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Uncertainty in the area-related QPF for heavy convective precipitation

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ABSTRACT

We studied five convective events producing heavy local rainfall with the help of the numerical weather prediction model LM COSMO. The model was run with a horizontal resolution of 2.8 km. We created an ensemble of 13 forecasts by modifying initial and boundary conditions. Uncertainties in the area-related quantitative precipitation forecast (QPF) were evaluated with the help of a fraction skill score that can quantify the ensemble spread and skill. The spread represents the differences between the control forecast and the forecasts provided by each ensemble member, and the skill evaluates the difference between the precipitation forecast and radar-based rainfall. Analyses show how the forecast lead time and spatial scale influence the spread and skill values. Despite the different areal structures of precipitation fields, the relationships between spread and skill appear to be similar.

1. Introduction

Forecast uncertainty is currently considered to be an inherent part of high-resolution quantitative precipitation forecast (QPF), and it is particularly pronounced when predicting heavy convective precipitation. Due to the large spatial and temporal variability of convective systems, deterministic QPFs of heavy convective precipitation are extremely difficult if local forecasts with sufficient accuracy are needed. Current operational Numerical Weather Prediction (NWP) models are capable of generating high-resolution prognostic precipitation fields with a mesh size on the order of 1 km. In principle, NWP models have achieved a stage at which QPF is a useful tool in hydro-meteorological forecasting and/or warning if we can determine a suitable QPF form (target area size, precipitation threshold or interval, etc.) and to estimate a forecast uncertainty. We can then provide users with the forecast and its uncertainty in a comprehensive form. In order to find a suitable QPF form, it is necessary to verify prognostic fields of precipitation-related variables. When assessing forecast uncertainties, it is useful to employ an ensemble approach.

Various ensemble prediction systems (EPSs) have been designed for various scales. The EPSs applied to medium-range forecasting are well known, like the ECMWF EPS, which deals with meteorological variables describing a larger scale. Nevertheless, an assessment of short-range predictability, mainly for potential severe-weather development, including heavy local precipitation, attracts a lot of attention (e.g., Arribas et al., 2005). The system COSMO-LEPS is an example of a regional mesoscale ensemble technique (see e.g., Marsigli et al., 2005; Federico et al., 2006; Verbunt et al., 2007) designed for short-range forecasting. Other approaches are based on multimodel ensembles derived from outputs of various models or model versions (e.g., Ebert, 2001; Stensrud and Yussouf, 2007). In our study, we applied a simple technique of modifying initial conditions of the NWP model LM COSMO in order to obtain an ensemble of 13 very short-range QPFs. The study concentrates on a very short-range forecast of local convective rainfall.

Large variability of both forecast and observed convective precipitation is a major difficulty in assessing the QPF performance (Collier, 2007). In most cases, the gauge networks cannot provide observation datasets suitable for verifying a high resolution QPF, since the networks are not sufficiently dense and stations are not evenly distributed. At present, a quantitative precipitation estimate (QPE) obtained by suitably processing radar information enables us to acquire reliable verification-related values (see e.g., Sokol, 2003; Rezacova et al., 2007). In that case, the observation data follow from merging radar-based precipitation with gauge information. A technique

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Table 1
CAPE and K index values from the sounding Prague Libus 12 UTC.

Date	13.7.2002	15.7.2002	10.6.2004	23.5.2005	30.5.2005
CAPE [J/kg]	513	401	2718	933	2830
K index [°C]	24.6	29.8	31.0	27.8	40.1

like this is used here to verify the QPF and determine the ensemble skill.

In an ensemble forecast regime, we analyzed five events with heavy convective precipitation that occurred in the Czech Republic (CR). Like in our previous papers (Rezacova and Sokol, 2003; Rezacova et al., 2007), we used the NWP model LM COSMO to obtain a high resolution very short-range forecast of summer convective precipitation. In our previous papers (Rezacova and Sokol, 2003; Rezacova et al., 2007), we studied the effect of cumulus parameterization on the quality of the convective precipitation forecast (Rezacova and Sokol, 2003) and defined a new "fuzzy" verification score to quantify the accuracy of area-related QPF (Rezacova et al., 2007). In this paper, we focus on evaluating an ensemble QPF. A regional ensemble of 13 members was formed by modifying the LM COSMO initial conditions, and the relationship between the ensemble spread and ensemble skill (Buizza, 1997; Grimit and Mass, 2007) was studied. Various scores can be calculated to evaluate the ensemble spread and skill (Grimit and Mass, 2007). In this paper we employ the so-called Fraction Skill Score (FSS), which expresses the extent to which the area of interest is covered by rainfall exceeding a given threshold (Ebert, 2008; Roberts, 2005). In Rezacova et al. (2007), we studied two storms in July 2002 and verified the precipitation forecast using various scores. In this paper, we examine a more extended set of 5 events and discuss the relationship between mean spread and skill of ensemble forecasts. In part 2, we

