Bulgarian Chemical Communications, Volume 47, Special Issue B (pp. 405–411) 2015

Tornado climatology for Bulgaria (2001-2010)

L. Bocheva*, I. Gospodinov

National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, 66 Tsarigradsko Chaussee Blvd., BG-1784 Sofia, Bulgaria

The present work is an attempt to summarize and analyze all documented cases of tornado or waterspouts in Bulgaria between 2001 and 2010. A list of all known tornadoes and waterspouts within the 10-year period has been given. It includes the time and the location of occurrence, the strength and the type of the terrain beneath. Most of the tornadoes in Bulgaria have been classified as F0-F1 of the Fujita scale. The given climatology of the occurrence of tornadoes and waterspouts consists of analysis of its spatial and temporal distribution. By space, tornadoes in Bulgaria tend to occur in the southwestern, southcentral and northestern parts of the country. The frequency of occurrence of tornadoes in Bulgaria appears to be about 0.32 per unit area of 10^4 km^2 per year. The highest probability has been found to be in the administrative regions of Sofia-city and Razgrad. By time, tornadoes tend to occur in the warm half of the year, most often in July, and in the afternoon. The large-scale atmospheric patterns and the thermodynamic parameters and instability indices of the environment associated with the occurrence of tornadoes and water spurts in Bulgaria have also been given.

Key words: tornado, waterspout, Bulgaria

INTRODUCTION

Tornadoes occur relatively rarely in Bulgaria compared to other parts of the world. They have scarcely been documented in Bulgaria prior to 1995 mainly in popular editions [1, 2]. These publications are based on media reports of eyewitnesses' accounts or other reports of experts who had investigated in situ the damage left by tornadoes. Tornadoes are naturally associated with convective storms and therefore they occur in the context of large scale atmospheric conditions favoring deep convection. Statistically tornadoes in Bulgaria occur mainly over mountainous terrain or over large water surfaces (lakes, water dams, and sea). Tornadoes in Bulgaria may often remain unreported when they occur in remote and weakly populated mountainous regions of the country or if they leave no significant damage behind. The number of reports of tornadoes in Bulgarian in the last 10-15 years however has significantly increased thanks to the revolutionary development of the information technology. There exist even amateur websites where one can find up-to-date summary of suspect tornado cases in the country given either by description of the damage or by photos of the object. While some of them were indeed tornadoes others were rather downbursts or funnel clouds not touching the ground.

More elaborated analyses of individual tornado cases in Bulgaria for example can be found in [3–5]. In [4] the weather patterns associated with the occurrence of tornadoes in Bulgaria are presented. However he relied on unverified scarce data of tornado occurrences gathered from media.

This study mainly summarizes general features of the tornado and waterspouts statistics such as the geographical, yearly, monthly and diurnal distributions. Characteristics concerning tornado intensity are also presented. The main synoptic patterns and the thermodynamic parameters and instability indices related to tornado occurrence are also given.

METHODOLOGY

The present work is based on a collection of data of 36 tornados and waterspouts in Bulgaria between 2001 and 2010. Data originated from eyewitness reports, site investigations, media news, reports of the local administration of damage in crops and infrastructure. Press and TV are often the richest source of images of the tornadoes and waterspouts themselves or the damage they have caused. Data from site investigations of damage, scientific publications, the meteorological data base of National Institute of Meteorology and Hydrology (NIMH) and the archives of the Bulgarian Hail Suppression Agency (BAHS) are also included. All cases have been verified by means of analysis of the weather patterns based on the NCEP/NCAR Reanalysis [6] and maps from NOAA/ESRL Physical Sciences Devision, Boulder Colorado (http://www.esrl.noaa.gov/psd/). The analysis of the vertical structure of the atmosphere at the location and the time of occurrence based on the

* To whom all correspondence should be sent:
lilia.bocheva@meteo.bg

© 2015 Bulgarian Academy of Sciences, Union of Chemists in Bulgaria

sounding data from the archives of NIMH. The method applied for the later is the one of [3]. Some of the cases were also verified by using radar images and data from the automated radar system of NIMH (X and S-band AMS-MRL5) based in Gelemenovo and the 3 radar systems of BAHS (S-band AMS-MRL5) which have been upgraded to Doppler capability since 2008 and have been equipped with IRIS (Interactive Radar Information System) for imaging. The tornado cases have also been classified by strength according the Fujita scale [7].

