Depolarization ratio of clouds and aerosols observed with a slant-path lidar: comparison between summer and winter measurements

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Abstract: Depolarization ratios of clouds and aerosols are measured using a slant-path lidar at the Center for Environmental Remote Sensing (CEReS), Chiba University on December 2018 (winter) and July 2019 (summer). Results show that aerosols and clouds that exist during summer have lesser depolarization ratios compared to aerosols that during winter.

Key Words: Depolarization ratio, Slant-path LIDAR, Aerosols, Clouds, Extinction Coefficient

1. Introduction

Aerosols and cloud particles have different shapes and sizes that vary depending on the components and season. The shapes can be deduced from lidar data by measuring the depolarization ratio from these scatterers. The depolarization ratio is the ratio of the perpendicular and parallel polarization signals and is a parameter that measures the sphericity of scatterers in the atmosphere[1-3]. Spherical scatterers, like water droplets, have depolarization ratio close to zero while ice crystals can have nonzero depolarization ratios[4]. In this work, we present the comparison of depolarization ratio values from aerosols and clouds observed in Chiba during winter 2018 and summer 2019 from slant-path lidar measurements.

2. Instruments and radiosonde data

2.1 Slant-path lidar

The slant-path lidar in CEReS was operated in depolarization mode during winter of 2018 and summer 2019 to measure the optical properties of clouds and aerosols. The laser has a wavelength of 532 nm and is operated at a frequency of 1 kHz. The system is placed on the 5th floor of the CEReS building and is pointed to the north direction with an elevation angle of 30^{o}. Data are obtained every 5 min. The lidar signals are digitized and stored in the computer for analysis.

2.2 Radiosonde data

To understand the thermodynamics of the atmosphere when the lidar data are obtained, radiosonde data from Tateno station in Tsukuba (47 km from Chiba University) are obtained from University of Wyoming website (*http://weather.uwyo.edu/upperair/sounding.html*). The thermodynamic parameters include vertical profiles of temperature, dew point temperature, frost point temperature and relative humidity. Radiosonde data are available every 09:00 and 21:00 JST. In this work, slant path lidar data during these times are compared with radiosonde measurements.

2.3 Visibility meter

A Vaisala PWD52 visibility meter takes the visibility of the atmosphere near CEReS every 1 min. A high visibility indicates low aerosol loading.

3. Results and discussion

The slant-path lidar data were obtained in winter of 2018 and summer 2019 every 5 min. A correction factor of 2.4 is applied to correct the sensitivity differences of the two PMTs[5].

During summer, when atmospheric temperature is greater than 0^{o}C in the lower troposphere (<3 km), aerosols are observed to have depolarization ratios in the range 0.02 to 0.1. This low depolarization can be attributed to the high relative humidity in the lower atmosphere. Average visibility is less than 35 km at this time. The higher water vapor concentration can lead to possible droplet formation of the aerosols making them more spherical in shape and contribute to the decrease of visibility. This situation is more likely the case in Chiba when ammonium sulfate and ammonium nitrate grows with RH[6]. Low level clouds observed in this season also show depolarization ratio values that range from 0.03 to 0.13. These indicate that ice crystals are not present. Fig. 1(a) shows the depolarization ratio profile of clouds and aerosols in the lower troposphere at around 21:10 on 05 July 2019 JST. Near surface aerosol layer (< 0.7 km) exhibit depolarization ratio around 0.037. From 0.7 to 1 km, a low cloud signal is observed with depolarization ratio of around 0.06. The NIES Chiba lidar data also observed clouds at around 1 km. These clouds are mostly water clouds. Fig. 1(b) shows the vertical profile of temperature and dew point temperature from radiosonde data at Tateno station. Although the radiosonde observation is far from Chiba, radiosonde data show that clouds are likely to form at around 2.5 km, when the temperature is near the dew point temperature.

