NU Science Journal 2007; 4(1): 25 - 30

# Observation of Tropospheric Aerosol Using Mie Scattering LIDAR at Srisamrong, Sukhothai Province

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## ABSTRACT

This work presents a performance study of signal detections from distinct recorders as PMT1 and PMT2 of Mie scattering LIDAR, installed at Srisamrong, Sukhothai province for an atmospheric radiation observation research conducted in cooperation with Thai and Japanese scientists. The vertical profiles versus range corrected signals of one day in winter 2001 during nighttime to daytime were plotted in order to show the significant differences of backscattering signals collected from both recorders and evidently there exists some spikes occurred due to cloud layers. Additionally, the depolarization ratios were determined by the analysis of signal depolarization which could distinguish aerosol from clouds. The effect of multiple scattering on measured depolarization values varied from 1-10% for dense ice crystal precipitation in water cloud, are observed with an increment of depolarization ratios from the cloud base.

*Keywords***:** Mie scattering LIDAR, aerosols, backscattering signals, photomultiplier tube, depolarization ratios

## INTRODUCTION

Aerosols and clouds have both direct and indirect influences on Earth's radiation balance. In this work, we use LIDAR (Light Detection and Ranging or Laser radar) as a tool for remote sensing of atmospheric aerosols and clouds. By this technique, a pulsed laser light is emitted into the atmosphere making a possibility to measure trace components presented in the air *etc*. (Recoleto and Alarcon, 2006). The light collected by a telescope is focused onto photomultiplier which yields an electronic signal proportional to the received light flux. With the dual-polarization measurement function, separated polarization components are detected with two photomultiplier tubes as PMT1 and PMT2, then non-sphericity of scatterers can be measured (Sugimoto, 2001), since aerosol backscattering is depended on the polarization. Single scattering from a spherical water droplet introduces no depolarization, whereas scattering from a typical non-spherical ice crystal introduces significant depolarization (Reagan *et al.*, 1989). Besides, the greater optical density of clouds gives rise to significant differences of characteristic LIDAR signal from clouds compared to normal atmospheric aerosols with quite narrowly broadened aerosol signal. In order to investigate the capability of observed backscattering signals from both detectors, Mie scattering LIDAR in Sukhothai province is therefore utilized to measure backscattering signals of lower troposphere in one day during winter 2001 from nighttime to daytime.

## EXPERIMENTAL PROCEDURE

### LIDAR System and Observations

NIES Compact Mie scattering LIDAR employs flashlamp pumped Nd:YAG laser for output energy of 30 mJ at 532 nm (and 20 mJ at 1064 nm) with a dual polarization receiver of 20-cm Schmidt Cassegrain telescope. The output from PMT1 and PMT2 connected respectively to CH1 and CH2 of a digital oscilloscope. Figure 1 shows a block diagram of Mie scattering LIDAR system. The LIDAR was set to operate for 5 min of every 15 min. Before every 5 min operation, the laser was warmed up for 1 min. The measurement program average 4 times along height before storing the data. Pulse repetition ratio was 20 Hz at maximum and pulse duration is approximately 10 ns. The observation was performed on November 1, 2001 of four periods as 00.00 AM, 06.00 AM, 12.00 PM, and 06.00 PM. Data from 6 to 24,000 m were recorded with 6-m height resolution. Most atmospheric aerosol concentration was dense in the first kilometers above ground level. Therefore the average of all returned LIDAR signals from height beyond 15 km were calculated for subtraction from the backscattering signals of the below levels, since it is assumed as noise background caused by sky radiance when the aerosol optical depth (AOD) evaluations during LIDAR data collections were not provided. However the linear depolarization ratio was determined to describe degree of polarization which can be used to distinguish aerosols from clouds. The depolarization ratio was defined by a ratio of returned signals in polarization planes perpendicular and parallel to the polarization of transmitted laser pulse. Clouds with depolarization ratio values less than 15% were classified as water clouds (Depolarization Ratio, 2006). The values of clear air depolarization are low and affected by photon counting statistics, while depolarization measurements are affected by the presence of multiple scattering of dense clouds. The change from ice to water was noticed as a drop in the depolarization ratio.

