Atmospheric Research 112 (2012) 1–11

Contents lists available at SciVerse ScienceDirect

Atmospheric Research

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

Estimation of raindrop size distribution parameters by maximum likelihood and L-moment methods: Effect of discretization

Marzuki [a,c,e,*], Walter L. Randeu [a], Toshiaki Kozu [b], Toyoshi Shimomai [b], Michael Schönhuber [d], Hiroyuki Hashiguchi [c]

[a] Institute of Broadband Communication, Graz University of Technology, Austria
[b] Interdisciplinary Faculty of Science and Engineering, Shimane University, Japan
[c] Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Japan
[d] Joanneum Research Graz, Austria
[e] Department of Physics, Andalas University, Padang, Indonesia

A R T I C L E I N F O

Article history:
Received 24 October 2011
Received in revised form 15 March 2012
Accepted 10 April 2012

Keywords:
Raindrop size distribution
Distrometer
Bin size
Discretization

A B S T R A C T

Disdrometer has been widely used to estimate raindrop size distribution (DSD) for broad list of application. However, it classifies or bins drops automatically into size groups and provides the DSD at nominal drop diameters that correspond to the mean of bin width. Selection of the bin width may influence shape and parameterization of DSD since the exact size of individual drop in each bin, of course, is not the same as the mean of its bin size. Therefore, we present a comprehensive follow-up of a previous studyon the effect of bin width selection of 2D-Video Distrometer data. We applied the L-moment method, along with the moment and maximum likelihood methods, to samples taken from simulated and measured gamma raindrop populations. It is found that L-moment is less sensitive to bin width selection than maximum likelihood and moment methods. The bias due to bin width selection for L-moment and maximum likelihood methods is not much influenced by the mean sample size in comparison with that of moment method . With samples from the DSD having large number of raindrop or a larger shape parameter μ, the bias due to bin width selection can be small or negligible. Using the midsize of bin as the representative value for the class (bin) of binned data (ΔD) was acceptable because it gives the parameters closer to drop-by-drop data basis than using mean, mode and median of raindrop size.

1. Introduction

Raindrop size distribution (DSD) is a key attribute to connect rainfall rate with cloud processes and remote sensing observations. Studies of DSD have motivated some engineers and meteorologists to develop instruments to observe the raindrop (e.g., Joss and Waldvogel, 1969; Löffler-Mang and Joss, 2000; Schönhuber et al., 2008). There are many different types of instruments available today and disdrometer seems to be the most widely used one. Rainfall properties estimated from disdrometer show great variability. There are three factors that can explain such variability: (1) climatological factors, (2) physical factors and (3) instrumental factors (Uijlenhoet et al., 2006). The latter includes any instrument malfunctioning, instrument limitations (resolution and sensitivity), and undersampling effect (e.g., Joss and Waldvogel, 1969; Uijlenhoet et al., 2006). In addition, disdrometers provide data at nominal drop diameters that correspond to the mean of bin sizes (or discretization interval) in order to reduce the amount of the data. Discretization procedure and model bias can generate error when estimating the DSD and integral rainfall parameters from disdrometer data (e.g., Kliche et al., 2008; Marzuki et al., 2010a). If we choose a too large bin size, binned data would not represent the shape of the underlying distribution (Shimazaki and Shinomoto, 2007). In this paper, we investigated the magnitude of variability caused by the

* Corresponding author at: Department of Physics, Andalas University, Padang, Indonesia.
E-mail address: marzuki@fmipa.unand.ac.id (Marzuki).

0169-8095/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.atmosres.2012.04.003

bin size selection. The analysis was restricted to the special (limiting) case of uniform bin size as applied in the 2D-Video Disdrometer (2DVD).

The 2DVD is a precipitation gauge, working on the basis of video cameras. It is a new instrument, capable of measuring not only size and fall velocity but also shape of hydrometeors (Schönhuber et al., 2008). The DSD for a size category i is computed by the formula

$$N_i = \frac{1}{\Delta t \Delta D} \cdot \sum_{j=1}^{m_i} \frac{1}{A_j v_j}, \tag{1}$$

where m_i is the number of drops within size class i, Δt is the integration time, ΔD is the width of the size class, A_j is the disdrometer effective measurement area during the collection of drop j and v_j is the fall speed of drop j. The user can adjust ΔD in the software which is provided by the manufacturer, based on their preferences, for example Marzuki et al. (2010b) used ΔD = 0.1 mm and Marzuki et al. (in press) used 0.2 mm. Some instruments such as Joss-Waldvogel disdrometer (JWD, Joss and Waldvogel, 1969) and Parsivel (Löffler-Mang and Joss, 2000) employ nonuniform bin size in which the bin sizes increase as raindrop sizes increase. Furthermore, they can not measure terminal velocity and calculation procedure assumes terminal velocity as a function of drop diameter. Hence, further errors may introduce due to wrong bin width selection. However, the possible error due to bin width selection for other instruments is beyond the scope of this article.

