Derecho-like event in Bulgaria on 20 July 2011

Ilian Gospodinov[1], Tsevetelina Dimitrova[2], Lilia Bocheva[1], Petio Simeonov[1], Rumen Dimitrov[2]

[1]*BAS, National Institute of Meteorology and Hydrology, 66 Tsarigradsko Shose, Sofia-1784, Bulgaria*
Ilian.Gospodinov@meteo.bg; Lilia.Bocheva@meteo.bg; Petio.Simeonov@meteo.bg

[2]*Agency Hail Suppression, 1606 Sofia, Bulgaria*
dimitrova_tsvetelina@abv.bg ; rumen_dimitrov1952@abv.bg

I. INTRODUCTION

According to Johns and Hirt (1987) derecho can be identified by fulfilling 4 criteria of the pattern of damage left behind a severe thunderstorm (STS) event that are:

1) The pattern should have a major axis length of at least 400 km. The damage should be caused by wind gusts of more than 26 ms^{-1} induced by strong convective processes;

2) The reports of damage should have chronological progression along the major axis of the spatial pattern that is to match the progression of the convective system along the same path;

3) There should be a sufficient number of reports of wind gusts of more than 33 ms^{-1} evenly distributed along the path of the derecho;

4) There can also be successive storms along the same path that cause damage by strong wind gusts. However they should be separated by not more than 3 hours.

Similarly to other authors (Gatzen, 2004; Punkka et al. 2006, Coniglio et al. 2011) we present in detail two individual STS events along the storm line that are observed on 20 July 2011 in the northwestern (NW) part of Bulgaria in the region of Knezha. They left behind significant damage in the towns and fields along their way that has been studied by the stuff of the Bulgarian Agency Hail Suppression (BAHS) and has been recognized to be caused by strong downburst wind gusts. The case for tornado was rejected.

II. GENERAL OVERVIEW OF THE EVENT AND SYNOPTIC-SCALE ANALYSIS

The STS occurred on 20 July 2011 in the NW part of Bulgaria (Fig. 1 and 3). There are two major air masses that dominate the scene in Europe on 20 July 2011 – a cold and humid one to the west of Bulgaria and a warm and dry one in Bulgaria and to the east.

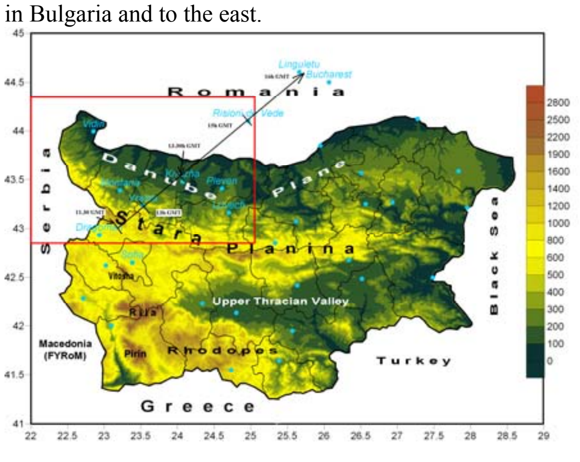
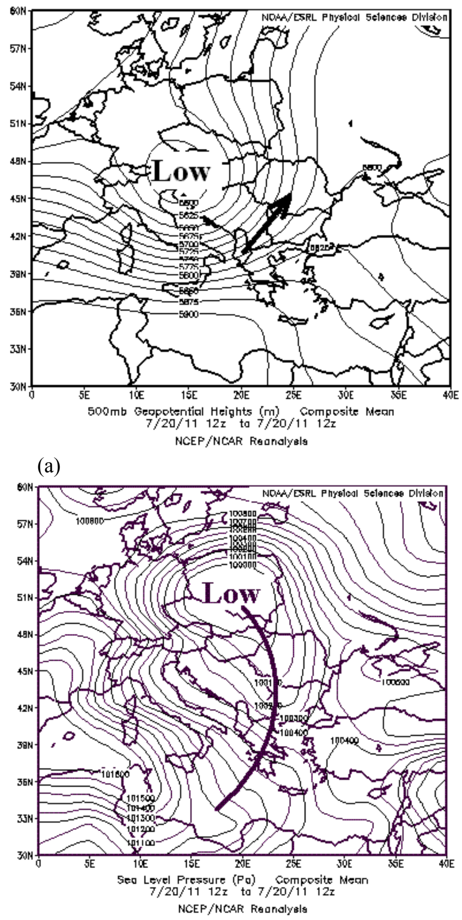


FIG. 1: Geography of Bulgaria with relief in color (m). The red contour limits the NW region used for the more detailed maps.

