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The use of weather radar measurement for hydrological applications and flood warning service in the Czech Republic

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1 Introduction

Weather radar is nowadays a commonly used tool for weather analysis and short-time forecasting (nowcasting) not only in qualitative, but increasingly in quantitative way. Leaving aside research activities, reflectivity interpretation and wind measurement, the most important quantitative output operationally used is the quantitative precipitation estimate (QPE).

The issue of quantitative precipitation estimation has been dealt with for a long time but many deficiencies inherent to the radar-based precipitation estimation are still far from being satisfactorily resolved. Errors of the radar precipitation are numerous and are many of them are dependent also on the precipitation type and meteorological conditions.

One of the commonly used methods for corrections of the radar-based precipitation estimates is the adjustment and sometimes some type of the combination with the raingauges. Although the adjustment concept is also a matter of serious discussions concerning their physical meaning, validity and appropriateness, many (hydro)meteorological agencies and organizations have taken a pragmatic approach and developed some adjustment algorithms for their applications (e.g., Gjertsen et al, 2004, Sokol et al., 2002).

Since 2002 The Czech Hydrometeorological Institute (CHMI) has been running a multisensor precipitation estimate which involves computations of original radar-based QPE, mean-field-biased radar QPE, raingauge-only (estimation, i.e. interpolation) QPE and a combination of the adjusted radar estimate and available raingauge measurement (Šálek et al., 2004). The outputs of the system are utilized for the verification of the numerical weather prediction models, as an optional precipitation input into some hydrological models and for flood warning service. The contribution briefly describes the concept of the multisensor analysis and the following application that are using the results.

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2 The concept of the multisensor analysis at the CHMI

The multisensor analysis is described in (Šálek et al, 2004) and will be only briefly outlined here. The radar-based QPE is being computed first separately for the radar domains of the two C-band single-polarization Czech weather radars. For the QPE the measurement of a (pseudo)CAPPI 2 km is used, i.e. the reflectivity closest to the altitude 2 km.

The (original) radar estimates are being computed using the standard Marshall and Palmer formula $Z=200R^{1.6}$ for every 10-minute measurement and are then subject to mean-field-bias (i. e. bulk) adjustment. The derivation of the adjustment coefficient is rather empirical and takes into account all the measurements of the raingauge stations within the range up to 150 km from the radar site. The length of the period used for the calculation of the adjustment factor is nowadays at least three days when precipitation was significant until predefined threshold of precipitation accumulation is exceeded.

The combined radar-raingauge estimate is using the modified algorithm of Double optimum estimation (Seo, 1998, Fulton et al., 1998) which is a linear combination of the radar-adjusted estimate and available raingauge readings, where the weights of the raingauge(s) measurements are inversely proportional to the distance to the raingauge(s).

Besides the original radar estimate, adjusted radar estimate and combination (merged field) the system computes also a raingauge-only areal estimation. Thus, there are four types of the rainfall estimates available for the radar domains at the grid 1x1 km and for every hour and longer intervals (3 hours, 6 hours at 00, 06, 12, 18 UTC and 24 hours at 06

UTC). Then the separate estimations are set up to single images covering the Czech Republic and the surroundings.

The visualizations of the results are based on thin client – server www technology, i.e. the estimates can be viewed by using common internet browsers. There are two types of the visualizations: An application JSPrecipView (see Fig. 1) based on JavaScript at the client site and PHP on the server is primarily oriented towards quick overview and routine work of the hydrologists and meteorologists on duty, while another application is rather diagnostic and allows better analyses of the radar-raingauge relationships, range dependency of the bias value, identification of the raingauge station and many other useful parameters.

3 Application of the precipitation analyses in warning service of the CHMI

The multisensor analysis is also providing automatic warning messages against heavy rainfalls, which are based on the detected maximum values at reasonably sized areas (80x80 km), while taking into account all the available estimates. It should be noted that these squares (80x80 km) are not fixed, but moving around the maxima found in the whole domain (see Fig. 2). After first (highest) extreme is found, then values in the square around the maximum are set to zero and next extreme is being searched in the whole domain (except the blanked square). Then all the extremes are put together and for those exceeding predefined threshold the corresponding values (the other three estimates at the given areal element 1x1 km) are found. There is also an algorithms reducing the possibility of the false alarms caused by speckles (e.g., remaining clutter). The resulting message is in the form of a bulletin, which is the formatted standardized message traditionally used for information interchange among weather services, but it can be elaborated easily at any information system (emailed, showed at a www page etc).

