P16.2 OPERATIONAL ADJUSTMENT OF *Z-R* RELATION COEFFICIENTS FOR RADAR RAINFALL ACCURACY IMPROVEMENT BY DUAL-WAVE ATTENUATION MEASUREMENTS

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1. INTRODUCTION

In operational practice for estimation of the rainfall rate ***R*** based on reflectivity ***Z*** data alone the power-law relation $\boldsymbol{Z = A \cdot R^b}$ is generally used now. Application of this relation with fixed Marshall-Palmer (MP) coefficients ***A***=200, ***b***=1,6 provides in ~80% of events acceptable accuracy 30% in our daily accumulated rainfall S-band measurements in Moscow region, however from time to time the errors increase up to 100÷150%.

In our opinion the most probable reason of the great error in radar rainfall measurements is significant DSD variability resulting in an alteration of the ***A*** and ***b*** coefficients. A great number of experimental studies were aimed to determine the "best" ***A*** and ***b*** coefficients depending on the precipitation type and other geophysical conditions (see, e.g., Battan 1973).

Additional information about DSD is contained in specific attenuation that can be used in calibration method intended for ***Z-R*** relation parameters retrieval.

The aim of the current study is to develop the method for the retrieval of averaging ***Z-R*** relation coefficients on base of the attenuation measurements.

The observations were carried out by the X, S-band operational weather radar sited in Moscow.

2. RADAR AND GAUGE RAINFALL ANALISYS

It is well known that discrepancy between radar rainfall evaluation and gauge data because of the different measurement nature, is decreased with the increase of time-space scale of data averaging (Borovikov et al. 1967). Therefore in our practice it is accepted to carry out radar observation quality estimation by comparison of the accumulated radar rainfall data with gauge measurements through the radar-to-gauge matching coefficient:

$$\mathrm{M} \equiv \sum_i q_i^{Radar} \Big/ \sum_i q_i^{Gauge} , \quad i = 1, \dots , N; \qquad (1)$$

where *N* – number of gauges within radar observation area. The radar accumulated rainfall for 24-hour interval and 4×4 km space bin q_i^{Radar} are compared with *i*-th gauge data q_i^{Gauge} in radar range up to 100 km.

The radar rainfall q^{Radar} in (1) depends on ***A*** and ***b*** coefficients in ***Z-R*** relation. We have decided to calculate ***M***(***A***,***b***) for different values from wide range: ***A***=10 ÷ 550, ***b***=0,5 ÷ 2,5 with using 144 saved 10-minutes S-band radar reflectivity fields for each of 24-hours intervals.

Our comparative analysis of 24-hours rainfall radar and gauge datasets for number of gauge sites in radar range for the long observation period 1998-2000, reveals that matching coefficient ***M(A,b)*** behavior has some peculiarities:

- *in range space of **A** and **b** parameters in **Z-R** relation radar data are in full agreement (**M**=1) with gauge data on **optimal curve** instead of unique value of **A** and **b**, as it would be possible to expect. The optimal curve has significant change location in (**A, b**)-space depending on variations of the averaged event characteristics, e.g. DSD,*
- *the maximum of correlation coefficient and the minimum of root-mean-square error (MSE) for radar-to-gauge rainfall datasets are reached at **b**≈1,4÷2,0 for most of examined events, so the retrieval of best data agreement by the **A** coefficient variation solely with fixed **b** (e.g., **b**=1,6) is accepted completely.*

Two examples of ***M(A,b)*** for heavy rains are presented on Figure 1: **(a)** typical case for September 1, 2000 when radar measurement with fixed MP coefficients has given good coincidence ***M***≈1,05 , and **(b)** exceptional case for July 20, 2000 when idem has given significant radar underestimating ***M***≈0,7.

3. CALIBRATION METHOD

The proposed method for identification of ***Z–R*** relation coefficients is based on the theory of incorrect inverse problems and embodied in minimization of the discrepancy ***E*** between two reflectivity profiles on X-band (λ_1): 1) radar measured reflectivity profile $\boldsymbol{Z^{Msr}}(\boldsymbol{r})$ and 2) calculated reflectivity profile $\boldsymbol{Z^{Clc}}(\boldsymbol{r})$:

$$E(A,b) \equiv \int_{\Omega} [Z^{Msr}_{\lambda_1}(\vec{r}) - Z^{Clc}_{\lambda_1}(\vec{r},A,b)]^2 \, d\Omega \;\rightarrow\; \min \qquad (2)$$

for all directions ***r*** in the observation region Ω.

The reflectivity profile $\boldsymbol{Z_{\lambda 1}^{Clc}}(\boldsymbol{r,A,b})$ is calculated by using of S-band (λ_2) measured non-attenuated reflectivity profile $\boldsymbol{Z_{\lambda 2}^{Msr}}(\boldsymbol{r})$ and the power-law relation $\boldsymbol{K = \alpha \cdot R^{\gamma}}$ between attenuation coefficient ***K*** and rainfall rate ***R***. The coefficients $\boldsymbol{\alpha}$ and $\boldsymbol{\gamma}$ are related to ***A*** and ***b*** coefficients by the "*rain parameters diagram*" (Atlas and Ulbrich 1974) that permits one to obtain the rain parameters ***Z, R*** or ***K*** from any pair of set.

Figure 2 shows the time variations of the ***A*** coefficient calculated by proposed calibration method for two mentioned events. The ***A*** coefficient averaged by MA method with 30-minutes window width and start value ***A***=200 is shown also. We can see from the Figure 2 that in the both cases suggested calibration method determines adequate values of the ***A*** coefficient which are in a good agreement with *a posteriori* rainfall data analysis results on Figure 1.

