

DISTROMETER RESULTS OBTAINED IN VARIOUS CLIMATES AND THEIR APPLICATION TO WEATHER RADAR DATA INVERSION

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INTRODUCTION

In the fields of radar meteorology and tropospheric wave propagation detailed knowledge on rain drop size distributions is one of the fundamentals required for successful modeling work. Distrometers are used to provide point monitoring spot checks of the precipitation microstructure. The rapid technological development changed the scene of precipitation measurement as well. Recently imaging distrometers are available, recording front and side view of each individual particle reaching the sensing area. Such results reveal some insufficiencies of standard rainfall models used so far. Measurements were performed in the tropical regions, in the Great Plains of the USA and in the European moderate climate zone. A significant dependence of the rainfall's structure on climate was observed. Tropical rain is of special interest when observing the global water cycle, furthermore for telecommunications, since in the tropical regions earth-space as well as terrestrial communication will strongly increase in the near future. On a case basis the benefit of precise knowledge on rainfall parameters is demonstrated, and the need for further measurements and analyses pointed out.

MEASUREMENTS AND DATA VALIDATION

The data for the present investigations stem from 2D-Video-Distrometer systems [1]. Measurements were performed in Graz, Austria, in Lae, Papua New Guinea (PNG), in Colorado, USA by quasi-mobile employment of the instrument, and in Norman, Oklahoma, USA. Data validation is made of three bases: Firstly the correct reproduction of individual particles is checked. Since the 2D-Video-Distrometer is an imaging device this may simply be done by dispensing high precision steel spheres. Fig. 1 shows the result in an 'Oblateness vs. Diameter' diagram with the dots indicating the actual and the yellow crosses the required values. Fall velocities of the calibration spheres differed from those of raindrops with the same size, thus for the bigger drops pretending a slightly better (i.e. smaller) spread around the mean oblatenesses. Fig. 2 presents a scatter diagram comparing rainrates by a tipping bucket raingauge versus those of a 2D-Video-Distrometer. A rain amount of 41.1 mm was recorded for this particular (tropical) rain event, the mean difference for the individual tips is less than 1 % with a correlation coefficient of 0.97. Typically this difference is less than 10 %. And finally the validation of 2D-Video-Distrometer data is based on automatically written log files, precisely reporting about any interruptions of the data acquisition task.

TYPICAL RAIN EVENTS

Four typical rain events are discussed in the following with emphasis laid on the distrometer-measured drop size distribution (DSD). Representative periods are taken out of these events and the measured DSD is compared with literature models. The well known Marshall-Palmer drop size distribution (MP-DSD) [2] is considered as well as the Joss-Drizzle (JD-DSD) and the Joss-Thunderstorm (JT-DSD) models [3]. These three are exponential models with the scaling factor N_0 fixed to 8000, 30000 and 1400 /m³mm respectively. The only variable left for the adaptation to natural rain is D_0 , thus these models may be called one-parametric DSDs. Comparisons of measured and literature DSDs may also be done in the domain of radar reflectivities and derived quantities. Based on their dependence on the drops' diameters power of six, reflectivities show the behaviour of DSDs in a more pronounced and at the same time application oriented way.

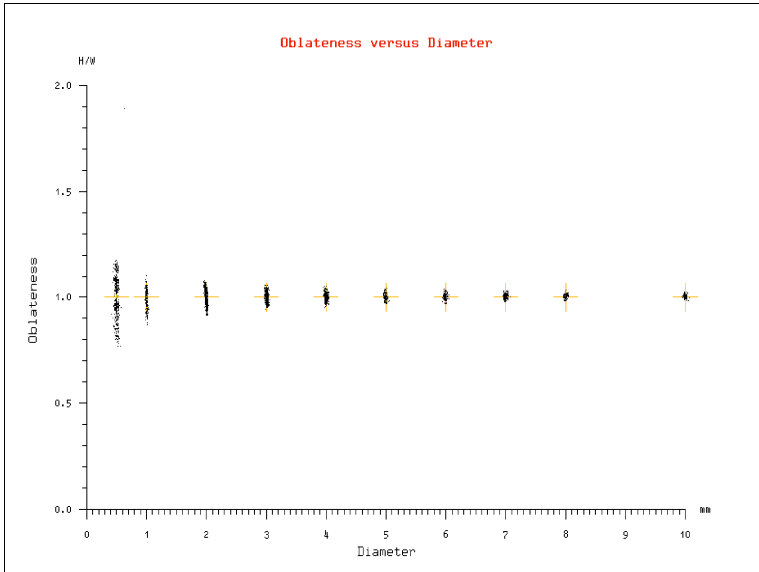


Fig. 1. Spheres in the 'Oblateness vs. Diameter' diagram confirming correct calibration state. Dots indicate actual, yellow crosses the required values.

