THE AEROSOLS OPTICAL PROPERTIES INVESTIGATION DURING THE DUST POLLUTION

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ABSTRACT:

At present, the air environment in China is characterized by complex pollution. In this paper, the pollutant sources, transport paths and aerosol optical properties during the dust pollution was conducted to analyse based on ground-based lidar, space-borne sensor and atmospheric transmission model. Firstly, the NMMB/BSC-Dust model, the VIIRS-Suomi NPP date and HYSPLIT were carried out to analyse the dust transport paths and the dust particle size, and then the concentration of particles was analysed. Finally, the optical properties of aerosol particles in the dust weather were studied. During the formation of this weather, there is high dust in the Gobi and Taklamakan deserts. With the influence of wind direction, the dust moves from north to south, and the dust load significantly increased in southern China. Dust at the low altitude is generally transported from the Taklamakan Desert, while dust at the high altitude is generally transported from the Gobi Desert. The hourly average change of PM_{10} is from 36μg/m^3 to 818μg /m^3, while the hourly average change of $PM_{2.5}$ is from 15μg/m^3 to 197μg/m^3. The dust was the main cause of the pollution weather. In this study, the formation process of the dust pollution revealed which can be used to provide guidance for government for the prevention work of dust pollution.

1. INTRODUCTION

Asian dust plays an important role in climate, ecosystem and air quality(Han et al., 2015; Liu et al., 2018; Mian et al., 2007). When large amounts of dust are injected into the atmosphere in a favourable climate, it can seriously affect human health and economic activities(Che et al., 2015; Chenbo et al., 2008; Gui et al., 2016). Because Asian dust travels long distances, its impact is global(Kulmala et al., 2015; Nie et al., 2015; Rong, 2015). When Asian dust enters an area, it often mixes with local pollutants, affecting the radiation-cloud-climate process(Kan et al., 2010; Yi et al., 2014).

Due to China's rapid economic development, air quality has become a major factor affecting the environment and human health. Especially from Mongolia and other areas of the impact of long-distance transport of dust, resulting in serious air pollution. In order to quantify the impact of Asian dust on the region and reduce the inaccuracy of the estimation of climate factors, this study combined ground-based lidar, space-borne sensor and atmospheric transmission model to analyse the dust weather in Huainan region on May 4-8, 2017.

2. METHODS

Huainan is located in the central and northern part of Anhui province, located in the hinterland of the Yangtze river delta. Huainan is an important node in the urban agglomeration along the Huai River (Figure 1).

Figure 1. The geographical location of Huainan

2.1 Ground-based and Satellite Data

The ground-based lidar is independently developed and manufactured by the Key Laboratory of Atmosphere Optics, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences. Ground-based lidar is used to detect atmospheric aerosols and obtain the vertical profile of extinction coefficient. The vertical resolution of lidar is 15m and the time resolution is 5min. In this study, the two-axis system is adopted. The backscattered light is received by the receiving telescope. Since all the returned signals can be received by the telescope only after a certain distance, the least square method is adopted in this paper to obtain 0-200m signals

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after signal fitting. The main parameters of lidar are shown in Table 1.

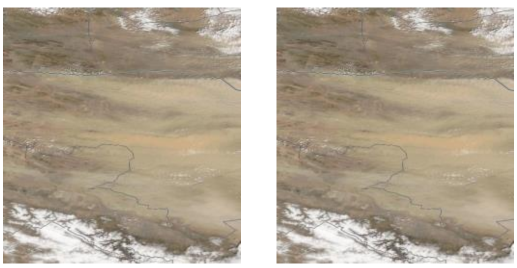
$PM_{2.5}$ and PM_{10} monitoring data: The inspection period is from 4 May 2017 to 8 May 2017. The real-time variation data of the mass concentration of $PM_{2.5}$ and PM_{10} are the national control point data provided by the Department of Ecology and Environment of Anhui Province.

Name	Technical parameters
Wavelength/mm	532
Single pulse energy/mJ	30
Telescope diameter/mm	200
Receive field of telescope/mrad	1
Transmittance of transmitting optical element	0.8
Transmittance of receiving optical element	0.3

Table 1. The parameters of ground-based lidar

CALIPSO (Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observation) is a joint mission between NASA and the French National Space Research Centre to measure aerosols and clouds to advance long-term climate change and climate variability forecasts.

