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# Research on Atmospheric Visibility Grading based on Remote Sensing Data

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**Abstract:** Theoretical research on atmospheric radiative transfer shows that aerosol optical depth (AOD) is positively correlated with atmospheric particulate matter (PM) concentration. Using satellite remote sensing data to retrieve the AOD, and monitor and analyze the atmospheric visibility and atmospheric pollution are gradually being widely applied. In this research, the data of moderate resolution imaging spectroradiometer (MODIS) is used for analysis. Firstly, geometric correction, data quality improvement, image stitching, vector cropping, and masking are performed to process the data. Then, the cloud detection tree algorithm is used to detect cloud, thereby eliminating the cloud interference. Finally, the classic dense dark vegetation (DDV) algorithm is used for the retrieval of AOD, and the distribution characteristics of the obtained AOD values are graded according to the retrieval results. This paper uses remote sensing data to grade the visibility of the atmosphere, which provides a reference for the prediction and assessment of the overall atmospheric environment.

**Keywords:** Atmospheric Visibility Grading, Remote Sensing Data, MODIS

**Introduction**

The aerosol compositions in the atmosphere react with atmospheric radiation through scattering and absorption, which directly affects the signal reception by optical remote sensors. AOD is of great significance for understanding climate change, researching cloud cover in the atmosphere, and real-time understanding of surface temperature. Currently, the AOD-based research of atmospheric visibility is mostly focused on using ground-based observations. However, it is difficult to fully reflect the spatial characteristics of PM in the air despite the accurate data used. Satellite remote sensing uses satellite images to retrieve the aerosol composition in the atmosphere, so as to quickly and effectively obtain the AOD value of the atmosphere, which provides an important basis for identifying the grade of atmospheric visibility.

In China, AOD-related research mainly focuses on the concentration, chemical composition, and spatial-temporal distribution of inhalable PM in the atmosphere. The research areas are mostly concentrated in large urban areas such as Beijing, Shanghai, Guangzhou, and the Yangtze River Delta. Song et al. (*Song et al., 2002*) conducted periodic observations on the PM2.5 concentration in Beijing during the period of continuous high temperature. They found that the PM2.5 concentration during this period was two to three times higher than that during the period of non-high temperature, and pointed out that continuous high temperature would promote the activity of photochemical reactions, and thus PM2.5 became the main source of fine particles in Beijing during this period. Huang et al. (*Huang et al., 2006*) analyzed the PM2.5 samples collected in Nanjing in winter and summer by X-ray fluorescence spectra and found that the components of the samples mainly originated from man-made pollution sources, with the top three being dust (37.28%), coal soot (30.34%) and building dust (7.95%).

Remote sensing image monitoring has the characteristics of real-time dynamic monitoring and a wide range of applications. The efficient use of this technology has an important role in the detection of atmospheric visibility. Grguric et al. (*Grguric et al., 2014*) used Terra and Aqua satellite image data to analyze the relationship between the near-ground PM10 concentration and AOD in Croatia from 2008 to 2012, and revealed the non-linear relationship between AOD and PM10. Kessner et al. (*Kessner, et al., 2013*) verified that MODIS aerosol products could be used for the evaluation and analysis of ground visibility through a comparative analysis of ground visibility and MODIS AOD. In recent years, increasing attention has been paid to this research field (*Alam et al., 2014; Chauhan et al., 2018; Cui et al., 2016; Fatima et al., 2017; Huang et al., 2019; Kutty et al., 2018; Prabhu et al., 2019; Ramachandran et al., 2018; Tan et al., 2015; Tariq et al., 2019; Zhao et al., 2017*). The research in this paper is an attempt to grade atmospheric visibility based on remote sensing data.


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## 2. Materials and Methods

2.1 Data acquisition

MODIS is the latest and most advanced optical remote sensing instrument in the world, with a maximum spatial resolution of 0.25 km. Since April 2000, MODIS has been releasing the monitoring data. China has established several receiving stations and started receiving data in March 2001.

Firstly, we searched the website for the satellite observation data with target time, region, and type. This paper uses the MODIS data in Jiangsu Province, China in December 2019. Because the cloud layer may affect the visibility of the atmosphere, the interference of cloud amount should be avoided when downloading the data. In the case of less cloud, the interference can be eliminated through post-processing.

