# Study on scanning Mie lidar profile data standardization method

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***Abstract*—For sharing the Mie scattering lidar profile data comes different lidar system, one of key challenge is tacking the heterogeneous format. In this paper, we analyses the temporal and spatial characteristics and two-dimensional structure of the scanning Mie lidar profile data. Based on the principle of scanning Mie lidar, and the meteorological of atmospheric parameters, we proposed a general data standardization and fill method for missing space. Experimental results shows that the method can accurately fill the space position of missing data, and can make scanning Mie lidar profile data standardized. It has realistic significance for sharing and analyzing of atmospheric monitoring lidar data.**

***Keywords-lidar; Mie scattering; lidar data; data standardization***

## I. INTRODUCTION

Atmospheric lidar is a class of instruments that uses laser light to study atmospheric properties from the ground up to the top of the atmosphere, and is an active instrument for profiling vertical structure of atmospheric with high accuracy, high spatial and temporal resolution, high sensitivity to environmental factors and the continuity of detection time. In recent years, the atmospheric lidar has made remarkable progress in atmospheric detection, and has become an effective tools for high precision remote sensing.

Scanning Mie lidar is a special atmospheric lidar, it obtains the spatial distribution and conveying information of aerosols from different angle of scanning area [1]. The echo signal data as input data can obtain the horizontal or vertical structure and spatial distribution characteristics of atmospheric parameters by solving the lidar equation. The spatial distribution and evolution characteristics of large area of atmospheric parameters can be obtained by sharing and analyzing of different lidar profile scanning data. The solid foundation for improving detection accuracy and optimization instrument structure can be provided. However, the structure of lidar data is closely related to the parameters of lidar system and measurement methods. Different lidar system have different physical variables and the different basic units, such as laser emission unit, receiving the optical unit, the subsequent optical unit, signal detection and acquisition unit, operation control unit and so on. It lead to the data heterogeneity in the data structure and signal intensity, etc. The heterogeneity of the data greatly hinders the study of the vertical structure, time variation and horizontal transmission mechanism of large area of atmospheric parameters.

Thus, the standardization of scanning Mie lidar profile scanning data is a key challenge of studying the spatial and temporal distribution characteristics of large area and transport evolution mechanism of atmospheric parameters. The structure, form and dimension are the main parts that affect the comparison and analysis of lidar data. In this paper, the data standardized method is proposed for studying the structure characteristics and dimension of the scanning Mie lidar profile data.

## II. THE DETECTING PRINCIPLE OF SCANNING MIE LIDAR

Scanning Mie lidar is a major method to study the spatial distribution of atmospheric parameters. It is a lidar system to measure the vertical profile structure and optical parameter of aerosol and cloud based on Meter scattering echo signal. It can measure the vertical profile distributions of atmospheric parameters by changing the azimuth angle and elevation angle of the laser light source. The lidar system consists of laser transmitting system, telescope receiving system, photoelectric conversion system and data acquisition and analysis system. The transmitting system is fixed on the receiving system, and the laser emission optical axis is parallel to the telescope receiving optical axis. It can scan the overall three-dimensional space.

The atmospheric backscatter echo signal received for the single scattering scanning lidar can be expressed as a function of extinction coefficient, denoted as $\alpha(z)$, and backscatter coefficient, denoted as $\beta(z)$. The lidar equation as in (1).

$$P(z,\lambda) = \frac{K}{z^2} \cdot \beta(z,\lambda) \cdot \exp[-2\int_{z_0}^{z} \alpha(z',\lambda)dz'] \quad (1)$$

where $P(z, \lambda)$ is the atmospheric backscatter echo signal (W) at $z$ (km), $\lambda$ is the Laser wavelength (nm), $K$ is lidar system constant ($W \cdot km^3 \cdot sr^{-1}$), $\beta(z, \lambda)$ is the backscatter coefficient ($km^{-1} \cdot sr^{-1}$) at $z$ (km), $\alpha(z, \lambda)$ is the extinction coefficient ($km^{-1}$) at $z$ (km), $z_0$ is the altitude (km) of lidar system. The aerosol optical characteristics can be described by extinction coefficient $\alpha(z, \lambda)$, backscatter coefficient $\beta(z, \lambda)$ and their relationships. These parameters relating with laser wavelength, particle size, shape and refractive index. The micro physical properties, such as concentration of particulate matter, particle distribution, refractive index, etc., can be obtained by solving the lidar equation as (1).

## III. THE DATA STRUCTURE OF SCANNING MIE LIDAR

The data structure of scanning Mie lidar is related to the scanning detection mode. The atmospheric parameters spatial structure of measuring the vertical profile of scanning Mie lidar system is a spherical coordinate system centered at lidar system and the distance from the measurement point to the lidar system of elevation angle, azimuth angle and detection direction [2].

