THE INFLUENCE OF BOUNDARY LAYER CONDITIONS ON STORM LIFE CYCLES

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I. INTRODUCTION

Convective storms are considered to be amongst the most devastating weather phenomena that cause great demage to crops and property, because they are associated by hail events and flash floods in small areas. Cloud-resolving mesoscale models (CRM) can be used to reliably forecast such events. The reliability of the model products strongly depends on the boundary layer characteristics taken for the initialization of the model. Single-soundings were sufficient to enable successful forecasting of maximum cloud tops by using one-dimensional convective cloud models (e.g. Ćurić and Janc, 1993). Meanwhile many disadvantages of single soundings become apparent by using two and three-dimensional convective cloud models as well as the CRM models in recent time. This is due to the fact that such initial state is not fully consistent with real case that characterizes non-homogeneity in horizontal. On the other hand convective storms are frequently initialized in interval between two subsequent routine soundings. This requires the adjustment of routine soundings data in boundary layer regarding both time and location.

There are at least two ways in which these problems can be solved. The first one is using several soundings over small area ($\sim 10{,}000\,\mathrm{km}^2$) performed two and more times a day. Only few countries are capable to provide the dense network of soundings sites due to high cost. The other one is data interpolation from larger-scale models in order to provide more real data distribution in time and space. However such models mainly cannot provide CRM models with data that are necessary for successful storm initialization. In praxis the CRM models therefore use single soundings that are close in time with occurence of convective storm (Swan, 1998) or idealized soundings with associated hodographs for different sensitive studies (Ćurić et al., 2003; Gilmore et al., 2004; van den Heever and Cotton, 2004). Our investigation is targeted to improvent of initial conditions given by a single sounding. This would be performed by the adjustment of temperature and wind profile in the boundary layer taking into account both place and time of a storm initialization. We select for our investigation the Western Serbia region as well-known source region for individual convective storms.

II. DESCRIPTION OF THE MODEL

The model used is developed by Ćurić et al (2003; 2006). This model numerically integrates the time-dependent, nonhydrostatic and fully compressible equations. The model uses the generalized terrain-following coordinate in the vertical, while the horizontal coordinates are the same as in the Cartesian system.

The model's basic prognostic variables are: Cartesian wind components, perturbation potential temperature and pressure, turbulent kinetic energy, mass concentration of water vapour, cloud water, cloud ice, rain, hail and snow and seeding agent as well as the number concentrations of rain, cloud ice, hail and snow.

For the simulation presented in this paper, the model was configured with the domain $64\,\mathrm{km}\times 64\,\mathrm{km}\times 18\,\mathrm{km}$ with the 600 m grid spacing in horizontal and 300 m in vertical. The simulations were terminated at 80 min. Long and short time steps are 3s and 0.5s respectively. The wave-radiating condition is applied for lateral boundaries. The upper boundary with the Rayleigh spongy layer is used, while the lower boundary is free slip.

Model bulk microphysics treats two categories of non-precipitating (cloud water and cloud ice) and three categories of precipitating elements (rain, hail and snow). Rain, hail and snow are each represented by an exponential size spectrum. Cloud water and cloud ice spectra are supposed to be monodisperse. Two-moment bulk microphysical scheme is used following Murakami (1990). The turbulence is treated by 1.5-order turbulent kinetic energy formulation. The Coriolis force is neglected in our simulations.

The reference state is homogeneous in the horizontal using a single sounding giving the values of temperature, humidity, pressure, wind velocity and direction. The model cloud is initiated by introducing an ellipsoidal warm bubble with 1.5 K amplitude in its centre having a horizontal radius of 10 km and a vertical radius of 1.5 km. The coordinates of the warm bubble centre are (x, y) = (16, 40) km in the horizontal and 1.5 km in the vertical. The midnight Belgrade soundings of 13 July 1982 is used. Temperature profile in adjusted regarding to storm initialization time by complex radiation-low equations adopted for clear sky conditions that are favourable for convective cloud occurence. Location of storm initialization is over Zlatibor plateau with expressed low-level winds from the Western Morava valley to mountain slopes in time of storm occurence. This initial conditions are favourable for isolated storm formation at this part of Serbia (Ćurić, 1982). Low-level winds have opposite direction compared to winds in original sounding. The upper level wind is mainly from NW direction, while its speed varies from 5 m/s near the ground to about 18 m/s at 10 km height. At lowest 3 km the water vapour mixing ratio reaches its maximum value of 14.5 g/kg at p=880 mb.

III. RESULTS AND CONCLUSIONS

For purpose of this study we shall present two model cases with the CRM model performed by Ćurić et al. (2003). The first one refers to original sounding (OS case), while the other one refers to modified sounding (MS case) regarding temperature and wind profiles in the boundary layer. The storm occurs by radar at 10.15 GMT over Zlatibor slopes and it moves towards the Western Morava valley. Some results of model storm simulation are presented in Figs. 1-4.

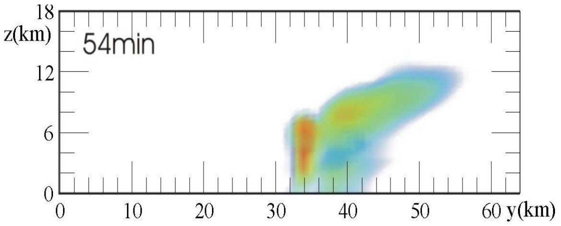

FIG. 1: Visual appearances of reflectivity greater or equal to 20 dBZ as viewed from the west at t=54 min of simulated time for theOS case.

