On Space-Time Distribution of Tornado Events in Bulgaria (1956-2010): analysis of two severe tornadic storms

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I. INTRODUCTION

In Bulgaria the tornado events related to severe convective storms (SCS) usually occur over crossed mountainous or hilled terrain or over the Black Sea as waterspouts. It is very difficult to predict such dangerous phenomena without specialized equipment. Only a few tornado events are well documented in Bulgaria. There are also very few works dealing with analysis of tornado events (Bojkov and Martinov, 1956; Simeonov and Georgiev, 2001; Simeonov and Georgiev, 2003; Latinov, 2006). Sometimes the damage caused by a downburst or a squall is taken for one done by a spout. In order to see whether it is a spout (tornado) and to determine its intensity, it is important to know the pattern of the damages. It is also necessary to know the physical, temporal and spatial characteristics of a given event.

The aim of this study is to contribute to the country's long-term (1956-2010) data records of real tornado cases and to attempt a space-time classification. It is based on the available present and archived meteorological data. The approach for the analysis of the tornado cases is similarl to that used by Brooks et al.(2001, 2003), Dessens and Snow (1989), Dotzek, (2001, 2003), Giaiotti et al (2007), Sioutas (2003). We have analyzed 54 tornados 9 of which are waterspouts. They occurred in 51 stormy days. A case study of two severe storms with the development of three tornadoes in northern Bulgaria is presented

II. RESEARCH APPROACH

In this study the long-term (55 years) list of tornadoes / waterspouts and their locations is presented. We have used for its preparation the published cases in scientific and popular literature, and media as well as the available documented testimonies of amateur observers. From the 1980s, thanks to the development of the satellite and radar observations and the more rigorous meteorological monitoring helped to correct the voluntary and media reports of tornadoes and waterspouts. Thus several cases of "non real tornado event" (rather "downburst" cases) were rejected from the data.

We also use classic observed weather data, synoptic analyses, upper-air sounding data, radar images, expert inquiry, and information of damages (from local authorities). We present case-studies of two stormy days with six tornado events from 2008 and 2009. The upper-air sounding data is processed by the same method as in Simeonov and Georgiev (2003) to represent the environmental characteristics near the storm location. The radar images from meteorological radar with suitable location (the radars of Varna airport as well as the radar at the Agency of Hail Suppression) are used for the analysis of the storm characteristics and structure. An attempt for classification of tornados according to Fujita scale (Fujita and Pearson, 1973, Fujita 1981) is made. Of cause, we also adapt the European scale (Dessens and Snow, 1989 and Dotzek et al., 2003) accordingly to the surface infrastructure in Bulgaria. The NIMH archive of weather data and reanalysis maps (provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from (http://www.esrl.noaa.gov/psd/) are used for the analysis and the classification of synoptic situations causing strong thunderstorms and tornados.

III. RESULTS AND CONCLUSIONS

1. Tornado and waterspout events in 1956-2010

The location of all selected tornados and waterspouts is given on the country map (Fig.1). As one can see the tornados occur mainly in the eastern half of northern Bulgaria and in south-western Bulgaria. According to landscape type the tornado locations are distributed as follow: mountain and hilly (12), wooded mountain and hilly (14), flat land (19) and water surface (9).

Tornadoes that occur in mountains (Vitosha, Rodopi) and hilly terrains usually do so along a river valley. However the information about such tornadoes (especially about weaker ones) is insufficient because of difficult access for observation and inspection. The importance of topography though for the formation and the development of this type of convective phenomena is obvious.

The monthly and seasonal distribution (Fig.2) gives that 93% of all 54 cases are observed within the warm half of the year (the maximum is in June). There are three unusual events that occurred in cold months and these are the cases of 15 February 2005, 24 March 2004, and 2 December 2010 in south Bulgaria. There is only one such event in the north-eastern region and this is the case of 21 March 2007. The explanation for the later one can be sought in the fact that the winter of 2007 was exceptionally warm and this helped development of summer type convective thunderstorms with heavy rain and hail. Also to be noted, that all known winter tornadic storms have occurred in the recent decade. An important factor for such processes is the warm and moist airflows from the Mediterranean and their convergence with cold air masses from the northeast.

