Vertical structures of storm:
Clues of microphysical processes and density of snow

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The vertical structures of radar reflectivity and radial velocity are a key component to understand the microphysical processes. A classical identification of stratiform and convective rain using the existence of radar bright band is a prominent example. Radar reflectivity provides a general idea on change of mass due to various microphysical processes and existence of melting process. In addition to radar reflectivity, radial velocity information at vertical incidence makes possible to calculate mass flux and a clue of density of snow. For example, snow aggregates have a typical velocity less than 1~2 m/s while rimed snow particles in particular graupel can have velocity larger than a few m/s. The effective density of snow aggregate is typically lower than that of rimed particles. This density difference provides very interesting characteristics of vertical structures of radar reflectivity, radial velocity, and Doppler spectrum.

In the equation of motion, the density or mass of snow is an important factor in change of fall velocity. Particles of high effective density can have fall velocity larger than that of low density. Thus, heavily rimed particles should have fall velocity larger than 1~2 m/s. When the melting process exists, this difference in density also appears in the characteristics of radar bright band. Strong aggregation leads to rapid increase of radar reflectivity while it melts. On the other hand, a rapid increase of radar reflectivity is not expected in bright band for heavy riming. In this paper, we will show the connection among intensity of bright band, microphysical processes, density of snow, and vertical structures of snow.

The use of vertical pointing radar for the study of microphysics has a long history. Recently, the vertical pointing radar can provide Doppler radial velocity and power spectrum in addition to radar reflectivity. These abundant information opens a possibility for more thorough studies of microphysical processes.

McGill University, Canada has been operating a vertically pointing x-band Doppler radar with disdrometers for several years in the Montreal area. This technology was transferred to Kyungpook National University, Korea (ROK). This radar is widely used for microphysical analyses during the summer and winter. We will show some interesting microphysical processes and vertical structures of storm. In addition, the variability of drop size distribution (DSDs) is tackled in terms of microphysics. The variability of DSDs is explained by the quasi-stochastic drop growth equation.

The density of snow is critical information to understand microphysical processes and to improve the accuracy of radar quantitative precipitation estimation (QPE) since it affects radar reflectivity and snowfall rate. A few methods were applied to derive the (effective) density of snow particle as a function of particle diameter. A precise measurement of snow size distribution and fall velocity is essential to solve radar QPE in snow. An extensive observation of snow was performed during the winter of 2005/06 and 2006/07 as a part of Canadian CloudSat/CALIPSO Validation Project. We show microphysical analysis from the various ground-based instrumentations: Hydrometeor Velocity and Size Detector (HVSD), Vertically pointing X-band radar (VertiX), Precipitation Occurrence Sensor System (POSS), C-band dual-polarization, etc.

The effective density of individual snow particle is derived from the equation of motion using the shape and terminal fall velocity of snow particle. The shape and velocity are obtained by HVSD for each particle. This method is verified by comparing the calculated radar reflectivity from HVSD and measured radar reflectivity from VertiX. Results show the significant variation of effective density- diameter relationship from storm to storm and within a storm. Microphysical processes are one of factors that control this variation which is linked with vertical structure of radar reflectivity and Doppler velocity measured by VertiX. In addition, we show systematic difference in the snow size distributions and their variation as functions of microphysical processes such as riming and aggregation. This variation is also consistent with conceptual models derived from quasi-stochastic drop growth equation.

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