P2-29 Field Experiments of the Atmospheric Boundary Layer with the Bistatic Imaging Lidar

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1. Introduction

In recent 30 years, various lidar systems have been developed and applied to atmospheric research. Until now a monostatic lidar has been widely used in the remote sensing of the atmosphere and a bistatic lidar has been applied only to particular purposes, such as a refractive index or size distribution of aerosols[1-4]. However, a monostatic lidar system is not effective for measuring the lower atmosphere because the transmitting beam does not overlap the telescope's field of view in the near range. The bistatic configuration can overcome the problem and give information on scattering angle dependence.

In previous papers[5,6], we have made the proposal of a compact and simple bistatic imaging lidar using a high sensitive cooled CCD camera with an image intensifier as a high speed shutter. We developed the bistatic imaging lidar system for measuring spatial distribution of aerosols, fogs and clouds in the lower atmosphere at daytime as well as nighttime.

The bistatic imaging lidar was applied to two field observation campaigns. One was made cooperatively with a wind profiler and a radiosonde at Moriya (36 km north of Tokyo) for 5 days from May 26 to 30, 1997 and another cooperatively with a monostatic lidar at Hakuba alpine ski area of Nagano for 10 days from February 7 to 16, 1998 during the period of the 18th Winter Olympic Games in Japan.

We report the results obtained at both campaigns and discuss the ability of this system in measuring the meteorological features of the local lower atmosphere under different conditions.

2. Bistatic imaging lidar system

The experimental set-up is shown in Fig. 1. The transmitter and receiver of lidar are separated in the same horizontal plane. A second harmonics of a Q-switched Nd: YAG laser (532nm) is used as the transmitter. The receiver is a cooled CCD camera. The Specifications of the bistatic imaging lidar system are summarized in Table 1.

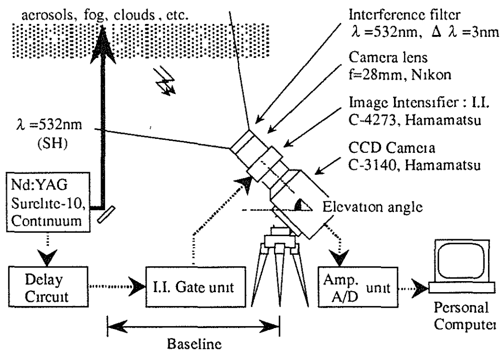

Fig. 1 Bistatic imaging lidar system

Table 1. Specifications of the bistatic imaging lidar

Transmitter	Field experiments
Laser	Flash lamp-pumped Nd: YAG laser (Surelite-10, Continuum)
Wavelength	532nm(SHG)
Pulse Energy	240mJ(Max)
Repetition rate	10Hz
Pulse width	6ns
Beam diameter	6mm
Beam divergence	0.6mrad
Polarization	Liner perpendicular to scattering plane
Receiver	**System**
CCD camera	C-3140 (Hamamatsu)
Image device	Interline CCD
CCD size(mm)	8.8(H)x6.6(V)
Pixel	510(H)x492(V)
Aperture efficiency	24%
Quantum efficiency	33%at 532nm
CCD temperature	-30℃
A/D resolution	12bit
Camera lens	Nikkor 28mm,F2.8
FOV(vertical)	314mrad(18deg)
FOV(pixel)	0.6mrad
Interference filter	532FS03-50 (Andover)
Bandwidth	3nm at 532nm
Image processor	PC-9801DA (NEC)

3. Field experiments and discussions

(1) Experiments at Moriya

The bistatic imaging lidar was operated at Moriya on May 26-30, 1997. The operational conditions of experiment are listed in Table 2. The atmospheric temperature and relative humidity at the level of the lidar were measured by a hygrothermoscope during the period of this campaign. In addition, a lower atmospheric wind profiler (LAWP) measured the vertical wind structure with a time interval of 30 minutes. Moreover, the vertical structures of temperature and humidity were observed by a radiosonde at 11:00 LST everyday during the experiments.