The sounding data from the national (Sofia) or the closest foreign aerological stations (Thessaloniki, Belgrade, Bucharest) have been used to calculate some thermodynamic parameters and indices of instability at the vicinity of occurrence of the tornadoes. Surface data (pressure, temperature, humidity parameters, wind speed and direction) from the closest weather station have been fitted to the lower part of the vertical profile. All computations have been made by the upgraded in 2013 non-adiabatic empirical model presented in [8]. Alternatively other data from http://www.esrl.noaa.gov/psd/ (NOAA/ESRL Physical Sciences Division, Boulder Colorado) have been used for some of the cases. Based on all these the instability has been summarized statistically by using data analysis software system StatSoft.

SPATIAL AND TEMPORAL DISTRIBUTION OF TORNADOES IN BULGARIA BETWEEN 2001 AND 2010

The above mentioned 36 tornado cases have occurred in 32 days. Sioutas [9] defined the frequency P of tornado occurrence as the number of events per area unit of 10^4 km^2 per year. The average number per year in Bulgaria is 3.6 (σ=1.8) which therefore makes up a frequency of P=0.32/10^4 km^{2}year^{-1}. Holzer [10] has published a similar frequency for Austria (P=0.3/10^4 km^{2}year^{-1}) while the one for Greece appears to be 4 times bigger (P=1.1/10^4 km^{2}year^{-1} - [9]).

Figure 1 illustrates P per administrative regions. As can be seen only 17 out of 28 administrative regions have registered tornadoes for the 10-year period. The Sofia-city region has the highest frequency of 2.2/10^4 km^{2}year^{-1} followed by Razgrad (1.1/10^4 km^{2}year^{-1}). The regions of Veliko Turnovo and Smolyan (0.9/10^4 km^{2}year^{-1}), Plovdiv and Varna (0.8/10^4 km^{2}year^{-1}), Targovishte and Kyustendil (0.7/10^4 km^{2}year^{-1}), and Vratsa (0.6/10^4km^2) exhibit frequencies grater than the national average. Only