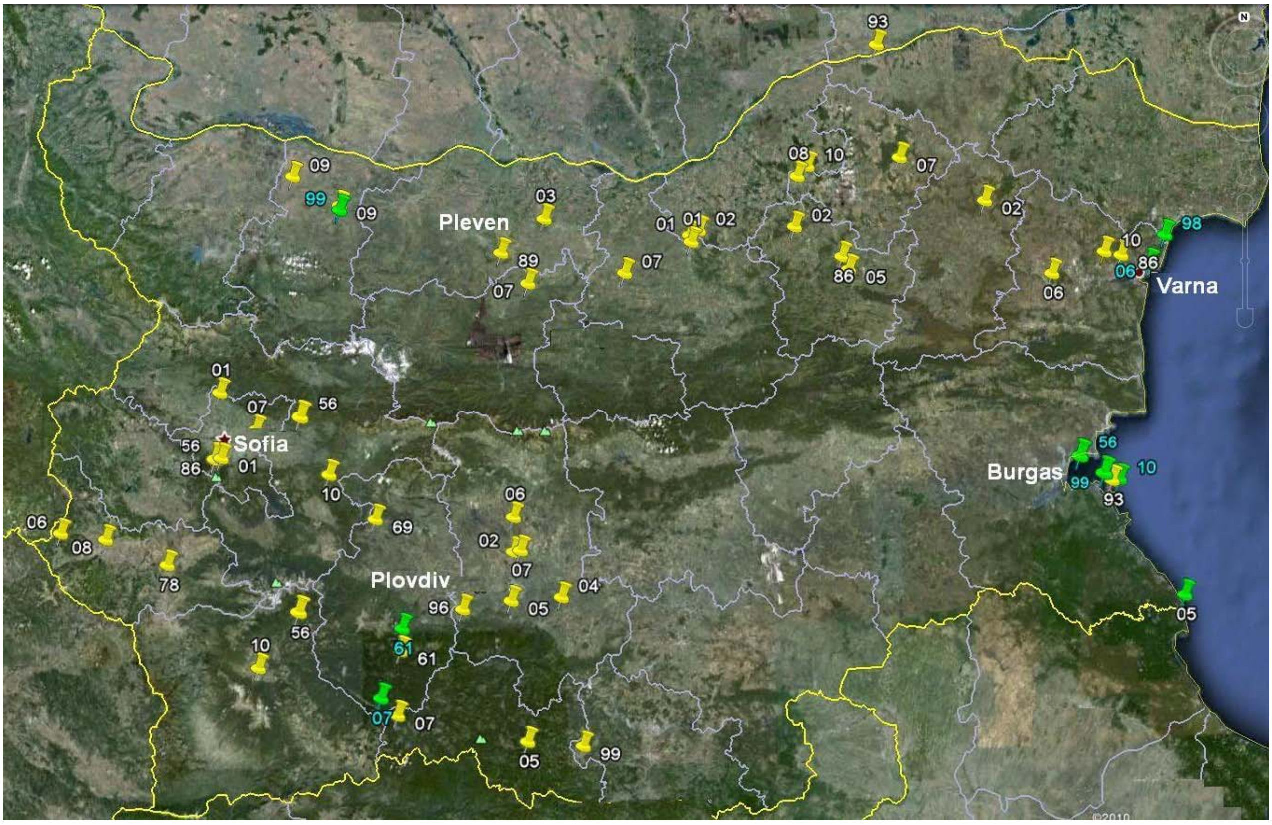

FIG. 1: Space distribution of tornadoes (yellow marker) and waterspouts (cyclamen marker) observed in 1956–2010 (signed with last two numbers)

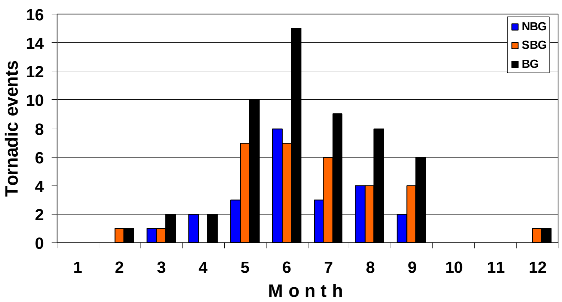

FIG.2: Monthly distribution of 45 tornadoes and 9 are waterspouts events over northern (NBG), southern (SBG) and all Bulgarian territory (BG).

