Interactive comment on “Climatological characteristics of raindrop size distributions within a topographically complex area” by S.-H. Suh et al.

Anonymous Referee #1

Received and published: 12 May 2015

Specific comments:

Title: Since this is a paper dealing with the climate of a particular region, I think that the region (Busan, Korea) should be mentioned in the title.

Author’s answer : Thank you for reviewer's comment. Actually, the first title name was same as you told. As my point, the results of present study is not limited to Busan area. However, for the objectivity, I modified the title name from ‘Climatological Characteristics of Raindrop Size Distributions within a Topographically Complex Area‘ to ‘Climatological Characteristics of Raindrop Size Distributions in Busan, Korea‘ as reviewer's comment.

Abstract: not mentioning radar simulations, see above.

Author’s answer : Thank you. I added the explanation about T-matrix simulation in the abstract as ’Also, to find the dominant characteristics of polarimetric radar parameters such as differential radar reflectivity (Z_{dr}), specific differential phase (K_{dp}) and specific attenuation (A_h), T-matrix scattering simulation was done.’

Line 12: The variable D_m is not described.

Author’s answer : I missed the description of the D_m. So, I modified and added the definition of D_m in the abstract as you told.

Page 4007:

Lines 18-19: How is the microphysical structure more complicated in the high latitudes? Certainly deep convection, which might be regarded as "more complicated", is more common at lower latitudes.

Author’s answer : I’m so sorry to make you confusing. Of course the convective rainfall system has more complicated microphysical structure compared to the stratiform rainfall type due to the strong upward wind. But, what I want to say here is that the microphysical structure of the same rainfall type (stratiform or convective) in the middle latitude region is more complicated compared to the low latitude region because of various atmospheric conditions like baroclinic atmospheric condition, crossing the warm and cold advection and seasonal variations and other atmospheric conditions. However, to avoid confusing, I removed this sentence.

Lines 28-29: This is true when the rain rate is held constant, however, convective rain tends to be more intense. Since rain rate correlates strongly with drop size, on average convective rain tends to have larger drop size.

Author’s answer : Thank you and I absolutely agree to reviewer's idea. I missed the specific comment. I modified and added the sentence as like ‘Fully-grown raindrops of maritime precipitation are smaller than those in stratiform rainfall due to the break-up mechanism in case of same rainfall rate'.

Page 4008:

Line 8: The comment above is supported by this reference from Bringi et al., where large drop size is clearly one of the criteria for classifying rain as convective.

Author's answer : First of all, I'm so sorry for missing of reviewer's point. In this paper, I classified the rainfall types into stratiform and convective(including continental, maritime precipitation) using the method proposed by Bringi et al. (2003). Of course the rainfall rate shows proportional relation to the raindrop diameter. However, I did not consider the raindrop diameter to classify the rainfall types. Also, continental or maritime-like rainfall was classified only for the convective rainfall not stratiform rainfall type.

Line 15: Are not sea winds generally associated with mornings rather than evenings?

Author's answer : Thank you for reviewer's point. I did not explain the detail duration. Sea winds usually blow from afternoon to early evening, as shown in Fig. 8g. I modified the sentence more clearly as 'Sea winds generally is occurred from afternoon to early evening'.

Page 4009:

Line 12: is D defined here as the volume-equivalent diameter?

Author's answer : Thank you for reviewer's comment. Yes, actually parameter D is the volume equivalent diameter or volume equivalent spherical diameter. I modified the word as 'where D is volume equivalent spherical raindrop size (mm)'.

Page 4010:

Eq. (9): The factor 3.6/10ˆ3 is apparently here for a unit conversion, but you don't say which unit R is supposed to have. I would consider it preferable to make the equations independent of the units wherever possible and only give the units where needed (for example, for empirical relations such as Eq. (10)).

Author's answer : This is good point. Thank you for reviewer's opinion. I missed the detail explanation. As reviewer's comment, I added the explanation of unit conversion as 'where the value of factor 3.6×10^{3} is the unit conversion which converts the mass flux unit (mg m^{-2} s^{-1}) to the common unit (mm h^{-1})for the convenience.'

Line 4011:

Line 7: What frequency was used? What are the channels? Please expand the explanation of the instrument.

Author's answer : First of all, channels means the detectable diameter range intervals of POSS. Detectable minimum and maximum diameter of POSS disdrometer is 0.34 and 5.34 mm, respectively (Shappard and Joe, 1994). Also, frequency of POSS radar pulse is 10.525 GHz (Shappard, 1990). The detailed channels are as follows;

TABLE 3. POSS channel parameters.

Channel	Diameter (mm)	Diameter interval (mm)	Measurement volume ($cm^3 s^{-1}$)
1	0.34	0.05	0.32E+06
2	0.38	0.05	0.44E+06
3	0.44	0.05	0.71E+06
4	0.49	0.05	0.78E+06
5	0.54	0.06	0.10E+07
6	0.60	0.06	0.13E+07
7	0.66	0.06	0.19E+07
8	0.72	0.06	0.24E+07
9	0.78	0.06	0.29E+07
10	0.84	0.06	0.37E+07
11	0.91	0.07	0.43E+07
12	0.97	0.07	0.52E+07
13	1.05	0.07	0.58E+07
14	1.12	0.08	0.69E+07
15	1.20	0.08	0.79E+07
16	1.28	0.08	0.86E+07
17	1.37	0.09	0.10E+08
18	1.46	0.09	0.11E+08
19	1.55	0.10	0.13E+08
20	1.65	0.10	0.15E+08
21	1.76	0.11	0.18E+08
22	1.87	0.12	0.21E+08
23	2.00	0.12	0.26E+08
24	2.12	0.13	0.30E+08
25	2.26	0.14	0.36E+08
26	2.40	0.15	0.41E+08
27	2.56	0.17	0.49E+08
28	2.73	0.18	0.58E+08
29	2.92	0.20	0.73E+08
30	3.14	0.23	0.92E+08
31	3.40	0.28	0.11E+09
32	3.70	0.36	0.13E+09
33	4.15	0.56	0.15E+09
34	5.34	1.84	0.19E+09

As reviewer's comment, I added the specific frequency in the sentence as '(10.525 GHz)' also, I added the more detail information of POSS disdrometer in Table 1.

Line 13: How were snow events detected? How about hail or graupel?

Author's answer : Thank you for reviewer's comment. The present study is focused on liquid raindrops. Therefore, we did not consider the snow, hail and graupel.

Lines 14-16: The sentence after (ii) is unclear. I don't understand what "DSD spectra was smaller than five consecutive channels" means.

Author's answer : I'm so sorry to make you confused. It means that the raindrop should be recorded at more than five channels for one minute (e.g., DSD spectra observed at 1st 2nd, 3rd, 4th and 5th (consecutive) channel of POSS is used, but those of 1st, 2nd, 4th, 5th and 6th (not consecutive) is removed as noise.

Line 16: Criterion (iii) effectively introduces a minimum size for the DSD, what is this?

