The use of radar-based QPE in the HR QPF verification

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1 Introduction

The paper summarizes the results we obtained at the comparative verification of the high resolution (HR) quantitative precipitation forecast (QPF). The set of forecasts was produced by three versions of the operational NWP model ALADIN-CZ. The operational product MERGE, which merges the radar based rain rate data with the data from operational gauge stations, was employed to obtain verification data set. Traditional and fuzzy verification techniques were applied to the verification.

We studied an episode with heavy convective precipitation which resulted in flooding in several parts of the Czech Republic in 2009. The start of the period was influenced by a front that crossed the Czech Republic, and the large precipitation associated with the front was generally forecasted well. Nevertheless, the precipitation during this episode was difficult to forecast, particularly over the final days of the time period, due to chaotic thermal convection.

In the study (Zacharov et al., 2013) we verified the QPF produced by several NWP model and model versions. The verification results indicated that the forecasts of the two ALADIN-CZ runs with different horizontal and vertical resolution were similar. It seems that the run with higher resolution did not provide any new skill. This was valid especially for cases without pronounced dynamic forcing. That is why the ALADIN-CZ was modified by the CHMI ALADIN Group and new results for the 2009 episode were provided for verification. In this contribution we present the results of comparative verification for ALADIN-CZ before and after the modification in order to prove the effect of the model modification.

2 Input data

In this study, we evaluate the QPFs that were obtained by various versions of the ALADIN-CZ NWP model, which is high-resolution limited-area model operated by the Czech Hydro-Meteorological Institute (CHMI). In the previous study (Zacharov et al., 2013), we verified the ALADIN-CZ results that were obtained by using two horizontal resolutions of approximately 9 km and 4.71 km. The first run with 9 km horizontal resolution and vertical resolution of 43 levels was operational during the flash flood period in 2009. The second set of results was obtained by reforecasting the 2009 period in the CHMI and corresponded to the ALADIN-CZ in the operational version from 2012. Apart from the horizontal resolution that was enhanced to 4.71 km, this ALADIN-CZ version also has a double vertical resolution of 87 levels. The third set of forecasts was prepared after finishing the verification study and after the ALADIN-CZ modification. The results correspond to the ALADIN-CZ topical operational version.

The prognostic data from ALADIN-CZ cover the area of the Czech Republic and its surroundings. The QPFs were verified on a verification domain of 545 km × 301 km. The radar data were obtained from the CZRAD network (Novak, 2007). The domain and the positions of both radars are shown in Figure 1.

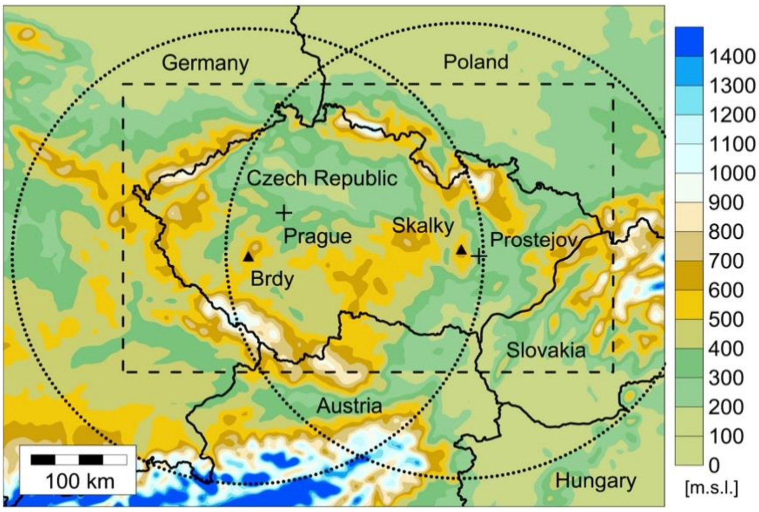

Figure 1: The verification domain that covers the area of the Czech Republic. The positions are indicated for the radars (black triangles) and sounding stations (crosses). The dashed line indicates the position of verification domain; the dotted line indicates the areas covered by the radars.