2. Case study on two severe storms with three tornadoes

The main environmental characteristics of the tornadic thunderstorms, obtained by the upper-air sounding data from a station close to their location are shown in Table I. As can be seen there, the highest value of the energy of instability E_i (analogue of CAPE) is for tornado No.1 (located to Kostandenets, 43°34'21"N and 26°11'03"E). The highest value of the dynamic index $\mathbf{\Delta v_{37}}$ (=28 m/s) is also in tornadic storm 1. The surface V_{max} is higher for tornadoes No.2 and 3 (located near to Hayredin 43°36'40"N, 23°38'46"E and Tarnava 43°30'11"N, 23°52'57"E).

The length and the width of a tornado track, the value of damage (or calculated loss) are among the most important characteristics used to define the severity of a tornado by the Fujita scale. Those two parameters are shown on Table II.

After having taken into account the relatively low cost of damaged property but long tracks of tornadoes 1, 2 and 3 we can attribute them class F2.

Date	No Tor-nado	W_{max} m/s	E_i J/kg K	Δv_{37} m/s	TT °C	V_{max} m/s
2008 0422	1	26.0	5387	29	54.4	29
2009 0602	2 3	19.8	3712	20	75.3	>35 35

TABLE I: The environment characteristics of tornadic storms

Notes: ***w_{max}*** *is the maximum value of updraft velocity;* ***E_i*** *is the analogue of CAPE;* ***Δv_{37}*** *is a deference between wind velocity at 300 and 700 hPa;* ***TT*** *(Total Totals by Miller);* ***V_{max}*** *is maximum wind speed on the surface.*

Date	No Tor-nado	Storm moving	Lp length km	Wp Width km	loss € x1000	Fujita scale
2008 0422	1	SW-NE	15	20-30	640	F2
2009 0602	2 3	SW-NE	14 3	80-100 50-80	134 225	F2 F2

TABLE II: Tornado characteristics and classification for the 3 events based on radar and inquiry data.

One can see the sample of cut and thrown down forest trees in Fig. 4. Another way to assess the scale of the tornado is to videotape it when it occurs. It becomes more frequent to get videos from eyewitnesses. Figure 4a, for example, shows a snapshot of the funnel of tornado 1. The field expert enquiry and the observed data suggest that the wind speed along the tornado's trajectory is above 20 m/s. There is a lot of damage all along the storm's path. In addition, the radar reflectivity of CAPPI (Constant Altitude Plan Position Indicator) is used for the evaluation of the parameters of motion of suspected tornado event and its possible validation. The radar image presented in Fig. 3 shows well contoured bow echo in the maximum stage of the storm development.

3. Synoptic analysis

The synoptic analysis suggests there is one typical structure that favours the development of tornados. It is a deep trough or a detached cyclone system to the west of the

Balkans so that the frontal jet goes through Bulgaria from southwest to northeast. In this circumstance, the generated convective systems are forced to migrate rapidly north-eastward and strengthen. This is the type of events 1, 2 and 3 (Table 1 and 2). This similarity becomes evident when comparing Figures 3a, and 5a.

(a) (b)

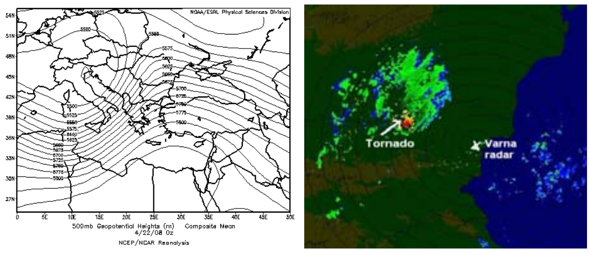

FIG.3: 22 April 2008, tornado (1) Kostandenets: (a) Height (m) of geopotential surface 500hPa; (b) C band radar-CAPPI image from hailstorm with tornado location (white arrow);

(a) **(b)**

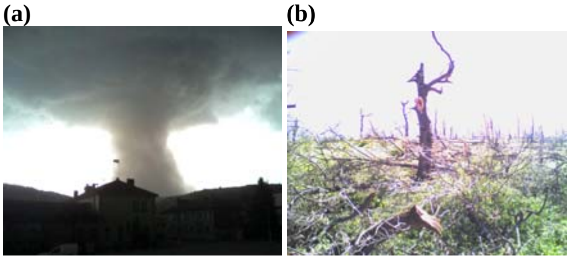

FIG.4: 22 April 2008, tornado (1) Kostandenets: (a) Photo from the tornado funnel ;(b) Damaged wood