Author's answer : Thank you for reviewer's comment. It means that the total drop numbers should be larger than 10 $m^{-3}mm^{-1}$ at the entire POSS channels.

Line 19: How common were cases with R > 200 mm/h?

Author’s answer : I’m really so sorry, I do not understand this question exactly. For my understanding, when rain rate (R) exceed 200 mm h^{-1}, disdrometer has a tendency to reduce of detection capacity of small raindrops. Therefore, we removed the samples in case of $R > 200$ mm h^{-1} to eliminate the noisy data.

Line 21: The threshold below which the DSD is overestimated depends on the disdrometer. Leinonen et al. (2012) used a different type of disdrometer.

Author’s answer : Thank you for reviewer's opinion. I agree to reviewer's idea. As far as I know, th e tendency of overestimating DSD in $D_0 < 0.5$ mm would be caused by characteristics of disdrometer type. However, it is also by intrinsic feature and threshold of gamma DSD model (Bringi et al., 2003; Leinonen et al., 2012). Therefore, I think it is possible to use this threshold in the present study.

Line 29: Please describe the results of the POSS-AWS comparison here.

Author’s answer : Thank you for reviewer's opinion. Figure 3 shows the comparison between POSS and AWS for entire period of the present study. And AWS data was used only for same rainfall event as POSS after quality control procedure. The correlation is good and RMSE is small about 0.162 mm.

Page 4012:

Line 3: What T-matrix implementation was used? Eq (11): This equation holds for the Rayleigh scattering regime; since you have omitted the radar wavelength, I cannot evaluate if it is applicable to reviewer's calculations.

Author’s answer : I’m so sorry, I missed that. The radar frequency in the T-matrix simulation is considered as S-band (2.85 GHz). I added the specification of this in the present study ’Also, the condition of frequency for electromagnetic wave of radar is 2.85 GHz (S-band).’

Page 4013:

Line 11: Please give the units (mm h^{-1}) for the SD as well.

Author’s answer : This is my mistake. Thank you for reviewer's guidance. I added the unit (mm h^{-1}).

Lines 20-24: Here, you seem to acknowledge that the sunrise/sunset times vary considerably and then say that you used fixed times regardless. Since analysis of the diurnal cycle is among the key points of reviewer's paper, surely you could use the actual sunset/sunrise times instead, in order to eliminate a known source of error?

Author’s answer : The purpose of the present study is to find the dominant characteristics of DSD between day and night. Also, its main research strategy is statistical analysis using long-term DSD data (four years). Therefore, we used the fixed daytime and nighttime for the entire period. Of course, classification method of daytime and nighttime applied each sunrise and sunset time is more logic and analytic. The usual sunset and sunrise with season in Korea were used even though they are not individual ones. That’s why the entire data was divided four seasons which has different sunrise and sunset times (you could find the time in and Table 4) to find more detail characteristics of DSD according to the wind. You could find the results of seasonal variations between summer and winter season. And I added the time series of sea winds frequencies in Fig. 8 and 11 for the objectivity.

Page 4014:

Lines 6-8: The description of Changma should be moved somewhere before first mention of it on the previous page. I suggest moving it to the introduction and expanding it to a paragraph giving a short introduction to the local climate and geography to readers who are not familiar with those aspects of the Korean peninsula.

Author's answer : Thank you for reviewer's comment. Changma is local rainfall phenomenon in Korea during early summer season (from mid June to mid July) which is similar to the Meiyu (China) or Baiu (Japan). However, in this study, there is no major results from Changma data. So I would like to live origin position and I modified this sentence like 'Changma is the localized rainfall system or rainy season that is usually present over the Korean Peninsula between mid-June and mid-July which is similar to the Meiyu in China or Baiu in Japan' as reviewer's comment.

Page 4015:

Line 24: This occurs in many places in the paper but I will just remark on it here: you cannot use a logarithm like this! If you take log(R), the result will be unitless but will depend on the unit of R. Therefore you cannot say that log(R) = 2 mm h^{-1}. All the occurrences of this should be fixed.

Author's answer : Thank you for reviewer's comment. reviewer's opinion is absolutely right. I did not consider unit of log parameters. I will eliminate unit of all log parameters in the manuscript.

Page 4016:

Line 7: "frequencies" should be "reflectivities"?

Author's answer : Thank you for reviewer's comment. Actually, 'Frequencies' means the value of PDF. To avoid confusing, I modified the sentence like 'Conversely, for convective rainfall, the value of PDF lie between ~'

Page 4017:

Line 24: Eq. (15) is not linear.

Author's answer : Thank you for reviewer's comment. Strictly speaking, reviewer's comment is right. I'm so sorry to make you confused. However, what I want to say is the relationship between $\log(N_w)$ and D_m shows linear relation. I will revise the sentence more correctly. So, I modified the sentence as 'the simple linear equation is derived using D_m and $\log_{10}(N_w)$ as follows:'

Page 4018:

Line 15: In which direction is the coastline?

Author's answer : The coastline is located at the eastern side of the observation site and I added the sentence as 'The observation site of POSS was installed at the western side of the closest coast line, the distance is about 611 m. It means that the effect of the land and sea winds would have been recorded.'

Lines 19-21: I am not sure that any conclusions can be drawn about peaks in mu, the data in Fig. 8 mostly looks like noise.

Author's answer : Thank you for reviewer's comment. Similar to reviewer's comment, I did not find the general diurnal characteristics of shape parameter. Therefore, I just explain its maximum and minimum values.

Line 22: While I agree that there is clearly a drop in D_m, 0.1 mm is hardly "dramatic".

Author's answer : Thank you for reviewer's comment. Actually, 0.1 mm of D_m is not large in the case study as reviewer's comment. However, in long-term statistical analysis, 0.1 mm is not small difference to be ignored . Furthermore, in relatively short time scale (diurnal variation), the small difference of D_m (e.g., about 0.1 mm) could be considered as significant difference. Also, to avoid confusing, I modified the word as 'remarkably' from 'dramatically'

Line 24: Fig. 5a clearly seems to show an inverse relationship. Between D_m and mu.

Author's answer : Yes. However, this explanation in the manuscript is just limited to time series analysis as shown in Fig. 8 not for the dominant relationship between D_m and N_w as shown in Fig. 5. Of course, it is common that the D_m and N_w has inverse relationship. However, in Fig. 8(b) and (c), it is hard to find the inverse relationship of time series between D_m and N_w.

Page 4019:

Line 8: "A larger number of smaller and larger raindrops": this sentence makes no sense.

Author's answer : I'm so sorry for make you confused. it means that the number concentration (N(D)) of relatively small (D < 1 mm) and large (D > 3 mm) raindrop was increased. To avoid confusing, I modified the sentence as 'A larger N(D) of small or large raindrops would be expected in NT than in DT.'

Lines 9-11: Since you are already separating stratiform and convective precipitation, it would be interesting to see if there are larger differences between day and night if you also differentiate between convective and stratiform. (In particular: is the daytime convective DSD different from that at nighttime?)

