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ON THE ACCURACY OF RADAR MEASURED RAIN FALL AMOUNTS

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by

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Zusammenfassung :

Aufgrund von Messungen mit einem Regentropfen-Disdrometer wird die Genauigkeit der Regenmengenmessung abgeschätzt, die mit Radargeräten höchstens erreicht werden kann.

Résumé :

A l'aide des mesures par un disdromètre pour les gouttes de la pluie on estime la précision des mesures de la pluie, qui peut être atteinte au maximum par radar.

Riassunto :

Partendo dalle misure con un disdrometro per le gocce della pioggia, viene stimata l'esattezza delle misure della pioggia, che può essere al massimo raggiunta con radar.

Summary :

Measurements of a rain drop disdrometer are used to assess the accuracy with which rain amounts can at the best be measured with radar equipment.

1. Introduction

At our institute an electro-mechanical rain drop disdrometer has been constructed (Joss and Waldvogel, 1967) which is able to continuously record the impacts of rain drops in the diameter range from 0.3 to 5 mm. Analogue computing devices process the pulses produced by the impacts and provide real-time data of the rain drop distribution and several of its parameters, such as the rain fall rate R *):

$$R = \frac{\pi}{6} \cdot \int_{D_{min}}^{D_{max}} N(D) \cdot V(D) \cdot D^3 \cdot dD \qquad (1)$$

the rain amount Q :

$$Q = \int R \cdot dt \qquad (2)$$

and the radar reflectivity factor Z :

$$Z = \int_{D_{min}}^{D_{max}} N(D) \cdot D^6 \cdot dD \qquad (3)$$

As we see, the disdrometer actually simulates two instruments, an ordinary rain-gauge (measuring R resp. Q) and the weather radar (measuring Z). Its measurements may be used, therefore, to assess the accuracy of rain amounts which can be best attained with radar equipment. In the following this possibility will be illustrated using data which have been recorded during one year at Locarno-Monti in Switzerland. This measuring site lies just south of the Central Alps. Due to this geographical situation, the rain drop distributions in this region show some pecularities which in general cannot be found elsewhere. Thus, the results presented here, may not exactly apply at other sites.

*) N (D) number of drops of diameter D per volume and per diameter

V (D) fall velocity of drops of diameter D

2. Adjustment of the "radar measured" rain amount QZ

For the proposed investigation we need the "rain-gauge measured" rain amount Q and the "radar measured" rain amount QZ. Both quantities have been calculated from the rain drop distribution recorded by the disdrometer. The length of the time intervals for which Q and QZ have been integrated is about 20 minutes. The values of QZ, like those of Q, have been calculated by the analogue computer with a time step of about 20 seconds and the formula:

$$QZ = \int (RZ) \cdot dt = \int (Z/A)^{2/3} \cdot dt = A^{-2/3} \cdot \int Z^{2/3} \cdot dt \qquad (4)$$

which implies the Z-R relation:

$$Z = A \cdot (RZ)^{B} \qquad (5)$$

with B = 3/2. The more involved of the two parameters of the Z-R relation is B, because it influences the value of the integral part of the formula for QZ. Fortunately, through several years measurements its value of 3/2 is fairly well established for our measuring site.

We are left, therefore, only with the paramter A for the adjustment of QZ, a calculation which can now also be done after the processing in the analogue computer. The values QZ have been adjusted with four different sets of the parameter A. The stratification schemes which are based on precipitation types are shown in Table 1. The first part of the table shows the most detailed of the schemes, consisting of the six rain types occuring at places just south of the alpine chain. The remaining three schemes are assembled from the first one, producing sets of respectively three, two and one A. Each data pair Q, QZ has been labeled with the appropriate type of the first scheme.

The different values of A of the sets have been averaged with the rain amount Q as weighting function. Inspecting now in the sets these mean values, we see that they generally differ only slightly from each other, most of them being in the range from

255 to 297 mm^6/m^3. The only exception is the value for local precipitations (350), respectively local thunderstorms (417). But their contribution in time (27 % resp. 8 %) as well as in rain (17 % resp. 10 %) is not very considerable. Compared with sets of A measured at other sites, which in general show large differences between the single values of A, the sets presented in Table 1 look rather differently. One of the reasons for this pecularity may be, that most of the rain at the measuring site is orographically induced or, at least influenced, and that the prevailing precipitation producing air mass is of the mediterranean type.