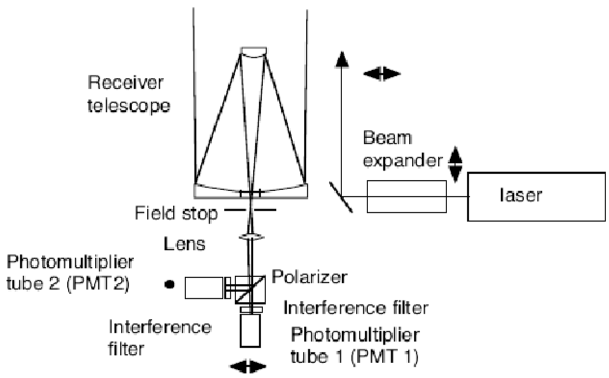



**Figure 1** Block diagram of NIES Mie scattering LIDAR (Sugimoto, 2001).

**LIDAR Equations**

From LIDAR theory basis, in the case of a coaxial LIDAR system (where the laser beam axis is parallel and close to the collecting mirror axis), the backscattering collected signal is defined as (Biral, 2003)

$$P(r) = P_0\, k\ \frac{c\tau}{2}\frac{\mathbf{A}}{\mathbf{r}^2}\,\beta(r)\,T^2(\mathbf{r}) \qquad (1)$$

Where $k$ is a constant function of intrinsic efficiencies of the experimental apparatus, $c\tau$ refers to laser pulse length in the atmosphere (the factor 2 refers to pulse round-trip), and $A/r^2$ is a solid angle comprised by the collecting mirror of area A. The term $\beta(r)$ is volume backscattering coefficient, and the term $T(r)$ refers to transmissibility offered by the atmospheric path to photons traveling from ground to a given distance $r$. Usually, this attenuation term can be described as a negative exponential by the so-called Bouguer-Lambert law which is essentially valid as in the case of fairly transparent atmospheres. Moreover, several terms in equation (1) are constants, so the equation can be presented in term of range corrected or range normalized signal:

$$X(r) = P(r) \times r^2 = C\,\beta(r)\ e^{-2\int_0^r \alpha(r')\,dr'} \qquad (2)$$

Where $C$ is the LIDAR system calibration factor, $\alpha(r')$ is the linear attenuation coefficient and $r'$ is any intervening distance between $0$ and $r$. Hence, the LIDAR equation can be solved if some kind of relationship between the backscattering coefficient and the attenuation coefficient is assumed.

The depolarization ratio, $\delta(r)$ is the ratio of the perpendicular polarized signal to the parallel polarized signal as given by (Iokibe *et al*., 2005)

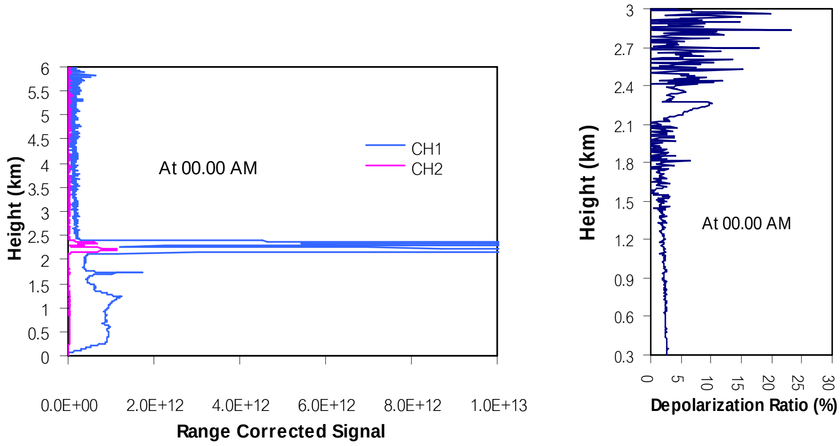
$$\delta(r) = \frac{P_{\perp}(r)}{P_{\parallel}(r)} \qquad (3)$$

where $P_{\perp}(r)$ and $P_{\parallel}(r)$ are the received powers of the backscattered light (as a function of range $r$) with linear polarization perpendicular and parallel, respectively in respect of the transmitter polarization axis. The depolarization ratio is a measure of the non-sphericity of aerosol and cloud particles. Spherical particles like water droplets cause no depolarization with $\delta = 0$, whereas non spherical particles, such as ice clouds and mineral dusts do produce depolarization, so that $\delta > 0$.

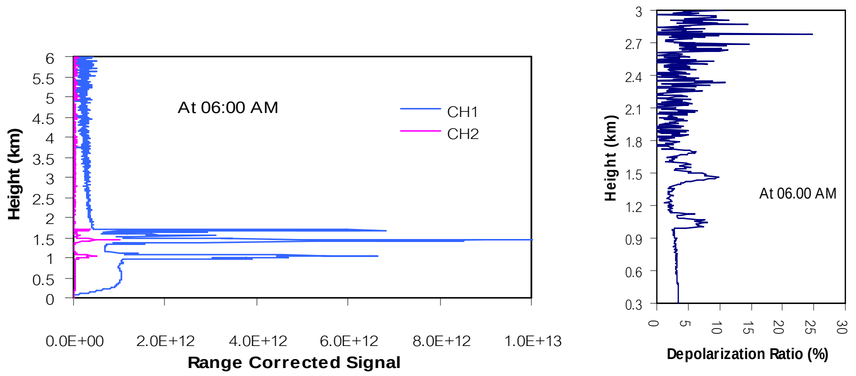
Thus, the depolarization ratio can be used to classify types of clouds and aerosol in atmospheric science applications.