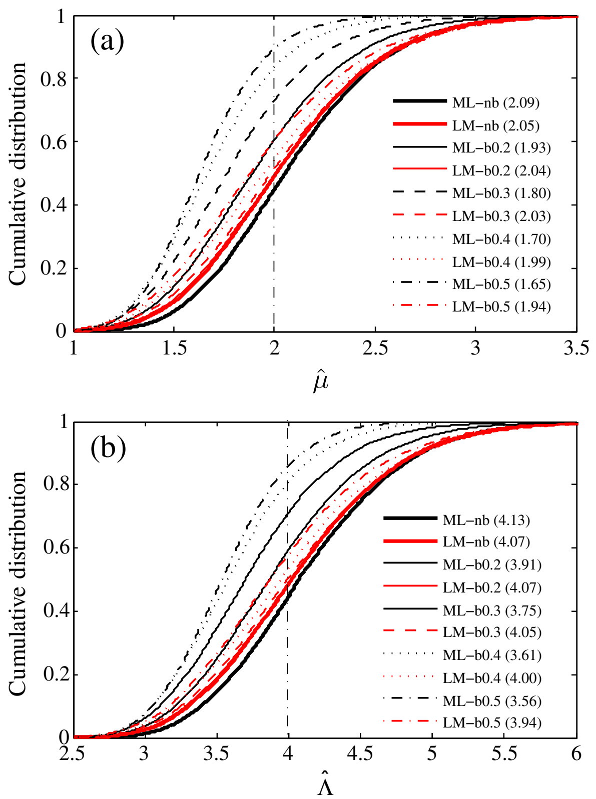

Fig. 1. Cumulative distribution of estimated gamma shape ($\hat{\mu}$) and scale parameter ($\hat{\Lambda}$) using ML and LM methods for different values of bin width indicated in the legend. Letter "nb" denotes drop-by-drop data (without binning), b0.2, b0.3, b0.4 and b0.5 indicate the data are binned at 0.2, 0.3, 0.4 and 0.5 mm, respectively. Vertical dashed line indicates the population value. Population DSD: gamma, μ = 2, Λ = 4, N_T = 100. Total sample for each initial parameter is 10^4. Values in parentheses correspond to the mean estimated parameter.

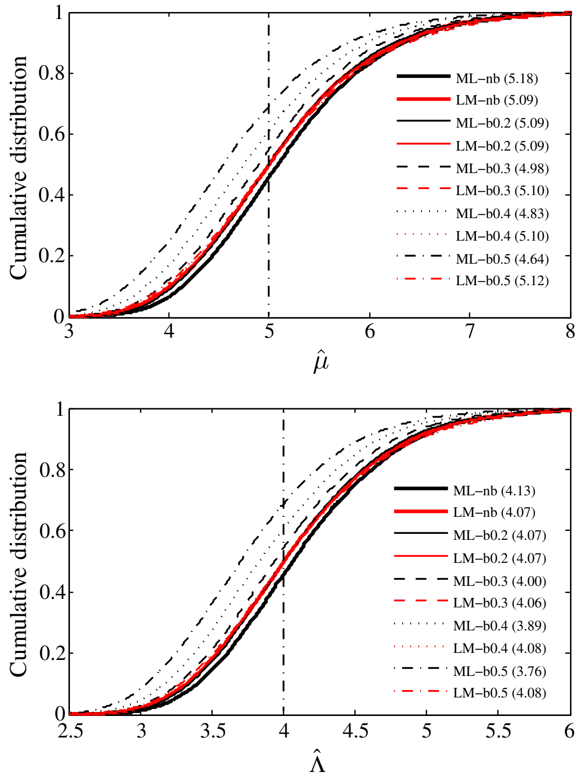

Fig. 2. Same as Fig. 1, but population DSD: gamma, μ = 5, Λ = 4, N_T = 100.

Fraile et al. (2009) elucidated the possible effect of discretization for the exponential distribution of hailstone by means of moment method (MM). Recently, such effect for the modified gamma distribution of DSD was studied by Marzuki et al. (2010a). Moment estimator is inherently biased in which it tends to give erroneous DSD parameters when the total number concentration of drops are small (Smith and Kliche, 2005). In general, Marzuki et al. (2010a) found that mean DSD parameters increased with increasing bin width and for very large number of raindrop which is normally accompanied by heavy rain, the bias due to bin width selection was relatively small. It seems the variability of DSD parameters due to bin size selection through MM is in tune with that of the MM error. Therefore, the variability of DSD parameters in Fraile et al. (2009) and Marzuki et al. (2010a) are probably influenced by the bias due to the moment error. Although it is in principle difficult to distinguish accurately between both types of bias, a better knowledge of the magnitude of the variability associated with bin width selection, that is of the fluctuations in DSD parameters in the absence of method bias, would certainly provide a step in the right direction. Current study is a follow up of Marzuki et al. (2010a), by applying the L-moment (LM) estimators (Hosking, 1990) and maximum likelihood (ML)