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The Measurement of cloud velocity using the pulsed laser and image tracking technique

Seong-Ouk Kwon [a*], Seung-Hoon Baik [a], Seung-Kyu Park [a], Nak-Gyu Park [a], Dong-lyul Kim[a], Yong-Jin Ahn [a]
[a]*Korea Atomic Energy Research Institute, 150 Dukjin-Dong, Yuseong, Daejeon 305-353, Rep. of Korea*
[*]*Corresponding author: sokwon@kaeri.re.kr*

1. Introduction

The height of a cloud is an important parameter because it is an indicator of the cloud type [1.3]. High clouds are formed from ice crystals whereas low clouds are formed from water drops. Such different clouds types have, in turn, a very different influence on the radiation field and consequently on the climate. The height of the clouds is also important for the three-dimensional radiative interaction of aerosols and clouds, since the radiative effects vary strongly depending whether the cloud is above, below or even embedded in an aerosol layer [4]. Clouds play an important role in climate change, in the prediction of local weather, and also in aviation safety when instrument assisted flying is unavailable. Presently, various ground-based instruments used for the measurements of the cloud base height or velocity. Lidar techniques are powerful and have many applications in climate studies, including the clouds' temperature measurement, the aerosol particle properties, etc. Otherwise, it is very circumscribed in cloud velocity measurements In this paper, we propose a new method to measure the cloud velocity. The cloud base height was measured using lidar's range detection method, and the cloud velocity was measured using the application of the tracking technique for the lidar's range detection.

2. Experimental setup

We used lidar signals to measure the distance of L. As shown in Fig. 1, lidar signals show the laser light traveling time from the light source to the cloud. We can acquire the length of L easily by multiplying the traveling time with the light speed. In addition, the height of the cloud can be acquired by using the distance of L and a laser illuminating angle of θ. If the distance is acquired once, we can calculate the actual area of the telescope's field of view at the position of the cloud. Then the ratio (R=Csize/LCCD) of the imaged cloud pixel size (LCCD) of CCD to the actual size (Csize) of the cloud within the field of view is acquired. Thus, the moving distance of the cloud image in the monitor is converted into the actual moving distance per unit time by the application of this ratio. We intended to configure the cloud monitoring system as mentioned above, and the following are the configurations of the optical and tracking systems.

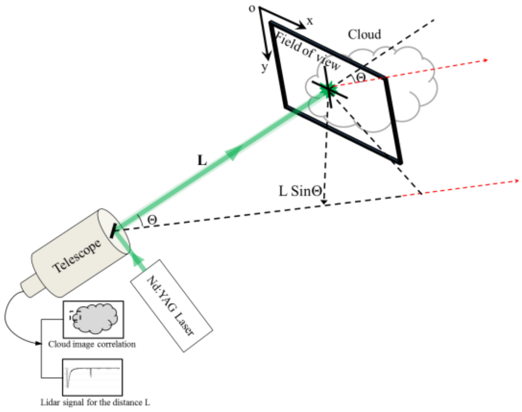

Fig. 1. Schematic diagram of the tracking system configuration.

3. Experimental results

We used a telescope to acquire the lidar signal and cloud image and found the target cloud by adjusting the 2-axis scanner. The cloud image acquired with the lidar signal was shown in the monitor screen of the tracking system. A target cloud image is shown in Fig. 2. The pulse laser illuminated the center of the field of view area of the telescope, and the acquired lidar signal is shown in Fig. 3. If the tracking cloud images have similar pixel values in the entire area, the tracking algorithm acquires almost the same correlation coefficient at many points in the next image and the tracking system can't track the images. Therefore, we made our system observe the boundary area of a cloud to adjust 2-axis scanner and set-up the tracking image area in the boundary area. The scattered laser beam on the target cloud is acquired. The movements in the cloud images are tracked through pixel coordinate values of the CCD camera. Therefore, to determine the actual movement distance of the clouds, the pixel unit size is converted into the actual distance value. Equation (1) shows the method for determining the distance per pixel to convert the pixel unit value to the actual distance of the movement.

$$f_t : l_c = L : l_x \qquad (1)$$
$$l_x = (l_c \times L)/f_t$$

As shown in Fig. 4, the cloud displacements of the pixel unit acquired by track are converted into the actual displacements when applying equations (1), and the velocities of the cloud can be acquired to divide the cloud displacements by the unit time (0.1 second) for the moving directions of x and y, respectively. Finally, the cloud velocities were acquired to sum vectors of the x-axis velocities and y-axis velocities, as shown in Equation (2)

$$\mathrm{v} = \sqrt{v_x^2 + v_y^2} \quad (2)$$

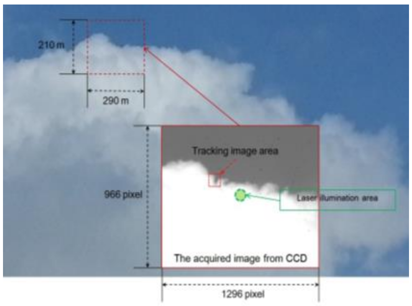

Fig. 2. Photograph of a target cloud.

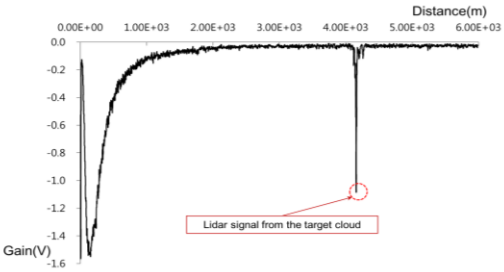

Fig. 3. Lidar signal from the target cloud.

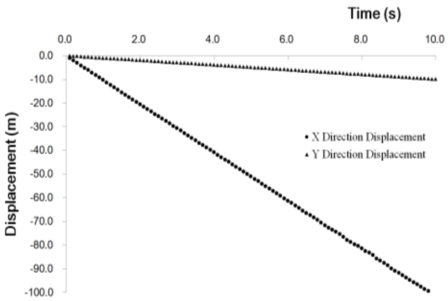

Fig. 4. Actual cloud displacements.

4. Conclusion

In this paper, we presented a method for the measurement of the cloud altitude and velocity using lidar's range detection and the tracking system. For the lidar system, we used an injection-seeded pulsed Nd:YAG laser as the transmitter to measure the distance to the target clouds. We used the DIC system to track the cloud image and calculate the actual displacement per unit time. The configured lidar system acquired the lidar signal of clouds at a distance of about 4 km. The developed fast correlation algorithm of the tracking, which is used to track the fast moving cloud relatively, was efficient for measuring the cloud velocity in real time. The measurement values had a linear distribution. If the experimental condition is the same (CCD, distance to cloud, telescope), our system can measure the velocity with a resolution of about 0.1 m/s because our tracking system discriminates one-tenth of the pixel size. If a CCD with a greater number of pixels is applied to the system, the velocity resolution will be more precise. The velocities begin with a value of 10.5 m/s and decrease slowly. The measurement values are distributed linearly.

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