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Classification of rain types using drop size distributions and polarimetric radar: Case study of a 2014 flooding event in Korea

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ABSTRACT

To classify precipitation types as either convective or stratiform, drop size distributions (DSDs) measured by the Parsivel (PARticle size VELocity) instrument, and DSD parameters including median volume diameter (D_0) and normalized number concentration (Nw) retrieved by S-band polarimetric radar (BSL), were analyzed for a heavy rainfall event that occurred in southern Korea on 25 August 2014. The rainfall system was clearly identified as stratiform or convective rain at various times of day, at measurement sites at Changwon and Busan. New rainfall classification lines were derived from the Parsivel and BSL data, and were compared with existing classification methods based on climatological rainfall data.

The classification methods using logNw-D_0, logN_0-rainrate, and slope-rainrate domain proposed in previous two studies performed well when applied to the new data if the slope and/or intercept values were changed. Another method using logN_0-slope domain was not possible to classify the precipitation types well in the study area, as the best-fit line could not be obtained. The average measured D_0 and Nw values obtained from polarimetric radar were compared with climatological precipitation data, measured in both the tropics and mid-latitudes. And new separation line was obtained for the rainfall at the southern part of Korea.

1. Introduction

Precipitation can be classified as either convective or stratiform, according to the vertical velocity and the temporal and spatial scales of the cloud system. Updraft velocities in stratiform (convective) clouds are weaker (stronger) than the fall velocities of snow and ice crystals (Houze, 1993). Thus, the microphysical processes controlling cloud droplet growth operate very differently in convective and stratiform clouds. In regions of convective precipitation, cloud droplets grow primarily through the collection of water by coalescence and/or riming, whereas in stratiform systems droplets grow by vapor diffusion (Houze, 1997).

Numerous studies have addressed the differences between the two types of precipitation. Simple threshold methods have been applied to rain gauge data (Austin and Houze, 1972; Balsley et al., 1988; Johnson and Hamilton, 1988) to distinguish between the two types. Bringi et al. (2003) used the temporal variability in rainfall rate, measured by a disdrometer, to classify convective and stratiform rainfall. This method has been employed in subsequent studies (Marzano et al., 2010; Leinonen et al., 2012; Tang et al., 2014; Suh et al., 2016). Marzano et al. (2010) and Tang et al. (2014) (hereafter TA14) classified rainfall as stratiform if the instantaneous rate was 0.1–5 mm h^{-1} for 10 consecutive samples and had a temporal standard deviation of less than 1.5 mm h^{-1}; otherwise, the rainfall was classified as convective. TA14 also found strong regional variability, among three regions within China, in precipitation measured by drop size distributions (DSDs). Tokay and Short (1996) (hereafter TS96) proposed an empirical discrimination method based on the intercept parameter (N_0), rainfall rate (R), and slope parameter (Λ), for disdrometer observations from the Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Research Experiment. Caracciolo et al. (2006) reported improved classification of the two rainfall types, relative to the TS96 method, using the relationship between Λ and the shape parameter (μ), applied to DSD data from mid-latitude regions. They also explored the use of N_0 and Λ for classification purposes, using Pludix disdrometer data from Italy (Caracciolo et al., 2008, hereafter CA08).

Steiner et al. (1995) presented a modified version of the Steiner and Houze (1993) classification technique, using horizontal radar reflectivity data. Bringi et al. (2009) (hereafter BR09) proposed a classification boundary derived from median raindrop diameter (D_0) and log-normalized droplet number concentration (logNw), measured from a C-band polarimetric radar and a dual frequency profiler at Darwin, Australia. Penide et al. (2013a) analyzed DSD parameters and rainfall

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Table 1
The specifications of the wind profiler.

Frequency	1290 MHz
Wavelength	23 Cm
Transmitter power	3.5 kW
One-way beam width	9°
One vertical beam (elevation angle)	90°
Four oblique beam (off-zenith angle)	17°
Antenna type	Five panel dipole array
Beam operating type	DBS (Doppler Beam Swinging)

rates for both precipitation types during the wet season in northern Australia, using the BR09 method. Penide et al. (2013b) compared the ST96 and BR09 methods, and proposed three modified equations using the peakedness criterion to reduce the rate of misclassification using DSDs retrieved by a C-band polarimetric radar. More recently, Thompson et al. (2015) suggested that the logNw-D$_0$ method is superior to the BR09 method for precipitation over the equatorial Indian and West Pacific Oceans.

