Research on the Relevant between AOD and Concentration of PM_{10} Pollutant in Tianjin Region of China

Wen Yu Hai [1], Ni Xiao Chang [1],Li Tong [1],Kong Wei Jing [1],Li Li [1]
[1] Tianjin University of Technology and Education,
Tianjin 300222 China

Abstract: **In April 2006, the CALOPSO (Cloud-Aerosols Lidar and Infrared Pathfinder Satellite Observations) satellite launched by NASA enabled to obtain high-altitude, long-range and long-range high-resolution cloud and aerosol data to make up for the traditional ground-based Lidar limitation.In this paper, we selected the 5km profile data of CALIPSO satellite Level2 and screened the data using the relevant screening quality parameters. The extinction coefficient of 532nm channel was extracted. According to the definition of aerosol optical depth(AOD), the program was compiled with Matlab software and the extinction coefficient was integrated to get the AOD. In order to explore the relevant between AOD and PM10 concentration, the five equations: linearity, quadratic, logarithm, power and exponential are selected to fit the data. Experimental results show that the fitting degree of correlation is better and the quadratic fit is the best one.**

Keywords: CALIPSO; AOD; PM_{10}

INTRODUCTION

Aerosol refers to the small particles suspended in the atmosphere, often in solid or liquid granular existence. Aerosol particle diameter changes a wide range, usually between 0.001 microns to tens of microns.Aerosol composition is complicated and its physical characteristics are diverse[1]. And its source, scale, concentration, chemical composition and spectral distribution vary greatly with time and space. Therefore, it is very difficult to analyze and study aerosol properties.Aerosol in the atmosphere a small proportion, but the harm to the human body is very large, it can in the air can absorb many harmful germs and harmful chemicals. These particles have a great harm to the human body, after breathing into the human body, smaller particles are difficult to excreted, resulting in the human body, especially the respiratory system continues to accumulate, which induced a variety of diseases.

Great progress has been made in the analysis of aerosol properties using the CALIPSO satellite sounding data. NASA's Vaughan et al. Analyzed the algorithm of satellite Lidar and proposed a feasible scheme (Vaughan et al. 2004).Using the 2007 annual observation data of CALIPSO satellite combined with the HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory Model) model, Liu et al. Conducted an annual range-scale diffusion analysis of sand-dust aerosols in Tibet (Liu et al. al. 2008).Omar et al. Obtained the 500nm aerosol optical thickness data of AERONET and the 532 channel aerosol optical thickness data of CALIPSO, respectively, and compared the two data to find that the correlation coefficient was 0.42, which proved that CALIPSO satellite data can be used to analyze ground gas Sol (Omar et al. 2013).

Some achievements have been made in the analysis of aerosol in China through CALIPSO satellite data. Zhao Yiming and Jiang Yuesong introduced the data storage structure and data extraction methods of CALIPSO satellite data in detail and analyzed the first-order data combined with the depolarization theory to analyze aerosol. The results show that aerosol backscattering coefficient and polarization degree information Able to well recognize aerosol information (2009).Shen Lili and others made use of the CALIPSO satellite data and the HYSPLIT model to analyze the dust weather in Inner Mongolia from May 25 to May 29, 2008 (2010). Liu et al. Used CALIPSO to analyze a primary dust storm in 2013 in China. Based on the aerosol model simulation, the vertical distribution and transport characteristics of dust aerosols during strong dust weather (2015) were analyzed. Yu Jianhua et al. Analyzed the variation characteristics of PM_{10} and $PM_{2.5}$ concentrations in Beijing from January to April 2003, and analyzed the diurnal variation characteristics of the two in air. Wei Yuxiang and others studied the atmospheric data of Nanjing for five consecutive years from 2002 to 2006, analyzed the variation characteristics of PM_{10}, SO_2 and NO_2, and analyzed the annual variation and monthly variation characteristics, and from the weather conditions under different conditions further analysis. When Li Hongliang and others did a data analysis on a large area of haze events in the Beijing-Tianjin-Hebei region, PM_{10} concentration was also one of the focuses of the analysis. Therefore, the study of PM_{10} on the atmospheric environment is of great significance.

