Radar-based QPE for the modeler oriented QPF verification by traditional and spatial techniques.

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1. Introduction

Quantitative precipitation forecasts were evaluated by using spatial verification techniques and by analysing the results. The forecasts were produced by the limited-area numerical weather prediction (NWP) models the ALADIN-CZ and COSMO. Each model was run using two horizontal resolutions.

The forecast quality was studied for the 14 days of the flash flood period in June and July 2009 when the 1h and 3 h convective rainfalls with return periods over 100 years caused local, devastating floods in several Czech localities. Radar-based rainfalls were used to verify the forecasts. In order to merge radar-derived rainfalls with the rainfall values that were measured by ground rain gauges we applied the CHMI operational product MERGE and, for comparison, the which the results of RAG technique, which uses the interpolation of modified ratio between the rain gauges and radar measurement. A series of 56 consecutive forecasts of 3 h rainfalls were verified by using traditional and spatial verification techniques.

2. The NWP models and verification techniques

We studied the QPFs obtained by two NWP models. The ALADIN-CZ model is operated by the Czech Hydro-Meteorological Institute (CHMI), and the COSMO model is operated by the German weather service (DWD). Each model was run using two horizontal resolutions and the prognostic 3h rainfalls were verified over the domain covering the Czech Republic. We verified the ALADIN_CZ results which were obtained with horizontal resolutions of approximately 9 km and 4.71 km. The first run with 9 km resolution was operational during the simulated period in 2009. The second set of results follows from the ALADIN_CZ in its topical version. These results were obtained by reforecasting the 2009 flash flood period. The COSMO model outputs were obtained by using resolutions of approximately 7 km and 2.8 km. We used the operational forecast of COSMO-EU that was produced by DWD using an approximately 7 km horizontal resolution. The integration began at 0000UTC and the prognostic data were recorded each hour of the model integration. The COSMO-EU data provided the initial and lateral boundary conditions for the COSMO-CZ, which was integrated at the Institute of Atmospheric Physics with the horizontal resolution of 2.8 km over the domain covering the Czech territory. The forecasts were performed using version 4.11 of the COSMO NWP model and the COSMO-CZ integration began at 0900UTC.

For the verification we applied traditional skill scores and two spatial techniques: the fractions skill score (FSS) (e.g. Roberts and Lean, 2008) and the structure-amplitude-location (SAL) technique (Wernli et al., 2009). In this paper we present only the results of the comparative verification by FSS, the other results will be included in the poster presentation. The FSS compares the fractional coverage of events, i.e., occurrences of rainfall values that exceed a certain threshold, in elementary areas (EA) that surround the observations and forecasts. The FSS has a range of [0, 1] (0 for a complete forecast mismatch, and 1 for a perfect forecast). The score is sensitive to rare events or to small-rain areas and depends on the EA dimension and precipitation threshold. Two reference FSS values are considered by Roberts and Lean (2008). The first value, FSS_random = f0, was obtained from a random forecast with a fractional coverage that corresponded to f0, where f0 is the fraction of observed points with precipitation that exceeds the threshold over the domain. The second value, FSS_uniform = 0.5+ f0/2, was obtained at the grid scale from a forecast with a fraction that was equal to f0 at every point. The uniform forecast is always reasonably skillful, whereas the random forecast has low skill unless the value of f0 is large.

We applied the FSS-based verification in order to evaluate the QPFs for single convective events with heavy precipitation (Rezacova et al., 2009; Zacharov and Rezacova, 2009). In this comparative study, we use the FSS in a different way. We computed the FSS values for increasing EA size, and for each forecast we determined the smallest EA size for which FSS > FSS_uniform. Each model and horizontal resolution is then characterized by the fraction of forecasts that fulfill the condition FSS > FSS_uniform given EA size.

