LOCAL EASTERLY WIND "KIYOKAWA-DASHI" OBSERVED BY COHERENT DOPPLER LIDAR IN JAPAN DURING THE SUMMER 2004

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ABSTRACT

The two-axis scanning coherent Doppler lidar and 4 weather stations were used to examine the three-dimensional structure and dynamics of the Kiyokawa-dashi. The line-of-sight (LOS) wind speed distributions were measured by the 2μm eye-safe two-axis scanning coherent Doppler lidar with three scan modes, the range height indicator, the plan position indicator, and the velocity-azimuth display. The range height indicator showed fine structures that the Kiyokawa-dashi existed below the critical level (horizontal wind velocity = 0 m/sec) at an altitude of about 600 m, and that the depth of the Kiyokawa-dashi was very shallow. Although the plan position indicator suggested that the Kiyokawa-dash was almost stationary, the indicator showed that the Kiyokawa-dash had small fluctuations within a short time. The LOS wind speed distributions obtained by the coherent Doppler lidar measurements were used to compare with the wind speed distributions simulated by using a non-hydrostatic mesoscale numerical model with a horizontal grid spacing of 1 km. Although there was small bias between them, the LOS wind speed distributions were consistent approximately the simulated wind distributions.

1. INTRODUCTION

In this study, the temporal evolution and spatial structure of the local easterly wind "Kiyokawa-dashi" in Japan is investigated by the observational data obtained with the 2μm eye-safe two-axis scanning coherent Doppler lidar (CDL), and four weather stations. The Kiyokawa- dashi is one of the most well-known local winds which occur over the Shonai plain in Yamagata. The characteristics of the Kiyokawa-dashi are low temperature and low humidity, and continuing duration of one day to about 1 week. The occurrence of the Kiyokawa-dashi results in the white head of rice plant and the rice blast, and causes severe crop damage. Many studies address various evolution mechanics of the Kiyokawa-dashi, such as acceleration of down-stream flow [1], gap wind [2], and deformation of atmospheric airflow passing over Gassan and Asahi (38.15°N, 139.55°E) ranges [3]. Since, however, only minimal data from ground-based meteorological studies and from short-term pilot balloon observations has been available [4], spatial information about of the Kiyokawa-dashi has been limited. Thus observational analyses of the atmospheric flow are significant for a better understanding of the evolution of the Kiyokawa-dashi. The main objectives of this study are to investigate wind profiles of the Kiyokawa-dashi to contribute to the investigation of the Kiyokawa-dashi and to improve the computational algorithm to obtain vertical and horizontal wind profile. For the objectives, we observed wind speed distributions of the Kiyokawa-dashi, and compared with those simulated by the numerical prediction division unified nonhydrostatic model of the Meteorological Research Institute.

2. 2μm EYE-SAFE TWO-AXIS SCANNING COHERENT DOPPLER LIDAR

The CDL was installed to measure the LOS wind speed at the exit of the Mogami Valley, Kiyokawa (R1), during the summer 2004 (Fig 1). The Mogami Valley is located in between two high mountains, Mt. Chokai (39.06°N, 140.02°E, 2236m MSL) of the Hinotodake hills and Mt. Gassan (GAS; 38.33°N, 140.01°E, 1984m MSL) of the Asahi range, and the Mogmi river runs through the Mogami Valley. Four automatic weather stations were installed to observe meteorological elements at Kiyokawa (R1), Karikawa (R2), Mawadate (R3), and Hirono (R4). There are no tall buildings that cause heavy turbulence near each observational site. The CDL consists of a 2μm laser transmitter-receiver unit manufactured by the CTI, a scanning device, and electric devices. The CDL uses a diode-laser-pumped single-longitudinal-mode high- power Q-switched Tm:YAG pulse laser that operates at a wavelength of 2.012 μm and at a pulse repetition frequency of 100 Hz. The laser pulse is transmitted into the atmosphere through the telescope and the scanning device. The laser pulse was backscattered and Doppler-shifted by the moving aerosol particles. The Doppler frequency Δf is obtained from the difference between the frequencies of the transmitted laser pulse and the backscattered signal. The Doppler frequency Δf directly determines the LOS wind speed. The LOS wind speed V_{LOS} of about 1m/sec corresponds to a frequency shift Δf of 1MHz at the laser wavelength λ_L of 2μm ($V_{LOS} = \lambda_L \cdot \Delta f/2$). In early 2004, we developed a two-axis scanning device and evaluated the CDL performance. Measuring the LOS wind speed with repeating the scans, the CDL can be used to measure three-dimension volumes of wind data. Three scan modes, the range height indicator (RHI), the plan position indicator (PPI), and VAD, are executed with the two-axis scanning device. The RHI scan is performed by holding the azimuth angle fixed while sweeping the elevation angle and can obtain the vertical cross section of the LOS wind speed. The PPI scan is performed by holding the elevation angle fixed while sweeping the azimuth angle and can obtain the horizontal cross section of the LOS wind speed. In this study, the RHI was performed at the azimuth angles of 45° and 315° changing the elevation angle which is along the Mogami Valley, and the PPI was performed at the elevation angle of 2° changing the azimuth angle of 270 to 315°. Meteorological elements measured by each automatic weather station were wind speed, wind direction, temperature, and relative humidity. Wind speed, wind direction, maximum instantaneous wind speed, and observed times were measured by the R. M. Young 05103 at each observational site. The analog signals of meteorological elements were converted to digital formats with using 13-bit A/D converters installed in the datalogger (CR10X, Campbell Science Inc.). Average values of pressure for each one hour and other meteorological elements for each ten minutes were automatically stored in the memory of the datalogger.

