Spatial and Temporal Variability of Raindrop Size Distribution within the TRMM/GPM Radar Footprint

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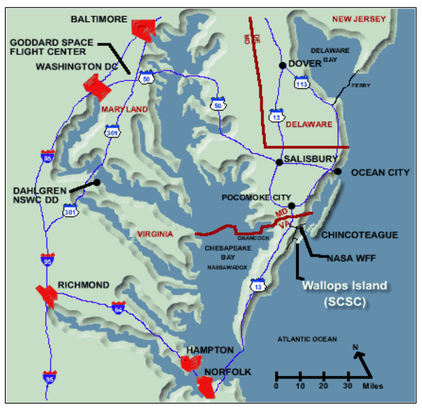
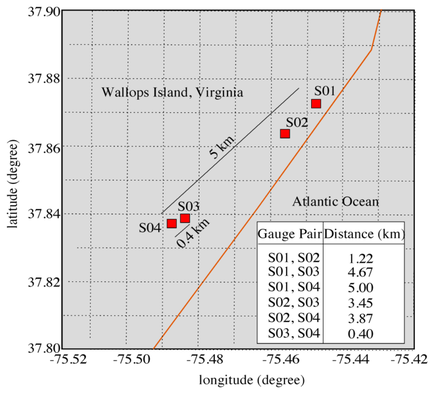
1. Introduction





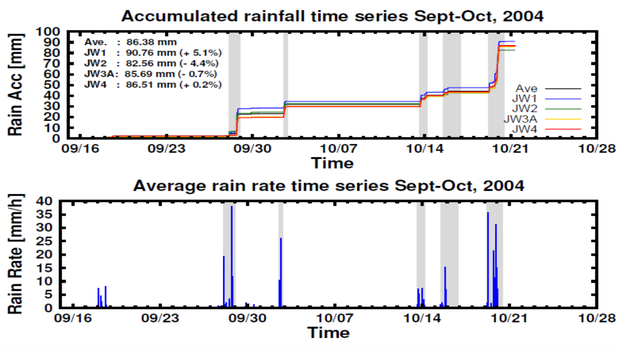
Gauge Pair	Distance (km)
S01, S02	1.22
S01, S03	4.67
S01, S04	5.00
S02, S03	3.45
S02, S04	3.87
S03, S04	0.40

Research Objective

Investigate the spatial and temporal variability of raindrop size distribution within the TRMM/GPM radar footprint.

The disdrometer network included four sites that were separated from 0.4 to 5 km and positioned in a line. The sites included an impact type Joss-Waldvogel (JW) disdrometer and a tipping bucket (TB) rain gauge. One of the sites had two additional JW disdrometers and one additional TB gauge which helps to determine the measurement accuracy. The experiment was conducted in September and October 2004 during which about 94 mm of rainfall fell in 2,135 1-minute observations. There were five major rain events which featured the remnants of Hurricane Jeanne (2004), isolated convection, and frontal systems.

2. Rain Events

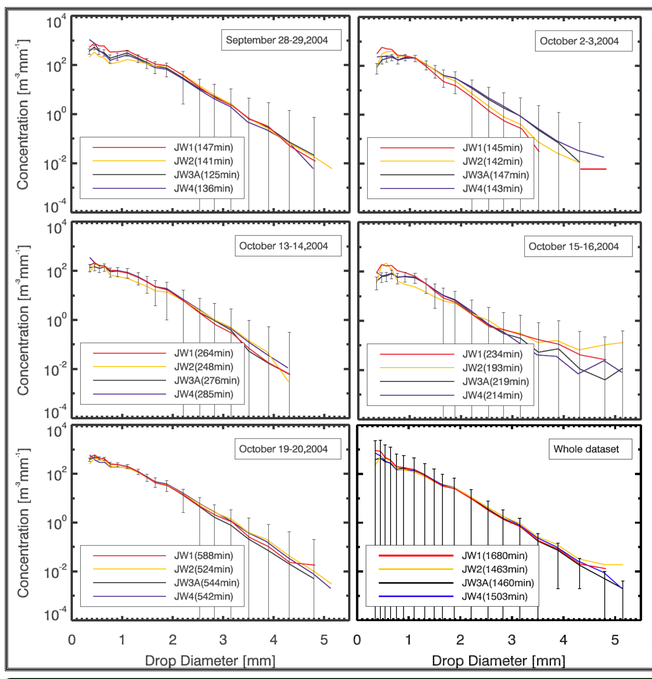


The rain accumulations of the individual disdrometers show noticeable differences from the areal mean with a maximum percent absolute bias of 12.6% for JW2 (S02).

