A CASE STUDY OF COLD AIR PARCEL EVENT PASSING TOKYO OBSERVED WITH RAYLEIGH-MIE RAMAN LIDAR

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ABSTRACT

A Rayleigh–Mie Raman lidar system at a wavelength of 355 nm has been used for measurements of atmospheric temperature, relative humidity and aerosol profiles simultaneously in the lower troposphere, particularly the planetary boundary layer. Lidar operation every three hours indicates there was a cold air flow passing Tokyo from Feb. 21st to 22nd, 2005. Layer with very high relative humidity and temperature inversion layer appeared and then increased while the convection was weaker and weaker during night time. Lidar measurement results are evaluated by comparison with radiosonde measurements，which show a similar change. Backward trajectories with HYSPLIT model revealed this cold air parcel started from Mongolia three days ago. As it moved over Mongolia, Northeast China, then to Tokyo, Japan, the cold air parcel at high altitude had an obvious downward vertical motion. Air from higher latitude and altitude made the local air colder.

1. INTRODUCTION

Since laser was invented and lidar was used, we have a new tool to do some progressive atmospheric research. Many kinds of lidar were applied to make aerosol observations, measurements of temperature, relative humidity and wind profiles etc.

Recently, a Rayleigh-Mie Raman lidar that is capable of simultaneously measuring the temperature, water vapor concentration or relative humidity and aerosol backscattering ratio in the troposphere was developed [1-2]. Moreover, more atmospheric boundary layer phenomena were observed in the urban/rural and above the sea, and more sensors and methods evaluated [3-8]. On Feb. 21st to Feb. 22nd, 2005, strange but interesting aerosol signals were captured during the Rayleigh-Mie Raman lidar experiments at Tokyo. In this paper, we try to explain the phenomena by analysis the measurement results and compared with other data source.

2. DATA SETS AND INTERPRETATIONS

2.1 Aerosol backscattering by Rayleigh-Mie Raman lidar

A Rayleigh–Mie Raman lidar system has been upgraded for simultaneous measurements of atmospheric temperature, relative humidity and aerosol profiles in the troposphere [2]. The Lidar system uses an injection seeded Nd:YAG laser to transmit its third harmonics 355nm with 200-mJ laser energy per pulse to the air. A 25-cm-diameter telescope collects the atmospheric backscattered light and couples it into a multimode fiber. The output of the fiber is collimated and sent directly through a high-resolution grating. In this setup, the temperature is determined from the molecular Rayleigh scattering linewidth and the water vapor density is determined from the intensity of the water vapor vibration Raman line centered at 407.5 nm.

The Rayleigh-Mie Raman lidar measures and collects data for 3.5 minutes every three hours, from 15:00 of Feb. 21st, to 15:00 of Feb. 22nd, 2005. All the time mentioned here is Japan local time (UTC + 9-hour). For convenience, we named the aerosol range corrected signal of lidar (Fig. 1) A2115, A2118…The meaning of the name corresponds aerosol and collecting time, for instance, A2115 means the aerosol profile was observed at 15:00, on Feb. 21st 2005, and so on.

A2115 shows it was a clear sky with free of cloud till up to 3.5km altitude from the earth surface at 15:00 on Feb. 21st, 2005. Starting from 18:00 (A2118), a big signal peak result from clouds appeared at about 1.8km. Although the cloud layer seems not so thick, we think it's much thicker than what it looks. The line jumps to zero means the laser pulse maybe not penetrates through this layer. A2121 shows its uplift to about 2.5~3km. Generally, the atmospheric boundary layer will descend and leave the residual layer at this time (also see Fig. 4). At 21:15, it starts to light rain shower intermittently till to 22:00. The cloud maintained through A2203 to A2212 with its thickness and altitude decrease.

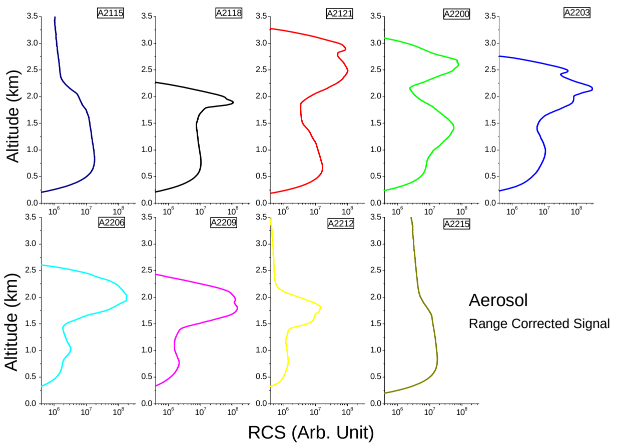

Fig. 1 Range corrected aerosol signal of the lidar

2.2 Simultaneously radiosonde measurements

In order to evaluate the lidar system, radiosonde also was used to simultaneously measure the temperature (Fig. 2), relative humidity (Fig. 3) etc. T2115, meaning the temperature result of 15:00, Feb. 21st, indicates temperature inversion layers existing at about 1.5km、3km、4.5km, but the difference is only a few degrees. Beginning from T2118, a relative big temperature difference of inversion layer appeared (maximum difference in temperature is about 5 degree for T2118). The relative humidity profile also shows a high-relative-humidity layer appearing at the same height of strong aerosol backscattering signal. The relative humidity is close to 100%.

