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# Comparison of Raindrop Size Distribution Characteristics Across the Southeast Asia Region

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***Abstract***

*Satellite communication requires reliable estimates of the channel characteristics, especially with the future use of higher frequencies. Regardless of the rain rate, the shape of rain drop size distribution (DSD) start to considerably effect the specific attenuation. In this study DSDs are studied using ground-based two-dimensional video disdrometer measurements taken from Johor, Malaysia as well as two similar datasets from Gan and Manus, two equatorial islands. Integral rain parameters are studied to explain DSD variations across the Southeast Asia region. Slightly higher raindrop concentrations and larger diameters were observed in Johor than in Gan or Manus, which is due to Johor being affected by not only oceanic rain- fall but land rainfall as well. The measured rainfall was classified into convective and stratiform precipitation types; the results showed that the Southeast Asia region is dominated by convective rain in terms of accumulated rainfall amount, but stratiform rain occurred more frequently. Further, seasonal variations observed in Johor were insignificant and the DSD variation was mostly due to changes in percentage occurrence of the precipitation types for each monsoon season.*

***Keywords****: raindrop size distribution, seasonal variations, convective rain, stratiform rain*



## 1. Introduction

In satellite communication and remote sensing, knowledge of channel characteristics is of utmost importance. Rain rate data are available on a global scale. For a known rain rate, however, the specific attenuation may considerably vary, depending on the shape of the rain drop size distribution (DSD) [1]. It is necessary to understand the variability of DSD to improve quantitative precipitation estimation (QPE) and microphysics parameterisation, ensuring accurate quantitative precipitation forecasts (QPF) [2, 3].

Despite their heavy rain characteristics, DSDs of equatorial rainfall are not commonly studied because they require measurements to be done in remote locations for extended periods of time [4, 5]. Thus, the main goal of this study is to analyze DSDs across the Southeast Asia region, and to elucidate the variations of those DSDs. To that aim, we used new 2D video disdrometer (2DVD) measurements from Johor, Malaysia (12-month) [6]. and compared these measurements with similar datasets from the equatorial Gan Island in the Indian Ocean (3.5-month record) and Manus Island in the West Pacific Ocean (18-month record) [7]. The locations where data were collected, as well as other locations of DSD research are shown in Figure 1.

Bringi [8] found that DSD characteristics demonstrate a clear separation between convective and stratiform events in terms of the $\log_{10} N_W$ versus $D_0$ variation, with three separate regions (convective, stratiform, and transitional rain). The fitting procedure has been described previously in [9], and goodness of fit was later tested by [10] and [11]. In the current study, separation was conducted using these methods to obtain an overview of occurrence and percentage statistics. Additionally, to address seasonal variation in Johor, the year was separated into two primary mon- soon seasons, as described by [12]: Northeast (NE) and Southwest (SW), which correspond to June-September and December to March, respectively. Smaller inter-monsoon seasons were designated as Pre-southwest and Pre-northeast. A brief description of the DSD database and methods used is given in Section 2. DSD characteristics

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comparisons and seasonal variations are presented in section 3. Finally, section 4 includes concluding remarks.

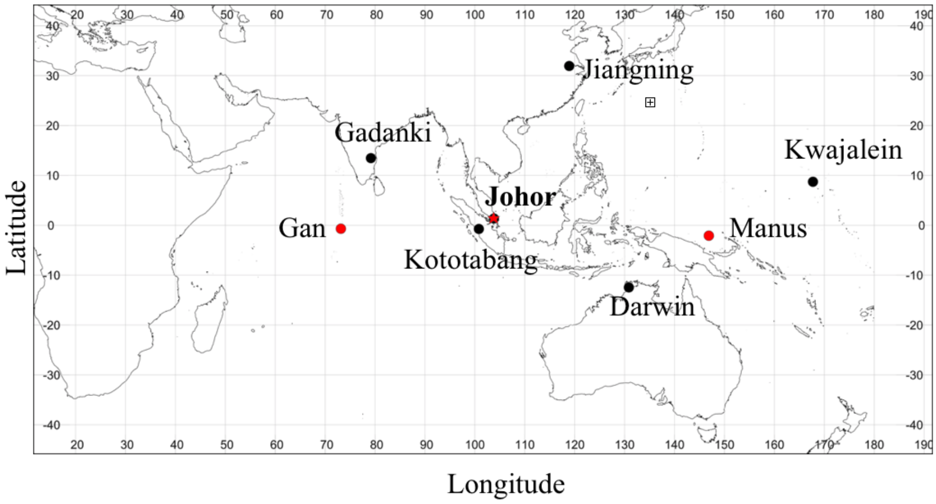



Figure 1. Location of Johor, Gan Island, Manus Island, with other location of DSD research in the South-east Asia region

## 2. The Raindrop Size Distribution Database

The 2DVD in Johor has been operational since 1 July 2015; the data examined here were collected for one year starting from that date [6]. The data from the Manus and Gan Islands were described in [7]. The Inter Tropical Convergence Zone (ITCZ) varies over the year following the suns zenith point and at times passes over Malaysia, causing the trade winds to change from a northeast direction (NE) to southwest direction (SW). This results in two major seasons (monsoons) and two inter-monsoons over Malaysia. Figure 2 shows the monthly accumulated rain and ground temperature in Johor, Malaysia averaged over 3 years of measurements at the same location. March appears as the rainiest month in a year, while July exhibits the relatively highest temperature.