Although the differences between the values of A are small, their averages have been calculated from samples most of which are statistically different from each other at a high significance level. The samples have been tested with the Wilcoxon-Test (also Mann-Whitney-Test or U-Test) with Q as weighting function. The results of this statistical test are shown in Table 2. From this table we see that most of the stratification schemes are quite reasonable as they generally lead to statistically different A-samples for the different types in the schemes. The reason why stau* and cold frontal precipitations do not produce significantly different samples is that the discrimination between the two types is rather difficult, because pratically every stau situation ends with the passage of a cold front with barely noticeable differences in the rain structure. The astonishing result, that the thunderstorm and non-tunderstorm As are not significantly different, may be found in the following explanation. The discrimination has been made with the use of a sferics counter. However, this method does not exclude that there remains some convective activity in the non-thundery precipitation; this is especially true for the stau situation. Thus, non-thundery - thundery does not mean non-convective - convective. To apply this other scheme on our data, which would be the more reasonable one, is a rather difficult task and can probably be done only with the method 2 mentioned at the end of paragraph 4.

*) orographic rain

3. The accuracy of the "radar measured" rain amounts QZ

As a measure for the accuracy of the "radar measured" rain amounts QZ the root mean square RMS of the ratio K_i :

$$K_i = QZ_i \; / \; Q_i \tag{6}$$

has been calculated for each time interval:

$$RMS = \sqrt{\sum_{i=1}^{N} (K_i - 1)^2 \; / \; N} \tag{7}$$

respectively with the rain amount Q_i as weight:

$$RMS = \sqrt{\sum_{i=1}^{N} (K_i - 1)^2 Q_i \; / \; \sum_{i=1}^{N} Q_i} \tag{8}$$

These calculations have been done with the different A-sets of Table 1 and for different lengths of the measuring interval, i.e. for the basic one of about 20 minutes, and for 6, 12 and 24 hourly periods.

A summary of the results is shown in Fig. 1, where weighted and unweighted accuracies for two A-sets are plotted versus the length of the measuring interval. The dashed curve gives the unweighted accuracies which have been obtained using the single A = 300. It represents the accuracy which can be expected without taking into account the relative contribution of the measuring intervals to the total rain amount. More meaningful are the solid curves which have been constructed using the equation (8). With A = 300 the upper curve results; the lower one is obtained with the A-set of the first stratification scheme in Table 1. The accuracies calculated from the remaining two schemes (stau, cold front, local respectively thundery, non-thundery) can be found in the area between the two solid curves. The relatively small improvement of 1 % to 4 %, which is brought on by the six-valued A-set over the single-valued one, is due to the already discussed predominance of similar values of A in the six-valued set. A further value, marked X, has been plotted in Fig. 1 in the upper right hand corner. It indicates the unweighted accuracy for daily rain amounts, which has been measured in another experiment (Joss et al. 1970). In this carefully designed experiment data of one year's measurements, obtained with a vertically pointing radar 200 m above the antenna and the rain-gauge, have been adjusted with A=300 and B=1.5.

4. Conclusions

The lower solid curve in Fig. 1 represents the accuracy of the rain amounts QZ at best attainable with radar equipment and with a reasonable yet not perfect adjustment scheme. For the accuracy of daily rain amounts, for instance, we get a value of 15 %. This accuracy is probably sufficient for most of the purposes. However, the accuracy of an ordinary rain-gauge at the same site is 6 %, as has been found by Joss et al. 1970 from a comparison between two identical rain-gauges.

For a comparison with real radar measurements we may take the value X in Fig. 1 (42 %). Its corresponding point of 29 % in the disdrometer data may be found on the dashed curve. It results in this case that there still remains a difference of accuracy of 13 % which could be improved on.

The validity of the curves plotted in Fig. 1 is limited because of two reasons, the geographical pecularity of the measuring site and a not perfect stratification scheme for the adjustment of the data. One might question, whether the limits calculated here could be further reduced, using a more sophisticated adjustment scheme. One could think of two possibilities which have already been mentioned by Joss and Waldvogel 1970. Either a few disdrometers are operated in the radar-covered area, which would monitor the drop size distribution for a continuous adjustment of the Z-R- relation. For a good coverage this method would probably end up in another net of rain-gauges, yet of sophisticated ones! A second possibility would be to deduce the Z-R relations from the patterns of the radar echo-structure. This method looks more promising than the first one, although an elaborate system will be needed for the processing of three-dimensional radar data.

