Estimation of Raindrop Size Distribution Parameter with TRMM Precipitation Radar

#Toshiaki Kozu[1], Toshio Iguchi[2], Yukari Takayabu[3], Hiroshi Hnado[4], and Naofumi Yoshida[5]
[1]*Interdisciplinary Faculty of Science and Engineering, Shimane University*
1060 Nishi-kawatsu Matsue, Shimane 690-8504 Japan. kozu@ecs.shimane-u.ac.jp
[2]*National Institute of Information and Communications Technology (NICT),*
Koganei, Tokyo Japan.
[3]*Center for Climate System Research (CCSR)/University of Tokyo,*
Kashiwa, Chiba, Japan.
[4]*Japan Aerospace Exploration Agency (JAXA),*
Tsukuba, Ibaraki Japan.
[5]*Remote Sensing Technology Center of Japan (RESTEC),*
Chuo-ku, Tokyo Japan.

Abstract

Properties of a raindrop size distribution (DSD) parameter estimated from TRMM Precipitation Radar (PR) measurements are examined. The DSD parameter, called "ε" which is equivalent to the estimate of "a" in the radar reflectivity (Z) – rail rate (R) relation, $Z = aR^b$, shows a clear contrast between over land and over ocean. It also has a clear correlation with rain-top height and lightning activity derived from TRMM LIS measurement. Moreover, the seasonal variations of "a" over South India and Singapore show good correlations with ground-based disdrometer measurements. These results suggest that ε provides a means of global mapping of DSD.

1. INTRODUCTION

TRMM Precipitation Radar (PR) has a capability to estimate a parameter of raindrop size distribution (DSD) from a combination of radar reflectivity profile and a path-integrated attenuation with the surface reference technique [1]. The directly derived DSD parameter called "ε" which is the adjusting parameter of the coefficient α in $k = \alpha Z_e^{\beta}$, where k and Z_e are attenuation coefficient and effective radar reflectivity at 13.8 GHz, respectively. In other words, adjusted α is expressed as $\alpha = \varepsilon\alpha_0$ where α_0 is a standard coefficient derived from a standard DSD model. It is necessary, however, to validate the estimated DSD parameter since the ε estimate is subject to various errors such as non-uniform beam filling and variation of surface back-scattering coefficient. On the other hand, if ε provides the information of DSD, it would be extremely useful to improve the accuracy of radar rainfall measurement and to understand the climatology of cloud micro-physical processes [2-3].

In this paper, we present basic properties of ε and corresponding coefficient a in $Z = aR^b$ relation where Z and R are radar reflectivity and rain rate, respectively, and a and b are coefficient and exponent in the Z-R relation, respectively. From such properties, we discuss the validity of the ε estimate.

2. DSD MODEL FOR TRMM PR

Figure 1 shows the concept of the DSD model and estimation of ε in the PR measurement. First we give a set of Z-R relations as DSD models. These models are converted to N_0-Λ relations assuming the gamma distribution with $\mu = 3$ fixed. Using these N_0-Λ relations for various rain intensities, $k = \alpha Z_e^{\beta}$ relations or $\alpha = \varepsilon\alpha_0$ are calculated with the Mie theory.

In the PR data processing algorithm called 2A25, an appropriate ε is estimated from a comparison of Z_e profile-derived path integrated attenuation and that from the surface reference technique [1]. This process also provides an estimate of N_0-Λ and Z-R relations. Thus the estimation of ε can be recognized as the estimation of a DSD parameter. Note that $\varepsilon = 1$ corresponds to a standard DSD model (*i.e.* standard Z-R relation), and $\varepsilon < 1$ and $\varepsilon > 1$ correspond to DSDs having larger diameter and smaller diameter drops, respectively. That is, the larger the ε, the smaller the a coefficient in $Z = aR^b$ relation. This relation is shown in Figure 2.

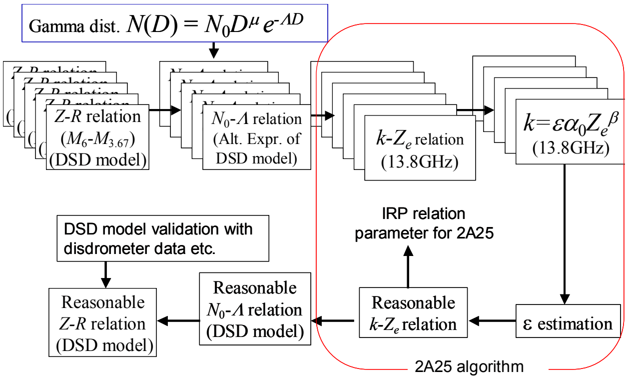

Fig.1: Concept of DSD model and ε estimation in the PR data processing algorithm 2A25.