Table 2. Operational conditions

	Moriya	Hakuba
Laser energy	80mJ	100mJ
Baseline	15.3m	11.2m
Elevation angle	81.0deg	81.0deg
Gate time	20μs	20μs
Accumulating time	10s	10s
Time resolution	1min	1min

Figure2 is time-height representation of the laser return signal intensity measured with the bistatic imaging lidar from noon May 26 to noon May 30, 1997. The temporal variations of temperature and relative humidity near the surface are shown in Fig. 3.

In this experiment we observed the significant increase of boundary height of lower aerosol layer below a height of 1.5km occurred 2.5 hours before a severe thunderstorm with hailstone happened around 19:40 LSTon May 26.

We could determine the daily mixing sequence by identifying the top height of boundary layer by different color signal strength. The mixing depth was approximately 1200m from noon May 28 to noon May 30, corresponding to the mixing depth determined by the radiosonde on 11:00 May 29. The observation of vertical distributions of aerosol layer explained the boundary layer mixing processes.

We also observed the aerosol layer from different source. Figure 2(d) shows the second aerosol layer between 600m to 700m around the midnight of May 29 (21:00 LST to 2:00 LST on May 30). From the LAWP wind direction data, we could find significant difference of horizontal wind direction between below and above a height of 600m. The wind blew southwesterly at lower layers, but northeasterly in the 600-700m layer. It suggested that the thin aerosol layer above 600m was

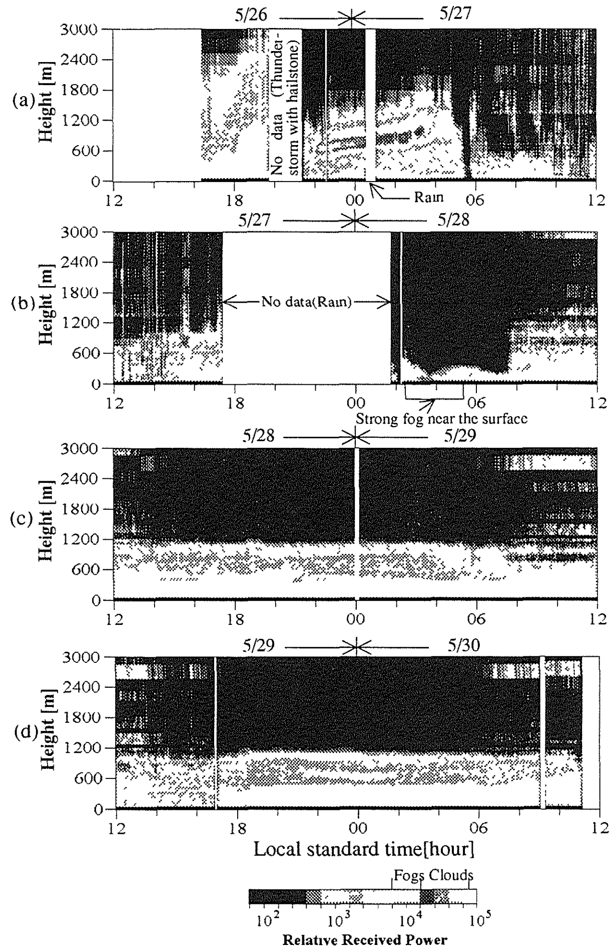

Fig.2 Time-height representations of the laser return signal intensity measured at Moriya from noon May 26 to noon May 30,1997.