Author's answer : Thank you for reviewer's comment. Actually, in my opinion, data of convective rainfall is considerably small (about 6.11%) compared to stratiform rainfall type (about 62.93%), you could find the result in Table. 3. Therefore, it is not enough samples to compare between stratiform and convective rainfall type. As reviewer's recommendation, I added the PDF analysis for convective rainfall type in Fig.13 which is also required way to find the climatological characteristics of DSD as continental or maritime like precipitation.

Line 24: KST for non-Korean regions?

Author's answer : Thank you so much. Gadanki is located in India. I modified the time from KST to LST.

Page 4020:

Lines 2-4: What does Fig. 9f say about the relationship between Z and R? All it seems to do is report the distribution of Z.

Author's answer : Thank you for reviewer's comment. Actually, reflectivity (Z) has the proportional to rain rate (R) and LWC. Because of this, we describe the PDF analysis of Z with those of rain rate and LWC together. Also, there is no worth noticing the PDF of Z as my point. Also, to avoid confusing, I modified the sentence as 'The Z has similar pattern with LWC and R during the DT (NT) was higher (lower) than in the NT (DT) in the range below (above) about 27 dBZ (Fig. 9f).'

Page 4012:

Line 8: The inverse behavior of Dm in summer vs. winter is an interesting result. This might be a topic for another study, but do you have any guesses as to why this is happening?

Author's answer : Thank you for reviewer's interest. In our opinion, considerable difference of DSDs between daytime and nighttime might be come from the wind effects blowing from land or ocean which is already described in conclusion part. Also, to verify the results, I added the time series of normalized frequency for ocean wind on Fig. 8 and 11 which could be considerably match with those of DSDs, even though more detailed analysis would be needed.

Figure 8: are these the 1-hour averages of these parameters?

Author's answer : Thank you for reviewer's comment. The interval of time series is 2 hr which is described in page 4020 line 19. Also, to avoid confusing, I added the specific express in the captions at Fig. 8 and 11 as 'Two hour interval time series ~'

References

Bringi, V., Chandrasekar, V., Hubbert, J., Gorgucci, E., Randeu, W., and Schoenhuber, M.: Raindrop size distribution in different climatic regimes from disdrometer and dual-polarized radar analysis, Journal of the atmospheric sciences, 60, 354-365, 2003.

Sheppard, B. E.: Measurement of raindrop size distributions using a small Doppler radar. J. Atmos. Oceanic Technol., 7, 255–268, 1990.

Sheppard, B. E. and P. I. Joe: Comparison of raindrop size distribution measurements by a Joss–Waldvogel disdrometer, a PMS 2DG spectrometer and a POSS Doppler radar. J. Atmos. Oceanic Technol., 11, 874–887, 1994.

Interactive comment on "Climatological characteristics of raindrop size distributions within a topographically complex area" by S.-H. Suh et al.

Anonymous Referee #2

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Major concerns:

1) Page 4007, line 23-25 states: "The raindrop size distribution of stratiform rainfall observed at the ground is larger than that of convective rainfall, due to the resistance of ice particles to break-up mechanisms". This statement might be true for maritime precipitation as e.g. observed by Tokay and Short, 1996. However, for continental precipitation it is really dependent on the type of precip around the zero degree isotherm (snow vs. ice) whether the average diameter is smaller or larger for stratiform precipitation in comparison to convective rainfall. See for an in depth discussion on this issue Hazenberg et al. 2011.

> **Author's answer :** Thank you for your comment and I agree to your opinion. I would like to explain the common characteristics of each rainfall type at the same rainfall rate but I did not describe the specific word. I added the words like 'for a same rainfall rate' in the manuscript. Also, your comment about DSD features according to the climatological condition of DSD is very useful to understand DSD of rainfall system. Busan shows maritime-like climatology. So, I modified the sentence more explicitly as 'Fully-grown raindrops of convective precipitation are smaller than those of stratiform rainfall in maritime precipitation in case of same rainfall rate due to the break-up mechanism'.

2) Page 4011 line 21: "(vi) The DSD tends to be overestimated when D_m < 0.5 mm." This line is unclear and should be rephrased. :

> **Author's answer :** Thank you for your comment. gamma DSD showd that D_0 equation overestimates D_0 at < 0.5 mm (Leinonen et al., 2012). Also, Bringi et al. (2003) defined the range of D_0 for gamma DSD model as between 0.5 and 3.5 for the same reason. So I added and modified this sentence as 'The value of D_0 which is calculated by Eq.(3) tends to be overestimated when D_0 < 0.5 mm'

3) Page 4014-4015, lines 23-3 "The value of mu : : : in the negative mu range". These sentences are not very clear and should be rephrased. From what I understand, the authors state that in the current work, the values of mu are generally smaller for convective rainfall, which is in contrast to other previous studies. The authors note that a larger value of mu for convective precipitation is to be expected, because of the fact that due to break-up mechanisms the number of larger drops decreases, while the number of larger drops decreases. I only partially agree with the authors on this. A decrease of the number of larger drop would indicate an increase in the slope parameter of the gamma distribution (which is the combined value -(4+mu)/D_m value). Furthermore, mu generally tends to be heavily influenced by the number of small

droplets. For South Korea these apparently observed quite frequent for convective precipitation and result in small values of mu (mu<0). This is in contrast with other maritime studies where the number of small droplets decrease due to below cloud evaporation.

Author's answer : Thank you for your comment. I agree to your idea. In present study, however, we used normalized gamma DSD. Therefore, I could not use the slope parameter. Also, what I want to say is the dramatic change of distribution of shape parameter for a convective rainfall type. As reviewer's comment, shape parameter is heavily influenced by the number of small droplets. I think that it is also the result from the break mechanism of relatively larger raindrops for convective rainfall. Also, to avoid confusing, I modified the sentence as follows; 'The value of μ for convective rainfall is higher than that for stratiform rainfall because the break-up mechanism would make the number concentration of small raindrops increased.'

4) Page 4015, lines 10-12 "Generally, stratiform : : : of raindrops." See previous comment 1 above.

Author's answer : Thank you. I added the specific word like as 'in the same rainfall rate'

5) Page 4015, line 23 "The PDF : : : (Fig. 4d and e)" This is to be expected since LWC is related to the third moment of the DSD while R is related to about the 3.67 moment of the DSD.

Author's answer : Thank you. Reviewer's idea is absolutely right. Also, my explanation is a little bit short in the manuscript. To avoid confusing, I added the specific sentence, 'It is infer that the similar results come from the using of alike moment of DSD as 3.67 and 3 for R and LWC, respectively.' as reviewer's comment.

6) Page 4016, lines 12 "The method : : : in Busan." Since the work of Gamache and Houze Jr. (1982) many different type of algorithms have been developed to identify convective precipitation in a radar image. In e.g. the work by Steiner et al. (1995) a step wise approach was taken where all precipitation with Z>42 dBZ is identified as convective, while for lower reflectivity values, horizontal variabilities are taken into account. As such, the statement by the authors is a bit dated and can be removed.

