NATIONAL INSTITUTE OF METEOROLOGY AND HYDROLOGY – *BULGARIAN ACADEMY OF SCIENCES*

On Space-Time Distribution of Tornado Events in Bulgaria (1956-2010): Analyses of Two Severe Tornadic Storms

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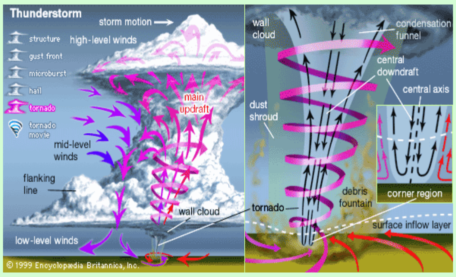


FIG. 1. *(Left)* Tornadic thunderstorm: The rotating updraft that produces the tornado extends high into the main body of the cloud.*(Right)* Anatomy of a tornado: Air feeds into the base of a tornado and meets the tornado's central downflow. These flows mix and spiral upward around the central axis. The tornado's diameter can be much greater than that of the visible condensation funnel. At times the tornado may be hidden by a shroud of debris lifted from the ground (*Encyclopedia Britannica, 1999*).

In Bulgaria the tornado events conjunction with severe convective storms (SCS) usually occurs over crossed mountainous or hilled terrain or over the Black Sea as waterspouts. Only a few tornadoes 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, not only the physical, temporal and spatial characteristics of a given events.

On the base of available the present and archived meteorological data and reports the aim is to complete and contribute to the country's long-term (1956-2010) data records of real tornado cases and make some space-time classification. The approach for the analysis of the tornado cases is similarly to that used in Brooks et al.(2001, 2003), Dessens and Snow (1989), Dotzek, (2001, 2003), Giaiotti et al (2007), Sioutas (2003).

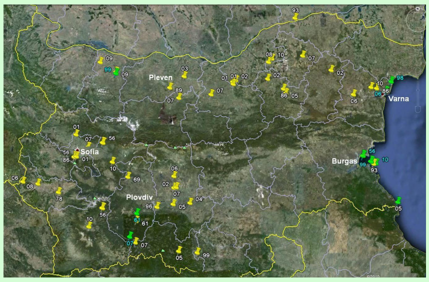


FIG. 2: Space distribution of tornadoes (yellow marker) and waterspouts (green marker) observed in 1956–2010 (signed with last two numbers of each year)

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.

III. RESULTS AND CONCLUSIONS

III.1. Tornado and waterspout events in 1956-2010

The location of all selected tornados and waterspouts is given on the country map (FIG.2). 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).

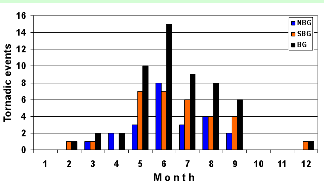


FIG.3. Monthly distribution of 45 tornadoes and 9 waterspouts over northern (NBG), southern (SBG) and all Bulgarian territory (BG)

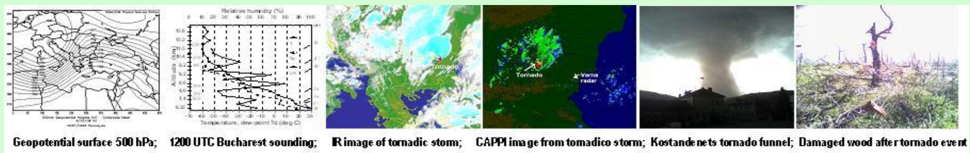
FIG.4. Synoptic, upper air (temperature, humidity and wind), satellite, and radar features of tornadic storms: **(a)** 22 April 2008, tornado (1) Kostandenets and **(b)** 02 June 2009, tornado (2) Hyredin and (3) Tarnava.

The monthly and seasonal distribution (FIG.3) 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 seen 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.

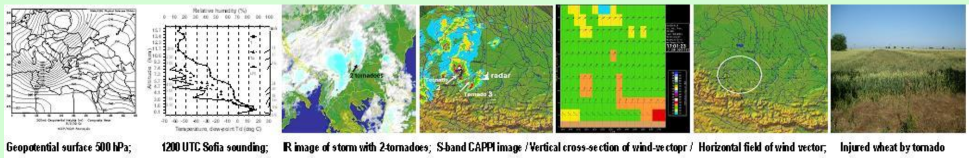
III.2. Case study on two severe storms with three tornadoes

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 Ei (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 **Δv37** (=28 m/s) is also in tornadic storm 1. The surface Vmax 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).

(a)



(b)



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.

No.	Tornado location	Date	Start time UTC	Local storm duration	Direction of storm moving	Cloud top	Max radar echo	Max hailstone size	W_{max}	Ei	Δv_{37}	Vmax wind	Lp length	Wp width	Tornado damage	Fujita scale
			hhmm	minutes		km	dBZ	cm	m/s	J/kg K	m/s	m/s	km	km	EURO	
1	Kostandenets	22 April 2008	1355	80	SW-NE	13.1	63	6.0	26.0	5387	29	29	15	20-30	640 000	F2
2	Hayredin	2 June 2009	1258	75	SW-NE	15	62	9.0	19.8	3712	20	>35	14	80-100	134 000	F2
3	Tarnava	2 June 2009	1335	75	SW-NE	15.1	62	7.5	19.8	3712	20	35	3	50-80	225 000	F2

TABLE I: The environment characteristics of tornadic storms and tornado characteristics and classification for the 3 events based on radar and inquiry data.

***Notes:** w_{max} is the maximum value of updraft velocity; **Ei** is the analogue of CAPE; **Δv_{37}** is a deference between wind velocity at 300 and 700 hPa; **Vmax** is maximum wind speed on the surface.*

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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