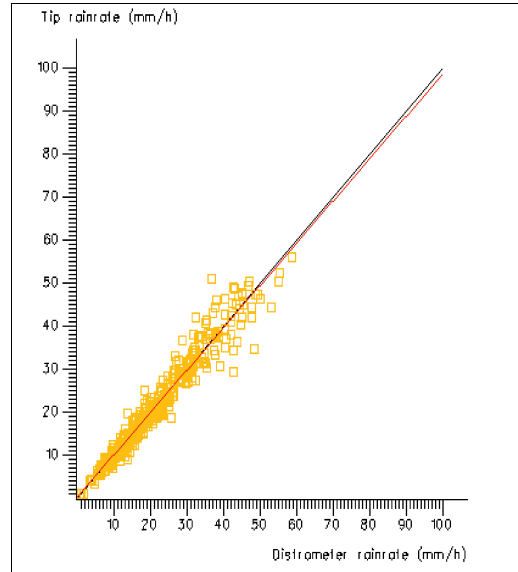


Fig. 2. Scatter diagram comparing rainrates by tipping bucket vs. 2D-Video-Distrometer 41.1 mm rain recorded in Lae / PNG, Aug. 30 1995, 21:00 - 24:00

Widespread Rain Event recorded in Norman, Oklahoma, USA

A widespread rain event was recorded on April 27, 1998, as representative part the period 02:45 - 03:45 is chosen. Fig. 3 shows the measured DSD in comparison with the before mentioned models. Mean rainrate (R) for this hour is 10.81 mm/hr, made out of drops smaller than 5 mm in equivolumetric sphere diameter. It is clearly visible, that such a widespread rain DSD may very well be described by the literature models, it falls well within the range defined by the JT-DSD and the JD-DSD. This result is not surprising since the before mentioned models are based on statistically significant observations in the moderate climate zone, carried out by instruments very well capable of measuring drops in the observed size range.

Storm Event recorded in Graz, Austria

Fig. 4 shows distrometer DSD - derived radar reflectivities Z_H (red) vs. time for a convective event recorded in Graz, Austria. The result obtained from $Z_H=200 \cdot R^{1.6}$, approximately representing the MP-DSD, is given as black line. At times enormous differences of up to 16 dBZ are observed, because in this case the standard models strongly underestimate the number of 'big' drops. Whereas rainrate never exceeds 30 mm/hr drops up to 7.5 mm are observed, this is a totally unexpected result.

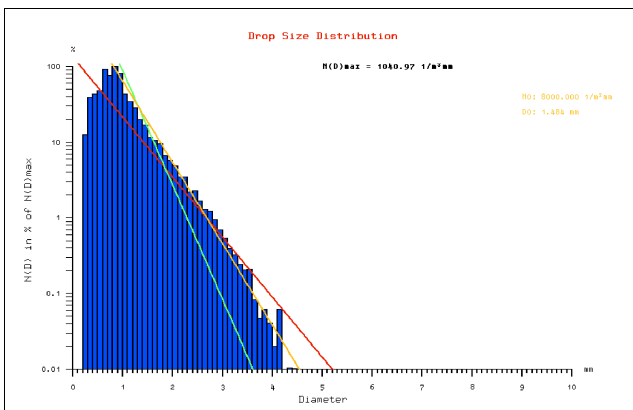


Fig. 3. DSD of widespread rain on April 27, 1998, 02:45 - 03:45, in Norman, OK, USA. Class width = 0.1 mm, uncalibrated below 0.5 mm. MP-DSD (yellow), JT-DSD (red) and JD-DSD (green) indicated. Mean R = 10.81 mm/hr.

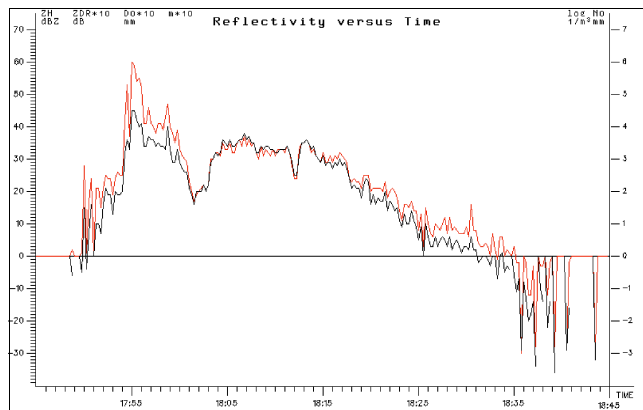


Fig. 4. Radar reflectivities vs. time, derived from distrometer DSD (red) and rainrate (black, using $Z_H=200 \cdot R^{1.6}$), for storm event recorded on June 18, 1997, 17:45 - 18:45, in Graz, Austria. Period considered in Table 1 is 17:54 - 18:00.