Author's answer : Thank you for your detailed comment. The reason why I explained the convective rainfall threshold of other research result is that rainfall type threshold is dependent on the location. Also, I did not consider recent research papers as reviewer's comment. As your recommendation, I removed the results of Gameche and Houze Jr. (1982).

7) Page 4017, lines 3-4 "Based on : : : (Table 2).": It is not clear to me why a comparison is made to observed DSD in Finland. Such a motivation is also not provided in the Introduction or Section 2. In case the authors wish to provide comparisons to other locations, it would be nice if the authors could add a number of extra sites for which these parameters were estimated.

Author's answer : The purpose of comparison with Finland is to find out the characteristics of DSD between high and middle latitude. Also DSD data in Finland collected for around 5 years which is similar duration to the present study (4 years). Furthermore, analysis method is very similar. Therefore, I compared with Finland's results. Editor also recommended that comparison with Finland is removed. So I eliminated the results of comparison with Finland.

8) Page 4019 line 8 "A larger : : : in DT." Please motivate this statement.

Author's answer : In case of negative value of μ, distribution of N(D) shows convex-downward. It means that N(D) of small and larger is increased based on the shape of distributions. Therefore, I explained like that.

9) Page 4019 lines 19-21: "In accordance : : : convective system." For me this statement is quite counter intuitive, since convective events usually occur during daytime under influence of boundary layer processes influence by solar energy flux. It would be nice if the authors could elaborate on the type of processes that result in convective precipitation at night time.

Author's answer : I'm so sorry to make you confusing. Actually, the point of the sentence is not convective rainfall type but continental rainfall type. Continental and maritime rainfall are originated by convective rainfall type. In short, continental (maritime) rainfall relatively dominant during NT (DT) than DT (NT) because of land (sea) winds.

10) Page 4019, line 28 "In the : : : are similar." See comment 5) above.

Author's answer : Thank you. Also, my explanation a little bit short in present paper same as review No. 5). I added the additional explanation as follows; 'In the present study, the shape of the PDF of LWC and R for DT and NT are similar because of the same reason as shown in Fig. 4e-f'.

11) Fig. 10: In order to improve comparison between panel a) and b). Please add both histograms into one figure with summer and winter bars next to each other.

Author's answer : It is very good opinion. I merged two figure as one in Fig. 10a.

12) Fig. 11. See previous comment 11.

Author's answer : Thank you for your comment. Also. I merged as one figure which could be find on Fig 10b.

13) Please combine Fig. 12 and 13 into one figure to improve comparison.

Author's answer : Thank you for your comment. I merged as one figure in Fig 11.

14) Please combine Fig. 14 and 15 in a joint 4 panel figure to improve comparison.

Author's answer : Thank you for your comment. I merged as one in Fig 12.

15) In section 3.3.2 the authors show differences in the DSD characteristics between summer and winter, and between daytime and night time. These results show that there is both an impact of season and of the period of the day on the DSD. However, the authors do not provide any additional information on the

meteorological characteristics that cause these differences. As such, the authors currently only present the results and fail to provide any in depth understanding/hypotheses. I would suggest to add an extra discussion section that addresses this issue.

Author's answer : Thank you for your comment. I absolutely understand and agree with your idea. I also thought that there is another reason and hypothesis for a diurnal variation of DSD. However, in present study, the point is wind effect of DSDs. So I recently added the time series of normalized frequency for ocean wind in the Fig. 8 and 11. It would be good information to verify the relationship between DSDs and wind effects. DSD variations for other atmospheric effects will be remained for further study.

Minor concerns:

1) Please remove "within a topographically complex area" from the title as this paper does not deal with that. Instead just state "as observed in South Korea."

Author's answer : Thank you for your point. I did not explain the reason why Busan region is topographically complex. Busan has so many mountains in there and includes ocean. Also, the area of the ocean is relatively small and Busan is very close to Japan. However, for the objectivity, I modified the title name from 'Climatological Characteristics of Raindrop Size Distributions within a Topographically Complex Area' to 'Climatological Characteristics of Raindrop Size Distributions in Busan, Korea' as reviewer's comment.

2) Page 4010, line 6 should be: "the ratio between the standard deviation (SD) of D_m and D_m.

Author's answer : This is my mistake. Thank you for your comment. I modified as 'as the ratio between the standard deviation (SD) of D_m (σ_m in mm) and D_m'

3) Page 4010, eq. 9: rho_w should be v(D)

Author's answer : Your opinion is absolutely right. I modified the equation as reviewer's comment.

4) Fig. 2: Please add an x- and y-axis or some kind of distance scale to the lower panel

Author's answer : Thank you for your comment. I changed and added the figure and x and y axis, respectively.

5) Fig 4: Legend should be "(h) A_h and (i) K_dp"

Author's answer : Thank you for your point. I changed the position.

6) Table 3: Change "Entire rainfall" with "All rainfall". Does this table provide rainfall rate (as mentioned in the legend) or do the number show the total number of minutes observed?

Author's answer : Thank you for your comment and I am so sorry to make you confused. I changed the word from 'Entire precipitation' to 'Total precipitation' in upper part.

7) Fig 5 change "with respect to stratiform rainfall" into "for stratiform rainfall". Furthermore, what does the dashed line in this figure indicate? For panel b) would be nice if the authors could zoom in on the D_m 1-2 mm range.

Author's answer : Thank you for your comment. The dashed line is the broken grey line shown in Fig. 5 a-b that explained in the caption of Fig. 5. Also, it is good question to zoom in on the D_m 1-2 mm range. However, I would like to show the result of dominant characteristics of DSD. Therefore, I explained just two part like as heavy rainfall type and the others in present paper. Also, I changed the word from 'with respect to' to 'for'.

8) Table 4 please rephrase "Type" for "Period"

Author's answer : Thank you for your comment. I modified as reviewer's comment.

References

Bringi, V., Chandrasekar, V., Hubbert, J., Gorgucci, E., Randeu, W., and Schoenhuber, M.: Raindrop size distribution in different climatic regimes from disdrometer and dual-polarized radar analysis, Journal of the atmospheric sciences, 60, 354-365, 2003.

Gamache, J. F., and Houze Jr, R. A.: Mesoscale air motions associated with a tropical squall line, Monthly Weather Review, 110, 118-135, 1982.

Leinonen, J., Moisseev, D., Leskinen, M., and Petersen, W. A.: A climatology of disdrometer measurements of rainfall in Finland over five years with implications for global radar observations, Journal of Applied Meteorology and Climatology, 51, 392-404, 2012.

Interactive comment on "Climatological characteristics of raindrop size distributions within a topographically complex area" by S.-H. Suh et al.

Anonymous Referee #3

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Specific comments

1. Description of the DSD.
It would be helpful to have a short description of the DSD and its bulk parameters early in the manuscript. Describe what bulk parameters mean and their units, before introducing (e.g. on page 4008, line 7 where Dm is introduced without explanation). Units are often missing in bulk variable definitions. It is important to explain what each bulk variable means. For example, Dm provides one measure of the characteristic drop diameter of the DSD.