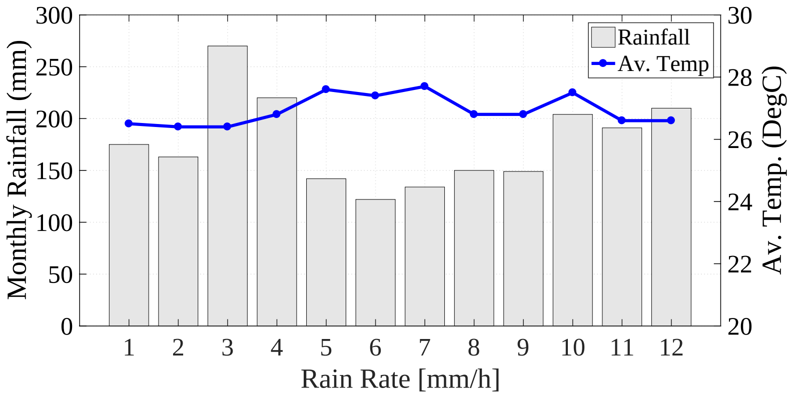
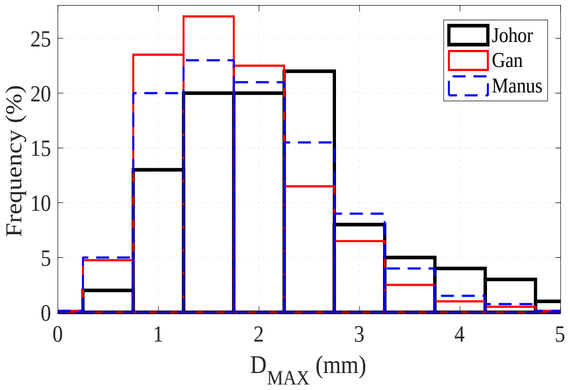



Figure 2. Monthly rainfall and temperature in Johor averaged over 3 years of measurements

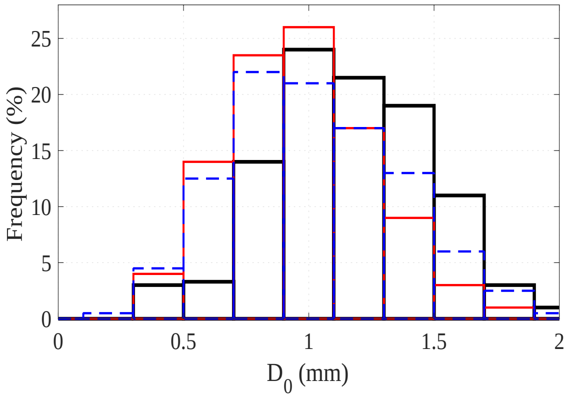
To prepare the database for the present study, only 1-minute DSD data with a minimum of 100 drops or a rain rate of 0.05 mm/h during at least 3 consecutive rainy minutes were analysed. This was done to exclude minutes containing only a few small drops of rainwater, which could skew the analysis [9].

### 3. Results and Analysis

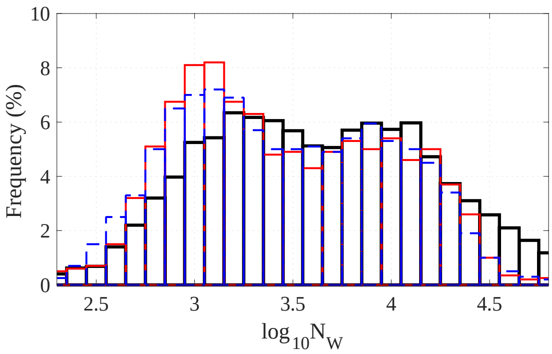
To represent DSD variability, the maximum raindrop diameter $D_{MAX}$, the median diameter $D_0$, and the number concentration $\log_{10} N_W$ histograms normalised by the length of each dataset are shown in Figure 3.




