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Atmospheric Aerosol Nonsphericity Over the Loess Plateau in Northwest China

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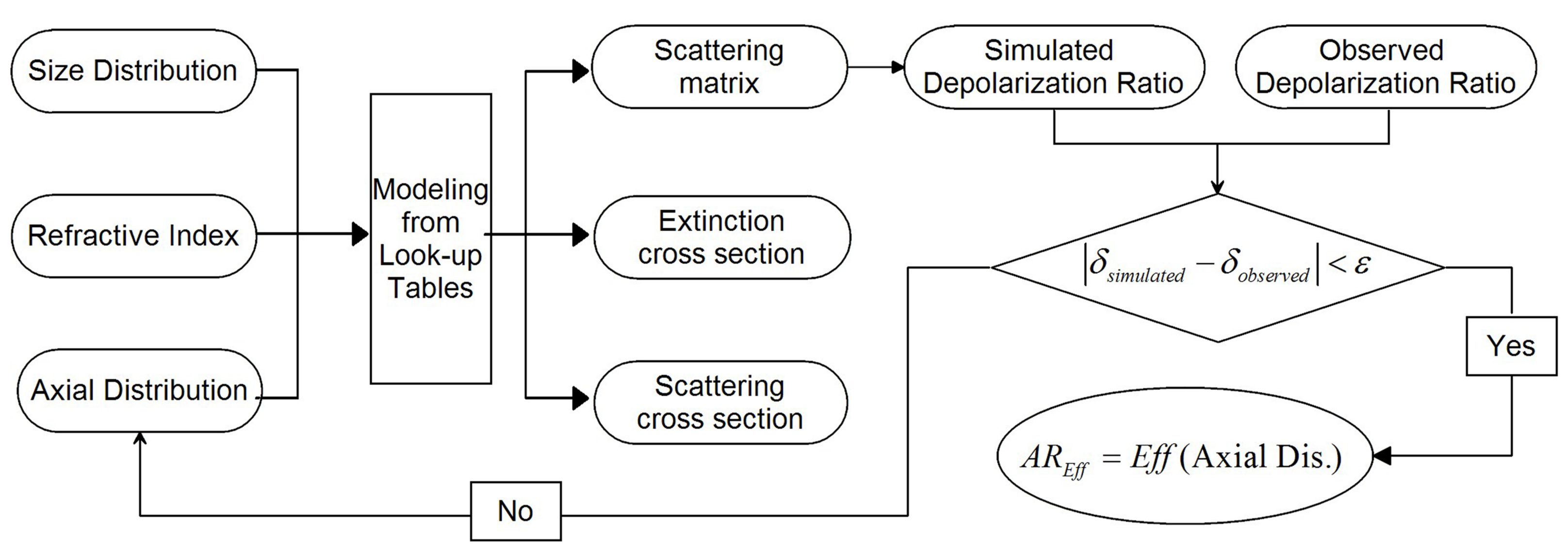
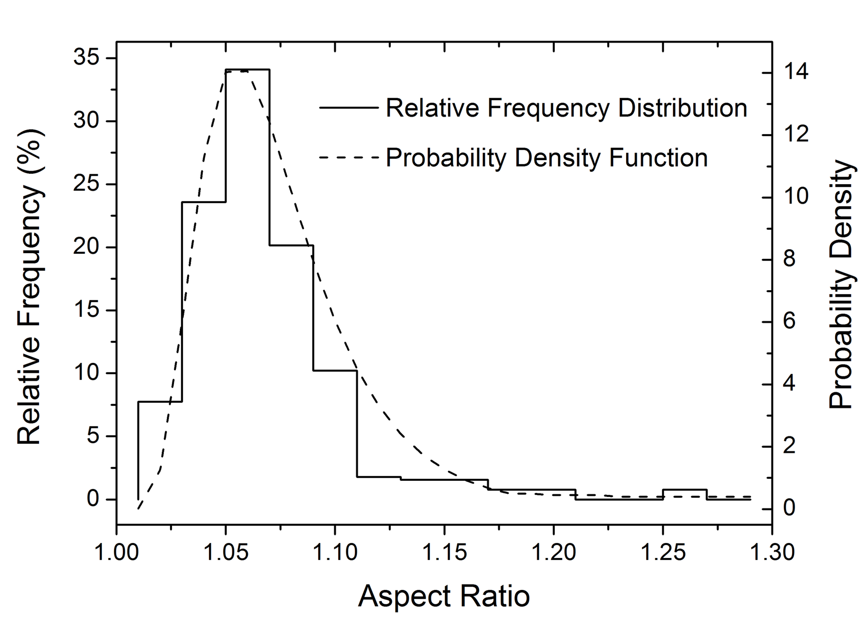
Introduction