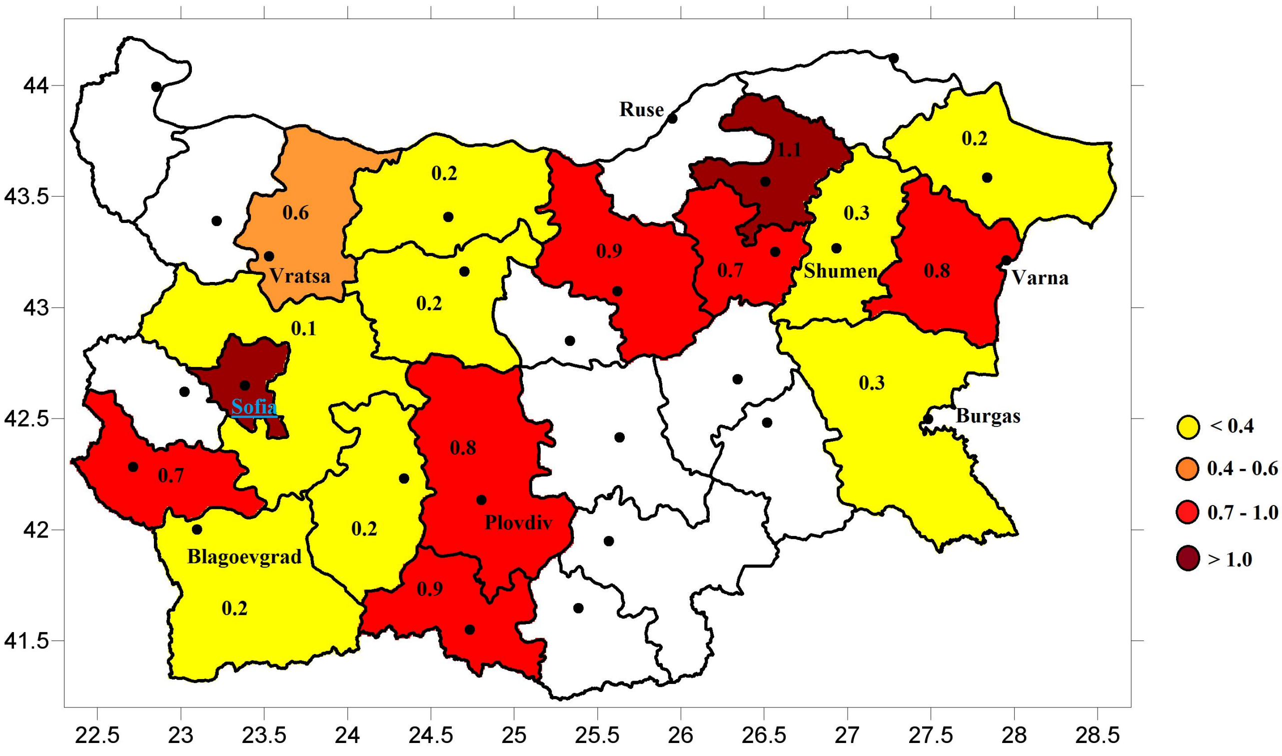


Fig. 1. Mean annual frequency of tornado occurrence in Bulgaria per administrative provinces (2001-2010).

Table 1. Tornadoes and waterspouts in Bulgaria (2001-2010): mw – mountainwooded; m – mountain; hw – hilly wooded; h – hilly; f – flat; WS (Ws) – waterspout; T – tornado

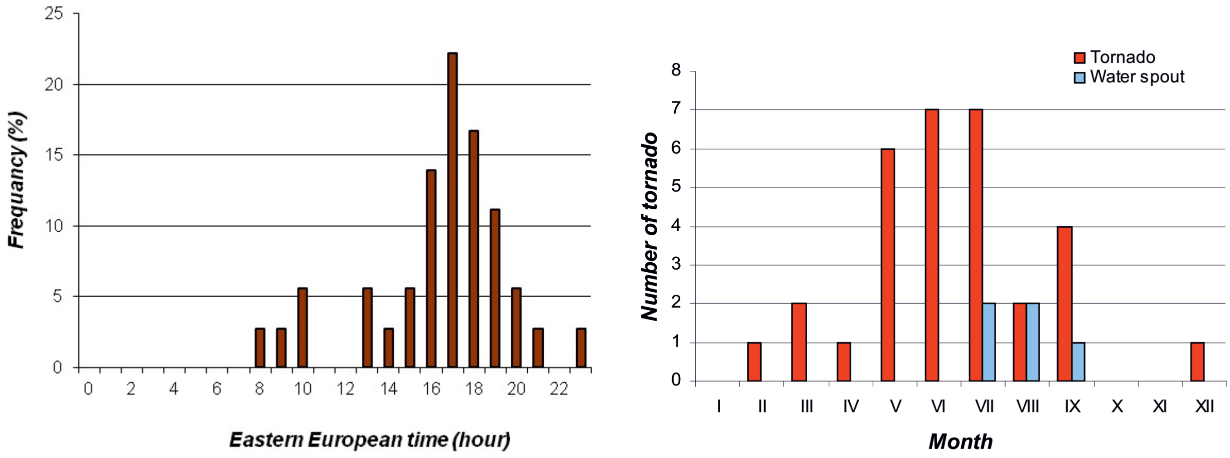
Tornado location	**Date**	**Type**	**Time**	**F-scale**	**Land-scape**
Zheleznitsa	22 May 2001	T	PM	F1-F2	mw
Dobroslavtsi	29 Aug 2001	T	PM	F1	f
Radanovo	11 Sept 2001	T	AM	F0	h
P. Trambesh	25 Sept 2001	T	PM	F0	h
Voivoda	10 June 2002	T	PM	F1	h
Palamartsa	23 June 2002	T	PM	F1	h
Trud	19 July 2002	T	AM	F2	f
Kavarna	20 July 2002	Ws	PM	?	WS
Karantsi	12 Aug 2002	T	PM	F1	h
Slavyanovo	23 May 2003	T	PM	F2	f
Bolyartsi	24 March 2004	T	PM	F1	f
Gramade	27 Sept 2004	T	PM	F1	m
Fatovo	15 Feb 2005	T	PM	F1	m
Alexandrovo	29 May 2005	T	PM	F2	hw
Perushtitsa	01 July 2005	T	PM	F1	m
Rezovo	05 Sept 2005	Ws	PM	?	WS
Bobeshino	02 June 2006	T	AM	F1	mw
Kaloyanovo	14 June 2006	T	PM	F0	f
Provadiya	28 July 2006	T	PM	F0	h
Varna	28 Aug 2006	Ws	PM	?	WS
M. Yonkovo	21 March 2007	T	PM	F1	h
Yoglav	21 May 2007	T	PM	F1-F2	h
Kalekovets	21 May 2007	T	PM	F1-F2	f
Krivina	21 May 2007	T	PM	F1-F2	f
Pavlikeni	12 July 2007	T	PM	F1	hw
dam Dospad	06 Aug 2007	Ws	PM	?	WS
Dospad	01 Sept 2007	T	PM	F0	mw
Kancelovo	22 April 2008	T	PM	F2	hw
Kyustendil	08 July 2008	T	PM	F0	f
Vulchedrum	02 June 2009	T	PM	F2	f
Tarnava	02 June 2009	T	PM	F2	f
Tsar Kaloyan	16 June 2010	T	PM	F1	hw
Vakarel	01 July 2010	T	AM	F0	f
Sozopol	26 July 2010	Ws	AM	?	WS
Slunchevo	26 July 2010	T	AM	F0	h
Bansko	02 Dec 2010	T	AM	F0	m