Major rain events are indicated by grey bars. They comprise convective, stratiform and mixed rain events. The precipitation systems are mostly moving from southwest to northeast, perpendicular to the experimental set up.

Event	Date	Event characteristics	Moving direction	Mean rainy minutes	Max rain rate [mm/hr]	Mean rain total [mm]	Mean % occurrence (rainrate < 5mm/hr, rainrate > 10 mm/hr)
1	28-29 Sept	Hurricane Jeanne (2004)	N & E	137	67.4	20.2	58.3, 28.0
2	2-3 Oct	Cold front, convective,stratiform	N	144	57.8	8.5	77.3, 5.9
3	13-14 Oct	Occlusion, stratiform	NE	268	20.5	8.7	92.2, 1.2
4	15-16 Oct	Occlusion, stratiform	NE	215	32.5	3.7	98.3, <1
5	19-20 Oct	Stationary front, stratiform,convective	N-NE	550	73.0	42.2	68.9, 9.9

3. Composite Raindrop Size Distribution



Rain rate, event 1	All sizes [mm/hr]	Small drops (<1 mm)	Midsize drops (1-3 mm)	Large drops (>3 mm)
R_{JW1}	10.36	0.44	2.09	0.06
R_{JW2}	8.96	0.40	2.81	0.10
R_{JW3A}	8.56	0.36	7.43	0.78
R_{JW3B}	7.79	0.37	6.92	0.50
R_{JW3C}	8.15	0.40	7.21	0.54
R_{JW4}	7.41	0.30	3.60	0.28

Reflec-tivity, event 1	All sizes [mm^6m^{-3}] ([dBZ])	Small drops (<1 mm)	Midsize drops (1-3 mm)	Large drops (>3 mm)
Z_{JW1}	7,458 (38.7)	48	5,567	1,843
Z_{JW2}	7,554 (38.8)	17	5,564	1,972
Z_{JW3A}	6,729 (38.3)	30	4,663	2,036
Z_{JW3B}	5,407 (37.3)	31	4,173	1,203
Z_{JW3C}	5,775 (37.6)	33	4,387	1,355
Z_{JW4}	5,595 (37.5)	26	4,079	1,490

4. Rainfall Statistics, Normalized Gamma RSD Model and Partial Beam Filling

$$N(D) = N_T^* f(\mu_1)\left(\frac{D}{D_{mass}}\right)^{\mu_1} \exp\left[-(4+\mu_1)\frac{D}{D_{mass}}\right]$$

$$f(\mu_1) = \frac{(4+\mu_1)^{\mu_1+1}}{\Gamma(\mu_1+1)} \qquad N_T^* = \frac{N_T}{D_{mass}}$$

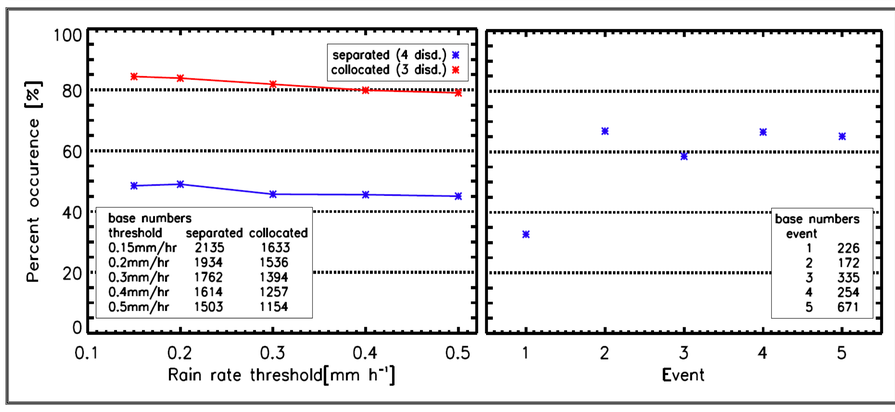
$$N(D) = N_W g(\mu_2)\left(\frac{D}{D_{mass}}\right)^{\mu_2} \exp\left[-(4+\mu_2)\frac{D}{D_{mass}}\right]$$

$$g(\mu_2) = \frac{6(4+\mu_2)^{\mu_2+4}}{256\Gamma(\mu_2+4)} \qquad N_W = \frac{256W}{\pi\rho_w D_{mass}^4}$$

D = drop diameter
μ = shape parameter
D_{mass}= mass-weighted drop diameter
W = liquid water content

N_T^* = normalized intercept parameter with respect to the total concentration
N_W = normalized intercept parameter with respect to the liquid water content