- Aerosols are a primary component of the atmosphere and directly affect the radiative budget of the earth-atmosphere system by scattering and absorbing solar radiation and by absorbing and emitting infrared radiation.
- The shape of aerosols is a key factor that affects their optical properties and radiative effects (Dubovik et al, 2006). For nonspherical conditions, the assumption of a simplified spherical shape will cause large differences in optical property calculations and great uncertainties in radiative forcing simulations (Kahnert et al., 2007).
- The aspect ratio (AR) and lidar backscattering depolarization ratio are two prime parameters that represent the nonsphericity of particles. Aspect ratios measured at a low relative humidity differ greatly from those measured at ambient atmospheric conditions and therefore cannot be used directly to assess the radiative budget of the earth-atmosphere system (Zieger et al., 2013).
- Aerosol nonsphericity over SACOL was investigated based on observations from a depolarization lidar, a sun photometer, and a simulation of T-matrix and an improved geometric optics approach.

Column integrated aerosol aspect ratio

- The retrieval of the aspect ratio is summarized in the following flowchart. And look-up tables and the software package from Dubovik et al. (2006) were used in the forward numerical computations in this research. The numerical computations were conducted by a 0.01 step of the integral averaging of the axial ratio distribution from 1.00 to 3.00.





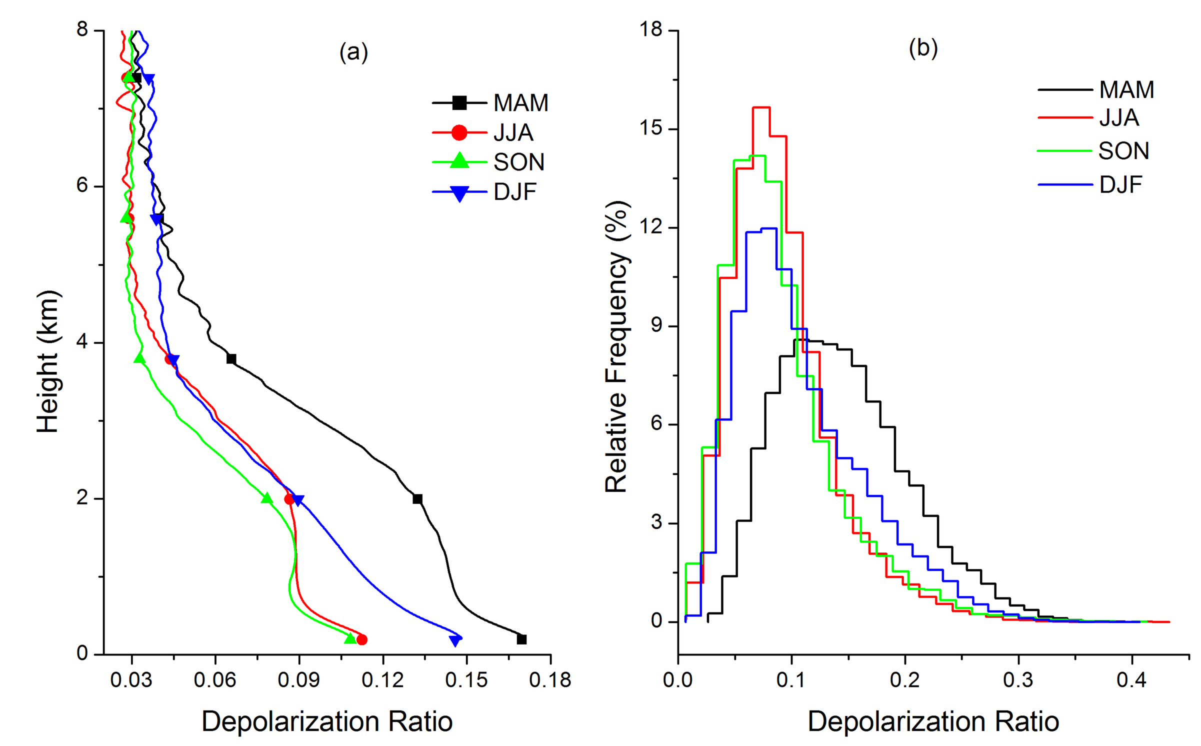
- The frequency distribution is similar to a log-normal distribution and peaked at approximately 1.06 which was lower than that found by Kocifaj et al. (2008). This was because Kocifaj et al. (2008) researched aerosol aspect ratios just near the ground, while in this research, the total column-averaged atmospheric aerosols were considered.
- The frequency distribution of the derived aspect ratios was parameterized by a modified log-normal distribution function:

