P13.5 ON IMPACT OF DROP SIZE DISTRIBUTION MODELS ON RADAR MEASUREMENT

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1. INTRODUCTION

The rain drop size distribution (DSD) and its appropriate parameterisation plays an important role in the proper interpretation of the meteorological radar measurement as well as in the estimation of the radiowave attenuation due to rain. This contribution is focused on the discussion of basic rain types (drizzle, continuous rain, shower and thunderstorm) and their impact on the radar measurement (influence on the radar reflectivity factor as well as on the specific rain attenuation).

2. DSD IN DIFFERENT RAIN TYPES

The radar reflectivity factor Z is proportional to the rain intensity *R*, however, the rain intensity R is a function of the drop size distribution (DSD); the rain intensity is defined by the following equation:

$$R = \frac{3.6}{10^3}\pi\int_0^\infty D^3 v(D) N(D) dD .$$

The following fact can be deducted: the same numerical value of the rain intensity causes different value of radar reflectivity factor *Z* or a different specific rain attenuation α in different DSDs being typical for certain rain types. The radar reflectivity factor Z depends on the DSD through the following expression

$$Z = 10\log_{10}\{\frac{\lambda^4}{\pi^5 K^2}\int_0^\infty \sigma(D) N(D) dD\} .$$

This definition is often simplified in the Rayleigh scattering region by

$$Z = 10\log_{10}\{\int_0^\infty D^6 N(D) dD\} .$$

The specific rain attenuation α is computable from the next general formula:

$$\alpha' = 4.3434 * \lambda * 10^3 \int_0^\infty \operatorname{Im} f(D) N(D) dD .$$

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The information about the parameters N_0 and λ of the exponential DSD model

$$N(D) = N_0 \exp(-\lambda D) ,$$

in different rain types is rare. In [1] there was published the exponential model of the DSD giving the parameters N_0 as well as λ of DSD for drizzle, continuous rain and thunderstorm&shower [see Tab 1]. The values were derived from the measurements at Locarno (Switzerland) from limited time series.

The information about the parameters N_0, λ and μ of the Gamma DSD model

$$N(D) = N_0 D^\mu \exp(-\lambda D)$$

for different rain types is much more rare than in the exponential DSD model case. For instance according to [2] the parameter values leastwise for stratiform and convective rains in tropical regions were found (see also Tab. 1). The DSD analytical models in accordance with parameters in Tab. 1 are plotted in Fig.1.

Tab. 1 *Parameters of the exponential (Locarno) and gamma (Kapingamarangi) DSD model for different rain types*

Exponential	N_o	λ
Rain type	$mm^{-3} m^{-3}$	mm^{-1}
Storm & shower	1 400	$3 * R^{-0.21}$
Continuous	7 000	$4.1*R^{-0.21}$
Drizzle	30 000	$5.7*R^{-0.21}$

Gamma	N_o	λ	μ
Rain type	$mm^{-3-\mu}m^{-3}$	mm^{-1}	-
Convective	$6.29E5*R^{-0.416}$	$8.35R^{-0.185}$	3
Stratiform	$2.57E4*R^{0.012}$	$5.5R^{-0.129}$	3
Average MP	8 000	$4.1*R^{-0.21}$	0

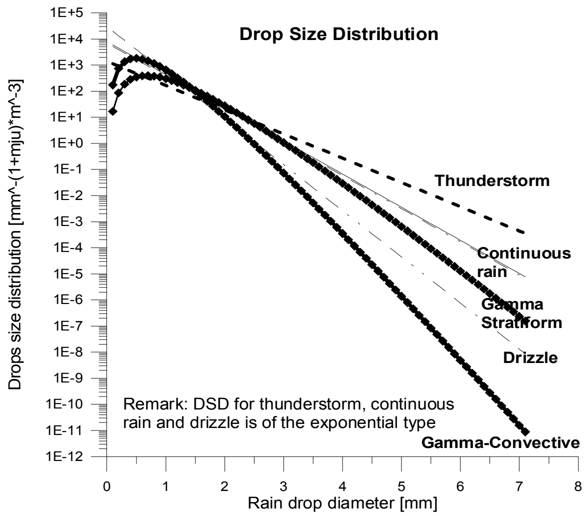

Fig. 1 *The drop size distributions of the gamma type (for tropical region) and of the exponential type (for European region), modelled in accordance with Tab. 1*

3. THE DSD IMPACT ON THE RADAR REFLECTIVITY FACTOR AND ON THE SPECIFIC RAIN ATTENUATION

Fig.2 (S band) and Fig. 3 (X band) demonstrate the interesting relationship between the radar reflectivity factor and the specific rain attenuation for different rain types which have been modelled exponentially in accordance with [1]. The role of the rain type is obvious. It can be deducted, for instance, that the rain attenuation in the continuous rain is greater than in the thunderstorm when the same radar reflectivity factor was measured.