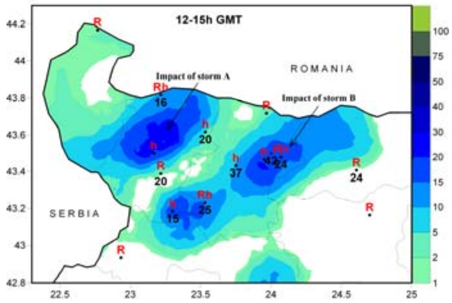
There is a deep trough over Western Europe (Fig. 2a). It is associated with a cyclone which center is positioned over Poland (Fig. 2b). The cold front is oriented from southwest to northeast along the southwestern mid-troposphere jet in the forehead of the trough. The cold front moves eastwards through the Balkan peninsula during day-time and reaches the western border of Bulgaria at midday. The convective clouds associated with the front hit first in the northwest from 12:00 to 15:00 UTC which is 15:00-18:00 local time (LT). There further evolution is in Romania. Figure 3 shows 3h-precipitation amount analysis for the date. There are two deep blue zones on figure 3a associated with the analyzed storms A (left deep blue zone) and B (right deep blue zone).



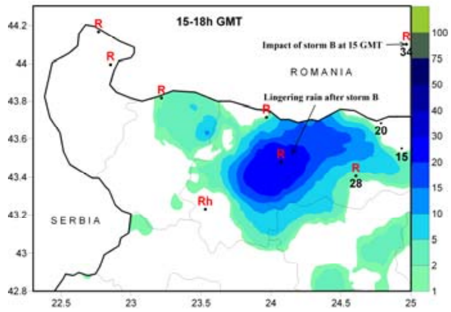
(a)

(b)

FIG. 2: 20 July 2011 12:00 UTC fields: (a) 500 hPa geopotential height (m); (b) Sea level pressure (Pa). All plots: left axis – latitude in degrees; bottom axis – longitude in degrees.



(a)



(b)

FIG. 3: Three hours precipitation amount on 20 July 2011. (a) 15:00 UTC; (b) 18:00 UTC. Red "R" or "h" - thunder activity or hail. Black numbers - wind speed ≥14 ms^{-1}.

Storm A originates from the mountainous region at the western border between Bulgaria and Serbia. It pops up at about 11:00 UTC and starts its movement northeastwards transported by the mid-troposphere flow. Figure 4 shows the aerological profile of sounding data from the nearest station of Sofia at 12:00 UTC. Ground data from the nearest weather stations of Knezha is suited to the upper-air profile. The data is processed by the RAwinsonde OBservation (RAOB) model. As it can be seen from Fig. 4 the wind speed is very high at all levels. It reaches maximum of 52 ms^{-1} at about 200 hPa level. Table I shows computed various indices. They suggest moderate instability conditions that are good enough for the development of STS possibly 16-18 km of height and capable of producing heavy rain and hail. The R_{CAPE} ratio of 55% suggests that the bigger part of the convective available potential energy is in the upper part of the troposphere which is another condition favorable to the development of STS.

Storm A matures on its way mostly in the administrative region of Montana (Fig. 3a). Then it leaves Bulgaria and goes into Romania where it declines when reaching the Carpathian mountain chain.

Storm B follows behind on roughly the same path but shifted eastwards by 20-30 km and within a delay of about half an hour. It first hits the region of Vurshets and Vratsa that are positioned right at the footstep of Stara planina (Fig. 1). Then it matures on its way northeastwards and goes through the region of Borovan and Knezha where it hits the most (Fig. 3a). Storm B continues its way in Romania and hits further the region of Risiorii de Vede about 15:00-15:30 UTC (Fig. 1, 3b) and later the region of Bucharest at about 16:00 UTC (Fig. 1).

Maps in Fig. 3 are produced on http://www.esrl.noaa.gov/psd/ (NOAA/ESRL Physical Sciences Division, Boulder Colorado) and are based on NOAA Reanalysis (Kalnay et al. 1996).

