Estimation of Rain Rate and Drop Size Distribution from Polarimetric Radar Quantities derived from Disdrometer Measurements

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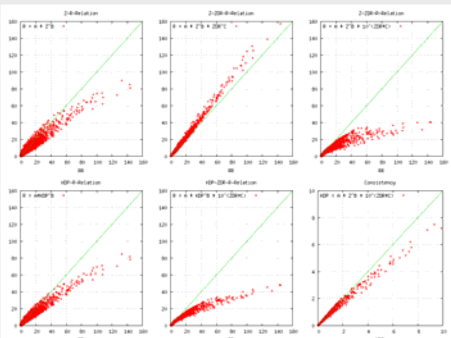
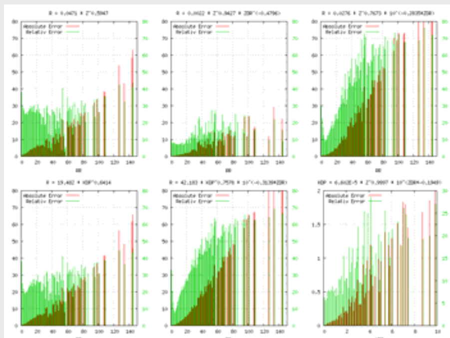
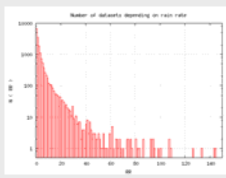
Introduction:
Since the rainfall rate is proportional to the 3.7th moment of the raindrop size distribution (RDSD) and the radar reflectivity is proportional to the 6th moment, it is not possible to estimate rainfall rate exactly by simple Z-R relations. One possibility to improve rainfall estimation by radar measurement is the use of polarimetric quantities like differential reflectivity (ZDR) or the differential propagation phase (KDP). In order to derive the empirical relation it is necessary to use the right RDSD observations. Therefore an optimized parametrisation of RDSD for mid latitudes is estimated and computation of the specific polarimetric quantities for C-Band radar are performed. The aim is to use the results to estimate the RDSD and to improve rainfall rate measurement by polarimetric radar for mid latitudes and C-Band. Measurements in the scope of the AQUAradar project (cf. paper by C. Simmer et al.) will be used to validate the retrieval of the RDSD. The calculations and results refer to measurements with a Joss-Waldvogel-Disdrometer between 16.8.1999 and 14.12.1999 at DLR Oberpfaffenhofen/Germany, which gave more than 16000 usable minute-averaged datasets.

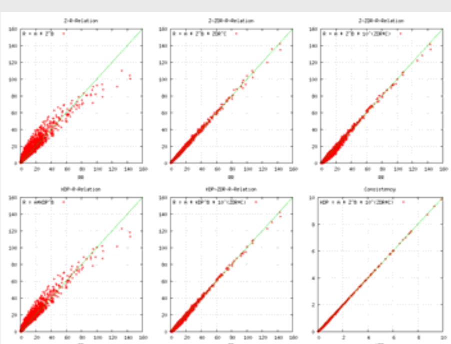
Rainrate Estimation from polarimetric quantities:
First the parameters N0, Λ and μ for a Gamma Size Distribution in the form $N(D) = N_0 D^{\mu} \exp(-\Lambda D)$ are calculated by a method of moments using the second, fourth and sixth moment (Ulbrich 1997). Then the polarimetric quantities ZHH, ZDR and KDP are calculated using T-Matrix and the Gamma Distribution bounded by the minimum and maximum observed raindrop diameter. The first set of figures shows the result of linear regression to calculate Rain Rate by polarimetric quantities using several approaches and the absolute and relative error depending on rain rate. The sixth figure shows a consistency check between the three quantities (Scarchilli 1996).

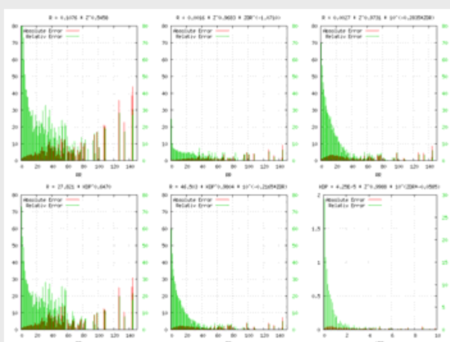




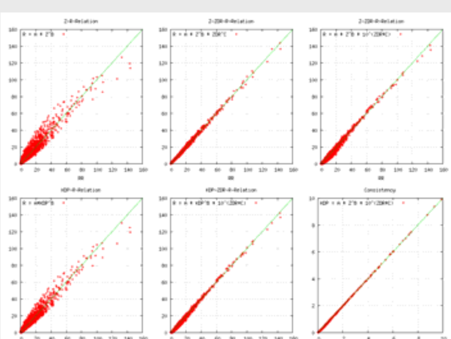
At first sight there is no good correlation especially for higher rain rates between calculated and measured rain rate.
The figure on the right shows that most of the datasets imply low rain rates, so events with high rain rates are not taken into account sufficiently.
The next set of figures shows the result, if only datasets containing high rain rates are considered for regression. Several test with various limiting values showed, that acceptable results are generated by using datasets with rain rate > 40 mm/h or KDP > 3 respectively. This solution is not very elegant but produces results with acceptable absolute errors.