Radar reflectivity fields located 2 km above sea level (CAPPI 2 km) were used in this study. To determine the verification rainfall values, we applied the MERGE product (Salek and Novak, 2008), which adjusts the radar data with gauge measurements. The gauge-adjusted 3h precipitation totals were interpolated into model grids. An example of QPF and MERGE data fields are shown in Figure 2.

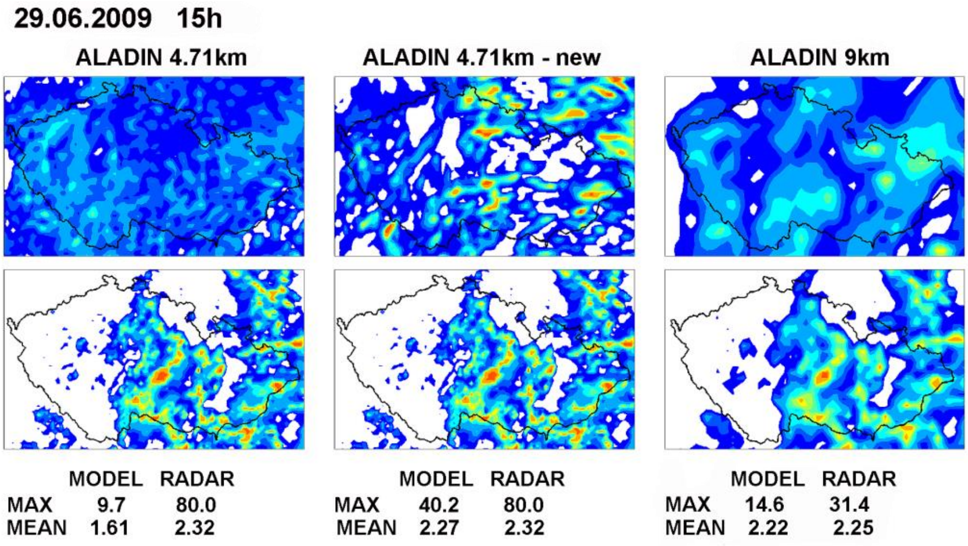

Figure 2: An example of the 3h rainfall fields as given by NWP models (1st row) and by radar-based data (2nd row). The models are marked at the top of each column, and the date and hour are marked at the top of each column. The values at the bottom give domain related maximum and mean 3h rainfall.

3 Forecast verification

For comparative verification of ALADIN-CZ versions, we used four 3h precipitation totals from the second half of each day of the flash flood period. The 3h intervals ended at 1500, 1800, 2100 and 2400UTC. The forecasted period lasted for 14 days, which means that we evaluated 56 prognostic fields of 3h precipitation totals for each ALADIN-CZ version. We used traditional categorical skill scores to verify grid point 3h precipitation totals, together with two spatial verification methods. For the definitions of verification measures see e.g. the Appendix in (Zacharov et al., 2013).

3.1 Traditional verification

Well-known skill scores such as POD, FAR, CSI and BIAS were determined from a contingency table which gives the number of hits (correctly forecasted events), false alarms (incorrectly forecasted non-events), misses (incorrectly forecasted events), and correct rejections (correctly forecasted non-events). An event was defined as the occurrence of 3h grid point precipitation greater than or equal to a given threshold value. An example of traditional verification is shown in Figure 3.