I. POLARIZED SPACEBORNE LIDAR DETECTION PRINCIPLE AND AOD THEORY

In the case of a single scattering, for a space-borne lidar, which receives the target backscattered echo power p 'from the ground z', the meters of scattering lidar equations are expressed as [2][3]:

$$p(z') = \frac{cE_0 Y(z')\beta(z')A_r T^2(z')T_r T_t}{2(z-z')^2} \qquad (1)$$

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In the expression, z represents the height of the ground from the laser radar; z'represents the height of the ground from the detection target; p(z') be the backscattered echo power of the satellite at the target z' from the ground; c represents the speed of light; E0 represents the laser Emitters emit laser pulse energy; Y represents the geometric correction parameters of laser radar; represents the atmospheric backscatter coefficient ($km^{-1}sr^{-1}$) detected, which is divided into two parts: the backscatter coefficient of atmospheric molecules and aerosol particles The backscatter coefficient is:

$$\beta(z')=\beta_m(z')+\beta_a(z') \tag{2}$$

The a is the effective receiving area of the telescope (m^2); TrTt is the transmissivity of the laser radar receiving and transmitting system; T is the laser Radar to the ground from the height of z' at the transmittance of its specific expression:

$$T(\lambda,z')=\exp\{-\int_{z'}^{z}a(\lambda,z')dz'\} \tag{3}$$

$$a(\lambda,z')=a_m(\lambda,z')+a_a(\lambda,z') \tag{4}$$

Where a is the atmospheric extinction coefficient (km-1) at height z' and the sum of the extinction coefficients of atmospheric molecules and aerosol particles(as expressions(4)), with the subscript m as the atmospheric molecule and the subscript a as the aerosol particle.

For CALIPSO, its lidar equation can be expressed as:

$$p(r)=\frac{E_0\xi\beta(r)T^2(r)}{r^2} \tag{5}$$

r is equal to (1) where (z-z') is the system parameter and is determined by CALIOP's various instrument parameters, including the receive area of the eyeglass, the quantum efficiency of the detector, the optical efficiency of the receiver, the signal detection circuit Electronic gain and geometric overlap factor. Its value will follow these changes in the parameters of changes in the data processing we generally expressed as $\xi=G_A C$,G_A on behalf of the amplifier gain factor, C said the calibration parameters of the laser radar.

Aerosol Optical Depth is one of the parameters to describe aerosol's atmospheric climate change. It refers to the total diminution of light by aerosol particles. It is a dimensionless physical quantity, which is the integral of the extinction coefficient in the cloudless condition in the vertical direction[4][5]. The size of aerosol optical thickness can characterize the degree of atmospheric pollution to a certain extent. Therefore, AOD of the inversion calculation is of great significance, its calculation publicity as follows:

$$\tau_\lambda=\int_{H_1}^{H_2}\sigma_\lambda N(z)dz \tag{6}$$

Where τ_λ is the optical thickness of the atmosphere, λ is the wavelength, H_1 is the lower bound of the calculated atmosphere, H_2 is the calculated upper bound of the atmosphere, σ_λ is the extinction cross-sectional area of the particulate, and N(z) is the vertical distribution of the particulate The distribution of It is very important to calculate and analyze the aerosol optical thickness. It is an important factor to evaluate aerosol-induced climate effect and air pollution. The research on the aerosol optical thickness has received extensive attention from scholars at home and abroad, and has been deeply studied both globally and regionally. However, it is difficult to estimate the concentrations of PM_{10} and $PM_{2.5}$ by AOD because the AOD is affected by pollutants and environmental conditions, and its consistency in time domain and spatial region is very poor.

II. CALIPSO SATELLITE DATA PROCESSING

In this paper, CALIPSO satellite Level2 data of 3-5 months of 2016 crossings were downloaded from Tianjin area (with longitude: 39.08005N and latitude: 117.122395E as the center and radius of 100km), all the signal parameters extracted directly are not After the correction of the parameters of the revised data, the reliability of these data is not high, and some even invalid data, the use of CALIPSO secondary data The cloud-aerosol discrimination score (CAD Score), extinction quality control (extinction QC), atmospheric volume description (AVD) Three attribute descriptive flags to filter the data. Through the screening of the three parameters, a more reliable extinction coefficient is obtained, and then the corresponding aerosol optical thickness is obtained by integration.

CAD Score is a parameter used to measure cloud and aerosol confidence. It uses multidimensional histograms obtained from scattering properties to identify clouds and aerosols. Between histograms, the characteristics of a region are considered completely confident if there is no overlap That is, completely cloud or aerosol, and the lower the level of confidence, the larger the area of overlap. The value of a CAD Score is -100 to 100 A negative value for the detected target means the target is aerosol, otherwise it is cloud. The greater the absolute value, the higher the confidence that the target is to be detected [6][7].