(a)




(b)




(c)

Figure 3. Normalised histograms of measured 2DVD DSD data in the three research locations (Johor, Gan, Manus): (a) maximum diameter DMAX (mm), (b) median diameter D0 (mm), and (c) number concentration log10 NW (unitless)

Further, Table 1 includes integral parameters variances, means, standard deviations, minima, maxima, and 5th and 95th percentiles. While similar trends can be seen over the three locations, higher means were detected in Johor, indicating the continent effects.

Table 1. Mean, Variance (Var), Standard Deviation (Std), Min, Max, and 5th and 95th Percentiles of Integral Rain Parameters ($D_{MAX}$, $D_0$, $\log_{10} N_W$, and Liquid Water Content (LWC)) at the Three Research Locations (Johor, Gan, Manus)

| Parameter | Location | Mean | Var | Std | Min | 5% | 95% | Max |
|---|---|---|---|---|---|---|---|---|
| | Johor | 2.44 | 0.86 | 0.93 | 0.80 | 1.10 | 4.30 | 7.90 |
| $D_{MAX}$ | Manus | 2.16 | 0.73 | 0.85 | 0.80 | 1.00 | 3.66 | 8.54 |
| | Gan | 2.06 | 0.69 | 0.83 | 0.80 | 1.01 | 3.55 | 7.61 |
| | Johor | 1.28 | 0.13 | 0.35 | 0.46 | 0.74 | 2.10 | 4.12 |
| $D_0$ | Manus | 1.11 | 0.11 | 0.33 | 0.34 | 0.61 | 1.65 | 3.83 |
| | Gan | 1.08 | 0.10 | 0.32 | 0.35 | 0.62 | 1.62 | 3.35 |
| | Johor | 3.65 | 0.32 | 0.56 | 1.70 | 2.74 | 4.60 | 5.76 |
| $\log_{10} N_W$ | Manus | 3.70 | 0.28 | 0.53 | 1.57 | 2.89 | 4.55 | 5.22 |
| | Gan | 3.72 | 0.29 | 0.54 | 1.97 | 2.95 | 4.59 | 5.75 |
| | Johor | 0.47 | 0.62 | 0.80 | 0.01 | 0.02 | 2.03 | 12.9 |
| LWC | Manus | 0.35 | 0.58 | 0.76 | 0.00 | 0.01 | 1.72 | 12.6 |
| | Gan | 0.32 | 0.43 | 0.65 | 0.01 | 0.02 | 1.56 | 8.75 |

The bimodality in log10 NW distribution were similar to other maritime locations found by [13]. This is produced by the differences between convective and stratiform rain. Many other tropical DSD studies [9, 10] list similar mean $D_0$ and $\log_{10} N_W$. The convictive and stratiform separation (C/S) was estimated for Johor using the method described in [11] the transitional period between the two types of rain which lies on the separation line is also highlighted, though not included with the stratiform and convective rain. Table 2 shows the variability of C/S rain fraction and frequency of occurrences.

Table 2. Variability of Rain Type Fraction by Number of Samples (Minutes), Rain Rate (mm/h), Total Accumulated Rain (mm) and the Percentages of Accumulation and Occurrence

| Rain Type | Sample (min) | RR (mm/h) | R (mm) | % Accumulation | % Occurrence |
|---|---|---|---|---|---|
| Convective | 1837 | 36.83 | 1110.6 | 71.84 | 13.7 |
| Stratiform | 9614 | 2.19 | 182.8 | 11.82 | 71.74 |
| Transitional | 1952 | 7.86 | 252.5 | 16.34 | 14.56 |
| Total | 13403 | 7.05 | 1.28 | 100 | 100 |

The C/S rain statistics for Johor were 71/12% in total rain accumulation and 14/72% of all rain occurrences. A similar trend was observed in Manus where C/S accumulated rain accounts for 81/19% and 41/59% of all occurrences [7]; however, the differences in occurrence might be due to the seasonal variations.

Figure 4 shows the percentages of occurrences of each type of rain in each monsoon and inter-monsoon season. While similar trends were observed in the NE and SW seasons, higher convective percentages occurred during the inter-monsoons, reflecting more localised climates.

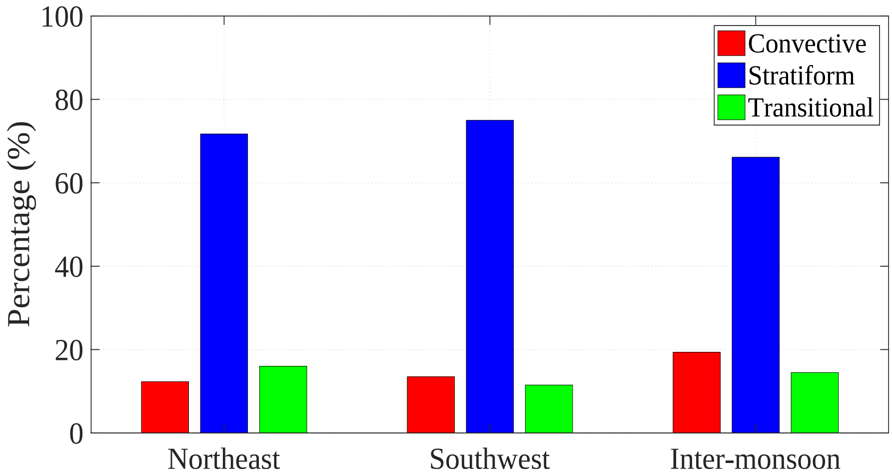



Figure 4. Percentages of occurrences of each type of rain in each monsoon and inter-monsoon season in Johor