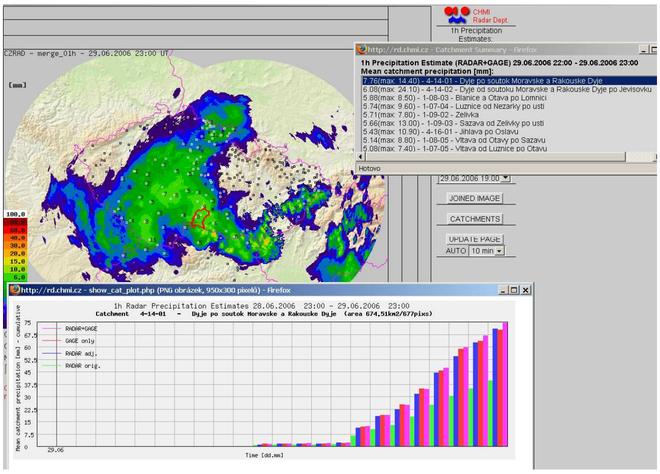

Fig. 1. Example of the combined (merged) QPE in the application JSPrecipView, along with the rainfall accumulation at a predefined catchment that can be chosen by the user. The accumulations are computed for all the types of the precipitation estimate. The tiny squares on the map indicate the raingauge locations.

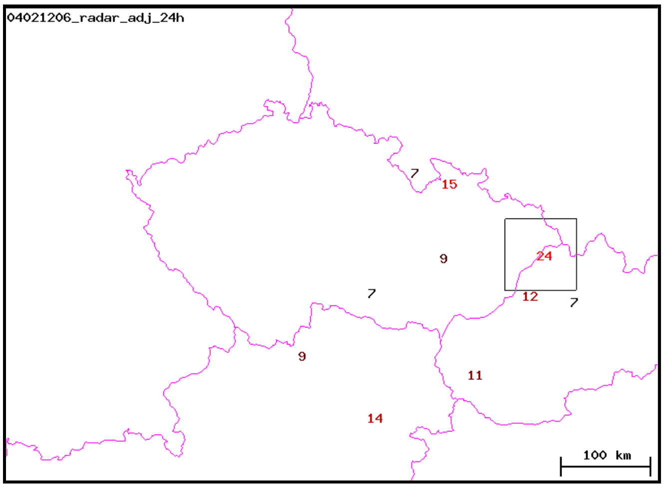

Fig. 2. The square for which the maximum value are "representative". After the first maximum in the domain is found, then the area around (the square 80x80 km) is blanked and the following less extreme is being searched.

The example of a warning message is in the Table 1.