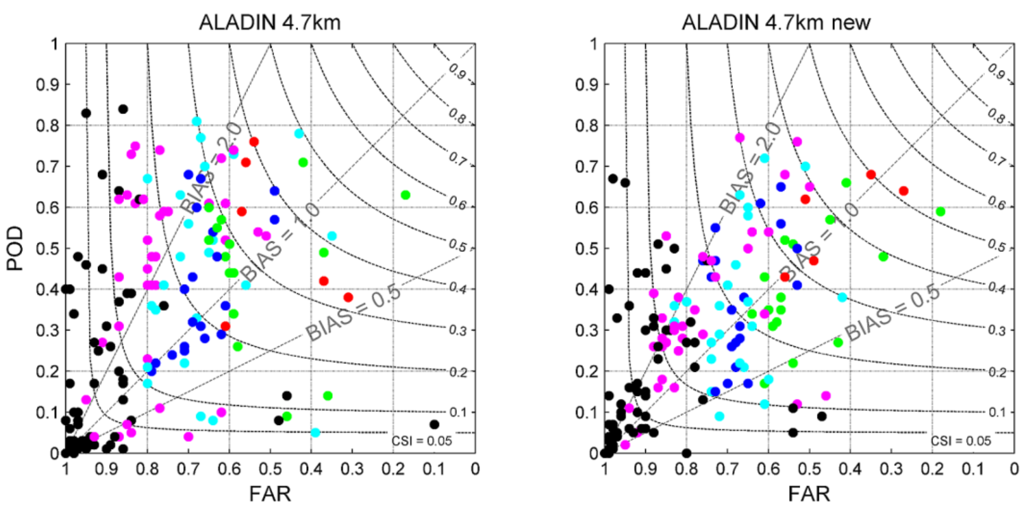

Figure 3:Verification of the grid-point precipitation forecast by categorical skill scores for threshold precipitation of 1mm/3h. Left plot: The previous ALADIN version; right plot: the modified new ALADIN version. In each plot, the probability of detection (POD) is given on the vertical axis, and the horizontal axis indicates the false alarm ratio (FAR). The dashed curves represent the critical success index (CSI) and the grey, dashed, diagonal lines represent the frequency bias. The colour marks the mean grid-point rainfall, Rmean [mm/3h], over the verification domain as indicated by MERGE data (black: Rmean ≤ 0.5, magenta: 0.5 < Rmean ≤ 1, cyan: 1 < Rmean ≤ 1.5, blue: 1.5 < Rmean ≤ 2, green 2 < Rmean ≤ 2.5,and red: 2.5 < Rmean).

The best forecasts are represented by a minimum FAR, maximum CSI and POD, and a BIAS equal to 1. In each graph, they are located at the top right corner. Figure 3 indicates that the majority of points in the plot for ALADIN-new shifted to the right which means lower BIAS and FAR and higher CSI values. However, the difference is not too pronounced.

3.2 SAL technique

The first spatial method that we used for verification is the SAL technique (Wernli et al., 2009). The SAL provides a three-component, feature-based quality measure, where the components quantify the quality of the forecast in terms of its structure (S), amplitude (A), and location (L). The SAL technique is an object-based method that separately identifies precipitation objects within the observed and forecasted precipitation fields. However, one-to-one matching between the identified objects in the observed and simulated precipitation fields is not requested. The SAL technique depends on the precipitation threshold because a given threshold dictates the selection of the objects in the precipitation fields. Perfect QPF is characterised by zero values for all of the SAL components.