To relate the DSD to radar remote sensing, one of the most important DSD characteristic properties to represent is the average DSD. Figure 5 presents the average DSD at Johor for the specified rain rates of 3 mm/h (4.77dBR) and, for the four monsoon seasons, 30 mm/h (14.77dBR). The selected rain rates are commonly used to represent light and heavy rain rates. Similar to [12] findings in Singapore, minimum seasonal variation was observed in Johor, which will, in turn, produce similar Z-R relationships among the different monsoon seasons.

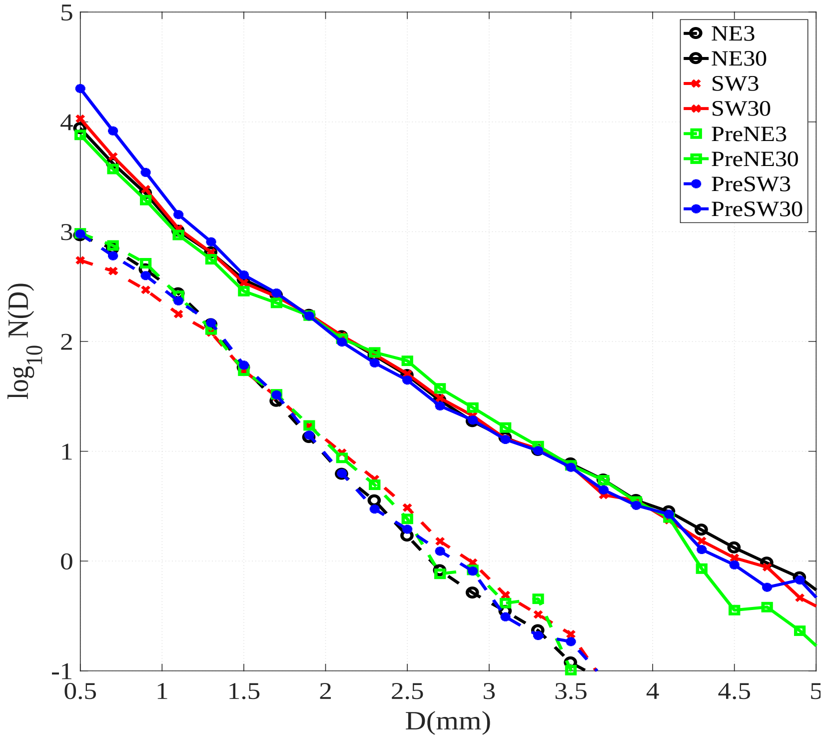



Figure 5. Average DSDs in Johor around 3 mm/h and 30 mm/h for the four monsoon seasons (Northeast, Southwest, Pre-southwest, and Pre-northeast)

## 4. Conclusion

In this study, the characteristics of DSD in Southeast Asia have been studied using a 1- year (2015-2016) dataset collected by 2DVD in Johor, Malaysia, which was then compared with two similar data sets from the Gan and Manus Islands. The normalised integral rain parameters for these locations were compared, revealing higher drop sizes and number concentration in Johor compared to Gan and Manus. The Johor dataset was further divided into convective and stratiform types based on the log10nw (D0) method and into monsoon seasons (NE, SW, Pre-NE, Pre-SW), with statistics presented.

It is concluded that the slightly higher concentration with higher drop sizes in Johor com- pared with the other two locations is due to the fact that Johor is affected both by land and oceanic rainfall, while Gan and Manus are open ocean locations. The recorded rainfall was dominated by convective rain in terms of accumulated rain amount, while stratiform events occurred more frequently. Seasonal variations were limited where the rain type characteristics remained stable for the whole year, which will, in turn, produce similar Z-R relationships among the different monsoon seasons; however, the frequency of occurrence was different for each monsoon.

The results shown here could influence regional satellite studies on propagation impairment mitigation techniques. Longer measurements should be used as more data are collected. Future researchers can investigate more detailed rain type classifications as well as the relations between microphysical processes and DSD using radar data. The vertical structure of DSD can also be studied to evaluate DSD during raindrops fall.

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