Interaction between Cloud Particles and Winds observed with W-band Cloud Profiling Doppler Radar FALCON-I and Wind Profiler

*Toshiaki TAKANO[1], Ryo FUEDA[1], Hyuga MORITA[1], Keisuke HIKAWA[1], Tomohiro ARAI[1], Yohei KAWAMURA[1], Hiroyo OHYA[1], Hiroyuki NAKATA[1], Masayuki YAMAMOTO[2], Seiji KAWAMURA[2]

1. Chiba University, 2. National Institute of Information and Communications Tecnology

Observation of clouds with radars in millimeter wave range is one of the most useful remote sensing methods to derive information on interior of clouds. We have developed and operated cloud profiling FMCW (Frequency Modulated Continuous Wave) Doppler radar named FALCON-I (FALCON= FMCW Radar for Cloud Observations) in W-band at 95GHz. FALCON-I is a bistatic antenna system, which is usually used for FMCW radar, and consists of two 1m-diameter antennas. FALCON-I observes around zenith with high spatial resolution of 0.18 degree FWHM, which corresponds to 3m diameter area at 1km height. A High range resolution of 49m can be realized with the FMCW type radar, which is about several times higher than those of normal pulse type radars. FALCON-I has enough sensitivities for faint clouds and fine rain, and has quite high velocity resolution in Doppler measurements.
In order to investigate interaction between cloud particles and winds, we made simultaneous observations with the cloud profiling radar FALCON-I and a wind profiler in March 2018. A wind profiler WPR LQ-13 of National Institute of Information and Communication Technology (NICT), Japan was used for simultaneous observations. WPR LQ-13 is a phased array radar at 1.36 GHz and has a ranging resolution of about 60 m, which is comparable to that of FALCON-I. Beam size of LQ-13, however, is 3.17 degree, which is 18 times larger than that of FALCON-I.

On March 20, 2018, we observed clouds simultaneously at zenith with both FALCON-I and WPR LQ-13 at the height of 0.5 to 1.5 km. Fig.1 shows Doppler spectral map obtained with FACON-I at 11:04:40 UT (=20:04:40 JST). The cloud bottom locates at about 0.7 km and the cloud top is at 1.5 km in height. Doppler velocities at the cloud bottom spread from -0.2 to -1.58 m/s and velocity widths of the cloud are getting narrower from the cloud bottom to the cloud top. Negative Doppler velocities mean downward motions. We calculate weight center of each Doppler spectrum of FALCON-I and plot on the map with blue dots shown as “V-cloud” in Fig.1 WPR LQ-13 produces similar Doppler spectral maps of wind to those with FALCON-I and can detect winds not only at the height of the cloud but also at under the cloud bottom and over the cloud top. We calculate weight center of Doppler spectra of WPR and plot in Fig.1. with black dots shown as “V-wind”. We can recognize in Fig.1 that at and around the cloud bottom, upward wind exists at 11:04:40 UT, whose V-wind is up to +0.5 m/s, whereas V-cloud reaches up to -1.0 m/s. We calculate differences of both velocities as “V-diff” = “V-cloud” - “V-wind”, i.e. in that case V-diff is -1.5 m/s. When we divide the cloud into two parts as the lower part which is from 0.5 to 0.9 km in height and the upper part which is above 0.9 km, V-diff’s in the upper part of the cloud is about -0.5 m/s except for at the cloud top. If we assume that V-diff’s would be terminal velocities of cloud particles against to the wind, the diameters of particles would be about 0.15 mm for -0.5 m/s in the upper part of the cloud and be about 0.34 mm for -1.5 m/s in the lower part of the cloud. These results suggest that larger cloud particles whose sizes reach up to 0.34 mm exist at around the cloud bottom of this cloud.

Fig.1. Doppler spectral map obtained with the W-band cloud profiling Doppler radar FALCON-I at 11:04:40 UT on 2018 March 20. We calculate weight center of Doppler spectrum of FALCON-I and plot on the map with blue dots shown as “V-cloud”. We also calculate weight center of Doppler spectra of WPR and plot with black dots. We can see the velocity difference V-diff = V-cloud –V-wind reaches to -1.5

m/s at around cloud bottom. If we assume this velocity is to be a terminal velocity of cloud particle, the size would be about 0.34 mm in diameter.

Keywords: Cloud Profiling Radar, W-band Radar, Wind Profiler, FMCW Radar, Cloud Particles, Size Distribution of Cloudlets