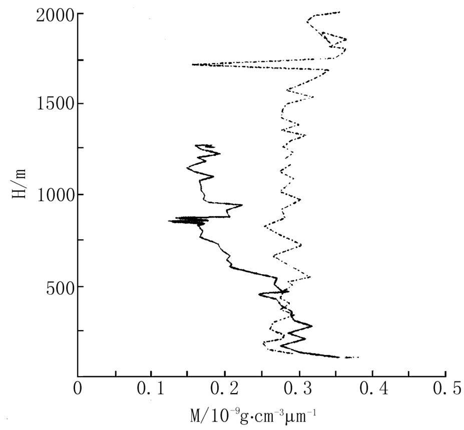

Fig. 4 Daily variation of aerosols quality concentration; the real line: in the morning; the dot and dash line: in the afternoon.

Spectrum distribution of aerosol particles had also changed (Fig. 5 and 6).

There is little change with height for N_0 in the morning at 4th October. And the value is between 2.8×10^5—3.5×10^5 $cm^{-3}\cdot\mu m^{-1}$; N0 increases with height in the afternoon, and the value is between 2.5×10^5—4.5×10^5 $cm^{-3}\cdot\mu m^{-1}$. In the same day λ increases with height in the morning, with a value between 12—16 μm^{-1}; and λ value as 14 μm^{-1} do not change in the afternoon. That is to say the particle spectrum in lower level is wider in the morning than in the afternoon, and it is opposite for upper level. Informed by ground observation data of October 4th, from 10 to 11 am and 5 to 6 pm, we can find that the relative humidity are respectively 38% and 28%. The relatively humidity drops in the afternoon, and it is less than the low limit （40%）[4] for the increase of moisture of aerosol particles. Thus influence of particles high humidity can be eliminated. The major cause of the aerosol distribution variation is that the reinforcement of the turbulence movement can contribute to the upward transportation of aerosol particles.

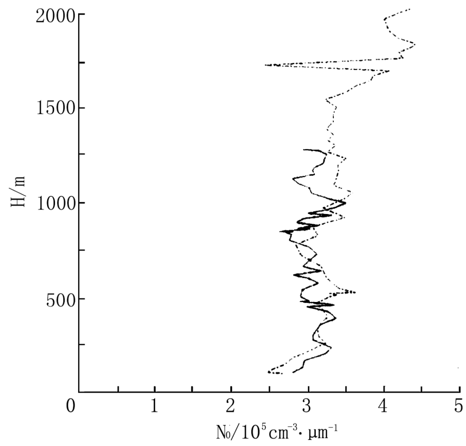

Fig. 5 Distribution of the parameter N_0 in the fitted line with height; the real line: in the morning; the dot and dash line: in the afternoon.

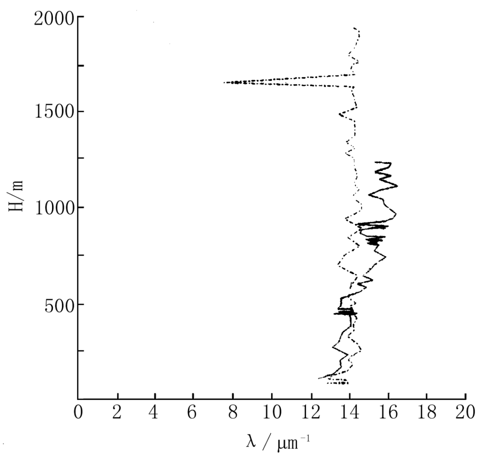

Fig. 6 Distribution of the parameter λ in the fitted line with height; the real line: in the morning; the dot and dash line: in the afternoon.

5. CITY INFLUENCE ON THE HORIZONTAL DISTRIBUTION OF AEROSOL PARTICLES

To analyze the city influence on the horizontal distribution of aerosol particles, we use the 450-500m upper air observation data from Shijiazhuang to Yuanshi of horizontal fly-time and 2000m upper air observation data of horizontal fly-time from northern Shijiazhuang to the neighborhood of airport. The aerosol particle number density above Shijiazhuang can reach to $6\times10^5\cdot cm^{-3}$ in the 500m height. The number density decreases as the distance to Shijiazhuang become longer. And it come down to

4.4×10^5—$4.7\times10^5\cdot cm^{-3}$ above Yuanshi. Above 2000m the density of urban is 7.2×10^5—$7.3\times10^5\cdot cm^{-3}$,and in north-west suburban it decreased to 6.4×10^5-$6.6\times10^5\cdot cm^{-3}$ in 500-2000m height. The aerosol particle number density of urban is greater than that in suburban area by 15%-30%, because of the straw burning in suburban country area around Shijiazhuang. The smog's upward spread is slow; however, the tropical island effect is remarkable, makes a large amount of smog converge to urban, thus the aerosol particle concentration of urban can increase.

6. CONCLUSIONS

6.1 In clear condition, the atmosphere aerosol in nearby area of Shijiazhuang is generated locally, when weather changes, the aerosol spectrum distribution eigen value λ and N_0 can be affected. The distribution feature of aerosol particles is bound up with weather condition.

6.2 The inversion layer is an important factor for the control of aerosol particles vertical transportation. When temperature inversion emerges, the quality concentration and spectrum density is discontinuous between above and under inversion level, the inversion blocks the upward transportation of big particles.

6.3 The spectrum distribution of aerosol particles has obvious daily variation. Below 2000m the quality concentration distribution in the morning is approximately negative index type, while in the afternoon it arises with height, and is approximately slant line type. The low level spectrum in the morning is averagely wide than that in the afternoon, and the upper level spectrum in the morning is narrow than that in the afternoon, with strong turbulence movement, and thus can help upward transportation of the aerosol.

6.4 The tropical island effect can have great influence on the distribution of aerosol particles. There is always aerosol particles peak over city, and this difference is more obvious in low level.

ACKNOWLEDGEMENTS

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