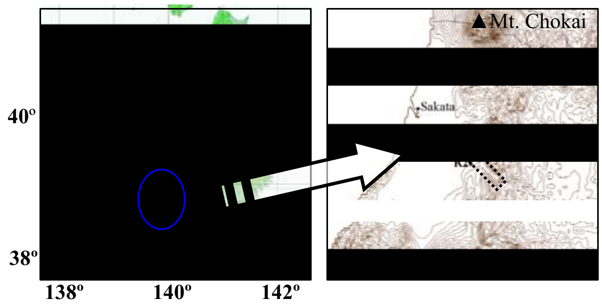

Fig 1. Target area and automatic weather stations: Kiyokawa (R1; 38.80°N, 140.01°E, 20m MSL), Karikawa (R2; 38.79°N, 139.99°E, 15m MSL), Mawadate (R3; 38.81°N, 139.92°E, 10m MSL). The CDL was installed at R1.

Table 1. Specifications of two-axis scanning coherent Doppler

Transmitter-Receiver unit	
Laser	: Tm:YAG
Wavelength	: 2.012 μm
Pulse energy	: 7 mJ/pulse
Pulse width	: 560 nsec
Pulse Repetition	: 100 Hz
Telescope clear Aperture	: 5inch ϕ
Detector	: InGaAs
Scanning device	
Effective clear diameter	: 10 cmϕ
Elevation scanning angle	: -20 - 200°
Azimuth scanning angle	: -10 - 370°
Available moving speed	: 0 - 60 deg/sec
Data Processing	
Signal processing	: 8 Bit A/D conversion
Sampling frequency	: 500 MHz
Sampling number	: 65336 points

3. NUMERICAL SIMULATION MODEL

The Kiyokawa-dashi was simulated by the numerical prediction division unified nonhydrostatic model of the Meteorological Research Institute (MRI-NPD NHM). The MRI-NPD NHM is a three dimensional, non-hydrostatic mesoscale model developed by the Japan Meteorological Agency (JMA). This model used the terrain following coordinate system with 38 layers and lowest layer was set for 20 m above the ground. The initial and boundary data were generated by the JMA mesoscale reanalysis (MANAL) which updated every 6 hours with 10 km of horizontal grid size. For this simulation, 5 km and 1 km resolution domain were nested using one-way interface.

4. RESULTS

Figure 2 shows the vertical cross section of the LOS wind speed obtained by the RHI scan at the azimuth angles of 135˚ and 315˚ changing the elevation angle at 9:22-9:42 JST (=UST+9) on August 30, 2004. The easterly wind was observed by the CDL at altitudes of lower than 600 m MSL, on the other hand, the westerly wind was observed at altitudes of higher than 600 m MSL. Figure 2 indicated that the easterly wind was almost stationary, and that the maximum easterly wind speed assumed to be about 10 m/sec. The top of the easterly wind was assumed to be 600 m MSL, suggesting that the critical layer existed at the altitude. The altitude of the critical layer was not changeable, and was slightly lower than altitudes of the crest of mountains around the target area. Figure 3 shows the horizontal cross section of LOS wind speed measured by the PPI scan at the elevation angle of 2º with changing the azimuth angle at 15:34-15:52 JST on the same day. Although the plan position indicator suggested that the Kiyokawa-dash was almost stationary, the CDL captured the small fluctuations that changed within 5 to 10 minutes. We can see from Fig. 3 that the LOS wind speed was accelerated westward at the range of 2 to 4 km. Figure 4 shows an example of the vertical cross-section of wind speed simulated along the Mogami valley by the NHM. In this numerical simulation, the altitude of the calculated critical layer was approximately 300 m lower than the altitude observed by the CDL. Figure 5 shows an example of

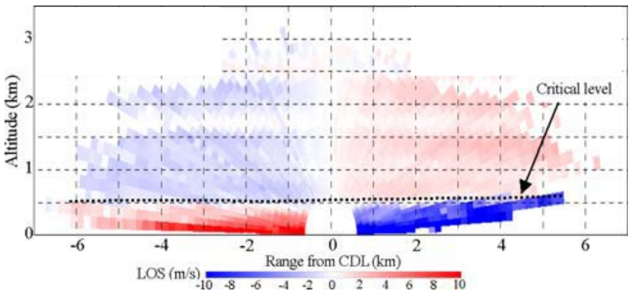

Fig. 2 RHI scan of the LOS wind speed along the Mogami valley at 9:22-9:42 JST on August 30, 2004. The two-axis scanning device was set to scan between 0 and 90º in elevation at azimuth angles of 135º and 315º. The elevation angle was stepped in 2º increments. The laser pulse accumulation was 500 for the each elevation angle. It took about twenty minutes to obtain one RHI scan. Blue shows towards the CDL, and red shows away form the CDL.

