Proceedings of ERAD (2004): 193–196 © Copernicus GmbH 2004

ERAD 2004

Radar verification approach to the QPF for local flash flood storms

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Abstract. Local flash flood storms with a very rapid hydrological response are the real challenge of precipitation forecasting. It is relevant to assess the space dimensions, where the QPF results are applicable to the forecasting and/or warning. In this paper we attempt to express the forecasting capability of a high-resolution NWP model by means of area-related radar verification. The presented results concern the local convective event on 13 July 2002, which occurred in the Czech Republic and caused a local flash flooding. The 18 h forecast gave rainfalls in the horizontal resolution of 2.8 km. Verification made use of corresponding radar rainfall totals adjusted to the rain gauge data. Grid point-related RMSE value was calculated over a square around the grid point; the calculation was based on the assumption that the rainfall values were randomly distributed inside the square. The mean RMSE characterized the forecast accuracy over the whole verification domain. In this paper we show the dependence of the RMSE field as well as of the mean RMSE on the square size.

1 Introduction

Two very local convective storms, which were recorded in the territory of the Czech Republic (CR) in July 2002, have been studied by non-hydrostatic NWP model (the Lokall Model – LM COSMO). The storms developed in different parts of the CR during the afternoon on 13th and 15th July. The flash precipitation on 13th July produced local flooding and severe damage in the Sazava river basin (central part of the CR) and the recorded rainfall amount exceeded 100 mm in about 3 h. The 15th July storm occurred in an eastern part of the CR and the recorded maximum 2 h rainfall reached 171 mm. The both storms caused flooding in several villages located in the area struck by precipitation. Such storms accompanied with a very rapid local hydrological response are a real challenge of precipitation forecasting. It is relevant to assess the time and space dimensions, where the QPF results are applicable to the forecasting and/or warning. In this paper we present first results of an attempt to assess the forecast ability of a high-resolution NWP model by means of new area-related radar verification. The results are related to the event on 13 July 2002, and a similar analysis of the storm on 15 July is under way. The LM code, provided to the IAP (Institute of Atmospheric Physics) by the DWD (German Weather Service) for research, was used in an experimental two-step configuration in order to assess the model ability to predict precipitation amounts, sites and timing of rainfall. The predicted rainfalls were compared with the radar rainfall totals adjusted to the rain gauge data. The aim of analysis is to examine the LM results in dependence on the area size. The area surrounding a grid point is considered and the area size is related to the accuracy of the precipitation forecast.

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2 The arrangement of LM runs

We followed the LM arrangement used in the previous case studies to simulate convective events that had occurred in the region of the CR in 1998 and 2000 (Rezacova et al., 2002). Firstly, the driving LM model (LLM) was integrated over a domain covering a larger part of Europe. Secondly, a nested LM model (SLM) was run over a subdomain covering the territory of the CR. In this study we used the LM 3.9 version and the initial and lateral boundary conditions derived from ECMWF analyses. The LLM model was integrated with the horizontal resolution of 11 km. The driven SLM version used the horizontal resolution of 2.8 km and a domain of 251 × 191 grid points. The initial and boundary conditions for the SLM were obtained from the LLM forecasts. Considering the storm occurrence in the afternoon, the LLM was run with the data from 00 UTC and the integration finished after 24 h. The SLM integration started with the LLM data from 06 UTC and terminated at 06+18 h. The LLM model was integrated in a standard way with Tiedtke cumulus parameterization (Doms

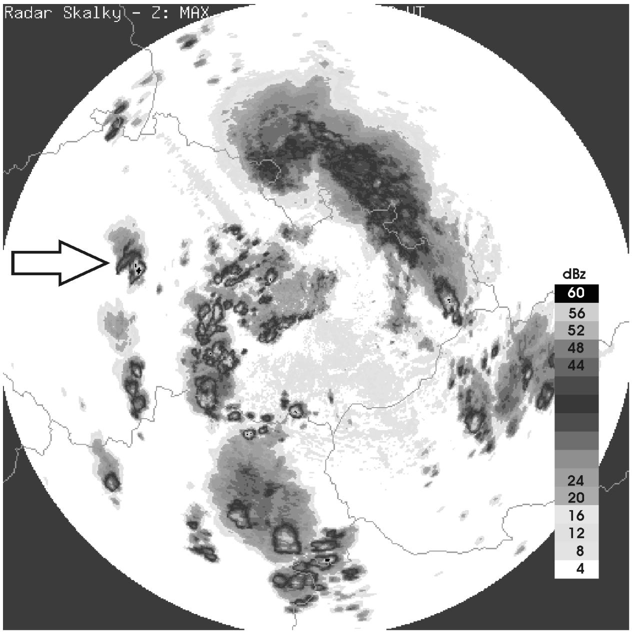

Fig. 1. Column maximum reflectivity measured by radar Skalky (Gematronik METEOR 360AC) on 13 July 2002 at 13.18 UTC. The arrow indicates the position of flash flood storm. The picture was adapted from operational CHMI output.