In our opinion the proposed calibration method deserves further development.

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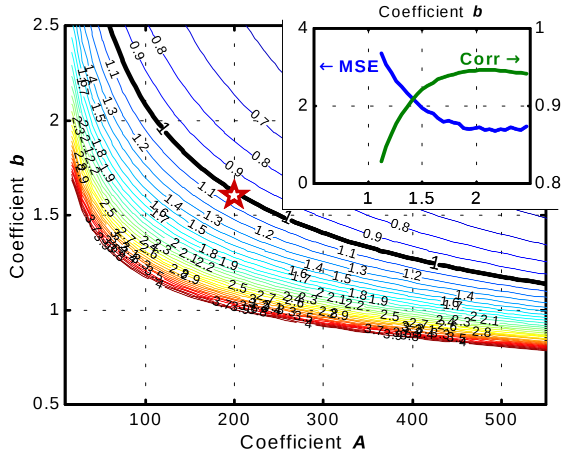

Fig. 1a. Isolines of the 24-hours radar-to-gauge precipitation amounts ratio ***M*** as a function of the ***A*** and ***b*** coefficients in ***Z–R*** relation for 09/01/2000 event in Moscow (*a posteriori rainfall data analysis*).

*The heavy line is optimal curve **M**=1. The precipitation radar data are in full agreement with gauge data <u>for arbitrary points</u> (**A** and **b**) on this curve. "Starlet" signed standard values for our precipitation calculations – Marshall-Palmer parameters: **A**=200, **b**=1,6. For this event our precipitation calculation without calibration gives **M**=1,05 for S-band radar data.*

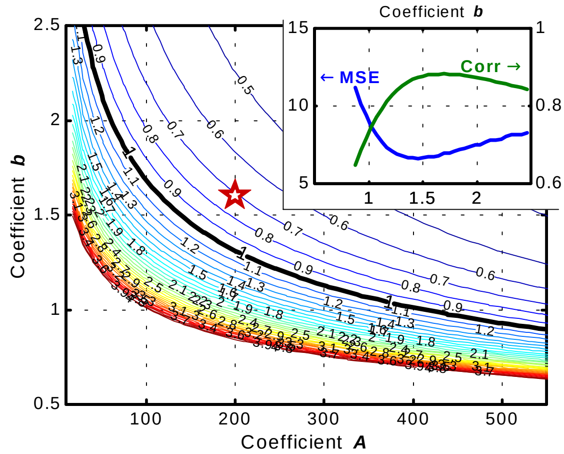

Fig. 1b. Same as **Fig. 1a,** except for 07/20/2000 event in Moscow when our precipitation analysis without calibration information gives ***M***=0,71 for S-band radar data.

*<u>MSE</u> is root-mean-square radar-to-gauge error (mm), and <u>Corr</u> is radar-to-gauge precipitation data correlation coefficient variations along the optimal curve **M**=1. The MSE(**b**) and Corr(**b**) functions are shown in clip figure in the right top corner. Values of coefficient **b**≈ 1,4÷2,0 are interesting, at which the minimum for MSE and the maximum for Corr are reached.*

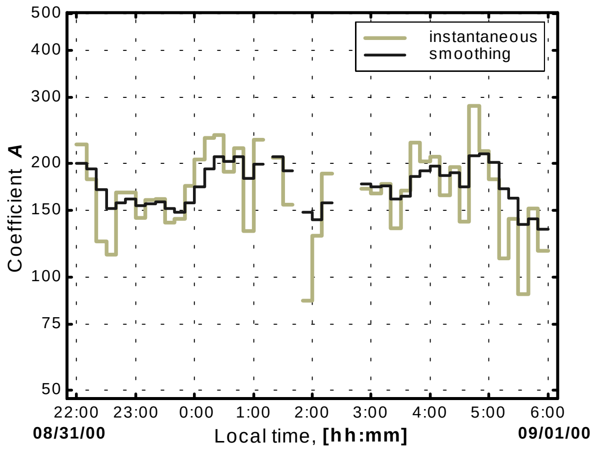

Fig. 2a. The time variations of the ***A*** coefficient in ***Z–R*** relation for 09/01/2000 event derived from the propose calibration method.

*The **A** coefficient is approximately equal 200 for this event by our calibration method.*

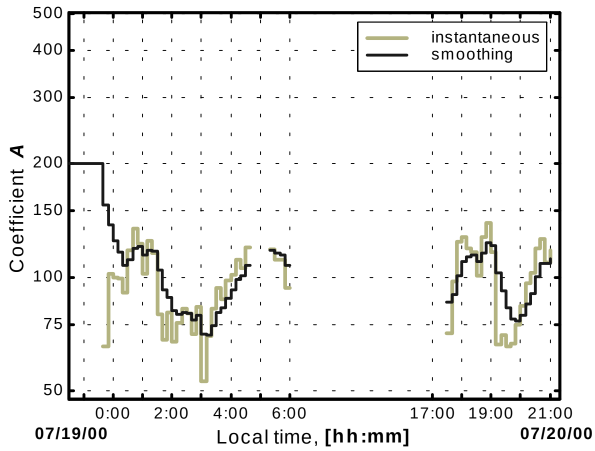

Fig. 2b. Same as Fig. 2a, except for 07/20/2000 event.

*The instantaneous (for each 10 minutes) and smoothed by MA values of **A** coefficient are presented.*

*The allowance for the calibrating information shifts the estimated radar-to-gauge ratio **M** to 1.*

4. REFERENCES

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