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LIDAR OBSERVATION OF THE TROPOSHERE IN TOKYO

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1. INTRODUCTION

Recently air pollution due to NO_X and SPM (Suspended Particulate Matter) mainly from car exhaust gas in urban areas become an objective of public concern in Japan. So we have started a lidar study for the monitoring of urban atmosphere in the heart of Tokyo city for the first time. As the first step, we have constructed a compact Mie scattering lidar and observed the vertical distribution of aerosol and the depolarization ratio in lower atmosphere. Some interesting results are obtained as described below. Similar works have been extensively done for the last two decades [1].

2. LIDAR SYTEM

We have assembled a biaxial lidar system based on the pulsed Nd:YAG laser (Quanta-Ray GCR-130-10) in a ground-floor air-conditioned room. The SHG output (λ=532 nm) via beam expander is transmitted with 45-degree elevation angle through a window by deflecting with a mirror. The pulse repetition rate is 10 Hz. Backscattered lights are received by a 25-cm diam. Schmidt-Cassegrain telescope (Mead LX200-25). A narrowband interference filter ($\Delta\lambda$=2 nm) is attached to an iris diaphragm at the focal plane so as to avoid its effect on the geometrical form factor (GFF) of the lidar function. Refocused lights by a plano-convex lense which acts as the eye piece are converted to electrical signals by a photomultiplier tube (PMT, Hamamatsu R1463-01). The output of PMT is gained by the preamplifier (SR-445) with 50 Ω input impedance and recorded by a digital storage oscilloscope (LeCroy 9310). The acquired data are transferred into a PC via GPIB interface after each averaging run. The parameters of system were optimized with considering the following points. To get overall information of the atmospheric boundary layers it is preferable to take data from the lower altitude. Lower power density of pulsed laser beam is strongly recommended for the eye-safety in the urban airspace. In the following experiments, the parameters are set as follows: laser beam divergence; 1.3 mrad, laser power; 5 mJ/pulse, field-of-view of the telescope; 3-4 mrad. The applying voltage to PMT is limited to avoid the

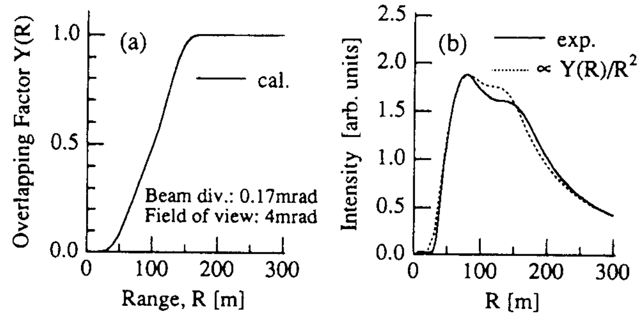

Fig.1 GFF (a) and a typical return signal (b).

saturation effect due to near-field backscattered radiation. In such a large field-of-view case, a characteristic dip appears in the return signal as shown in Fig. 1(b), especially when the laser beam divergence is less. This dip is well reproduced by the numerical calculation of GFF [2] as shown in Fig. 1(a) and interpreted as an effect due to the secondary mirror of the telescope.

3. BOUNDARY LAYERS

We have observed the atmospheric boundary layers every hour during day and night. Each run has been accomplished for 60 or 100 seconds. The data are analyzed together with metrological data which are continuously obtained on the top of the building 30 m high in the campus. An example of range-squared lidar profiles in the daytime when an anticyclone covered Kanto aera is shown in Fig. 2. The rapid growth of the mixed layer is observed in the morning. For the well-developed mixed layer around the midday, the extinction coefficient can be easily evaluated by the slope method e.g., the value at 13 h in Fig. 2 is evaluated as 0.580 km^{-1} which corresponds to the visibility of 5.16 km. The temperature on the ground has a good correlation with the height of the transition layer. Other example of lidar profile in the night in winter is shown in Fig. 3. Very stable ground inversion is clearly seen. It broke up at 7 h just after the sunrise and a large increase of signal was observed. In such a inversion layer, pollutants are strongly confined so that high concentration of pollutants is expected in the ground level. The lidar observation like this should be quite useful for the monitoring and warning of the high-level air pollution.

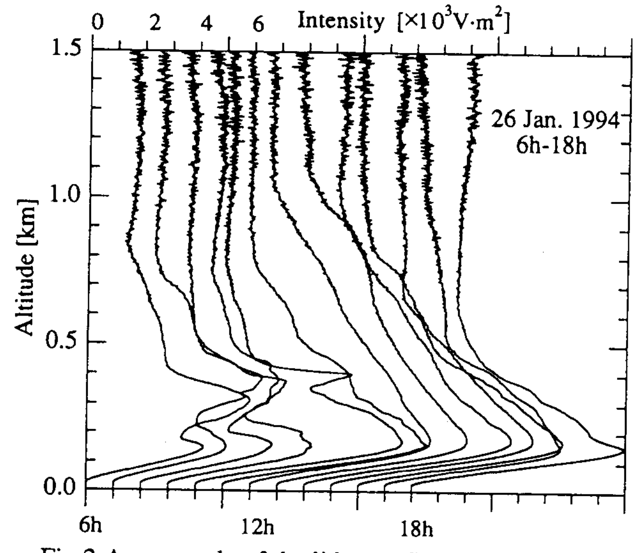

Fig.2 An exmaple of the lidar profiles in the daytime.