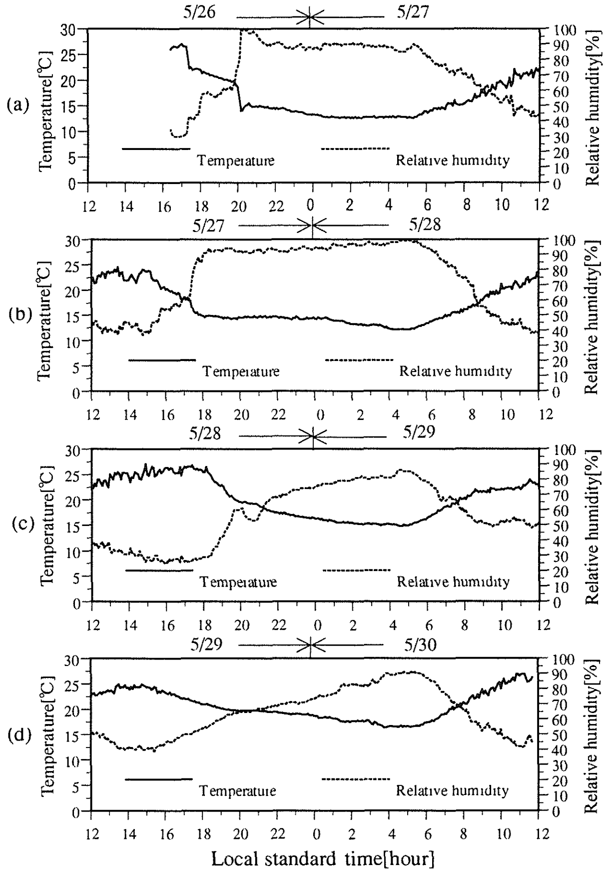

Fig. 3 Temporal variations of temperature and relative humidity near the surface at Moriya from noon May 26 to noon May 30,1997.

brought by northeasterly wind and the lower layer by southwesterly wind.

(2) Filed experiments at Hakuba during the 18th Winter Olympic Games in Japan.

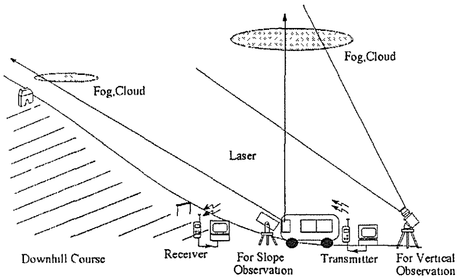

Fig.4 Schematic of observation at Hakuba

The second experiments were made cooperatively with the monostatic lidar measurement at Hakuba alpine ski area of Nagano on Feb. 7-16, 1998 as shown in Fig. 4. The latter system was used to measure the atmosphere along the mountain slope of Happo-one. A second harmonics of a Q-switched Nd: YAG laser was separate into two laser beams with a half mirror. One laser beam emitted in the vertical direction was for the bistatic lidar and another in the direction of mountain slope of Happo-one for the monostatic lidar. A Schmidt-Cassegrain telescope was used as a receiver of the monostatic lidar, which diameter was 355mm, focal length 3910mm, field of view 2mrad, and elevation angle 14degree. The operational condition of the bistatic lidar at Hakuba is also listed in Table 2.

Figure 5 is time-height representations of the laser return signal intensity measured with the bistatic imaging lidar (left) and the monostatic lidar (right) at Hakuba from noon Feb.7 to noon Feb.16, 1998.

We made a comparison between the results of two lidar systems. In cloudy weather (21:30, Feb.7~9:40, Feb.8; 12:00, Feb.9~3:00, Feb.10; 16:17, Feb.14~2:00, Feb.15; 9:50, Feb.15~9:40, Feb.16) the two systems also observed well the temporal variations of cloud base height in foot and slope of the mountain. However, the cloud base heights observed by the bistatic imaging lidar were not so exactly compare with the monostatic lidar. Because the height resolutions of the former lidar were not better than the later one and were influenced by multiple scattering.

In snowy weather (16:30, Feb.8~12:00, Feb.9; 3:00 ~22:10, Feb.10; 2:00~7:30, Feb.15) the results of two lidar systems were different. Using the bistatic imaging lidar we could observe well the laser scattering signals from snowflake above 35m near the surface. However, the measurement of monostatic lidar couldn't obtain the laser scattering signals, because the transmitting beam didn't overlap the telescope's field of view in the near rang (Elevation angle was 14 degree, the rang was about 400m). The transmitted laser beam greatly attenuated out of snowflake scattering.

In local measurement used the two lidar systems we could overcome the disadvantages of one lidar system with another. During the 18th winter Olympic games we provided important information, especially the information about cloud base height and fogs in nighttime.

4. Conclusion

According to analyses of the lidar data obtained by two field experiments, we demonstrated the bistatic imaging lidar's unique ability in measuring detail meteorological features of the local lower atmosphere under different conditions. We could show the usefulness of a bistatic imaging lidar for measuring the lower atmosphere by indicating some interested examples such as temporal evolution of a severe thunderstorm, diurnal variations of vertical structure of aerosols layer and effect of convection mixing on vertical distributions of aerosols. The bistatic imaging lidar effectively operated and provided the data of fogs, snow and cloud base height even under bad weather condition such as snowstorm except rainfall.