Table 1. An example of the warning message issued when significant precipitation is detected.

```
WGCZ66 OKTB 271815

Time:   27.4.2006 18 UTC.     Accumulation: 6 h.
Issued: 27.4.2006 18.15 UTC.

   49.7      54.0 *     2.1      36.9     Ustecky                 13.918 50.487

   62.1      69.2 *     7.2      56.5     Outside CZ              17.506 48.562

-------------------------------------------------------------------------------
Rad. orig. Rad. adj. Raingauge  Merged    Region(district)      longit. latitude

-------------------------------------------------------------------------------
    Significant precipitation in the Czech Republic and the surroundings
 from the weather radar of the CZRAD network and available raingauge measurements

          Warning: This information must be verified visually at
         na http://rd.chmi.cz/rad/ or http://kalanka.chmi.cz/merge.
             High values can be reported by system errors

-------------------------------------------------------------------------------
                   Prepared: Milan Salek, salek@chmi.cz
-------------------------------------------------------------------------------
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4 Verification of the automatic warning messages

The performance of the automatic warning messages has been verified only for the daily (24-hour) accumulations for which other sets of data from manually operated raingauges are available, which are not utilized in the operationally available estimates. Only the reduced radar domain up to 150 km from the radar site was used for the verification, because it is the reasonable range for the relatively good radar-based QPE. The verification was not based on the actual messages because the extremes are usually not at the raingauge locations (at the areal element where the verifying raingauge is located). Under the assumption that the measurement of a raingauge is representative enough for the areal (1x1 km) radar estimate, we compared the collocated values of the four types of estimates against the verifying raingauges, while concentrating on the relatively high values. The threshold was set to 30 mm although the actual value operationally used is 40 mm. The reason for this was relatively low frequency of the raingauge records above 40 mm/24h.

The verification was done for the period April-September 2005 because the majority of the messages is issued during spring and summer. For radar Brdy 322 independent raingauge stations were available, in the Skalky radar we used 280 raingauges. Excluded from the comparisons were these days when availability of the (10 minute) radar reflectivity measurement was below 90%, i.e., when the radar measured less than 90% of the 24-hour period.

For the verification the usual skill scores have been computed for both radar domains; the results are summarized in the table 2 and 3.

Table 2. Skill scores of the ability of the different QPE to indicate the significant precipitation amounts exceeding 30 mm for the Brdy radar domain (within the range 150 km). POD – probability of detection, FAR – false alarm rate, TS – threat score in percents. Gage-only QPE means using only *operationally available* raingauges.

QPE type	POD	FAR	TS
Gage only	34.15	35.44	28.76
Radar orig.	4.69	16.00	4.65
Radar adj.	37.05	47.47	27.76
Merged	37.50	29.11	32.50

Table 3. Skill scores of the ability of the different QPE to indicate the significant precipitation amount exceeding 30 mm for the Skalky radar domain (within the range 150 km). For the abbreviation see Table 2

QPE type	POD	FAR	TS
Gage only	53.64	28.63	44.14
Radar orig.	9.60	32.56	9.18
Radar adj.	47.68	40.50	36.00
Merged	56.95	23.21	48.59

From the skill scores of both radars it is obvious that original radar-based QPE has rather poor performance, but the probability of detection can be significantly increased by the adjustment algorithm. Although the adjustment causes also higher rate of the false alarms, the threat score (also called critical success index) is considerably better at the adjusted estimates. The adjusted radar has similar POD as raingauge-only estimates but higher false alarms. Concerning almost all the scores, for both radars the merged (combined) estimate is the best QPE type. The reason of considerably higher performance of the radar Skalky original and adjusted estimation is not known, whilst the better scores of the gage-only and merged field in the radar Skalky domain are probably the consequence of the higher density of operationally available raingauges (see also Fig. 1, radar Skalky is located in the eastern part of the Czech Republic).

5 Comparisons of the radar-based QPE and raingagues

The multisensor analysis does not only provide the most exhaustive QPE but the application is able also to easily compare the performance of the different sensors at the location of a raingauge. Although it might be sometimes questionable to compare the raingauge measurement with the area 1x1 km where the QPE is roughly estimated by the radar, it has proved to be very useful in diagnosing malfunctioning of the raingauge or even the radar.

On the Fig. 3 is an example of the comparison which can be achieved simply via www interface.

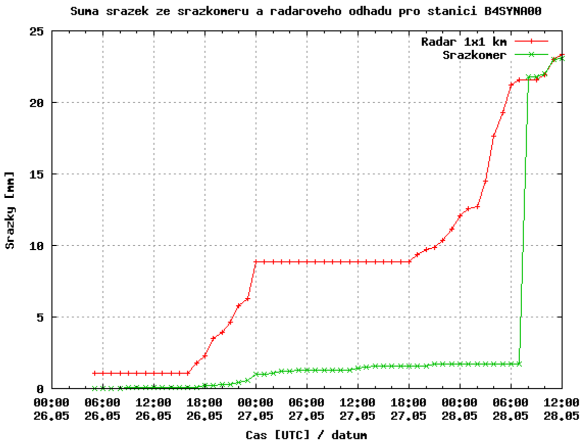

Fig. 3. Example of the comparison of raingauge measurement (lower curve) and collocated radar-based QPE indicating an error of tipping bucket raingauge.

6 Hydrological applications of the multisensor QPE

The rainfall-runoff hydrological model Hydrog (Starý, 2006) has been used in at the regional office Brno of the CHMI for a several catchments since 2001. It is a distributive model, i.e. it requires spatial representation of precipitation and thus the multisensor QPE was a suitable option to the traditional areal estimates by the raingauges; the resolution of the input rainfall must coincide with a schematization (spatial distribution within the catchment). For the description of the Hydrog model see Šálek et al., 2006.

After some testing (Šálek and Březková, 2004) the radar QPEs are used operationally as an alternative to raingauge station network in two versions – adjusted radar estimate (mainly for convective precipitation type where raingauge data are not representative) and combined (merged) data. The system calculates average precipitation in one hour step for a given areas – Thiessen polygons represented by a raingauge station (Fig 3). With the help of radar data hydrological forecast can be updated every hour.

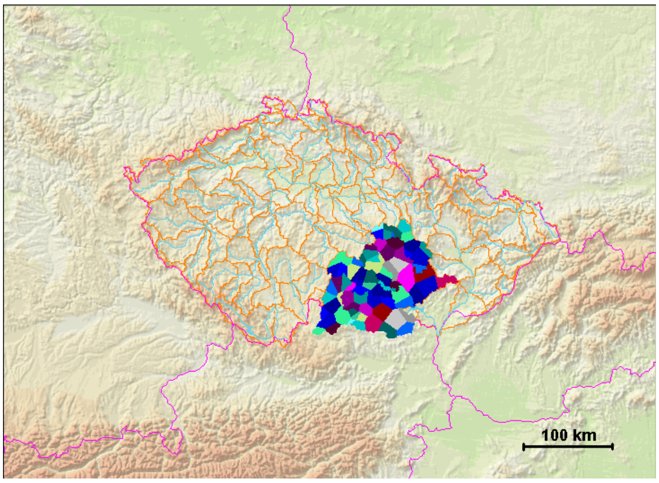

Fig. 3. Thiessens polygons used for areal representation of the rainfall measured by raingauges. The radar and merged estimates in 1x1 km grid are also used for the calculation of the mean areal rainfall for each polygon.

The main advantage of this system is the prompt availability of the data that can be easily imported to the hydrological model, which is very important in operation.

7 Final remarks

The use of the radar is now common in hydrological simulation and warning service but the user must inspect visually the results because of the complexity of the radar measurement and possible malfunctioning of the radar technology. The accuracy of the QPE achieved by single polarization radar is significantly enhanced by the raingauge adjustment and merging algorithm.

The ongoing work will concentrate more on the utilization of the quantitative precipitation nowcasting and on estimating the time when it is more useful than the precipitation output of the numerical weather prediction models. First tests have been already made (Šálek et al., 2006).

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