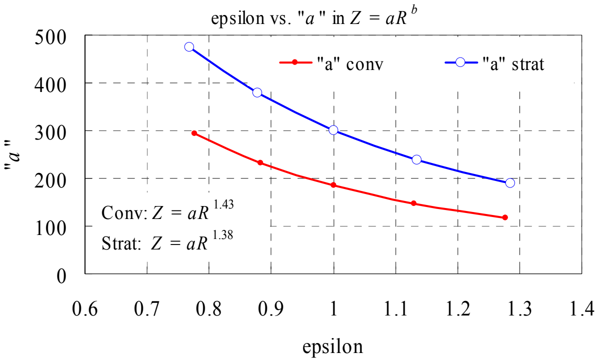

Fig.2: Relation between ε (epsilon) and coefficient a in $Z = aR^b$ relation. "conv" and "strat" stand for convective and stratiform rains, respectively.

3. GLOBAL DISTRIBUTION OF EPSILON.

TRMM PR covers tropical to mid-latitude regions up to about ±36-degree latitude. Within this coverage, ε shows climatological dependences as shown in Figure 3(a). It is clearly shown that over land ε is smaller than over ocean, that is, DSDs over land contain more large drops than those over ocean. The land/ocean contrast is more evident in the summer hemisphere than the winter hemisphere. It is interesting that DSDs over tropical ocean are narrower than mid-latitude ocean regions. In Figure 3(b), monthly mean rain-top height derived from the PR measurement is shown. By comparing Fig.3(a) with (b) we find that high rain-top height generally corresponds to small ε (*i.e.* large drop diameter).

Similar to the ε – rain-top height correlation, it is found that the number of lightning, *i.e.* lightning activity, is well correlated with the DSD parameter ε as shown in Figure 4.

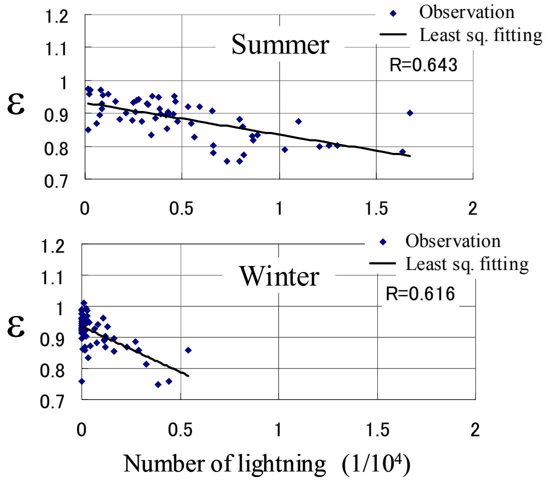

Fig.4: Scattergram between number of lightning (3 months accumulation, averaged over 3 years 1998-2000) and ε (3 month and 3 year average) in winter and summer seasons.

In Figure 4, the "summer" means June-August in northern hemisphere and December-February in southern hemisphere. The "winter" is defined in reverse. From this figure, we find that "intense" convective rains associated with much lightning would produce large raindrops. This result is consistent with old (mid-latitude) [4] and recent (tropical) [5-6] findings from disdrometer measurements.

Recently Takayabu and Katayama [7] proposed a method to classify rainfall types from TRMM PR measurements. It is noted that evening shower over land and precipitation associated with low pressure system over ocean have relatively low ε (large drops). See Figure 5.