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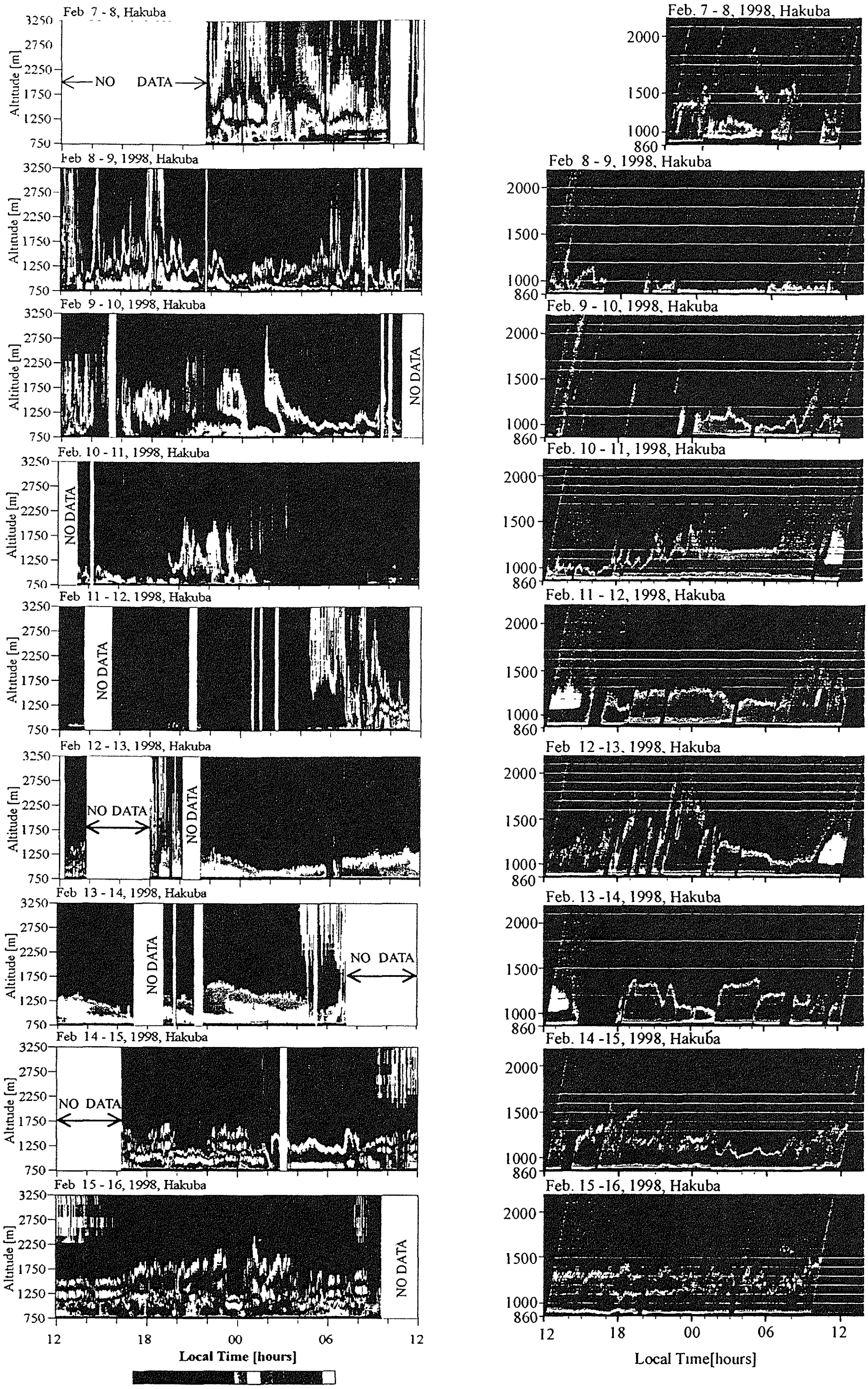

Fig.5 Time－height representations of the laser return signal intensity measured with bistatic imaging Lidar (left) and monostatic lidar (right) at Hakuba from noon Feb.7 to noon Feb.16, 1998