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Derecho-like event in Bulgaria on 20 July 2011

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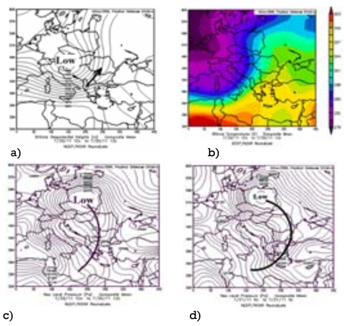
Derecho events have not been identified in Bulgaria before. The Bulgarian Agency Hail Suppression (BAHS) has been equipped with state-of-the-art meteorological Doppler radars since 2008. The available data allows more thorough analysis of the evolution of big-impact convective clouds occurring in the vicinity of the radar location. In this work we present a severe convective storm system development that has been classified as derecho-like. It occurred on 20 July 2011. The storm line affected a big part of the country but the strongest impact was in the northwestern region of Bulgaria. The heaviest damage has been found in the municipality of Knezha. We present an overview of the damage in the region. We present analysis of the evolution of two successive convective clouds based on the radar data. The analysis reveals wind speed above 30 ms^{-1}, cloud top height of 17 km, and maximum radar reflectivity factor of 63 dBZ. The storms are associated with a rapid cold front passing through at midday. The field investigation reveals pattern in the damaged sunflower fields typical for strong wind gusts and this, among other things, classifies the event as derecho-like.

Bulgaria is a relatively small country. It is about 500 km from west to east and about 350 km from south to north. This limits the chance to observe a full scale derecho within its territory. It is also mountainous (*Fig. 1*). This limits further the available flat-land extend. Flat land is mainly in the north of the country namely the Danube plane. It has zonal extend of about 400 km and stretches from the west border with Serbia to the northeast border with Romania. Meridionally it is constrained from south by the mountain chain of Stara planina and from north by the Danube River (*Fig. 1*). The Danube plane actually is the flat land along the both sites of the Danube River and the bigger part of it is in Romania. Thus the meridional extends of the available flat land totals about 200 km. This geography makes the Danube plane a suitable terrain for possible observation of derecho in the region of Southeast Europe. However the evolution of the storm line should be exclusively from west to east so that a full scale derecho can develop along the zonal axis of the Danube plane. In this paper we analyze mostly data provided by the BAHS gathered within the Bulgarian side of the Danube plane. We also give in support the some data from the Romanian side (Paraschiv et al. 2012).

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

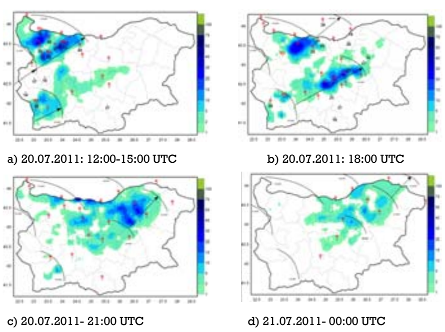
The convective clouds associated with cold front hit first in the northwest from 12:00 to 15:00 UTC which is 15:00-18:00 local time (LT). There further evolution is in Romania. Figure 3 shows 3h-precipitation amount analysis for the date. There are two deep blue zones on figure 3a associated with the analyzed storms A (left deep blue zone) and B (right deep blue zone).

Fig.1. Geography of Bulgaria with relief in color (m). The red contour limits the NW region used for the more detailed maps. Thin black contour limits the administrative regions. Blue dots show the location of the administrative centers and other cities and towns along the path of the derecho. Left axis – latitude in degrees. Right axis – longitude in degrees.



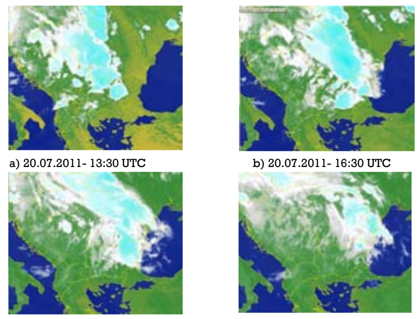
a) b) c) d)

Fig. 2. **20.07.2011 12:00 UTC** fields: a) 500 hPa geopotential height (m). Arrow shows the direction of the mid-troposphere flow; b) 850 hPa air temperature (K); c) sea level pressure (Pa); d) **21.07.2011 00:00 UTC** sea level pressure (Pa). The black line shows the progression of the cold front.



a) 20.07.2011: 12:00-15:00 UTC
b) 20.07.2011: 18:00 UTC
c) 20.07.2011- 21:00 UTC
d) 21.07.2011- 00:00 UTC

Fig. 3. Three hours precipitation amount. Color scale in millimeters. Red "R" or "h" show weather stations with thunder activity or hailfall. Black numbers show the attained wind speed $\geq$14 ms^{-1}.



a) 20.07.2011- 13:30 UTC
b) 20.07.2011- 16:30 UTC
c) 20.07.2011- 19:30 UTC
d) 20.07.2011- 22:30 UTC

Fig.4. Infra- red satellite images by EUMETSAT

Fig.5. Geography of the NW region of Bulgaria. Red ellipses show the zones of impact of storms A and B.