The detection data is the scanning detection signal value, denoted as $\boldsymbol{D}(\boldsymbol{R}, \gamma, \pi/2\text{-}\boldsymbol{\Theta})$, where $\boldsymbol{R}$ is the distance from origin point $O$ to the data $D$. So, $\boldsymbol{R}$ is a set of same interval discrete data points, where the interval distance is determined by the sampling frequency of the lidar system, the range resolution of lidar, denoted as $r$. $\gamma$ is the azimuth angle of lidar system, and $\boldsymbol{\Theta}$ is a set of different elevation angle $\theta$ of lidar system .

The vertical profile is a sector area that consist of different elevation angle $\theta$, same azimuth angle $\gamma$, and detection distance $\boldsymbol{R}$. The detection data, a two-dimensional structure, is a set of different elevation angle $\theta$ in $\boldsymbol{\Theta}$ and different $r$ in $\boldsymbol{R}$, and mainly spreaded in 2-dimension distribution. The lidar detection data set can be represented by the two-dimensional polar coordinate as $\boldsymbol{D}(\boldsymbol{R}, \boldsymbol{\Theta})$. Where $\boldsymbol{R}=\{r_i\}$, $i=1,2,\ldots,n$, $\boldsymbol{\Theta}=\{\theta_j\}$, $j=1,2,\ldots,m$, $n$ is the number of sampling points of the lidar in the elevation direction, $m$ is the number of elevation angle. So, the lidar data can be written as $d(r_i, \theta_j)$, and $r= r_{i+1}- r_i$, $\theta_{j+1}>\theta_j$.

## IV. SCANNING MIE LIDAR PROFILE DATA STANDARDIZED METHOD

The heterogeneity of vertical profile of scanning Mie lidar data structure are the elevation angle, range resolution and detection data value from the above. So, it is necessary to convert the structure of lidar to the same one in the elevation angle and range resolution.

There is the missing data in the areas between of the elevation angle and the points between of the range resolution in the every elevation angle of the scanning Mie lidar data. The distribution of the scanning Mie lidar profile data is shown in Fig. 1.

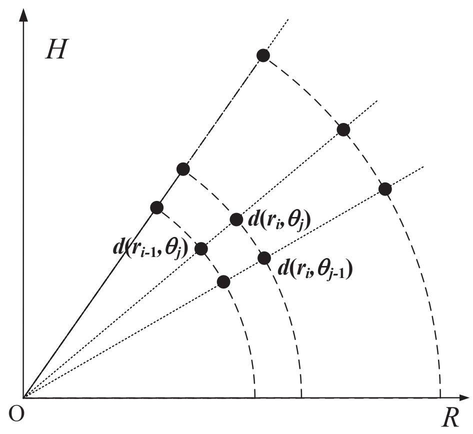


Figure 1. The distribution of the scanning Mie lidar profile data

Because the different scanning Mie lidar have different the detection elevation angles and detection range resolutions, with makes the scanning Mie lidar data has different structure in the detection elevation angle and detection range resolution, and the data positions is in the data missing of the detection elevation angle or the detection distance in the different data comparing. Therefore, the key problem of scanning Mie lidar profile data standardization is to interpolate the missing data between of the data comparing positions.

Let $\boldsymbol{A}$ and $\boldsymbol{B}$ are two different scanning Mie lidar profile data, and the polar representation denoted $\boldsymbol{A}(\boldsymbol{R}_A,\boldsymbol{\Theta}_A)$ and $\boldsymbol{B}(\boldsymbol{R}_B,\boldsymbol{\Theta}_B)$, here, $\boldsymbol{R}_A=\{r_{Ai}\}$, $(i = 1, 2,\ldots,m)$, $\boldsymbol{\Theta}_A=\{\theta_{Aj}\}$, $(j=1,2,\ldots,n)$, $\boldsymbol{R}_B=\{r_{Bi}\}$, $(i=1,2,\ldots,p)$, $\boldsymbol{\Theta}_B=\{\theta_{Bj}\}$, $(j=1,2,\ldots,q)$, $m$, $p$ is the number of detection points, and $n$, $q$ is the number of detection elevation angles. The lidar data $\boldsymbol{A}$ and $\boldsymbol{B}$ have heterogeneity in detection range, detection elevation angle and detection data value. The detection range sets of standardized data is $\boldsymbol{R}$, $\boldsymbol{R}=\boldsymbol{R}_A \cup \boldsymbol{R}_B$, and the detection elevation angle sets of standardized data is $\Theta$, $\Theta=\Theta_A \cup \Theta_B$.

Currently, common interpolation method for missing data is linear interpolation method or polynomial interpolation method in the curve of sector area [3]. These methods suffer from low accuracy and do not meet the variation of the atmospheric parameters.

The vertical structure of the atmosphere and the vertical spatial distribution of atmospheric parameters show that the atmospheric parameters in vertical structure change is more obvious, and in horizontal structure is the stable state [4]. According to the lidar equation in (1), the echo signal intensity of the lidar is inversely proportional to the square of its detection distance, and exponentially attenuated with the increase of the distance. Therefore, the missing data value is related to the detection points around of it. The missing data value can be accurately imputed from these basic data of detection points. In this paper, the missing data is filled to standardize the scanning Mie lidar profile data raw on the spatial distribution of atmospheric parameters and the principle of lidar.