LARGE WAVELENGTH DEPENDENCE OF THE LIDAR RATIO IN ASIAN DUST LAYERS OBSERVED BY DUAL-WAVELENGTH RAMAN LIDAR

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ABSTRACT

We observed the intense elevated Asian dust events on April 30, 2005 with a multi-wavelength Mie-Raman lidar based on Nd:YAG lasers in Tokyo, Japan. The highly depolarizing layer indicating dust signature exhibits a large discrepancy in the lidar ratios between 355 and 532 nm, i.e., the lidar ratios at 355 and 532 nm were 58.4 ± 6.1 and 41.7 ± 4.6 sr. We have compared the observations with the calculations using *T*-matrix theory [1] taking account of the non-sphericity of the mineral dust. The wavelength dependence is explained partly without introducing the wavelength dependence of the refractive index of the dust particle.

1. INTRODUCTION

We have performed multi-wavelength Mie-Raman lidar observations for tropospheric aerosols and water vapor in routine base at Etchujima campus, Tokyo University of Marine Science and Technology Tokyo (TUMSAT; 35.66° N, 139.80° E) in Tokyo, Japan [2]. In spring, the wind-blown mineral dust from desert areas in China and Mongolia is one of major components of aerosols in the free troposphere in this region. Many field campaigns on regional aerosol characterization have been conducted recently [3, 4]. Nevertheless, the radiative properties of the mineral dust are still not fully resolved from the deficiency of the observations of the elevated dust layers. The non-sphericity and absorption property of the dust are classical but major concerns even today especially in the remote sensing. Only few observations with dual-wavelength Raman lidars have been reported for Asian and Saharan dusts [2, 5]. These measurements indicate that the lidar ratio at 355 nm is somewhat higher than that at 532 nm. Here we present an apparent and large wavelength dependence in the lidar ratio for the elevated dense dust layers observed in the end of April of 2005.

2. OBSERVATION

Unusual intense Asian dust phenomena were observed over the northern half of Japan on April 30, 2005 [6, 7]. The dust source is estimated to be the southern Mongolia and transported in the free troposphere on the pathway even at Beijing [6]. So far, we can expect more pure property of the mineral dust, i.e., not mixed with pollution et al., in this event. At TUMSAT, the aerosol optical thickness was ~0.8 at 500 nm with a low Angström exponent of ~0.2 in the late afternoon of the day from the Sun-sky radiometer observation. The dust layer occupied in 2-5 km altitudes through the nighttime. Obtained vertical mean profiles of the aerosol optical properties and water vapor are indicated in Fig. 1.

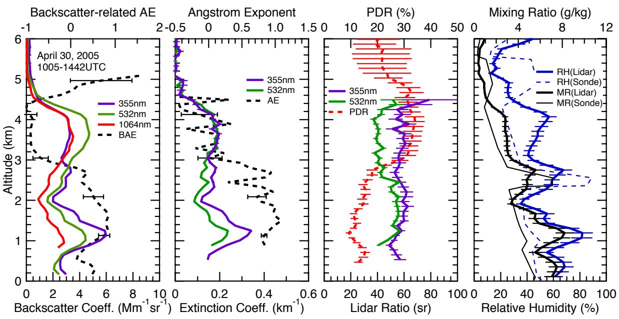

Fig. 1. Mean profiles of the aerosol optical properties (backscatter and extinction coefficients, backscatter- and extinction-related Ångström exponents between 355 and 532 nm, lidar ratios, particle depolarization ratio), water-vapor mixing ratio and relative humidity for the measurement from 1005 to 1442 UTC on April 30, 2005. The mixing ratio and relative humidity obtained from the radiosonde observation at Tateno (12 UTC) are shown for reference.

In this data we can see clearly a large difference between the lidar ratios in 355 and 532 nm only in the dust layer; the mean values between 3.05 and 4.37 km, where the mean particle depolarization ratio (≡S/P) is 32.5 ± 3.6 %, are 58.4 ± 6.1 and 41.7 ± 4.6 sr, respectively. In addition, we note that the corresponding backscatter- and extinction- related Ångström exponents are –0.88 ± 0.17 and –0.04 ± 0.26.

It is worth to mention that we have obtained similar aerosol optical properties in the successive measurements in the nighttime including cirrus clouds appeared over 10 km, which indicate almost no color dependences in these optical properties though the particle depolarization ratio was higher than the dust layer.

3. DISCUSSIONS

Several literatures addressed and discussed the non-sphericity issue in the lidar ratio of Asian dust [8, 9]. In this study, we treated this issue with *T*-matrix code approximating the dust as the spheroid with a typical aspect ratio of 1.4 [1, 10]. We performed the calculation with the frequently used lognormal size distribution (a geometric mean radius of 0.5 μm and a standard deviation of 2.0) ranged from 0.06 to 4.1 μm, and the wavelength-independent complex refractive index (m^*=1.50 + 0.005i) [9]. Thus yielded results are as follows. The lidar ratios at 355 and 532 nm are 40.2 and 29.9 sr, respectively. The backscatter- and extinction-related Ångström exponents are –0.85 and –0.12. The particle depolarization ratio at 532 nm is 37 %. Increase of the real refractive index, e.g., 1.55, lowers the lidar ratios but still larger than the calculations using Mie code [11], which give the lidar radios at 355 and 532 nm as 29.2 and 21.7 sr, respectively.

Although the *T*-matrix calculation closely reproduced the values of the particle depolarization ratio, backscatter- and extinction- related Ångström exponents, but 40-45 % smaller values than the observed values in the lidar ratios. The reason of later poor agreement should be investigated by considering plausible variability of the size distribution, the shape and the refractive index. However, the tendency of the color dependence in the lidar ratio is well captured by the calculations, which might be due to a larger relative absorption effect for a larger size parameter [12]. Further accumulation of observations is indispensable to clarify the UV-absorption property of the mineral dust [13].

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