> **Authors answer :** Thank you for reviewer's comment. I did not consider a short description of the DSD and other parameters and I appreciate to reviewer's kind comment. And I added the short description including each unit in the manuscript.

2. Instrument description.
Please provide a reference to (a) paper(s) describing the operation of the POSS disdrometer, its manufacturer. A brief description of its operating principle should be provided in the manuscript. The coordinates of the instrument location should be given.

> **Author's answer :** Thank you for reviewer's comment. While I modifying the present paper, some part of sentence related with POSS disdrometer is removed. Sheppard (1990) studied intrinsic features of POSS disdromter. I added more description of POSS disdrometer in Chapter 2.2 and Table 1. I also missed the detail explanation of location of POSS disdrometer in Sec. 2. The coordinate of the instrument location was described at the abstract and page 4008 line No. 22. It is located at 35.12° N, 129.10° E. To avoid confusing, I added the specific location of POSS disdrometer in Chapter 2.2.

3. Data quality control.
It is important that care is taken with quality control, and the authors have done a good job of explaining their quality control procedures. A description of the way in which the POSS disdrometer detects precipitation type would be helpful. On Page 4011, line 21, it is not clear whether DSDs with Dm < 0.5 mm were removed or not. What is the temporal resolution used? On Page 4011, line 25, the accumulated rainfall amount is stated as "about 4269 mm" but it is not clear what "about" means in this context.

> **Author's answer :** Thank you for reviewer's comment. The threshold is not D_m < 0.5 mm but D_0 < 0.5 mm. Also, the purpose of D0 threshold method is to reduce the tendency of overestimates D0

when use to Eq (3). So I modified correctly. And the temporal resolution is 1 minute for the entire period which is already explained in the Table 3. However, I added the specific expression as follows; 'After performing all quality control procedures, 99,388 spectra were left from an original total of 166,682 for 1-min temporal resolution' in Chapter 2.2. Also, I agree with reviewer's comment. I modified the word to '4261.49 mm'. During revision works, I found calculation error in total accumulated rainfall amount and changed it accordingly.

4. POSS to AWS comparison.
The comparison of POSS-derived rain amount with AWS-derived rain amount is important because it speaks to the performance of the POSS disdrometer. The RMSE is provided (units should be specified), but I would also like to see the bias. The plot (Fig. 3) is in log-log scale which means that differences at the start of the time series are highlighted, while differences at the end of the time series are hidden. Please provide the plot in linear scale. The final amounts (5081 mm for AWS vs 4269 mm for POSS) show that the there is significant bias between the two instruments and this should be addressed in the manuscript.

Author's answer : Thank you for reviewer's comment. I did not consider the unit value of RMSE for a rainfall amount between AWS and POSS disdrometer. I added its unit (mm) in Fig. 3. I changed the scale of plot chart as linear. The reason why accumulated rainfall amount was not small is caused by not only distance between instruments (~368 m) but also different temporal resolution (AWS : 5mm, POSS : 1-min) in my opinion.

5. Mathematics. Equations
2, 6, 9, and 10 all require revision (see the following technical comments for details).

Author's answer : Thank you for reviewer's kind comment.

6. Drop-shape model.
On page 4012, line 9, the authors state that they have performed numerical simulations and wind tunnel tests for the drop shape from drop diameter relation, yet no results or further discussion is provided. It is not explained why the diameter ranges for different drop-shape algorithms are so chosen. The two drop shape models are inverted (ie Eq. 13 is actually Beard and Chuang 1987, while Eq. 14 is Andsager 1999).

Author's answer : Thank you for reviewer's comment. This is fatal type error and I am so sorry to make you confused. What I want to say in present paper is not 'we performed' but 'we applied the results ~'. We assumed the drop shape relations proposed by Andsager et al. (1999) and Beard and Chuang (1987) as used by Bringi et al. (2003). So, I modified this sentence as follows; 'we applied the results of numerical simulations and wind tunnel tests employing a forth-polynomial equation, as in many previous studies ~'.

7. Radar equations.
The radar equation in Eq. 11 is for non-polarimetric weather radar reflectivity derived from the DSD. Strictly, Eq. 12 is incorrect; it is not the definition of Zh but rather the conversion of non-polarimetric Z from linear units to dBZ. The diameter D used in Eq. 11 should be specified (i.e. is it the equivolume drop diameter?). The definitions of Zdr and Kdp used are not provided, and nor is the assumed radar frequency.

Author's answer : Thank you for reviewer's comment. I thought the horizontal radar reflectivity is same as the non-polarimetric radar reflectivity (Z). I modified the definition of equation properly as 'non-polarized radar reflectivity (Z, dBZ)' in Chapter 2.3. And, the symbol 'D' means 'the volume-equivalent raindrop diameter'. I added the definition of D in the Chapter 2.1 which is expressed in the bottom part of the definition of N(D). Last, the polarimetric variables like as Z_{dr}, K_{dp} and A_h are derived by T-matrix simulation based on the POSS data. The condition of T-matrix simulation is already explained in page 4012 line 8 to page 4013 line 3.

8. The comparison with Järvenpää.

What are the similarities and differences between Busan and Järvenpää, in terms of climate type and topographical complexity? For the comparison to be properly done, a section should be devoted to it and much more information, analysis, and results should be given. The few comparisons in the current paper read like an afterthought and should be expanded.

Author's answer : Thank for reviewer's comment. I am so sorry to make you confused. The reason why the results in Busan compared with Järvenpää is that the observation period (Järvenpää : 5 years, Busan : 4 years). Also, I want to show the differences of dominant DSD between two region (Järvenpää : high latitude, Busan : mid latitude). Also, observation site in Järvenpää is considerably close to the ocean (about 30 km). However, I did not explain the reason why the present results are compared to Järvenpää. Editor also recommended to remove the results of Finland. As reviewer's and editor's opinion, I removed the results of Finland and Table was also removed.

9. Division into convective and stratiform.

In Table 3, the percentages of convective and stratiform rain do not add to 100%. An explanation of what the non categorised rainfall is should be included. On page 4016, lines 12-14, the authors conclude that classifying rainfall as convective for Z > 38 dBZ would not be suitable, based on radar reflectivities in their classification using R (from Bringi et al. (2003)). It is not proven by this study whether the R-based method is, however, appropriate. This difference is important to state, but the authors lack sufficient evidence to conclude that radar reflectivity thresholds as per Gamache and Houze Jr. (1982) can not be used.

