Case Study of Severe Windstorm over Slovakia and Hungary on 25 June 2008

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I. INTRODUCTION

A large system of thunderstorms, which developed near a cold front, passed through several central European countries on 25 June 2008. Heavy rainfall, hail and severe wind gusts were reported from several places in Slovakia and Hungary. The wind gust peak measured at Bratislava Ivanka airport reached 40 m/s and material damages were caused by wind in Bratislava, Senec and other districts, mostly in the west and southwest of Slovakia. Condensation clouds (probably wall clouds or funnel clouds) were observed and photographed at Blahová, in the south of Slovakia. The windstorm was weaker over Hungary, however, wind gusts up to 25 m/s were measured at Bakony hills (at the meteorological station Kab-hegy) and at lake Balaton. According to SYNOP observations and other weather reports from Austria, Czech Republic and Germany the weather event had some characteristics of a derecho.

II. SYNOPTIC OVERVIEW

Thunderstorm clouds were present already in the morning hours of 25 June 2008 over the east of France and the west of Germany in the area of large, but shallow surface trough, which slowly propagated eastward. At 12 UTC convective systems developed close to the surface convergence zones over the east and central part of Germany. In the afternoon further development of deep convection can be associated with cold front over Bavaria. At 18 UTC this front was over the middle part of Czech Republic and Austria. According to soundings and ECMWF analysis and forecasts there was a southerly advection of pre-frontal warm air, which caused a buoyancy increase at middle- and upper levels. The Prague sounding at that time shows a significant increase of low-level wind speed (25 m/s westerly wind at 850 hPa) behind the front. The convective system entered the territory of Slovakia and Hungary after 20 UTC. At the same time it was possible to observe high surface pressure gradient (more than 4 hPa/100 km), which developed between the high pressure region over northern Austria and lower pressure over the southwest of Slovakia and the north of Hungary. On 26 June 2008 00 UTC the cold front reached the area of central Slovakia and Hungary. The intensity of the convective system decreased in the morning hours of 26 June 2008 over eastern part of Slovakia and Hungary.

III. SATELLITE AND RADAR OBSERVATIONS

The mesoscale conditions for thunderstorm evolution can be documented by Meteosat Second Generation (MSG) imagery and convective indices (GII) inferred from satellite data. The indices show that the pre-frontal, cloud-free air was relatively buoyant at mid-troposphere with low to moderate total precipitable water content (Fig. 1). About 16 UTC the convective activity was concentrated over Bavaria, northern and western part of Czech Republic, where the thunderstorms formed into a line propagating southeastwards. At the same time a cluster of thunderstorms started to develop over the Alps in Austria. The 10.8 µm IR channel shows the evolution of cold U- and V-shapes in cloud-top temperature field between 1810 and 2200 UTC in this cluster over the north of Austria, while the convection in the northern part of the cold front seems to become weaker.

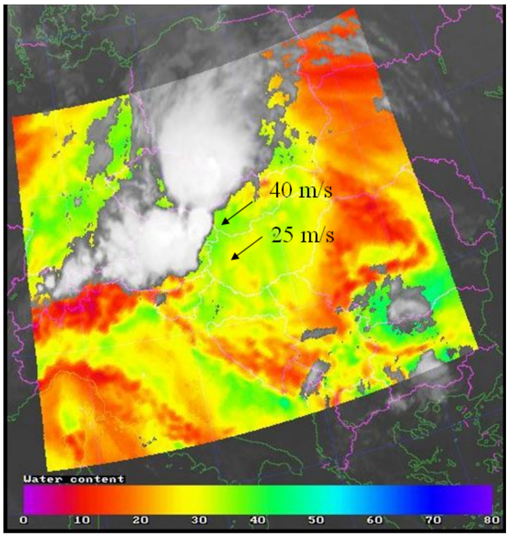

FIG. 1: The composite image of MSG IR 10.8µm channel (over cloudy areas) and derived (GII) product of total precipitable water content field (over clear areas) at 1915 UTC. The arrows mark the position of the highest wind gusts measured in Slovakia and Hungary.

The column maximum radar reflectivity of the cells propagating from Czech Republic and Moravia significantly decreased from 55 dBZ to 40-45 dBZ after 1930 UTC. Both systems merged together and new thunderstorm cells appeared over the southwest of Slovakia and the northwest of Hungary after 2100 UTC. Bow echoes and line echo wave patterns could be observed. At some stages the radar reflectivity images show a chain of relatively independent cells developing along the leading edge of the convective system. Strong lightning activity, heavy rain and severe wind occurred also in the rear side of the system, where the radar reflectivity was weaker (e.g. the highest wind gust at Bratislava was measured at 2138 UTC nearly 50 km behind the line of the heaviest thunderstorms).

