Inversion of AOD and PM2.5 Mass Concentration in Taihu Lake Area —— Based on MODIS Data

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Abstract. Aerosols are an important factor in the balance of atmospheric radiation and global climate change, and have a significant impact on the environment and the physical health of the human body or other organisms. Accurate detection of aerosol optical depth and PM2.5 mass concentration of accessible particulate matter is important for studying ambient air quality and climate change. In this paper, the aerosol optical depth of Jiangsu Province was retrieved by using the MODIS L1B data from July to December 2017. Based on this, the relational model between PM2.5 mass concentration and AOD was established. The results show that the linear fitting results are better than the neural network. The prediction result of a linear function fitting is the best, followed by the quadratic function, and finally the cubic function.

1. Introduction

With the rapid development of China's economy and the acceleration of urbanization, urban aerosol pollution [1-3] is becoming more and more serious. Aerosol is an important factor affecting atmospheric radiation balance and global climate change, and has a great impact on the environment and the physical health of humans or other organisms. As people's awareness increases, aerosols, especially PM2.5, a small particle size respirable particulate matter, are gaining more and more attention. Therefore, timely and effective implementation of spatial monitoring of AOD and PM2.5 mass concentration, scientific and accurate prediction has become an urgent problem to be solved.

At present, common aerosol monitoring methods include ground monitoring and remote sensing monitoring. Ground monitoring is the main means of atmospheric aerosol monitoring, but since ground monitoring can only be carried out at limited ground stations, it is difficult to obtain a wide range of more accurate aerosol data and its changing trends using only ground-based observations. Satellite remote sensing observation has the characteristics of wide observation range, strong real-time performance and high resolution. It can use satellite remote sensing to monitor the temporal and spatial distribution and trend of environmental air pollution, which provides a possibility for people to understand the atmospheric conditions in a large area in real time.

At present, the main AOD inversion algorithms are mainly divided into two categories: one is to perform inversion based on single remote sensing image data, and usually requires a lot of prior knowledge of the surface before inversion, among which Kaufman's dark pixel method [4-5] and Hsu's dark blue algorithm [6-7] is widely used, the dark pixel method is mainly applied to the aerosol surface thickness inversion of the dark surface, and the deep blue algorithm is mainly used for the inversion of
the bright surface.

The other is to obtain the relative values of aerosol optical thickness for different phases in a given region by comparing remote sensing image data of different regions in different time phases. This method is based on the dual-view satellite image inversion algorithm proposed by Flowerdew et al. [8], Tang Jiakui et al. [9] combined with satellite binary and Aqua observation data binary star inversion algorithm, Lu Lu Shiqing et al [10] through the establishment of a clear sky The atmospheric background of the atmospheric radiation parameters is used to invert the aerosol optical thickness algorithm, but there are some differences in the aerosol properties observed at different times.

This paper selects the Taihu area as the research area. Taihu Lake is located in the southern part of the Yangtze River Delta. The geographical range is between 30°55′40″-31°32′58″ north latitude and 119°52′32″-120°36′10″ east longitude, spanning the two provinces of Jiangsu and Zhejiang. The terrain in the Taihu Lake region is dominated by plains, and the probability of blockage of pollution gas may be small due to the influence of topographic factors in different seasons.

The AOD data was inverted using MODIS L1B data, and the inversion data was compared with the observation data of the ground AERONET Taihu monitoring station to verify the validity of the aerosol optical thickness inversion data. The relationship model between PM2.5 concentration and AOD in Taihu Lake area was further established, and the PM2.5 inversion model suitable for Taihu Lake area was selected to provide theoretical support for remote sensing monitoring.

2. Research methods and technical routes

2.1. AOD’s inversion principle

The methods of inverting AOD based on MODIS L1B data mainly include the following steps: radiation correction of MODIS image (HDF), geometric correction, cloud detection and aerosol inversion. The aerosol inversion algorithm uses the classical dark pixel method, also known as the dense vegetation method, so the aerosol effect for the winter inversion is not good, and the effect is better for the period from March to September.

The lookup table for aerosol inversion is obtained by calling the 6S radiation model from IDL, using the general parameters.

![Figure 1. Inversion of AOD Process Based on MODIS L1B Data](image)

The purpose of aerosol optical depth inversion is to establish its relationship with PM2.5.
2.2. PM2.5 inversion principle
The PM2.5 mass concentration data is derived from the national urban air quality real-time release platform. The time range is from July 2017 to December 2017, with a total of 97 monitoring sites.