NASA launched the Suomi national polar-orbiting satellite (NPP) on October 28, 2011, with the cross-track infrared explorer (CrIS) combined with four other new detectors. The project will provide researchers with more accurate information about the earth's atmosphere and improve weather forecasting and climate cognition. Figure 2 shows the VIIRS Suomi NPP 1 km true-colour images during the dust storm on 3 May 2017. The left panel is the dust storm arising from the Gobi Desert in Inner Mongolia; The right panel is the dust storm arising from the Taklimakan Desert.



(a) (b)

Figure 2. VIIRS Suomi NPP 1 km true-colour images on 3 May 2017: (a) Gobi Desert in Inner Mongolia; (b) Taklimakan Desert in the northwest China

2.2 Model Products

The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) is a professional model for calculating and analysing the transport and diffusion trajectories of atmospheric pollutants of the National Oceanic and Atmospheric Administration (NOAA).

The NMMB/BSC-Dust model is an online multi-scale atmospheric dust model developed at the Barcelona Supercomputing Centre (BSC-CNS) in collaboration with the NOAA's National Centres for Environmental Prediction (NCEP), the NASA's Goddard Institute for Space Studies and the International Research Institute for Climate and Society (IRI). The model evaluates the global scale dust from three aspects: aerosol optical depth, surface area concentration and deposition. Through this model, we improve the study of regional dust cycle.

2.3 Data inversion

When the laser is transmitted in the atmosphere, it is mainly affected by the extinction of aerosols and molecules in the atmosphere. Some of these signals are scattered back along the original path and are picked up by the telescope. The attenuated backscattered return signal can be expressed as:

$$P(z) = \frac{CE_0\left(\beta_a(z)+\beta_m(z)\right)*\exp\left(-2\int_0^z\left(\alpha_a(z)+\alpha_m(z)\right)dz\right)}{z^2} \quad (1)$$

where $P(z)$ = the lidar return power

z = the distance between the lidar and the target

C = the lidar constant

$\beta_m(z)$, $\alpha_m(z)$ = the backscattering coefficient and extinction coefficient of molecules

$\beta_a(z)$, $\alpha_a(z)$ = the backscattering coefficient and the extinction coefficient of the aerosols

Fernald method(Fernald et al., 1972) is usually used to invert the extinction coefficient of aerosol. Fernald forward integral algorithm expression:

$$\beta_a(z) = -\beta_m(z) + \frac{P(z)\cdot z^2\cdot\exp\left(-2(S_a-S_m)\int_{z_c}^{z}\beta_m(z')dz'\right)}{\frac{P(z)\cdot z^2}{\beta_a(z)+\beta_m(z)} - 2S_a\int_{z_c}^{z}P(z')\cdot z'^2\exp\left[-2(S_a-S_m)\int_{z_c}^{z'}\beta_m(z'')dz''\right]dz'} \quad (2)$$

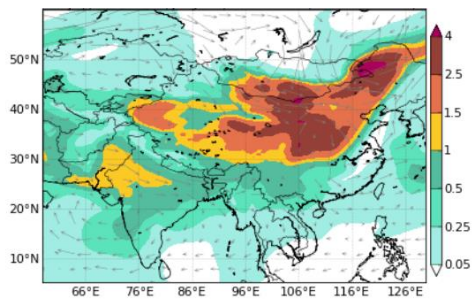
In this paper, the lidar ratio is set to 50Sr(Gong et al., 2015).