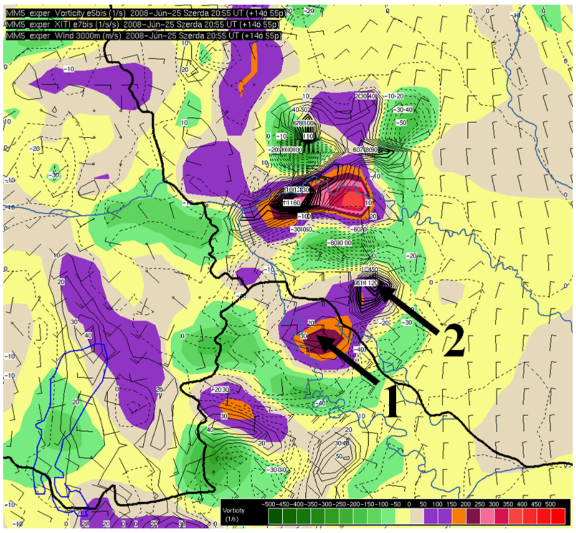

FIG. 2: Forecast of vorticity (color, 10^{-5} s^{-1}), vorticity tilting term (lines, 10^{-7} s^{-2}) and storm relative wind (barbs, m/s) at 3 km height in MM5 run based on 25 June 2008 06 UTC, valid for 2055 UTC.

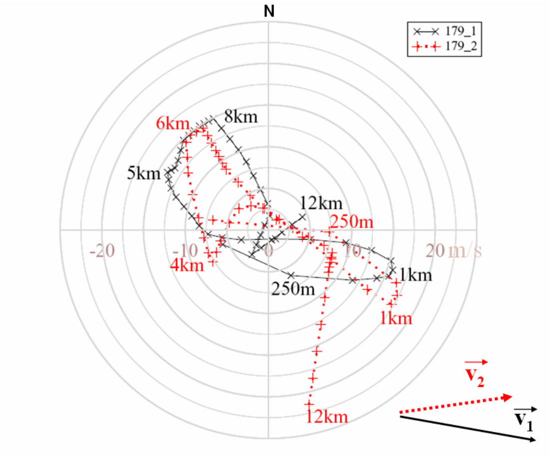

FIG. 3: Hodographs of storm relative wind derived from MM5 forecast at points 1 and 2 (Fig. 2). The density-weighted wind over 0-6 km layer was considered as "storm motion" vector (v_1 and v_2).

IV. NUMERICAL SIMULATIONS

The numerical models MM5 (Dudhia, 1993) and WRF (Skamarock et al., 2008) were integrated at 3 km horizontal resolution using non-hydrostatic dynamics. Both models were coupled by ECMWF boundary and lateral conditions. Several setups of physical parameterization (turbulent fluxes, microphysics) were tested. The operational version of the MM5 model based on the 25 June 2008 06 UTC run successfully forecasted several mesoscale features mentioned in sections above (e.g. the merger of two convective systems, wind gust peak in the Bratislava region, etc.). The forecasted system consisted of several, rapidly developing cells. Some of them were marked by significant mid- and low-level vorticity (0.003 s^{-1}), moderate updrafts (10 ms^{-1}) but relatively weak downdrafts (only few ms^{-1}). The low-level wind was enhanced in the rear side of these cells as a consequence of locally increased pressure gradient. The structure of the cells is more similar to meso-gamma scale vortices (Weisman and Trapp, 2003) than to classic or HP supercell. The mid- level vorticity originates mostly from the crosswise vorticity tilting (Fig. 2) that also agree with the conceptual model of mesovortices. Similar vortices develop also in model runs with different parameterisation of turbulent fluxes (Eta PBL or MRF PBL closure schemes) or by higher (1.5 km) resolution. On the other hand, in WRF simulation the strong low-level wind is rather related to high pressure gradient along the cold front line, which is of larger scale than by the MM5 simulation. It is important to note that the above mentioned model runs did not forecast the decrease of mid-level cloud water quantity or simulated radar reflectivity, which were observed by radars.

V. CONCLUSION

Forecasters usually pay high attention to large-scale convective systems connected with cold fronts and convergence lines, which can be nowadays well detected and forecasted several hours in advance. Nevertheless, some features (e.g. temporal decrease of radar reflectivity) can be sometimes misleading in predicting the system intensity and severity. Numerical simulations indicate that severe windstorms similar to the 25 June 2008 case can arise from several reasons. Except of downdrafts and convective outflows or large scale pressure gradient flow, low level wind can be enhanced in the rear flank of meso-gamma scale vortices embedded in the system. The detection (verification) of such mesovortices is rather difficult. Radar doppler velocity simulated by MM5 model shows that such objects do not always exhibit a significant MVS (Mesocyclone Vortex Signature) pattern because their vorticity is usually weaker than the vorticity of supercell mesocyclones. Thus, forecasts of high-resolution numerical models can be very useful in specifying the character and intensity of the event, though their results are not perfect and depend on many factors (boundary conditions, parameterisation of microphysics, etc.). Satellite observations and derived parameters provide further useful information about the buoyancy and humidity distribution in the pre-frontal airmass that can help to specify the potential for severe convective storms development.

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VII. REFERENCES

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