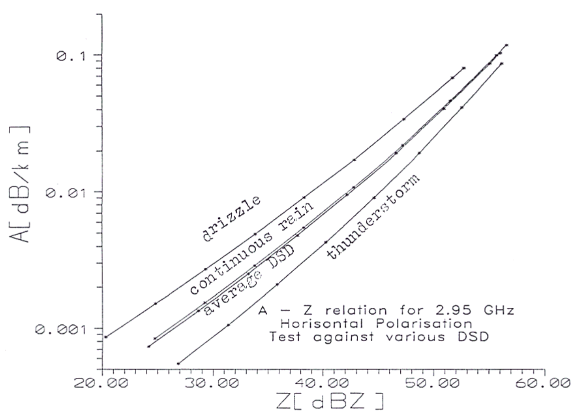

Fig. 2 *Relation between the specific rain attenuation and the radar reflectivity factor for different rain types (S band)*

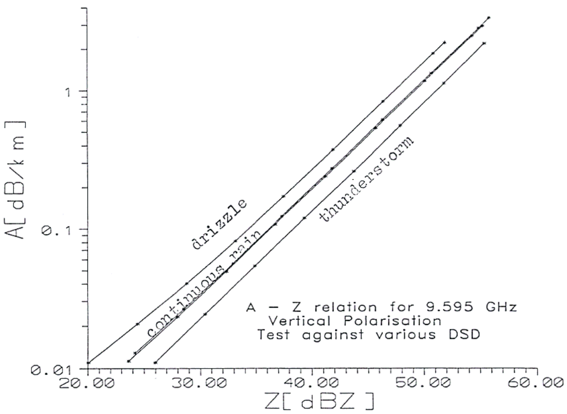

Fig. 3 *Relation between the specific rain attenuation A and the radar reflectivity factor Z for different rain types (X band)*

Fig.4 shows the dependence of the radar reflectivity factor on the rain rate as well as on the rain type in the Rayleigh scattering region based on data in [1].

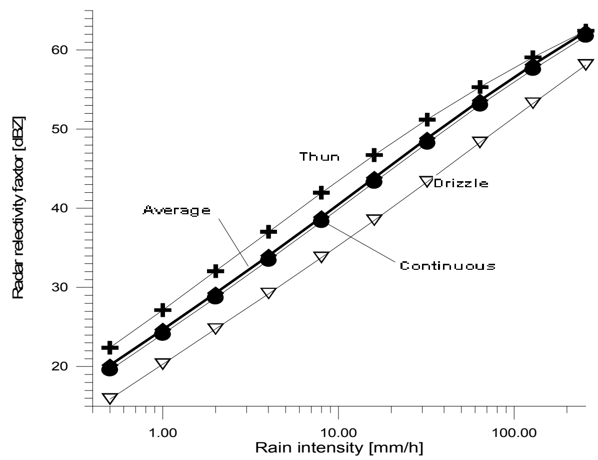

Fig. 4 *The radar reflectivity factor for different rain types*

Fig. 5 shows the interesting ratio of the specific rain attenuation in different rain types related to the attenuation computed from the average Marshall-Palmer DSD [4] in the X frequency band. The relative difference (caused by replacing the average DSD by the DSD modelled in [1]) for different rain types is under 20% in the thunderstorm, shower and continuous rain case; in the case of drizzle the error can achieve 30% (we cannot consider rain rates above 2 mm/h in the drizzle even if they are plotted).

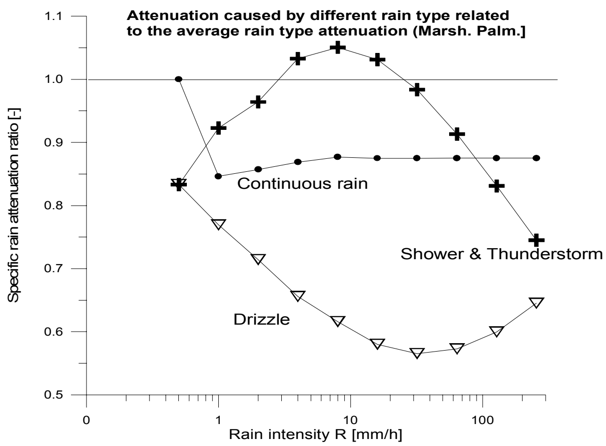

Fig. 5 *Ratio of the specific rain attenuation in different rain types described in [1] to the attenuation computed through the Marshall-Palmer average DSD [4].*

4. CONCLUSION

This contribution has shown the importance of the right DSD modelling in radar measurements. The possible inaccuracy of the radar reflectivity factor or specific rain attenuation estimation due to the rain type interchange is of the order of tens percentages and was demonstrated in figures. The gamma (or log-normal) DSD model should be preferred but the μ parameter should be specified. Its numerical value strongly depends on the DSD's integration time and on the method of computation as well.

Based on distrometer measurement in the Czech Republic it was estimated that for smoothed (long termed) DSD the μ achieves the value of about 0.6 in the average [3] . The μ value is close to 1.6 in convective rain while it is about 2 in drizzle. In the non-smoothed one minute DSDs the μ is much larger in average (it varies from 2 to 12).

5. ACKNOWLEDGEMENT

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6. REFERENCES

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[2] Iguchi T.: Personal communication, August 1999

[3] Fišer O., Schoenhuber M, Pešice P.: First results of DSD measurement by videodistrometer in the Czech Republic in 1998-1999, submitted to the "Studia Geophysica et Geodetica" in 2001

[4] Marshall, Palmer:"The distribution of raindrops with size." Journal Meteorol., 5, 1948,p. 165

EXPLANATION OF SYMBOLS

N drop spectrum (DSD) [m^{-3} $mm^{-1-\mu}$]

D rain drop diameter mm]

N_0 intercept parameter of the DSD [$m^{-3}mm^{-1-\mu}$]

λ (in DSD) slope of DSD [mm^{-1}]

μ "shape" of the DSD

α(or A) specific rain attenuation [dB/km]

Z radar reflectivity factor [dBZ]

R rain rate [mm/h]

v fall velocity of rain drop [m/s]

λ (generally) wave length [cm]

σ back scattering cross section [cm^2]

f forward scattering function [cm^{-1}]

m complex refractive index of water

$$K^2 = \left| \frac{m^2 - 1}{m^2 + 2} \right|$$