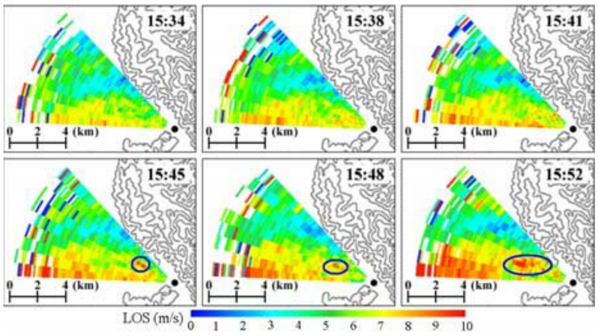

Fig. 3. PPI scan of the LOS wind speed along the Mogami valley at 15:34-15:52 JST on August 30, 2004. The two-axis scanning device was set to scan between 275 and 315º in azimuth at an elevation angle of 25º. The elevation angle was stepped in 5º increments. The laser pulse accumulation was 1000 for the each azimuth angle. It took three and half minutes to obtain one PPI scan.

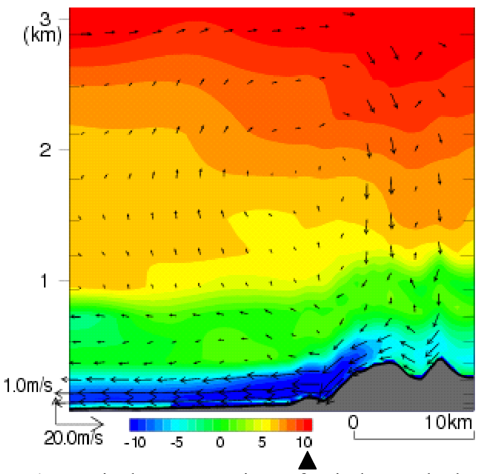

Fig. 4. Vertical cross-section of wind speed along the Mogami valley by the NHM at 9:00 JST on August 30, 2004. Closed triangle shows the CDL observation point. Wind speed and wind direction are shown by the vectors on the cross-section. Color shade shows the wind component U.

the horizontal cross-section of wind speed simulated by the NHM were. Although small area acceleration (e.g. ellipses in Fig. 3) was less pronounced in the numerical simulation of 1km resolution , the NHM reproduces the wind field fluctuations. The calculated wind speed distribution shows that wind speed was accelerated from south gradually. The results suggested that, although the physical mechanism is not clear, there are some different wind field patterns in the Kiyokawa-dashi (e.g. stable or unstable).

5. SUMMARY

We performed ground-based measurements to examine the three dimensional structure and dynamics of Kiyokawa-dashi using a two-axis scanning coherent Doppler lidar during the summer of 2004. The detailed horizontal and vertical cross-sections of Kiyokawa-dashi were obtained by the coherent Doppler lidar measurements. The wind speed distributions were simulated by the numerical prediction division unified nonhydrostatic model. The results obtained by the numerical simulations were compared with those obtained from the coherent Doppler lidar measurements. The coherent Doppler lidar captured temporal variations of Kiyokawa-dashi and the structure of the critical layer. Although the altitude of the critical layer observed by the coherent Doppler lidar was 600 m MSL, that of the critical layer obtained by the numerical simulations were approximately 300 m MLS. Although the result indicated that the calculated wind speed had a bias, the calculated wind speed distributions were consistent approximately with that measured by the coherent Doppler lidar. Further continuous measurements of this research are required not only to improve numerical simulations, but also to discuss the three-dimensional structures and physical mechanisms of the Kiyokawa -dashi.

6. REFERENCES

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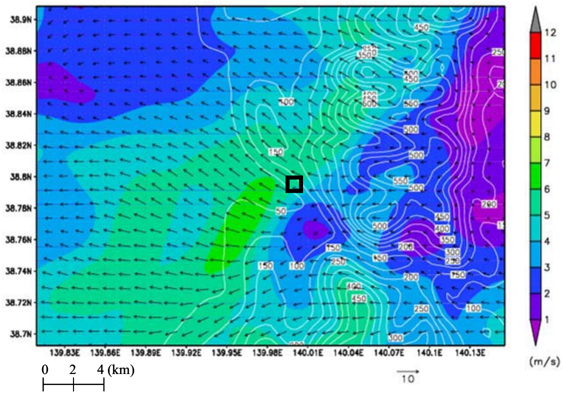

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