5. Partial Beam Filling and Stretched Correlation Function



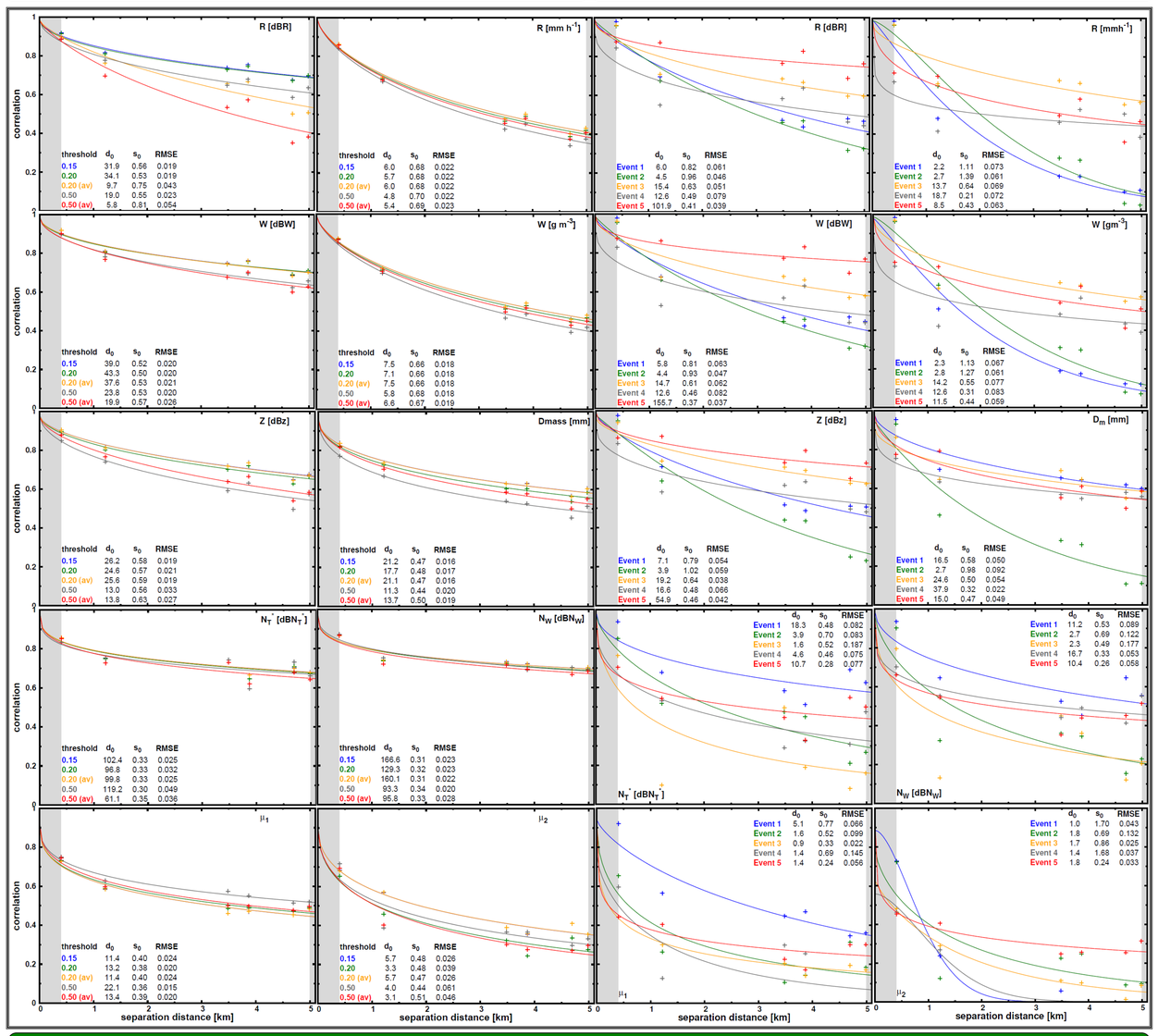
$$r(d) = r_0 \exp\left[-\left(\frac{d}{d_0}\right)^{s_0}\right]$$

r = correlation coefficient
r_0=nugget parameter (correlation between collocated disdrometers)
d =separation distance
d_0=decorrelation distance
s_0 =shape parameter