3. RESULTS AND DISCUSSION

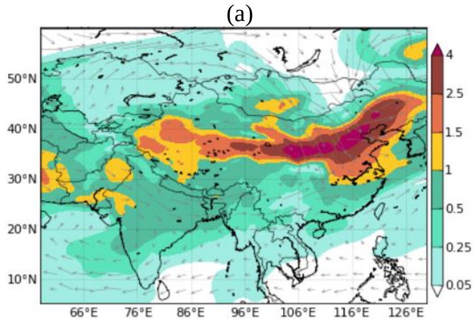
A wide range of sand-dust weather occurred in northern China On 4 May. The air quality index (AQI) was extraordinary for the Beijing-Tianjin-Hebei region. Due to the influence of dust transportation, dust and sand floating weather occurred in the north of Huai river in Anhui province in the early morning of May 5, with the concentration of particulate matter reaching light to heavy pollution. Among them, on May 4, the air quality index (AQI) reached 52， the air quality is good. Over the next few days, it kept going up. On May 5, the AQI index rose to 135, reaching light pollution. On May 6, the AQI index peaked at 500, reaching severe pollution. On May 7, the AQI index fell back to 337, still heavily polluted. On May 8, the AQI index dropped to 67, and the dust weather ended

3.1 The Dust Transport Paths

Figure 3 shows the dust load (g/m^2) and 3000m wind from the NMMB/BSC-Dust model on 4 May ang 5 May. As can be seen, On May 4, there is high dust in the Gobi and Taklamakan deserts, but dust load in eastern China is not high. With the influence of wind direction, the dust moves from north to south, and the dust load significantly increased in southern China on May 5.



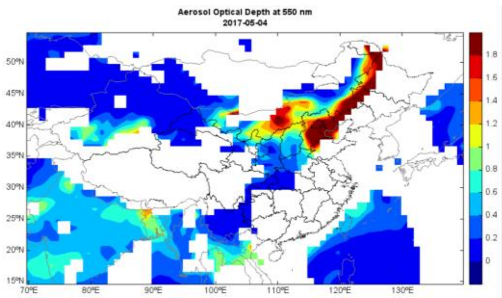
(a)



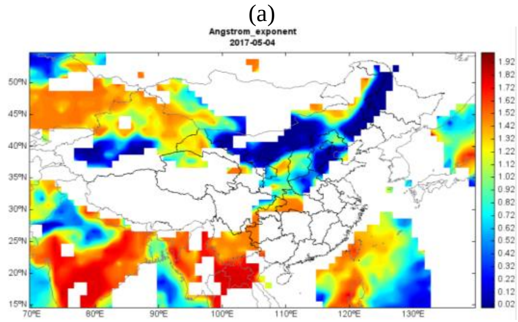
(b)

Figure 3. The dust load (g/m^2) and 3000m wind from the NMMB/BSC-Dust model: (a) 4 May 2017; (b) 5 May 2017

Figure 4 shows the VIIRS-Suomi NPP Level-2 aerosol optical depth (AOD) and angstrom exponent (AE) on 4 May. AOD in land and desert areas is inverted by Dark-Target algorithm and Deep Blue algorithm, but there is no inversion result when there are many clouds. It can be seen from the figure that in the desert area, the AOD value is larger and the AE value is smaller, indicating that the sand source is dominated by the coarse mode. At this time, the dust that invaded the Beijing-Tianjin-Hebei region was also dominated by the coarse model.



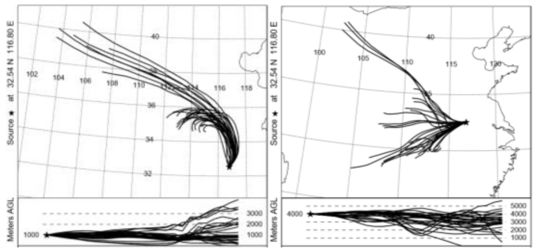
(a)



(b)

Figure 4. VIIRS-Suomi NPP Level-2 aerosol optical depth (a) and angstrom exponent (b) on 4 May 2017

To identify the transport path of the dust，Figure 5 shows the 24-h backward trajectories. Dust at the low altitude of 1000m is generally transported from the Taklamakan Desert, while dust at the high altitude of 4000m is generally transported from the Gobi Desert.