water spurts have been reported in the regions of Dobrich and Burgas which border the Black sea.

All documented tornado cases in Bulgaria from 2001 to 2010 have been classified by strength according to the Fujita scale and by the type of the topography and the land use of the terrain upon which they occurred (see Table 1). For these classifications the approach presented in [11] is used. There are 12 cases upon mountainous or hilly terrain covered by shrub or grass; 8 cases upon wooded mountainous or hilly terrain; 11 cases over flat terrain (plain); and 5 waterspouts. More than half (above 55%) of all cases in Bulgaria therefore have occurred over mountainous or hilly terrain which contrasts with other parts of Europe where tornadoes most often form and develop upon flat terrain or near water bodies [9, 12, 13]. All mountainous tornadoes were in the southwestern part of the country and mainly in the mountain of Rhodopes except 2 cases: one on the northern slopes of the mountain of Pirin and another one on the northern slope of the mountain of Vitosha right to south of Sofia. The outcome of mountainous tornadoes often remains unnoticed if they have been relatively weak or if they have occurred in relatively remote and hardly accessible parts of the mountains.

The classification by strength given in Table 1 excludes the 5 waterspouts. The reason is that they left no damage and this inhibits the attempts to classify them according to the Fujita scale. Most of the tornadoes (68%) from Table 1 match or even do not reach the F1 level of the Fujita scale which means that they were weak. This result corresponds well to similar statistics for Germany (55%, [14]) and Austria (62%, [10]) but is significantly less than in Finland (86%, [15]). There is an overall tendency of increase of the documented weak tornadoes in various databases in both Europe and the USA [14, 16]. The same has been identified for Bulgaria as well [5]. About 13% of all cases in Table 1 have been attributed with an intermediate class F1-F2 because the damage data corresponds to the higher class F2 but the wind data suggest only class F1. There have been no documented casess of a class higher than F2 in Bulgaria.

The diurnal ditribution of tornadoes and waterspouts in Bulgaria within the studied period is presented on Fig. 2a. Naturally most of the cases (about 80%) occured within the afternoon hours between 14:00 and 18:00 local time (East European Time (EET) which in summer is 3 hour ahead of the Universal Coordianted Time (UTC) and in winter – 2 h). This corresponds to the diurnal maximum of the thunder storm activity in Bulgaria [17] and also to similar statistics for other European countries [15, 18]. All documented cases occurred in daytime between 07:00 and 20:00 EET. This fact of course can be linked to the nature of the convective clouds which develop mostly in the afternoon hours. Another contributing factor could be the fact that people tend to report tornadoes during day when they are more active.