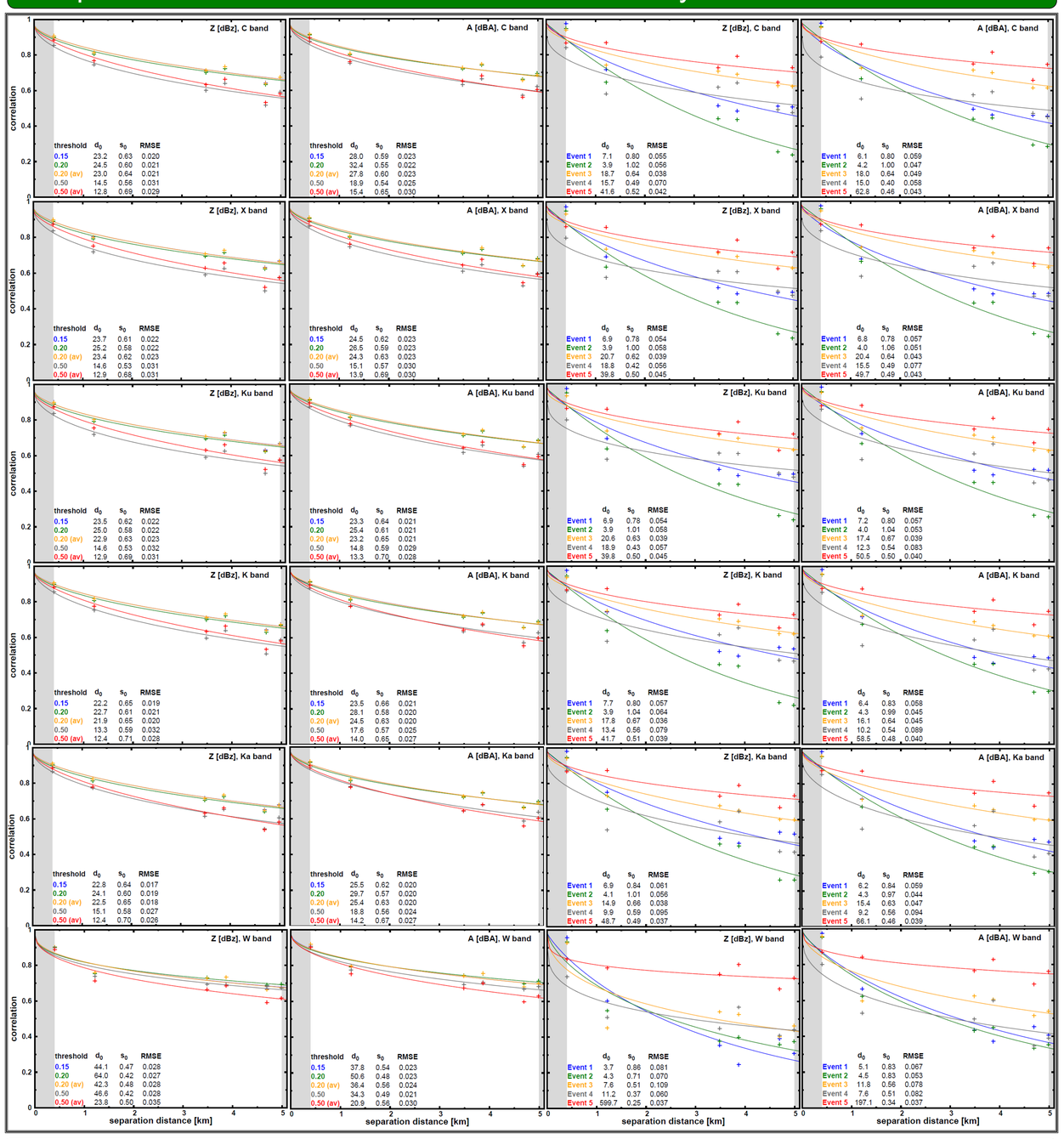
7. Spatial Correlation of Integral Rainfall and RSD Model Parameters

7a. Combined data set

7b. Events



7. Spatial Correlation of Attenuation and Reflectivity of various radar bands



9. Conclusions

- Midsize drops are the main contributor to rain rate, while midsize and large drops contribute at most to reflectivity. For the total concentration, small and midsize drops are the main contributors. (Section 3)
- Partial beam filling is evident. One or more didrometers did not report rainfall about 50 % of the time. (Section 5)
- r_0 ranges mainly between 0.96 and 0.99 for all integral rainfall and RSD parameters
- d_0 ranges between 4.5 km (event 2) and about 100 km (event 5) for rain rate, corresponding to different event characteristics. Events 4 and 5 have uniform rainfall resulting in high correlations, whereas events 1 and 2 exhibit high variability, resulting in relatively low correlations. (Section 7)
- Regarding the normalized parameters, d_0 is relatively low for the whole data set of two months. This is due to the fact that the normalization makes N_T^* and N_W being more independant on the rain intensity
- The cdf/pdf plots for the four seperated disdrometers show good agreements as it is expected for averaging over a longer time period
- The correlation tends to increase for reflectivities and attenuations which are affected by Mie scattering (section 8). The results for the events show, that this may not be stated in general. The long and intense event 5 has a large impact on the results for the entire data set.