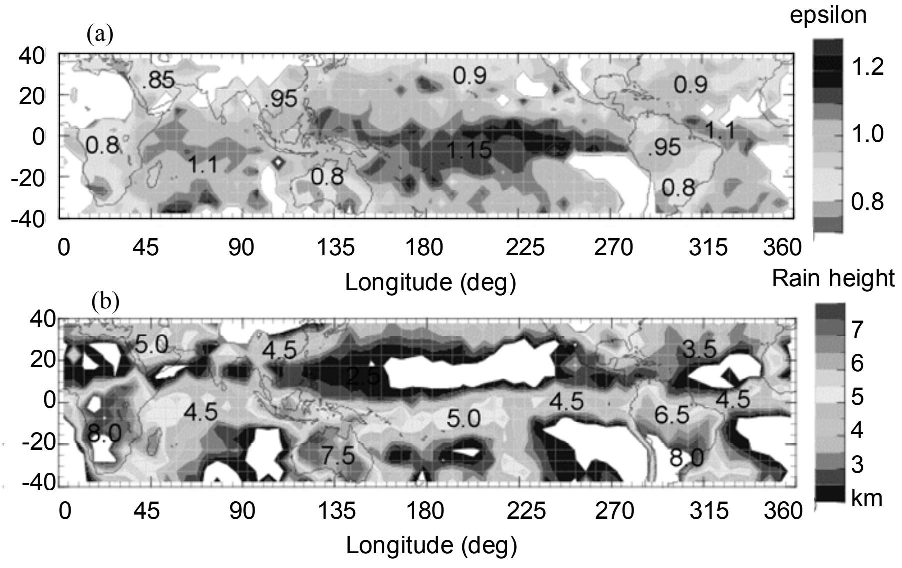

Fig.3: Global distribution of DSD parameter (a) ε and (b) rain-top height derived from PR measurements. January 1998, one month average.

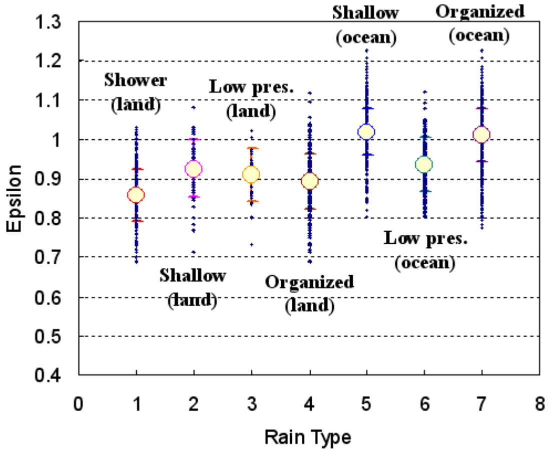

Fig.5: Dependence of ε on the Takayabu-Katayama [7] rainfall types in June-August 1998.

4. COMPARISON WITH DISDROMETER DATA

Although the properties of ε are in general reasonable from physical considerations, it would be necessary to compare with DSDs directly measured on the ground. Figure 6 shows examples of such comparisons where ε is converted to a in $Z = aR^b$ (b = 1.43). Disdrometer measurements in South India and Singapore were conducted at Gadanki about 120 km northwest of Chennai, and at Nanyang Technological University (NTU), west edge of Singapore Island. Corresponding TRMM PR data (ε) were averaged over a month within 1-degree×1-degree area around the disdrometer site for 8 years from 1998 to 2005. As shown in this figure, seasonal variations of a from TRMM PR are well correlated with disdrometer counterparts. In this figure, comparisons over land area are shown. For ocean areas such as Kwajalein [8] and Kapingamarangi [9], correlation is not as good as land areas. Disdrometer-derived a is somewhat greater than that from PR. This may be due to the "island effect" on DSD properties.

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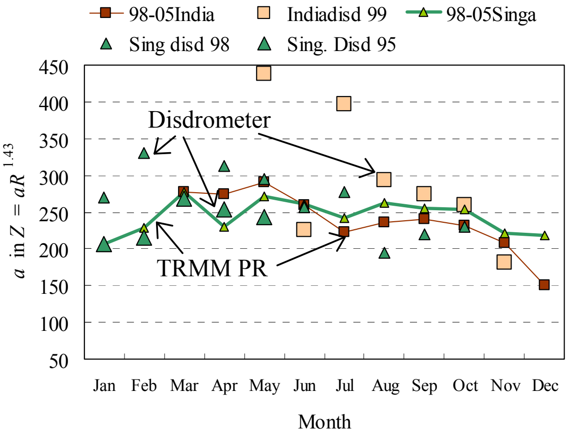

Fig.6: Comparison of TRMM PR derived monthly mean a in $Z = aR^{1.43}$ with disdrometer-derived ones in South India (Gadanki) and Singapore