Plan Position Indicator (PPI) Lidar Measurement of Horizontal Distribution of Aerosol Extinction Coefficient

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Abstract: Observation has been conducted for near-surface aerosol extinction profiles by means of a plan position indicator (PPI) lidar coupled with a slant path (SP) lidar. The lidar wavelengths are 349 and 532 nm for PPI and SP lidar. The purpose of these observations is twofold. First, we examine the consistency of the lidar-derive aerosol extinction with the aerosol data measured using ground-based sampling instruments, namely an integrating nephelometer, aethalometer, and an optical particle counter. The difference in humidity conditions between the instrumental and ambient conditions is taken into account through the Mie-scattering calculation. Second, the horizontal distribution measured with PPI is compared with the aerosol distribution derived from satellite data such as Landsat, MODIS, or Himawari 8. In this paper, we describe the results of our preliminary observation and analysis.

Key Words: Boundary layer aerosol, PPI lidar, Mie scattering, Satellite retrieval

1. INTRODUCTION

Aerosols are liquid and solid particles floating in the atmosphere. Originating from both natural and anthropogenic sources, aerosols exert large impact on radiation balance of the Earth's atmosphere both directly and indirectly [1]. Optical remote sensing from ground-based as well as satellite platforms can provide good understanding of aerosol optical characteristics [2]. Besides, routine observation of boundary aerosol particles has been conducted at the Center for Environmental Remote Sensing (CEReS) by means of sampling instruments. The purpose of the present paper is to extract information on boundary layer aerosol from the combination of lidar, sampling, and satellite observations.

Satellite data such as Landsat, Himawari-8 and MODIS, can provide information on both the surface reflectance and atmospheric scattering [3]. The technique of atmospheric correction is to carry out radiative transfer calculation for separating the contributions from the surface and the atmosphere. The difficulty in this procedure often arises from the lack of detailed knowledge on aerosol particles. Thus the ground-based observations using a lidar and/or a sunphotometer concurrently conducted during satellite overpass are considered to be useful. The advantage of a lidar over a sunphotometer is that the former can give information on the aerosol profile along the laser beam path, while the latter can measure the total optical thickness integrated through the entire atmosphere.

In the present paper, we describe aerosol observations with a plan position indication (PPI) and a slant path (SP) lidar operated at CEReS [4], [5]. Since the elevation angles of these lidars are small (10° for PPI and 30° for SP), the major target of these instruments is the aerosol particles in the atmospheric boundary layer. When applying the Fernald analysis [6], however, the far-end boundary values cannot usually be obtained for PPI and SP lidar. Thus, instead of the far-end boundary, here we propose the use of near-end boundary conditions that are available from the ground-based sampling instruments. In this procedure, we also consider the change of relative humidity (RH) from the ambient (humid) to instrument (dry) conditions [7]. Such an effect can be considered by introducing a factor of $f(RH)$, which is defined as the ratio between the aerosol scattering cross-section $\sigma(RH)$ and the corresponding cross-section under dry condition, $\sigma(RH_{dry})$ [8].

2. INSTRUMENTS

The PPI lidar was installed at the roof top of 9th floor of engineering building (CEReS-Chiba University) about 30 m above the ground. The PPI lidar raw signal was generated 349 nm wavelength radiation by a diode-laser-pumped Nd:YLF with 60 µJ/pulse and pulse repetition 1-3 kHz. This tool was equipped by telescope for collecting backscattering signal, Photo Multiplier Tube (PMT) to strengthening signal, transient recorder connected to personal computer for recording signal. The PPI lidar was completed by rotator table and rotator controller for transmitting and receiving signal within 360° in horizontal direction. To monitor aerosol this instrument operated by shooting laser beam with 10° of elevation and rotating from 0° to 360°. The PPI lidar design is showed in Figure1.

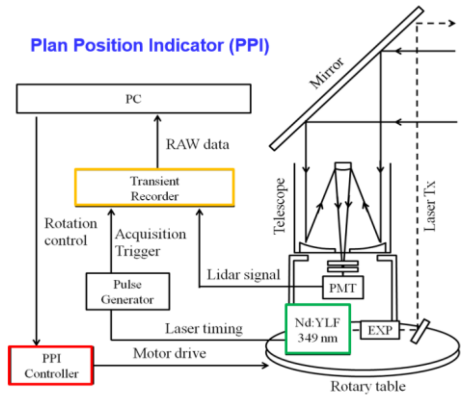

Figure 1: PPI lidar design turned on at rooftop of 9th floor of engineering building Chiba University.