(a) (b)

Fig. 2. Diurnal (a) and monthly (b) distribution of all studied and proven tornadoes in Bulgaria (2001-2010).

On the other hand about half of all waterspouts over the Black sea take place in the morning hours (09:00–12:00 EET). This can be explained by the different surface conditions over water compared to those over land.

Figure 2b shows the monthly distribution of tornado cases from the list. Almost all cases (93%) occurred within the warm half of the year between April and September. The months of June and July exhibit the highest frequency. This corresponds to the statistics for other countries in Central and Eastern Europe. July appears to be the month with a maximum number of tornadoes in Germany [14], Austria [10], and Greece [9]. In Southern Europe however the maxima tend to occur later in August (Italy [13]) or in September (Spain [12]). Waterspouts in Bulgaria seem to occur between July and September as revealed by Fig. 2b. This matches the time of year when the sea water is the warmest. It also corresponds well to similar statistics for other neighbor countries (Croatia [19] and Northern Greece [9]).

In the list of documented tornadoes in the 10-year period there are 4 "winter" cases which occurred within the cold half of year: 3 of which in Southern Bulgaria and 1 - in Northeastern Bulgaria. They were associated with strong thunderstorms which developed along rapid and intense cold fronts introducing cold and moist air masses in Bulgaria after a prolonged period of unseasonably warm and dry weather. The newly detected "winter" tornadoes in the recent years can be due to the overall global warming trend or it can be the result of the revolutionary development of the information technologies.

METEOROLOGICAL CONDITIONS FAVORING DEVELOPMENT OF TORNADOES IN BULGARIA

Synoptic scale conditions

More detailed analisys and classification of synoptic-scale patterns conditioning tornadoes in Bulgaria have been given in our prvious works [5,20]. Based on these we can say that it seems that most tornadoes (90%) developed in the context of a cold front system with predominantly meridional extent from southwest to northeast which was associated with a strong air flow in the middle and upper troposphere [4, 5, 20]. The cold-front system should have crossed the country. Such cold fronts are most often associated with a deep upper-level trough to the west of Bulgaria over the Central Mediterranean. When associated with tornadoes though, they appear to be rather stationary for a certain period of time or progress slowly through the country. Additional factors play a favorable role for the development of tornadoes such as the time of day within which the cold front goes through the country and the characteristics of the terrain. The convection is facilitated if the front crosses the country during day time and if the front orientation is transversal to orographic obstacles like mountain chains [20].

Thermodynamic conditions

Similarly to [9, 21] we present short analysis of the thermodynamic conditions within which the tornadoes in Bulgaria developed. Only those 31 cases observed over land have been taken into account. There are many difficulties when attempting to study the thermodynamics at the vicinity of occurrence of tornadoes. First of all, there are only a few sounding profiles available in the region. The NIMH operates only one aerological site and conducts only one sounding per day at 12:00 UTC which is in the afternoon. This inhibits the attempts to see the instability factors prior to events occurring before noon for example. Secondly, the tornadoes are a very short-lived phenomenon associated with strong convective storms. Quite very often the instability factors, if measured by popular indices like CAPE (Convective Available Potential Energy) for example, disappear when the storm passes. Depending on the location of the storm and the tornado associated with the storm the sounding data may or may not exhibit appropriate values of CAPE. These reasons led to the choice of 4 specific indices of instability based on sounding profiles of temperature, humidity, and wind in the lower and middle troposphere and they are:

- **K** **I**ndex [22]

$$KI = (T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700}) \quad (1)$$

- **T**otal **T**otals Index [23]

$$TTi = (T_{850} - T_{500}) + (T_{d850} - T_{d500}) \quad (2)$$

where T_{850}, T_{700}, and T_{500} denote temperature at levels 850, 700, and 500 hPa and T_{d850} and T_{d700} denote dew point at levels 850 and 700 hPa.

- **L**ifted **I**ndex [24]

$$LI = (T_L - T_{500}) \quad (3)$$

where T_L is the temperature of an adiabatically (dry or wet depending on the level of saturation) ascending air parcel from level 850 hPa to level 500 hPa; T_{500} is the air temperature at level 500 hPa.