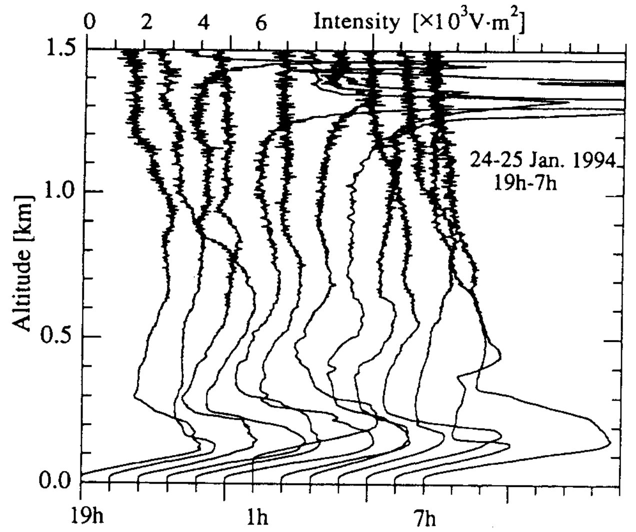

Fig.3 An example of the lidar profiles in the night.

4. POLARIZATION STUDY OF THE LOWER AEROSOL

For the depolarization ratio (δ_p) measurement, the backscattered lights were separated in two polarization components by a polarizing beamsplitter inserted between the focused aperture and the lenses and detected by two PMTs. The direction of the linear polarization of laser beam is carefully tuned relative to the detection system by using an additional half-wave plate. An example of δ_p measurement of the lower dusty layer in the daytime is shown in Fig. 4(a). The absolute accuracy of δ_p is ±10 %. The detection range of δ_p for the lower aerosol layer is presently limited to about 300 m in altitude because the intensity of the perpendicular polarization component of the backscattered lights is so small. The value of δ_p tends to decrease with altitude. The change of the averaged values of

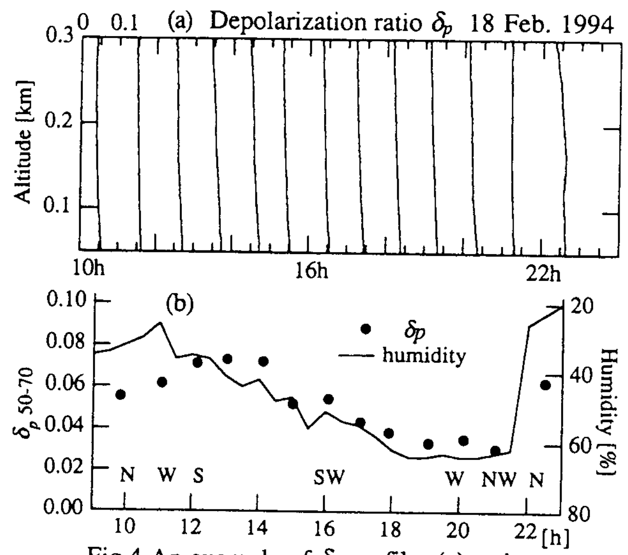

Fig.4 An example of δ_p profiles (a) and the comparison with the humidity (b).

δ_p from 50 to 70 m is illustrated in Fig. 4(b) with the humidity and the wind direction at 30 m. One can easily see that δ_p tends to decrease with increasing the humidity. The sudden changes of δ_p and humidity were occurred when the wind direction was changed owing to the land and sea breezes. Thus the measurement of δ_p gives an insight of the constituent of aerosol.

5. SUMMARY

We have successfully developed the Mie scattering lider for the observation of the atmospheric boundary layer in the center of Tokyo and demonstrated that the lidar is a quite useful tool for the study on air pollution monitoring. We have also found that the the depolarization ratio correlates closely with the humidity in the lower dusty layer. Extension of the present lidar system is earnestly desired to detect directly the concentration of NO_2 or other pollutant molecules by the DIAL technique with an additional tunable laser.

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References

1) e.g., Sasano Y, A. Shigematsu, H. Shimizu, N. Takeuchi and M. Okuda, J. Meteorol. Soc. Jpn **60**, 889 (1982), W.R. McNeil and A.I. Carswell, Appl. Opt. **14**, 2158 (1975).

2) Formula are given in the textbook: R.M. Measures, *Laser Remote Sensing* (John Wiley & Sons, 1984) Chapter 7.