3. Input data from the rainfall period in 2009

Between the 22nd of June and the 5th of July of 2009, the weather in central Europe was influenced by a low pressure that was localized over the Balkan Peninsula. Simultaneously, a high pressure occurred above the Northern Seas and northwestern Russia. Such pressure distribution caused a moist and warm airflow that moved from the northeastern and other eastern directions into central Europe. The synoptic situation was exceptional because it lasted 12 days and the duration of such an extreme, eastern, cyclonic pattern in the CR has not been witnessed since 1946. The CR region was affected by severe, convective activity almost daily, which manifested as local, heavy precipitation and torrential rains. In several cases, heavy rains were accompanied by local flash floods, which resulted in several casualties. (Danhelka and Kubat, 2009)

Radar reflectivity fields that were located 2 km above sea level (CAPPI 2 km) were used in this study. The radar data were obtained from the CZRAD network (Novak, 2007). To determine the verification radar-based rainfall values, we applied two procedures, which adjust the rainfalls determined from raw radar data with gauge measurements from the Czech territory. Apart from the CHMI operational MERGE product based on the kriging (Salek and Novak, 2008), we applied the RAG technique, which uses the interpolation of modified ratio between the rain gauges and radar measurement (Sokol and Rezacova, 2000).

4. Results

For verification, we used four, 3h precipitation totals from the second half of each day. The 3h intervals ended at 1500, 1800, 2100 and 2400UTC, and the forecasted period lasted for 14 days, which means that we evaluated 56 prognostic, 3h precipitation totals for each model. The gauge-adjusted precipitation totals were interpolated into each model grid with different resolutions and projections so that they covered the verification domain.

The figure 1 shows the distribution of 3h rainfall values over the COSMO 2.8km grids and all forecasts. It indicates wider interval of adjusted rainfall values in comparison to raw radar data. While the RAG indicates values between 90mm/3h and 10mm/3h the MERGE gives rainfalls up to 90mm/3h. Maximum rainfall values for each 3h interval are shown in Fig.2.

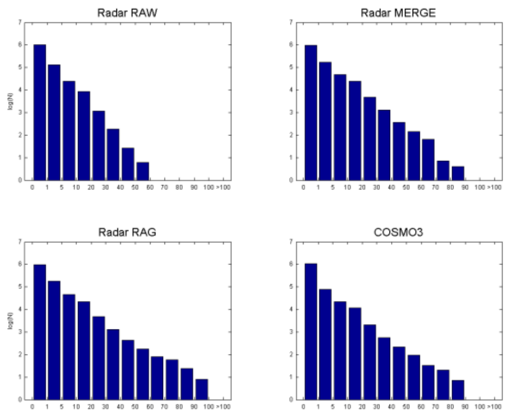

Fig. 1 The distribution of grid-point 3h precipitation over the verification domain and for all days of the convective period. The subpanels show raw radar precipitation (Radar RAW), the adjusted QPE values for MERGE (Radar MERGE) and RAG (Radar RAG) and for the rainfall predicted by COSMO 2.8km (COSMO3).Vertical axis show the number of rainfall values in logarithmic scale, horizontal axis indicates the 3h rainfall values.

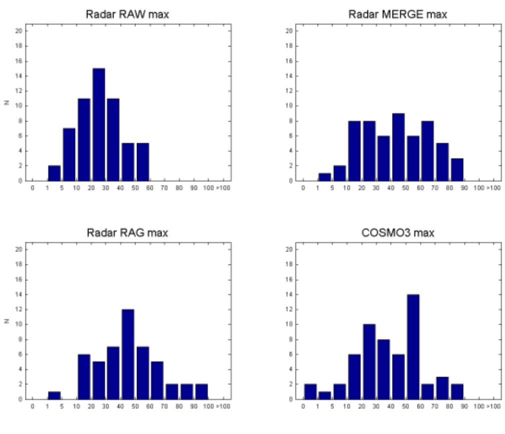

Fig. 2 The same as in Fig. 1 but for the maximum 3h rainfall over the verification domain.