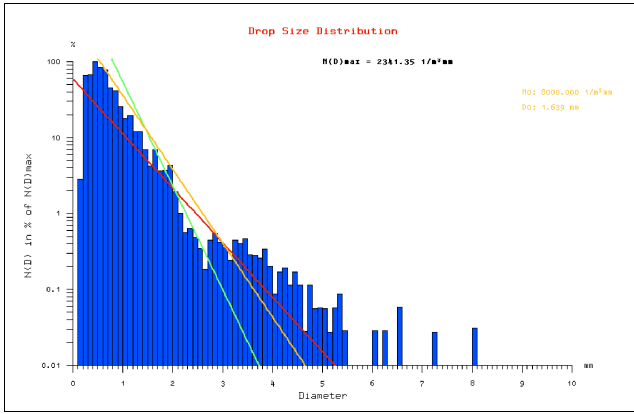


Fig. 5. DSD of out of storm, recorded on June 05, 1996, 21:15 - 21:18, in CO, USA, during chase campaign. Same representation as in Fig. 3. Mean R = 17.38 mm/hr.

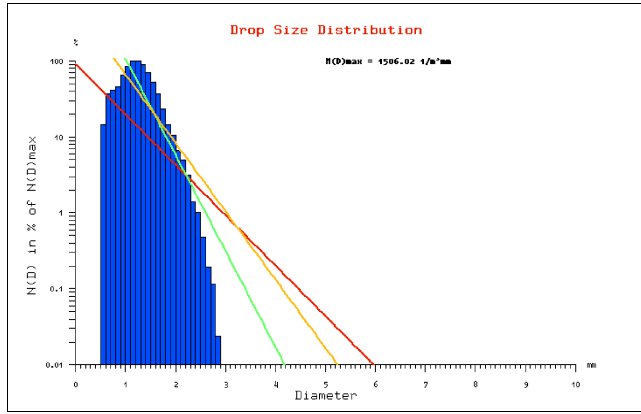


Fig. 6. DSD out of tropical rain, recorded on August 30, 1995, 22:10 - 22:30, in Lae, Papua New Guinea. Same literature models as in Fig. 3. Mean R = 25.24 mm/hr.

Storm Event recorded in Colorado, USA

Very similar as in the storm event in Graz discussed before (Fig. 4) the measured DSD considerable deviates from the literature models also for this storm event recorded in Colorado, USA. Fig. 5 presents the DSD for a three minutes interval with a mean rainrate of 17.38 mm/hr, including a sharp peak of 67.73 mm/hr (at 15 seconds integration intervals). Drops up to more than 8 mm in equivolumetric sphere diameter were recorded, again a totally unexpected observation. The reason for the literature models underestimating the number of 'big' drops may indeed be the fact, that many distrometers used so far did not classify such big drops. Especially electromechanical (impact type) distrometers suffer from the fact, that fall velocity saturates. For a 5 mm drop e.g. fall velocity is expected to be 9.14 m/s, for an 8 mm drop the estimate gives similar 9.57 m/s. Fig. 7 presents front and side view of the biggest drop out of the DSD in Fig. 5. It may break up soon, since the equilibrium shape (e.g. given in [4]) is still recognized but not redrawn in its pure form. The yellow lines represent the axes of symmetry (and their canting angles) as determined by software. However in reality this drop's views do not reveal perfect symmetries, as the irregularly bent lines between the blue and black halves clearly show.

Tropical Rain recorded in Lae, Papua New Guinea

In contrast to moderate climate storms for tropical rainfall literature models often do overestimate the number of 'big' drops. Fig. 6 gives a typical example. Twenty minutes out of a several hours lasting event are represented, the mean rainrate was 25.24 mm/hr. The significant difference to moderate climate models may be explained by the different height of the zero degree isotherm. In the tropics it is frequently found near to 5 km M.S.L., this fall height allows the DSD to develop much further than in moderate climate regions.