### 2.2 Data processing

#### 2.2.1 Data preprocessing

MODIS data preprocessing is the primary work before further use, which includes geometric correction, data quality improvement, image stitching, vector cropping, and masking, etc. The ENVI software, the most commonly used software for remote sensing image processing, was used to process the MODIS data. The software can identify most of the data formats, and is easy to use in terms of processing, parsing, and drawing. In this research, a MODIS image was downloaded every week in December 2019 and the downloaded image was opened in the software ENVI for preprocessing.

After the preprocessing by geometric correction, data quality improvement, image stitching, vector cropping and masking, etc., emissivity, reflectivity, and various angles (satellite zenith angle, satellite azimuth angle, solar zenith angle, solar azimuth angle) were processed to complete the synthetic tailoring.

#### 2.2.2 Cloud detection

Because the cloud may interfere with the image data, the cloud needs to be removed before the retrieval of AOD to obtain more accurate image data. Currently, the cloud detection methods using textures or gray levels cannot 100% identify the cloud layers in the image. Therefore, a cloud detection tree (CDT) algorithm is adopted in this paper. This algorithm integrates multiple detection algorithms to improve the efficiency of cloud detection. The algorithm process is as follows (*Wallace et al., 2014*):

(1) An image is divided into multiple blocks, and the gray threshold, fractal dimension, and angular second order of each block are calculated.

(2) For each block, the gray threshold is used to judge whether it is a cloud. The value above 80% is considered as a cloud, value of 20%-80% as a cloud or a ground feature, and the value less than 20% as a ground feature.

(3) The fractal dimension is used to make judgments based on the values given in the image.

(4) The angular second order is used to make judgments based on the values given in the image.

(5) The morphological expansion algorithm is used to perform morphological expansion on the cloud area to form a cloud binary image and complete cloud detection.

#### 2.2.3 Retrieval of AOD

AOD retrieval is conducted using the DDV algorithm. The DDV algorithm conducts atmospheric correction mainly relying on the information of images. The basic principle is to assume that there are dense dark vegetations in the remote sensing image to be processed, and that the atmospheric properties are uniform, the land surface presents Lambertian reflection, and the multiple scattering and irradiation effects of neighboring pixels in the atmosphere can be ignored. Due to the influence of the atmosphere, the brightness of dark pixels with little radiation brightness or small reflectivity will be relatively increased. The path radiance is calculated by the DDV algorithm, and then substituted into an appropriate atmospheric correction model. After calculating the corresponding parameters, the true emissivity of the surface object can be obtained (*Gillingham et al., 2012; Peng et al., 2008*).

## 3. Results and Discussion

3.1 Tailoring result

The image was processed according to the preprocessing method of remote sensing data. Then, the emissivity and reflectivity were combined to obtain the tailoring result of the area for Jiangsu Province, as shown in Fig. 1.

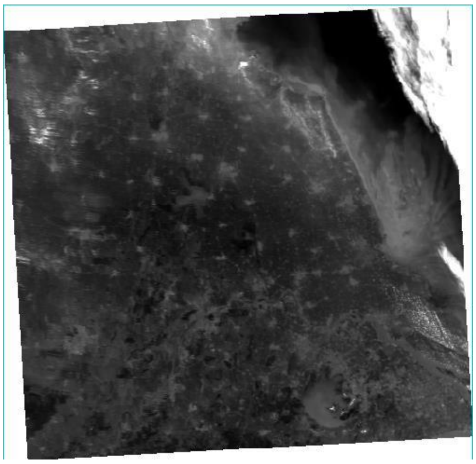

Figure 1: Tailoring result of emissivity and reflectivity

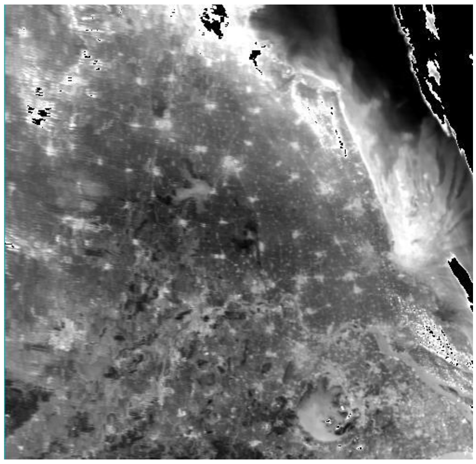

Figure 2: Image with cloud interference removed

### 3.2 Cloud detection result

Cloud was detected using the CDT algorithm. The image with cloud interference removed is shown in Fig. 2.

### 3.3 Result of AOD retrieval

Based on the remote sensing images without cloud interference, the result of AOD retrieval by DDV algorithm is shown in Fig. 3. The tailoring result of Jiangsu Province is shown in Fig. 4.

