Precipitation forecast by the COSMO NWP model using radar and satellite data

Z. Sokol, P. Pešice

Institute of Atmospheric Physics AS CR, Boční II, 1401, Prague, Czech Republic, sokol@ufa.cas.cz

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I. INTRODUCTION

Forecasting local heavy convective precipitation is a difficult and complex task. At present, numerical weather prediction (NWP) models with a resolution of the order of 1 km are capable of generating fine-scale precipitation fields, the structure of which is similar to observed reflectivity by meteorological radars. However, observed and predicted precipitation cores differ in rainfall amounts, positions, and temporal evolutions. The errors in the forecast can be attributed to two main sources: the model's ability to correctly simulate dynamical and physical processes, and initial and boundary conditions supplied to the model (e.g. Stensrud, 2007).

It is known that improvement of the model initial conditions, especially humidity parameters, including cloud water content, rain water, and ice, is important for more accurate precipitation forecasts for the first several hours of model integration (Ducrocq et al., 2002). Another frequently used approach is the assimilation of radar data, which not only improves the model initial conditions but also initiates a model state using detailed information on the development of convective storms before the forecast starts. Numerous studies have shown that assimilating radar data of both types, Doppler wind velocity, and reflectivity (or derived radar-based rain rates), can improve the quality of precipitation forecasts (e.g. Jones and Macpherson, 1997; Snyder and Zhang, 2003; Tong and Xue, 2005; Zhang et al., 2004). In this paper we study the impact of assimilation of radar reflectivity and satellite data on the precipitation forecast for next 1-3 hours. Most studied cases include events when NWP model forecasts without assimilation are not able to develop precipitation in corresponding regions and times.

II. PRESENTATION OF RESEARCH

In this study we use COSMO NWP model (version 4.6), which is integrated with the horizontal resolution of 2.8 km over the territory of the Czech Republic (Fig. 1). Cumulus parameterization is switched off, but parameterization of shallow convection is included. Prognostic fields of LME (Local model - Europe of German Weather Service) model are used as initial and boundary conditions. The assimilation method is based on corrections of model water vapour (WVC) (Sokol, 2009) and consists of adding/removing water vapour into/from the model water vapour mixing ratio which are performed using nudging technique. Oversaturation or undersaturation, which can follow the corrections, result in releasing or absorbing heat, and consequent changes in the model temperature. In this way, the WVC method is similar to latent heat nudging (Jones and Macpherson, 1997).

The corrections of model water vapour are based on the observed radar and satellite data and three types of variables are assimilated: (i) observed radar reflectivity; (ii) satellite data and (iii) measured and forecasted hourly precipitation.

Radar reflectivity is measured by two radars whose positions are indicated in Fig. 1. Radar reflectivity is first transformed into rain rate R (mm/h) using standard Z-R relationship and then the rain rate is expressed as water vapour mixing ratio q (kg/kg) making use of an empirical relationship

$$q(R) = \frac{70.2026}{\rho} R^{0.9143},$$

where ρ is the air density (kg/m^3).

Satellite data are considered complementary to radar reflectivity. The assimilation procedure uses brightness temperatures from two channels: 10.8 (T10.8) and 6.2 (T6.2) μm measured by Meteosat 8. The difference T10.8 - T6.2 is applied to identify vertically developed convective cloudiness and to estimate rain rate which is again transformed into q (Sokol, 2009). Satellite data are assimilated into the model in a grid point only if radar does not observe rain, the model does not forecast rain and satellite data indicate significant precipitation.

Hourly precipitation obtained by merging radar reflectivity measurements and gauge observations is the third type of assimilated data. Beside the observed data also nowcasting forecasts of hourly precipitation are assimilated in the same way as observed data. The nowcasting forecast is obtained by simple advection of radar echo using COTREC technique (Novak, 2007). The motivation for making use of nowcasting data is the experience that the COTREC forecast is quite accurate in case of severe convection for the first hour.