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Table 1: STRATIFICATION SCHEMES FOR THE ADJUSTMENT OF THE "RADAR MEASURED" RAIN AMOUNTS QZ

18 May - 30 September 1969

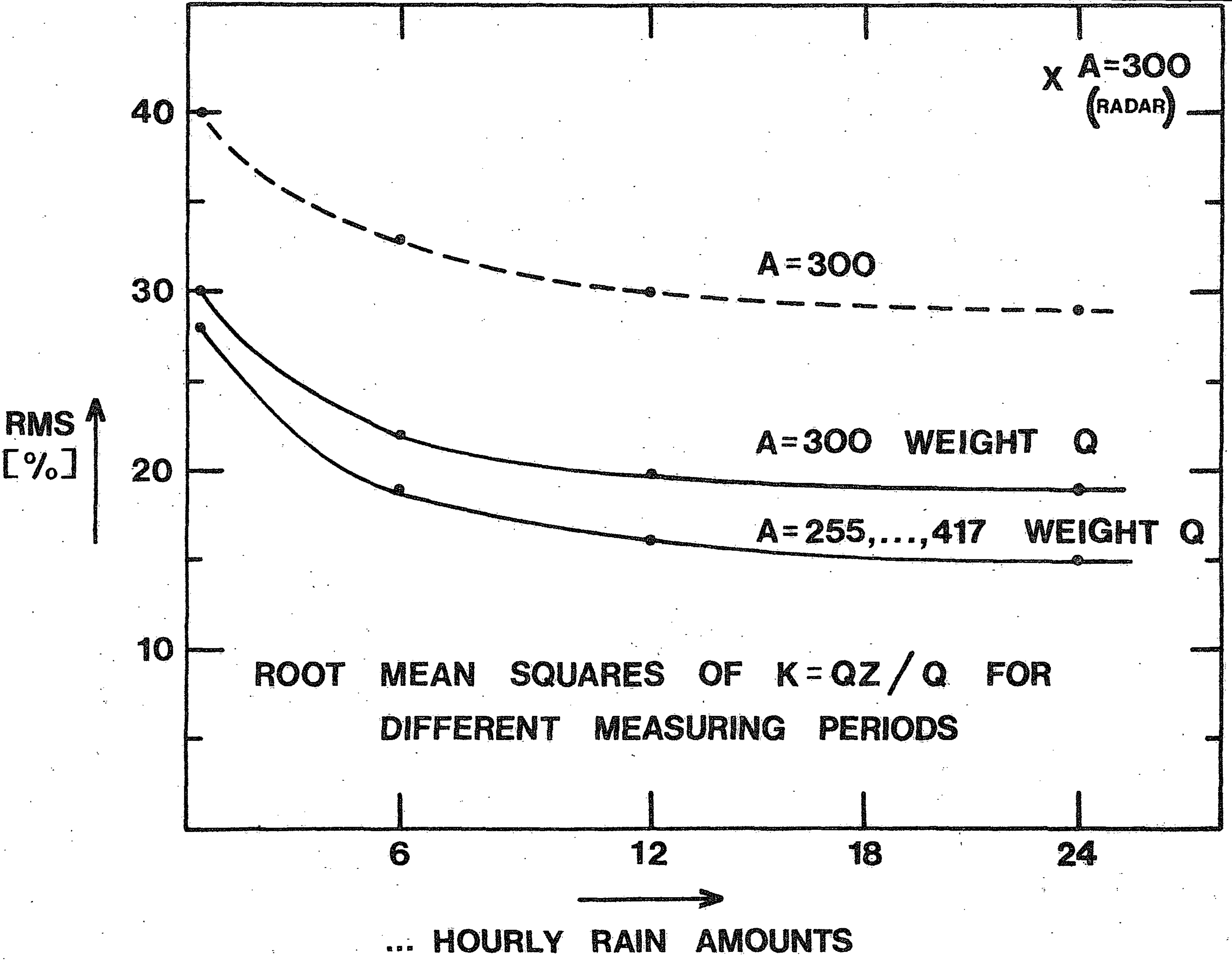
Hours of rain	230
Amount of rain	800 mm

Type of rain	Percentage of time	Percentage of rain amount	Q-weighted $\bar{A}$
Stau NTH	22	22	255
Stau	18	22	264
Cold front NTH	10	7	267
Cold front TH	23	32	281
Local NTH	19	7	258
Local TH	8	10	417
Stau	40	44	260
Cold front	33	39	279
Local	27	17	350
Non-thundery	51	36	258
Thundery	49	64	297
All data	100	100	300

NTH: non-thundery
TH : thundery
Stau: orographic rain

Table 2: RAIN TYPES WITH SIGNIFICANTLY DIFFERENT Z-R RELATIONS (WILCOXON TEST, Q-WEIGHTED)

Local NTH	↔	Local TH	Significance level 1 °/oo
Stau TH	↔	Local TH	
Cold front TH	↔	Local TH	
Stau	↔	Local	
Cold front	↔	Local	
Cold front NTH	↔	Cold front TH	Significance level 5 %
Stau NTH	↔	Local NTH	
Cold front NTH	↔	Local NTH	



ROOT MEAN SQUARES OF K=QZ/Q FOR DIFFERENT MEASURING PERIODS