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Assimilation of radar reflectivity data for triggering of convective phenomena

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Abstract. Convective events are very sensitive phenomena concerning theirs appearance in place and time. Even at cases with correct objective analysis, it is hard to predict the first appearance of thunderstorms because theirs breaking out can be determinated by subgrid events. NWP studies show that high resolution models are able to forecast convection, but the forecast quality depends on where the model generates the first cells. During studies we found several cases where model generated convection life cycle and activity were close to the reality but cells appeared far from the real place. To upgrade the quality of thunderstorm forecast, radar data were applied to force the model to place thunderstorms to correct places. Using MM5 model with high resolution (3 km horizontal) the nudging technique was applied in such a way, that in the first two hours initial conditions were perturbed on places where thunderstorms were observed by radars. The perturbation consists of the following: on grid points where radar reflectivity indicates thunderstorms, the equivalent potential temperature is considered as vertically constant from up to the cloud base and the relative humidity profile is considered 100 percent. The temperature profile is calculated back from these conditions. Case studies show that this method helps to upgrade thunderstorm forecasts by placing triggers to the right places.

1 Introduction

Thunderstorms and theirs related phenomena can cause serious problems in the Carpathian basin (Horvath and Geresdi, 2001). In the operative practice of the Hungarian Meteorological Service (HMS) there are two approach of thunderstorm prediction. The first is the synoptic approach when meteorologists using general meteorological information (instability indexes, numerical models, soundings, etc.) indicate the probability of the thunderstorms for smaller or larger regions for a given time period ("this afternoon"). The second approach is the nowcasting of severe convective activity, using radar, satellite and other real time data. The nowcasting system of HMS, named MEANDER has been developed for this reason: it uses all real-time data and calculates advections of thunderstorms (Horvath et al. 2003). This system is able to forecast of 60% of severe thunderstorms 1 hour ahead. The remaining 40% comes from "unexpected" convections: from cases where the evolution of phenomena is stronger than theirs advection. The first problem to forecast the place and time of the first appearance of thunderstorms, which can determinate the weather of the next few hours. The second problem is the evolution of thunderstorms: pure replacement of convective cells can cause unacceptable errors beyond 30–40 min. A possible solution of this problem could be the "fast responding model run": to run a numerical model when the first significant appearance of convective activity takes place in such a way, that strong trigger effects indicates the real place of existing thunderstorms in the objective analysis. It gives a chance, that the model develops thunderstorms on the right place and makes better predictions than linear replacement.

The problem of radar data assimilation for NWP is a fast developing field, this works is supported by COST 717 action (COST 717. 2003, Macpershon 2000, Gregoric 2001).

In this experiment the PSU/NCAR meso-scale model, MM5 was chosen (Grell et al., 1994). This model has well developed cloud physic and planetary boundary layer schemes and the applied high resolution (3 km) horizontal grid allows to avoid using cumulus parameterization schemes but consider direct convection. The nudging capability of the model allows to do nudging procedure which partly useful for decreasing spin up time of the model and partly it helps to create longer time period perturbations to indicate thunderstorms in the objective analysis.

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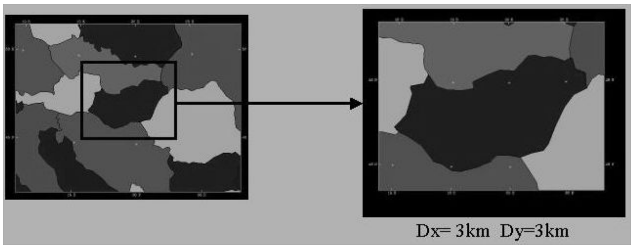

Fig. 1. The larger and the smaller domain of the applied MM5 model.

2 The numerical model and objective analysis

The MM5 model is applied in two steps. A larger domain model is used to run for a longer term (36 h) which provides boundary conditions for the meso-scale version of MM5 (Fig. 1).

The horizontal resolution of the large model is 10 km, the small scale model is 3 km. The small scale model uses ETA planetary boundary model (Janic, 1994), Reisner mixed-phase explicit moisture scheme (Reisner 1998), and a rapid radiative transfer model for radiation scheme (Mlawer, 1997). The surface scheme is a five layer soil model (Dudhia, 1996).