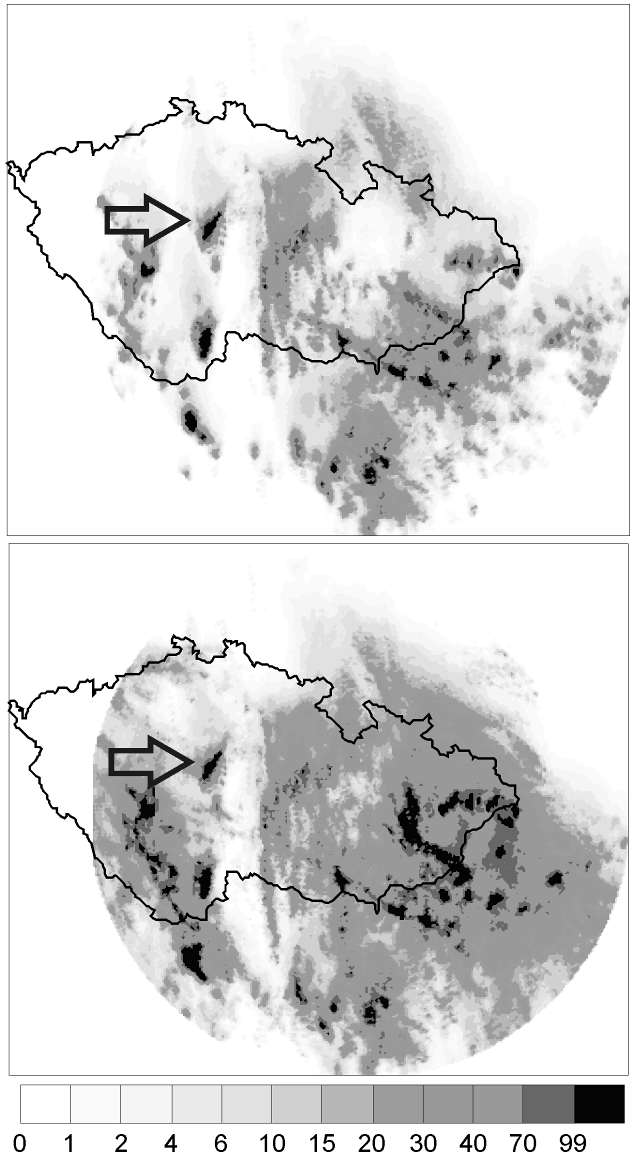

Fig. 2. Radar rainfall calculated from the radar Skalky measurement on 13 July 2002. The bold line indicates the border of the CR and the arrows show the position of the storm. Upper picture demonstrates the radar rainfall for the time period 12–18 UTC, lower picture relates to the accumulation interval 06-18UTC. The rainfall values in mm are given in the legend.

and Schaettler, 1999; Tiedtke, 1989). For the SLM integration we switched the cumulus parameterization off and used the explicit expression of cloud and rain processes.

3 Radar data processing

The number of ground gauges in the area affected by local convective rainfalls is too limited to provide proper data for the model verification. On the contrary, radar data represent dense area information about precipitation. However, a direct application of radar-based precipitation determined from measured radar reflectivity is restricted by errors and uncertainties in derived estimates. A correction of radar precipitation fields by adjusting radar precipitation to rain gauge measurements is one of the frequently used methods to improve the quantitative precipitation estimation over an area of interest. Therefore, we compared the forecast precipitation with radar-based rainfall values after applying the procedure, which adjusted radar pixel rainfall by merging radar data and rain gauge measurements. We used the outputs of the Czech Doppler weather radars Skalky (Gematronik METEOR 360AC) and Brdy (EEC DWSR-2501C), operated by the Czech Hydrometeorological Institute (CHMI). An example of the maximum reflectivity field indicated by radar Skalky on 13 July 2002 is shown in Fig. 1. In order to determine the radar rainfall values we followed the basic CHMI procedure of processing of radar measurements described, e.g., in Kracmar et al. (1998). Column maximum reflectivity, Zmax, was converted into rain rate, R, using the standard Marshall-Palmer relationship Zmax=200 $R^{1.6}$, and integrated in time. The fields of radar rainfall with accumulation time 6 h and 18 h are shown in Fig. 2. The radar-based rainfall values, employed in the verification, were obtained by merging the radar and ground rainfall values. The procedure (Sokol, 2003; Sokol et al., 2002) was applied to adjust the radar rainfall values to the ground precipitation. The both radars provided data in 256×256 pixels where each pixel represented the area of 2×2 km. The composite precipitation field of the size of 356×356 pixels was prepared by using the maximum radar rainfall value in overlapping pixels. Data from more than 800 gauges entered the adjusting procedure. It combined radar and gauge values in one variable that was

