Atmospheric Research 169 (2016) 416–423

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Separating stratiform and convective rain types based on the drop size distribution characteristics using 2D video disdrometer data

M. Thurai [a,*], P.N. Gatlin [b], V.N. Bringi [a]

[a] Colorado State University, Fort Collins, CO, USA
[b] NASA/MSFC, Huntsville, AL, USA

ARTICLE INFO

Article history:
Received 19 January 2015
Received in revised form 8 April 2015
Accepted 11 April 2015
Available online 19 April 2015

Keywords:
Stratiform and convective rain
2D video disdrometer data
Vertically pointing Doppler radar
UHF profiler
GPM ground validation campaign

ABSTRACT

A technique for separating stratiform and convective rain types using the characteristics of two of the main drop size distribution (DSD) parameters is presented. The method was originally developed based on observations from dual-frequency profiler and dual-polarization radar observations in Darwin, Australia. In this paper, we will present the testing of the method using data from 2D video disdrometers (2DVD) from two very different locations, namely, Ontario, Canada, and Huntsville, Alabama, USA. One-minute DSDs from 2DVD are used as input to a gamma-fitting procedure and our separation technique uses the fitted values of $\log_{10}(N_W)$ and D_0 (where N_W is the scaling parameter and D_0 is the median volume diameter) and an "index" to quantify where the points lie in the $\log_{10}(N_W)$ versus D_0 domain.

For the Ontario location, the output of the classification is compared with simultaneous observations from a collocated, vertically pointing, X-band Doppler radar. A "bright-band" detection algorithm is used to classify each height profile as either stratiform or convective, depending on whether or not a clearly defined melting layer is present at an expected height. If present, the maximum reflectivity within the melting layer and the corresponding height are determined. Similar testing is carried out for two events in Huntsville and compared with observations from a collocated UHF profiler (with Doppler capability). Additional case studies are required, but these results indicate our separation technique seems to be applicable to many different locations and climatologies based on previously published data.

1. Introduction

It is well known that stratiform and convective rain are associated with different microphysical processes leading to different latent heating profiles, which can have a significant impact on the evolution of precipitation (e.g., Houze, 1993). Thus, there has been much interest across the remote sensing, modeling, and hydrologic communities to characterize precipitation as either convective or stratiform, but a variety of definitions/techniques have been employed. Houze (1993) gives a formal definition—stratiform precipitation is characterized by vertical air motion less than the terminal fall velocity of ice, all else is convective in nature. According to standard definitions (Glossary of Meteorology, American Meteorological Society), convective precipitation particles are formed in the active updraft of a cumulonimbus cloud, growing primarily by the collection of cloud droplets (i.e., by coalescence and/or riming) and fall out not far from their originating updraft, whereas a region of stratiform precipitation is associated generally with weak vertical air motions and in especially well-developed stratiform precipitation, precipitating ice particles fall and grow by vapor deposition and further aggregate

* Corresponding author at: Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, CO 80523-1373, USA.
E-mail address: merhala@engr.colostate.edu (M. Thurai).

http://dx.doi.org/10.1016/j.atmosres.2015.04.011
0169-8095/

to form relatively large snowflakes which then melt and produce a bright band on radar. As a result of the differences in the vertical distribution of hydrometeors, the 3D structure of reflectivity is also generally different for these distinct rain types, which gave rise to radar-based techniques (e.g., Steiner et al., 1995). Many studies in the past have also examined differences in rain drop size distributions between stratiform and convective rain using ground-based disdrometers (e.g., Tokay and Short, 1996; Bringi et al., 2003) or airborne particle imaging probes (e.g., Testud et al., 2001; Atlas et al., 2000; Ulbrich and Atlas, 2002; Yuter and Houze, 1997). In fact, Yuter and Houze (1997) assert that the separation of convective–stratiform rain cannot be made in terms of the drop size distribution characteristics such as mean volume diameter. On the other hand, Bukovčić et al. (2015) have utilized 2DVD DSD data to separate stratiform and convective rain by applying a multi-variable Bayesian classification algorithm, whereas Caracciolo et al. (2006) have examined DSD characteristics for stratiform and convective rain using data from a Joss–Waldvogel disdrometer. Differences in cloud top height have also been exploited to identify regions of convection and stratiform precipitation using satellite-passive microwave measurements (e.g., Adler and Negri, 1988).

