Numerical modeling of severe convective storms occurring in the Carpathian basin

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I. INTRODUCTION

In the evening of 20th of August in 2006 severe thunderstorms hit Budapest. The storm stroke the downtown in the same time when the Constitution Day firework just started and killed five and wounded thousands of spectators crowded on embankments of Danube. The Budapest Storm was the most spectacular phenomena of the supercells that frequently appear in the Carpathian basin every summer. Supercells and the related tornado formation in territory of Hungary was described first in Horvath (1997). As weather radar network of Hungarian Meteorological Society became more accurate, more supercell cases were recognized (Horvath and Geresdi 2003). These case studies show that synoptic conditions of severe weather are similar in North American region and Carpathian Basin. However, some phenomena, like strong directional wind shear is less frequently observed in Hungary than in USA. Supercells can appear among cells of a squall line and sometimes they separates from the line of thunderstorms (Horvath et al. 2006, Mahovic 2007). Supercells and squall lines are very complex atmospheric phenomena, so they can be simulated only with state-of art numerical models, which involves non-hydrostatic version of equation of motion, detailed description of short and long wave radiation, processes occurs in the boundary layer and formation of precipitation and cloud elements (Wilhelmson 2001). In this paper results of numerical case studies are presented. The applied numerical model was the Version 3 of the MM5 (NCAR-PSU Mesoscale Model) (Dudhia, 1993).

II. NUMERICAL EXPERIMENTS

In MM5 model experiments the predictive variables are: pressure perturbation, three momentum components, temperature, specific humidity and the mixing ratio of five different types of hydrometeors (cloud water, cloud ice, rain, snow and graupel particles). For case studies, the model is integrated with horizontal resolutions of 1.5 km, and with 27 vertical levels. The initial and lateral conditions for the MM5 were taken from ECMWF deterministic model run.

After several numerical experiments it was found that MM5 model were able to simulate severe thunderstorms and most of times supercells, too. The success of a case study depended on the quality of ECMWF analysis and the chose of the appropriate model domain. When the humidity and/or wind fields of ECMWF were correct, after the spin up time MM5 simulated the severe convection properly. The model domain had to choose in such a way that the initial stage of the supercell was in inner part of the domain. When the squall line "drifted in" the model domain due to the lateral conditions, the model was not able to simulate supercells. The numerical studies showed that supercells in the developed phase are not sensible for surface conditions, modifications of lake and skin temperature did not affect their motion and development. However, perturbation of initial conditions could modify the place and time of appearance of initial stage of supercells (Horváth, 2006).

II. RESULTS

Model experiments suggested that there are two main supercell classes in the Carpathian basin. In the first type supercells appear in front of squall lines or cold fronts. These are slow moving systems and the thunderstorms generated cold pool and the wet air masses with high equivalent potential temperature (EPT) on low levels have important roles in the life cycles (Rotunno 1982). Typical case of this type of supercell occurred on 18th May 2005 (Fig 1a) in estern part of Hungary.

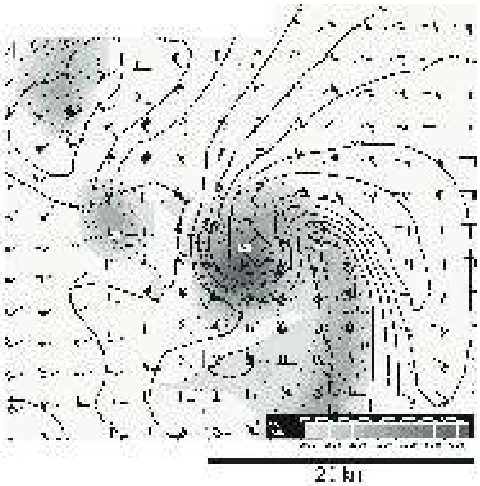

Fig 1 a.
Simulated mean sea level pressure, 950 hPa wind field and 700 hPa mixing ratio of rain water at 16 UTC May 18th 2005.

Simulated EPT fields prove the “competition” between thunderstorm cells for unstable wet air. The thunderstorm cell which was able to get larger “watershed” became stronger (Fig 1.b).

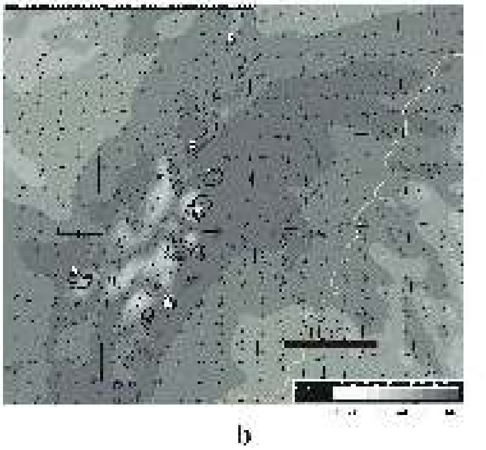

Fig.1.b. Equivalent potential temperature (shaded fields) and wind of 925 hPa at 13 UTC May 18th 2005. Contouring lines show thunderstorm cells.

The second class of supercells is represented by the Budapest storm. In this situation the movement of squall line or cold front is faster than in the first class. Supercells can be generated along the squall line and their movements are not influenced by EPT values of prefrontal air masses. In this case the cold front aloft and the convergence determinate thunderstorms. Most of nocturnal supercells could be classified in the second class. MM5 model was able to simulate the rotating system of the evening Budapest storm (Fig 2 a).

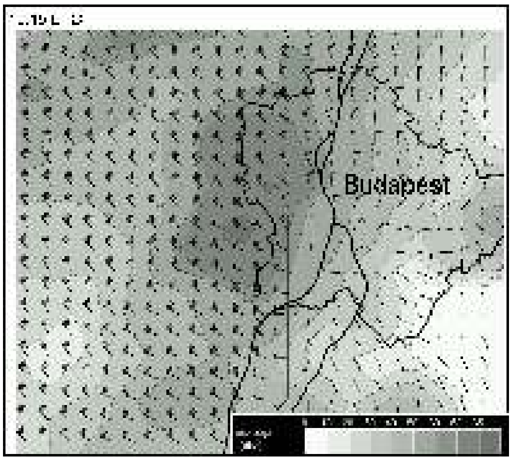

Fig 2a. Simulated wind field on 925 hPa and calculated radar reflectivity (shaded field) at 19:15 UTC.

The model was also able to simulate the multi cell structure of the fast moving squall line (Fig 2 b).

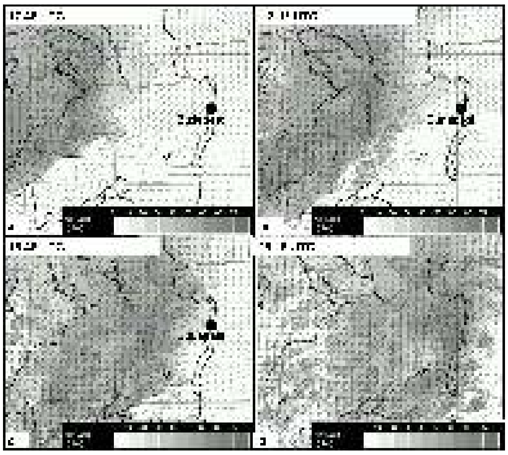

Fig 2.b. Simulated wind field of 925 hPa and calculated radar reflectivity of the Budapest Storm.

IV. AKNOWLEDGMENTS

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