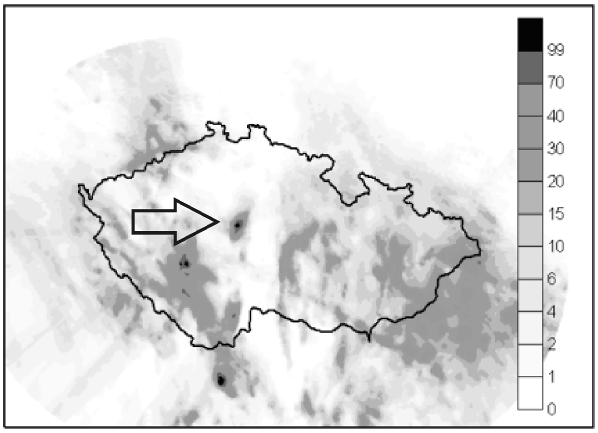

Fig. 3. Adjusted rainfall values for the time period 06–18 UTC. The bold line indicates the border of the CR and the arrow shows the position of the storm. The rainfall values in mm are given in the legend.

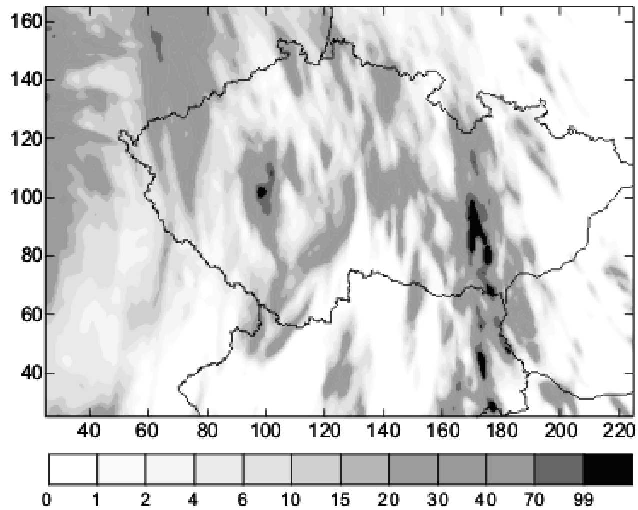

Fig. 4. The 18 h forecast of accumulated precipitation (06–18 UTC) resulting from the integration of the SLM model. The bold line indicates the border of the CR and neighbouring countries. The rainfall values are indicated in the legend. The axis labels are in model grid points, the whole SLM domain includes 251×191 grid points with horizontal resolution 2.8 km.

interpolated by kriging method into all radar pixels. The adjusted pixel precipitation was calculated from the radar precipitation and from the value of the combined variable. The 18 h radar rainfall after application of the adjustment procedure is shown in Fig. 3.

4 Radar based verification of precipitation forecast

High-resolution NWP models such as the SLM produce detailed precipitation forecasts, which are comparable with the structures contained in the radar-derived precipitation fields.