- **S**evere **WEA**ther **T**hreat index (SWEAT) [23]

$$SWEAT = 12T_{d850} + 20(TT - 49) + 2V_{850} + V_{500}g + 125(\sin(dd_{500} - dd_{850}) + 0.2) \quad (4)$$

where TT is the Total Totals index, V_{850} and V_{500} denote the wind velocity at levels 850 hPa and 500 hPa respectively, and $dd_{500} - dd_{850}$ is the difference between the directions of wind in degrees at the two levels.

High values of these 4 indices indicate increased instability. According to other authors [25] $KI > 25$ and $TT > 49$ indicate conditions favorable for the development of strong thunderstorms with hail and/or tornadoes. Table 2 summarizes some statistics of the 4 indices for the studied tornado cases. As it can be seen the means of KI, TTi, and LI (column 1) are above the threshold values. The TTi also corresponds to what has been found by David [26] for tornado cases in the USA. The means of LI and TTi are grater than those obtained for Northeastern India and Bangladesh [27]. The mean $SWEAT$ is greater than the one for Greece [9] but lower than 400 which was found to be a threshold value for summer tornado storms in the USA [26]. Nevertheless the mean $SWEAT$ corresponds to the one for the month of May in USA (253, [26]). The month of May is one of the months with the highest occurrence of tornadoes in the USA. The means of KI, TTi, and LI for Bulgaria correspond well to those for Greece and for the same 10-year period ($KI = 29.2$, $TTi = 48$, $LI = -1.6$ [9]).

Table 2. Instability indices of the environment of Bulgarian tornadoes

Index	*Mean*	*MIN*	*MAX*	*SDV*
KI, °C	30.6	13.9	43.7	7.8
TTi, °C	51.7	42.5	61.0	4.3
LI, °C	-5.4	-13.7	2.5	3.3
$SWEAT$	240.7	107.8	399.9	89.1

Table 3. Thermodinamic and wind parameters of the environment of Bulgarian tornadoes

Parameter	*Mean*	*MIN*	*MAX*	*SDV*
ΔT_{500}, °C	7.8	2.8	10.7	2.2
DT_m, °C	10.0	6.0	16.6	2.8
S_{DT754},°C	21.1	10.5	31.2	5.7
$w_{\max}$, m/s	17.1	12.0	24.5	3.5
Δv, m/s	13.0	-3.0	45.0	12.3
H_0, m	4454	2278	5899	917
$LfcEL$, m	11637	8484	13254	1305

The parameters in Table 3 are:

ΔT_{500} – temperature difference between the temperature profile and the adiabatic profile at level 500 hPa;

DT_m – the maximum temperature difference between the temperature profile and the adiabatic profile;

S_{DT754} – the sum of the temperature differences at levels 700 hPa, 500 hPa, and 400 hPa;

$w_{\max}$ – the maximum value of updraft velocity;

Δv – wind shear 300-700 hPa (for wind speed only);

H_0 – altitude of 0 °C;

$LfcEL$ – lifted convective equilibrium level.

They all show up near or above threshold values for strong thunderstorms in the warm half of the year in Bulgaria found by other authors [28, 29]. The values of ΔT_{500} and DT_m indicate conditions favorable for deep thermal convection. This correlates with the high value of $w_{\max}$. The values of Δv suggest that for 85% of all cases the maximum vertical velocity of the ascent is in the upper part of the convective cloud. The values of $LfcEL$ match those of [28] identified as being informative for the development of hail producing summer convective storms. The mean value of $LfcEL$ is even grater than the one of [29].

CONCLUSION

The analysed 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 warnings as well as for studying the climate variability of such severe weather phenomena. Tornadoes in Bulgaria mainly occur in the north-central, north-eastern and south-central regions of Bulgaria over mountainous terrain but also over plains. There is a tendency of increase of the documented number of tornado events in Bulgaria during the last 10 years. From one side the mechanism of this trend from physical point of view remains to be studied but, from the other side, it may also be due to the fact that information (including amateur photos and videos) about such rare and short-lived meteorological phenomena have become available more frequently in the recent years. The intensity analysis indicated that the majority of the tornadoes in Bulgaria can be classified as F0-F1 of the Fujita scale which is equivalent to "weak" tornadoes. The analysis of the selected thermodynamic indices and wind parameters showed values comparable to those found in the literature. However, the high dispersion suggests that tornadoes can form and develop in significantly varying thermodynamic environments.