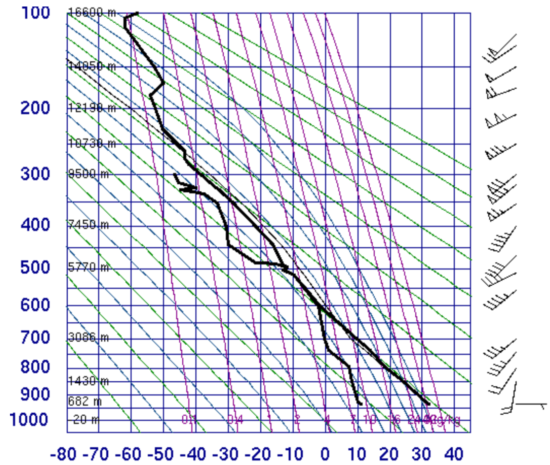


FIG. 4: The Stuve-gramme of Sofia sounding on 20 July 2011 at 12:00 UTC
(source: http://sweather.uwyo.edu/upperair/europe.html)

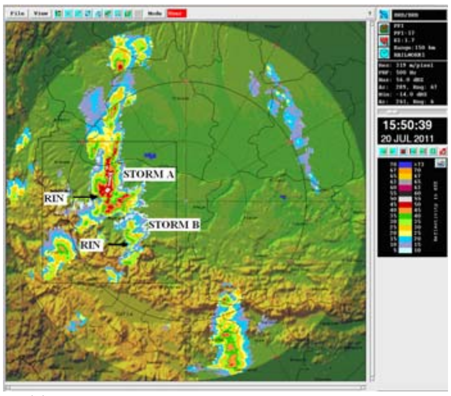
Index	*Unit*	***RAOB mod*** 12:00 UTC Sofia (**Knezha**)
DTm	℃	6.0
S_{DT75}	℃	8.2
LfcEL	*km*	11.0
LCL	*km*	2.0
LI	℃	-4.7
TT	℃	51
KI	℃	37
SWEAT		334.4
CAPE	*J/kg*	1424
R_{CAPE}	*ratio*	0.55
$\Delta v_{300\text{-}700}$	*m/s*	15

Table I: Basic environmental characteristics on 20 July 2011 in the vicinity of storms A and B (processed by RAOB model)

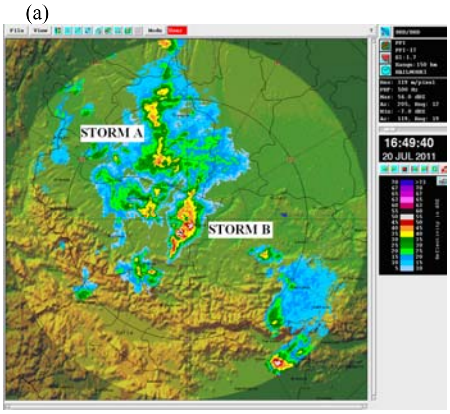
III. FINE-SCALE ANALYSIS OF DOPPLER RADAR DATA

BAHS has been operating a state-of-the-art S-band Doppler radar since 2008. It is located near the village of Bardarski geran in the administrative region of Vratsa (Fig. 1). Images from that radar are used to illustrate storms A and B.

The bigger storm on Fig. 5a positioned to the north develops first (storm A). The upper left arrow shows the Rear Inflow Notches (RIN) behind the strong cell. The top of the cell reaches its highest between 15:50 and 16:20 LT with the formation of a bounded weak echo region (BWER) (Fig.6a). The 15 dBz reflectivity zone that is associated with the top of the cloud reaches 15 km and the 55 dBz reflectivity zone that is associated with the core of the cloud reaches 7 km. The registered maximum reflectivity is 63 dBz. The horizontal shear of the wind measured with the radar is above 14 $m\ s^{-1}km^{-1}$ and this indicates the presence of a microburst (Holleman, 2008). At 16:23 LT the storm collapses to 55 dBZ reflectivity at less than 2 km above-ground-level height. At the same time divergence is found underneath the apex of the storm (Fig.6b).