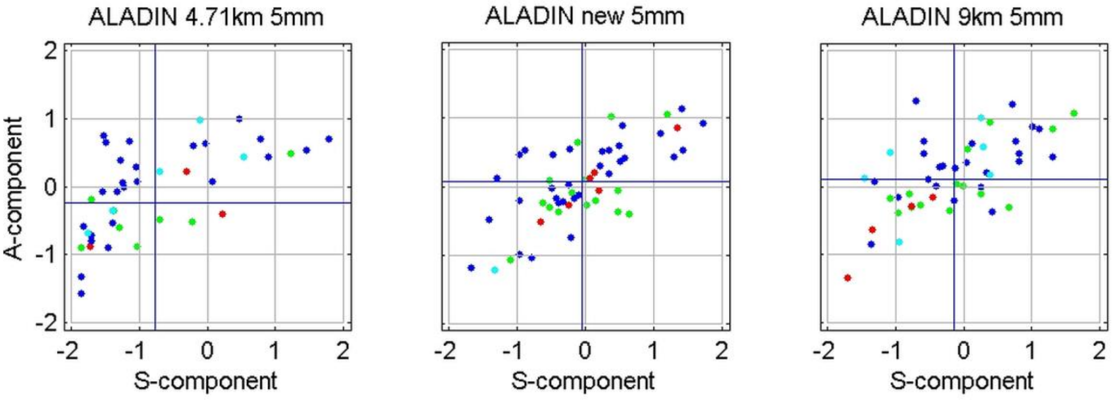

Figure 4: Examples of SAL verification for the threshold rainfall 5 mm/3h In each panel, single forecasts are represented by marks, whose colours show the magnitude of the L parameter (red: $L \leq 0.1$, green: $0.1 < L \leq 0.2$, blue: $0.2 < L \leq 0.5$, cyan: $0.5 < L \leq 1$ and black: $1 < L$). The crossed lines depict the mean values of S and A components.

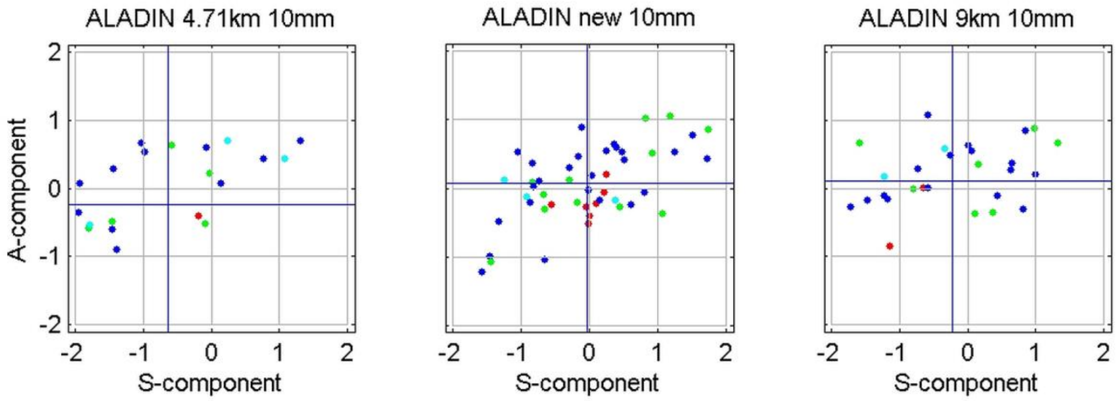

Figure 5: The same as Figure 4 but for the threshold rainfall 10 mm/3h

SAL verification provides the lowest BIAS for the ALADIN_CZ new forecasts. It means that the mean A component is close to the zero value. The same is valid for the S component, which qualifies the over/underestimation of the object area extent, which appears better in average for the modified version. For lower thresholds (not shown) the object extent is slightly overestimated. In addition, the objects with larger thresholds are more frequent in the new version of ALADIN-CZ. It means that there are more points in SAL panels. More frequent forecasts with high thresholds and simultaneously the improved SAL component values can be interpreted as improved forecasts with larger rainfall values.

3.3 Fraction skill score

A second spatial method that we applied in QPF verification was the evaluation of fractions skill score (FSS) values for various scales (e.g. Roberts and Lean, 2008). The FSS compares the fractional coverage of events (i.e., occurrences of rainfall values that exceed a certain threshold) in windows that surround the observations and forecasts. When considering only a spatial window, we can use the term elementary area (EA). The FSS has a value of 0 for a complete forecast mismatch, and 1 for a perfect forecast. If no forecast exceeds the threshold and some observation occurs or some exceeding values are forecast but do not occur, the FSS is 0. Furthermore, as the EA size increases, the score will asymptotically approach a value that depends on the ratio of the forecasted and observed frequencies of the event. This score is sensitive to rare events and small rain areas.

The FSS verification was represented by a relative frequency of forecasts with FSS larger than a given reference value $FSS_{uniform}$. For each forecast, we computed the FSS values for increasing EA size, and we determined the $EA_{uniform}$ size as the smallest EA for which FSS > $FSS_{uniform}$. Each model was characterised by the relative number of useful forecasts in terms of the $FSS_{uniform}$ values. The results of the FSS verification are shown in Figure 6.