These results, although modest, will contribute to the enrichment of the tornado climatology of the Balkans and Europe. Further climatological research is needed for quantitative and qualitative improvement of the tornado and waterspout database.

Acknowledgments. *We are grateful to the experts from the BAHS of the Ministry of Agriculture and Food for the provision of radar images and data of damage left by some of tornadoes.*

REFERENCES

[1] B. Vekilska, *The atmosphere in motion, Small-scale vortices*, Publ. Narodna prosveta, Sofia, 1983 (in Bulgarian).

[2] M. Sirakova, D. Sirakov and K. Donchev, *Meteorology for everyone, Tornado*, edited by M Krumova, Publ. Science and art, Sofia, 1989 (in Bulgarian).

[3] P. Simeonov and Ch. C. Georgiev, *Atmos. Res.* **67–68**, 629–643 (2003).

[4] L. Latinov, *Wheather conditions for snow storms, frost, duststorms and tornado in Bulgaria, Tornado*, edited by B. Hristov, Publ. LITO Balkan AD, Sofia, 2006 (in Bulgarian).

[5] P. Simeonov, L. Bocheva and I. Gospodinov, *Atmos. Res.* **123**, 61–70 (2013).

[6] E. Kalnay, M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, A. Leetmaa, B. Reynolds, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K. C. Mo, C. Ropelewski, J. Wang, R. Jenne and D. Joseph, *BAMS* **77**, 437–471 (1996).

[7] T. T. Fujita, *J. Atmos. Sci.* **38**, 1511–1534 (1981).

[8] P. Simeonov, *J. Appl. Meteorol.* **35**, 1574–1581 (1996).

[9] M. Sioutas, *Atmos. Res.* **100**, 344–356 (2011).

[10] A. M. Holzer, *Atmos. Res.* **56**, 203–212 (2000).

[11] J. Dessense and J. T. Snow, *Weath. and Forecasting* **4**, 110–132 (1989).

[12] M. Gaya, *Atmos. Res.* **100**, 334–343 (2011).

[13] D. Giaiotti, M. Giovannoni, A. Pucillo and F. Stel, *Atmos. Res.* **85**, 534–541 (2007).

[14] P. Bissolli, J. Grieser, N. Dotzek and M. Welsch, *Glob. And Plan. Change* **57**, 124–138 (2007).

[15] J. Rauhala, H. E. Brooks and D. Schultz, *Mon. Weath. Rev.* **140**, 1446–1456 (2012).

[16] N. Dotzek, *Workshop: Tornadoes and Hail* Bermuda, November, 2000.

[17] L. Bocheva, P. Simeonov and T. Marinova, *BJMH* **18**, 38–46 (2013).

[18] S. Szilard, *Atmos. Res.* **83**, 263–271 (2007).

[19] T. Renko, J. Kuzmic and N. Strelec Mahovic, Ext. abs. of 7$^{\text{th}}$ ECSS, 3-7 June 2013, Helsinki, Finland (http://www.essl.org).

[20] P. Simeonov, I. Gospodinov, L. Bocheva and R. Petrov, *BJMH* **11**, 78–85 (2011).

[21] H. Brooks, J. W. Lee and J. P. Craven, *Atmos. Res.* **67–68**, 73–94 (2003).

[22] J. J. George, *Weather Forecasting for Aeronautics*, Academic press, New York, 1960.

[23] R. C. Miller, *Notes on the analysis and severe-storm forecasting procedures of the Air Force Global Weather Central*, Air Weather Service Tech. Rept. 200 (Rev.), Air Weather Service, Scott Air Force Base, IL, 1972, pp 190.

[24] J. G. Galway, *BAMS* **37**, 528–529 (1956).

[25] M. Siedlecki, *Theor. Appl. Climatol.* **98**, 85–94 (2009).