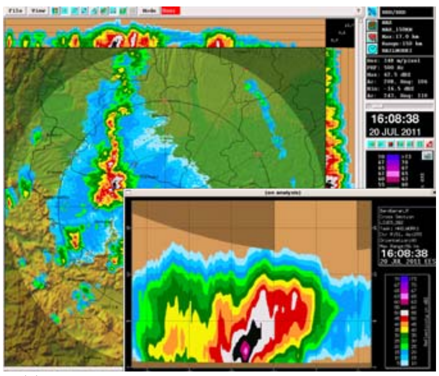


(a)



(b)

FIG. 5: Radar reflectivity (dBz), 1.7° elevation angle, radius 150 km, 2011.07.20: (a) 15:50 LT. Arrows point the RIN for storm A (upper left) and storm B (lower right); (b) 16:49 LT – comma-head shaped echo of storm B.



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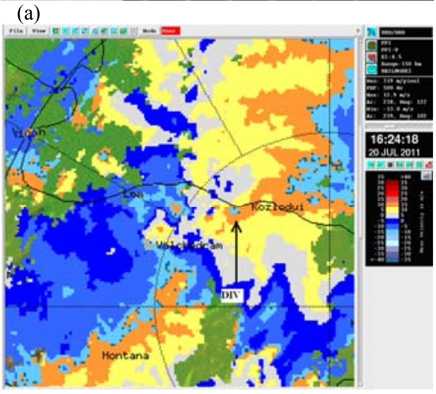
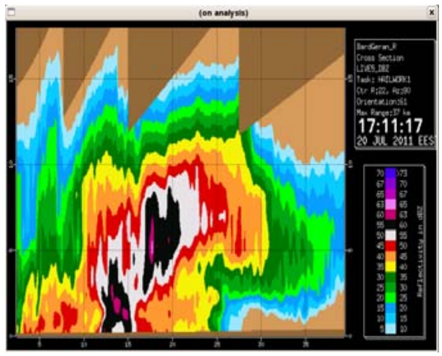


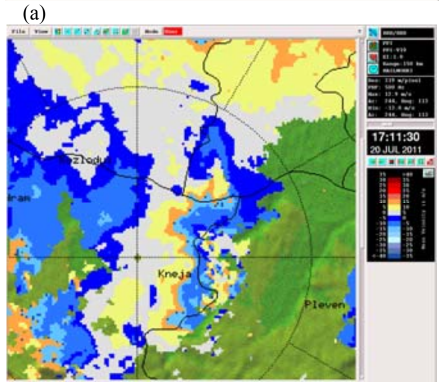
(b)

FIG. 6: Maximum development of storm A: (a) larger image – maximum reflectivity (dBz); smaller imbaded image –vertical cross-section of reflectivity (dBz) at 16:06 LT; (b) Doppler velocity (m/s) at 16:24 LT. The arrow points to the area of divergence.

The maximum of storm B is between 16:12 and 17:25 LT (Fig. 5b). The northern end of storm B becomes comma-head shaped between 16:45 and 16:56 LT (Fig. 5b). There is a well defined convergence line at low altitude (Fig. 7b). The radar reflectivity increases at the front-side of the storm. There are two RIN observed at that stage of storm B. At its strongest the cloud top reached 18 km and the core of the cloud – 9 km (Fig. 7a). The registered maximum reflectivity is 60-63 dBz and the life time of this maximum is more than 30 min. There is well pronounced BWER (Fig. 7a) and the reflectivity gradient at low levels behind the storm has increased as the reflectivity maximum has reached 60 dBZ. The wind shear measured with the radar is again above 14 $ms^{-1}km^{-1}$ but the area of wind shear >8 $ms^{-1}km^{-1}$ is bigger compared to storm A.



(a)



(b)

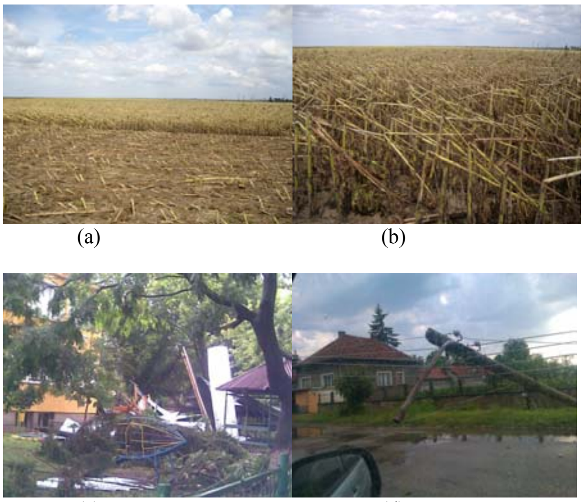
FIG. 7: Maximum development of storm B at 17:11 LT: (a) vertical cross-section of reflectivity (dBz); (b) Doppler velocity (ms^{-1}).