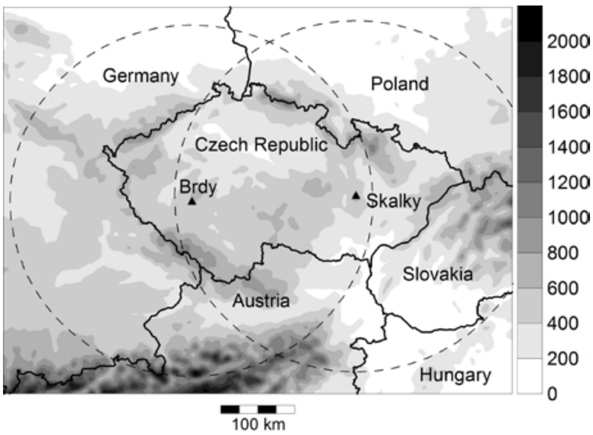

FIG. 1: The model domain with topography (in m above MSL) and with marked positions of two radars as well as areas covered by the radar data (dashed circles).

An example of forecasts with and without assimilation of hourly precipitation is shown in Fig. 2.

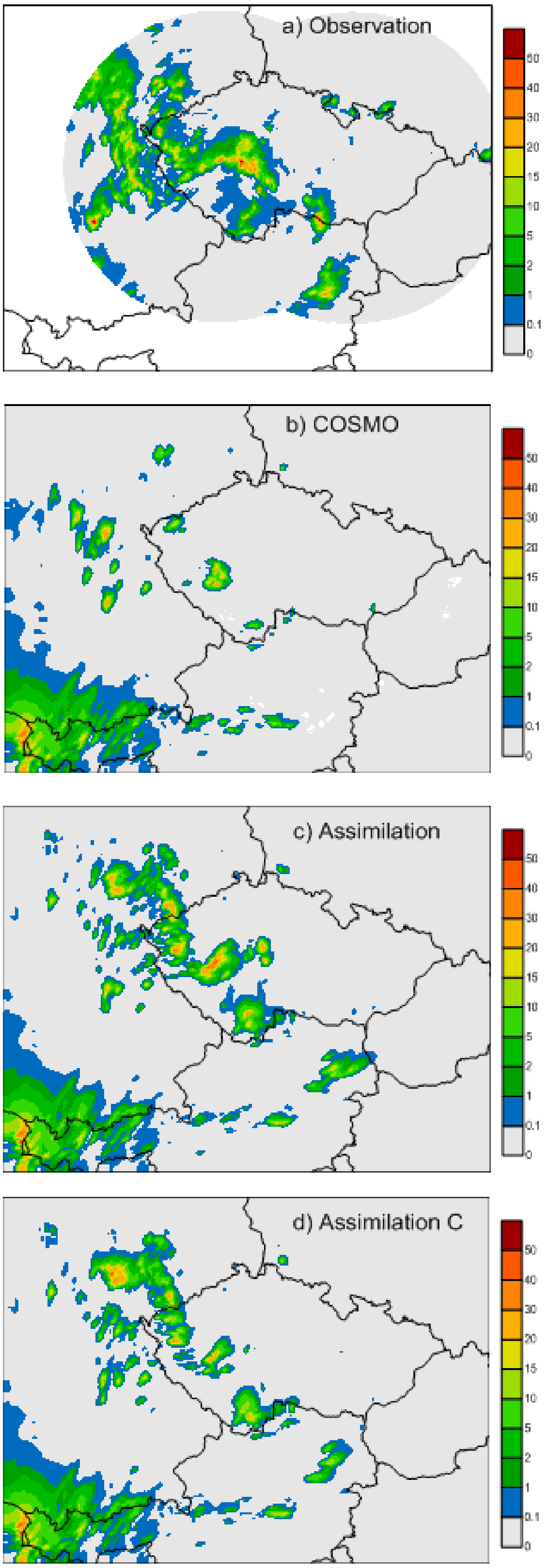

FIG. 2: Observed and forecasted precipitation (3 June 2008, 12-15 UTC) by COSMO without assimilation (b), with assimilation of observed hourly precipitation (c) and as (c) but using also the forecast by COTREC (d).

III. RESULTS AND CONCLUSIONS

Our preliminary results show that the assimilation of radar and satellite data improves the precipitation forecasts in comparison with the model runs without assimilation. In all cases, fairly good forecasts were obtained for lead times two or three hours minimum. If the precipitation forecast is reasonably accurate for the model without the assimilation, then useful forecasts are obtained for longer lead times.

The inclusion of the COTREC forecast into the assimilated data improved precipitation forecasts in all tested cases. This is due to the fact that in all tested cases we predicted development of well organized convection and the COTREC prediction was reasonable. However, further investigations are needed.

IV. AKNOWLEDGMENTS

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