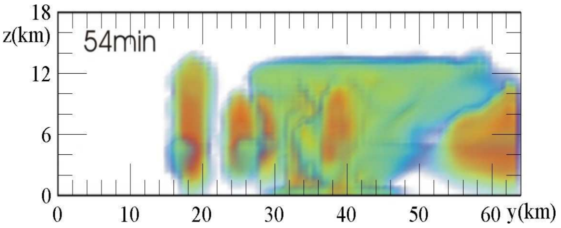

FIG. 2: As in Fig. 1 but for the MS case.

Fig. 1 and 2 show clearly that the simulated storm radar reflectivity fields are quite different for the OS and MS cases. In the OS case only single-cell storm is simulated moving fastly in NW-SE direction with mid-tropospheric wind. In the MS case the storm is the multi-cell one that propagates more slowly towards the Western Morava valley. With regard to accumulated precipitation at the ground, the OS case shows only one cell with maximum around 8 mm at t=80 min as it is presented in Fig. 3. In contrast the accumulated precipitation encircles much wider area having two distinct cells with local maxima for the MS case (Fig. 4). This is attributed to the storm splitting in sharp-sheared environment (van den Heever and Cotton, 2004).

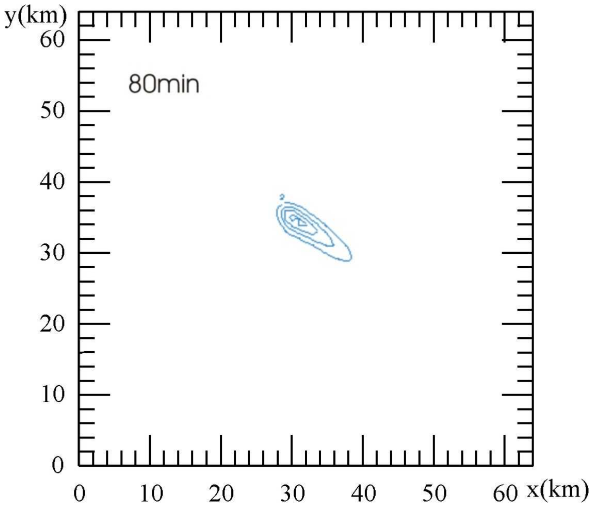

FIG. 3: Distribution of cumulative precipitation at the surface for the RS case at t=80 min with contour intervals of 2 mm starting at 2mm.

Given results clearly show that the storm development, cell-organization, cloud life cycle, propagation speed as well as the accumulated precipitation at the surface crucially depend on initial conditions in the boundary layer. Such results would not be essential if they cannot match the observations. Meanwhile, the good agreement between radar and model storm characteristics is occurred for analyzed storm. Also, the accumulated precipitation data taken from the dense rain-gauge network agree well with their model counterparts. Investigations presented here give the idea how the problem of initial boundary-layer conditions for storm initialization by the CRM model may be solved in successful way.

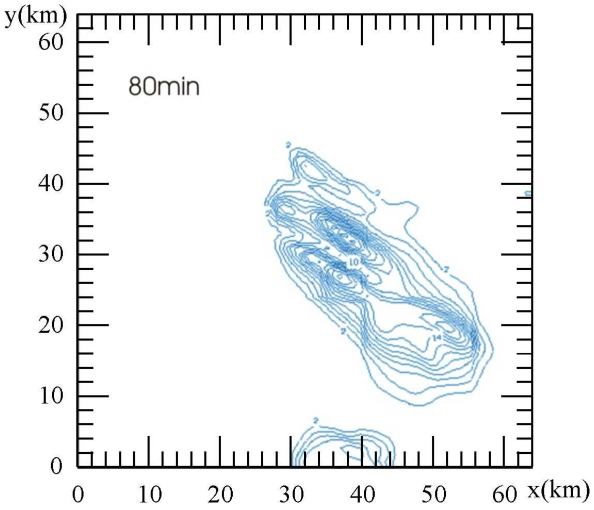

FIG.4: As in Fig. 3 but for the MS case.

IV. AKNOWLEDGMENTS

This research was supported with the Ministry of Science of Serbia. We gratefully acknowledge Mr. D. Bulatović for technical preparing of pictures.

V. REFERENCES

Ćurić, M.,1982: The development of the cumulonimbus clouds which move along a valley. In: Cloud Dynamics (eds. Agee,E.M., Asai,T.). Dordrecht: D. Reidel, 259-272.

Ćurić, M., Janc, D., 1993: Predictive capabilities of a one-dimensional convective cloud model with forced lifting and a new entrainment formulation. *J. Climate Appl. Meteor.*, 32, 1733-1740.

Ćurić,M., Janc,D.,Vujović,D.,Vučković,V., 2003: The effects of a river valley on an isolated cumulonimbus cloud development**.** *Atmos. Res.*, 66 123-139.

Gilmore, M.S., Straka J.M., E.N. Rasmussen,E.N., 2004: Precipitation uncertainty due to variations in precipitation particle parameters within a simple microphysics scheme. *Mon. Wea. Rev.*, 132 2610-2627.

Murakami, M., 1990: Numerical modeling of dynamical and microphysical evolution of an isolated convective cloud- The 19 July 1981 CCOPE cloud-. *J. Meteor. Soc. Japan* , 68 107-128.

Swan, H, 1998: Sensitivity to the representation of precipitating ice in CRM simulations of deep convection. *Atmos. Res.*, 47-48 415-435.

van den Heever, S.C., Cotton, W.R., 2004: The impact of hail size on simulated supercell storms. *J. Atmos. Sci.*, 61 1596-1609.