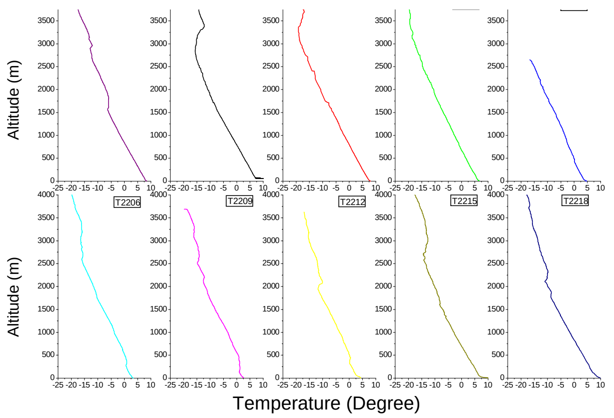

Fig. 2 Simultaneously temperature data from radiosonde

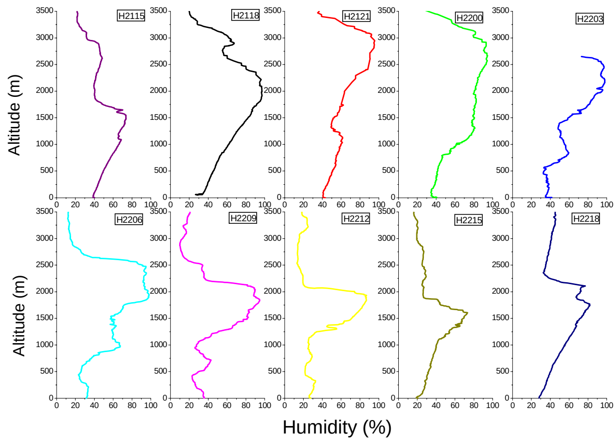

Fig. 3 Simultaneously relative humidity data from radiosonde

Combination with relative humidity profile data and aerosol signal, we find the temperature inversion layer is just above the strong backscattering layer and the high-relative-humidity layer. One possible reason is complexity of urban meteorology and atmospheric vertical structure. Another possibility is that there was cold air arrival to the local but not so obvious or strong.

Weather map indicated there was a big cold eddy existing to the northwest of Japan on Feb. 21st 2005. Westerly wind prevailed and passed Tokyo. After the air flow comes, local warmer and wetter air was uplift above the colder and drier air from other place. The uplift trend of aerosol layer from A2118 to A2121 also exists in the temperature inversion layer and high-relative-humidity layer similarly.

The center of strong backscattering layer in A2200 began to decrease in height, compared with foregoing results. Similar phenomena can be found in the relative humidity and temperature data. Here it should be noticed that ground temperature began to decrease heretofore. Six hours later, five degree drop happened to the ground temperature. Although after rain shower, relative humidity on the ground decreased. We think the cold air drive the local warm and wet air out of the urban area, replace with the cold and dry air.

Potential temperature, retrieved from radiosonde, indicated the temporal change of the top height of convective atmospheric boundary layer (Fig. 4), also called the mixed-layer. All the strong backscattering signal, temperature inversion layer, high-relative-humidity layer existed above the mixed layer.

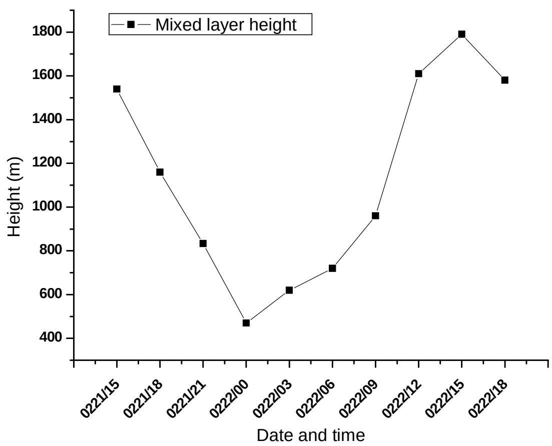

Fig. 4 Mixed-layer height retrieved from radiosonde

2.3 HYSPLIT backward trajectories

NOAA HYSPLIT [9-10] model was run to know about the backward trajectories ending at 15:00 JST, on Feb. 22nd, 2005. Results show cold air, about 20 degree lower the local temperature, went through Russia and Mongolia heading to Tokyo 96 hours later. Model output of every three hours and 48 hours duration, Fig. 5, indicates the air were all from the Northeast of China. Especially, the air parcel went from high altitude and moved downward to Tokyo. All of these carried cold air and made air colder.

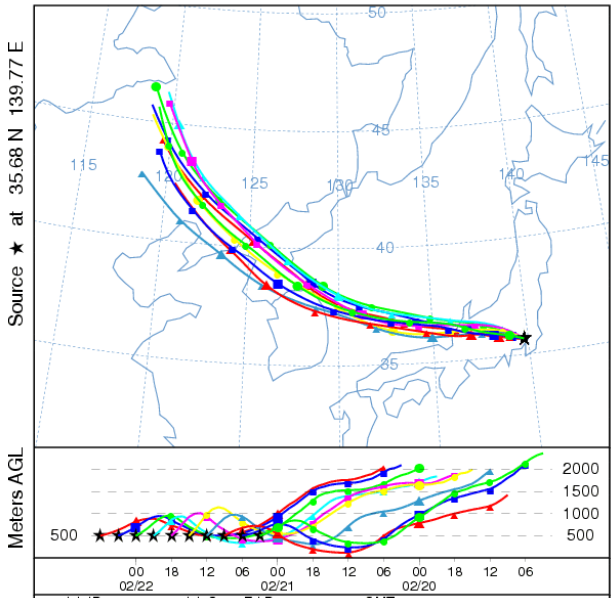

Fig. 5 Backward trajectories with HYSPLIT

3. SUMMARY AND CONCLUSIONS

Multi-sensors and data are used to understand a process case that took place in the atmospheric boundary layer, at Tokyo. Rayleigh-Mie Raman lidar is shown to be a powerful tool to reveal more information. Further sophistication of meteorology will help to understand atmospheric boundary layer with available lidar system.

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