(a) **(b)**

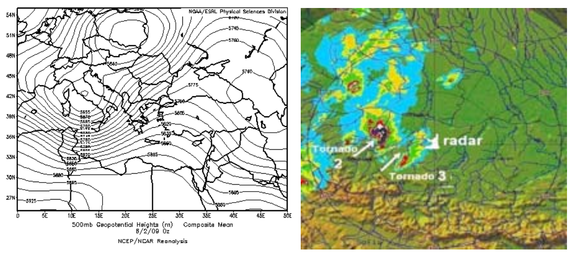

FIG.5: 02 June2009, tornadoes (2) Hayredin and (3) Tarnava: (a) The same as Fig.3 (a); (b) S-band radar-CAPPI image of hailstorm with two tornadoes

(a) **(b)**

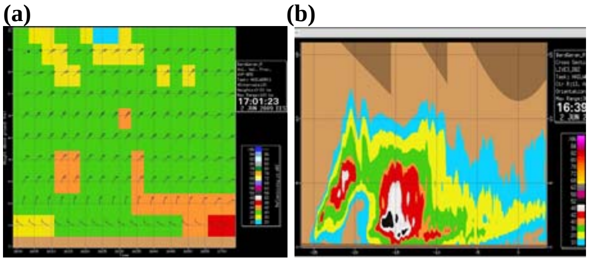

FIG.6: 22 April 2008, tornado (3) Tarnava: (a) Doppler wind vertical profile; (b) RHI cross section;

Finally, the analyzed cases will enrich the database of NIMH of severe storm events and can be used for further improvement of techniques and practices for severe weather warning as well as for studying the climate variability of such severe weather phenomena.

IV. ACKNOWLEDGMENTS

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REFERENCES

Bojkov R., Martinov M., 1956: A vertical axis vortex in Vitosha mountain on 14 June 1956. *Hydrology and Meteorology*, 5, 59-65 (in Bulgarian).

Brooks, H. E., and C. A. Doswell, 2001: Some aspects of the international climatology of tornadoes by damage classification. *Atmos. Res.*, **56**, 191-202.

Brooks, H. E., J. W. Lee, and J. P. Craven, 2003: The spatial distribution of severe thunderstorms and tornado environments from global reanalysis data. *Atmos. Res.*, **67-68,** 73-94.

Dotzek N., 2001: Tornadoes in Germany. *Atmos. Res*. 56, 233-251.

Dotzek N., 2003: An updated estimate of tornado occurrence in Europe. *Atmos. Res*. 67-68), 153-161.

Dessens J., J. T. Snow (1989) Tornadoes in France. *Weather and Forecasting*. 4, 233-251.

Fujita, T.T., and A. D. Pearson (1973) Results of FPP classification of 1971 and 1972 tornadoes. *Preprints 8th Conf. on Severe Local Storms*, Denver. AMS, Boston, pp. 142-145.

Fujita, T.T., (1981) Tornadoes and downbursts in the context of generalized planetary scales. J. *Atmos. Sci*. 38: 11511-1534.

Giaiotti D., Giovannoni M, Pucillo A, Stel F., 2007: The climatology of tornadoes and waterspouts in Italy. *Atmos. Res.*, 83, 534-541.

Kalnay, E. and Coauthors, (1996) The NCEP/NCAR Reanalysis 40-year Project. *Bull. Amer. Meteor. Soc*., 77: 437-471.

Latinov L., (2006) Synoptic conditions of snowstorms, black ices, tornadoes, and dashes storms in Bulgaria, Ed., B. Christov, Sofia, pp.191(in Bulgarian).

Simeonov P., Georgiev C.G., 2001. A case study of tornado-producing storm south of Rhodopes mountain in the East Mediterranean. *Atmos. Res*. (57): 187-199.

Simeonov P., Georgiev C.G., 2003. Severe wind/hail storms over Bulgaria in 1999-2001 period: synoptic- and meso-scale factors for generation. *Atmos. Res*. 67-68, 629-643.

Sioutas M., 2003.Tornadoes and waterspouts in Greece. *Atmos. Res*. 67-68, 645-656.