For completing our group planning to combine radiative transfer calculation of satellite data and ground based instruments, we have operated several instrument in CEReS-Chiba University. Slant-path lidar (532 nm) is operated for covering the non-overlapping region of the vertical observation lidar beside PPI lidar (349 nm) for scanning horizontal distribution. Raman lidar also has installed for validating the Mie scattering analysis in determining lidar ratio (S_1). Simultaneous measurement using lidar systems the multi wavelength lidar has also quantitatively measured size distribution and non-sphere of scattering particles. The others ground-based equipment for calibrating the multi wavelength lidar and the Mie scattering calculation we have also operated the three-wavelength integrating nephelometer (TSI, Model 3563), the aethalometer (Magee Scientific, AE-31), and the particle counter (Rion, KC-22B). On the other hand, the five wavelength of sun photometer has perfectly in monitoring aerosol optical depth (AOD) which has possibility as an instrument to validate AOD product of satellite data. To employ analysis about relative humidity effect as aerosol growth representation due to hygroscopic particles, in CEReS-Chiba University has also provided several tools of environmental monitoring. The ground based instruments installed and operated in CEReS Chiba University will be employed in the next analysis.

3. METHODOLOGY

Measurement process using PPI LIDAR was carried out at free cloud condition in May 13th 2016 at night from 19.02 until 21.04 JST (Japan Standard Time) in Chiba area which is located in coordinate of 35.63°N and 140.10°E. In measurement we used laser beam with 349 nm of wavelength, 18,000 shots, and 300 Hz frequency. It means that the PPI lidar collected signal within 360° as long as 30 minute with 1 raw data in 1 minute due to it rotated in 0.02 degree per minute. To obtain aerosol we employed Fernald analysis using python module under Linux. In this analysis we used 8.51 sr^{-1} of molecule scattering and 30 sr of lidar ratio[2], [9], [5].

4. RESULTS

The samples of extinction coefficient were plotted in four main directions (North-1, East, South, West, and North-2) which is represented in Figure 2. The meaning of North-1 is the extinction coefficient when the PPI scanned in the default position while the North-2 mean initial position before scanning in reversal rotation. The complete horizontal distribution is showed in Figure 3 after interpolation process while the distribution in time high indicator show in Figure 4.

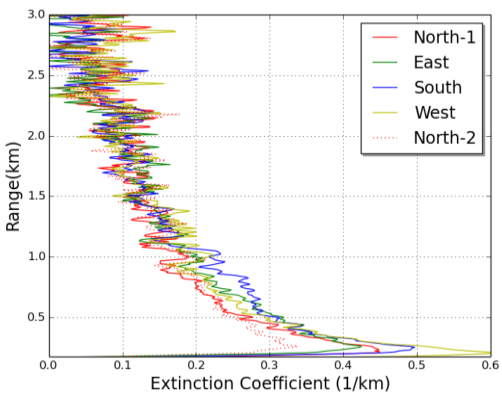

Figure 2: Horizontal aerosol extinction coefficient in normal direction at first scanning process from 19:01:58 to 19:32:29

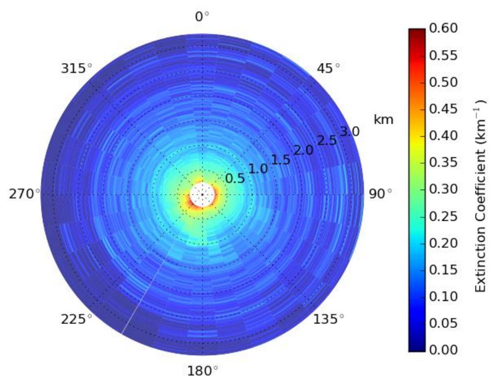

Figure 3: Horizontal distribution of aerosol extinction coefficient in normal direction at first scanning process is scanned from 19:01:58 to 19:32:29.

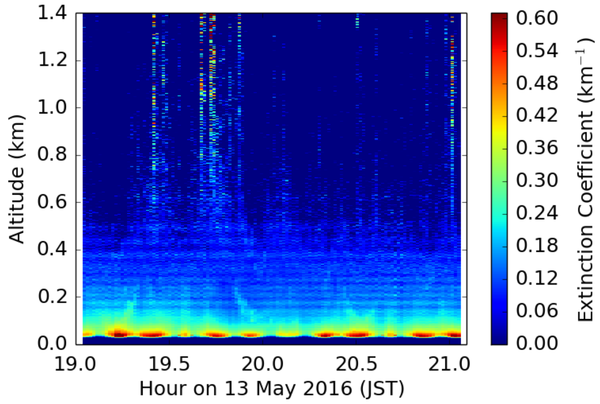

Figure 4: Distribution of aerosol extinction coefficient in time high indicator as comparison scanned from 19.00 to 21.00.

5. CONCLUSSION

This experiment shows that the PPI lidar as a ground based instrument capable in derivation horizontal distribution of aerosol extinction coefficient.

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