Author's answer : Thank you for reviewer's comment. First of all, rainfall type classification method is cited by Bringi et al. (2003). Stratiform rainfall is assigned when rainfall rate larger than 0.5 mm h^{-1} as well as standard deviation of rainfall rate smaller than 1.5 mm h^{-1} and convective rainfall type is assigned when rainfall rate larger than 5 mm h^{-1} as well as standard deviation of rainfall rate larger than 1.5 mm h^{-1}. It means that this method does not consider the rainfall rate less than 0.5 mm h^{-1} and this threshold also matched to the condition of standard deviation of R. Therefore, sum percentage of stratiform and convective rainfall is not equal to 100% (in present study, sum percentage of stratiform and convective rainfall is 69.03%). Second, considering rainfall division method proposed by Bringi et al. (2003), PDF of convective rainfall is higher than that of stratiform rainfall in case of Z > 35 dBZ. So, original purpose is to show the convective rainfall classification methods depend on the location. To avoid confusing, I removed this sentence.

10. Stratiform/convective PDFs (Section 3.1).

There is a lot of discussion of PDFs in the manuscript, and the writing is often unclear. A distribution cannot be "more frequent" as stated on Page 4014, line 21. The word "frequencies" on page 4016, line 7, is misused; the authors mean that most values lie between 25 and 55 dBZ. On page 4015, lines 11 to 17, a

contradiction is found (stratiform rainfall has larger raindrops than convective, yet the opposite is observed). This contradiction requires explanation. Overall, many results are stated from the plots, but there should be more discussion of what the results mean and imply.

Author's answer : Thank you for reviewer's comment. I want to say the value of PDF as 'Frequency'. I am so sorry to make you confused. I changed the word as 'the value of PDF' from 'frequency(ies)' as reviewer's comment. And, I missed the specific explanation like 'for a same rainfall rate' in the manuscript. And origin purpose is that raindrop diameter is proportional to rain rate regardless of rainfall types (stratiform, convective). To avoid confusion, I modified full sentence as follows; 'Generally, stratiform rainfall developed by the cold rain process shows weaker upward winds and less efficient break-up of raindrops. Therefore, in the same rainfall rate case, stratiform rainfall tends to produce larger raindrops than convective rainfall developed by the warm rain process. However, the average D_m values for convective and stratiform rain for the entire period are approximately 1.45 and 1.7 mm, respectively. In short, D_m is proportional to R regardless of rainfall type. This finding is consistent with the results of Atlas et al. (1999) who found that the D_m of convective rainfall is larger than that of stratiform rainfall on Kapingamarangi Island, Micronesia.'

11. Climatological characteristics (Section 3.2).
Figure 5b shows Dm vs. log10(Nw) with vertical lines representing the standard deviation around the mean value of log10(Nw). Horizontal bars should show the spread in Dm as well.

Author's answer : First of all, thank you for reviewer's good advice. However, using standard deviation of D_m would be complex. Because, mean value of each parameter is concentrated each other. Also, D_m has smaller deviation compared to $N_{w..}$

A linear model for the relationship between these two variables is found using the mean values for Typhoon events; it would be better to fit this relationship to all data.

Author's answer : I am so sorry to make you confused. Equation (16) (Equation number was changed) is made by the mean value of 10 categories rainfall type for all convective rainfall data not only Typhoon events. Therefore, reviewer's comment is same as the present study and I changed the Equation as linear scale.

Instead of using standard deviation, I would recommend using an interquartile range to give an indication of the skewness of the distributions for these variables.

Author's answer : Thank you for reviewer's kind recommendation about using interquartile. However, quartile would make the figure intricately. Because, mean value of each parameter is concentrated each other. So, let me remain this for the further research.

12. Diurnal variation (Section 3.3).
Figure 8 shows (presumably) average values of various variables. These distributions are likely to be skewed (indeed as shown in Fig. 9) and should therefore be shown through, for example, box-and-whisker plots instead of simple means. At the least, the skewness of the distributions should be mentioned in the manuscript, and it should be explicitly stated that Figure 8 shows mean values.

Author's answer : Thank you for reviewer's comments and opinions. Actually, it is good method to use skewness. However, we could find the clear feature of time series easily in Fig. 8.

Also, shape of PDF (Fig. 9) is similar to the previous study (Leinonen et al., 2012). It means that I could show the intrinsic distribution of DSD and integral parameters between daytime and nighttime. I think that it is more clear to compare between daytime and nighttime than using other method.

The paragraph on Page 4019, lines 22 to 27 should either be moved to the introduction/literature review section, or should have further explanation on how these previous results compare to the current results.

Author's answer : Thank you for reviewer's comment. I realize repeated expression for the cite of Qian (2008) in Chapter 3.2 and 3.3. So I move this sentence to the results of Fig. 11 in Chapter 3.3.

The results on diurnal variations of DSDs with respect to season are interesting. The paragraph on Page 4021, lines 13 to 18, is unclear.

Author's answer : I'm so sorry to make you confused. As far as I understand, I modified the sentence more clearly as follows; 'The PDF distribution of summer D_m displays a relatively large DT frequency compared with NT when D_m < 1.65 mm, except for the range between 0.6 and 0.9 mm. However, in the range of D_m > 1.65 mm, the NT PDF displays a larger frequency (Fig. 12a). The PDF of $\log_{10}(N_w)$ for DT (NT) has a larger frequency than the NT (DT) when $\log_{10}(N_w)$ > (<) 3.3 but smaller frequency when $\log_{10}(N_w)$ < (>) 3.3 (Fig. 12c).'

Fig 12 again shows mean values for variables that are likely to have skewed distributions, so box-and-whisker plots should be used.

Author's answer : Thank you for reviewer's comment. I added the quartile point (Min, Q1, Q2 (median), Q3, Max) per each time in the figure of time series of DSD in Figs. 8 and 11.

Technical comments

• Page 4006, line 7: specify that the 'shape parameter' is the DSD model shape parameter and refer to model definition.

Author's answer : Thank you for reviewer's comment. I modified the definition of shape parameter as 'the DSD model shape parameter' for specific expression.

• Page 4006, line 11: The categories not only cover different temporal and spatial scales, but different rainfall types.

Author's answer : Thank you for reviewer's kindness explanation. I modified like 'the entire period of recorded rainfall was divided into 10 categories not only cover different temporal and spatial scales, but different rainfall types.'

- **Page 4006, line 24: The DSD describes microphysical properties, it does not control them.**

  Author's answer : Thank you for reviewer's comment. This is type error. I modified like as 'is controlled by -'.

- **Page 4007, line 23: Replace "fall to ground" with "fall to the ground".**

  Author's answer : Thank you for reviewer's kindness. I modified it.

- **Page 4009, line 5: Define the DSD mathematically (as N(D)).**

  Author's answer : Thank you for reviewer's comment, I added more detail explanation of DSD definition as follows; DSD is defined by $N(D)=N_0 exp(-ΛD)$ ($m^{-3}mm^{-1}$) and the one of the methods to reflect the microphysical characteristics of rainfall using the number concentration of rainfall drops.

- **Page 4009 and onwards: Equations should be followed by punctuation (e.g. a comma or full stop).**

  Author's answer : I missed the punctuation for all equations. I added the punctuation in all equations.