The extinction QC is a 16-bit addressable integer variable that records the wavelength of the light extinction coefficient received by each lidar, and only 532nm of the extinction of the cloud. It is the original as well as the final state of extinction inversion. In extinction inversion, we can usually use extinction QC values to filter the appropriate lidar ratio (ratio of object extinction coefficient and backscatter coefficient). When performing the inversion of the data, it is usually assumed that the Lidar ratio is fixed or limited in the reflection process, so the value is 0 or 1 at this time. When processing Level2 data in this paper, we also consider extinction QC to be valid only for data 0 or 1[7][8].

AVD is the profile description feature for data in Level 2 data in CALIPSO satellites. Using AVD values we can differentiate between probes, removing invalid and broken data profiles. The range of data it describes includes a classification within 5 km horizontal resolution, 60 m vertical resolution (or 5km horizontal resolution, 80m vertical height resolution) space. The eigenvalues range from 0 to 7, and each sub-type corresponds to a different sub-type of target,

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representing values of "clean atmosphere", cloud, aerosol, polar stratosphere or stratospheric aerosol, Under the table, no signal (total attenuation). Therefore, when we carry out the data screening work, only the data with the characteristic value of 3 can be selected on the AVD parameters to filter the aerosol data[7][8].

III. PM_{10} MASS CONCENTRATION AND AOD RELATIONSHIP MODEL

Firstly, the extinction coefficient of Level2 data of CALIPSO satellite was extracted from March to May in 2016, and the extinction coefficient of each sample data was averaged as the extinction coefficient of each level of the transit day weather, and each level was obtained The average extinction coefficient, and then combined with the AOD formula, the preparation of the corresponding Matlab program to calculate the extinction coefficient obtained after screening, AOD obtained on behalf of the day's data. And then find the corresponding concentration of PM_{10} on the China Environmental Testing Center, one by one, get the relationship model of AOD and PM_{10} concentration. Figure 1 is a chart of 36 sample data.

The obtained data were simulated and fitted to the AOD of 36 sample data as independent variables, PM_{10} concentration as the dependent variable.Then we establish a mathematical model of the two.In this paper, we choose five types of linear, quadratic, logarithmic, exponential and exponential functions to fit the two. The results are shown in Table 1.

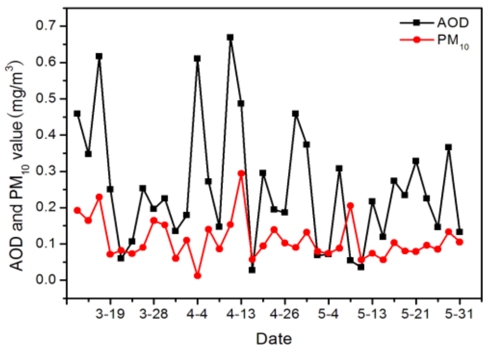

Fig.1 Relationship between PM_{10} and AOD from March to May in 2016

Table 1 March-May 2016 PM_{10} and AOD fitting model

Model type	Equations of fitting model	R^2
linear	y=0.15113+0.12545x	0.27231
quadratic	$y=0.06985+0.19632x-0.09323x^2$	0.31817
logarithmic	y=0.12842+0.02918ln(x+0.0201)	0.17223
power	$y=0.067+0.12622x^{1.13416}$	0.18591
exponential	$y=0.11258e^{0.70722x}$	0.15489

According to the results in Table 1, it can be concluded that the superiority and inferiority of the five function models are the quadratic, linear, exponentiation and exponential models, respectively, based on the value of the correlation coefficient R2, but in general, The correlation coefficient values of the five function models are not high, the highest is only 0.31817. The quadratic model with the largest correlation coefficient is selected as the annual relationship model between AOD and PM10. Figure 2 shows the fitting results of the quadratic model of AOD and PM10.

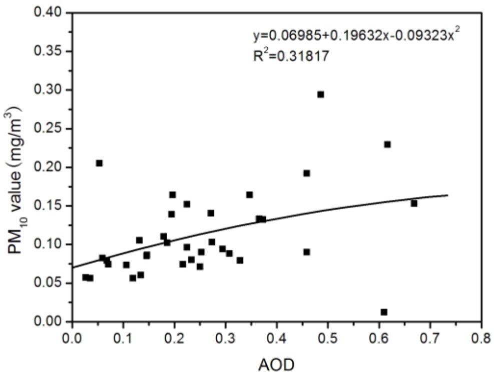

Figure 2 AOD and PM_{10} quadratic model fitting results

IV. PM_{10} MASS CONCENTRATION AND AOD RELATIONSHIP MODEL REVISION

A. *humidity correction*

Studies have shown that aerosol concentration at a certain concentration, the key factor affecting the aerosol extinction coefficient is relative humidity (RH), different relative humidity, aerosol extinction coefficient will produce a few times or even ten times the change. Due to the PM10 concentration released by the Environmental Protection Agency, the collected air is dried during the treatment, and the results indicate the PM10 concentration at a certain relative humidity. The extinction coefficient obtained by CALIPSO is the raw data without drying. When the relative humidity is increased, some water-soluble aerosols will hygroscopic expansion, make the particle size larger, resulting in several times the extinction coefficient increases, thus increasing the data error, so in extracting CALIPSOLevel2 data extinction coefficient, It is very necessary to correct the humidity. The relationship between humidity and relative humidity can be seen as a simple expression:

$$f(RH) = 1/(1 - RH/100) \qquad (7)$$

B. *Aerosol - Corrected CAD Score*

The greater the absolute value of CAD Score from -100 to 0, the higher the confidence that the more the probe is aerosol. Therefore, when the value of the CAD score is larger, the accuracy of the data is higher. During data fitting, Reliability is relatively high, but if the absolute value of the choice is too large, it will lead to the lack of data, and some do not even have the data, the amount of data is too small, the greater the

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chance of statistics in the small amount of data, it can not represent a Feature, so in doing CAD Score correction not only to maintain a certain amount of data, to ensure data reliability. Therefore, in order to obtain more accurate and reliable data, the selection of CAD Score values needs to be revised. After many revisions, the CAD Score value is selected to be -100 to -48. Data greater than -48 are considered invalid or inconspicuous data is removed, further improving the reliability of fitting the PM10 mass concentration to the AOD.

C. revised PM10 mass concentration and AOD relationship model

Through the humidity, CAD Score corrected PM_{10} and AOD relationship model shown in Figure 3

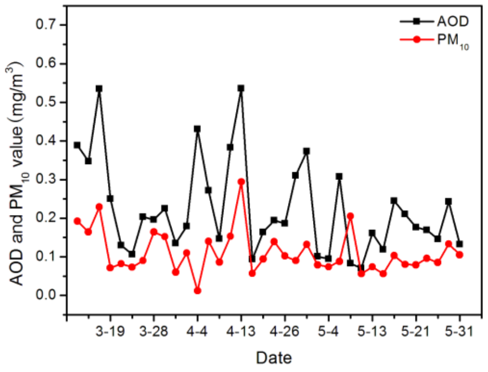

Figure 3 Corrected PM_{10} and AOD model after March-May 2015

The obtained data were simulated and fitted, and the linear, quadratic, logarithmic, exponential and exponential functions were selected and the two were fitted respectively. The results are shown in Table 2.

Table 2 Corrected PM_{10} and AOD Fitting Models after Revised

Model type	Equations of fitting model	R^2
linear	$y=0.13255+0.11756x$	0.40031
quadratic	$y=0.10494+0.2125x+0.83369x^2$	0.49779
logarithmic	$y=0.18435+0.04017\ln(x+0.0121)$	0.32253
power	$y=0.0673+0.24632x^{1.15466}$	0.31531
exponential	$y=0.14159e^{0.82322x}$	0.39459

From the results of Table 2, it can be concluded that the superiority and inferiority of the five function models are followed by a quadratic, linear, exponential, logarithmic and exponential function. The quadratic model is still optimal, and the one with the largest correlation coefficient The quadratic model serves as a model of the relationship between AOD and PM_{10}. Figure 4 shows the fitting results of the quadratic model of AOD and PM_{10}.

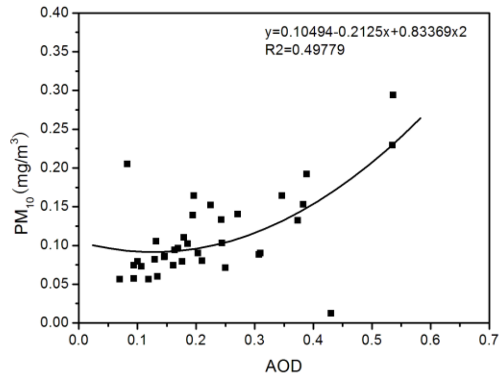

Figure 4 AOD and PM_{10} after revision quadratic model fitting results

V. CONCLUSION

In this paper, the aerosol optical depth is obtained through the screening, calculation and calculation of the extinction coefficient of Level 2 profile data of CALIPSO satellite. Then the model is established with the concentration of PM10 provided by China National Environmental Testing Center, and the correlation between the two is explored through five functional models Corrections were made to the extinction coefficient and found that the correlation was very high after the revision. This shows that CALIPSO data can be used to detect ground air quality and future work can be further analyzed for more data such as year-round and seasonal sub-regions.

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