In the last two decades, a unified Khrgian-Mazin size distribution proposed by Puppacher and Klett (1978) for the entire liquid water was applied in numerical modeling. There is observational evidence that a strom splitting, hail field characteristics and cumulative total precipitations are simulated more accurately by the KM distribution function. KM size distribution produces more small raindrops and less large ones compared to the Marshall-Palmer one, where both have the same rain water mixing ratio using 1-D time-dependent model (Ćurić et al., 1998) and three-dimensional mesoscale model (Ćurić et al., 2009). The number of newly created drops is a few orders less than unfrozen water drops, but can still be very important for further transformations due to gravitational coagulation and other microphysical processes (Vuković and Ćurić, 1998; Vuković and Ćurić, 2005). Ćurić et al. (2010) showed that the cloud-resolving model with KM size distribution exhibits a better agreement with the observed mean, median and range of extreme values of accumulated convective precipitation than that with Marshall-Palmer size distribution. Ćurić and Janc (2011a) found that the model simulations with KM size distribution most closely match observations for the flat land area with a correlation coefficient of 0.94, while it is somewhat lower (0.89) for the mountainous area using the comparison between the 15-yr period convective precipitation observation and cloud-resolving model. Ćurić and Janc (2011b) showed that the cloud-resolving model reproduces well the accumulated convective precipitation obtained from the rain gauge network data in the area with frequent split storms using twenty-seven convective events.

There have been relatively few studies of the classification of rainfall types using DSD parameters in Korea. You et al. (2005) analyzed variations in R and reflectivity (Z_H), measured by a disdrometer in Busan, and classified precipitation using the TS96 method without modification. In addition, You and Lee (2015) studied decadal variability in rainfall DSD over Korea. To our knowledge, however, no previous study has considered rainfall classification using Korean climatological data and retrieved DSD measurements. A classification of convective and stratiform rainfall in Korea using DSDs, including those retrieved from polarimetric radar, is therefore required.

This study compares existing classification methods and proposes a new method for Korean climatological precipitation. The remainder of this paper is organized as follows. In Section 2, the data and methodology are introduced. Specific rainfall events and associated DSD characteristics are presented in Section 3, and rainfall is classified using measurements from disdrometers and polarimetric radar. Finally, a summary of results and conclusions are presented in Section 4.

2. Data and methodology

2.1. Data set

The rainfall data from rain gages operated and quality controlled by the KMA (Korea Meteorological Administration) were used to evaluate the accuracy of radar rainfall. Two rain gages (ID 942 and ID 155) located within the radar coverage area were selected in the analysis to know the hourly rainfall distribution.

The DSD data were observed from the Parsivel (PARticle size VELocity) disdrometer The Parsivel disdrometer is a laser-optic system that measures 32 channels from 0.062 mm to 24.5 mm (detailed specifications are described by Loffler-Mang and Joss, 2000). Before calculation of DSD parameters, the data quality control algorithm for Parsivel disdrometer was applied using the method proposed by Friedrich et al. (2013). In addition to this, unreliable data defined as belonging to the following categories, were removed: 1-min rainfall rate less

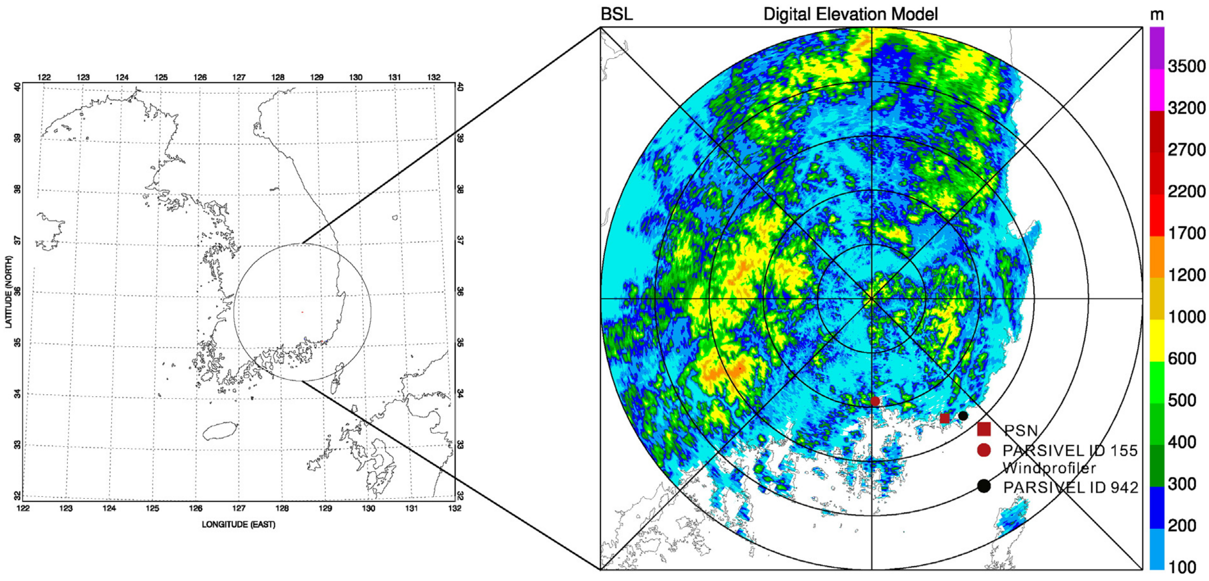

Fig. 1. The location of PSN (red square), the Parsivel disdrometer and wind profiler at Changwon (ID 155, red circle), and the Parsivel disdrometer at Busan (ID 942, black circle), on a map of surface elevation (shading, m). The BSL radar is located at the center of the right panel, and concentric circles are drawn around it with radii at 30 km intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)