**RESULTS AND DISCUSSION**

The data reliability from distinct recorders was investigated by plotting the vertical profiles of range corrected signals and depolarization ratios for four distinct periods as shown in Figure 2a-2d. Obviously, there are significant differences of the outputs from PMT1 and PMT2 at the lower troposphere of 3.0-3.8 km where are the aerosol layer, and some spikes occurred due to cloud layers. Figure 2a shows the depolarization values of around 3% at 1.7 km height with very narrowly broadened aerosol signal, while two peaks of water clouds are closely observed at 2.2 and 2.3 km. The depolarization values of 1-10% for dense ice crystal precipitation in this region from 1.9-2.4 km are close to one of water and ice mixture and are noticeably affected under the influence of multiple scattering with an increment of depolarization ratios from the cloud base at 1.9 km. Similar observations are visible in Figure 2b-2c. Furthermore, the high aerosol depolarization values up to 3-4% at 06.00 PM in Figure 2d in the distance of 0.2-0.4 km were obtained without cloud observation, while other cases in the same region, the aerosol depolarization values are only 2-3%.

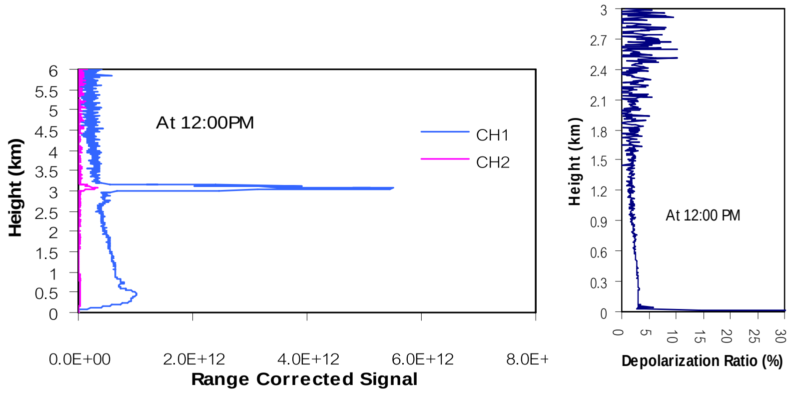



**2a**

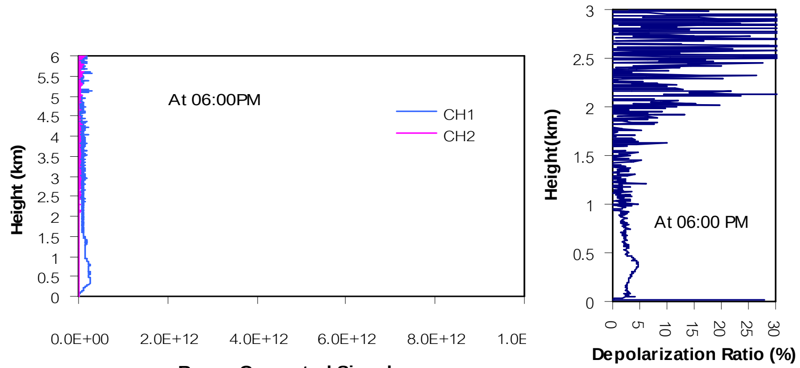



**2b**

**Figure 2a-2d** The vertical profiles of corrected signals range and depolarization ratios at 00.00 AM, 06.00 AM, 12.00 PM and 06.00 PM respectively, measured by PMT1 and PMT2 on November 1, 2001 at Srisamrong, Sukhothai province.




2c




2d

**Figure 2 (Continued)**

## CONCLUSIONS

It can be seen that the depolarization ratios along with the backscattering signals of aerosol and cloud measurements by Mie scattering LIDAR can be used to distinguish aerosols from cloud layers. Effects of multiple scattering on depolarization in the returned LIDAR signal from a dense water cloud were distinctively observed and so that the separation of aerosol from cloud can be explained. We found the different aerosol depolarization values of distinct period in a winter day from 0.2-0.4 km height at Srisamrong, especially the high aerosol depolarization ratios up to 4% at 06.00 PM. Hence, it would be reasonable to conclude that the larger size of aerosol particles is existed in the atmosphere at that moment.

## ACKNOWLEDGEMENTS

The authors are grateful to the National Institute of Environmental Studies of Japan and Department of Geology, Faculty of Science, Chulalongkorn University for supporting all facilities and data in this work. Additionally we would like to thank senior undergraduate students from the department of Physics, Srinakharinwirot University for their good assistances.

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