The model uses four dimensional data assimilation using nudging technique. Two hours analysis nudging is applied. The objective analyses at 0 h, +1 h and +2 h model time are made by the MEANDER system analysis segment. The radar data are taken into account in the objective analysis. Model experiments show that vertical profiles of equivalent potential temperature (EPT) of well developed thunderstorms have characteristic profiles, they can be considered as conservative values in the middle troposphere. This experience is confirmed by some cross section of EPT field, calculated by MM5 (Fig. 2).

The basic idea is that on grid points, where radar data indicates thunderstorms, profiles of EPT are considered constant values. Supposing that the relative humidity is 100% in thunderstorms, the modified temperature profile can be recalculated as a function of the pressure profile. This modified humidity and temperature values represent thunderstorms in the objective analysis. Obviously it is important question how to determinate EPT anomalies in the thunderstorms. In this experiments EPT of thunderstorms are calculated from the lowest 1000 m humidity and temperature values which were taken from the objective analysis of the MEANDER system.

The above described method works only for convective precipitating systems, it is not proper for stratiform clouds. To distinguish thunderstorms, only grid points with radar reflectivity higher then 40 dBz were considered.

3 Experiments and a case study

10 case studies were made for different convective situations. These studies show that introductions of thunderstorms can be used to upgrade short term (3–5 h) forecasts. Most successful cases are prefrontal unstable situations and isobarless synoptic patterns. At cases of unsuccessful objective analysis the effect of radar nudging goes down rapidly in time, soon after the end of the nudging period. There are some cases when the enhanced nudging forcing may help to catch the strong convective phenomena, despite the poor objective analysis. The following case study is a good example for this case.

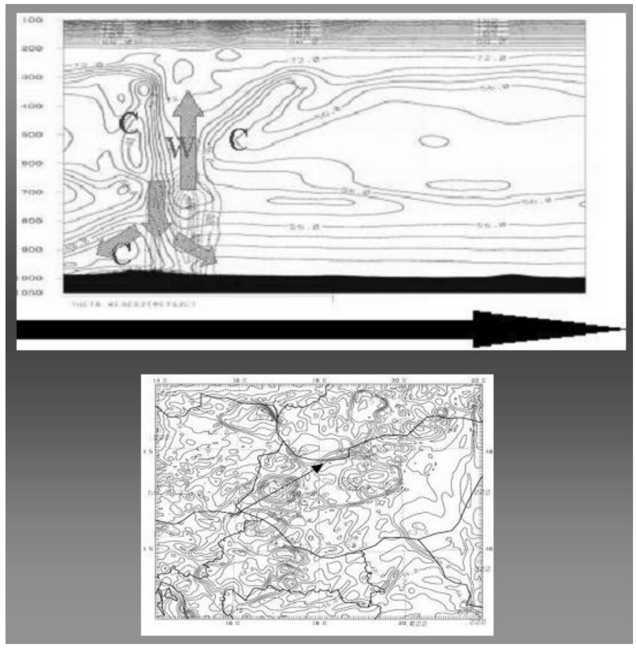

Fig. 2. A vertical cross section of EPT at a case of severe thunderstorms (upper figure). The lower figure shows EPT field at the surface, and the arrow indicates the direction of the cross section.

In Jun 9, 2002 at 18:00 UTC a squall line hit the middle part of Hungary. There were two supercells in this system which caused tornadoes in Budapest and in Kecskemet (100 km southeast of Budapest). These cells were indicated by the radar network of HMS (Fig. 3).

Large scale MM5 (and other models like ECMWF) did not predicted any convective activity in this region. A model run of small scale model (started at 15 UTC) with two hours of analysis nudging did not generate convection, either. When radar data were introduced in the initial time (at 15 UTC) the convection appeared but died out in 1 h. When radar data were introduced in two hours analysis nudging, thunderstorms remained active (Fig. 4).

When the nudging coefficients of temperature and humidity were screw up to the magnitude of Coriolis forece, one of thunderstorms (which hit Kecskemet) showed supercell signature on the wind field (Fig. 5).