- **Page 4009, Eq 2 is incorrect, the first numerator in Testud et al. 2001 for f() is Γ(4), not 6.**

  Author's answer : Thank you for reviewer's comment, Actually, the previous study (Bringi et al., 2003) used 6 not Γ(4). Also, Γ(4) is same as 6.

- **Page 4010: Units are missing for Dm, LWC, and R.**

  Author's answer : Thank you for reviewer's comment, I added the units for each parameter.

- **Page 4010, line 6: Define "SD" before use.**

  Author's answer : Thank you for reviewer's comment. I missed the definition of SD in the manuscript. This is abbreviation of standard deviation (SD). I added the sentence in the manuscript.

- **Page 4010, line 11: Remove "and rainrate (R)"**

  Author's answer : Thank you for reviewer's comment. I eliminated this word.

- **Page 4010, Eq 6 is incorrect, this is the expression for m, not m=Dm (see Leinonen et al., 2012).**

  Author's answer : Yes and thank you for reviewer's comment. I modified it.

- **Page 4010, Eq 9 is incorrect, R requires v(D).**

Author's answer : Thank you for reviewer's comment. Also, it is already advised by previous anonymous reviewer. I modified it correctly.

• **Page 4011, Eq. 10 is incorrect, -0.6 should be -6.**

Author's answer : Thank you for reviewer's comment. The unit of D is mm not cm in the manuscript. But in previous study (Atlas et al. (1973)) applied the unit of cm not mm. Also, For the unity, I applied the same unit of D in mm.

• **Page 4013, line 3: The fact that one-minute DSDs are used should be mentioned in the instrument description in Section 2.2.**

Author's answer : Thank you for reviewer's comment. Despite already shown in Table 3, I added the specific expression as follows; 'After performing all quality control procedures, 99,388 spectra were left from an original total of 166,682 for 1-min temporal resolution.' in Sec. 2.2. And repeated expression is removed.

• **Page 4013, line 20: "especially Busan" should be removed since Busan is mid latitude.**

Author's answer : Thank you for reviewer's comment, I changed the word from 'especially' to 'including'

• **Page 4014, line 10: Section 3.1 is really more about comparison between stratiform and convective rainfall than DSD and radar parameters.**

Author's answer : Thank you for reviewer's comment. However, the main purpose of Sec. 3.1 is to show the dominant characteristics for an each parameters in Busan. The results of stratiform and convective rainfall is subordinate part.

• **Page 4014, line 19: The table reference is incorrect and should be Table 3. The convective contribution is stated in the table as 5.7% but 5.8% here.**

Author's answer : Thank you for reviewer's comment. I modified and unified it correctly.

• **Page 4015, line 21: "often" is too vague.**

Author's answer : It is compared to the word 'rarely' in line 20. The reason why I want to use the word 'often' is that convective data also exist > 5.5 compared to the stratiform data. However, to avoid confusing, I modified the word from 'often > 5.5' to 'higher at > 5.5 than that of stratiform'

• **Page 4016, line 12: What are the differences between the frequency distributions in Busan and Darwin?**

Author's answer : Thank you for reviewer's comment. The PDF shape of radar reflectivity (Z) for the convective rainfall at lower altitude (3 km from MSL) in Darwin is similar to those of Busan. However, PDF shape for the stratiform rainfall type is considerably different from each other. The reason why I explain the results of Darwin is to show the difference of DSD according to the locations.

- **Page 4016, line 17: From Fig. 4g, this value (0.8) should be 1.8 dB?**

  Author's answer : Thank you for reviewer's comment. I modified the word from 0.8 to 1.8.

- **Page 4017, line 7: Table 3 should be introduced when the catagorisation is first mentioned (Section 2.4).**

  Author's answer : Thank you for reviewer's comment. I understand and agree with reviewer's idea However, actually we considered the Table 3 as the one of the results. Therefore we select the location of Table 3 at the part of results.

- **Page 4017, line 13: An average cannot "spread". Specify that what is meant is standard deviation around the mean to represent distribution spread.**

  Author's answer : Thank you for reviewer's comment. What I want to say 'spread' is that 'the 10 mean values of D_m and N_w are distributed between 1.2 and 1.5 mm and 3.2 to 3.5, respectively'. I am so sorry to make you confused. I changed from the 'spread' to the 'distribute'. And, standard deviation of $\log_{10}(N_w)$ shows the accuracy of mean value of each parameter implicitly.

- **Page 4020, lines 24-25: This sentence contains repeated information.**

  Author's answer : Thank you for reviewer's comment. The sentence in line 24-25 is similar to the sentence in line 20-21. I removed this sentence.

- **Page 4020, line 27: No clear pattern for any Nw value; "larger values" is unclear (refers to time of day?).**

  Author's answer : Thank you for reviewer's comment, Actually, the target of 'larger values' is D_m not N_w. Commonly D_m and N_w has negative relationship (you could find the feature in Figs. 5 and 6). However, time series of N_w in entire period (Fig. 11b) does not show the negative relationship compared to the D_m (Fig. 11a). For the convenience of explanation, I used the value of D_m instead of N_w. Also, the word 'larger' is matched to the 'relatively small' for D_m in line 26. To avoid confusing, I modified the sentence as follows; 'However, the inverse relation between $\log_{10}$ (N_w) and D_m is not remarkable.'

- **Page 4022, line 27: Replace "DT" with "day".**

  Author's answer : Thank you for reviewer's comment. I modified the word 'night' to 'NT' not 'DT'

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Andsager, K., Beard, K. V., and Laird, N. F.: Laboratory measurements of axis ratios for large raindrops, Journal of the Atmospheric Sciences, 56, 2673-2683, 1999.

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Beard, K. V., and Chuang, C.: A new model for the equilibrium shape of raindrops, Journal of the Atmospheric sciences, 44, 1509-1524, 1987.

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Sheppard, B. E.: Measurement of raindrop size distributions using a small Doppler radar. J. Atmos. Oceanic Technol., 7, 255–268, 1990.

Interactive comment on "Climatological characteristics of raindrop size distributions within a topographically complex area" by S.H. Suh et al.

Anonymous Referee #4

Received and published: 13 July 2015

Comments of the 4th referee:

Title: I think that the "Busan" and/or "Korea" should be inserted in the title.

Author's answer : Thank you for reviewer's comment. I modified the title as follows; 'Climatological characteristics of raindrop size distributions in Busan, Korea'

Page 4006, line 12: Please define Dm

Author's answer : Thank you for reviewer's comment. I added its definition in the manuscript.

Page 4006, Lines 19-22 (minor remark): Even if DT and NT are well defined, the reader thinks about diameters and concentrations...

Author's answer : Thank you for reviewer's comment. The reader would think DT as a diameter and NT as a concentrations. However, I tried to explain the abbreviation in the manuscript and the reader could understand them.

Page 4006, Line 24: DSD doesn't control microphysical processes. It's the contrary.

Author's answer : Thank you for reviewer's comment. reviewer's comment is absolutely right. I modified the this word 'control' to 'is controlled by'

Page 4007, line 6 and for each following equations: Please precise the units.