The fraction of forecasts that fulfill the condition FSS > FSS_uniform as a function of the EA dimension is shown in Fig.3, 4, and 5. The figures differ in threshold values that were used in FSS calculations. The both models and corresponding horizontal resolutions are included. The figures shows (i) how the models perform with increasing threshold values (1mm/3h, 5mm/3h, and 10mm/3h), and (ii) how the verification data following from MERGE and RAG influence the verification results.

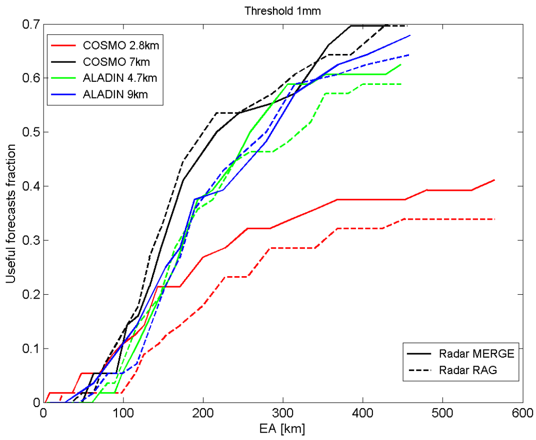

Fig. 3 Fraction of forecasts with FSS values larger than FSSuniform for the precipitation threshold 1mm/3h. Horizontal axis represents the EA size in kilometers. The models and adjustment techniques are indicated in the legends.

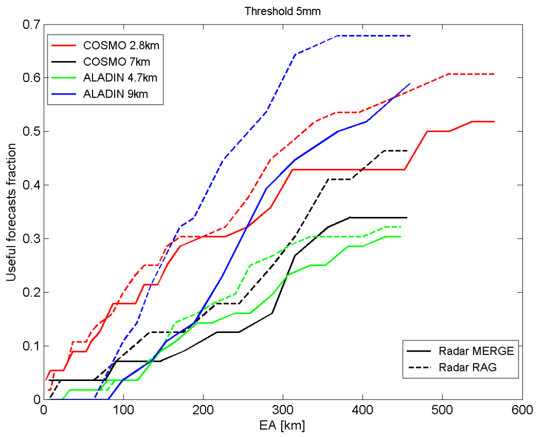

Fig. 4 The same as in Fig. 3 but for the precipitation threshold 5mm/3h

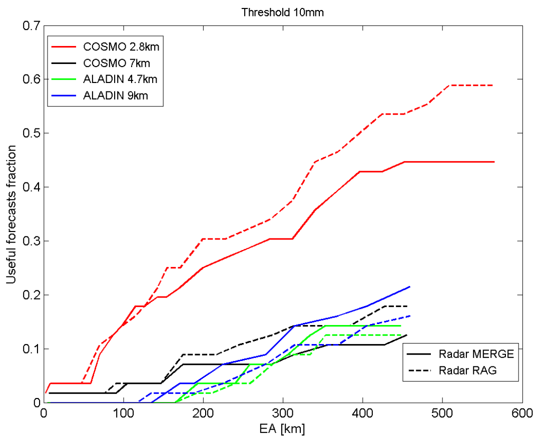

Fig. 5 The same as in Fig. 3 but for the precipitation threshold 10mm/3h

5. Conclusion

The QPF quality depends strongly on the scale of convective precipitation, and all models provide a good forecast quality for extended rainfall systems. The opposite is valid for local and more or less chaotic convection during the final portion of the time period. The FSS indicates how the results depend on the threshold and the scale of precipitation. The COSMO 2.8 model is able to determine the largest local rainfall values, but models with smaller resolution, such as the ALADIN 9 km and COSMO 7 km, give better results for lower thresholds and larger scales. There is not large difference in QPF quality between the two resolutions of ALADIN_CZ model. On the contrary the same difference at the non-hydrostatic COSMO model is quite pronounced. We obtained different verification results for the different adjustment techniques. However, the substantial features in verification results do not changed. The first results do not indicate preference for any of two techniques.

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