The prezented analysis illustrates how conditions 1 and 2 for derecho of Johns and Hirts (1987) are partly satisfied.

IV. ANALYSIS OF WIND AND DAMAGE DATA

Storm A produces damage mainly in the administrative region of Montana. There are numerous reports of wind damages which include: branches broken off trees; shallow-rooted trees pushed over; broken electric towers; and some damage to chimneys and roofs. Maximum wind gusts recorded during storm A in the region are about 17-20 ms^{-1} (Fig. 3a). About 10000 families are left without electric power more than 12 hours after the storm.

Storm B hits Borovan (near Knezha) at about 15:30 LT. The weather station at the airport for agriculture services near the village reports wind gust of 135 kmh^{-1} (37.5 ms^{-1}). The total rainfall is about 65-70 mm. There is strong rain and hail with size of the hail stones similar to corn or beans. The hail stones fall obliquely and attain very big speed. Storm B hits Knezha from 17:00 to 17:29 LT. The wind reaches 153 kmh^{-1} according to anemometer positioned in the yard of the local agribusiness cooperative of Knezha. The total rainfall with hail there is about 90 mm. The size of the hail stones is similar to beans, hazelnuts, or small walnuts. At this second location there are hundreds of uprooted and broken trees. The wheat, corn, and sunflower crops lean strongly towards the wind direction. In Knezha there is one casualty and the roofs of about 150 houses are fully or partly blown away (Fig. 8c, d).



(a) (b) (c) (d)

FIG. 8: Damage left behind storm B in Knezha: (a) and (b) bands of flattened sunflower crops; (c) Kinder garden in Knezha – the roof is in the yard; (b) Broken electric pole.

Figures 8a and b show the documented pattern of struck sunflower plants in a crop land. The sunflower sticks lean towards the wind direction. Along the front path there are bands of struck crops. These bands are about 50-60 m wide and about 100 m long. Within a band the plants are totally flattened to the ground while the plants in the surrounding area are less damaged. There is well defined limit between the band of fully damaged crops and the rest. There are about 20-25 such bands within 1 km² along the path of the storm.

Storm A hits Risiorii de Vede in Romania at 15:00-15:30 UTC (Fig. 1, 3b). The weather station there reports heavy thunderstorm and wind gusts of 34 ms^{-1} (Fig. 3b). Storm B passes to the north of the region of Bucharest, the capital city of Romania, at around 16:00 UTC (Fig. 1). The weather station in Bucharest reports thunderstorm and wind gusts 13 ms^{-1}. Parachiv et al. (2012) describe the outcome of the passage of storm B in the region of Linguletu, right to the northwest of Bucharest. According to the radar data, provided to the author by the Romanian meteorological administration, the wind gusts reach 26 ms^{-1}.

In total there are at least 5 reports of wind gusts above 26 ms^{-1} within which 3 reports for wind speed above 33 ms^{-1} and they are positioned chronologically along the path of storm B as seen by the Doppler radars of BAHS and the Romanian meteorological administration.

V. CONCLUSION REMARKS

The large scale analysis in section II explains the STS event in Bulgaria on 20 July 2011 as one corresponding to condition 1 for derecho given in the introduction. The storms' path stretches for about 300 km from southwest to northeast including its origin in Western Serbia and its further evolution in Southern Romania (Fig. 1). The damage data given in section IV, together with other reports of damage near Bucharest in Romania, have chronological progression along the path of storm B. Apart from that, the damage data from NW Bulgaria also show chronological progression which is to satisfy condition 2. There are at least 5 reports of wind gusts above 26 ms^{-1} and 3 reports above 33 ms^{-1} that are positioned along the path of storm B in chronological order. This allows us to believe that condition 3 for derecho is at least partly satisfied. The analysis of the two storms in section III shows how they succeed each other at roughly the same area within the 3 hours-time limit imposed by condition 4. All above allows us to classify the described event as derecho-like.

VI. REFERENCES

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