[26] Cl. David, *Mont. Weath. Rev.* **104**, 546–551 (1976).

[27] R. Bhattacharya, A. Bhattacharya and R. Das, *International Journal of Electronics and Communication technology* **4**, 92–94 (2013).

[28] P. Boev and A. Marinov, *Hidrologiya I Meteorologiya XXXIII* **4**, 10–17 (1984) (in Bulgarian).

[29] P. Simeonov, P. Boev, R. Petrov, D. Sirakov and V. Andreev, *Problems of Hail Suppression in Bulgaria, Climate hail phenomena in the Upper Thracian valley*, edited by S. Panchev, University Publ. "Climent Ohridski", Sofia, 1990 (in Bulgarian).

КЛИМАТИЧНО ИЗСЛЕДВАНЕ НА ТОРНАДО (СМЕРЧ) В БЪЛГАРИЯ

Л. Бочева, Ил. Господинов

Национален институт по метеорология и хидрология, Българска академия на науките, бул. "Цариградско шосе" №66, 1784 София, България

(Резюме)

Макар и рядко, при обстановки, свързани с развитието на мощни конвективни бури, у нас се образуват торнада – най-често над пресечени планински терени или над морската акватория. Торнадото е дребномащабно и кратко по време опасно явление, което е трудно за прогнозиране без наличие на специализирана техника. Често смерчът се бърка с т.нар. "падащ" или шквалист вятър. За отличаването и определяне силата му по скалата на Фуджита (Fudjita) например, е важно да се знаят освен физически и пространствено-временни характеристики и данни за характера и размера на щетите.

През последните 10-15 години, благодарение на бурното развитие на електрониката, телекомуникациите, Интернет и др., съобщенията за торнада в медиите значително се увеличиха. Настоящето изследване се базира на данни за 36 случая на торнада и водни смерчове, регистристрирани в България през периода 2001-2010 г. Те са взети както от метеорологичните архиви и научни публикации, така и от медии, разкази на очевидци, данни от архивите на Национална служба „Гражданска защита", полеви обследвания и справки за щети от местната администрация. За потвърждение и доказване на случаите са използвани синоптична информация от метеорологичната база данни на Националния институт по метеорология и хидрология (НИМХ), радарна информация, данни от аерологичните сондажи в София, Солун, Белград и Букурещ, спътникови данни от EUMETSAT и синоптични карти от реанализите на NCEP/NCAR.

За 10-годишния период на изследване е получена средна годишна честота на торнадата в България от 0.32 на единица площ от 10^4 km^2. Изчислена е и средната годишна честота на явлението за всяка област в страната. Най-голяма е регистрираната годишна честота в областите София – град (2.2/10^4 km^2) и Разград (1.1/10^4 km^2). Изследвано е и денонощното разпределение на торнадата и водните смерчове в България. Около 80% от всички случаи на сушата са регистрирани в следобедните часове, главно между 14:00 и 18:00 часа местно време, докато над 50% от водните смерчове се развиват преди или около пладне. В близо 70% от случаите в България става дума за слаби торнада от категории F0-F1 според международната скала на Фуджита. Месечното разпределение на торнадата и водните смерчове показва, че те възникват главно през топлото полугодие – 89% от тях са регистрирани в периода април-септември. Все пак има регистрирани и 4 случая на торнадо през студеното полугодие, което може да е следствие както от наблюдаваното повишение на зимните температури (ефекта на т.нар. глобално затопляне), така и от бурното развитие на електрониката и комуникациите, причина за по-често документиране на торнада през последните години. И четирите случая на „зимно" торнадо са свързани с развитието на нетипични за сезона синоптични обстановки.

Изследвани са синоптични обстановки и е направена обобщена класификация на типичните синоптични структури, свързани с развитието на смерчове в страната. Изчислени са и редица термодинамични характеристики на атмосферата, както и набор от индекси на неустойчивост за всички случаи на торнадо над сушата. Пресметнати са и някои статистически характеристики на получените индекси на неустойчивост. Получените резултати са сравними с тези, пресметнати за територията на Гърция, Унгария и други страни от Средна и Южна Европа.