DISCUSSION OF THE MEASURED DSDs AND THEIR IMPLICATIONS

The before mentioned four DSDs are summarized in Table 1. As general information the event type, the relevant figure number and the length of the period considered are specified. Based on the distrometer-measured DSDs the radar reflectivities Z_H , Z_{DR} and the rainrate are given. Parameters for reflectivity calculations were a frequency of 5.625 GHz, a

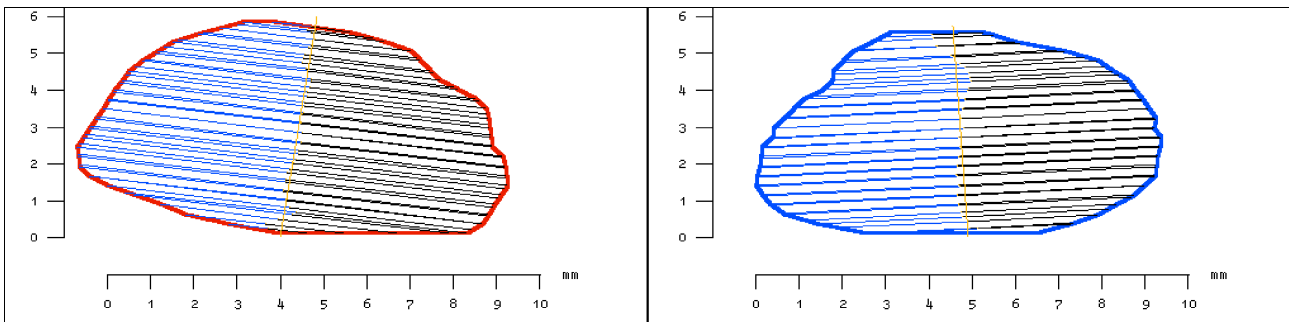


Fig. 7. Biggest drop out of DSD shown in Fig. 5. Recorded at 21:17:07.625, equivolumetric sphere diameter = 8.05 mm, height / width ratio = 0.62, fall velocity = 8.99 m/s. Canting angles indicated by yellow lines.

Table 1. Summary of the four events and their representative DSDs, derived values and comparison with literature models

general			distrometer-based			Z_H, Z_{DR}, R - derived			comparison with literature models						
event type	cf. Fig	per.	Z_H	Z_{DR}	R	N_0	D_0	μ	R_{MP}	$\cdot R$	$R_{2par.}$	$\cdot R$	$N_{expon.}$	a	b
		min	dBZ	dB	mm/hr	/m ³ mm	mm	1	mm/hr	%	mm/hr	%	/m ³ mm	1	1
wide	3	60	40.13	1.45	10.80	13875	1.99	5.3	12.87	+ 19.2	15.14	+ 40.2	5000	307	1.45
storm	4	6	51.34	5.69	8.15	200	2.98	-1.5	57.61	+606.9	6.75	- 17.2	110	407	2.26
storm	5	3	53.76	5.38	17.63	325	3.25	0	77.52	+339.7	17.63	0	325	364	1.84
trop.	6	20	40.33	0.79	25.24	14495750	1.58	12.	13.44	- 46.8	33.7	+ 33.5	54250	129	1.37

drop temperature of 10 deg C, an antenna elevation angle of 0 deg and the drop shape model of the ROPEX group [5]. From these Z_H, Z_{DR}, R triplets the parameters for the gamma type DSD model [6] were found. Whereas the tropical rain event is characterized by an extremely high dispersion factor of $\mu = 12$, the Graz storm DSD yields a negative value of $\mu = -1.5$. For comparison with standard models the Z_H values were interpreted by means of the MP-DSD, especially in the storm events resulting in huge overestimates of the rainrate. To a great extent these overestimates can be avoided by use of a dual polarization radar, as the values for the two-parametric method in Table 1 clearly show. This method [7] estimates the rainrate by use of radar measured Z_H, Z_{DR} pairs. N_{expon} states the scaling factor for pure exponential DSDs ($\mu=0$) to match the given Z-R pair. Thus N_{expon} allows a direct comparison with the N_0 range defined by the JD-DSD and the JT-DSD (1400 - 30000 /m³mm), it is exceeded by far. Finally also the coefficients for Z-R regression formulae are given complying with the form $Z = a \cdot R^b$. Again literature values are exceeded (for example cf. the parameter set for an extreme case Z - R relationship given in [8]). It should be pointed out explicitly, that Table 1 represents data from four individual events only, by no means statistical significance can be deduced from.

CONCLUSIONS AND OUTLOOK

Using an imaging disdrometer measurements under various climatic conditions were performed. It is shown, that especially two facts rise the demand for improved modeling work regarding rainfall parameters and their applications (weather radar, wave propagation etc.): on the one hand there is a considerable number of 'big' drops up to 8 mm and more contained in many rain events, whereas in the tropics rain is tendentially made out of more and smaller drops than in moderate climate. The present paper presents results of four typical events only, statistical significance however is required. More measurements under the individual climatic conditions, especially in the tropics are therefore recommended. Future work should consider the climatic dependence in the DSD modeling, even the development of a global map with characteristic DSD types is conceivable.

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