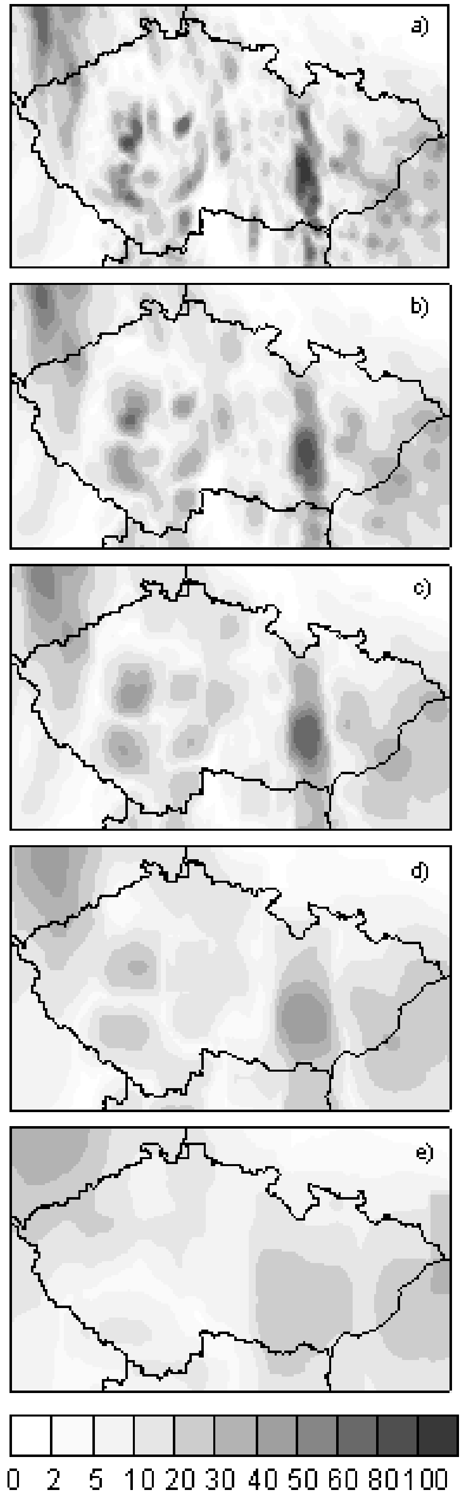

Fig. 5. The area distribution of the RMSE values resulting from the 18hr forecast of accumulated precipitation on 13 July 2002. The verification domain comprises 111x181 grid points of the SLM domain with horizontal resolution 2.8 km. The sides of the verification squares of h=3, 7, 11, 21, and 41 grid points relate to the figures a), b), c), d), and e), respectively. The scale indicates the RMSE values in mm.

Standard rain gauge networks can hardly recognize details like these. It is therefore suitable to include the radar data in the derivation of precipitation fields and to use the merged information at the verification of precipitation forecast. Forecast precipitation on 13 July 2002, resulting from the SLM integration, is shown in Fig. 4. The fact that the NWP model is capable to generate precipitation fields is undoubtedly positive but a large variability of both forecast and observed precipitation fields, especially in summer convective season, causes difficulties in assessing the QPF performance. Various approaches to the QPF verification by radar rainfalls were presented by Rezacova et al. (2002). It was shown that the verification of area precipitation could provide suitable information about the QPF accuracy. To analyze the QPF for very local storms, a modified verification approach has been studied. The verification approach stems from the fact that the NWP model is capable to simulate individual convective systems and rainfalls. However, locations of the forecast rainfalls and their timing do not need to be accurate. It is supposed that forecast precipitation amounts in the vicinity of the right position are randomly distributed. A square with a side of h grid points is considered around each grid point of the verification domain. The verification is dependent on the changing h value. The verification procedure sorts monotonically the forecast rainfalls as well as the radar based values in each square from the lowest to the largest values and calculates the RMSE between the both series. An example of resultant RMSE fields is shown in Fig. 5. The overall accuracy of the forecast for the whole evaluated domain is expressed by mean RMSE over all squares. The mean RMSE values 20.1, 19.6, 18.8, 17.2, and 15.2 mm/18 h correspond to the square size of h=3, 7, 11, 21, and 41 grid points. The use of the squares of various sizes can express the forecast accuracy in dependence on the area size and this knowledge could be employed in warning systems against the heavy convective rainfalls.

5 Summary and conclusions

Taking into account Fig. 5 and the mean RMSE values in dependence on the square size we can see the influence of the increasing area size. We suppose that the mean RMSE could be a useful measure used in event-related verification. Nevertheless, the results described in this paper are to be considered preliminary and it is important to test the verification approach at more than one case study. The verification of the precipitation forecast for the storm on 15 July 2002 is in progress and we also reckon on the cases cited in (Rezacova et al., 2002) to be included in the tests. The results of presented verification technique are to be discussed from the view of other verification approaches.

Acknowledgements. This work was supported by the grant GACR205/04/0114 and by the COST717 collaboration. The DWD is acknowledged for the provision of the LM COSMO code as well as for the necessary assistance at the LM implementation. The CHMI kindly provided the data from the Czech region

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