P1-27 An Attempt of Discriminating Aerosol from Tropospheric Mixed Phase for Polarized Lidar Signal

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1 Introduction

It is well known that tropospheric aerosols play an important role in climates, due to their attribution to cloud formation and sunlight attenuations.[1]Polarized Lidar is excellent in detectting tropospheric particles. The classical backscattering coefficient or depolarization ratio versus altitude are employed to describe results of observations for aerosol and cloud. This paper presents 2-D coordinates to discriminate phases of aerosol and cloud. It is shown that diverse aerosol phases can be better separated by using these coordinates.

2 Coordinates perpendicular and parallel to the laser polarization

The depolarization ratio is often described as function of LIDAR monitoring. Let aerosol, cloud and molecule simultaneously exist in the atmophere, and β_a, β_c and β_m be the backscattering coefficient of these, respectively. Consider two elements together to discuss particles phases, for example, aerosol and molecule or cloud and molecule. The total backscattering cross section can be expressed as

$$\begin{aligned}\beta(Z) &= \beta_{(a,c)}(Z) + \beta_m(Z) \\ &= \beta_{(a,c)\perp}(Z) + \beta_{(a,c)\parallel}(Z) + \beta_m(Z), \qquad (1)\end{aligned}$$

where $\beta_{(a,c)}$ represents the backscattering coefficient of aerosol or cloud. In general, we can define the three phases of tropospheric particles with solid, liquid and mixed phase. Let β_s represents the liquid phase in the aerosol or cloud layer, Then $\beta_{(a,c)}$ is given by

$$\beta_{(a,c)}(Z) = \beta_{(a,c)\perp}(Z) + \beta_{(a,c)\parallel}(Z) + \beta_s(Z). \qquad (2)$$

The depolarization ratio is given by

$$\delta(Z) = \frac{\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)}{\beta_s(Z) + \beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z)}. \qquad (3)$$

If we define two functions K(Z) and C(Z) as

$$K(Z) = \frac{\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)}{(\beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z)}, \qquad (4)$$

$$C(Z) = \frac{\beta_s(Z)}{(\beta_{(a,c)}(Z) + \beta_m(Z))}, \qquad (5)$$

then $\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)$ is derived as

$$\begin{aligned}&\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z) = \\ &\quad \frac{K(Z)(\beta_s(Z) + \beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z))}{1 + C(Z) + C(Z)K(Z)} \\ &\quad = H(Z)(\beta_s(Z) + \beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z)). \qquad (6)\end{aligned}$$

Equation (6) expresses the relation between $\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)$ and $(\beta_s(Z) + \beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z))$. From equations above, contributions of the liquid and solid phases to backscattering for any point in the plot can be determined from their coordinates by equation (4) and (5).
Thus backscattering coefficient for solid and liquid phase are given by

$$\begin{aligned}&\beta_s(Z) = \\ &\quad (\beta_s(Z) + \beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z)) \\ &\quad - \frac{\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)}{K(Z)}, \qquad (7)\end{aligned}$$

$$\begin{aligned}&\beta_{(a,c)\perp}(Z) + \beta_{(a,c)\parallel}(Z) = \\ &\quad \frac{1 + K(Z)}{K(Z)}(\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)) - \beta_m(Z). \qquad (8)\end{aligned}$$

Equations (7) and (8) show that the backscattering coefficient of liquid and solid particles are just determined by the value of $K(Z)$ which reflects particle volume, surface area.

3 Result of simulation

Two trial lidar signals were examined for the above algorithm. Figure 1 show the backscattering coefficient and depolarization ratio of the simulation lidar signals in the troposphere. Figure 2 show the results using the method. When all particles are solid, or C(Z)=0, $\delta(Z)$=K(Z), the solid phases of particles is located along a curve of depolarization ratio $\delta_{a,c}(Z)$, such as symbols 4 and 5. When all particles are liquid, or $\beta_{(a,c)\perp}(Z)=0$, $K(Z) < \delta_m = 1.4\%$[2][3], where δ_m denotes the depolarization ratio of molecule, liquid phases of particles, such as symbols 3, will be located between the parallel axis and the slope of molecule denoted by symbols 2. For mixed phases of particles, such as symbols 1, will be located between the slope of molecule and that of $\delta_{(a,c)}(Z)$ slope. If $H(Z)$ is constant, the $\beta_{(a,c)\perp}(Z) + \beta_{m\perp}(Z)$ will increase linearly with $(\beta_s(Z) + \beta_{(a,c)\parallel}(Z) + \beta_{m\parallel}(Z))$ along a line with H less than K. The particle phases are well separated by applying the perpendicular and parallel coordinates. If we use 3-D expression, the information about altitude can be incorporated herein. Associating with the above algorithm in 2-D coordinates, the distribution of the diverse particles phases, such as water droplet, aerosol and so on, can be derived with the predetermined altitude resolution.

4 Conclusion

In conclusion, both the classical backscattering or depolarization ratio versus altitude, and the perpendicular and parallel coordinates are interpretations of particles phases. It is shown that diverse aerosol phases can be better separated by using of the latter coordinates. In addition to this, we can know the backscattering coefficient and depolarization ratio at the same figure. Using the 3-D system, we can further distinguish the diverse particles phases with limited altitude resolution. In other words, we can separate the liquid phases from the solid phases, and the mixed phase locates between the solid phase and liquid phases. It is also a useful tool to analyze the aerosol formation and growth in the troposphere.

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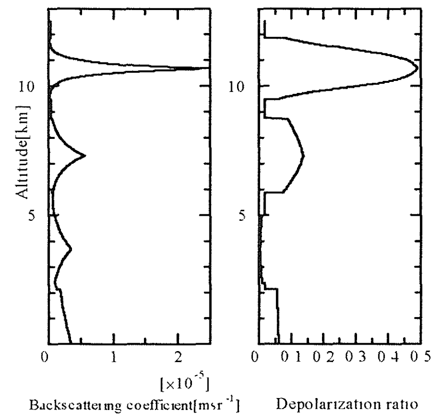

Fig.1 A Simulation lidar signal.

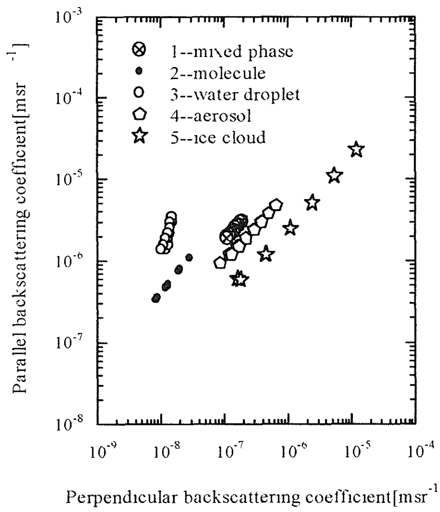

Fig.2 Result of simulation expressed by perpendicular and parallel coordinates.