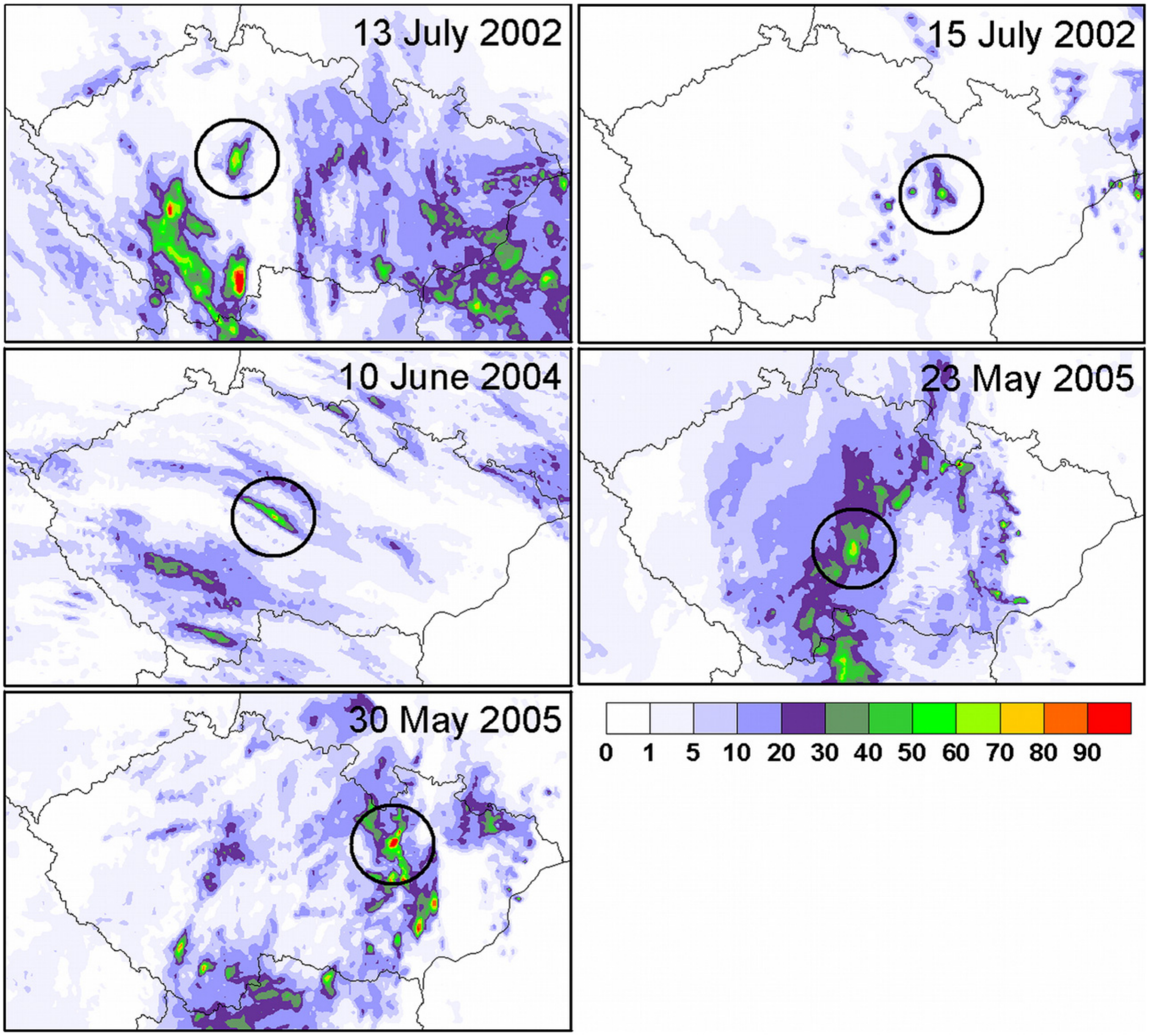

Fig. 1. Radar-based 12 h (10 UTC–22 UTC) rainfall for the five considered events. The date is marked in each panel. The circles indicate the positions of local floods. The rainfall values in mm/12 h are indicated in the legend.