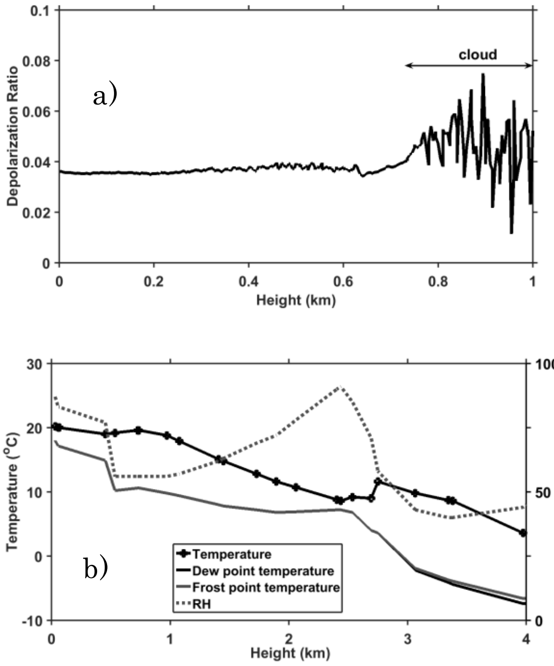

Fig 1. a) Depolarization ratio derived from slant-path lidar at around 21:10 on 05 July 2019 JST. b) Radiosonde data from Tateno station indicating the temperature and dew point temperature near the ground.

In winter, depolarization ratios of aerosols and clouds are higher compared to that of summer. Aerosols and cloud depolarization ratios are observed to reach up to 0.25 and 0.3, respectively. Fig. 2(a) shows height profile of depolarization ratio of aerosols and clouds obtained at 21:04 on 26 December 2018 JST. Fig. 2(b) shows the temperature and dew temperature profiles from radiosonde measurements. The aerosol layer from 0.5 to 2.5 km shows a decreasing depolarization ratio from 0.2 to 0.03. Visibility in Chiba is around 25 km, indicating relatively high aerosol loading in the lower atmosphere. These aerosols near the ground are highly nonspherical in shape as observed from lidar data. From radiosonde measurements, RH profile range from 60 to 80% up to 2 km and suddenly drops to 20% at around 3km. At around 3 km, a cloud layer is observed from lidar. Radiosonde data indicate a cloud layer at around 4 km over Tateno. The observed cloud from the radiosonde data shows frost point temperature less than -10°C, indicating the possibility of ice particles inside the clouds. Assuming a similar clouds observed over Chiba, these ice crystals have depolarization ratio of 0.3.

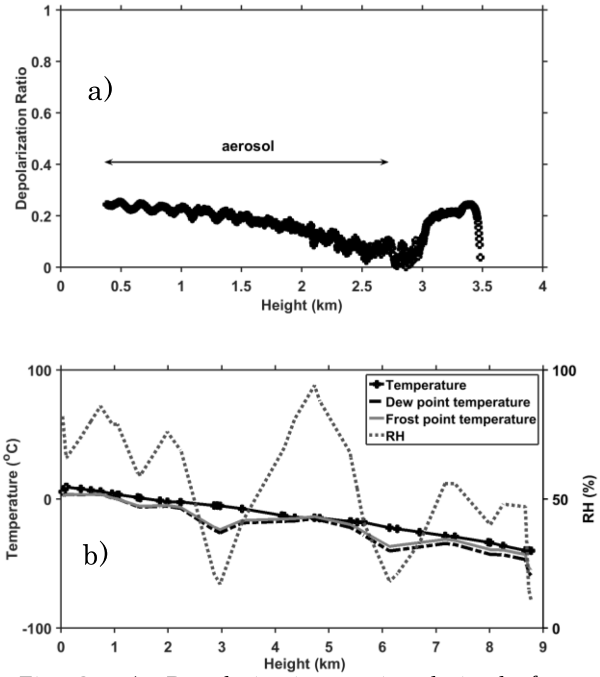

Fig 2. a) Depolarization ratio derived from slant-path lidar at around 21:04 on 26 Dec. 2018 JST. b) Radiosonde data from Tateno station.

4. Conclusion

Aerosols and cloud depolarization ratios during summer and winter show different values as observed from slant-path lidar measurements. During summer, lower depolarization ratios are observed for both clouds and aerosols indicating the effect of RH on aerosols. Clouds near the ground during summer are mostly composed of water droplets. During winter, the low and decreasing temperature profile in the atmosphere can lead to the formation of ice crystals inside clouds with shapes that can be qualitatively described from lidar observations.

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