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. As it can be seen from Fig. 6 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 computed by the sounding data. They suggest moderate instability conditions that are good enough for the development of STS possibly 16-18 km of height (level of convection) and capable of producing heavy rain and hail. The RCAPE 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, 5). Then it leaves Bulgaria and goes into Romania where it declines when reaching the Carpathian mountain chain. 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. About 10 000 families are left without electric power more than 12 hours after the storm (Fig. 11).

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 Varshets and Vratsa that are positioned right at the footstep of Stara planina (Fig. 5). Then it matures on its way northeastwards and goes through the region of Borovan and Knezha where it hits the most (Fig. 3a). 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 in 3 towns more than 70% of all houses are without roofs. 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).

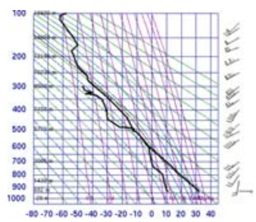
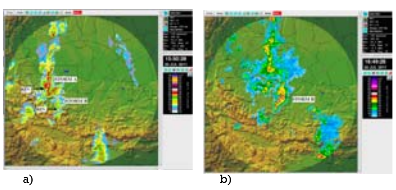


Fig. 6. The Stuve-gramme of Sofia sounding on 20.07.2011 at 12:00 UTC (http://weather.uwyo.edu/upperair/europe.html)

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
$\Delta v_{300-700}$	*m/s*	15

Table I. Basic environmental characteristics on 20.07.2011 in the vicinity of **storms A and B** (processed by **RAOB** model)



a) b)

Fig. 7. Radar reflectivity (dBZ), 1.7° elevation angle, radius 150 km, 20.07.2011: 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.

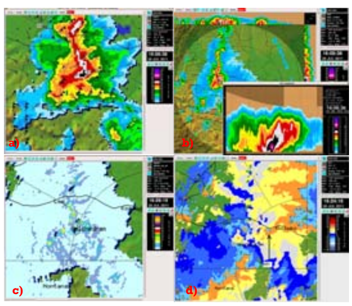


Fig. 8. **Storm A at 16:08 LT**: a) radar reflectivity (1.0° elevation angle) and Doppler wind speed and direction (vectors); b) maximum reflectivity and vertical cross section ; c) Wind shear at 16:09 LT; d) Doppler velocity at 16:24 LT. The arrow points to the area of divergence.

Storm A. The upper left arrow (Fig.7a) shows the 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.8b). The 15 dBZ reflectivity zone (cloud top) reaches 15 km and the 55 dBZ reflectivity zone (cloud core) of the cloud reaches 7 km. The registered max reflectivity is 63 dBZ. The horizontal shear of the wind measured with the radar is above 14 ms^{-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.8d).

Storm B maximum is between 16:12 and 17:25 LT (Fig. 9). The northern end of storm B becomes comma-head shaped between 16:45 and 16:56 LT (Fig. 7b). There is a well defined convergence line at low altitude (Fig. 9a,c). 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. 9b). The registered maximum reflectivity is 60-63 dBZ for 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 maximum has reached 60 dBZ. The wind shear measured with the radar is bigger compared to storm A.

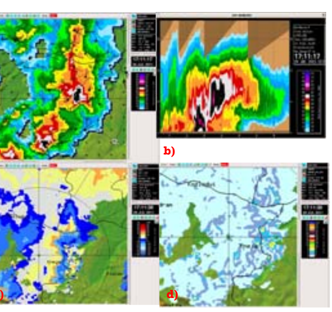


Fig. 9. **Storm B at 17:11 LT**: a) Radar reflectivity and Doppler velocity (vectors) – 1.0° elevation angle ; b) vertical cross-section of reflectivity; c) doppler radial velocity – 1.0° elevation angle ; d) wind shear

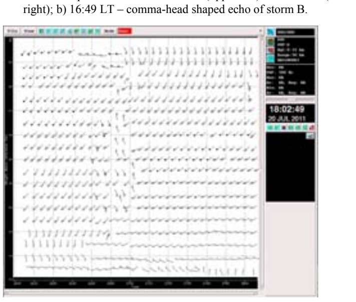


Fig. 10. **Storm B:** The volume-velocity-processing (VVP) wind profile (vectors) - increase of the vertical wind shear in the period 16:40-17:10 LT

Fig. 11. **Damage left behind storm B in Knezha:** Pine-trees fallen on the house; Broken electric pole ; Kinder garden in Knezha – the roof is in the yard; bands of flattened sunflower crops

Concluding remarks

The large scale analysis above explains the STS event in Bulgaria on 20 July 2011 as one corresponding to all conditions for derecho given by Johns&Hirt, 1987.

1. The front crosses the country within the afternoon and the evening and there are powerful storms along its path. 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).
2. The damage data (wind damage reaching class F0 – F1 on the Fujita scale and few of the cases can be classified as F2 category) , 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.
3. 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. However, the rest of the strong wind speed reports (>14 ms^{-1}) in Northern Bulgaria are below 26 ms^{-1} . This allows us to believe that condition 3 for derecho is at least partly satisfied.
4. The analysis of the two storms shows how they succeed each other at roughly the same area within the 3 hours-time limit.

All above allows us to classify the described event as derecho-like.

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