The use of profilers is important in that the vertical structures of both reflectivity and Doppler spectra are available, which permits generally unambiguous classification (Williams et al., 1995; Tokay et al., 1999). Previous work by Bringi et al. (2009) used dual-frequency profiler data and dual-polarization radar (C-Pol) data in Darwin for rain drop size distribution (DSD) retrievals and found that stratiform and convective rain could be separated in the N_W versus D_0 domain, where N_W is the intercept parameter and D_0 is the median volume diameter. Later, Thurai et al (2010) confirmed that both the dual-frequency profiler data-based separation of stratiform and convective rain and the C-Pol-based separation were consistent with each other. Thus, the applicability of such separation using disdrometer measurements to obtain the DSD parameters requires investigation. However, differences in spatial resolution (i.e., sampling volumes) can complicate comparison with the dual-polarimetric separation technique.

In this paper, we examine the use of 2D video disdrometer (2DVD; Schönhuber et al., 2008) data for such classification, noting that the 2DVD data represent point measurements at ground level whereas radar and profiler data represent “volume” measurements aloft. DSD measurements from the 2DVDs are utilized to derive the above-mentioned parameters, N_W and D_0, which are two of the main parameters characterizing the normalized gamma DSDs (Illingworth and Blackman, 2002; Bringi et al., 2003). Results from our separation method are then compared with observations from collocated profilers—with Doppler capability—for validation purposes. Data and observations from two climatically different locations are considered.

Analysis of a widespread cold-season rain event in Ontario, Canada, is given in Section 2, and analyses of two summer events with widely varying rainfall rates in Huntsville, Alabama, are given in Section 3. We also consider previously published data from other locations in Section 4 and summarize our findings in Section 4.

2. The Ontario event

The Ontario event was a widespread, largely stratiform cold rain event, which occurred on January 17, 2012, the first day of the official start of GCPEx, the GPM Cold-season Precipitation Experiment (Hudak et al., 2012). The event was captured by several ground instruments and polarimetric radars. Among the ground instruments were five 2D video disdrometers at various locations near and at the CARE site (Centre for Atmospheric Research Experiments) belonging to Environment Canada. The 2D video disdrometer at the CARE site was installed inside a double wind fence and collocated with it was a vertically pointing X-band Doppler radar, VertiX, (Lee et al., 2009) belonging to McGill university.

Fig. 1 top panel shows reflectivity versus height as time series from VertiX for a 5-h time period. The bright band is clearly visible around 1.5 km above ground level throughout this time period, but with varying thickness and intensity. The echo top heights also vary, with some rain below bright band at the beginning of the event, followed by echo top heights ranging from 4 km to 6 km for a 2-h period, followed by

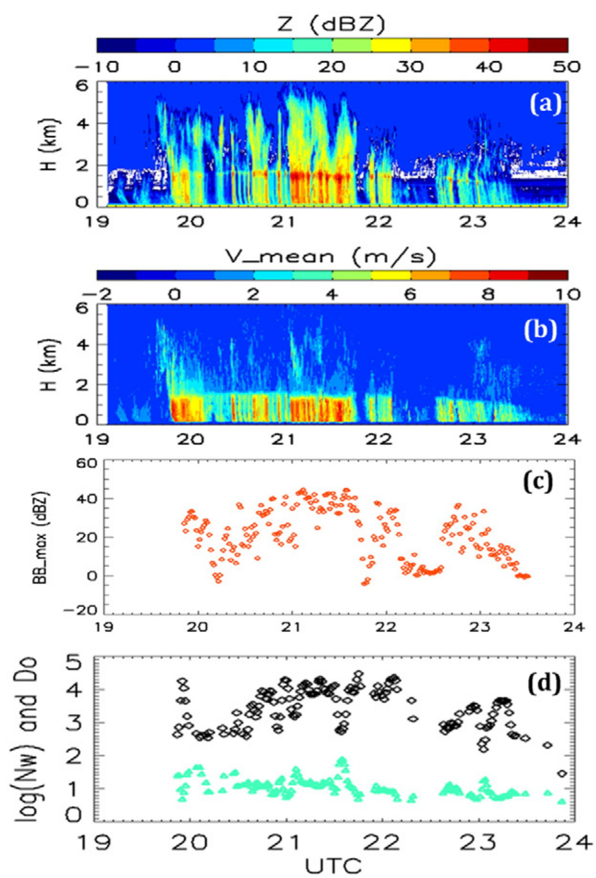

Fig. 1. (a) Reflectivity versus height as time series from the X-band Doppler profiler, VertiX, in Ontario (for the January 17 cold rain event). (b) the corresponding Doppler mean velocity. (c) the maximum bright-band intensity (if detected) using an automated bright-band detection algorithm. (d) $\log_{10}(N_W)$ (black) and D_0 (green) values from the collocated 2DVD 1-min DSD measurements at ground level. Units of N_W and D_0 are $mm^{-1}\ m^{-3}$ and mm, respectively.