Author's answer : Thank you for reviewer's comment. I added the unit values of rain rate (R in mm h^{-1}) and raindrop (D in mm).

Page 4010, equation 4: The numerator has to be reversed with the denominator.

Author's answer : Thank you for reviewer's comment and I'm so sorry to make you confused. There is no problem in the sentence (Page 4010, Line 1-2 : Mass-weighted mean diameter (Dm) is calculated as the ratio of the fourth to the third moment of the DSD:), but the equation (6) is reversed as reviewer's comment. However, there is no problem in the program code. I modified the equation correctly.

Page 4010, equation 9: D3 and v(D) are missing !!!

Author's answer : Thank you for reviewer's comment. I modified the equation as reviewer's comment.

Page 4011, line 14-15: I do not understand the second quality control.

Author's answer : Thank you for reviewer's comment and I'm so sorry to make you confused. Let me explain this using example; e.g. 1), The following DSD data is removed: 1-min DSD data existed in only No.11, No.12, No.13, No.14, No.16 channels is removed (not consecutive), e.g. 2) 1-min DSD data existed in only No.11, No.12, No.13, No.14, No.15 channels is not removed (consecutive). Also, if 1-min DSD data existed in only smaller than 5^{th} channel (No.5) or larger than 10^{th} channel (No.10), it is removed.

Page 4011, line 18 and Page 4013, line 10: Several thresholds on R and Dm are used. It is therefore very important to indicate on what timestep R is computed and for what timestep R and Dm are used in the cited literature.

Author's answer : Thank you for reviewer's comment. I missed the time step of R. I add the time step of DSD as follows; 'After performing all quality control procedures, 99,388 spectra were left from an original total of 166,682 for 1-min temporal resolution' in Chapter 2.2. All DSD and rain integrated parameters are computed using 1-min DSD data.

Page 4011, Some more explanation and reference about the POSS are missing. Moreover, I wonder how is the accuracy of POSS observations in presence of strong winds (typhoons)

Author's answer : Thank you for reviewer's comment and I absolutely agree with reviewer's comment. I missed the explanation of characteristics and structure of POSS disdrometer. According to reviewer's comment, I added the information of POSS disdrometer more detail.

Of course the disdrometers are sensitive to the wind effect including POSS disdrometer. Sheppard (1990) and Sheppard and Joe (1994) noted that the overestimation of small drops at winds larger than 6 m/s is occurred. However I did not consider the wind effect in present study because of beyond the research bound. And I added the shortcomings of POSS for wind effect in this sentence.

Page 4011, Line 28, and Figure 3: The graph and the written values on the graph seem to be not consistent.

Author's answer : Thank you for reviewer's comment. I explained the accumulated rainfall as round half down value for simplification of main sentence. As reviewer's comment, I modified the value precisely.

Page 4012, line 10: I didn't find the reference to Hamilton in the list of references. Moreover, a threshold of 0.5 mm/h for average 5min rainfall intensity seems to me very low!

Author's answer : Thank you for reviewer's comment. Actually author name is not Hamiltion (1988) but Johnson and Hamilton (1988). The threshold seems very low however, I chose the same threshold of classifying the rainfall types used by Johnson and Hamilton in 1988.

Page 4013, line 8: "Gamadre" should be replaced by "Gamache"

Author's answer : Thank you for reviewer's comment and I modified the author name correctly as reviewer's comment.

Page 4014, line 3: Units are wrong (replace by mm)

Author's answer : Thank you for reviewer's comment. It is an accumulated rainfall amount (mm) not rainfall rate (mm h^{-1}). I modified the unit.

Page 4014, line 21: "The distribution of μ: : : is more frequent", this kind of sentence is not clear. The following sentence seems to be contradictory with the previous (I'm not sure).

Author's answer : Thank you for reviewer's comment and I'm so sorry to make you confused. The word 'more frequent' means 'μ has more value of PDF for convective rainfall type compared to those of stratiform rainfall in case of $\mu < 0$.' Also you cloud find the results in Fig.4a.

Page 4015, lines 19, 20 and 23: Units for log-transformations should be removed

Author's answer : Thank you for reviewer's comment, I removed all units for log values ($\log_{10}$(Nw), $\log_{10}$(R), $\log_{10}$(LWC)).

Page 4015, line 21-22: What is the usefulness of this information? In fact, the PDF curves are crossing each others on each graph and they usually have therefore some common values.

Author's answer : Thank you for reviewer's comment. Actually, PDF result would show the many kind of feature of each parameter. What I want to say in this sentence is that the value of $\log_{10}(N_w) = 4.4$ would be used as the threshold of classifying the rainfall types (stratiform, convective) because we used almost 4 years DSD data.

Page 4015, line 28 and Page 4016, lines 12: I don't understand totally this sentence. Is the beginning of the sentence necessary?

Author's answer : Thank you for reviewer's comment and I'm sincerely sorry to make confusing you. What I want to say is similar to the previous question. The PDF distribution of rain rate for convective rainfall type is larger at $\log(R) > 0.65$ than those of stratiform rainfall. Also this distribution has a peak value at the $\log(R) = 0.9$. To avoid confusing, I modified the sentence more detail as follows; 'Furthermore, the frequency of the PDF for convective rainfall was higher than that of stratiform rainfall in case of $\log_{10}(R) > 0.65$ and the peak value was 0.9.'

Page 4035, I think that graph (b) is not easily readable. Maybe the authors may zoom on 1<Dm<2 mm?

Author's answer : Thank you for reviewer's comment. Originally, I considered making the detail (zoom-in) distribution of each mean parameter as reviewer's comment. However, I think that showing the dominant distribution of DSD in Busan area is more adequate to explain the purpose of this study.

Page 4017, line 18, I think that the sentence beginning with "The distribution of 1min: : :" could be the beginning of a new paragraph.

Author's answer : Thank you for reviewer's comment. I changed it in the manuscript.

Page 4018, the last lines about the disagreement with Chang and al. (2009): My personal point of view is that the scale of a typhoon is large and the characteristics of DSD certainly differ according the location

inside the typhoon and/or the development stage of the typhoon.

Author's answer : Thank you for reviewer's comment and I considerably agreed with reviewer's comment. If the research study is case study of typhoon, characteristics of DSD in typhoon case for each position would be the most important issue. However, the present study is the statistical research study based on long term DSD data. Therefore, I only touched the entire typhoon case data observed in Busan area to find out the dominant characteristics of DSD.

Page 4019, line 24: Could you add a reference for "Nw generally varies inversely to Dm" ?

Author's answer : Thank you for reviewer's comment and I'm so sorry for that I can not find related sentence in page 4019, line 24 but I found the similar sentence at page 4018, line 24. The relation between Dm and Nw was inverse as shown in Figs. 5 and 6 and this result is consistent with previous study by Bringi et al. in 2003. And the research done by Bringi et al. (2003) was included in the manuscript.

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