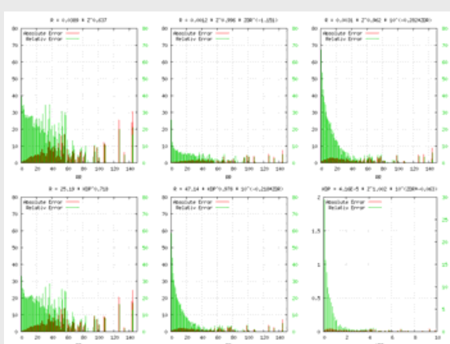






The best correlation between measured and calculated rain rates is produced by a method of weighted regression, which minimises the sum of squares devided by a weighting factor where the number of datasets with the same rain rate (in 1 mm/h steps) is chosen, see next set of figures.

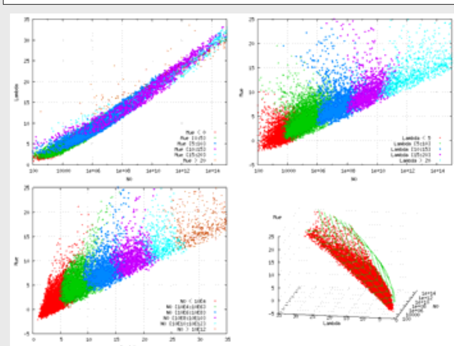




This table shows all the retrieved coefficients for the different equations and the medium absolute and relative error over all values:

Regress	Equation	A	B	C	AE	RE%
all	R=A*Z^B	0.0471	0.595		0.916	31.9
	R=A*^B*ZDR^C	0.0022	0.943	-0.867	0.304	8.5
	R=A*Z^B*10^(C*ZDR)	0.0276	0.767	-0.480	0.778	22.6
	R=A*KDP^B	19.48	0.641		0.816	28.8
	R=A*KDP^B*10^(ZDR*C)	42.18	0.758	0.314	0.773	23.0
	KDP=A*Z^B*10^(ZDR*C)	6.60E-5	1.000	-0.195	0.009	6.4
truncated	R=A*Z^B	0.1076	0.546		1.484	88.0
	R=A*^B*ZDR^C	0.0016	0.968	-1.071	0.225	14.5
	R=A*Z^B*10^(C*ZDR)	0.0027	0.973	-0.283	1.005	53.9
	R=A*KDP^B	27.82	0.647		1.019	54.7
	R=A*KDP^B*10^(ZDR*C)	46.50	0.980	-0.216	0.756	43.9
	KDP=A*Z^B*10^(ZDR*C)	4.25E-5	0.999	-0.059	0.009	26.2
weighted	R=A*Z^B	0.0389	0.637		0.884	34.4
	R=A*^B*ZDR^C	0.0012	0.996	-1.151	0.263	15.9
	R=A*Z^B*10^(C*ZDR)	0.0031	0.962	-0.282	0.944	51.4
	R=A*KDP^B	25.19	0.718		0.677	27.1
	R=A*KDP^B*10^(ZDR*C)	47.16	0.978	-0.218	0.726	42.8
	KDP=A*Z^B*10^(ZDR*C)	4.17E-5	1.002	-0.063	0.010	26.4

Estimation of parameters N0, Λ and μ for a gamma drop size distribution from polarimetric quantities:
The quantities Z and ZDR are measured at every gate by polarimetric rain radar, whereas KDP is the range derivative of ΦDP, the differential phase, over a number of gates. Therefore, only Z and ZDR are used for DSD parameter retrievals. Since the gamma distribution has three parameters, a further relation is needed. There are several proposals to relate two of the three parameters, e.g. a N0-μ-relation proposed by Ulbrich 1983 or a constrainedΛ-μ-relation proposed by Zhang et. al. 2001. The first three figures below show scatter plots of two of the three parameters in each case, the fourth figure gives an impression of the correlation of all three parameters.



The figures 1,2 and 3 show, that a relation between two of the three is more or less noisy, whereas a relation between all three parameters is well approximated by the displayed structure (as well as a 2-D-Plot can show 3-D-relations).

Conclusions and Outlook:
Polarimetric radar quantities are appropriate to estimate rain rate exactly. Measurements in the scope of the AQUAradar project (Summer 2006) will show the practical use. Also the methods for estimating parameters of DSDs by polarimetric radar quantities will be developed and tested next time.

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