(a) (b)

Figure 5. HYSPLIT 24-h backward trajectories: (a) at the low altitude of 1km, air mass from the Taklamakan Desert; (b) at the high altitude of 4km, air mass from the Gobi Desert

3.2 The Particulate Matter Concentration Impacts on the Air Quality

The concentrations of $PM_{2.5}$ and PM_{10} and the concentration ratio of $PM_{2.5}$ to PM_{10} are given in Figure 6 and Figure 7, respectively. PM_{10} and $PM_{2.5}$ have good synchronicity. The hourly average change of PM_{10} is from 36μg/m^3 to 818μg /m^3, while the hourly average change of $PM_{2.5}$ is from 15μg/m^3 to 197μg/m^3. Beginning in the early morning of May 5, $PM_{2.5}$ and PM_{10} began to increase gradually, but as can be seen from Figure 6, the ratio of $PM_{2.5}$ to PM_{10} became smaller after the start of dust weather, indicating that the weather was in the process of pollution，the dust has become a major pollutant. On the afternoon of May 6, the concentration of particulate matter gradually decreased, and the ratio of the two also gradually increased. On May 8, the particulate matter concentration dropped to the lowest value and the dust weather ended.

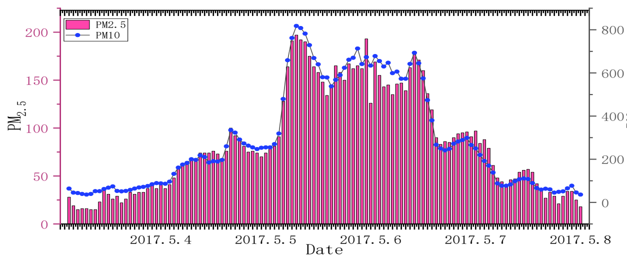


Figure 6. Concentrations of $PM_{2.5}$ and PM_{10} in Huainan

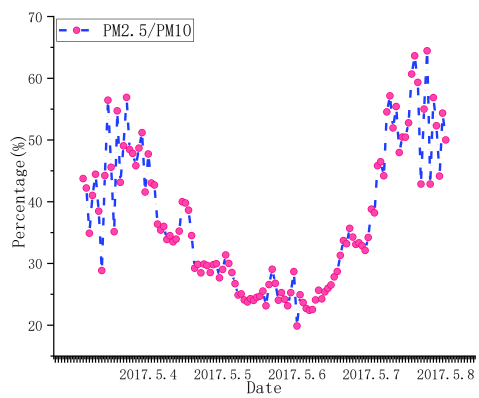


Figure 7. Concentration ratio of $PM_{2.5}$ to PM_{10}

When pollutants invade the clean atmosphere, inversion is likely to occur. Inversion leads to difficult diffusion of pollutants in the vertical direction, which further aggravates the pollution weather. Figure 8 shows the vertical temperature profile obtained by radiosonde at the weather station nearest to the location of ground-based lidar when dust occurs. The results show that when the dust is transmitted to the Huainan area, the inversion phenomenon occurs on May 6 and May 7, and the inversion layer is lower. Since the dust weather lasts for a short time, the effect of inversion temperature is small.

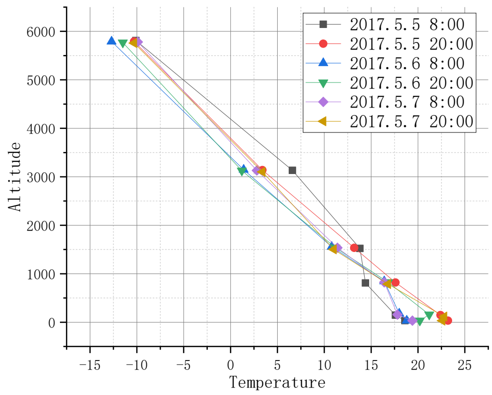


Figure 8. Vertical temperature profile during the dust pollution

3.3 The Dust Optic Properties

Figure 9 shows the aerosol subtype on the 7 and 8 May 2017. Through the observation of the vertical profile of the satellite sensor, the pollutant concentration is between 1000 and 10000m.According to the classification of aerosol subtypes, it can be seen that the maximum dust aerosol can reach 15000m.In this dust event, Huainan area became one of the routes of dust transmission. It can be seen from the figure, polluted dust mainly concentrated in the middle in the atmosphere, and the dust is mainly concentrated in the middle and upper atmosphere. That dust was the main cause of the pollution.