$$h(AR) = \frac{1}{\sqrt{2\pi}\sigma(AR-1)} \exp\left[-\frac{1}{2}\left(\frac{\ln(AR-1)-\mu}{\sigma}\right)^2\right]$$

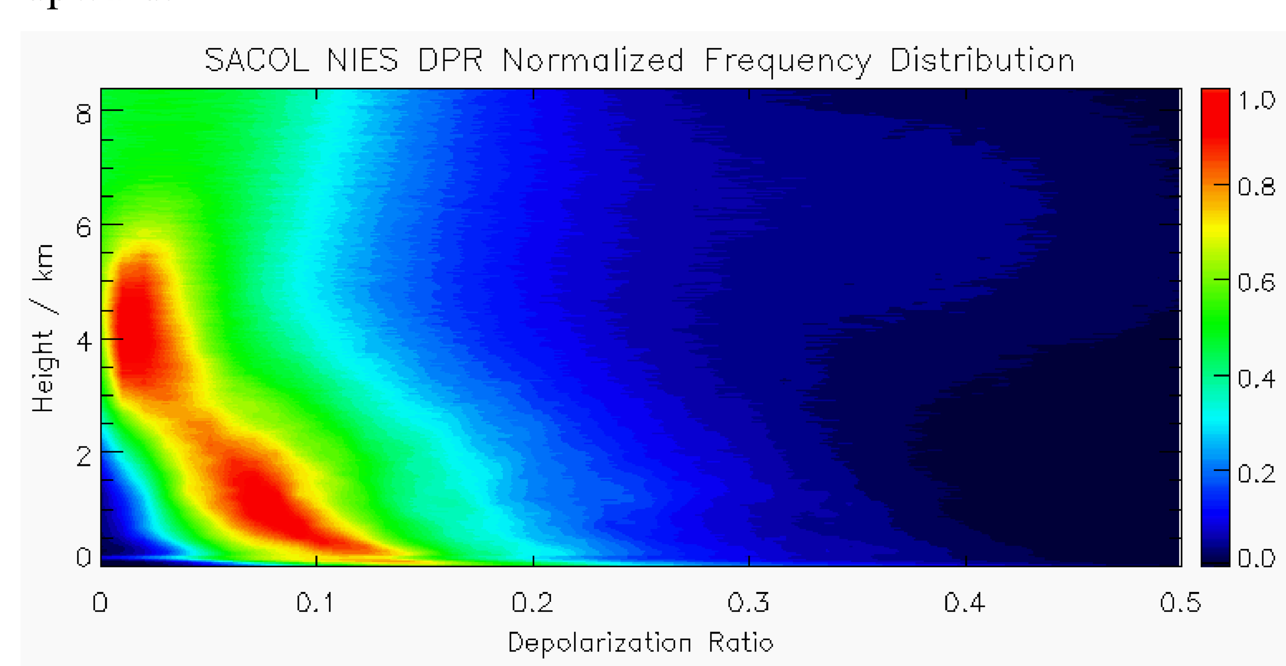
- The derived aspect ratios provided a better shape input for aerosol optical modeling.