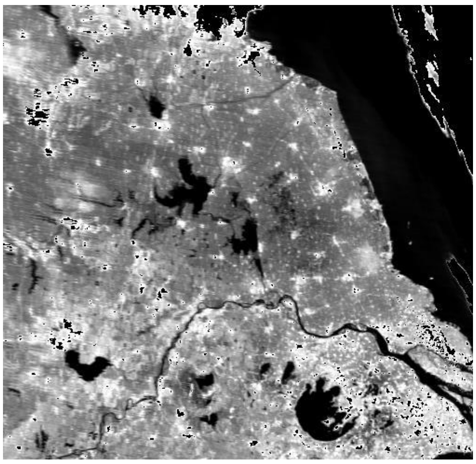

Figure 3: Result of AOD retrieval.

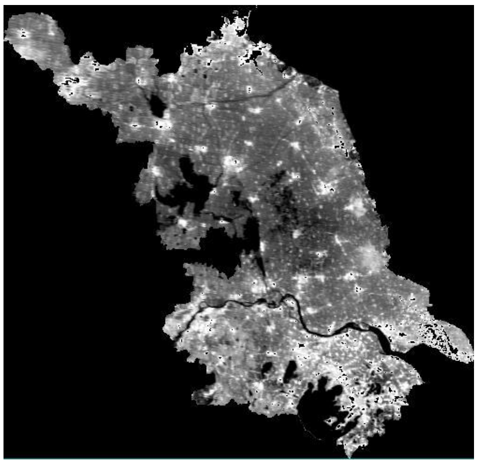

Figure 4: AOD retrieval of Jiangsu Province.

### Results of atmospheric visibility grading

According to the retrieval results, the distribution characteristics of the AOD values were graded. In order to make the images more intuitive and clearer, the gray values were segmented using the Raster Color Slices tool, and different colors were used to represent different gray value intervals. Fig. 5 shows the result of atmospheric visibility grading in Jiangsu Province obtained from the remote sensing images in the four weeks of December 2019. The larger the atmospheric visibility is, the lower the atmospheric visibility obtained by AOD retrieval is, and the corresponding color approaches red. Besides, the higher the atmospheric visibility, the closer the color is to blue.

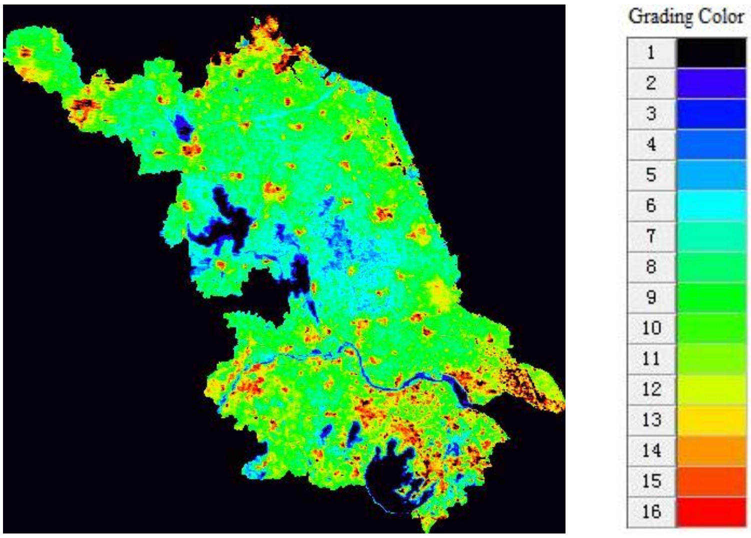


Figure 5: Result of atmospheric visibility grading in Jiangsu Province.

**Conclusion**

In this research, the aerosol compositions in the atmosphere in the images downloaded by satellites are taken as the research object to grade the atmospheric visibility. This research focuses on studying the process of aerosol information contained in the atmospheric images obtained by remote sensing, so as to retrieve the atmospheric visibility using AOD data. Then, the atmospheric visibility is graded by different AOD values and distribution rules of the obtained images. Using the method of spectral processing, the calculated grade of atmospheric visibility is more intuitive and clearer.

At present, remote sensing technology cannot achieve real-time monitoring, observation, and information operations on the weather. Research on the atmospheric visibility grades needs further efforts, and technology products are also continuously updating. Efforts should be made to develop more accurate and complete algorithms to fully understand the impacts of hazy weather on the environment, climate, and economy, etc., thereby finding effective measures.

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