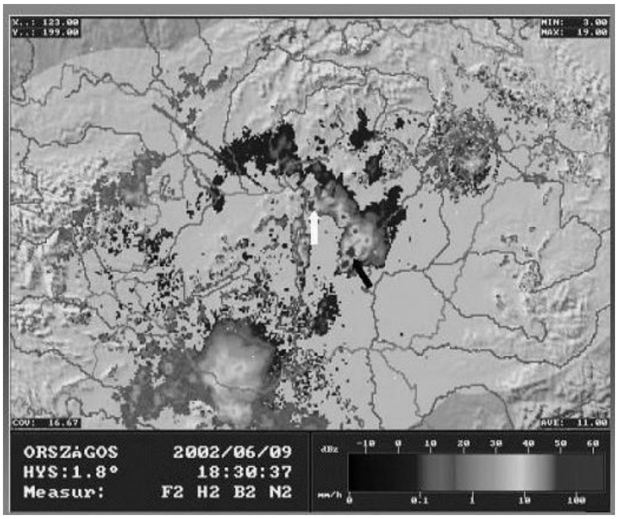

Fig. 3. Radar image of 09.06.2002. 18:30 UTC. Arrows show supercells close to Budapest and Kecskemet.

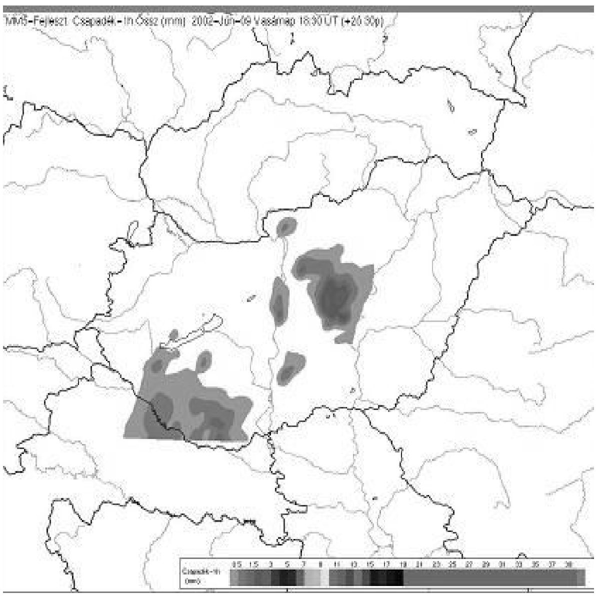

Fig. 4. Forecast of hourly accumulated precipitation for 19 UTC, 09.06.2002.

4 Summary

Case studies show that using radar data as trigger effects in numerical model may help the model to place the convective events to the "right" place. It seems, that four dimensional nudging assimilation method also helps to develop severe convective phenomena like supercells. It is important to start the model in the very beginning of the convective activity and doing as long nudging term as possible because it may help the model to breed real convection and decrease not realistic ones.

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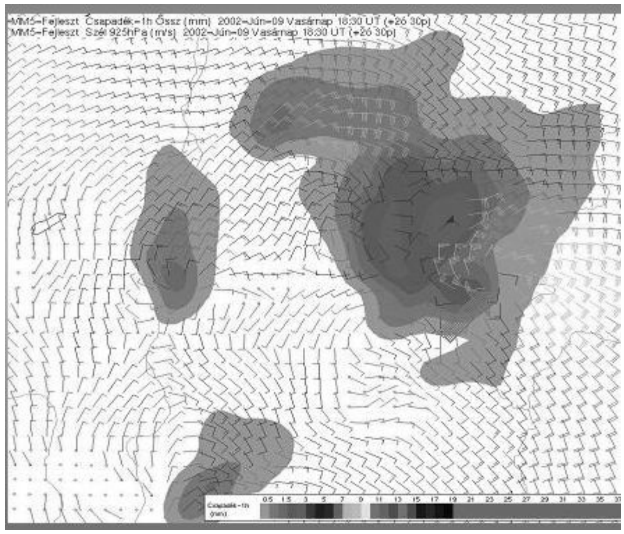

Fig. 5. Forecast of hourly accumlated precipitation and wind of 925 hPa for 19 UTC, 09.06.2002.

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