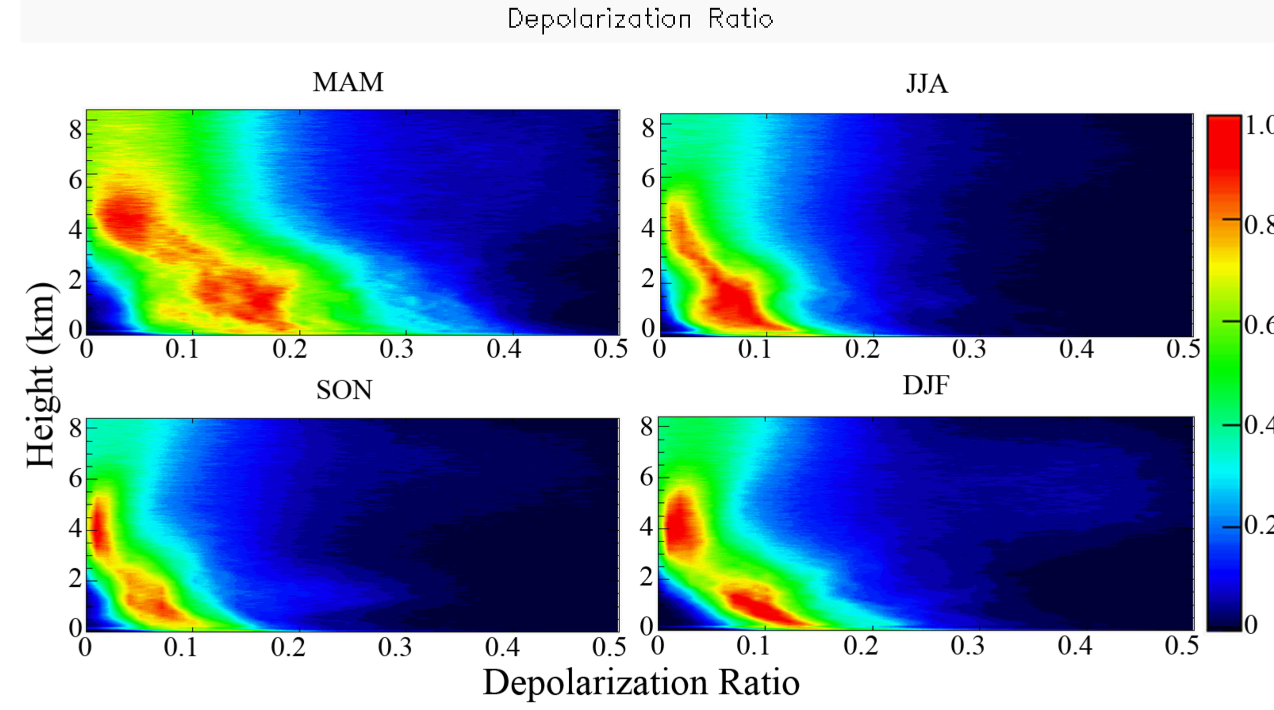
Lidar observations

- The aerosol depolarization ratio generally decreased with increasing height. The average depolarization ratio profile of each season was greater than 0.10 near the ground, and it decreased to less than 0.04 at the height of 6 km.



- The normalized frequency distribution (NFD) of the lidar-observed depolarization ratios is calculated in order better show the spatial distribution. The maximum NFD decreased with increasing height, indicating that nonspherical aerosols were generated at the surface and that the sphericity decreased as aerosols were transported upward.