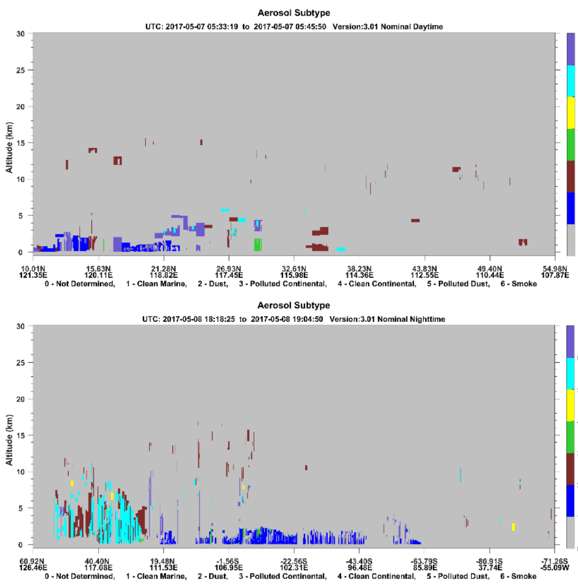


Figure 9. Aerosol subtype during the dust pollution

Through the continuous observation of the lidar placed in huainan area, the formation process of pollutants on May 6 and 7 was selected because the correct target location could not be selected when the dust weather was more serious. Through continuous observation (Figure 10), it can be found that in this dust weather, the dust aerosol particles are mainly concentrated below 4000m and the maximum load is below 2000m.In the early morning of May 6, dust invaded Huainan area, and the extinction coefficient of aerosol increased. With the influence of ground wind, the dust settled to the ground. Sandstorm weather continued to be severe on May 7 at 6:00 am due to strong ground winds. Accordingly, lidar observed that the planetary boundary layer increased, and the extinction coefficient of aerosol at 2000m increased. The variation of aerosol extinction coefficient is basically consistent with that of particle concentration. On the afternoon of May 7, the extinction coefficient decreased and the particle concentration decreased, and the AQI index recovered well on May 8.

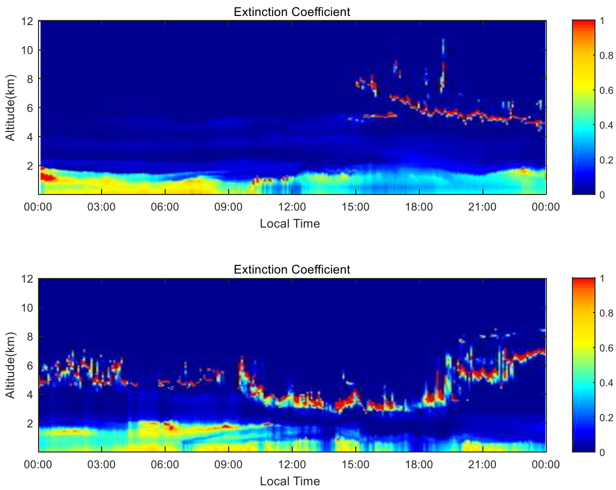


Figure 10. Aerosol extinction coefficient profile

4. CONCLUSION

In this paper, the dust weather in Huainan city from May 4 to 8, 2015 was observed and studied based on the data of ground-based lidar, space-borne sensor and atmospheric transmission model. In this paper, the pollutant sources, transport paths and aerosol optical properties are studied.

During the formation of this weather, On May 4, there is high dust in the Gobi and Taklamakan deserts. With the influence of wind direction, the dust moves from north to south, and the dust load significantly increased in southern China on May 5. Dust at the low altitude of 1000m is generally transported from the Taklamakan Desert, while dust at the high altitude of 4000m is generally transported from the Gobi Desert. PM_{10} and $PM_{2.5}$ have good synchronicity. The hourly average change of PM_{10} is from 36μg/m^3 to 818μg /m^3, while the hourly average change of $PM_{2.5}$ is from 15μg/m^3 to 197 μg/m^3. The dust was the main cause of the pollution weather.
The analysis of the weather process in this paper can provide a research basis for the dust pollution in Huainan region. However, the dust impact on climate processes and the

chemical processes of pollutants need to be analysed in the future work.

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