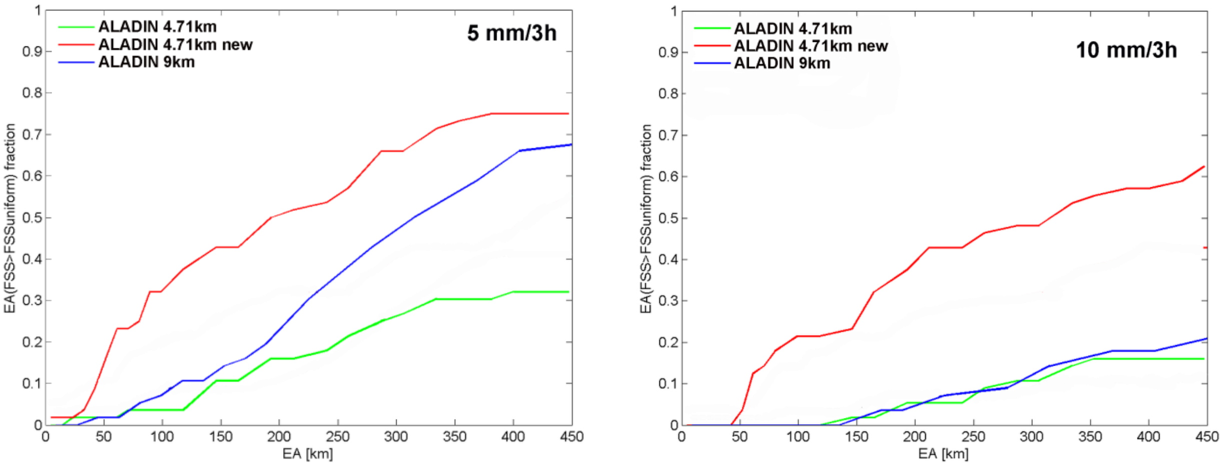

Figure 6: Cumulative fraction of forecasts with FSS values larger than $FSS_{uniform}$ for precipitation thresholds of 5 mm/3h (left plot), and 10 mm/3h (right plot). The horizontal axis represents the EA size in kilometres. The models are indicated in the legend.

Heavy convective rainfall values were reported during the 2009 flash flood episode. Consequently, the location errors are significant at smaller scales. Nevertheless the FSS evaluation indicates a pronounced improvement of the QPF produced by the new ALADIN-CZ version. The new version gives maximum number of useful forecasts for all threshold values and EAs.

4 Conclusion

The verification indicates a pronounced improvement in QPF produced by ALADIN-CZ new in particular in cases with convective precipitation without a strong synoptic forcing. The new ALADIN-CZ version is able to produce isolated structures in the precipitation field which show high rainfall values. Consequently, the traditional verification often evaluates the forecast performance as similar (or even worse as shown by RMSE – not presented here). The spatial verification techniques identify not only the improvement in single forecasts but also a global improvement over the whole 2009 episode.

At present a QPF verification of ALADIN-CZ precipitation forecasts is in progress for the whole summer period 2013. The results and their interpretation will be presented in the ERAD poster.

Acknowledgement

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References

Novak, P., The Czech Hydrometeorological Institute's severe storm nowcasting system. Atmos. Res. 83, 2007, 450–457.

Salek, M., Novak, P. Experience gained by five years of the utilization of the radar-based quantitative precipitation estimation at the Czech Hydrometeorological Institute'. ERAD2008 The Fifth European Conference on Radar in Meteorology and Hydrology, Helsinki, 2008.

Roberts, N.M., Lean, H.W. Scale-selective verification of rainfall accumulations from high-resolution forecasts of convective events. Mon. Weather Rev. 136, 2008, pp. 78-97.

Wernli, H., Hofmann, Ch., Zimmer, M. Spatial forecast verification methods intercomparison project: application of the SAL technique. Weather Forecast. 24, 2009, 1472–1484.

Zacharov, P., Rezacova, D. and Brozkova, R. Evaluation of the QPF quality for convective flash flood rainfalls from 2009. Atmos. Res. 131, 2013, 95-107.