Table 1: A part of 97 monitoring sites around Taihu Lake

| ID   | Monitoring station     | longitude | latitude  |
|------|------------------------|-----------|-----------|
| 1    | Magao Bridge           | 118.803   | 32.1083   |
| 2    | Caochang Gate          | 118.749   | 32.0572   |
| 3    | Shuina Road            | 118.778   | 32.0723   |
| 4    | Zhonghua Gate          | 118.777   | 32.0144   |
| 5    | Ruxin Road             | 118.903   | 32.0314   |
| 6    | Xuanwu Lake            | 118.995   | 32.0775   |
| 7    | Fuqu          | 118.626   | 32.0878   |
| 8    | Anhui Center          | 118.727   | 32.0002   |
| 9    | Xianjun College Town   | 118.907   | 32.105    |
| 10   | Shangshan Mountain     | 120.561   | 31.2742   |
| 11   | Nan Gate               | 120.628   | 31.2864   |
| 12   | Caiwei                 | 120.591   | 31.3019   |
| 13   | Ruiyuan               | 120.996   | 31.3204   |
| 14   | Wuhuogu District       | 120.613   | 31.2703   |
| 15   | Suzhou New District    | 120.543   | 31.2994   |
| 16   | Suzhou Industrial Park | 120.669   | 31.3007   |
| 17   | Xiangcheng District   | 120.641   | 31.3708   |
| 18   | Nanyue                 | 120.913   | 31.96     |
| 19   | Hongqiao               | 120.85    | 32.0006   |
| 20   | Changzhou              | 120.87    | 32.02     |
| 21   | Xinghua Park           | 120.94    | 31.93     |
| 22   | Zilang College         | 120.81    | 32.0417   |
| 23   | Monitoring Station     | 119.176   | 34.5895   |
| 24   | Hongche Park           | 115.141   | 34.5896   |
| 25   | Xugou                  | 119.368   | 34.7507   |

Studies have shown that there is a correlation between AOD and near-surface particulate matter. Early studies have shown that the AOD corresponding to the inversion of visible light and near-infrared is 0.1-2 nm, which is very close to the particle size range of PM2.5, which provides a theoretical basis for the establishment of the AOD-PM2.5 model. The AOD data obtained by using ENVI to process MODIS images is combined with real-time monitoring and weather website data to obtain the PM2.5 concentration, and the two data are plotted as a relationship scatter plot. In order to get a suitable model, multiple model analyses were performed in MATLAB and the most appropriate model was selected.

3. Results and analysis
Based on the Visual Studio 2010 C++ integrated development environment, the road marking line automatic extraction experiment of this paper is realized. The experimental platform is configured for Intel Core i7-6900k 3.2GHz, 64GB of memory, and is equipped with Windows 10 system.

3.1. Data introduction
The data in this paper uses the data from July 7 to December of MODIS L1B in the NASA website for experimental effect verification. PM2.5 real-time data comes from 97 cities in the province of Jiangsu Province, which is a real-time release platform for urban air quality.
3.2. Experimental results and analysis

The summer AOD value is higher than the autumn overall, which is basically consistent with the seasonal trend of national AOD. At the same time, the AOD distribution has obvious regional differences, and the north is significantly higher than the south.

Table 2. Actual air quality

| Time    | Urban environmental air quality compliance rate | Primary pollutant |
|---------|-----------------------------------------------|-------------------|
| 2017.07 | 76.7%                                         |                   |
| 2017.08 | 81.9%                                         | O_3              |
| 2017.09 | 86.7%                                         |                   |
| 2017.10 | 91.6%                                         | PM2.5            |
| 2017.11 | 70.8%                                         | PM2.5            |
| 2017.12 | 49.9%                                         | PM2.5, NO_2, PM10|

![Figure 3. AOD inversion results from July to December 2017](image)

It can be found that the measured PM2.5 has good consistency with the inverted AOD data.
The observed data value of the ground AERONET Taihu monitoring station is 0.3022, and the inversion value is 0.25.

The AOP inversion results were tailored using ground PM2.5 monitoring site data. The monitoring station PM2.5 real-time data is written into the sample set in one-to-one correspondence with the corresponding AOD data.

Taking the July data as an example, Linear fitting, quadratic fitting, cubic fitting, and neural network BP were performed respectively.

Table 3. Fitting function and precision

| Function fitting times | Function         | SSE    | R-square: | RMSE |
|------------------------|------------------|--------|-----------|------|
| Linear fitting         | $y=31.49x+4.034$ | 1.994e+04 | 0.09216   | 16.64|
| Quadratic fitting      | $y=9.205x^2-16.59x+9.02$ | 1.99e+04 | 0.09359   | 16.74|
| Cubic fitting          | $y=-24.97x^3+68.31x^2-22.66x+16.81$ | 1.987e+04 | 0.09529   | 16.85|

Figure 4. Neural network training results

Figure 5. Neural network training error
4. Conclusion and discussion

In this paper, the AOD data inversion is performed according to the classical dark pixel method. The PM2.5 data is predicted by linear fitting, quadratic fitting, cubic fitting and neural network BP respectively. The SSE value represents the variance, and the closer the SSE is to 0, the better the model selection and fit, and the more successful the data prediction. The closer the R-square (determination coefficient) is to 1, the stronger the ability of the equation to interpret y, and the model fits the data better. RMSE (root mean square) represents point-to-point error. From these three perspectives, linear fitting is better than quadratic fitting, and quadratic fitting is better than cubic fitting. The neural network prediction results are not stable.

The experimental results show that the accuracy of the inversion results is not very good due to the accuracy of AOD data and the small number of PM2.5 data stations.

The northwest is dominated by industrial areas, so the air quality is poor in the province. It is mainly based on urban pollution sources. The air quality from north to south is getting better, which is consistent with the actual situation.

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