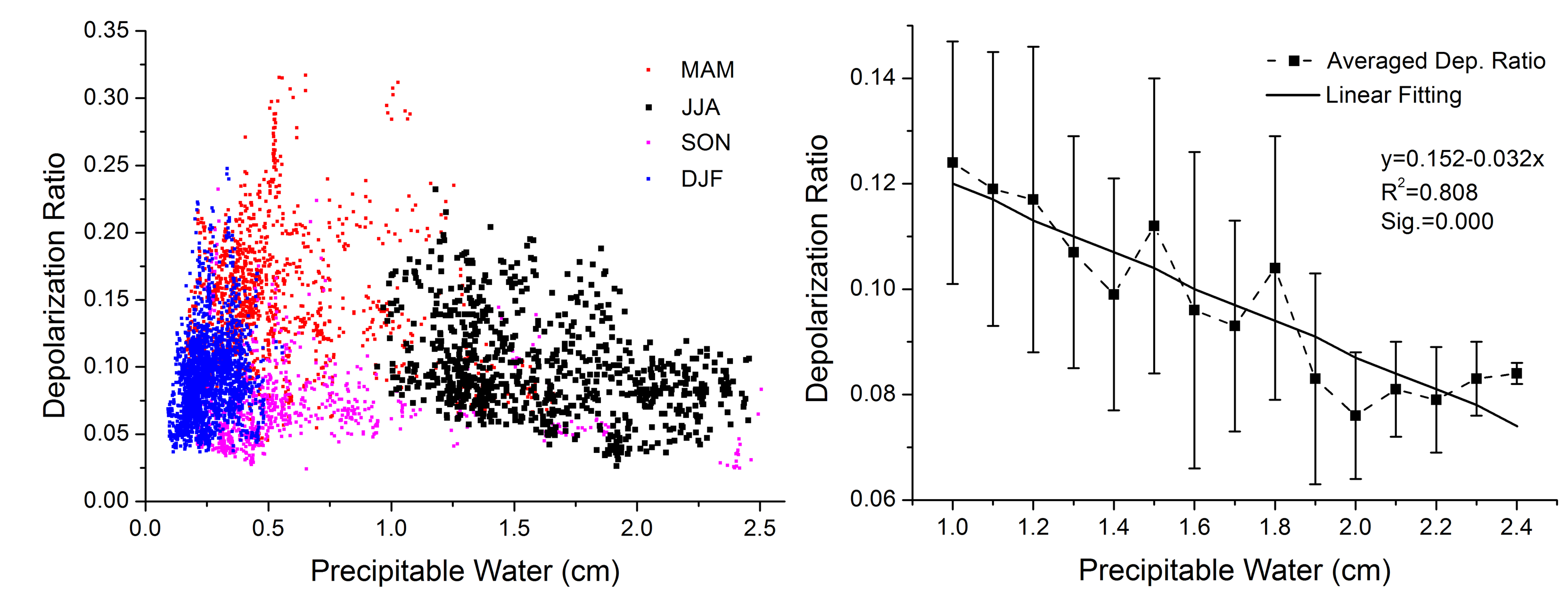




- The spring season experienced a much larger NFD range of values greater than 0.4 than in the other seasons; this indicates that more nonspherical aerosols were transported upward to the free troposphere during the spring.

Influence of water vapor on aerosol nonsphericity

- By modifying the shape and size distribution of the aerosols, water vapor alters the aerosol optical properties (Tang et al., 1994; Sakai et al., 2003; Titos et al., 2014).
- The column integrated atmospheric precipitable water exhibited considerable seasonal variations with a pronounced summer maximum and winter minimum. It was mostly less than 0.5 cm in spring and reached 2.5 cm in autumn. The depolarization ratio had an apparent dependency on precipitable water in summer when there was continues sufficient precipitable water.



- The linear fitting results showed a significant decreasing trend of the depolarization ratio with increasing precipitable water; moreover, the precipitable water explained 80.8% of the variation in the averaged depolarization ratio in summer when there was ample precipitable water.

Conclusions

- The aerosol depolarization ratios decreased with increasing height. Aerosol nonsphericity exhibited considerable seasonal variations with a pronounced maximum in spring, when more nonspherical aerosols were transported upward to the free troposphere.
- The derived aspect ratios ranged from 1.00 to 1.30, and the frequency distribution was akin to a log-normal distribution that peaked at approximately 1.06. A modified log-normal function was fitted to the frequency distribution of the derived aspect ratios, thus yielding a log-normal distribution parameterization.
- When the precipitable water was quite small, there was no obvious dependency between the aerosol depolarization ratio and precipitable water. However, in summer, when there was sufficient precipitable water, there was a significant decreasing trend of the depolarization ratio with increasing precipitable water.

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